MARKETING SCIENCE
Vol. 13, No. 1, Winter 1994
Printed in U.S.A.

GAINING MORE BY STOCKING LESS: A COMPETITIVE ANALYSIS OF PRODUCT AVAILABILITY

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The price competition between two firms can affect their decisions about product availability. With occasional stockouts a firm loses from foregone sales, yet it may indirectly benefit from the higher price a competitor is able to charge. The more prone customers are to search elsewhere for the product upon encountering a stockout, the greater is the gain from the reduced price competition between firms.

This paper establishes conditions whereby the strategic interaction of reduced price competition between firms outweighs the loss from foregone sales. In such cases, a firm can increase its expected profits by choosing to stock less. These results provide a competitive rationale for the high stockout levels observed in some retail situations and have implications for the analysis of product availability in public policy settings.

(Competitive Strategy; Pricing Research; Product Policy)

1. Introduction

Product availability is a fundamental issue in many marketing channels. For example, a comprehensive survey of major advertised items distributed nationally to American supermarkets estimated the overall unavailability level at 28%: 18% from stores' not carrying items and 10% from stores' stocking out of items they usually carried (*Progressive Grocer* 1968b). Other studies report similar findings, though product availability levels vary widely by item, time, and place (Mason and Wilkinson 1976, 1981; Dion et al. 1989). Even with widespread use of computerized shelf-management and buying systems, stockout levels in supermarkets have grown steadily because of chronic labor shortages, an expanding array of new items, financial pressures to trim inventories, and decreased performance in supplier delivery (Thayer 1989). In a number of cases, the Federal Trade Commission has even taken action against firms that did not have advertised items available.

Prior research in marketing on product availability primarily examines customers' responses to stockouts (e.g., Mason and Wilkinson 1977).[1] One study reports that when

[1] Product availability has also been examined in consumer choice models (Jeuland 1979, Farquhar and Pratkanis 1993), in market share models (Farris et al. 1989, Straughn 1991), and in inventory models (Bowersox 1974, Ibrahim and Thomas 1986).

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faced with a favorite item being out-of-stock, 48% of British supermarket shoppers decided to visit other stores to purchase the unavailable item, 30% decided either not to buy the item or to wait until the next shopping trip, 17% switched to another brand or product, and 5% substituted a different size of the same brand (Schary and Christopher 1979).

Unlike this earlier research, the present paper examines how competition affects product availability at firms. Many firms do set target levels for product availability (Germain and Cooper 1990). Grocery retailers, for instance, aim for in-stock service levels of at least 98% on popular items, but the typical supplier provides service levels of less than 94% (Elman 1989). General merchandise catalogers try to average "fill ratios" on initial orders of 90% to 95%. Their philosophy is, "You can't sell what you don't have" (Bass 1989). Other catalogers, such as specialty merchandisers, reportedly stock less than 80% of their currently advertised items; not surprisingly the most frequent complaint among mail-order customers is "out-of-stock items" (*Consumer Reports* 1987).

A firm's long-term decisions on supplier selection, store capacity, regional warehouses, and communication systems affect its likelihood of stockouts. For example, Wal-Mart's computer technology, Retail Link, enabled its headquarters staff and store employees to communicate via satellite and thus led to more timely replenishment of the stores and to fewer stockouts (*Discount Store News*, December 14, 1987, p. 60). Similarly, Haggar Company reduced retail stockouts of its men's wear by transmitting sales information on styles, sizes and colors directly from points-of-purchase to the corporate headquarters (*Dallas Business Journal*, August 15, 1988, p. 14).

But there are different perspectives on the value of product availability in a competitive setting. One manager maintains that stockouts do not matter much because ". . . the customer has been so beaten down by out-of-stock everywhere . . . that she more or less accepts it." (*Progressive Grocer*, 1968a, p. S-4). When Harley Davidson's prolonged stockouts left customers waiting months for its motorcycles, some dealers saw an advantage in that they did not have to cut prices to stimulate sales (*The Business Journal–Milwaukee*, August 5, 1991, p. 11). Similar reports appear in many other industries.[2]

This paper establishes that a rationale for limiting product availability is to reduce price competition. We analyze the basic situation where two firms sell a single product. Each firm chooses an availability level for its product (i.e., the probability of not having a stockout); firms then compete on the price of the product. An important feature of our model is that customers consider both the price of the product and the probability of its availability in choosing between firms. We derive the optimal availability levels for the firms in terms of a subgame perfect equilibrium (see Moorthy 1985). If customer search costs are low, both firms will choose to have occasional stockouts. Even when higher availability levels are costless in the long run, firms gain more by stocking less.

The strategic effect of firms' availability level choices on their pricing decisions explains this surprising result. When a firm chooses to have occasional stockouts, its competitor loses fewer customers from charging a higher price for the product. Moreover if customer search costs are low, the competitor serves all customers who encounter a stockout at the other firm. Both considerations allow the competitor to charge a higher price, which benefits the firm with stockouts. This reduced price competition outweighs the direct loss from foregone sales due to a stockout. Thus the firm's expected profits are higher with occasional stockouts than with sure availability.

On the other hand, when customer search costs are high, customers who face a stockout at one firm are more responsive to the competitor's price. If the competitor increases

[2] For example, *Purchasing* (1988, p. 4) reports, "Buyers believe mill warehouses and distributors are well stocked and the long leadtimes [for delivery] are an attempt by producers to artificially limit supply in a try to boost prices again. . . . Much the same is true in the length of deliveries of plastics, chemicals, plastic and rubber goods, and paper products."

prices too much, customers may drop out of the market by not purchasing the product. Thus the competitor tends not to increase its price very much, and the strategic effect diminishes substantially. Therefore firms do not gain from stockouts and will maximize profits with sure availability.

Our results therefore establish conditions under which the strategic interaction between competing firms outweighs the direct loss from stockouts. These results provide a competitive rationale for the low continuity in assortment found in off-price retailing and for the higher stockout levels observed in discount stores. Extensions and limitations of our results are discussed in §5.2.

2. A Competitive Model of Product Availability

2.1. *Extending the Hotelling Model*

The Hotelling (1929) model consists of two firms A and B that can locate anywhere along a linear market of length L. Both firms sell a single product and have the same constant marginal cost. The products are differentiated only by the firms' locations. The Hotelling model assumes initially that customers are uniformly distributed with unit density over the linear market. Each customer buys one unit of the product (regardless of price) and incurs a transportation cost depending on distance. Customers know the firms' respective prices and select the firm that minimizes their purchase price plus transportation cost. Hotelling used this model to analyze the location decisions of competing firms.

We extend Hotelling's model to accommodate the impact of uncertain product availability. We assume that firms A and B choose availability levels α_A and α_B, respectively, where $0 < \alpha_A, \alpha_B \leq 1$. Although other definitions are possible, an *availability level* α_i for $i \in \{A, B\}$ implies here that firm i sells to all customers who visit the store with probability α_i, and sells to no one with probability $1 - \alpha_i$. Product availability is therefore independent of customer demand. We thus regard the availability level as a reduced-form variable representing a firm's long-term policies regarding suppliers, production, and distribution.

Since we do not analyze firms' location decisions, we locate firms A and B at opposite ends of the linear market of length L and thereby avoid the technical difficulties caused by nonexistence of equilibria in Hotelling's original model. We assume both firms have equal marginal cost, which is set to zero without loss of generality. We assume that customer demand is inelastic up to a finite reservation price r; hence it is possible that some customers will not purchase the product.

Customers know the firms' prices, p_A and p_B, and the availability levels, α_A and α_B. Similar to the retail settings discussed in the introduction, customers ascertain if the product is available only upon visiting the firm.[3] Customers pay a one-way "unit search cost" of $c/2$ per unit distance to visit a firm, whether or not they succeed in obtaining the product. Customers endeavor to maximize their expected surplus, as measured by the reservation price less the sum of the purchase price and search cost. If the purchase price plus expected search cost is greater than r, customers do not purchase the product and instead substitute an "outside product" for which the surplus is zero. The "outside product" is a product not supplied by either firm.

Our model assumes that customers may search more than one firm if they find the product unavailable. In the case where $\alpha_A < 1$ and $\alpha_B < 1$, a customer has five possible search strategies.[4]

[3] This assumption makes product unavailability costly to customers because of their search costs. Relaxing this assumption does not affect our results.

[4] Throughout the paper, the subscripts i and j are used to denote either firm A or firm B. Thus $S_i \in \{S_A, S_B\}$ and $S_{ij} \in \{S_{AB}, S_{BA}\}$.

S_0: Purchase nothing and substitute the outside product.

S_i: Travel to firm i and purchase the product if it is available; otherwise return home and substitute the outside product.

S_{ij}: Travel to firm i and purchase the product if it is available; otherwise travel to firm j and purchase the product if it is available; otherwise return home and substitute the outside product.

Analysis of our model begins with the specification of the reservation price r, the search cost c, and the market length L. In the first stage, firms simultaneously choose their availability levels α_A and α_B, which are then known by all customers and firms. In the second stage, firms simultaneously set prices p_A and p_B. Before the uncertain availability is resolved, each customer in the market chooses a search strategy that maximizes expected surplus given the parameters r, c, and L, and knowing the availability level and price at each firm. (Firms cannot change prices after the uncertain availability is resolved, because such short-term price changes are presumably too costly.) Each firm maximizes its expected profit as a function of customers' search strategies. Figure 1 illustrates the sequence of actions and events in this model.

2.2. *Customers' Search Strategies*

The optimal search strategy for each customer in the market is a function of the availability levels and prices. For a given availability level α_i and price p_i, we define firm i's *market area* by the farthest customer it can attract. Such a customer obtains a zero expected surplus from purchasing at firm i (using strategy S_i); this customer is located at a distance $\alpha_i(r - p_i)/c$ from firm i. Thus, a firm with a lower availability level enjoys a smaller market area, other things being equal. Note that as the price p_i decreases, the market area of firm i expands until it includes the entire linear market.

If we consider the market areas of the two firms together, four basic configurations are illustrated in Figure 2. Appendix A states the conditions on prices for each configuration.

Figure 2(a) illustrates a situation where the market areas of firms A and B do not overlap. The firms' prices are said to be *monopolistic* because all customers in a firm's market area attempt to purchase only from that firm. Customers outside the market areas of firms A and B substitute the outside product.

Figure 2(b) illustrates a situation where the two firms' market areas do overlap. If, in addition, a firm's market area does not include the entire market, then its price is said to be *competitive.* In Figure 2(b), both firms' prices are "competitive" by this definition. The optimal search strategies are identified by the upper envelope of the expected surplus curves. Customers in the overlap region use the contingent search strategies, S_{AB} or S_{BA}. Customers from firm A to the point Y_A use S_A. Between this point and X, customers use S_{AB}. Moving to the right of point X, customers switch to S_{BA}; between Y_B and firm B, customers use S_B.

Figure 2(c) illustrates a situation where both firms' prices are *supercompetitive*. Each firm's price is low enough that its market area includes all customers in the linear market. Unlike the case for competitive prices, the contingent search strategy S_{ij} uniformly dominates the one-stop search strategy S_i, when firm j's price is supercompetitive. Any

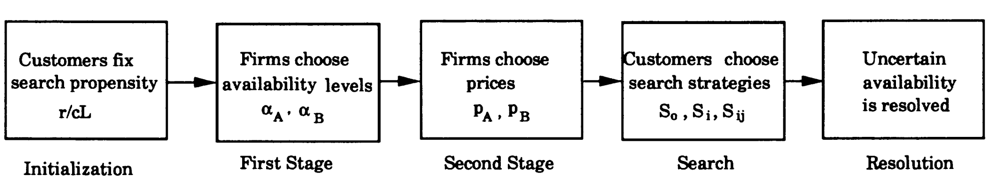

FIGURE 1. Sequence of Activities in the Availability Model.

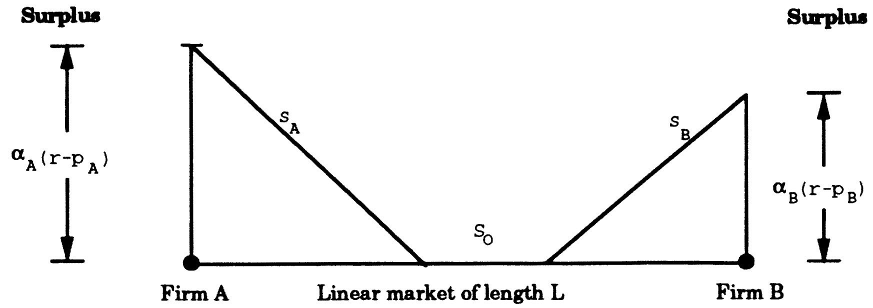

FIGURE 2a. Monopolistic Configuration.

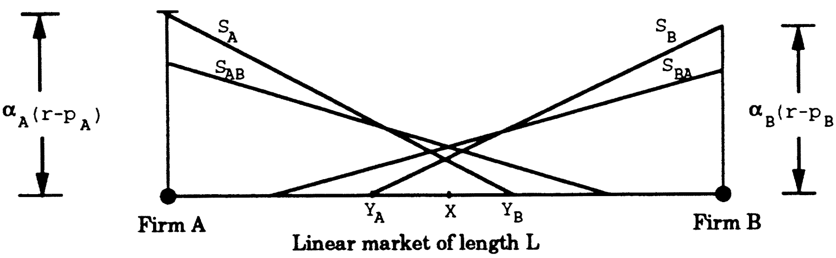

FIGURE 2b. Competitive Configuration.

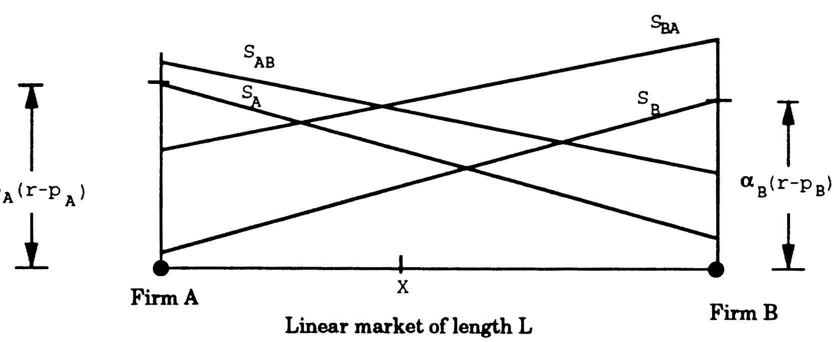

FIGURE 2c. Supercompetitive Configuration.

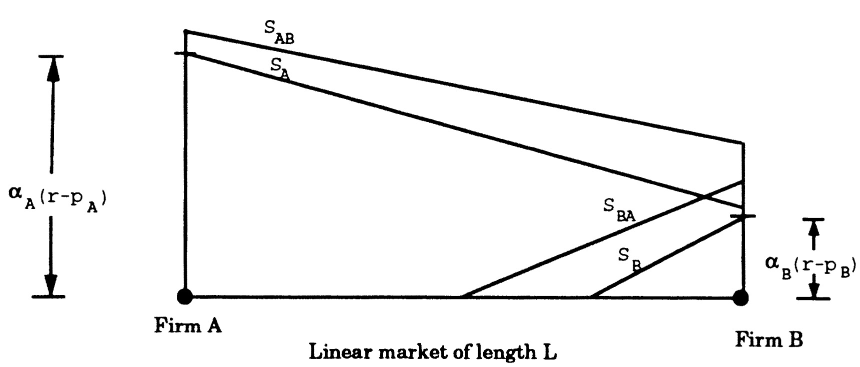

FIGURE 2d. Undercutting Configuration.

FIGURE 2. Four Configurations of Search Strategies.

customer who visits firm i first and finds the product unavailable will therefore search firm j for the product.

Figure 2(d) illustrates a situation where firm A charges an *undercutting* price. If firm i lowers its supercompetitive price sufficiently, it can "undercut" firm j so that the entire market chooses to visit firm i first. Firm j then only serves customers in its market area with probability $(1 - \alpha_i)$. Figure 2(d) illustrates the case where $i = A$ and $j = B$.

2.3. *Firms' Profit Functions*

The computation of firms' profit functions requires (i) the conditions for prices to be monopolistic, competitive, supercompetitive, or undercutting and (ii) the locations of the points X, Y_A, and Y_B in Figure 2. For a given set of prices p_A and p_B, the previous section determines the optimal search strategy for each customer in the market. This information enables the calculation of firm i's profit function $\pi_i(p_i, p_j)$ in a straightforward way. The profit functions are displayed in (1), where

$$x_i = [\alpha_i/(\alpha_i + \alpha_j)] \cdot [L + \alpha_j(p_j - p_i)/c],$$
$$y_i = L - \alpha_j(r - p_j)/c \quad \text{and} \quad i, j \in \{A, B\}.$$

Appendix A gives the calculations for the profit functions.

$$\pi_i(p_i, p_j) = \alpha_i \cdot p_i L \quad \text{if} \quad 0 \le p_i \le p_j - cL/\alpha_i, \tag{1a}$$
$$= \alpha_i \cdot p_i[x_i + (1 - \alpha_j)x_j] \quad \text{if} \quad p_j - cL/\alpha_i \le p_i \le r - cL/\alpha_i, \tag{1b}$$
$$= \alpha_i \cdot p_i[x_i + (1 - \alpha_j)(x_j - y_j)]$$
$$\text{if} \quad r - cL/\alpha_i \le p_i \le r(\alpha_i + \alpha_j)/\alpha_i - \alpha_j p_j/\alpha_i - cL/\alpha_i, \tag{1c}$$
$$= \alpha_i^2 \cdot p_i \cdot (r - p_i)/c$$
$$\text{if} \quad r(\alpha_i + \alpha_j)/\alpha_i - \alpha_j p_j/\alpha_i - cL/\alpha_i \le p_i \le r, \tag{1d}$$
$$= (1 - \alpha_j) \cdot \alpha_i^2 \cdot p_i \cdot (r - p_i)/c$$
$$\text{if} \quad p_i \ge p_j + cL/\alpha_j \quad \text{and} \quad p_i \ge r - cL/\alpha_i, \tag{1e}$$
$$= (1 - \alpha_j) \cdot \alpha_i \cdot p_i \cdot L$$
$$\text{if} \quad p_i \ge p_j + cL/\alpha_j \quad \text{and} \quad p_i \le r - cL/\alpha_i. \tag{1f}$$

3. An Equilibrium Analysis of the Availability Model

The profit functions in (1) are used to derive the Nash equilibrium prices p_A^* and p_B^* in the second stage of the model for fixed availability levels. Thus the profits for a given r, c, L, α_A, and α_B satisfy

$$\pi_A(p_A^*, p_B^*) \ge \pi_A(p_A, p_B^*) \quad \text{for all} \quad p_A \in [0, r] \quad \text{and}$$
$$\pi_B(p_A^*, p_B^*) \ge \pi_B(p_A^*, p_B) \quad \text{for all} \quad p_B \in [0, r]. \tag{2}$$

We restrict our analysis to pure strategies in prices.[5] The second-stage equilibrium prices are then used to analyze the full game over both availability levels and prices.

3.1. *Analysis of the Price Subgame*

Figure 3 shows the various equilibria that can exist in the second-stage price game. If the market areas of the two firms do not overlap in equilibrium, we have a "monopolistic" equilibrium. If the market areas just touch each other, we have a "touching I" equilibrium.

[5] The main implications of the paper are not affected by this restriction, even though an equilibrium in pure strategies may not exist for some parameter values as illustrated in Figure 4.

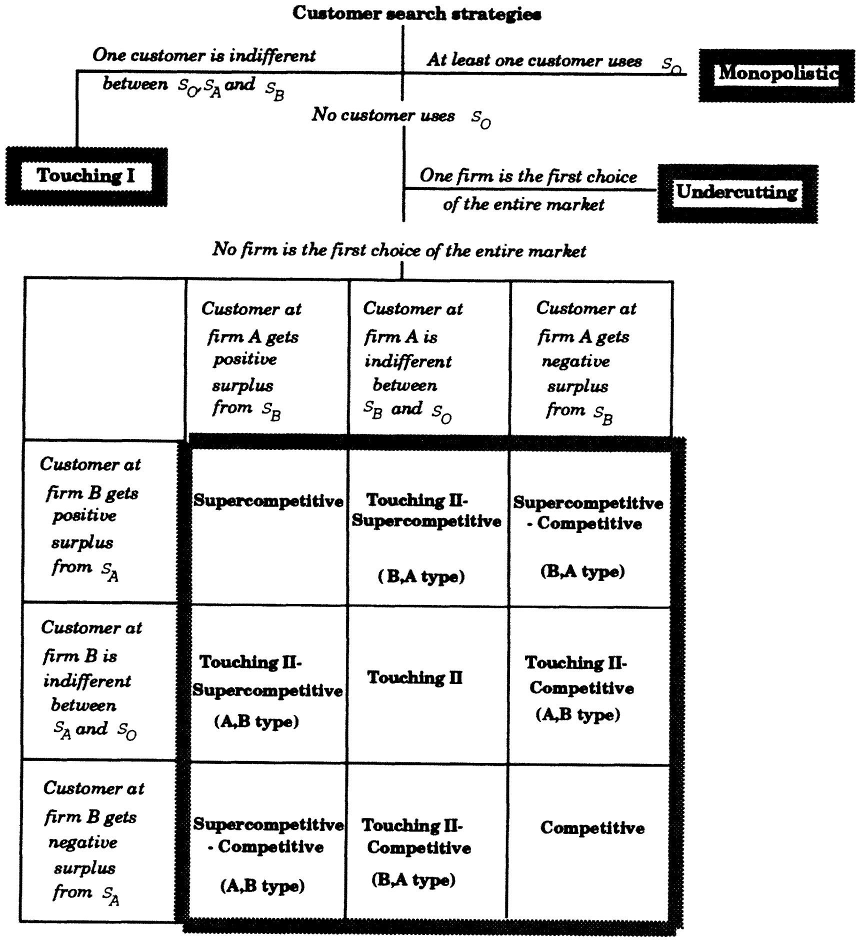

FIGURE 3. Pure and Hybrid Configurations.

On the other hand, if the market areas of the two firms overlap, then other equilibria are possible. If a firm undercuts its competitor in equilibrium, we have an "undercutting" equilibrium. Other equilibria depend on whether one or both firms charge competitive prices, supercompetitive prices, or "touching II" prices. The latter case occurs when firm i's market area just touches firm j at the far end of the market line.

THEOREM 1. *For a given reservation price r, search cost c, market length L, and product availability levels α_A at firm A and α_B at firm B, Table* 1(a) *provides necessary and sufficient conditions for the existence of the Nash equilibrium prices and profits in Table* 1(b).

PROOF. See Appendix B.

3.2. *Analysis of the Availability-Price Game*

This section derives a symmetric solution for the first-stage availability game and shows that this solution is the only equilibrium of the full game. An availability equilibrium in the first-stage game is a pair of availability levels α_A^* and α_B^* that satisfy the following conditions for a given r, c and L:

$$\pi_A(\alpha_A^*, \alpha_B^*, p_A^*, p_B^*) \geq \pi_A(\alpha_A, \alpha_B^*, p_A^*, p_B^*) \quad \text{for all} \quad \alpha_A \in [0, 1],$$

$$\pi_B(\alpha_A^*, \alpha_B^*, p_A^*, p_B^*) \geq \pi_B(\alpha_A^*, \alpha_B, p_A^*, p_B^*) \quad \text{for all} \quad \alpha_B \in [0, 1], \qquad (3)$$

TABLE 1(a)

Conditions for Equilibrium in the Price Subgame

The following are the conditions for different equilibria when $\alpha_i \geq \alpha_j$, $i, j \in \{A, B\}$.

Equilibria	Conditions	Equilibria	Conditions
Monopolistic	$0 \leq r/cL \leq \mu_1(\alpha_i, \alpha_j)$	Touching II–Supercompetitive	If $(\alpha_i^2 - \alpha_j^2 - \alpha_i\alpha_j^2 - 2\alpha_i^2\alpha_j^2) \geq 0$, $\mu_5^{ij}(\alpha_i, \alpha_j) \leq r/cL \leq \mu_6^{ij}(\alpha_i, \alpha_j)$; Otherwise, $\mu_5^{ij}(\alpha_i, \alpha_j) \leq r/cL \leq \mu_7^{ij}(\alpha_i, \alpha_j)$.
Touching I	$\mu_1(\alpha_i, \alpha_j) \leq r/cL \leq \mu_2(\alpha_i, \alpha_j)$		
Competitive	$\mu_2(\alpha_i, \alpha_j) \leq r/cL \leq \mu_3^{ij}(\alpha_i, \alpha_j)$	Supercompetitive	$\mu_7^{ij}(\alpha_i, \alpha_j) \leq r/cL \leq \mu_8^{ij}(\alpha_i, \alpha_j)$, $(\alpha_i^2 - \alpha_j^2 - \alpha_i\alpha_j^2 - 2\alpha_i^2\alpha_j^2) \leq 0$.
Touching II–Competitive	$\mu_3^{ij}(\alpha_i, \alpha_j) \leq r/cL \leq \mu_4^{ij}(\alpha_i, \alpha_j)$	Undercutting	$\mu_6^{ij}(\alpha_i, \alpha_j) \leq r/cL \leq \mu_9^{ij}(\alpha_i, \alpha_j)$, $(\alpha_i^2 - \alpha_j^2 - \alpha_i\alpha_j^2 - 2\alpha_i^2\alpha_j^2) \geq 0$.
Touching II	$\mu_4^{ij}(\alpha_i, \alpha_j) \leq r/cL \leq \mu_5^{ij}(\alpha_i, \alpha_j)$		

Note 1. $\mu_1(\alpha_i, \alpha_j) = 2/(\alpha_i + \alpha_j)$,

$\mu_2(\alpha_i, \alpha_j) = (2\alpha_i + 2\alpha_j - \alpha_i\alpha_j)/[(\alpha_i + \alpha_j)(\alpha_i + \alpha_j - \alpha_i\alpha_j)]$,

$\mu_3^{ij}(\alpha_i, \alpha_j) = 2(2\alpha_i + \alpha_j - \alpha_i\alpha_j)/[\alpha_i(2\alpha_i + 2\alpha_j - 2\alpha_i\alpha_j + \alpha_j^2)]$,

$\mu_4^{ij}(\alpha_i, \alpha_j) = 2/\alpha_j$,

$\mu_5^{ij}(\alpha_i, \alpha_j) = (\alpha_i + \alpha_j + \alpha_i^2 - \alpha_i\alpha_j)/[\alpha_i^2\alpha_j]$,

$\mu_6^{ij}(\alpha_i, \alpha_j) = (\alpha_i + \alpha_j + \alpha_i^2 + \alpha_i\alpha_j)/(\alpha_i^2\alpha_j)$,

$\mu_7^{ij}(\alpha_i, \alpha_j) = (2\alpha_i^2 + \alpha_j^2 + 3\alpha_i\alpha_j + \alpha_i\alpha_j^2 - \alpha_i^2\alpha_j)/[3\alpha_i^2\alpha_j^2]$,

$\mu_8^{ij}(\alpha_i, \alpha_j) = [(2\alpha_i^2 - \alpha_i^2\alpha_j + 3\alpha_i\alpha_j - 2\alpha_i\alpha_j^2 + \alpha_j^2)^2 + 9\alpha_i^2\alpha_j^2(1 - \alpha_j)(\alpha_i + \alpha_j)]/$
$[9\alpha_i^3\alpha_j^2(1 - \alpha_j)(\alpha_i + \alpha_j)]$,

$\mu_9^{ij}(\alpha_i, \alpha_j) = (\alpha_i + \alpha_j - \alpha_i\alpha_j)/(\alpha_i\alpha_j^2)$.

Note 2. No equilibrium exists in pure strategies when $r/cL \geq \mu_9^{ij}(\alpha_i, \alpha_j)$ and $(\alpha_i^2 - \alpha_j^2 - \alpha_i\alpha_j^2 - 2\alpha_i^2\alpha_j^2) \geq 0$, or $r/cL \geq \mu_8^{ij}(\alpha_i, \alpha_j)$ and $(\alpha_i^2 - \alpha_j^2 - \alpha_i\alpha_j^2 - 2\alpha_i^2\alpha_j^2) \leq 0$.

where p_A^* and p_B^* satisfy the second-stage conditions in (2) with $\alpha_A = \alpha_A^*$ and $\alpha_B = \alpha_B^*$.

A *symmetric* Nash equilibrium of the first-stage availability game is a pair of availability levels satisfying (3) with $\alpha_A^* = \alpha_B^* = \alpha^*$. In this case, the prices will also be symmetric with $p_A^* = p_B^* = p^*$. When both firms choose the same availability level α in the first stage, Table 2 gives necessary and sufficient conditions from Table 1 for the existence of Nash equilibrium prices and profits in the second-stage game.

The common availability level α is an equilibrium of the first-stage availability game if and only if neither firm can gain by changing α. We now examine how a firm's profits in the price subgame change as a function of the firm's availability level.

THEOREM 2. *Suppose firms A and B choose a symmetric availability level α in the first stage of the model.*

(a) *If the equilibrium in the price subgame is* supercompetitive, *then*
  (1) $\partial\pi_i(p^*)/\partial\alpha_i(\alpha) < 0$, *and*
  (2) $\partial p_i^*/\partial\alpha_i(\alpha) < 0$ *and* $\partial p_j^*/\partial\alpha_i(\alpha) < 0$.

(b) *If the equilibrium in the price subgame is* competitive, *then*
  (1) $\partial\pi_i(p^*)/\partial\alpha_i(\alpha) > 0$, *and*
  (2) $\partial p_i^*/\partial\alpha_i(\alpha) < 0$ *and* $\partial p_j^*/\partial\alpha_i(\alpha) < 0$.

(c) *If the equilibrium in the price subgame is* monopolistic, *then*
  (1) $\partial\pi_i(p^*)/\partial\alpha_i(\alpha) > 0$, *and*
  (2) $\partial p_i^*/\partial\alpha_i(\alpha) = 0$ *and* $\partial p_j^*/\partial\alpha_i(\alpha) = 0$.

PROOF. See Appendix B.

The first part of Theorem 2 states that a firm gains by *lowering* its availability level with supercompetitive prices and by *raising* its availability level with competitive or monopolistic prices. The second part of Theorem 2 states that the equilibrium prices

TABLE 1(b)

Equilibrium Prices and Profits of the Price Subgame

The following are the equilibrium prices and profits when $\alpha_i \geq \alpha_j$, $i, j \in \{A, B\}$.

Monopolistic Equilibrium

$p_i^* = p_j^* = r/2,$

$\pi_k(\bar{p}^*) = [\alpha_k^2 r^2]/4c, \quad k = i, j.$

Touching I Equilibrium

$p_i^* = p_j^* = r - cL/(\alpha_i + \alpha_j)$

$\pi_k(\bar{p}^*) = [\alpha_k^2/(\alpha_i + \alpha_j)] \cdot p_k^* \cdot L, \quad k = i, j.$

Competitive Equilibrium

$$p_i^* = [\alpha_j(2\alpha_i + 2\alpha_j - \alpha_i\alpha_j) \cdot cL + (\alpha_i + \alpha_j) \times (2\alpha_i + 2\alpha_j - 4\alpha_i\alpha_j - \alpha_j^2 + \alpha_i\alpha_j^2) \cdot r] / [4(\alpha_i + \alpha_j - \alpha_i\alpha_j)^2 - \alpha_i^2\alpha_j^2],$$

$$p_j^* = [\alpha_i(2\alpha_i + 2\alpha_j - \alpha_i\alpha_j) \cdot cL + (\alpha_i + \alpha_j) \times (2\alpha_i + 2\alpha_j - 4\alpha_i\alpha_j - \alpha_i^2 + \alpha_j\alpha_i^2) \cdot r] / [4(\alpha_i + \alpha_j - \alpha_i\alpha_j)^2 - \alpha_i^2\alpha_j^2],$$

$$\pi_k(\bar{p}^*) = [(\alpha_i + \alpha_j - \alpha_i\alpha_j) \cdot \alpha_k^2 p_k^{*2}] / [c(\alpha_i + \alpha_j)], \quad k = i, j.$$

Touching II—Competitive Equilibrium

$p_i^* = r - cL/\alpha_i; \quad p_j^* = r/2,$

$\pi_i(\bar{p}^*) = [\alpha_i/(\alpha_i + \alpha_j)] \cdot p_i^* \cdot [L(\alpha_i + \alpha_j) - \alpha_i\alpha_j^2 r/2c],$

$\pi_j(\bar{p}^*) = [\alpha_j^2/(\alpha_i + \alpha_j)] \cdot [\alpha_i + \alpha_j - \alpha_i\alpha_j] \cdot r^2/4c.$

Touching II Equilibrium

$p_k^* = r - cL/\alpha_k, \quad k = i, j,$

$\pi_k(\bar{p}^*) = [\alpha_k/(\alpha_i + \alpha_j)] \cdot p_k^* \cdot [L(\alpha_i + \alpha_j - \alpha_i\alpha_j)].$

Touching II—Supercompetitive Equilibrium

$p_i^* = r - cL/\alpha_i,$

$p_j^* = r/2 + cL \cdot [(\alpha_i + \alpha_j - \alpha_i^2 - \alpha_i\alpha_j)/(2\alpha_i^2\alpha_j)],$

$\pi_i(\bar{p}^*) = \alpha_i \cdot p_i^* \cdot L \cdot (2\alpha_i + \alpha_j - \alpha_i\alpha_j),$

$\pi_j(\bar{p}^*) = \{\alpha_i^2\alpha_j^2/[c(\alpha_i + \alpha_j)]\} \cdot p_j^{*2}.$

Supercompetitive Equilibrium

$p_i^* = [cL(2\alpha_i^2 - \alpha_i^2\alpha_j + 3\alpha_i\alpha_j - 2\alpha_i\alpha_j^2 + \alpha_j^2)/(3\alpha_i^2\alpha_j^2)],$

$p_j^* = [cL(2\alpha_j^2 - \alpha_j^2\alpha_i + 3\alpha_i\alpha_j - 2\alpha_j\alpha_i^2 + \alpha_i^2)/(3\alpha_i^2\alpha_j^2)],$

$\pi_k(\bar{p}^*) = [\alpha_i^2\alpha_j^2/(\alpha_i + \alpha_j)] \cdot p_k^{*2}/c, \quad k = i, j.$

Undercutting Equilibrium

$p_i^* = r - cL/\alpha_i,$

$p_j^* = r - cL(\alpha_i + \alpha_j)/(\alpha_i\alpha_j),$

$\pi_i(\bar{p}^*) = \alpha_i \cdot (1 - \alpha_j) \cdot (r - cL/\alpha_i) \cdot L,$

$\pi_j(\bar{p}^*) = \alpha_j \cdot [r - cL(\alpha_i + \alpha_j)/(\alpha_i\alpha_j)] \cdot L.$

Note 1. $\bar{p}^* = (p_i^*, p_j^*)$.

Note 2. The equilibrium prices are unique except for the touching I equilibrium, where there is a continuum of prices defined by the relation $\alpha_i p_i^* + \alpha_j p_j^* = r(\alpha_i + \alpha_j) - cL$. We chose $p_i^* = p_j^* = r - cL/(\alpha_i + \alpha_j)$ because at the boundary of the touching I region both firms' prices are equal in the adjacent monopolistic and competitive regions.

increase with lower availability levels in the supercompetitive and competitive cases; the equilibrium prices in the monopolistic case do not depend on the availability level.

We use the results in Theorem 2 to establish conditions for the existence of a symmetric availability level α from which neither firm would deviate in the full game.

THEOREM 3. *In the two-stage availability-price game, the symmetric equilibrium availability level is given by*

(a) $\alpha^* = 1$ *if* $0 < r/cL \leq 2$,

(b) $\alpha^* = [2/(r/cL)]^{1/2} < 1$ *if* $2 < r/cL \leq 6.84$.[6]

Furthermore when $0 < r/cL \leq 6.84$, *the symmetric equilibrium is the unique solution of the full game. If* $r/cL > 6.84$, α^* *cannot be computed because a pure strategy equilibrium does not exist in the price subgame. In this case, however,* $\alpha = 1$ *is never optimal.*

PROOF. See Appendix B.

3.3. *Remarks*

The ratio r/cL is said to be a customer's *search propensity* for obtaining the product; it is the reservation price divided by the cost of traveling to both firms. When the search

[6] The minimal value with respect to α of the function $\xi_5(\alpha)$ is 6.84. The function $\xi_5(\alpha)$ defines the upper boundary of the supercompetitive region with respect to r/cL in Table 2 (see also Figure 4).

TABLE 2

Price Subgame Equilibrium Conditions, Prices, and Profits when $\alpha_A = \alpha_B = \alpha$

Monopolistic Equilibrium	Touching II Equilibrium
$0 < r/cL < \xi_1(\alpha)$, $p^* = r/2$, $\pi(p^*) = [\alpha^2 r^2]/4c$.	$\xi_3(\alpha) \le r/cL \le \xi_4(\alpha)$, $p^* = r - cL/\alpha$, $\pi(p^*) = (\alpha/2)(2 - \alpha)(r - cL/\alpha)L$.
Touching I Equilibrium	**Supercompetitive Equilibrium**
$\xi_1(\alpha) \le r/cL \le \xi_2(\alpha)$, $p^* = r - cL/2\alpha$, $\pi(p^*) = (\alpha/2)[r - cL/2\alpha]L$.	$\xi_4(\alpha) < r/cL \le \xi_5(\alpha)$, $p^* = cL(2 - \alpha)/\alpha^2$, $\pi(p^*) = (\alpha^3/2)(p^{*2}/c)$.
Competitive Equilibrium	
$\xi_2(\alpha) < r/cL < \xi_3(\alpha)$, $p^* = [cL + r(1 - \alpha)]/(4 - 3\alpha)$, $\pi(p^*) = \alpha^2(2 - \alpha)p^{*2}/2c$.	

Note 1. $p_A^* = p_B^* = p^*$,
$\xi_1(\alpha) = 1/\alpha$,
$\xi_2(\alpha) = (4 - \alpha)/[2\alpha(2 - \alpha)]$,
$\xi_3(\alpha) = 2/\alpha$,
$\xi_4(\alpha) = 2/\alpha^2$,
$\xi_5(\alpha) = (4 - 2\alpha - \alpha^2)/[2\alpha^2(1 - \alpha)]$.

Note 2. No equilibrium exists in pure strategies in price when $r/cL \ge \xi_5(\alpha)$.

Note 3. The equilibrium prices are unique except for the touching I equilibrium, where there is a continuum of prices defined by the relation $\alpha p_B^* + \alpha p_A^* = r(2\alpha) - cL$. We chose $p_A^* = p_B^* = r - cL/(2\alpha)$ because of symmetry.

propensity is low (i.e., $r/cL \le 2$), some customers will decide not to search firm j if they find the product is unavailable at firm i. In this case, the firms' equilibrium availability level is $\alpha^* = 1$; each firm maximizes its profits by always having the product in stock. These results are entirely consistent with popular recommendations to have as high an availability level as possible (Bass 1989).

Such recommendations are mistaken, however, when customers' search propensity for the product is high (i.e., $r/cL > 2$). Theorem 3 shows that firms can profit from occasional stockouts. The equilibrium availability level (if one exists) is $\alpha^* = [2/(r/cL)]^{1/2} < 1$; even if an equilibrium does not exist, it is still not optimal to have $\alpha = 1$. Section 4.1 explains this result in terms of the reduced price competition between firms.

Given the symmetry assumed between firms A and B, no asymmetric equilibria exist for the full game, and hence the symmetric availability level α^* is the unique equilibrium (Balachander 1991). On the other hand, asymmetries between the two firms could occur, for example, if customers were not uniformly distributed over the linear market or if the costs of maintaining product availability differed across firms (e.g., see Balachander and Farquhar 1992). Section 4.2 also considers a special case of asymmetry where one firm precommits to sure availability.

Figure 4 is a "phase diagram" illustrating the equilibrium regions obtained in the price subgame as a function of customers' search propensity r/cL and the common availability level α. Figure 4 also traces the optimal availability level α^* for firms as a function of r/cL. The figure shows that for $2 < r/cL \le 6.84$, the availability equilibrium occurs at the boundary of the supercompetitive and touching II equilibria, which is represented by the function $\xi_4(\alpha)$ (see also Table 2).

Figure 4 also illustrates the nonexistence of price equilibria when $r/cL > 6.84$. Nevertheless a firm's expected profits with an availability level α satisfying $r/cL = 2/\alpha^2$ are

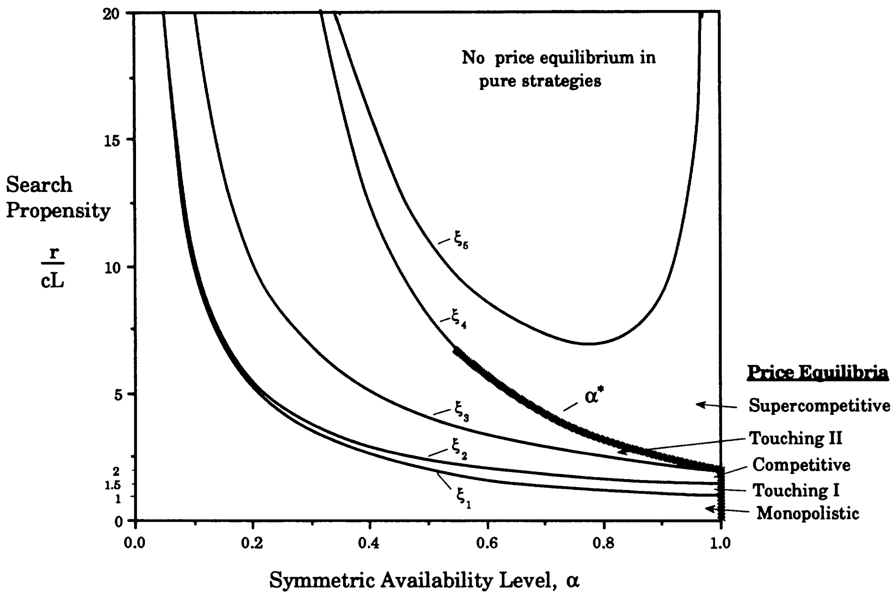

FIGURE 4. Phase Diagram of Equilibrium Analysis when $\alpha_A = \alpha_B = \alpha$.

always greater than those with sure availability level. Thus $\alpha = 1$ is never optimal for $r/cL > 6.84$.

4. Further Results

4.1. *Strategic Interactions*

The results in Theorems 2 and 3 can be explained by examining the sensitivity of equilibrium profits for firm i to changes in the availability level α_i (cf. Fudenberg and Tirole 1984, Moorthy 1985). Let q_i denote the expected quantity sold by firm i. Then

$$\partial\pi_i(p_A^*, p_B^*)/\partial\alpha_i = p_i^*(\partial q_i^*/\partial\alpha_i) + p_i^*(\partial q_i^*/\partial p_j)(\partial p_j^*/\partial\alpha_i) + (\partial p_i^*/\partial\alpha_i)[p_i^*(\partial q_i^*/\partial p_i) + q_i^*]. \quad (4)$$

The first term on the right in (4) captures the *direct effect* of a change in the availability level α_i on the expected quantity sold by firm i. Furthermore, a change in α_i may indirectly affect the expected quantity sold by firm i through firm j's pricing behavior; the second term on the right in (4) represents this *strategic effect*. Finally, the change in α_i may affect firm i's optimal price in the second stage. The third term in (4) represents the impact on firm i's profits due to a change in its optimal second-stage price. If the change in firm i's price is in the neighborhood of the optimal value, then it has a negligible effect on firm i's profits. Indeed, the last term on the right in (4) is zero because of the first-order conditions required for an equilibrium in the price subgame.

A firm's choice of an availability level α therefore depends on the sum of the direct effect on the expected quantity sold and the strategic effect on the firms' prices. The key to understanding the relative tradeoff between the direct effect and the strategic effect is to examine the search propensity of customers. In the supercompetitive region of Figure 4, where the search propensity is high,

$$q_i^* = [\alpha_i/(\alpha_i + \alpha_j)] \cdot \{L[\alpha_i + (1 - \alpha_j)\alpha_j]\}, \qquad i = A, B,$$

$$\partial q_i^*/\partial\alpha_i = [(\alpha_i^2 + 2\alpha_i\alpha_j)/(\alpha_i + \alpha_j)^2] \cdot L + [\alpha_j^2(1 - \alpha_i)]L/(\alpha_i + \alpha_j)^2 > 0. \quad (5)$$

Therefore, the direct effect is positive—with prices fixed, a lower availability level reduces the expected quantity sold, which in turn reduces profits.

On the other hand, Theorem 2(a) states that a lower availability level at firm i results in higher prices at both firms. The intuition is that when firm i chooses to allow occasional stockouts with $\alpha_i < 1$, the competing firm j loses fewer customers by charging a higher price. Moreover, firm j serves all customers who encounter stockouts at firm i, because of the high search propensity of customers. Both considerations result in higher prices charged by firm j, which in turn allows firm i itself to charge a higher price. Thus the strategic effect between firms is negative—both firms can increase their prices and profits when the availability level is decreased.[7]

The overall sign of $\partial\pi_i(p_A^*, p_B^*)/\partial\alpha_i$ in (4) depends on the relative magnitudes of the direct effect and the strategic effect. In the supercompetitive region, the strategic effect outweighs the direct effect, so firm i's profits increase as α_i decreases within this region. Thus both firms can gain by having occasional stockouts.

On the other hand, the strategic effect need not always outweigh the direct effect. For the competitive equilibrium, Theorem 2(b) shows that the strategic effect on firm i's prices is driven by $\partial p_j^*/\partial\alpha_i$, which is negative. This strategic effect is not strong enough, however, to overwhelm the positive direct effect. Hence, a firm decreases profits by reducing its availability level.

The lower search propensity in the competitive region explains the diminished strategic effect. Since the prices of both firms are "competitive," some customers substitute the "outside product" if they find the product unavailable at either firm. Thus if a firm lowers its availability level, prices cannot be increased as much as in the supercompetitive case, where customers do not drop out of the market.

For the monopolistic price equilibrium, Table 2 shows that the equilibrium prices do not depend on α and hence the strategic effect is zero. Since the direct effect is positive, firm i always loses by lowering its availability level.

4.2. *Precommitment to Sure Availability*

An asymmetry occurs if firm B precommits to having sure availability, $\alpha_B = 1$, before firm A has chosen an availability level in the first stage of the model. Such circumstances might occur, for example, if firm B simultaneously serves a significant monopoly segment that would be jeopardized if its product were unavailable. Using an analysis like that in §3, Farquhar and Balachander (1990) show that firm A may choose to have occasional stockouts even though firm B has sure availability. If $2 < r/cL \le 7.46$, then

$$\alpha_A^* = [1 + (6r/cL - 3)^{1/2}]/(3r/cL - 2) < 1. \qquad (6)$$

The basic result in this asymmetric situation is the same as before. If customers' search propensity r/cL is high enough, firm A can gain more by reducing price competition through occasional stockouts than it loses from foregone sales.

4.3. *Cooperation Between Firms*

Suppose that both firms cooperate to maximize their combined profits, or that a parent corporation owns both firm A and firm B. Can the two firms increase their combined profits by introducing uncertain product availability at one or both firms?

[7] The following special case further illustrates the intuition of reduced price competition. Suppose that the unit search cost c is zero, so customers can search the two firms effortlessly and purchase from the firm having the product available at the lower price. If both firms offer sure availability of the product, the result is an equilibrium price and profits of zero for each firm (Bertrand 1883).

Suppose now that firm i chooses an availability level of 0.80, for example. Given that all customers have a positive reservation price r, firm j is thus assured of an expected profit of $0.20Lr$ if it charges r. If firm j is able to capture the entire market of length L, the lowest price it would charge is $0.20r$; otherwise firm j would do better by charging r and selling with probability 0.2 to the entire market. Firm i, in turn, can charge a price at least $0.20r$. Thus both firms have higher prices and profits by constraining product availability. (An anonymous reviewer suggested this illustration (see also Edgeworth 1897).)

THEOREM 4. *When firms A and B cooperate to maximize their combined profits, the optimal availability levels are* $\alpha_A^* = \alpha_B^* = 1$, *for all values of* r, c, *and* L.

PROOF. See Appendix B.

The answer in Theorem 4 is no, because strategic effects are absent in the cooperative outcome. When firms coordinate setting prices, they do not need to forego the loss in sales incumbent with occasional stockouts to increase prices and profits. Thus the optimal policy is sure availability at both firms.

5. Discussion

5.1. *Comparing the Availability Model with Other Models*

A key in analyzing the availability model is the *search propensity* r/cL, the ratio of customers' reservation price to the search cost in visiting both firms. If this ratio is high enough, then in equilibrium all customers who do not find the product available at firm i will search firm j. In this case, the model implies that both firms will offer the same availability level α^*, which is less than 1. Both firms will charge higher prices and make higher profits than with sure availability.

On the other hand, the search propensity r/cL might not be high if customers have either (i) a relatively low reservation price r (purchasing the product is not much more attractive than substituting the outside product), or (ii) relatively high search costs cL (traveling to the second firm is unattractive for some customers who find the product out-of-stock at the first firm). In either case, the lower search propensity creates the possibility of customers dropping out of the market and thus reduces the firms' incentive to increase prices with an occasional stockout. Both firms therefore choose sure availability.[8]

The results of our availability model can be compared with the recommendations of other models. The conventional wisdom about product availability is drawn primarily from inventory models (e.g., Bowersox 1974). If higher availability levels are costless to achieve, inventory models argue for sure availability. Our analysis shows that the optimal availability level is less than one, however, if customers' search propensity is high. Ignoring the effects of reduced price competition can therefore lead to the wrong conclusion about product availability levels.

It seems natural to compare the availability model to models of capacity-constrained price competition (e.g., Edgeworth 1897, Kreps and Scheinkman 1983). While these models suggest that capacity constraints can soften price competition between firms, the attractiveness to customers of a capacity-constrained firm is largely ignored.[9] Such models thus assume that a firm's demand is unaffected by its inability to supply everyone interested in purchasing its product. In contrast, the availability model assumes that a firm's demand *is* affected by its stockout level. Extrapolating the results of capacity-constrained price competition to the situations considered in this paper therefore is not as straightforward as might first appear.

Occasional stockouts can reduce price competition, though other strategies share the same objective: constraining capacity (as described above), differentiating by store location or product attributes (Hotelling 1929, Moorthy 1984), developing brand loyalty among customers (Schmalensee 1983, Narasimhan 1988, Raju et al. 1990), and using channel intermediaries (McGuire and Staelin 1983). A firm can use multiple strategies if they are compatible. Off-price retailers such as warehouse outlets may reduce price competition,

[8] Daugherty and Reinganum (1991) independently obtained similar results on product availability in a somewhat different framework.

[9] Peters (1984) and Dixon (1990) attempt to model this problem in the context of capacity-constrained price competition. Also, Carlton (1978) and Gould (1978) analyze the simultaneous choice of capacity and price by undifferentiated firms when demand is affected by the probability of a stockout.

for example, by both choosing less popular locations and having higher stockout levels. On the other hand, it may be difficult for a retailer to both develop brand loyalty and have high stockout levels.

There are other competitive rationales for limited product availability besides reducing price competition. Hess and Gerstner (1987) show that firms may intentionally understock a loss-leader product and offer rainchecks. The firms then sell impulse goods when customers make a second visit to the firm to redeem their rainchecks. Also, Gerstner and Hess (1990) show that firms may understock a featured product to sell customers a more profitable product promoted only in the store.[10]

5.2. *Extensions and Limitations*

The model's basic results on limiting availability hold even under alternative interpretations. For example, a "product" can be regarded as a customer service, a shopping basket of different products, or any one of a set of substitutable products. A more general model could include product switching behavior at each firm.

Each "firm" in the model might be interpreted as a single firm or a cluster of firms at one location. While there are many natural duopoly settings, the assumption of two firms makes the model analysis tractable. As the number of firms in a market increases, we would predict a weakening of the strategic effect because each firm's ability to influence other firms' prices would be diminished. Extensions of the Hotelling model to more than two firms, however, have been problematic (Graitson 1982).

The "linear market" can be interpreted as a unidimensional space wherein customers' positions represent their ideal preferences for firms' products. The decision problem facing customers is thus one of choosing between firms offering different prices, availability levels, and distances from their ideal products. The "search costs" from customers' ideals to either firm could include the additional costs in adapting a firm's product to specific customer needs. Other extensions of the model might relax the assumption of linear search costs (d'Aspremont et al. 1979, Economides 1986). Allowing customers to have different search costs may result in firms segmenting the market by offering different availability levels (Prescott and Visscher 1977).

Nonuniformity in the distribution of customers can affect the results of the model. A high concentration of customers may make it optimal for one firm to have sure availability, while another firm serving fewer customers may benefit from occasional stockouts.[11] The fundamental relationship between direct and strategic effects, however, remains the same (Shilony 1981).

The availability model also assumes that the product's marginal cost is identical for both firms and equal to zero. In practice, however, the marginal cost is likely to be an increasing function of the availability level. Availability levels can depend on the number of employees with the firm, the reputation of the firm's suppliers, the number and proximity of warehouses, the backroom storage space in the firm's stores, and other long-term factors. Balachander and Farquhar (1993) explore the impact of relaxing this assumption.

[10] The motivation for Hess and Gerstner's results is quite different than ours. Their findings depend on firms selling at least *two* products, while competing in price on only one of the products (e.g., the loss-leader or the featured product). Ibrahim and Thomas (1986) derive analogous results from the spillover effects in a multi-item inventory model: a firm may intentionally understock one item to benefit from the higher sales of another item. The availability model, however, requires only a single product to obtain results on the competitive effects of stockouts.

[11] If the distribution of customers were skewed towards firm B in the market, for example, its direct loss from foregone sales would likely be much higher than firm A's loss. Unless the strategic effect was very strong, we would expect firm B to choose sure availability (see §4.2). On the other hand, the skewed customer distribution would encourage firm A to have occasional stockouts if customers' search propensity were high enough. Therefore, with the customer distribution skewed towards firm B and a high search propensity, we would predict that $\alpha_A^* < 1$, $\alpha_B^* = 1$ and $p_A^* < p_B^*$.

The availability model might also be extended to incorporate dynamic elements, such as product availability levels that vary over time, customer learning of firms' availability levels and reduced patronage after experiencing a stockout, customers' hedging against product unavailability by stocking up, or firms' backordering of out-of-stock products. Even though the availability model is static, its results hold for finite repetitions of the game. Infinite repetitions of the game, however, may allow other equilibria that depend on punishment strategies (Friedman 1971).

Empirical research might focus on the relationship among the frequency of stockouts, customer search propensity, and price sensitivity. The availability model yields predictions that can be tested empirically (e.g., see Wilkie and Dickson 1985, Straughn 1991).

5.3. *Policy Implications*

Our research shows how a desire to reduce price competition can lead firms to increase their incidence of stockouts. This result offers an explanation for the retail store behavior observed by the Federal Trade Commission (FTC) in its investigations of the availability of advertised items in food stores and other retail outlets. One government survey of 137 stores operated by 10 leading food chains in San Francisco and Washington, DC reported,

> . . . a total of 11 percent of the advertised items in the two cities were found to be unavailable . . . Between 5 and 10 percent of the stores had fewer than half of the items featured in advertisements available . . . (*Federal Register*, 1971, v. 36, n. 93, pp. 8777–8778).

On the basis of these findings, the FTC enacted the "Unavailability Rule" in May 1971 making it an "unfair or deceptive act or practice" if "stores do not have the advertised products in stock and readily available to customers" (*Federal Register*, 1971). Between 1973 and 1978, the Commission entered nine cease-and-desist orders against food chains charged with failing to have advertised items available. The FTC also charged a discount store chain, the Zayre Corporation, in 1977 for "failing to have . . . advertised items readily available for sale to customers."

The policy implications of the availability model are straightforward. When firms choose to have a higher frequency of stockouts, customers can suffer from higher search costs, a greater likelihood of not obtaining the product, and higher regular prices. In particular, we observe that customers are unlikely to complain about the higher regular prices with occasional stockouts, because customers never actually see the (lower) prices that would have been charged with sure availability!

Customers will complain about the increased search costs caused by stockouts, however, as the Federal Trade Commission learned recently in its 1989 hearings on amending the Unavailability Rule. The FTC received over 3000 letters from individuals including the following,

> Do you remember how much it costs to make all those trips to a store on the other side of town to be told they're all out? I bet my costs are a lot higher in gas, time, trouble, and temper (*Wall Street Journal*, July 3, 1985).

The recently amended FTC Rule now allows firms to issue rainchecks and quantity disclaimers as a defense against unavailability. While the government's economic analysis of stockouts does recognizes higher customer search costs, it ignores the strategic effects of stockouts for firms. Based on evidence presented by industry trade groups, the FTC concluded that a higher frequency of stockouts would decrease prices because of lower costs at stores (*Federal Register* 1989). In sharp contrast, our research shows that profit-maximizing firms may choose a higher frequency of stockouts to increase prices (even if firms' costs of maintaining availability at stores were zero). Our arguments are particularly relevant wherever only a few stores compete in a given market and customers tend to search stores until the products are available. These findings point to the need for further discussion on the public policy debate concerning product availability.

The availability model also has implications for off-price retail outlets that tend to buy merchandise opportunistically and thus sacrifice continuity of assortment. In Memphis, for example, Bud's Warehouse Outlet competes with Wal-Mart and other large discount chains.

> Wal-Mart's strength is in offering basic merchandise that is "replenished on a day-to-day basis in order to provide customers with a consistent assortment that they can depend on at excellent, everyday low prices." . . . Bud's merchandise, however, is largely comprised of. . . "one-time buys that may or may not be available for re-order. You can't walk into Bud's expecting to pick up a tube of Crest toothpaste. We might not have it" (*Memphis Business Journal*, November 26, 1990, p. 38).

An off-price outlet like Bud's could strive for better product availability by mixing regular purchases (of Crest toothpaste, for example) with opportunistic purchases (of "close-outs, over-runs, and irregulars"). One might argue that higher availability levels would attract more customers and enable the off-price outlet to charge somewhat higher prices. Our research maintains that such a strategy could be counter-productive because of the potential for increased price competition between the off-price retailer and other firms. The lower availability level at Bud's actually helps the off-price outlet to differentiate itself from full-service stores that offer higher continuity and availability.

In summary, limited product availability can benefit a firm if the strategic effect of lower price competition outweighs the direct effect of lost sales. In oligopolistic markets, where strategic interactions exist between firms, occasional stockouts can lower price competition between firms whenever customers are prone to search elsewhere upon encountering unavailability. Such behavior enables firms to charge higher prices and obtain higher profits than with sure availability. If customers are less prone to search further upon encountering unavailability, then firms optimize by not allowing stockouts.[12]

Acknowledgements. This research was supported by the National Science Foundation under Grant SES-8810846 (Farquhar), the Center for Product Research at Carnegie Mellon University, and the Product Strategy Institute at The Claremont Graduate School. The paper is based, in part, on Subramanian Balachander's doctoral thesis. The authors gratefully acknowledge research assistance by Ajay Agarwal; helpful comments from Robert F. Bordley, Anne Coughlan, Esther Gal-Or, Rashi Glazer, Francine Lafontaine, Rajiv Lal, Timothy W. McGuire, Anthony R. Pratkanis, Kannan Srinivasan, and three anonymous reviewers; and the suggestions of seminar participants at the University of California at Berkeley, the University of Rochester, Carnegie Mellon University and Rutgers University. The authors acknowledge Dennis Epple's assessment of the impact and direction of this research. Earlier versions of this paper were also presented at the ORSA/TIMS Meeting (October 1988) and at the Marketing Science Conferences (March 1989 and March 1990).

[12] This paper was received November 22, 1991, and has been with the authors 8 months for 1 revision. Processed by John R. Hauser.

Appendix A

(a) *Monopolistic Prices*

The market areas of firms A and B will not overlap if and only if the following condition holds:

$$\alpha_A(r - p_A) + \alpha_B(r - p_B) < cL.$$

This inequality implies that p_A and p_B satisfy

$$p_i > r(\alpha_i + \alpha_j)/\alpha_i - \alpha_j p_j/\alpha_i - cL/\alpha_i.$$

The firms' profit functions are given by (1a).

(b) *Competitive Prices*

Firm i's price is competitive if

$$r(\alpha_i + \alpha_j)/\alpha_i - \alpha_j p_j/\alpha_i - cL/\alpha_i < p_i < r - cL/\alpha_i.$$

The profit functions require the coordinate of the point X at which a customer is indifferent between strategies S_{AB} and S_{BA}. The expected costs of strategies S_{ij} and S_{ji} are equal at X, so

$$\alpha_i[p_i + cx_i] + (1 - \alpha_i)\{\alpha_j p_j + c[(L - x_i) + x_i]\} = \alpha_j[p_j + cx_j] + (1 - \alpha_j)\{\alpha_i p_i + c[(L - x_j) + x_j]\}.$$

Hence,

$$x_i = [\alpha_i/(\alpha_i + \alpha_j)]\cdot[L + \alpha_j(p_j - p_i)/c)].$$

Of course, $x_A + x_B = L$. The location of X and Y_j determines the profit of firm i in (1b). If y_j is the distance of Y_j to firm j, $y_j = L - \alpha_i(r - p_i)/c$.

(c) *Supercompetitive Prices*

This situation occurs when $p_i < r - cL/\alpha_i$. Then $y_j < 0$ and firm i's market area covers the entire market. The additional condition required to prevent firm i from undercutting firm j is $p_i > p_j - cL/\alpha_i$. The profit in (1c) applies to a firm charging a supercompetitive price.

(d) *Undercutting Prices*

The condition for firm i to undercut firm j is obtained by setting $x_i \geq L$ and observing that $p_i \leq p_j - cL/\alpha_i$.

Appendix B

This appendix outlines the proofs. The complete proofs are available in a separate Technical Appendix upon request from the authors.

PROOF OF THEOREM 1.

Step 1. The characteristic conditions for each equilibrium can be obtained from Figure 3 and Appendix A. For each equilibrium, we use the characteristic conditions and local optimality conditions to derive equilibrium prices, and necessary conditions on r, c, L, α_A, and α_B for the equilibrium. For all equilibria, the conditions on r, c, L, α_A, and α_B are in the form of bounds on r/cL that are functions of α_A and α_B.[13] The expressions for the bounds often depend on which of α_A or α_B is larger, as can be seen from Table 2.

Step 2. We can show that π_i is concave over

$$[0, \text{Min}\,\{p_j + cL/\alpha_j, r\}] \qquad \text{for} \qquad i, j \in \{A, B\}.$$

Thus, if $p_j^* \geq r - cL/\alpha_j$, the price p_i^* satisfying the local optimality condition is a global maximum of $\pi_i(p_i, p_j^*)$ over $[0, r]$, for $i, j \in \{A, B\}$. The necessary conditions on r/cL identified in Step 1 are then sufficient. If $p_j^* < r - cL/\alpha_j$, additional conditions on r/cL may be needed to ensure that firm i cannot gain by changing from p_i^* to a price greater than $p_j^* + cL/\alpha_j$. □

PROOF OF THEOREM 2.

Part (a). In supercompetitive equilibrium, we have

$$\partial\pi_i(\alpha, p^*)/\partial\alpha_i = -[p^*L(2 + \alpha)]/12 < 0,$$

$$\partial p_i^*(\alpha_i, \alpha_j)/\partial\alpha_i = cL[(-3\alpha_i - 2\alpha_j + 2\alpha_i\alpha_j)/(3\alpha_i^3\alpha_j)] < 0, \qquad \text{and}$$

$$\partial p_j^*(\alpha_i, \alpha_j)/\partial\alpha_i = cL[(-4\alpha_j - 3\alpha_i + \alpha_i\alpha_j)/(3\alpha_i^3\alpha_j)] < 0.$$

Parts (b) *and* (c). In competitive equilibrium, we have

$$\partial\pi_i(\alpha, p^*)/\partial\alpha_i = \{(p^* \cdot L)[\alpha(4 - \alpha)(3\alpha^2 - 12\alpha + 16) + \alpha(256 - 640\alpha + 536\alpha^2 - 178\alpha^3 + 18\alpha^4) \cdot s]\}/[4(4 - \alpha)(3\alpha - 4)^2],$$

$$\partial p_i^*(\alpha)/\partial\alpha_i = cL[(4 - \alpha)(3\alpha - 2) + s \cdot (4\alpha - 9\alpha^2 + 3\alpha^3)]/[\alpha(4 - \alpha)(4 - 3\alpha)^2], \qquad \text{and}$$

$$\partial p_i^*(\alpha)/\partial\alpha_j = cL[(2\alpha - 8) + s(12\alpha - 11\alpha^2 + 3\alpha^3)]/[\alpha(\alpha - 4)(3\alpha - 4)^2],$$

where $s = r/cL$. For competitive equilibrium, s ranges between $\xi_2(\alpha)$ and $\xi_3(\alpha)$. We can show that $\partial\pi_i(\alpha, p^*)/\partial\alpha_i$ is positive at the limits for s, for all values of α. Similarly, $\partial p_i^*(\alpha)/\partial\alpha_i$ and $\partial p_i^*(\alpha)/\partial\alpha_j$ are negative at the limits for s, for all values of α. Since all quantities are linear in s, they have the same sign for intermediate values of s. The proof of part (c) is trivial. □

PROOF OF THEOREM 3.

Part (a). When $r/cL \leq 2$, we can only have monopolistic, touching I, or competitive equilibria (see Figure 4). We can show that $\partial\pi_i(p_i^*, p_j^*)/\partial\alpha_i > 0$ in the monopolistic and touching I equilibria. Also, Theorem 2 implies that $\partial\pi_i(\alpha, p^*)/\partial\alpha_i > 0$ in the competitive equilibrium. Thus the only candidate for a symmetric equilibrium is $\alpha = 1$. If no firm i gains by lowering its availability level from 1 given $\alpha_j = 1$, then $\alpha^* = 1$.

There are two cases to consider. First, if $\alpha = 1$ results in monopolistic or touching I equilibrium ($r/cL \leq 1.5$), then a lowering of firm i's availability level results in monopolistic or touching I equilibrium. Since $\partial\pi_i(p_i^*, p_j^*)/\partial\alpha_i > 0$ in the monopolistic and touching I equilibria, firm i loses by reducing α_i. Hence $\alpha^* = 1$.

On the other hand, if $\alpha = 1$ results in a competitive equilibrium ($1.5 < r/cL < 2$) or a touching II equilibrium ($r/cL = 2$), then a lowering of firm i's availability level results in the following sequence of equilibria: competitive, touching I and monopolistic. We have $\partial\pi_i(p_i^*, p_j^*)/\partial\alpha_i > 0$ in the monopolistic and touching I equilibria as seen above. Further, we can show that in the competitive equilibrium, $\partial\pi_i(\alpha_i, 1, p_i^*, p_j^*)/\partial\alpha_i > 0$. Hence firm i loses by lowering α_i below 1, so $\alpha^* = 1$.

[13] A supercompetitive-competitive equilibrium does not exist because the necessary conditions are impossible to satisfy.

Part (b). When $2 < r/cL \le 6.84$, and $\alpha = 1$, we have a supercompetitive equilibrium. By Theorem 2(a), $\partial\pi_i(\alpha, p^*)/\partial\alpha_i < 0$ in the supercompetitive equilibrium. Hence, any α that results in a supercompetitive equilibrium cannot be a symmetric equilibrium. When α is reduced from 1 and becomes low enough, the equilibria become touching II, competitive, touching I, or monopolistic equilibria. Theorem 2 and the proof of Part (b) establishes that $\partial\pi_i(\alpha, p^*)/\partial\alpha_i > 0$ in all these equilibria except the touching II equilibrium. Moreover, we can show that in the touching II equilibrium, $\partial\pi_i(p_i^*, p_j^*)/\partial\alpha_i > 0$. Hence a symmetric equilibrium can occur only at the boundary of supercompetitive and touching II equilibria. The equilibrium α^* is thus obtained by solving $r/cL = 2/\alpha^{*2}$.

We further show that no firm gains by changing from this α^*, given the other firm's choice is α^*. If firm i increases its availability level to α_i, it results in a supercompetitive equilibrium. Then, the increase in firm i's profits by the upward deviation from the equilibrium α^* is

$$\pi_i(\alpha_i, \alpha^*, p_i^*, p_j^*) - \pi_i(\alpha^*, \alpha^*, p^*, p^*) = cL^2[(\alpha_i - \alpha^*)(8\alpha_i^3 - 4\alpha_i^2\alpha^* - 8\alpha_i^3\alpha^* - 14\alpha_i\alpha^{*2} + 2\alpha_i^3\alpha^{*2} - 2\alpha^{*3} + 8\alpha_i\alpha^{*3} + \alpha_i^2\alpha^{*3})]/[18\alpha_i^2\alpha^{*2}(\alpha_i + \alpha^*)].$$

Since $\alpha_i > \alpha^*$, the sign of the above expression is

$$\text{sign}\,(8\alpha_i^3 - 4\alpha_i^2\alpha^* - 8\alpha_i^3\alpha^* - 14\alpha_i\alpha^{*2} + 2\alpha_i^3\alpha^{*2} - 2\alpha^{*3} + 8\alpha_i\alpha^{*3} + \alpha_i^2\alpha^{*3}) = \text{sign}\,[Q].$$

We can show that Q is negative for all $\alpha^* \ge 0.5$. Since $\alpha^* \ge 0.54$ when $r/cL \le 6.84$, firm i loses by increasing its availability level above α^*, given $\alpha_j = \alpha^*$.

If firm i lowers α_i, the equilibrium changes from touching II to touching II-competitive when r/cL is sufficiently high. We have $\partial\pi_i(p_i^*, p_j^*)/\partial\alpha_i > 0$ in the touching II equilibrium as seen above. Moreover, we can show that in the touching II-competitive equilibrium, $\partial\pi_i(p_i^*, p_j^*)/\partial\alpha_i > 0$. Hence firm i loses by decreasing α_i below α^*.

When r/cL is lower, a decrease in α_i from α^* results in the following sequence of equilibria: touching II, touching II-competitive, competitive, and touching II-competitive. We can show that

$$\partial\pi_i(p_i^*, p_j^*)/\partial\alpha_i(\alpha_i, \alpha^*) > 0$$

in the competitive equilibrium when $\alpha_i < \alpha^*$. Hence firm i decreases profits by reducing α_i below α^*; thus α^* is a symmetric equilibrium.

The nonexistence of an equilibrium in pure strategies when $r/cL > 6.84$ can be obtained from Table 3 and Figure 4. However, for all $r/cL > 6.84$, and $\alpha = 1$, we have a supercompetitive equilibrium. Since $\partial\pi_i(\alpha, p^*)/\partial\alpha_i < 0$ in the supercompetitive equilibrium, $\alpha = 1$ cannot be optimal. □

PROOF OF THEOREM 4. Suppose the firms maximize their combined profits when at least one of α_A or α_A is less than 1 with corresponding optimal prices, p'_A and p'_B. Such optimal prices exist because the combined profit function is continuous on a closed and bounded set. Let $p_{\max}$ and $p_{\min}$ be the maximum and minimum respectively, of p'_A and p'_B.

We show that the firms increase combined profits by choosing the following:

$$\alpha''_A = \alpha''_B = 1, \qquad p''_A = p_{\max}, \qquad p''_B = \text{Max}\,\{p_{\min}, \text{Min}\,[2r - (p''_A + cL), r]\}.$$

Assume that the configuration at the supposed optimum is monopolistic. Suppose the availability levels are set to 1, and the market areas still do not overlap. The colluding firms have gained by selling with certainty to a larger market area at the same prices. If the market areas overlap with sure availability at the firms, the proposed prices adjust $p_{\min}$ upwards until the market areas of the firms just touch. The colluding firms thus sell with certainty to the entire market, maintaining or increasing the number of customers sold at $p_{\max}$ while selling at a price higher than $p_{\min}$ to the rest. Thus the combined profits are higher. The idea behind the superiority of α''_A, α''_B, p''_A, and p''_B can be similarly understood when other configurations prevail at the supposed optimum. Hence $\alpha_A < 1$ or $\alpha_B < 1$ or both cannot be optimal. □

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