A Model of Price Dispersion in Internet-Enabled Markets

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Abstract

This paper intends to reconcile the inconsistencies between previous predictions from the search literature and empirical findings in Internet-enabled markets. With an analytical model incorporating two major sources of price dispersion documented in previous literature -- limited awareness and brand sensitivity -- we characterize the structure of price dispersion and offer several predictions that are consistent with empirical evidence in these markets. We show that when consumer search costs are different across customers and retailers, retailers follow an asymmetric pricing strategy. Moreover, we show that a well-known firm will, on average, charge a higher price than the less-known firm but will not always be the high-price provider. Our analysis further shows that when more people become informed, price dispersion may actually increase, challenging the common belief that price dispersion should decrease as search costs decline. We also examine the investment incentives for a less-known firm to increase customers' awareness of that firm. We find that even if the cost of building awareness is zero, less-known retailers have muted incentives to do so because increasing awareness also increases price competition *ceteris paribus,* suggesting heterogeneous awareness across retailers, and the resulting price dispersion, is a stable equilibrium in the market.

1. Introduction

The Internet and especially Internet-based comparison-shopping services (e.g., shopbots) have significantly lowered the effort required by consumers to learn about prices across a wide variety of retailers. As a consequence, it is widely believed that price dispersion -- the variation of prices for identical products across retailers -- would be reduced or eliminated completely in Internet-enabled markets. Nonetheless, empirical evidence suggests that there is substantial and persistent price dispersion across Internet retailers, in some cases more so than in traditional markets (Bailey, 1998; Brynjolfsson and Smith, 2000; Clemons, Hann and Hitt 2002; Scholten and Smith, 2002; Shankar et al., 2002). While it has been argued that price dispersion may just be a disequilibrium phenomenon that could vanish as Internet markets become mature, little evidence was found to support the view that price dispersion is being corrected over time (Baye et al., 2001; Pan et al., 2003).

The two leading explanations for price dispersion in online markets are: 1) differences in perceived or actual retailer quality, which make consumers willing to pay a brand premium (see e.g., Schmalensee, 1982; Smith and Brynjolfsson, 2001; Pan et al., 2002a), and 2) incomplete consumer search due to limited consumer awareness of some retailers (Smith et al., 1999; Ratchford, et al., 2003). Although empirical evidence suggests that both of these explanations contribute to price dispersion, they do not individually appear to be a complete explanation and have not been modeled jointly. Pan et al. (2002a) concluded that the proportion of the price dispersion explained by differences in "e-tailer" service quality is small. Studies that have controlled for retailer quality and service level also continue to find substantial price dispersion (Clay et al., 2001; Baye et al., 2002). In addition, these studies have also found that the apparent premium earned by well-known retailers tends to vary across products and over time, which does not directly follow from the quality difference explanation (Pan et al., 2002a). The role of consumer brand awareness has not been extensively studied, although there is evidence that consumers do engage in limited search among a relatively small number of familiar sites (Johnson et al., 2003; Adamic and Huberman, 1999).

In this paper, we develop an analytical model of retailer pricing strategy that integrates the role of these two effects -- limited awareness, in which some retailers are not known to some consumers, and brand sensitivity, in which consumers may be willing to pay a price premium for a specific retailer. We generate conditions under which different forms of price dispersion will prevail. Our model explains both differences in mean price levels across retailers and variation around this mean, as observed in many empirical findings. We also show that in our model, prices are only driven to marginal cost when there is no brand premium and consumers are fully aware of all retailers, and that price dispersion can actually increase as search costs decrease (Brown and Goolsbee, 2002; Pan, et al., 2001).[1] Both of these findings could provide additional insights into the failure of the "electronic markets hypothesis," which suggests that online markets will be subject to profitless Bertrand competition. In addition, our results appear to be consistent with empirical evidence on price dispersion, and they provide additional explanations for the complex and non-monotonic relationship between price dispersion and the "competitiveness" of a market (Stahl, 1989; Goolsbee and Chevalier, 2002).

We also consider why markets can persist with price dispersion generated by differences in awareness. We show that even if a less-known retailer can invest to increase their awareness (and therefore capture rents earned by well-known firms), it has limited incentive to do so because this intensifies competition. This may be a theoretical explanation of apparent "first mover" advantages in

[1] Stahl's (1989) model also shows an equilibrium in which price dispersion can increase as search costs decline, although with a different model setting from ours. He considers identical firms for a homogeneous good and asymmetric search costs across customers with a fraction of consumers, μ, having zero search costs and the other fraction having to pay a cost for every store they visit. In his model, customers adopt sequential search strategy starting with any random store. The results derived from his model is that when $\mu=1$, the Bertrand result prevails; when $\mu=0$, the Diamond result prevails, and when $\mu \in (0,1)$, there is a unique symmetric Nash Equilibrium in mixed strategies, producing price dispersion. Although Stahl does not study explicitly the relationship between price dispersion and consumer information, one can conclude from his results that because there is no price dispersion at the endpoints, this implies a non-monotonic relationship between price dispersion and consumer information. In addition, his model yields an equilibrium in which all firms have the same distribution of prices, yielding no price dispersion in expected prices over time and across products. Our model differs from that of Stahl's in that we consider different search costs not only across customers but also across firms in addition to possible brand sensitivity in the market. Our result shows price dispersion in both expected prices charged and also in variance. We also study the exact threshold, which is high, when price dispersion would fall as the share of informed customers goes up.

some online markets and also may explain why some firms continue to be relatively unknown despite a significant fall in advertising costs and a reduction in advertising expenditures by leading firms.

The critical difference between our approach and the prior literature is that we integrate the concepts of brand sensitivity and brand awareness into a single model that may more closely represent consumer behavior in online markets. The search literature in economics typically considers the price dynamics created by retailers responding to a market in which there are "informed" consumers who can identify low price retailers and "uninformed" consumers who choose a random retailer. These models typically assume that all stores have an equal chance of attracting uninformed consumers (Salop and Stiglitz, 1977; Varian, 1980; Stahl, 1989, 1996). While this is a good approximation for offline markets where physical proximity drives the choices of the uninformed consumers, uninformed consumers in online markets tend to concentrate their search on relatively few well-known retailers.[2] In our model, we capture this behavior by treating consumers as either being aware of both retailers or only the dominant retailer.

In addition, our model builds upon but is distinct from the literature on brand sensitivity in the marketing literature, such as models of competition between "store brands" and "national brands" (Lal, 1990, and Raju et al. 1990). This literature focuses on the fact that consumers are willing to pay more for certain brands (brand sensitivity) but does not consider issues of limited awareness of alternatives. Typically the characteristics and prices of all brands are assumed "known" to the buyers at the time of purchase in a particular store and they simply make decisions based on their level of brand sensitivity. For example, some buyers may be willing to pay more for a national brand while others may not. Our focus, however, is on the level of retailer brand and to explain why some consumers are willing to pay more to buy the same item from one retailer than from another, as commonly observed in online markets.

Thus, while the economics literature has extensively examined price dispersion arising from search cost and the marketing literature has focused on brand sensitivity, these two concepts have not been examined jointly. By studying their interaction, we may gain an additional understanding of the nature of price dispersion in electronic markets. In addition, we also consider the stability of a market in which there is equilibrium price dispersion resulting from differences in consumer awareness. Our model suggests that differences in awareness can persist since lesser-known firms have muted incentives to increase awareness – increases in awareness enable them to capture more customers, but also forces the better-known retailer to compete more aggressively. The interaction of these two effects leads to a situation where it is not optimal for the less-known retailer to invest to reach the awareness level of the better-known retailer. Thus, our model is self-consistent.

The remainder of the paper is organized as follows. We first present the basic model of duopoly pricing where awareness is considered fixed. We then extend the model to a setting where the less-known retailer can increase its awareness at a certain cost (which may be zero), and we examine whether heterogeneous awareness levels are sustainable. Finally, we compare our results to observed price patterns in Internet retailing and discuss some possible extensions to the model.

2. Model

To focus on issues of price dispersion and not product quality difference, we consider an identical item across different retailers. There are large numbers of heterogeneous consumers who are considering purchasing this identical product from one of two retailers: a *well-known* (or *branded*) retailer and a *less-known retailer*.[3] We designate the well-known retailer as Retailer 1 and the less-known retailer as Retailer 2. Retailers face a common marginal cost of c per unit and consumers have a common reservation price of r per unit, which is greater than c.[4] We also assume that consumers purchase at most one unit of the good. In contrast with previous literature that considers only different search costs across customers, we

[2] For instance, it has been observed that the top 1% of sites on the Web capture 50% of all visits to the Web (Adamic and Huberman, 1999) and that most consumers tend to concentrate their shopping activity on relatively few sites, in specific, less than 2 sites, on average, are visited for three popular product categories (Johnson, et. al, 2003).
[3] We do not believe the insights of the model to be unique to duopoly competition, however. Like many other competitive models, extension to arbitrary numbers of firms vastly increases the complexity without much potential gain for new insights. On the other hand, our simulation results of three firms with different awareness levels again show price dispersion.
[4] Since we consider price dispersion of an identical item, we assume fixed reservation price.

assume that search costs are also different across retailers,[5] in that a customer may face higher search cost in identifying or searching the lesser-known retailer than the well-known retailer, a situation especially relevant in internet-enabled markets. Asymmetric search costs across retailers naturally leads to different awareness levels of the retailers. We use the parameter, α, to capture the relative awareness level of Retailer 2 when compared to Retailer 1; that is, α is the fraction of people who would consider buying from either retailer, the remaining fraction (1-α) of consumers only consider the well-known retailer (Retailer 1). A smaller α indicates a greater difference between the two retailers in terms of awareness -- if α=1 the two retailers have the same level of awareness in the market. One can think of α as being closely related to the fraction of consumers who utilize shopping agents ("shopbots") since they will naturally be aware of all retailers. However, some consumers may be aware of both retailers for other reasons. Note that this implies that all consumers we consider are aware of Retailer 1. This normalization occurs without loss of generality since consumers who do not know about Retailer 1 are not in the market at all, giving α a relative awareness interpretation.

We capture the possibility of brand sensitivity in the market with the parameter z, which is the upper support of a uniform distribution (lower support zero)[6] characterizing the additional amount a consumer is willing to pay to buy from a branded retailer. This captures the fact that some customers are unwilling to pay for a brand name while others, perhaps those who are more risk averse or who face higher search costs, are willing to pay more for a well-known retailer. With this model, Retailer 2 could obtain all of the customers that consider both retailers if it undercuts the price of Retailer 1 by z, and proportionally less as the discount decreases (Figures 1a and 1b). This treatment of brand sensitivity is similar to the model analyzed by Lal (1990) or Raju et al. (1990). Finally, we assume that retailers are not able to distinguish customers with different awareness or brand sensitivity ruling out price

[5] Search cost may include the opportunity cost, frictional search cost as well as perceived search cost to get necessary information relevant for reducing quality uncertainty and reaching a purchase decision.
[6] The uniform distribution is utilized for simplicity consistent with common practice in demand models.

discrimination strategies based on these factors. With this setup, we can compute the demand *(q_1, q_2)* and profits *(π_1, π_2)*, given prices *(p_1, p_2)* and exogenous parameters (α, z, r and c):

$$q_1 = \begin{cases} 1 & \text{if } p_1 \le p_2 \\ 1-\alpha+\alpha\cdot(1-\frac{p_1-p_2}{z}) & \text{if } p_2 \le p_1 \le p_2+z \\ 1-\alpha & \text{if } p_1 \ge p_2+z \end{cases}$$

$$\pi_1 = \begin{cases} p_1-c & \text{if } p_1 \le p_2 \\ (1-\alpha+\alpha\cdot\frac{p_2+z-p_1}{z})\cdot(p_1-c) & \text{if } p_2 \le p_1 \le p_2+z \\ (1-\alpha)\cdot(p_1-c) & \text{if } p_1 \ge p_2+z \end{cases}$$

$$q_2 = \begin{cases} \alpha, & \text{if } p_2 \le p_1-z \\ \alpha\cdot\frac{p_1-p_2}{z} & \text{if } p_1-z \le p_2 \le p_1 \\ 0 & \text{if } p_2 \ge p_1 \end{cases}$$

$$\pi_2 = \begin{cases} \alpha\cdot(p_2-c) & \text{if } p_2 \le p_1-z \\ \alpha\cdot\frac{p_1-p_2}{z}\cdot(p_2-c) & \text{if } p_1-z \le p_2 \le p_1 \\ 0 & \text{if } p_2 \ge p_1 \end{cases}$$

2.1 Analysis

Our analysis will proceed by deriving the pricing strategies that represent equilibrium behavior by the two retailers given various values for the four exogenous parameters: reservation price (r), fraction of informed consumers (α), marginal cost (c), and the upper support of the brand sensitivity distribution (z). Proposition 1 characterizes the parameter space in which pure strategy equilibria prevail – that is, the conditions under which firms will offer fixed relative prices, possibly different across retailers.

Proposition 1*: a) When* $\alpha \ge \frac{1}{3}$ $\frac{9\alpha(1-\alpha)}{4} \le \frac{z}{r-c} \le \frac{3\alpha}{2}$ *there is unique non-cooperative pure strategy Nash Equilibrium (NE) in which* $(p_1^*, p_2^*) = (c+\frac{2z}{3\alpha}, c+\frac{z}{3\alpha})$. *b) When* $\alpha \ge \frac{1}{3}$ *and* $\frac{z}{r-c} \ge \frac{3\alpha}{2} \ge \frac{1}{2}$ *there is unique pure strategy NE in which* $(p_1^*, p_2^*) = (r, \frac{c+r}{2})$. *c) When* $\alpha \le \frac{1}{3}$ *and*

$\frac{\alpha}{1-\alpha} \leq \frac{z}{r-c} \leq \frac{1}{2}$ *, the unique pure strategy NE is* $(p_1^*, p_2^*) = (r, r-z)$ *and d) When* $\alpha \leq \frac{1}{3}$ *and* $\frac{1}{2} \leq \frac{z}{r-c}$ *, the unique pure strategy NE is* $(p_1^*, p_2^*) = (r, \frac{c+r}{2})$.

Proof: *See Appendix.*

The various regions in which pure strategy equilibria exist are depicted in Figure 2. When there are a relatively small proportion of informed customers ($\alpha \sim 0$), the pricing strategy depends on the strength of brand preferences. When brand preferences are weak (Proposition 1c, shown in the lower left corner of Figure 2), firms essentially divide up the market. The well-known retailer charges reservation price, and the less-known retailer charges reservation price less *z* and serves all customers that know that the less-known retailer exists. As the degree of brand sensitivity becomes larger, this transitions into a pricing region in which the well-known firm continues to charge the consumers reservation price, but the less-known firm now prices based on the tradeoff between higher prices for non-brand loyal customers and stealing share from the well-known retailer (Proposition 1d, depicted in the upper left in Figure 2). When awareness is high, a similar region also exists but requires a much greater level of brand sensitivity to support (Proposition 1b). When consumers have high awareness of both brands (Proposition 1a, depicted in the upper right in Figure 2), firms compete by dividing up the market in proportion to the degree of brand preference. All these cases yield a persistent price premium for the well-known retailer which yields time invariant price dispersion. Moreover, as α moves away from the origin in Figure 2, the well-known retailer charges a lower price and competition intensifies between the retailers. Note, however, that there is a large area in the center of the graph for which no pure strategy equilibrium exists. We now turn our attention to characterizing this region.

For the region without a pure Nash Equilibrium in this model, there exists at least one mixed strategy equilibrium (Dasgupta and Maskin, 1986). In the pricing games we consider, these strategies appear as prices that fluctuate across time or over different products according to a probability distribution, yielding price dispersion over time or over products.[7] A necessary and sufficient condition for a mixed strategy profile to be a Nash equilibrium is that each player, given the distribution of strategies played by his opponents, is indifferent among strategies played with positive probability. That is, all strategies yield the same expected profits given the behavior of the other retailer. Moreover, firms will never play a dominated strategy in a mixed-strategy equilibrium (Mas-Colell et al., 1995). Proposition 2 shows that the set of non-dominated strategy has the two retailers differing in price by the brand sensitivity parameter (*z*).

Proposition 2*: The set of non-dominated strategies for firm 1 is given by* $p_1 = [\underline{p_1}, r]$ *and the set of non-dominated strategies for firm 2 is given by* $p_2 = [\underline{p_1} - z, r - z]$ *where*

$$\underline{p_1} = \max\{c + \frac{\sqrt{\alpha z(r-c)(1-\alpha)}}{\alpha}, (r-c)(1-\alpha)+c\}.$$

Proof: *See Appendix*

Within this set of feasible, non-dominated strategies, we can use the technique of Moulin (1982) and that used by Raju et al. (1990) to construct a mixed-strategy equilibrium of this game, characterized by two (cumulative) distribution functions ($F_1(p_1), F_2(p_2)$). These distribution functions yield the probability that the firm will choose a price at or below this value. Proposition 3 constructs the equilibrium pricing strategies in the region where there the firms play mixed strategies. While in general, these strategies are difficult to visualize, we will devote the remainder of this section to characterizing several special cases that have intuitive interpretations.

Proposition 3*:* $(F_1(p_1), F_2(p_2))$ *constitutes a mixed strategy equilibrium for this game:*

$$\begin{cases} F_1(r) = 1 \\ (p_2 - c)\alpha(1 - F_1(p_2 + z)) + \int_{p_2}^{p_2+z} (p_2 - c)\alpha \frac{p_1 - p_2}{z} f_1(p_1)dp_1 = (\underline{p_1} - z - c)\alpha \ \forall p_2 \in [\underline{p_1} - z, r - z] \\ F_1(\underline{p_1}) = 0 \end{cases}$$

[7] A variety of marketing and economic models yield mixed strategy equilibrium that are interpreted similarly (see e.g. Varian, 1980; Narasimhan, 1988; Raju et al., 1990 and Lal, 1990).

$$\begin{cases} F_2(r-z)=1 \\ (p_1-c)(1-\alpha)F_2(p_1-z)+\int_{p_1-z}^{p_1}(p_1-c)[1-\alpha+\alpha\dfrac{p_2+z-p_1}{z}]f_2(p_2)dp_2+(p_1-c)(1-F_2(p_1)) \\ \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad =(r-c)(1-\alpha) \quad \forall p_1\in[\underline{p_1},r] \\ F_2(\underline{p_1}-z)=0 \end{cases}$$

Proof: *The distribution functions ($F_1(p_1), F_2(p_2)$) were constructed following the necessary and sufficient conditions of a mixed strategy equilibrium given by Mas-Colell et al. (1995). Q.E.D.*

One interesting special case is when there is no brand sensitivity (that is, z=0) – customers may or may not be well informed about the existence of Retailer 2, but they are unwilling to pay just for brand. This can arise in online markets as shopbots increasingly provide quality information (e.g., customer ratings or reviews) about the retailers they cover, lowering the degree of uncertainty a consumer faces in purchasing from a less-known retailer. Note that when customers are not brand sensitive, price dispersion is always (except when α=1) due to retailers randomizing their prices across time or over different goods rather than one retailer persistently charging higher prices than the others (see Figure 2). In a sense, the condition z=0 represents a "worst case" in terms of finding price dispersion. Proposition 4 provides the mixed strategy equilibrium pricing strategy when customers have no preference for the better known retailer.

<u>Proposition 4</u>*: when z=0, there exists a unique mixed strategy equilibrium given by:*

$$\begin{cases} F_1(p_1)=1 \ \ (f_1(p_1)=(1-\alpha)) & if\ p_1=r \\ F_1(p_1)=1-\dfrac{(r-c)(1-\alpha)}{(p_1-c)} & if\ \ p_1\in[(r-c)(1-\alpha)+c,r) \\ F_1(p_1)=0 & if\ p_1\in[0,(r-c)(1-\alpha)+c) \end{cases}$$

$$\begin{cases} F_2(p_2)=1 \ \ (f_2(p_2)=0) & if\ p_2=r \\ F_2(p_2)=\dfrac{1}{\alpha}-\dfrac{(r-c)(1-\alpha)}{(p_2-c)\alpha} & if\ \ p_2\in[(r-c)(1-\alpha)+c,r) \\ F_2(p_2)=0 & if\ p_2\in[0,(r-c)(1-\alpha)+c) \end{cases}$$

Proof: *Follows directly by setting z=0 in the result from Proposition 3. Q.E.D.*

Figure 3 shows the equilibrium distributions for both retailers under certain parameter settings (*r=1, c=0 and* α*=0.5*) based on Proposition 4. Proposition 4 shows that when brand sensitivity does not exist, Retailer 1 will place more weight on high prices in its randomization strategy when fewer customers know about the existence of Retailer 2. That is, competition is determined by consumer awareness. If this randomization is interpreted as pricing strategy over time, this result would predict that when not all customers use shopbots (or other technologies for identifying less-known retailers), prices will vary across Internet retailers even though shopbots exist and even if customers are not brand-sensitive. However, the well-known retailer will have higher prices on average, even though consumers are brand indifferent (beyond awareness).[8] However, the well-known retailer is not always the high price provider for all products or at all times. In the example provided in Figure 3, the mean prices charged by the well-known retailer and less-known retailer are 0.85 and 0.69, respectively, and the well-known retailer will charge a lower price than the less-known retailer about 25% of the time.

In Figure 4a and 4b, we show the expected price dispersion in the average price difference (measured by the difference of the expected prices charged by the two retailers, i.e., $E(p_1)-E(p_2)$) and variance in price dispersion (measured as the variance in difference in prices charged by the two retailers, i.e., $Var(p_1-p_2)$) respectively when we normalize marginal cost to zero and reservation price to 1.[9] As one would have expected, the mean prices charged by the two retailers are strictly decreasing in awareness (α),[10] however, the difference in mean prices is maximized when α is close to the middle (the maximum is approximately α=.57) (Figure 4a). The variance in prices is increasing in awareness up to a point where awareness is large (approximately α=.83) and then falls dramatically as prices are driven to marginal cost (Figure 4b). Note that these cutoff levels are exact, but we present them as approximations due to their complex mathematical form.

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[8] This is true because the price distribution for Retailer 1 stochastically dominates the distribution for Retailer 2 for all parameter values where these distributions are non-degenerate.
[9] Note that the values of *r* and *c* rescale the curve but do not change its shape.
[10] Consistent with the finding in Bakos (1997).

An interesting implication of this is that price dispersion may actually increase as consumers become better informed about lesser-known retailers, such as through increased penetration of shopbots or other online shopping and price comparison services. This is true as long as α is below a certain large value. It is only when a critical mass of informed consumers is reached that price dispersion declines when search cost decreases. In our model, this cutoff is $\alpha<.83$ if price dispersion is measured in variance, meaning that most (83%) customers would have to be informed to see a dramatic decrease in price dispersion with decreases in search costs. Note that our result differs from the comparable result in Stahl (1989) in that this non-monotonic relationship between search costs and price dispersion is only observed in his model with a small enough share of informed customers with zero search cost. Our result indicates that this non-monotonic relationship can be obtained even with a large share of informed customers.

This type of mixed strategy equilibrium arising solely from differences in awareness has other implications, especially for theories about market transparency and price dispersion. First, previous research has suggested that "advertised items" should have lower price dispersion (Clay et al., 2001) because consumers are presumably better informed about the prices and retailers. However, this result suggests that the reduction in price dispersion would only occur when nearly all consumers are informed about the retailers that carry the product. Second, previous research (e.g. Sorensen, 2000) has also suggested that price dispersion can represent a measure of market competitiveness. However, in our model, a more transparent, competitive market may yield greater price dispersion even though mean prices may decline, and thus, it can be misleading to use price dispersion as a proxy for the extent of competition in the market.

These results lend fundamental support to previous empirical findings showing that price dispersion in electronic markets can persist even when search costs have been significantly reduced or alternatively, as customers become better informed by using search cost lowering technology such as shopbots (Bailey, 1998; Brynjolfsson and Smith, 2000; Clay et al., 2001; Baye et al. 2002; Clemons et al. 2002; Scholten and Smith, 2002; Pan et al., 2003).

Another interesting analysis is to derive the conditions under which Bertrand (pure price) competition would arise in this market. Proposition 5 shows that the absence of brand premium (*z=0*) and full consumer awareness of competing retailers consumers (α=1) is <u>necessary</u> for the existence of pure price competition in our model. Stated another way, Proposition 5 suggests that the conditions under which profitless Bertrand competition will ensue in electronic markets is unlikely to appear in practice, at least for some time.

<u>Proposition 5</u>*: The Bertrand Equilibrium (both firms following the pure strategy of charging marginal cost) can only arise when there is no brand sensitivity (z=0) and full awareness (α=1).*

Proof: *When z=0, Proposition 4 implies that the Bertrand equilibrium can only be attained when α=0. Proposition 2 guarantees that no equilibrium exists with identical retailer prices when z>0. Q.E.D.*

Overall, we have shown that in markets where not all consumers are aware of the existence of all firms or where customers are brand sensitive, price dispersion will be a natural feature of the market. Price dispersion will arise either because firms are charging different fixed prices with well-known firms consistently higher than lesser known firms, or because they are playing mixed strategies, randomizing prices over time. When prices are random, a well-known firm will charge higher average prices, but the price distributions overlap such that the well-known firm will not have the highest prices all the time for all products.

A key assumption of this analysis is that the choice of awareness level for Retailer 2 (relative to Retailer 1), α , is fixed. However, given that a well-known retailer can earn higher profits than the less-known retailers, it raises the question as to why the less-known retailers, in a market with few entry barriers and available advertising (maybe at a cost), do not invest to build their awareness.[11] Interestingly, we show in the next section that even if a less-known firm can invest in advertising or otherwise build awareness on the same terms, it will tend not to do so. Thus, markets that begin with this difference in

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[11] Of course, this analysis is predicated on an ex-ante condition of retailers with different awareness levels. It is clear from previous research and direct observations of most common online markets that this condition holds. What factors created this initial condition is beyond the scope of our analysis.

awareness tend to show a form of first mover advantage without firm learning or cost advantages, two typical explanations of first mover advantage.

2.2 Model Extension – Awareness as a Choice

Consider the same model as in the previous section. Instead of α being a fixed exogenous variable, we allow Retailer 2 (the less-known retailer) to make an investment in awareness to change the level of α. Let the cost of awareness be designated by $C(\alpha) = a\alpha^2$. The marginal cost of a unit of awareness is $2a\alpha$, which is clearly increasing in α. We use the parameter a to vary this cost for computing comparative statics. The convexity of this function suggests that small improvements in awareness are relatively inexpensive, but the cost of large awareness changes grows rapidly. Since our focus here is on the choice of α, we will take z as given. We are interested in knowing whether Retailer 2 will have an incentive to change its relative awareness level to Retailer 1. We first consider the case when z=0, and then examine whether the insight holds for cases when $z>0$.

2.2.1. Sequential Choice Game

Initially, we consider Retailer 2 to make the awareness investment first (Period 1), given that Retailer 1 is well-known in the market. This awareness level is observed by both retailers, and then prices are chosen simultaneously by both retailers in Period 2. Using backward induction, the game starting from Period 2 is characterized by the basic model we presented in Section 2.1. That is, we can calculate Retailer 2's profit given any awareness level. Assume the profit for Retailer 2 for each period is $\pi_2(\alpha)$ with an awareness level of α, and assume the discount factor is δ. Retailer 2 will choose:

$$\alpha^* = \arg\max \frac{\pi_2(\alpha)}{1-\delta} - C(\alpha)$$

Proposition 6 then shows that in a sequential choice game, the lesser-known retailer will never choose full awareness.

<u>Proposition 6</u>: *In this sequential choice game, α^* is always smaller than 1. That is, Retailer 2 will not choose full awareness in equilibrium.*

Proof Sketch: From the analysis in 2.1, we know that $\pi_2'(\alpha) < 0 \ \forall \alpha > \bar{\alpha}$ where $\bar{\alpha} < 1$*, that is, the maximum profit for Retailer 2 is achieved for an intermediate* α*,* $\bar{\alpha}$*. Thus, the maximum awareness level Retailer 2 will choose is* $\bar{\alpha}$*, and the optimal investment is decreasing in marginal cost of awareness.*

2.2.2. Simultaneous Choice Game

Another setting of interest, appropriate for markets where retailers can make rapid promotional investments, is to allow Retailer 2 to fine-tune its level of awareness and set the price simultaneously. This type of strategy might reasonably characterize electronic markets with the availability of advertising strategies with short lead times and a high degree of pricing flexibility (or lower "menu costs"). Using the same notation as before, the quantities and profits are given by:

$$q_1 = \begin{cases} 1, & \text{if } p_1 \le p_2 \\ 1-\alpha, & \text{if } p_1 > p_2 \end{cases}$$

$$\pi_1 = \begin{cases} p_1 - c, & \text{if } p_1 \le p_2 \\ (1-\alpha)\cdot(p_1 - c), & \text{if } p_1 > p_2 \end{cases}$$

$$q_2 = \begin{cases} \alpha, & \text{if } p_1 > p_2 \\ 0, & \text{if } p_1 \le p_2 \end{cases}$$

$$\pi_2 = \begin{cases} \alpha\cdot(p_2 - c) - C(\alpha), & \text{if } p_1 > p_2 \\ 0, & \text{if } p_1 \le p_2 \end{cases}$$

Unlike the previous analysis, where there was a substantial region of the parameter space where firms chose fixed prices (pure strategy equilibria), no such equilibria exist when retailers set prices simultaneously in this game. Proposition 7 states this result formally.

<u>Proposition 7</u>*: There exists no non-cooperative pure strategy Nash Equilibrium when retailers set prices simultaneously in this game.*

Proof: See Appendix.

In addition, with the game specified in Section 2.2.2, we find that when *a* is sufficiently low, there is no equilibrium when the well-known firm acts as a price leader and the less-known firm follows. Specifically, when investing in awareness is an option for the less-known retailer and when it can change price at the same time, the well-known firm will prefer to behave as price followers rather than preemptively changing price strategy, because any attempt at setting a new price will encourage other firms to undercut on price and alter awareness. It is in the interest of both firms to allow the less-known firm to set prices first when advertising cost is relatively inexpensive. Proposition 8 shows that there does exist an equilibrium when the lesser known firm can simultaneously set price and awareness level, it always entails the lesser known firm (Retailer 2) acting a price leader.

Proposition 8: *When* $0 \leq a \leq \frac{(\sqrt{5}-1)(r-c)}{2}$*, there is an equilibrium in which Retailer 2 moves first:*

$$\alpha^* = \frac{r-c}{2(a+r-c)} \; and \quad p_2^* = \frac{2ar+r^2-c^2}{2(a+r-c)} \quad with \;\; \pi_2^* = \frac{(r-c)^2}{4(a+r-c)};$$

$$p_1^* = r \;\; and \;\; \pi_1^* = \frac{(2a+r-c)(r-c)}{2(a+r-c)}$$

Proof: *See Appendix*.

Of course, when the cost of awareness is sufficiently large, this issue is no longer a concern – the less-known firm will simply realize that there are not sufficient profits to be made by changing awareness level (under the optimal pricing strategy), and thus the general structure of the solutions described in Section 2.1 will hold.

We have just shown that Retailer 2 has no incentive to achieve full awareness when consumers do not show brand sensitivity (i.e., z=0). A relevant question that arises is whether Retailer 2 would want to achieve full awareness when z>0, where competition may be less intensive. Interestingly, Proposition 9 shows that the result of "limited awareness" generalizes to the case when z>0.

Proposition 9: Retailer 2 has no incentive to achieve full awareness in the market irrespective of consumers brand sensitivity (z) and advertising costs (a).

Proof: See Appendix.

The most interesting result in this section is that even if awareness is free, it is not optimal for the lesser-known retailer to be recognized by the entire market (that is, irrespective of a, α^* is never 1). This may seem counterintuitive at first, but is easily rationalized by noting that awareness is somewhat analogous to product differentiation. Since the well-known or branded retailer is located at one extreme in "awareness space," competition is softened when the entrant locates further away in this space, taking a smaller share of the market and inducing less aggressive price responses from the well-known retailer.

These results suggest that differences in awareness can persist since lesser-known firms have muted incentives to increase awareness – increases in awareness enable them to capture more customers, but also forces the better-known retailer to compete more aggressively, which creates pressure on the less-known retailers to lower price. Since the loss from competition is greater than the benefits from expanding its potential market, the less-known retailer does not find it optimal to invest to reach the awareness level of the better-known retailer. The result is such that firms are "differentiated" in the awareness space, consistent with previous literature on product differentiation, where firms prefer to locate away from their competitors. This strategy maximizes profits for both the well-known and less-known retailers (although the well-known retailer would, of course, prefer no competition). An implication of this result is that by being an early mover and achieving high awareness, firms can lock in a profit advantage. This also is consistent with the observation that most Internet markets are characterized by a few dominant firms in terms of consumer awareness, with large numbers of other firms restricting their promotional activities to niche markets or low cost channels like shopping agents. Collectively, this suggests that price dispersion will persist in online markets.

3. Discussions and Conclusions

3.1 Summary of Theoretical Results

This paper studies the structure of price dispersion with the interaction of two effects: limited awareness and brand sensitivity. This theoretical analysis not only complements previous research on price dispersion but also bridges the gap between previous theoretical predictions and empirical findings in Internet-enabled markets. There are three main results from our model:

First, we show that the level of awareness (α) and the degree of brand sensitivity ($z/(r-c)$) jointly determine the type of price dispersion in the market. As long as there is any degree of limited awareness or brand sensitivity, a well-known brand will charge higher prices on average than a lesser-known brand. Under some conditions, especially when degree of brand preference is "not too high", firms will tend to follow a mixed strategy, randomizing price over products or time. In this mixed strategy equilibrium, the mean price of the well known retailer will be greater than that of the lesser-known retailer, but the distributions overlap, such that some fraction of the time, the better-known retailer will charge a lower price. While most previous search literature suggests a *symmetri*c mixed strategy price equilibrium in a search model (Varian, 1980; Stahl, 1989), we show that when consumer search costs are different across customers and retailers, retailers follow *asymmetric* mixed strategies. This asymmetry will persist as long as some consumers are either brand sensitive or have limited awareness (or both). It is only in the absence of awareness differences and brand sensitivity that price dispersion will be removed, as predicted by some observers of online markets. However, the conditions that yield this outcome under our model's assumptions would be very difficult to realize in practice.

Second, while much of the literature about Internet-enabled markets has examined whether prices and price dispersion fall as more people become informed (either due to direct search cost reductions or improvements or diffusion of automated search technology, such as shopbots), our results indicate that there is no monotonic relationship between the proportion of consumers who are informed and price dispersion. While average prices in the market are reduced as consumers become better informed, there is no directional prediction on price dispersion. Indeed, until most consumers are well informed about prices to begin with, price dispersion actually increases as more consumers learn about available prices. Alternatively, as we show in our model, price dispersion can also be reduced when *less* people use shopbots. Our results on price dispersion and competition are consistent with arguments based on empirical observation by Goolsbee and Chevalier (2002) that suggest competitiveness and price dispersion are not directly related. In addition, our finding also offers some insights on the level of prices and price dispersion for advertised and unadvertised items. Traditional search literature predicts that the prices and price dispersion of advertised items will be lower than that for unadvertised items (Clay et al., 2001). Our finding suggests that the prices of heavily advertised items will be lower than for unadvertised items, which is consistent with previous theoretical literature. However, the direction of price dispersion is unclear, as it depends on whether the share of informed customers exceeds a certain large threshold.

Overall, our analysis suggests that it is important to take into account the existing level of consumer informedness (or the diffusion of search technology) in determining the drivers of price dispersion and in inferring the relationship between price dispersion and competition.

Third, our model also offers an alternative explanation about why price dispersion is a general phenomenon in electronic markets. Our result shows that price dispersion is likely to persist, as opposed to being a temporary phenomenon due to market immaturity, because different awareness in the market is likely to be a stable equilibrium. In particular, we show that even if a lesser-known retailer can invest to improve awareness, they have weak incentives to do so because this increases price competition. This is consistent with previous literature of product differentiation (either horizontally or vertically) which shows that firms have incentives to differentiate themselves by locating away from their competitors to reduce competition. Beyond real product-differentiation, we show that firms can also create "perceived differentiation" in the awareness space, which is especially relevant when product or service itself can not be easily or cheaply differentiated.

3.2 Empirical Support

Our assertion of limited consumer awareness and brand sensitivity is consistent with observed behaviors of Internet shoppers. For instance, in July 2000 using data from Media Metrix, we found that out of 3771 tracked customers who visited a bookseller, only 236 used a shopbot for books.[12] In this same sample, 80% of the customers who visited an online book retailer visited only one retailer in that category. Consistent with this finding, Adamic and Huberman (1999) found that the top 1% of sites on the Web capture 50% of all visits to the Web. Johnson et al. (2003) has also observed that the overall level of search is very low: ranging from 1.2 stores for books, 1.3 for CDs, and 1.8 for travel. Even more surprisingly, they found that 70% of the CD shoppers and 70% of the book shoppers were loyal to just one site. All of these findings support the idea that most customers limit their search to a few well-known

[12] The list of shopbots we considered were: dealtime.com(evenbetter.com); pricescan.com; bsilly.com; searchbook.net; addall.com; bestbookbuys.com; bigscoop.com; mysimon.com; searchvalue.com; compare.com; webmarket.com; shopping.altavista.com; shopping.yahoo.com; and valuefind.com.

sites. A recent study by StatMarket also suggests that the fraction of people utilizing search engines or shopbots is limited and is actually decreasing over time (Table 1). On the other hand, Smith and Brynjolfsson (2001) find that consumers are willing to pay a premium to buy from better-known retailers. All of these results collectively suggest that the actual market operates in a region where brand awareness is relatively low, and brand sensitivity is moderate. This is the parameter region in our model where mixed strategy equilibria prevail.

Given that current values of the parameters suggest actual markets are in the mixed-strategy region of our model, we can compare actually pricing results in the existing empirical literature with our model predictions. The pricing patterns observed by Baye et. al. (2004) are consistent with a mixed strategy, with which firms engage in short-term price promotions that result in temporal price dispersion. The prediction from this region that the well-known firm will on average charge a higher price than the lesser-known firm but not always be the high-price provider is also well supported by previous empirical findings (Bailey, 1998; Brynjolfsson and Smith, 2000; Smith and Brynjolfsson, 2001; Clay et al., 2001; Pan et al., 2001; Baye, et al., 2002). Pan et al.'s finding (2002b) that trust and early online entry enhance "e-tailer" traffic and prices also appears to be consistent with our model.

The findings that there is no monotonic relationship between consumer awareness and price dispersion are also (indirectly) supported by empirical studies. For example, Baye et al. (2001) found no statistical evidence of any decline in levels of price dispersion, despite the fact that consumer usage of price comparison sites increased by 12.9% during the time period of their study. Brown and Goolsbee (2002) examined the impact of the rise of Internet comparison shopping sites on the prices of life insurance in the 1990s and found that Internet search sites initially led to an increase in price dispersion in the market, but when the share of consumers using the technology exceeded a certain threshold, price dispersion began to fall. Using data from a variety of product categories, Shankar et al. (2002) also find that consumer awareness has no (linear) relationship with price dispersion. Clay et al. (2001)'s findings also conform to our predictions on the prices and price dispersions for advertised and unadvertised items.

They find that *New York Times* bestsellers have the lowest prices as a fraction of the publisher's suggested price. They also find that price dispersion is not necessarily lower for advertised items.

Finally, while the result that well-known firms may prefer to be price followers seems fairly abstract, it is indeed consistent with an unusual finding in Kauffmann and Wood (2000, Table 3). They found that well-known retailers tend to be followers to their competitors' price changes while many smaller retailers did not tend to respond to price changes at well-known retailers. Although Kauffmann and Wood did not test the exact prediction of our model -- that well-known retailers might be price followers to less-known retailers -- their finding is consistent with the same argument. Our theoretical result that it may not be in the retailers' interests for the limited-awareness situation to change substantially is also consistent with the finding that not all Internet retailers are investing in awareness; some simply prefer to utilize shopbots and other low-cost channels for reaching consumers.

Given these conditions, our model can assist in making predictions about how price dispersion in Internet markets may evolve. First, it is clear that there has been significant progress in search technologies to identify retailer quality (consumer reviews, feedback systems, etc.) which could lead to decreased brand sensitivity, at least to the extent brand sensitivity is driven by quality uncertainty. However, while this trend will tend to make markets more competitive, it will be limited by heterogeneity in retailer awareness. In general, our model suggests that heterogeneity in awareness may be a sustainable market equilibrium. This is reinforced by work by Baye and Morgan (2001) and Iyer and Pazgal (2003) that suggest that shopbots and other online information "gatekeepers" will never want full participation from firms. Similarly, Ellison and Ellison (2001) have noted that firms try to adopt a number of strategies that make search more difficult. All these findings suggest that limited awareness is likely to prevail. Indeed, this prediction is consistent with the observation that most Internet markets are characterized by a few dominant firms in terms of consumer awareness, with large numbers of other firms restricting their promotional activities to niche markets or low-cost channels like shopping agents, suggesting that price dispersion will persist in the market. In addition, several empirical studies of online commodities markets show that price dispersion does not appear to be decreasing over time (Clay et al., 2001; Baye et al., 2001; 2002), and even studies that show a decline in price dispersion still find the level of price dispersion to be substantial (Pan et al., 2003).

3.3 Future Work

A natural extension of our model is to consider multi-firm setting, including both static oligopoly and sequential entry situations, and to study the effects of the number of firms on competition and firms' pricing behaviors.[13] In addition, there are several ways to relax assumptions in these models. For example, we could relax constant marginal cost and assume variable marginal cost across firms. When the well-known retailers (incumbents) have cost advantage over the lesser-known retailers, our results may not change qualitatively. However, if the new entrants (less-known firms) enjoy a cost advantage, the result that the lesser-known firms have weak incentives to invest in increasing their awareness may change. Moreover, the lesser-known firms may choose to increase their awareness in certain niche markets if market segmentation is feasible. On the other hand, different type of retailers may adopt different pricing strategies, which in turn influences the price level and price dispersion in the market. For example, Ancarani and Shankar (2003) found that price levels and price dispersion vary across different retailer types. It would also be useful to examine whether the empirical distributions of prices correspond to our theoretical predictions by examining the price distributions that arise in different markets that might have ex-ante variations in brand premium distribution or awareness level.

Finally, while we have studied two important factors (limited awareness and brand sensitivity) that drive price dispersion, other factors which are not considered in this paper may also contribute to price dispersion. For example, different product scope at different retailers (presumably, large product scope retailers may enjoy some price advantage as they allow customers to economize on shipping costs) may also lead to price dispersion. The relationship between product brand and retailer brand may also drive price dispersion – for instance, Sony's online store may charge persistently higher prices for Sony products than other retailers due to market segmentation, access to early stage products, or a desire not to

[13] Baye et al. (2003) found that consumers save more when more firms list prices on the price comparison sites because competition intensifies as more firms participate on the price competition sites.

undercut retailer margins which would discourage retailers from stocking or promoting their products. It would also be an interesting question to study how product scope and the interaction between product choice and retailer choice affect price dispersion.

Figures:

Figure 1a:
Demand curve for Retailer 1 for a given p_2

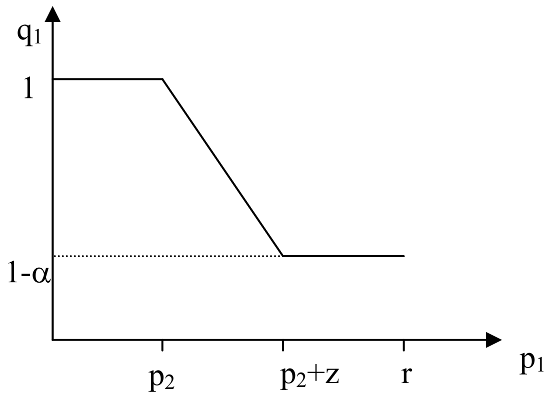


Figure 1b:
Demand curve for Retailer 2 for a given p_1

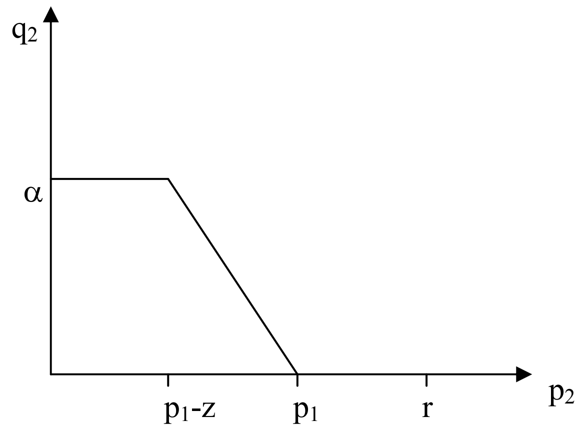


Figure 2: Possible Equilibria for Different Parameter Values

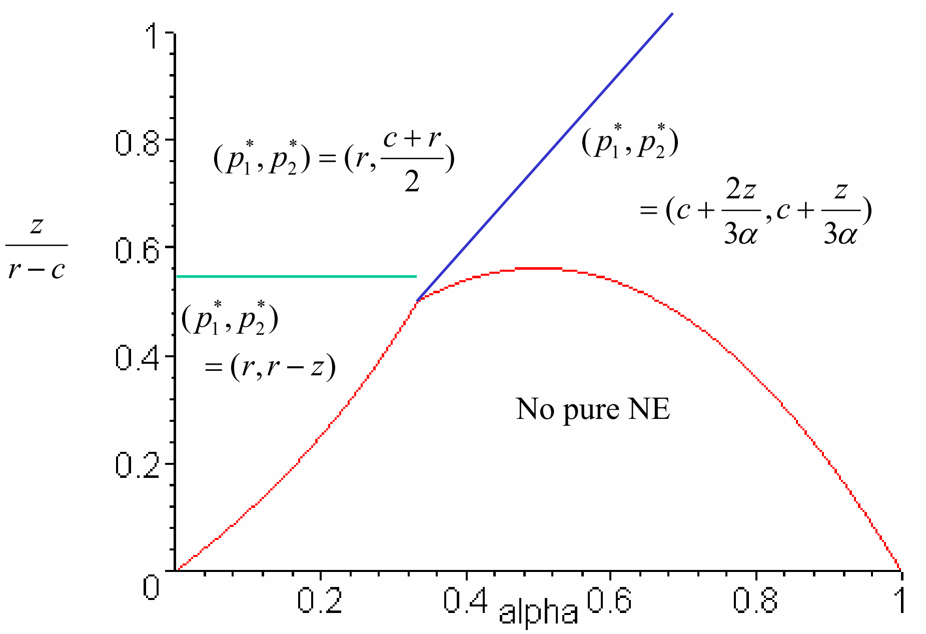


Figure 3: Equilibrium distributions (mixed strategy equilibrium) for the case where z=0, α= 0.5, r=1 and c=0.

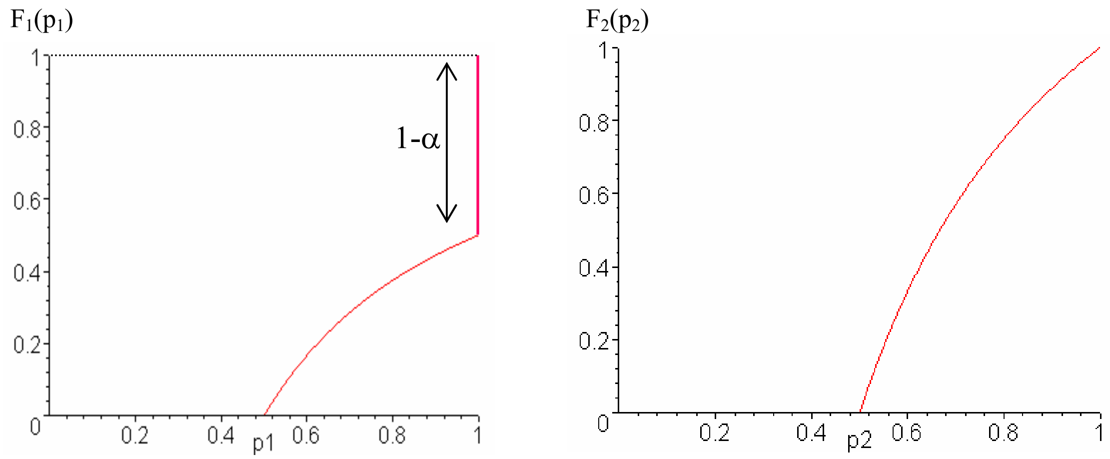
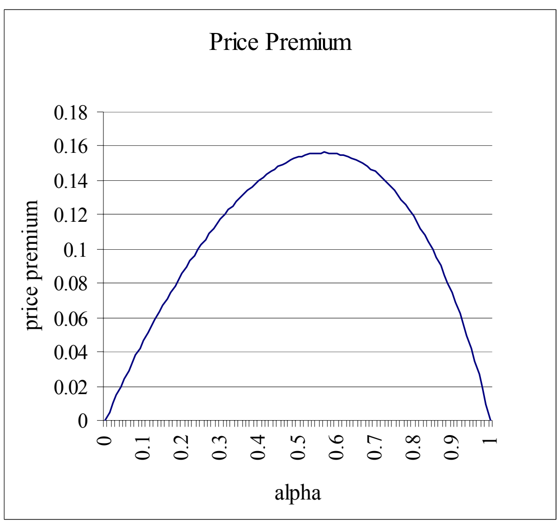
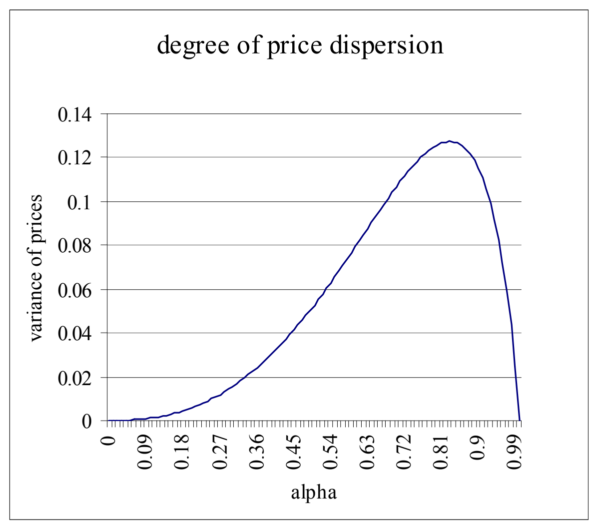


Figure 4a: Expected price premium charged by the well-known retailer (assume z=0)



r is normalized to 1 and c is normalized to 0.

Figure 4b: Price dispersion as measured in variance (assume z=0)



r is normalized to 1 and c is normalized to 0.

Tables:

Table 1: Internet usage over time

Global Internet Usage share			
Referring Type	**As of 2/03/03**	**As of 2/03/02**	**As of 2/03/01**
Direct Navigation	**64.43%**	**53.19%**	**48.14%**
Web Links/Search Engines	**35.55%**	**46.79%**	**51.85%**

Source: StatMarket 2003 (www.statmarket.com)

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Appendix

Proof of Proposition 1:

For Retailer 2, in searching for its best response to any price choice by Retailer 1, can restrict itself to prices in the interval $[p_1\text{-}z, p_1]$. Any price $p_2>p_1$ yields the same profits as setting $p_2=p_1$ (namely, zero), and any price $p_2<p_1\text{-}z$ yields lower profits than setting $p2=p1\text{-}z$. Thus, Retailer 2's best response to p_1 solves

$$\max_{p_2} \quad \alpha \cdot \frac{p_1 - p_2}{z} \cdot (p_2 - c)$$
$$s.t \;\; p_1 - z \le p_2 \le p_1$$

The necessary and sufficient (Kuhn-Tucker) first order condition for this problem is:

$$\frac{\alpha}{z}(c + p_1 - 2p_2)\begin{cases} \ge 0 & if \;\; p_2 = p_1 \\ = 0 & if \;\; p_1 - z \le p_2 \le p_1 \\ \le 0 & if \;\; p_2 = p_1 - z \end{cases}$$

Solving this, Retailer 2's best response function is:

$$p_2(p_1) = \begin{cases} c & if \;\; p_1 \le c \\ \dfrac{c + p_1}{2} & if \;\; c \le p_1 \le c + 2z \\ p_1 - z & if \;\; p_1 \ge c + 2z \end{cases}$$

For Retailer 1, it can always get at least a profit of $(1\text{-}\square)(r\text{-}c)$ by setting price equal to r. The profit maximizing price for a solution s.t. $p_1 \in [p_2, p_2 + z]$ solves:

$$\max_{p_1} \quad (1 - \alpha + \alpha \cdot \frac{p_2 + z - p_1}{z}) \cdot (p_1 - c)$$
$$s.t. \;\; p_2 \le p_1 \le p_2 + z$$

By solving the first order conditions, we get:

$$p_1(p_2) = \begin{cases} p_2 + z & if \;\; p_2 \le c + \dfrac{z}{\alpha} - 2z \\ \dfrac{c + p_2}{2} + \dfrac{z}{2\alpha} & if \;\; c + \dfrac{z}{\alpha} - 2z \le p_2 \le c + \dfrac{z}{\alpha} \\ p_2 & if \;\; p_2 \ge c + \dfrac{z}{\alpha} \end{cases}$$

Given these relationships, we can derive the best response functions of Retailers 1 and 2, and given the nature of the best response functions, there can be at most one crossing point, i.e., the solution is unique:

when $\alpha \ge \frac{1}{3}$, $(p_1^*, p_2^*) = (c + \frac{2z}{3\alpha}, c + \frac{z}{3\alpha})$ and $(\pi_1^*, \pi_2^*) = (\frac{4z}{9\alpha}, \frac{z}{9\alpha})$

For this solution to be a NE, $\begin{cases} \dfrac{4z}{9\alpha} \ge (1-\alpha)(r-c) \Rightarrow \dfrac{z}{r-c} \ge \dfrac{9\alpha(1-\alpha)}{4} \\ c + \dfrac{2z}{3\alpha} \le r \Rightarrow \dfrac{z}{r-c} \le \dfrac{3\alpha}{2} \end{cases}$.

When $\alpha \ge \frac{1}{3}$ and $\frac{z}{r-c} \ge \frac{3\alpha}{2} \ge \frac{1}{2}$, the crossing point is $(p_1^*, p_1^*) = (r, \frac{c+r}{2})$.

When $\alpha \le \frac{1}{3}$ and $\frac{\alpha}{1-\alpha} \le \frac{z}{r-c} \le \frac{1}{2}$, there is an unique pure strategy equilibrium in which $(p_1^*, p_2^*) = (r, r-z)$.

When $\alpha \le \frac{1}{3}$ and $\frac{1}{2} \le \frac{z}{r-c}$, $(p_1^*, p_2^*) = (r, \frac{c+r}{2})$ is the crossing point.

For other parameter settings, there can exist no crossing point for the best response functions of Retailer 1 and Retailer 2.

Q.E.D.

Proof of Proposition 2:

The proof follows directly from two Lemmas proven below.

Lemma 1: $p_1=r$ dominates $p_1 \le \underline{p_1}$, where $\underline{p_1} = \max\{c + \frac{\sqrt{\alpha z(r-c)(1-\alpha)}}{\alpha}, (1-\alpha)r + \alpha c\}$.

Proof: Retailer 1 is assured of at least *(1-□)* of the market at $p_1=r$ with profit *(1-□)(r-c)*. So even if retailer 1 gets the full market at a price $p_1 < (1-\alpha)r + \alpha c$, its profit will be less than setting the price at *r*.

Assume p_{2l} is such that $(1-\alpha+\alpha \cdot \frac{p_{2l}+z-p_1(p_{2l})}{z}) \cdot (p_1(p_{2l})-c) = (1-\alpha)(r-c)$, where the left hand side is an increasing function of p_{2l}, we get $p_{2l} = c + \frac{2\sqrt{\alpha z(r-c)(1-\alpha)}}{\alpha} - \frac{z}{\alpha}$ and $p_1(p_{2l}) = c + \frac{\sqrt{\alpha z(r-c)(1-\alpha)}}{\alpha}$, that is, $c + \frac{\sqrt{\alpha z(r-c)(1-\alpha)}}{\alpha}$ is the price on Retailer 1's best response function that makes Retailer 1 indifferent to charging a price of *r*, and Retailer 1 will never choose a price smaller than that, as its profit is less than charging a price of *r*. Q.E.D.

Lemma 2: $p_2 = \underline{p_1} - z$ dominates $p_2 < \underline{p_1} - z$,

where $\underline{p_1} = \max\{c + \frac{\sqrt{\alpha z(r-c)(1-\alpha)}}{\alpha}, (1-\alpha)r + \alpha c\}$ and $p_2 = r - z$ dominates $p_2 \in (r-z, r]$.

Proof: Given that $p_1 \ge \underline{p_1}$, Retailer 2 is assured of at least □ of the market at $p_2 = \underline{p_1} - z$. Its profits are less when $p_2 < \underline{p_1} - z$ as it does not increase any demand while at the same time reduces the profit margin.

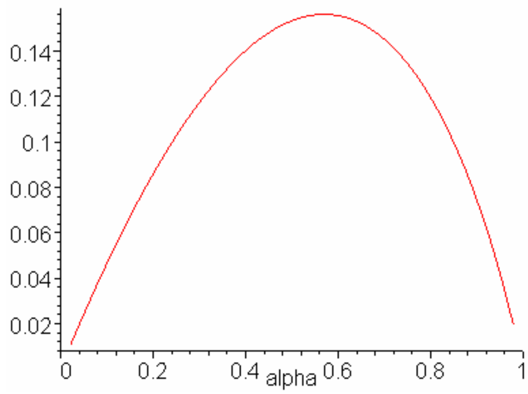
The best response function of Retailer 2 implies $p_2 = r - z$ dominates $p_2 \in (r-z, r]$. Q.E.D.

Proof of Proposition 6:

We can show this by showing that $\pi_2'(\alpha) < 0 \ \forall \alpha > \bar{\alpha}$ where $\bar{\alpha} < 1$, that is, the maximum profit for Retailer 2 is achieved for an intermediate □ $\bar{\alpha}$. For computational convenience, we assume r=1 and c=0.

$$E(\pi_2) = \int_0^1 p_2(\alpha - F_1(p_2)) f_2(p_2) dp_2$$

We plot this as a function of □ on the right-hand side. As evident from the figure, the maximum profit for Retailer 2 is achieved for an intermediate □ $\bar{\alpha}$. When a>0, $\alpha^* \le \tilde{\bar{\alpha}}$



So the maximum awareness level Retailer 2 will choose will never exceed $\bar{\alpha}$, and the optimal investment is decreasing in marginal cost of awareness. QED.

Proof of Proposition 7:
Retailer 2's best response solves:

$$\max_{p_2,\alpha} \ \alpha(p_2-c)-a\alpha^2 \quad s.t.\ p_2<p_1$$

or by expressing □ as a function of p_2, $\alpha(p_2)=\dfrac{(p_2-c)}{2a}$, we solve the following function:

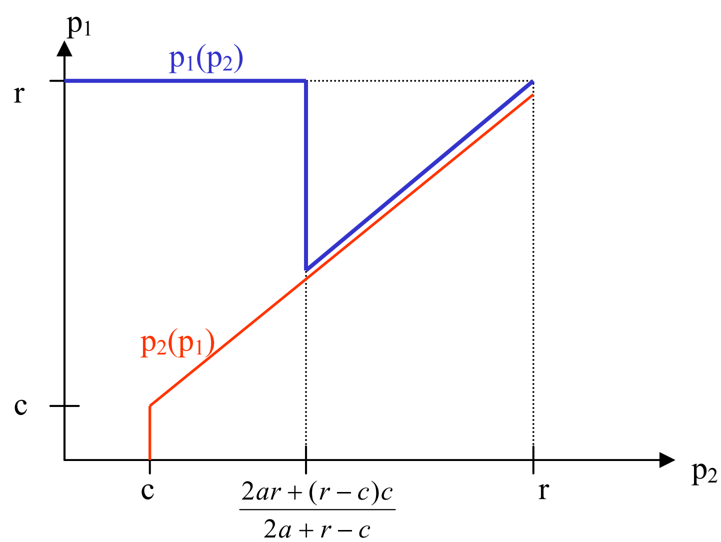
$$\max_{p_2} \ \frac{(p_2-c)^2}{4a} \quad s.t.\ p_2<p_1$$

Solving first order conditions gives us Retailer 2's best response functions:

$$p_2(p_1)=\begin{cases} p_1-\varepsilon & if\ p_1>c \\ c & if\ p_1\le c \end{cases}$$

Retailer 1's best response function:

$$p_1(p_2)=\begin{cases} r & if\ p_2\le \dfrac{2ar+(r-c)c}{2a+r-c} \\ p_2 & if\ p_2> \dfrac{2ar+(r-c)c}{2a+r-c} \end{cases}$$



Given these best response functions, there can't exist any NE, as shown in the graph, since these two best response functions do not cross anywhere. Q.E.D.

Proof of Proposition 8:
Case 1: When Retailer 2 moves first.

Knowing that Retailer 1 will respond to its price in the following way:

$$p_1(p_2) = \begin{cases} r & \text{if } p_2 \le (r-c)(1-\alpha)+c \\ p_2 & \text{if } p_2 > (r-c)(1-\alpha)+c \end{cases}$$

The highest price Retailer 2 can set while earn positive profits is $(r-c)(1-\alpha)+c$. Plugging this into Retailer 2's profit function: we get: $\alpha(r-c)(1-\alpha)-a\alpha^2$. Retailer 2 will then choose an □ to maximize its profit given Retailer 1's response:

$\alpha^* = \arg\max_{\alpha} \quad \alpha(r-c)(1-\alpha)-a\alpha^2$ and thus we get:

$$\alpha^* = \frac{r-c}{2(a+r-c)}$$

$$p_1^* = r,\ q_1^* = 1-\alpha^*,\ \pi_1^* = (1-\alpha^*)\cdot(r-c) = \frac{(2a+r-c)(r-c)}{2(a+r-c)}$$

$$p_2^* = (1-\alpha^*)\cdot r + \alpha^* c,\ q_2^* = \alpha^*,$$

$$\pi_2^* = \alpha^* \cdot (1-\alpha^*)\cdot(r-c) - c(\alpha^*) = \frac{(r-c)^2}{4(a+r-c)}$$

Case 2: When Retailer 1 moves first:

Knowing that Retailer 2 will respond to its price in the following way,

$$p_2(p_1) = \begin{cases} p_1-\varepsilon & \text{if } p_1 > c \\ c & \text{if } p_1 \le c \end{cases}$$

Retailer 1 will choose:

$$p_1^* = \arg\max_{p_1} \ (p_1-c)(1-\frac{p_1-c}{2a})$$

$$p_1^* = a+c; p_1^* = a+c-\varepsilon; \alpha^* = \frac{1}{2}; \pi_1 = \frac{a}{2} \ and \ \pi_2 = \frac{a}{4}$$

Given these, retailer 2 prefers moving first as long as: $\frac{(r-c)^2}{4(a+r-c)} \ge \frac{a}{4} \Leftrightarrow 0 \le a \le \frac{(\sqrt{5}-1)(r-c)}{2}$, and Retailer 1 prefers Retailer 2 moving first as long as: $\frac{(2a+r-c)(r-c)}{2(a+r-c)} \ge \frac{a}{2} \Leftrightarrow 0 \le a \le (r-c)$. But since *a* can't be greater than *(r-c)*, it is always Retailer 1's interest to let Retailer 2 moves first. Collectively, we get an equilibrium in which Retailer 2 moves first when $0 \le a \le \frac{(\sqrt{5}-1)(r-c)}{2}$. Q.E.D.

Proof of Theorem 2:

We already show that retailer 2 has no incentive to achieve full awareness when z=0. Now we show that retailer 2 also has no incentive to achieve full awareness when z>0. From Proposition 1, we can derive the profit level that retailer 2 can achieve at α=1 when z>0 as

$\pi_2(\alpha=1, z>0)=(c+\frac{z}{3\alpha})\cdot\frac{1}{3}-C(\alpha)=(c+\frac{z}{3\alpha})\cdot\frac{1}{3}-a\alpha^2$, which is decreasing in α even when a=0. As a result, retailer 2 is better off with a smaller-than-1 α*. QED.