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# BRAND AWARENESS AND PRICE DISPERSION IN ELECTRONIC MARKETS

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## Abstract

*Price dispersion, the variance in price for identical products across retailers, is a persistent feature of Internet-based markets, even those mediated by shopping agents (shopbots). In this paper, we propose a model for explaining this price dispersion based on limited consumer awareness of competing retailers and brand sensitivity, the willingness to pay a premium to buy from a leading retailer. We show that full awareness and the absence of brand sensitivity are necessary for markets to be characterized by Bertrand competition. When both of these are not simultaneously true (which is likely for most Internet markets), a number of other pricing strategies become optimal. Branded (high awareness) retailers tend to charge higher prices on average, but in some circumstances will randomize their prices such that they will be lower price than unbranded retailers on some products or some of the time. We also show that even if an unbranded retailer can invest to improve awareness, they have weak incentives to do so as this increases price competition. These observations are consistent with empirical research on pricing in Internet-based markets and may offer a more complete story of Internet price dispersion than some of the leading alternative explanations.*

**Keywords:** Electronic markets, information economics.

**ISRL Categories:** HA0702, AD02

## INTRODUCTION

Price dispersion, the variance in prices across retailers and over time for identical products, is a common characteristic of online markets. These price differences persist even though lower search costs or increased competition facilitated by the Internet should reduce or eliminate price dispersion (Bailey 1998a; Brynjolfsson and Smith 2000a; Clemons et al. 2000). While there are a variety of possible explanations for price variation, few of these explanations would predict price dispersion in markets heavily mediated by search agents (or “shopbots”). In these markets, consumers presumably have very accurate information about the true distribution of prices and can easily identify the lowest price. Nonetheless, Brynjolfsson and Smith (2000b) find significant price dispersion in products searched by shopbots. Even more strikingly, they also find that consumers using shopbots (whom we would expect to be highly price sensitive) are willing to pay a premium to buy from better-known retailers. While brand-specific effects such as overall quality, reliability, or customer loyalty could explain a systematic price premium, this is not fully consistent with the data: the brand premium varies by product and branded retailers sometimes charge *lower* prices than their less well-known competitors for some products at some times.

In this paper, we present a model which links price dispersion to differences in brand awareness and brand sensitivity that presents one possible explanation for these observations. In our paper, we define brand awareness as: (1) consumers know that the brand exists and (2) consumers are actually considering it as one of the alternatives to buy from at some (possibly discounted) price. If the customer demands a discount to purchase from a less known retailer, then in our terminology the customer shows brand

sensitivity.<sup>1</sup> We examine pricing in a duopoly market with a leading brand and a less well-known competing brand focusing on the interaction of two effects: the number of consumers who are aware of the competing brand and the degree of brand sensitivity (the price premium needed to encourage a customer who considers all brands to purchase a product from an lesser known or “unbranded” retailer).

Our results suggest that when consumers are indifferent to brand (zero premium) and all consumers consider both brands (full awareness), firms essentially engage in aggressive (Bertrand) price competition. However, absent both of these effects simultaneously, a number of other pricing strategies become optimal. Branded retailers will tend to have higher prices on average, but when there are moderate levels of brand premium and limited awareness, the only price equilibrium is in mixed strategies. In other words, branded retailers will sometimes charge lower prices than their unbranded competitors for some products or at some times. In addition, we also show that competitive markets will be characterized by differences in brand awareness across firms if there is any initial asymmetry in brand awareness. Even if costs of building awareness (e.g., advertising) are symmetric, unbranded retailers have muted incentives to do so because increasing awareness also increases price competition *ceteris paribus*. Our model is consistent with a variety of empirical results on price dispersion in Internet retailers and, as we argue in the conclusion of the paper, may provide a more reasonable explanation for the observed pattern of price dispersion on the Internet than many of the alternative explanations such as search cost reductions, product differentiation, or simple brand premia.

In the economics literature, previous research has linked differences in information (informed and uninformed consumers) to price dispersion across retailers and over time (Salop and Stiglitz 1977; Varian 1980). On the other hand, Bakos (1997) shows that symmetric search costs lead to an absence of price dispersion even in differentiated markets. The marketing literature considers brand identity and brand loyalty as important determinants of brand choices, since brand is a signal for quality or service levels (Lal and Sarvary 1999). Our analysis differs in the sense that it integrates two important aspects of consumer search in Internet markets: brand sensitivity due to quality uncertainty and risk aversion, familiarity, or advertising, and limited awareness where not all consumers are aware of all brands (similar to the economic search cost models).

In the next section, we present the basic model of pricing for two firms where awareness is considered fixed (that is, the unbranded retailer cannot or has no incentive to invest in increased awareness). We then extend the model to a case where the unbranded retailer can increase their awareness at a certain cost. Finally, we compare our results to observed patterns of price dispersion on the web and discuss the relationship of our model to previous work on price dispersion in online markets as well as the broader literature on the economics of price dispersion.

## MODEL

### Introduction

Consider a market where there are large numbers of heterogeneous consumers who are considering a product purchase from one of two retailers: a well-known *branded retailer* that all consumers consider, and an *unbranded retailer* who is known only to a fraction of all consumers.<sup>2</sup> In addition, those aware of both retailers also differ on their willingness to pay a premium to use the branded retailer.<sup>3</sup> We assume that all retailers have the same marginal cost of the product and that consumers have the same

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<sup>1</sup>Our definition of brand awareness is similar to the concept of a consideration set. Our definition of brand sensitivity is one possible manifestation of the broader concept of brand loyalty, which includes both price sensitivity effects as well as repeat purchase propensity.

<sup>2</sup>We do not believe the insights of the model to be unique to duopoly competition; however, like many other competitive models, extension to arbitrary number of firms vastly increases the complexity without much potential gain for new insights.

<sup>3</sup>The difference in awareness may be due to search costs or other factors, such as opportunity costs, risk aversion, or consumer inertia, that tend to limit search combined with different abilities of retailers to reach customers. For example, it may be essentially free to list on an Internet shopbot, while a full advertising campaign might be prohibitively expensive. The differences in brand premium could be due to a variety of factors such as familiarity with the branded retailer, risk aversion, heterogeneous valuation of quality differences, and switching costs to name a few. Most of these costs result from variations in preferences or cognitive limitations that are not likely to be altered by technological progress or reductions in search cost.

reservation price for the product, which is greater than marginal cost.<sup>4</sup> One could consider this setup to be similar to online book retailing in some sense: all customers know about Amazon.com, but only the fraction of customers that use shopbots are likely to know about A1Books.com. Moreover, even when A1Books is cheaper, not all consumers will buy from them. It is important to note that there are a variety of reasons that both brand premia and limited awareness could persist even if search costs were to become negligible or even zero.<sup>5</sup>

## Notation

We designate the branded retailer as Retailer 1 and the unbranded 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, and we assume that consumers purchase at most one unit of the good. Retailer 1 is known to all customers, while Retailer 2 is considered only by  $\alpha$  percent of customers (thus,  $1-\alpha$  only consider Retailer 1). We assume that the degree of price sensitivity (brand premium) of customers is given by a uniform distribution for those customers aware of both retailers with lower support 0 and upper support  $z$ . That is, 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 1 and 2). With this setup, we can compute the quantities sold ( $q_1, q_2$ ) and profits ( $p_1, p_2$ ), given prices ( $p_1, p_2$ ) and exogenous parameters ( $\alpha, z, r$  and  $c$ ):

$$q_1 = \begin{cases} 1, & \text{if } p_1 \leq p_2 \\ 1 - \alpha + \alpha \cdot \left(1 - \frac{p_1 - p_2}{z}\right) & \text{if } p_2 \leq p_1 \leq p_2 + z \\ 1 - \alpha & \text{if } p_1 \geq p_2 + z \end{cases}$$

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

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

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

<sup>4</sup>Fixed reservation price is a common assumption, but not essential to our results. Variations in reservation price could be subsumed in the brand premium in our model setup; this is a mathematical observation rather than a deeper statement of the economics of this problem.

<sup>5</sup>Even if search costs drop to zero, consumers can still incur costs for evaluating alternatives, encouraging limited search. Also, as noted by Varian and Shapiro (1999), switching costs, loyalty, or simple customer inertia may deter consumers from considering alternative retailers.

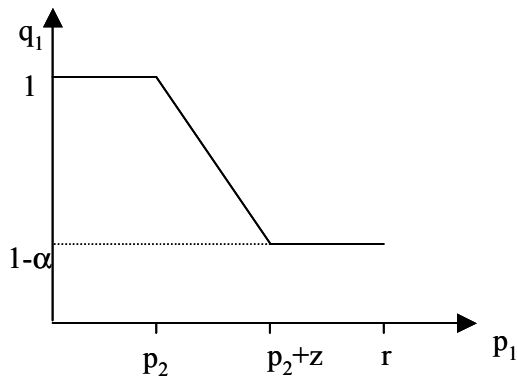


Figure 1. Demand Curve for Retailer 1 for a Given  $p_2$

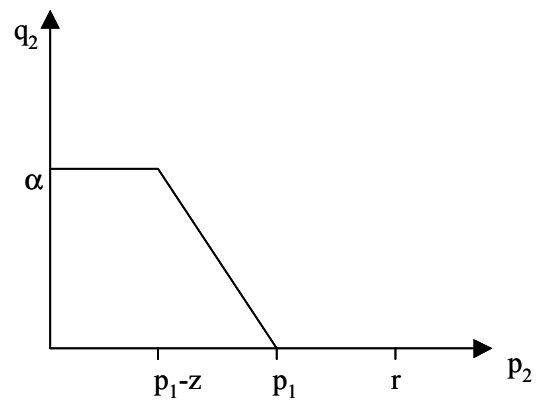


Figure 2. Demand Curve for Retailer 2 for a Given  $p_1$

### Analysis

Our analysis will proceed by deriving the pricing strategies that represent equilibrium behavior by the two retailers given various values for the exogenous parameters: reservation price ( $r$ ), fraction of informed consumers ( $\alpha$ ), marginal cost ( $c$ ), and distribution parameter of brand premium ( $z$ ). We begin by computing the region in which pricing is characterized by a pure strategy equilibrium—that is, the region in which firms offer fixed prices across products and over time.

**Proposition 1:** (a) When  $\alpha \geq \frac{1}{3}$  and  $\frac{9\alpha(1-\alpha)}{4} \leq \frac{z}{r-c} \leq \frac{3\alpha}{2}$  there is a unique non-cooperative Nash Equilibrium (NE) in

which  $(p_1^*, p_1^*) = (c + \frac{2z}{3\alpha}, c + \frac{z}{3\alpha})$ . (b) When  $\alpha \geq \frac{1}{3}$  and  $\frac{z}{r-c} \geq \frac{3\alpha}{2} \geq \frac{1}{2}$  there is a unique NE in which

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

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

Proof: See Appendix.

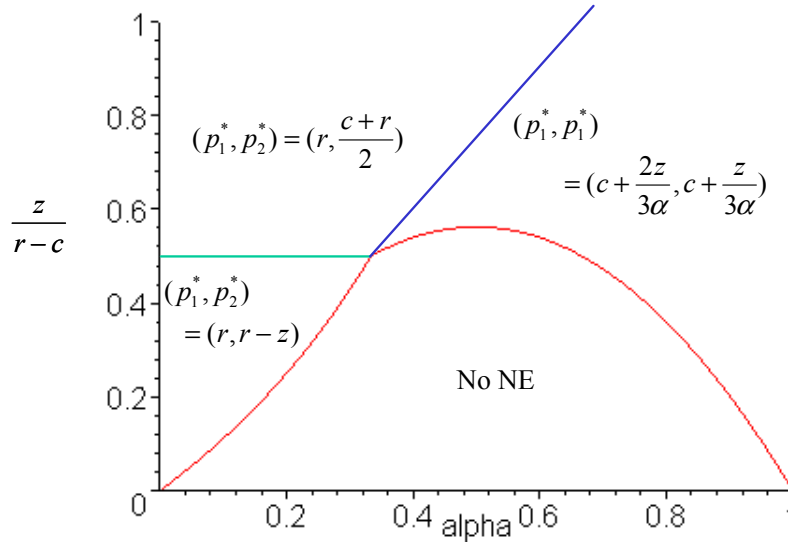
The various regions in which pure strategy equilibria exist are depicted in Figure 3. When there are a relatively small proportion of informed customers ( $\alpha \sim 0$ ) the pricing strategy depends on the strength of brand preferences. When brand preferences are weak (lower left corner of Figure 3), firms essentially divide up the market. The branded retailer charges reservation price, and the unbranded retailer charges reservation price less brand premium and serves all customers that know they exist. As the brand premium becomes larger, this transitions into a monopoly-like pricing region (upper left in Figure 3): the branded firm continues to charge the consumers' reservation price, but the unbranded firm now prices based on the tradeoff between higher prices for non-brand loyal customers and stealing share from the branded retailer. When consumers have high awareness of both brands (upper right), firms compete by dividing up the market in proportion to the brand premium. In all of these cases, the branded retailer charges a lower price and competition intensifies between the retailers as the  $\alpha$  moves away from the origin in Figure 3. 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, this strategy appears as prices fluctuate across time or over different products according to a probability distribution. This technique has been used in both economic and marketing literature to capture either consumers' or firms' actions in a strategic interaction (Raju et al. 1990; Varian 1980). A necessary and sufficient condition for the 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). By eliminating pricing strategies that are strictly dominated, we get:

**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  $p_2 = [\underline{p}_1 - z, r - z]$ .*

Proof: See Appendix



**Figure 3. Possible Equilibria for Different Parameter Values**

Within this set of feasible, non-dominated strategies, we can use the technique of Moulin (1982) and 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. Because we know from Proposition 1 that no pure strategy equilibrium exists in this region of the parameter space, Proposition 3 guarantees that the optimal pricing strategies will include firms randomly varying their prices in equilibrium.

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

$$\begin{cases} F_1(r) = 1 \\ (p_2 - c)\alpha(1 - F_1(p_2 + z)) + \int_{p_2}^{p_2+z} (p_2 - c)\alpha \frac{p_1 - p_2}{z} f_1(p_1) dp_1 = (\underline{p}_1 - z - c)\alpha \forall p_2 \in [\underline{p}_1 - z, r - z] \\ F_1(\underline{p}_1) = 0 \end{cases}$$

$$\begin{cases} F_2(r - z) = 1 \\ (p_1 - c)(1 - \alpha)F_2(p_1 - z) + \int_{p_1-z}^{p_1} (p_1 - c)[1 - \alpha + \alpha \frac{p_2 + z - p_1}{z}] f_2(p_2) dp_2 + (p_1 - c)(1 - F_2(p_1)) \\ = (r - c)(1 - \alpha) \quad \forall p_1 \in [\underline{p}_1, r] \\ F_2(\underline{p}_1 - z) = 0 \end{cases}$$

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.

Given that we have a general, but complex, characterization of pricing behavior in this region, it is useful to examine the behavior of these pricing strategies under different conditions. One interesting case is when there is no brand premium (that is  $z = 0$ ): customers may or may not be well informed about the existence of Retailer 2, but are unwilling to pay just for brand. The pricing strategy in this case is given by Proposition 4:

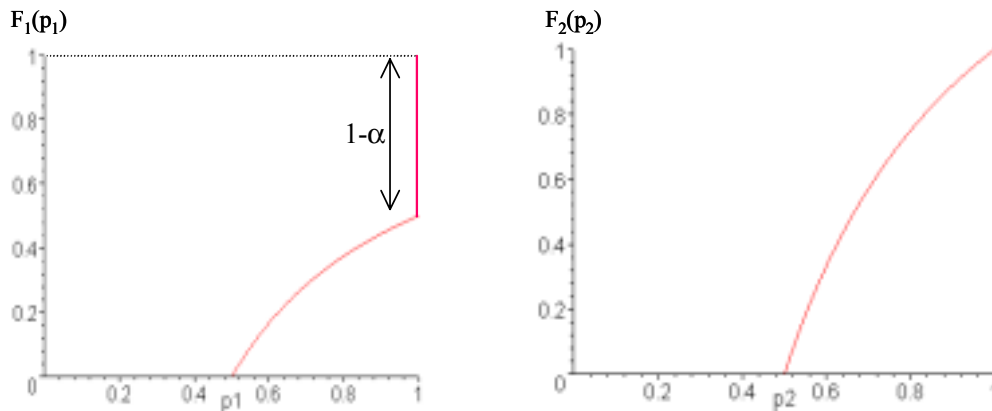
**Proposition 4:** *when  $z=0$ , there exists a unique mixed strategy equilibrium which constitutes:*

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

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

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

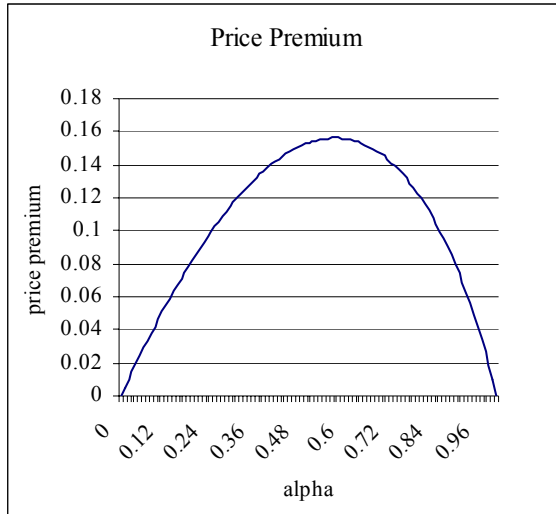
Figure 4 shows the equilibrium distributions for both retailers under some parameter settings based on Proposition 4. Proposition 4 shows that when brand premia do not exist, Retailer 1 will place more weight on high prices in their randomization strategy when fewer customers know about the existence 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 little-known retailers), prices will vary across Internet retailers even though shopbots exist and even if there is no brand premium. However, the branded retailer will have higher prices on average, even though consumers are brand indifferent (beyond awareness).<sup>6</sup> In Figures 5 and 6, we show the behavior of the average price premium and price dispersion (measured as the variance in difference in prices charged by the two retailers) respectively when



**Figure 4. Equilibrium Distributions (Mixed Strategy Equilibrium) for the Case Where  $z = 0$ ,  $\alpha = 0.5$ ,  $r = 1$ , and  $c = 0$**

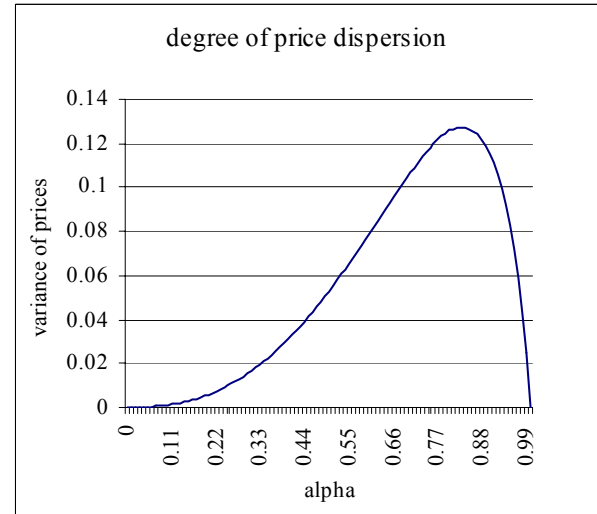
<sup>6</sup>This is true because the price distribution for Retailer 1 stochastically dominates the distribution for Retailer 2 for all parameter values where these distributions are non-degenerate.

we normalize marginal cost to zero and reservation price to 1.<sup>7</sup> Although mean prices charged by the two retailers are strictly decreasing in awareness ( $\alpha$ ), the difference in mean prices is maximized when  $\alpha$  is close to the middle (the maximum is approximately  $\alpha = .57$ ). The variance in prices is increasing in awareness up to a point where awareness is large (approximately  $\alpha = .83$ ) and then falls dramatically as prices are driven to marginal cost. Note that these cutoff levels are exact but we present them as approximations due to their complex mathematical form.



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

**Figure 5. Price Premium Charged by the Branded Retailer ( $z = 0$ )**



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

**Figure 6. Degree of Price Dispersion ( $z = 0$ )**

Another interesting result is to derive the conditions under which Bertrand (pure price) competition would arise in this market. Using our previous results, it is easy to show that the absence of brand premium ( $z = 0$ ) and full consumer awareness of competing retailers consumers ( $\alpha = 1$ ) is **necessary** for the existence of pure price competition. Stated another way, as long as not all consumers utilize shopbots (or other technologies where consumers can search all retailers), we would expect firms to earn positive economic profits.<sup>8</sup>

**Proposition 5:** *When  $z = 0$  and  $\alpha = 1$ , both firms charging marginal cost  $c$  is the unique pure Nash Equilibrium.*

**Proof:** *Follows directly from setting  $\alpha = 1$  in Proposition 4. Q.E.D.*

Finally, we can summarize the key points of all of these propositions regarding the existence of price dispersion in Internet-mediated markets.

**Theorem 1:** *Price dispersion exists in a market with well-known brands and less-known brands as long as the following two conditions do not hold at the same time: (a)  $z = 0$  and (b)  $\alpha = 1$ . Price dispersion is a result of either a persistent price premium for well-known brands or firms randomizing their prices.*

**Proof:** *This is a direct result of Proposition 1 and Proposition 3. Q.E.D.*

<sup>7</sup>Note that the values of  $r$  and  $c$  only scale up or down the curve but do not change the shape of the curve.

<sup>8</sup>The fact that most Internet retailers are not profitable is not necessarily inconsistent with this result. This result states that they earn a price above marginal cost. It does not necessarily say anything about whether this margin is sufficient to all average costs and thus creates overall profitability.



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. Branded firms will, on average, charge higher prices, either persistently or as a result of the randomization, and they may not always be the highest cost retailer.

A key assumption of this analysis is that the choice of awareness level is fixed. There was no action that an unbranded firm could take to increase their awareness level. However, given that branded retailers earn higher profits than unbranded retailers, it raises the question as to why unbranded retailers, in a market with few entry barriers and available advertising (at a cost), do not invest to build their awareness. Interestingly, we show in the next section that even if firms can invest in advertising or otherwise build awareness on the same terms, they will tend not to do so. Thus, markets that begin with this difference in awareness tend to show a form of first mover advantage without firm learning or cost advantages, two typical explanations of first mover advantage.

### Model Extension: Awareness as a Choice

Consider the same model as in the previous section. Instead of  $\alpha$  being a fixed, exogenous variable, we allow Retailer 2 (the unbranded retailer) to make an investment in awareness to change the level of  $\alpha$ . 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  $\alpha$ . 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 improvements in awareness grows rapidly. Using the same notation as before, the quantities and profits are given by:<sup>9</sup>

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

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

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

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

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 in this game. This is formalized below:

**Proposition 6:** *There exists no non-cooperative pure Nash Equilibrium in this game.*

Proof: *See Appendix.*

In addition, when  $a$  is sufficiently low, there is no equilibrium where firms set prices simultaneously or when the branded firm acts as a price leader and the unbranded firm follows. In other words, when investing in awareness is an option, branded firms will 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. Thus, it is in the interest of both firms to allow the *unbranded* firm to set prices first. Specifically:

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<sup>9</sup>We have assumed zero degree of brand sensitivity here.

Proposition 7: When  $0 \leq a \leq \frac{(\sqrt{5}-1)(r-c)}{2}$ , there is an equilibrium in which firm 2 moves first:

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

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

Proof: See Appendix.

Of course, when the cost of awareness is sufficiently large, this issue is no longer a concern: the unbranded 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 the previous section will hold.

Another interesting feature of Proposition 7 is that even if awareness is free, it is not optimal for the unbranded retailer to be recognized by the entire market (that is, irrespective of  $a$ ,  $\alpha^*$  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 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 branded retailer. This strategy maximizes profits for both the branded and unbranded retailers (although the branded retailer would, of course, prefer no competition at all). Thus, by being an early mover and achieving high awareness, firms can lock in a profit advantage: they will be the most profitable firm in the industry (in price-cost margin terms) as long as there is any profit to be made in the industry at all. This also is consistent with the observation that most Internet markets are characterized by a few (or even a single) dominant firm 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.

## DISCUSSION AND CONCLUSIONS

Our theoretical analysis has shown that price dispersion is a general phenomenon in the market where retailers have different levels of consumer awareness. As long as pricing is above marginal cost, well-known brands will charge higher prices on average than lesser-known brands. Under some conditions (especially brand loyalty that is “not too high”), firms will tend to randomize price. These observations are consistent with previous research that showed that brand premia exist even for shopbots users, but that branded retailers are not always the highest price. Our results suggest that these phenomena will exist as long as some consumers are brand loyal (unlikely to change) and not all consumers are fully aware of all available retailers and prices (also unlikely to change). This will also hold as long as any one of these conditions is still present. In the absence of awareness differences *and* brand loyalty, the inevitable outcome is Bertrand competition, as predicted by some observers of online markets.

Our assertion of limited consumer awareness and brand loyalty is consistent with observed behavior of Internet shoppers. For instance, in July, 2000, using data from Media Metrix, we found that only 236 customers out of 3,771 tracked who visited a book seller used a shopbot for books.<sup>10</sup> In this same sample, 80% of the customers who visited an online book retailer visited only one retailer in that category. This highlights the relevance of limited awareness and brand loyalty. These theoretical results also suggest why it may not be in the retailers’ interest for the limited awareness situation to change substantially: expansion of awareness of unbranded retailers brings increased price competition, which may lead to decreased profits for all participants.

Our results are consistent with (and may address unanswered questions from) previous work on price dispersion. The brand premia for well-known retailers at shopbots found by Brynjolfsson and Smith (2000b) are consistent with our results. It is also consistent with previous work that shows branded retailers are not always highest cost, although they are less likely to be the lowest cost (Bailey 1998b; Brynjolfsson and Smith 2000a). Our results on mixed strategy equilibrium in pricing suggest that this

<sup>10</sup>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.

is indeed an outcome of a well defined economic game, albeit one that abstracts some details away from the market. Finally, while the result that branded firms may prefer to be price followers seems fairly abstract, it is indeed consistent with an unusual finding in Kauffman and Wood (2000, Table 3). They found that branded retailers tend to be followers to their competitors' price changes while many smaller retailers did not tend to respond to price changes at branded retailers (although they did not test the exact prediction of our model, that branded retailers might be price followers to unbranded retailers, but it is consistent with the same argument). It 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.

Our theory may also be more theoretically plausible than other possible explanations of price dispersion, especially given known empirical results. For instance, the presence or absence of *search costs* are neither necessary nor sufficient for the existence of equilibrium price dispersion (see Bakos 1997). Similarly, price dispersion is not a feature of models of *horizontal differentiation* (products of equality that appeal to different consumer tastes). Price dispersion is a natural consequence of *vertical (quality) differentiation*, but in commodity markets such as book retailing, any differentiation has to be in characteristics of the retailer, not in characteristics of the good. As a result, this is equivalent to a brand premium. In our model (and arguments from previous work), this could create systematic price premia for some retailers, but does not explain why these retailers might randomize around this value. Previous authors have also proposed the notion of variation in switching costs as a contributor of price variation. Again, this explains static differences in pricing, but does not explain the variance within a particular retailer. While these do not exhaust all possible explanations, it does suggest that the relative explanatory power of our model (at least in terms of matching existing empirical results) is substantial.

An extension of our model is to consider a multi-firm setting, including both static oligopoly and sequential entry situations, and study the effects of the number of firms on competition and pricing behaviors. In addition, it would be useful to provide direct empirical tests of our results, better distinguishing between our predictions and their alternatives.

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## Appendix

### Proof of proposition 1:

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

$$\max_{p_2} \alpha \cdot \frac{p_1 - p_2}{z} \cdot (p_2 - c)$$

$$s.t. \ p_1 - z \leq p_2 \leq p_1$$

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

$$\frac{\alpha}{z} (c + p_1 - 2p_2) \begin{cases} \geq 0 & \text{if } p_2 = p_1 \\ = 0 & \text{if } p_1 - z \leq p_2 \leq p_1 \\ \leq 0 & \text{if } p_2 = p_1 - z \end{cases}$$

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

$$p_2(p_1) = \begin{cases} c & \text{if } p_1 \leq c \\ \frac{c + p_1}{2} & \text{if } c \leq p_1 \leq c + 2z \\ p_1 - z & \text{if } p_1 \geq c + 2z \end{cases}$$

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

$$\max_{p_1} (1 - \alpha + \alpha \cdot \frac{p_2 + z - p_1}{z}) \cdot (p_1 - c)$$

$$s.t. \ p_2 \leq p_1 \leq p_2 + z$$

By solving the first order conditions, we get:

$$p_1(p_2) = \begin{cases} p_2 + z & \text{if } p_2 \leq c + \frac{z}{\alpha} - 2z \\ \frac{c + p_2}{2} + \frac{z}{2\alpha} & \text{if } c + \frac{z}{\alpha} - 2z \leq p_2 \leq c + \frac{z}{\alpha} \\ p_2 & \text{if } p_2 \geq c + \frac{z}{\alpha} \end{cases}$$

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

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

Q.E.D.

**Proof of Proposition 2:**

The proof follows directly from two Lemmas proven below.

*Lemma 1:*  $p_1=r$  dominates  $p_1 \leq \underline{p}_1$ , 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  $(1-\alpha)$  of the market at  $p_1 = r$  with profit  $(1-\alpha)(r-c)$ . 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 best response function that makes retailer 1 indifferent from 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  $p_1 \geq \underline{p}_1$ , Retailer 2 is assured of at least  $\alpha$  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 it 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:**

Retailer 2 best response solves:

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

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

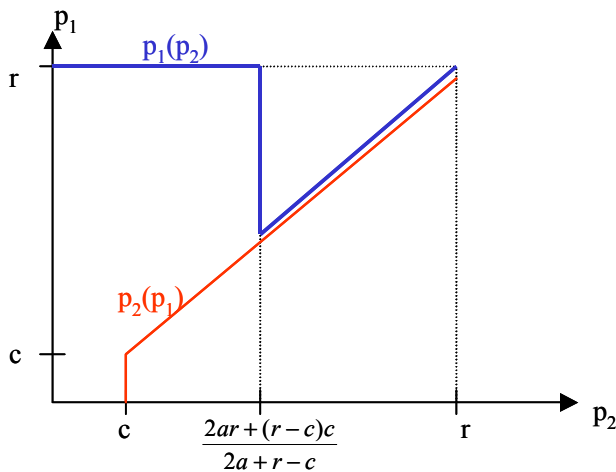
$$\max_{p_2} \frac{(p_2 - c)^2}{4a} \quad s.t. \quad p_2 < p_1$$

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

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

Retailer 1's best response function:

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



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

**Proof of Proposition 7:**

Case 1: When Retailer 2 moves first:

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

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

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

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

Retailer 1 will choose:

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

$$p_1^* = a + c; p_2^* = a + c - \varepsilon; \alpha^* = \frac{1}{2}; \pi_1^* = \frac{a}{2} \text{ and } \pi_2^* = \frac{a}{4}$$

Given these, Retailer 2 prefers moving first as long as:  $\frac{(r-c)^2}{4(a+r-c)} \geq \frac{a}{4} \Leftrightarrow 0 \leq a \leq \frac{(\sqrt{5}-1)(r-c)}{2}$ , and Retailer 1 prefers

Retailer 2 moving first as long as:  $\frac{(2a+r-c)(r-c)}{2(a+r-c)} \geq \frac{a}{2} \Leftrightarrow 0 \leq a \leq (r-c)$ . But since  $a$  can be greater than  $(r-c)$ , it is

always in Retailer 1's interest to let Retailer 2 move first. Collectively, we get an equilibrium in which Retailer 2 moves first

when  $0 \leq a \leq \frac{(\sqrt{5}-1)(r-c)}{2}$ . Q.E.D.