A Model of Internet Pricing Under Price-Comparison Shopping

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ABSTRACT: An empirical regularity in the price-promotion behavior of retailers of homogenous goods is explained theoretically. Based on this, a model is proposed for price competition in a market for a homogenous good with many asymmetrically positioned retailers. Asymmetry in this context refers to firms having potentially dissimilar loyal and switcher customer numbers that shape their pricing behavior in on-line markets. Incomplete information on the size of these segments results in distinguishable clusters of indistinguishable firms. To analyze these markets, a static game of price competition is developed and solved in an asymmetric oligopoly with numerous clusters of firms. The firms with the smallest ratio of switcher segment size to loyal segment size engage in fierce price competition, whereas the members of all other groups price their goods at reservation price points with no price promotions. This observation is a unique contribution and challenges the perception that all firms in markets for homogenous goods adopt mixed pricing strategies.

KEY WORDS AND PHRASES: Comparison shopping, e-commerce, economic analysis, Internet retailing, loyalty, pricing.

On-line customers who visit a price-comparison site are likely to be pleasantly surprised to find myriad on-line retailers selling the product for which they are searching. At least as surprising is the range and variety of prices these retailers quote for any particular product. Some questions arise from this scenario: (1) Is there any semblance of order to this seemingly chaotic pricing? (2) Is it possible to work out the characteristics of the type of competition that unfolds in a market consisting of many retailers selling a homogenous product? Of course, the potential customers who visit an on-line store do not all click through from a price-comparison site. However, the mere existence of price-comparing customers must have an effect on the pricing strategies of e-retailers.

The on-line markets for software, music, movies, computers, electronics, appliances, and books are typical of such markets. Because of the lack of entry barriers, gaining access to any of these markets is only as costly as setting up an e-commerce-enabled site. Thanks to the ease of market entry, many small players are able to offer their services to on-line buyers. When customers compare prices for a given identical product, these e-tailers are vying in direct competition with each other for that customer's business in regard to the product in question. The proliferation of price-comparison engines and shopping agents contributes to the practice of price-comparison shopping and has the potential to increase competition. Evidence of such competition is provided in recent research on competition between conventional retailers [20], conventional retailers and mail order stores [24], and conventional retailers and on-line stores [5, 12], as well as between on-line stores [7, 15, 23]. Consequently, much more attention is being paid to the competitive strategies that may emerge as information technologies change the way people shop.

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An Empirical Regularity

The theoretical work presented in this paper was motivated by an empirical regularity observed in some on-line markets for homogenous products. Based on pricing data from on-line markets, one can graph a retailer's average normalized prices in a category versus the temporal variability of the prices.[1] Three such graphs are presented in Figure 1. In its broadest form, the empirical regularity observed in these graphs is that retailers with comparably lower average prices exhibit higher levels of price variability. This price variability (the average standard deviation across products) may be regarded as an indicator of promotional activity.

Furthermore, firms with lower average prices have significantly higher promotional activity, with correlations all negative and significant at the 0.05 level for the printer and camcorder data, and at the 0.1 level for the book data. One may question the novelty of this observation. After all, many studies report a negative correlation between average prices and level of promotional activity [19, 21]. However, two distinctions need to be drawn. First, most of the theoretical studies that expect such a negative correlation are based on models of duopoly, and their fit to a market comprising many firms may be questionable. Second, a deeper look into the pricing of separate products rather than the aggregate picture may reveal observations of a finer detail with no literature precedence.[2]

Figure 2 presents graphs of retailer prices and promotions for three specific products from the on-line markets for camcorders, printers, and books. The graph in the first panel shows the scatter plot of the retailer-specific average prices versus the standard deviations in price for a total of 25 retailers across 30 days, as quoted for a typical consumer-level camcorder (Panasonic PV-DV600). The graph shows that for 22 of the 25 retailers, a static yet dispersed price existed, while three retailers, mostly with lower average-price levels, were also offering price discounts, as revealed by their nonzero standard deviations in prices. The second panel of Figure 2 shows a similar graph for the Lexmark Optra Color 45n printer, while the third panel exhibits a comparable graph for the book *Bridget Jones's Diary.* In fact, such graphs typically emerge for many homogenous products, such as CDs, DVDs, books, consumer electronics, and software. The common themes running through all the graphs can be summarized as follows:

- Two groups of firms exist in the on-line market.
- The group with higher average prices does not price-promote, as revealed by a temporal standard deviation in prices that is equal to zero.
- The group with lower average prices price-promotes with a nonzero frequency.
- The number of price-promoting firms is smaller than the number of firms with static prices.
- The group with higher, static prices has dispersed average prices, whereas the group with lower, varying prices shows little dispersion in average price.

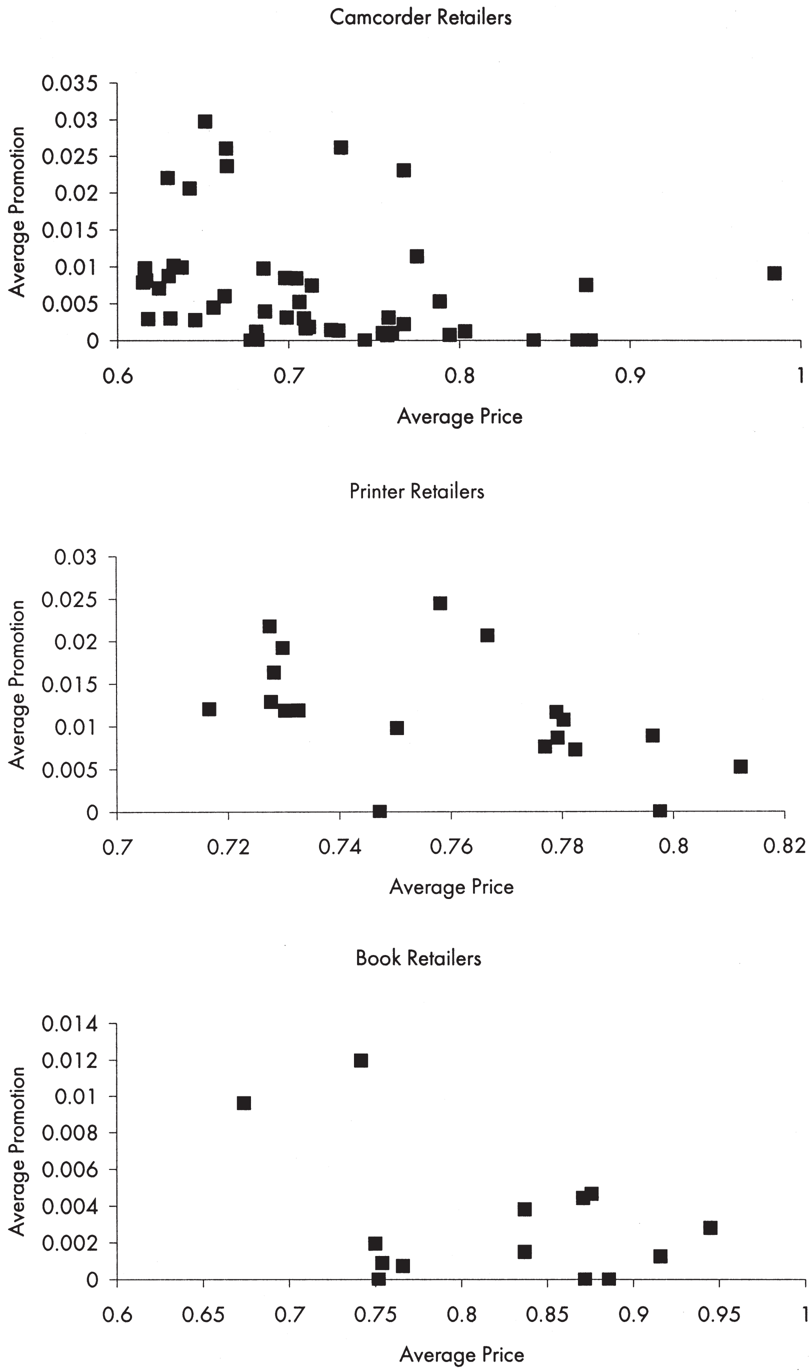

Figure 1. Scatter Graphs of All Retailer Prices and Promotions Aggregated Across All Products in the Three Categories

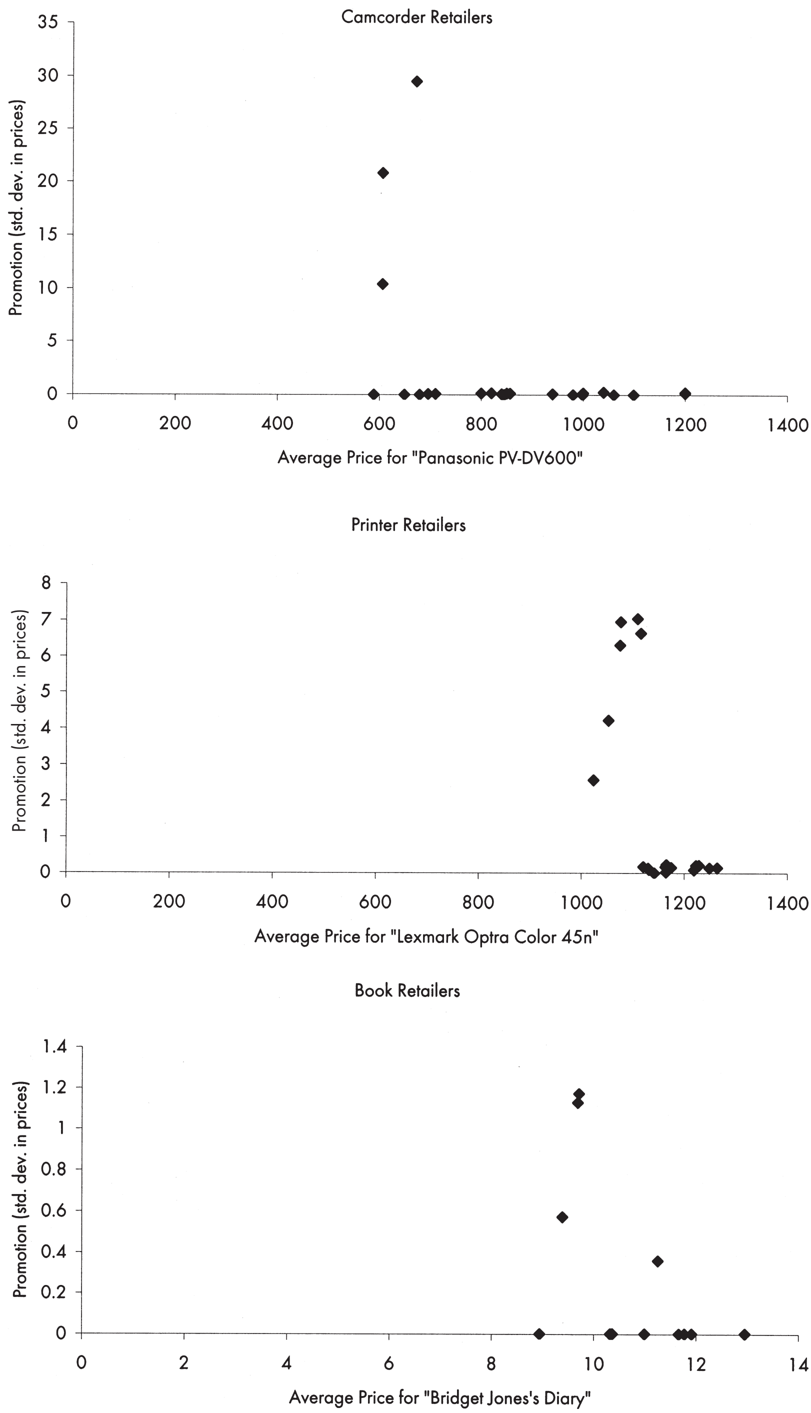

Figure 2. Scatter Graph of Retailer Prices and Promotions for Three Homogeneous Products. The Pattern of Prices Is Indicative of Two Strategies; a Price Promotion Strategy with Low Prices and a Static Price Strategy with Relatively High Prices

From both an empirical and a theoretical point of view, this observational regularity at the unique product level is completely novel. The present paper offers a model of price competition to analyze the rival forces that shape the pricing strategies of on-line retailers. In so doing, it attempts to understand the final conclusions revealed by these graphs. The goal is to explain why certain select firms engage in promotional activities, whereas most firms prefer to quote the same price over time.[3] Therefore the chief research question is: How can we explain the behavior presented in the graphs in Figure 2 and summarized in the preceding list?[4]

Literature Review

The information systems, economics, and marketing literatures contain rich research streams on pricing in a competitive environment. These research streams are either models based on game theory that seek equilibria in stylized models of profit-maximizing firms [17, 18, 19, 20, 21, 25] or empirical papers [4, 14]. Some key findings of the game-theoretical models are (1) that firms' pricing strategies are affected by the presence and size of loyal and switcher segments [19, 25]; and (2) that stronger versus weaker brands, in terms of brand/store loyalty and brand/store positioning, develop relatively diverse optimal pricing strategies [20, 21].

Recent works on pricing strategies in on-line markets have generally attempted to explain the reasons for dispersed prices and to explore the nature of pricing strategies [2, 5, 9, 10, 11, 15, 16]. One important consideration lies in the coexistence of collusive and competitive pricing strategies in on-line markets. For example, Kauffman and Wood show that industry- and firm-specific attributes may lead to either collusive or competitive pricing in an on-line market [15]. The results of their study parallel the findings in this paper that firm strategies are either collusive or competitive based on their relative segment sizes.

Although the studies mentioned above all employ a certain degree of abstraction, they aim to analyze markets with *many asymmetrically positioned* firms. A comprehensive analysis of markets with many asymmetrically positioned firms, therefore, becomes a necessary next step given the earlier works that dealt with the *many* and *asymmetrical* components separately. Asymmetry in this context refers to firms having dissimilar potential loyal and switcher customer sizes. Based solely on the research that treats these issues individually, one has to accept that all firms that compete in a homogeneous products market adopt mixed pricing strategies and offer price promotions. However, as both the opening examples of this research and daily experience suggest, this broad conclusion may not hold, and thus a comprehensive analysis is warranted.

In his seminal work, Varian examines the *many* component by analyzing a symmetric oligopoly, while Narasimhan examines the *asymmetrical* component by analyzing an asymmetric duopoly [19, 25]. Both of these studies use stylized models of price competition to show that firms engage in price promotions in order to simultaneously serve two market segments. With their regular prices, retailers maximize their profits from their loyal customers, while with their discounted prices, they hope to capture the switcher customer segment. Narasimhan's main finding is that asymmetric loyal segment sizes result in asymmetric strategies [19]. However, to a degree, both strategies involve price promotions.

In Varian's model, the symmetric oligopoly results in a symmetric equilibrium in which all firms engage in price promotions [25]. Herein, the probability of deeper price cuts is less than the probability of shallow price cuts. Narasimhan's asymmetric equilibrium displays promotional behavior that resembles Varian's in that both firms offer promotions [19, 25]. However, the firm with fewer loyal customers quotes lower prices with higher probability. A common result of both models is that there are no firms with static prices. Therefore, if one were to arrive at a conclusion about the nature of price promotions based solely on these models, the generalization would entail that all firms offer price promotions when comparison shoppers are present. This generalization is incomplete, largely because it depends on separate treatment of the *many* and *asymmetric* components.

Neither the Varian nor the Narasimhan model is sufficient to analyze a market comprised of many asymmetrically positioned firms [19, 25]. The present study analyzes an asymmetric oligopoly by introducing groups of retailers with various levels of loyal and price-comparing customers. The model deals with many asymmetrical firms. Although similar modeling assumptions are adopted, it is neither a direct interpolation nor a simple extension of the previous models. A direct proof of this claim lies in the fact that the model yields firms with degenerate strategies, where price-promotion does not exist. Such outputs would be completely unexpected in the previous studies.

Model

A stylized game-theoretical model of price competition in an oligopolistic market with identifiable clusters of unidentifiable firms will now be specified and solved. The equilibrium solution provides insights to the strategies firms adopt, which are discussed consecutively.

Model Introduction

The model represents an oligopolistic market made up of many asymmetrical firms. It is widely accepted that firms may be asymmetrically positioned in terms of number of loyal customers, but as discussed here, firms can also differ in respect to number of price-comparing customers. Firms may have access to switcher segments of different sizes. This contingency may arise from the existence of multiple price-comparison sites, where firms are listed in only some of the many on-line venues. Alternatively, other mechanisms may be set in place for partial price comparison by some customers. For example, some firms, such as Amazon.com (www.amazon.com) and Barnes and Noble online (www.bn.com), benefit from a larger "mind-share" in that their customers may compare prices only between these two e-tailers without utilizing price-comparison sites. Because these well-known Internet players are also listed in most price-comparison sites, less-known firms listed in such sites experience a potentially smaller number of switchers than these two firms. Therefore, two levels of switcher segment sizes are utilized to account for the possibility that firms may have access to different levels of price-comparing customers.[5]

Whereas the minimum number of firms in an oligopoly is three, real-world examples of the market types examined—as the data set also reveals—are formed with dozens of firms. In order to strike a balance between realism and simplicity, this market is modeled as one that consists of exogenously formed groups of firms. That is, due to incomplete information, the model assumes distinguishable groups of indistinguishable firms. This enables the model to accommodate even markets with hundreds of firms. To make the model as general as possible, four groups, or clusters, of firms are introduced. The analysis could easily be extended to a larger number of clusters. Each firm is categorized as possessing a small or large number of switcher customers and a small or large number of loyal customers. This categorization results in four clusters, which are named using the convention <Size_Loyal, Size_Switcher>. The clusters are referred to as LL, LS, SL, and SS clusters, where the first letter refers to the number of loyal customers (Large vs. Small) and the second letter refers to the number of switcher customers (Large vs. Small). The LS cluster, for example, is the group of firms with a large number of loyal customers and a small number of switcher customers. A typical firm in this category would be a niche click-and-mortar business that has an established loyal customer segment but a relatively negligible on-line presence. Typical examples from the on-line book market are Powell's (www.powells.com) and Wordsworth (www.wordsworth.com). On the other hand, a typical firm belonging to the SL cluster would be a pure on-line player with no established loyal customer segment but with a motivation to attract switcher segments by utilizing on-line traffic-generation strategies. Typical examples, again from the on-line book market, are VarsityBooks (www.varsitybooks.com) and eCampus (www.ecampus.com). Firms that belong to the LL cluster would be established on-line firms that have already invested in building customer loyalty while simultaneously competing for the business of switchers in hopes of retaining them as future loyal customers. A firm like Amazon is a typical example. Bigger click-and-mortar firms, such as Barnes and Noble, also belong to this cluster because of their high traffic generation and their loyalty potentials. Finally, a firm from the SS cluster would be a fringe player with neither a significant number of existing loyal customers nor an effective attempt to be found by switcher customers. Possibly hundreds of pure on-line booksellers could be categorized into this cluster.

The analysis that follows demonstrates that in a market with many asymmetrically positioned firms, only those firms that have a greater interest in the switcher segment engage in price-promotional behavior by offering any price discounts at all. The analysis shows that two diverse strategies emerge from this market. The first is adopted by the firms that fall into the LL, SS, and LS clusters, the second by firms in the SL cluster. Firms in the SL cluster compete for switchers. The competition results in randomized prices that range from the reservation price almost down to the marginal cost of the item. Driven away by this fierce price competition, firms falling into the other clusters do not price-promote at all. The selection of S and L sizes is somewhat random, but this choice is sufficient enough to demonstrate that only firms with the highest proportion of switcher customers will be offering price promotions.

The model and its solution are presented in the next section. The model's implications and limitations are discussed further on.

Model Specification

The assumptions and characteristics of the model are similar to those proposed by Varian and Narasimhan [19, 25]. However, as mentioned before, neither the Varian model nor the Narasimhan model suffice to analyze a market with many retailers, some with symmetric, others with asymmetric loyal segment sizes. Therefore, the model is neither a direct interpolation nor a simple extension of these previous models. By introducing groups of retailers with various levels of loyal customers, the model analyzes an asymmetric oligopoly. A market for a homogenous good is assumed, such as a book, a CD, a DVD, a brand name computer, an electronic device, or an appliance. There are two customer segments on the demand side: loyal customers and comparison shoppers. Each of these customers wishes to purchase a single unit of the good. There are $k \geq 3$ firms on the supply side of the model: Firm 1 through Firm k (some clusters may have no members at all). Each firm sells the same branded product, and its manufacturing/acquisition technologies are identical. Moreover, the marginal cost is assumed to be constant and equal to zero, without any loss of generality, resulting in a weakly declining average cost. There are no marketing costs and all firms are considered risk neutral.

The loyal customers are loyal to only one firm. The model represents the number of customers who are loyal to Firm i as n_i. It is assumed that n_i can take either of the two values, large (L) or small (S). This is not a strict assumption and can be restated with a larger set of values without any impact on the results. The comparison shoppers, s_i (switchers), are customers who are not loyal to any firm but buy from the one that has the lowest-priced product. The potential number of comparison shoppers, or switchers, who consider purchasing from a firm can also take either of the two values, large (L) or small (S). Again, this assumption could be restated with a larger set of values without any impact on the results. Moreover, the values large (L) and small (S) need not be identical for loyal and switcher segments. For simplicity's sake, however, they are assumed to be identical across segments. Consecutively, each firm belongs to any of the four clusters: LL, LS, SL, or SS.

Whereas loyal customers are exclusive to each firm, switcher customers are not. Thus it is assumed that all the switchers to whom an LS and SS cluster firm (clusters with small switcher segment sizes) can sell are also completely served by any firm in the LL and SL cluster (clusters with large switcher segments) when firms in these latter clusters offer better prices. That is, as sets of switcher customers, $S \subset L$.[6]

For the sake of simplicity, it is assumed that there are at least two firms in the SL cluster. This assumption is not crucial to the results. Even if an SL cluster had only one firm, that firm would price-promote along with the firm(s) in either the SS or LL clusters, and the overall results would remain the same. Customers buy from a firm only if the price they are given is less than their reservation price, r. This reservation price is analogous to the MSRP (Manufacturer's Suggested Retail Price), which is made public by the manufacturer and is exogenous to the model. A common homogeneous reservation price is widely assumed in models of duopolistic and oligopolistic competition. A heterogeneous reservation price version of the model will be solved later in the paper. While the sizes of the segments L and S and the reservation price r are common knowledge, firms cannot price discriminately because of imperfect addressability and targetability. Here targetability refers to the ability to predict whether the customer is a loyal or a switcher, and addressability refers to the ability to contact customers individually. The profit functions of the firms are given by the following:

$$\pi_i\left(p_i, p_{-i}\right) = \begin{cases} p_i\left(n_i + s_i\right) & \text{for} \quad p_i < Min\left[p_{-i}\right] \\ p_i\left(n_i + s_i / v\right) & \text{for} \quad p_i = Min\left[p_{-i}\right], \\ p_i n_i & \text{for} \quad p_i > Min\left[\mathrm{p}_{-i}\right] \end{cases} \tag{1}$$

where p_i represents the price quoted by Firm i, p_{-i} represents the vector of prices quoted by all other firms, and v represents the number of firms quoting the lowest price. As is evident from the profit function, it is assumed that in the event of a tie for the lowest price, the v firms with the lowest price serve the switchers equally.

Before proceeding further, it will be useful to briefly explain how strategic pricing behavior can be categorized. In general, pricing strategies can be classified as pure or mixed. A firm that chooses a single price is said to be adopting a pure strategy. However, if a firm chooses a set of prices, and in conjunction utilizes the probability measure that defines the likelihood that any of those prices will be quoted, the firm is using a mixed strategy. The analysis that follows will first show that there is no Nash equilibrium in pure strategies in this game. A Nash equilibrium is a set of strategies across all firms such that none of the firms finds it profitable to unilaterally deviate from its strategy. However, there is a mixed-strategy Nash equilibrium that will be sketched later on in the analysis.

An equilibrium in which a firm is using a mixed strategy can be interpreted as a situation in which the firm is offering price promotions. Because the firm will be choosing from among a set of prices, the highest price may be considered to be the regular price, while prices offered below this regular price will be considered price promotions. The analysis works out the details of this type of behavior in an effort to understand how certain firm characteristics lead to different pricing strategies. Solving for a mixed strategy, one can define the upper bound of the price support (the regular price), the lower bound of the price support (the price where the promotion depth reaches a maximum), and the frequency with which these and other prices are quoted.

The Analysis

The analysis begins by defining the upper and lower boundaries of firms' supports to determine the quotable prices in the game. Later, it shows that there are no pure-strategy equilibria by proving that when all firms have prices quoted with probability of 1, rival firms can undercut these prices. Furthermore, if all firms were to quote the lowest price, they would realize less profit than if they sold to their loyal customers at the highest possible price. After the lack of pure-strategy equilibria is proven, the equilibrium profits of all firms are determined. Given the strategic reactions of all the other firms, any price quoted by a firm has to result in a unique equilibrium profit for the firm. This fact follows from the definition of mixed-strategy equilibrium. Consequently, one can solve for the price points and their corresponding probability measure for all firms.

Defining the Upper and Lower Bounds

The upper bound of the feasible price set is the *reservation price.* Prices higher than the reservation price will result in no sales, while positive profits are possible when the reservation price is quoted. Therefore, the highest price that any firm can charge is the common reservation price, r. The lowest price any firm will ever consider charging is given by the formula $p_i^{\min} = n_i r/(n_i + s_i)$. To see this, note that Firm i can be motivated to reduce its price down to a level where, if the firm successfully captures the switchers, it makes at least the same profit as it would from selling to its loyal customers at r. That is, $(n_i + s_i)p_i^{\min} = n_i r$. Because the segment sizes are assumed to be identical for all firms in a given cluster, the minimum prices are also identical. Moreover, bigger loyal segment size will mean a higher potential loss in profit because of price reductions. Consequently, the lowest price at which the firm can still benefit from serving the switchers will be higher for firms with larger loyal segments. If the minimum price shared by the member firms of any cluster is referred to as $p^{\min}$, it is straightforward to note that $p_{SL}^{\min} = Sr/(L + S)$ will be lower than $p_{LL}^{\min}$, $p_{SS}^{\min}$, and $p_{LS}^{\min}$. Therefore, firms in the SL cluster will have the lowest minimum price. Because any given firm assumes that all firms with which it is in the same cluster share the identical segment size characteristics, it will assign the identical minimum prices to those other firms.

Equilibria in Pure Strategies

We first show the nonexistence of a pure-strategy Nash equilibrium.

> *Proposition 1: There is no Nash equilibrium in pure strategies.*

Proof: See Appendix.

The technical proof of the absence of a pure strategy is a minor step in the analysis and so is relegated to the Appendix. However, it will be helpful to provide an intuitive exposition. Note that the motivation to undercut the price of other lower-priced firms in order to capture the switchers results in a downward push in prices. This force is especially active among all firms in the SL cluster, because they are the firms that can undercut all the other firms. However, each low price can be further undercut by a lower price until the minimum price level is reached. At the same time, profits are lower if more than one firm offers the minimum price. If all firms were to quote the lowest price, they would realize less profit than if they sold to their loyal customers at the highest possible price. Therefore, if the switchers are not served with a lower price, the motivation to increase the price to the reservation price pushes prices up. The result is a lack of pure strategies.

From a managerial point of view, static prices for all firms are unattainable in the homogenous goods markets because lack of differentiation creates opportunities to undercut prices. Continuing the downward spiral, there is no end to this vicious cycle, which leads to lower profits. Consequently, the absence of pure-strategy equilibria signals the complexity of competing in such a market—there are no simple strategies that can guarantee profits. The possible ways out are either nonprice competition, which is beyond the scope of this paper, or the offering of randomized sales in order to diminish the predictability of pricing behavior. Consequently, in terms of randomized sales, firms benefit from selling not only to loyal customers but to price-comparing customers as well.

Equilibrium Profits

Before presenting the existence of mixed-strategy equilibrium by construction, it is also necessary to establish the equilibrium profits of all the firms. As mentioned above, in a mixed strategy, any price must yield the same expected profit. Otherwise, only prices with the higher-expected profits would be quoted.

> *Proposition 2: The equilibrium profits of all firms in this game will be equal to their reservation utilities, which are the lowest profits that a firm's opponents can hold it to by any choice of their own prices.*

Proof: For this game, the reservation utilities, or minmax profits, of all the firms are given by $n_i r$. Therefore, all firms in the LL and LS clusters have a reservation utility of Lr, while all firms in the SS and SL clusters have a reservation utility of Sr. These are the lowest profits Firm i's opponents can hold it to by any choice of p_{-i}, provided that Firm i correctly foresees p_{-i} and plays a best response to it. That is,

$$\pi_i^{mm} = \min_{p-i}\left[\max_{p_i} \pi_i\left(p_i, p_{-i}\right)\right] = n_i r \quad \forall i. \tag{2}$$

It will next be shown that the equilibrium profits of these firms will be equal to their minmax profits. To see that this is indeed the case, note that all k firms have a loyal segment that will buy from them, irrespective of the price, as long as the quoted price is lower than or equal to the reservation price. Hence, all firms can guarantee the profit $n_i r$ by choosing to price at r; that is, $n_i r$ is the lower bound. In terms of undercutting all other firms and serving the switcher segment, only firms in the SL cluster have an advantage. However, as there are at least two of these firms with small loyal segment sizes, they can also, at most, guarantee a profit of $n_i r = Sr$.[7] That is, no single firm has an absolute advantage in cutting down prices to assuredly capture the switcher segment. To see that $n_i r$ is the upper as well as the lower bound, note that there cannot be any point masses in the equilibrium supports of SL firms (see Varian's Proposition 3 [25]). Any point could be a point mass of a probability distribution if positive probability was concentrated at that point. Hence, in equilibrium, if one SL firm prices at r, all other SL firms will have a price lower than r with probability of 1, so that the firm pricing at r will for sure make $n_i r$; because the equilibrium profit has to be the same at all points of the support, the lower and upper bounds of the firms' profits are $n_i r$. Hence, the highest guaranteed attainable profits for the firms in this game are their minmax profits.

Equilibria in Mixed Strategies

Now that the support characteristics over the feasible range of prices have been established, it is possible to solve the firms' equilibrium pricing strategies. This is a major step in the analysis, because it is here that the equilibrium probability measure is decoded. This is where the mixed strategy is explored by construction.

Any firm will serve its loyal segments with the price it chooses as long as that price falls below the reservation price. Moreover, any firm can capture the switcher segment if the price it quotes is equal to the lowest price quoted by the competing firms. Therefore, for any price, p (except for any point where firms may have mass points, such as $p = r$), the pricing game's equilibrium conditions for k firms can be written as

$$E\left[\pi_i\right] = n_i r = n_i p + \prod_{\substack{j \in -i \\ j \leq k}} \left(1 - F_j\left(p\right)\right) p s_i \quad \forall i. \tag{3}$$

Note that in this formulation, the right-hand side contains a multiplicative term. Because $(1 - F_j(p))$ is the probability that Firm i will have a lower price than Firm j, this multiplicative term refers to Firm i having lower prices than all other firms, such that it can sell to the switchers at price p to make the profit ps_i. The first term on the right-hand side of the equation refers to the profit from the sale to the loyal customers, which is certain for any price below r.

Pricing Strategies of the SL Cluster Firms

Now that the equilibrium condition has been stated, it is necessary to see whether firms behave differently based on the asymmetry defined for them.

The next proposition presents the uniqueness of the positions held by the firms in the SL cluster. As this critical proposition demonstrates, only firms in the SL cluster have a motivation to engage in price promotions. Furthermore, the amount of promotional activity undertaken by the SL firms is sufficient for the other firms to engage in a degenerate strategy of pricing only at the reservation price.

Proposition 3: Only firms in the SL cluster will have positive support in the interval [p_{SL}^{min}, r] *or any other interval.*

Proof: The analysis starts in the interval with the lowest prices. Because in [0, $p_{SL}^{\min}$] no firm can realize a profit higher than its minmax profit, it is the next interval [$p_{SL}^{\min}$, $p_{e+}^{\min}$] in which the SL cluster firms can price. This notation refers to the minimum of ($p_{SS}^{\min}$, $p_{LL}^{\min}$) as $p_{e+}^{\min}$. The number of firms in the SL cluster is denoted as e, and the firms in either the SS or LL cluster with the next-lowest minimum price are referred to as Firms e+. Note that in the interval [$p_{SL}^{\min}$, $p_{e+}^{\min}$], all firms in the SL cluster will have lower prices than the rest of the firms with probability of 1, and thus they can capture the switcher segment if they price lower than the other firms in the SL cluster. Also note that non-SL firms cannot undercut prices in this interval, because their minimum prices are no lower than the interval's upper bound. The competition in this interval can be thought of as similar to that in Varian's model with two exceptions [25]. First, the number of firms is determined exogenously, and second, there are, in fact, other firms competing in the market, but not in this interval. Thus, the firms in the SL cluster, and no others, will randomize their prices in this interval so that the expected profits will be equal to the reservation profits. Also note that profits higher than the reservation profits would be possible if firms could somehow collude (i.e., quote reservation prices and share the switchers). However, firms compete noncooperatively, and as Proposition 2 puts forward, the equilibrium profit can equal the reservation profit at best. The equilibrium conditions for this interval can be written as

$$\pi^{mm} = Sr = Sp + \left[1 - F(p)\right]^{e-1} pL, \tag{4}$$

where e represents the number of firms in the SL cluster, as before. In this equation, the interactions solely with other firms in the SL cluster are included in the formulation because all other firms have minimum feasible prices above the interval's upper limit. The solution to this equilibrium condition is

$$F(p) = 1 - \left(\frac{(r-p)S}{pL}\right)^{1/e-1}. \tag{5}$$

Note that with this solution, $F(p_{SL}^{\min})$ equals zero, as expected (there are no mass points, or lumps of probability, at the lower bound), and the cumulative probabilities of SL cluster firms pricing below $p_{e+}^{\min}$ are given by

$$F\left(p_{e+}^{\min}\right)=1-\left(\frac{\left(r-p_{e+}^{\min}\right)S}{p_{e+}^{\min}L}\right)^{1/e-1}. \tag{6}$$

This concave, cumulative distribution function corresponds to a convex and decreasing probability distribution function. The managerial significance of the function's shape is that firms that compete in this interval have a better chance of quoting lower prices than higher prices. This characteristic defines the nature of the competition in this interval, where firms aggressively cut prices in order to serve the switcher segment.

This distribution function will be used for the analysis in the next interval. This cumulative function represents the mass of prices already lower than the remaining firms' prices. Hence, depending on the potentially detrimental sizes these functions reach for the intervals in which *e*+ firms can ever price, firms will decide whether to price at all. That is, if price competition is already too aggressive between the firms in this interval, other firms may prefer not to have any sales that would require upper-interval sale prices. In fact, as will be shown next, fierce price competition results in such a response in the upper intervals.

Pricing Strategies of the Non-SL Cluster Firms

After showing that the SL cluster *e* firms price in the interval $[p_{SL}^{\min}, p_{e+}^{\min}]$, it will now be shown that it is not possible for any other firm to have support in the interval $[p_{SL}^{\min}, r]$. Note that the lowest price that Firms *e*+ will ever quote is $p_{e+}^{\min}$, and at this price, the expected profit they will realize is given by the equation

$$\pi_{e+}\left(p_{e+}^{\min}\right)=n_{e+}p_{e+}^{\min}+\left[1-F\left(p_{e+}^{\min}\right)\right]^{(e+)-1}p_{e+}^{\min}s_{e+}. \tag{7}$$

Yet Firms *e*+ will never price at $p_{e+}^{\min}$ if $\pi_{e+}(p_{e+}^{\min})$ is less than their minmax profit of $n_{e+}r$. Inserting values from Equation (6) into Equation (7), we see that $\pi_{e+}(p_{e+}^{\min}) < n_{e+}r$ always holds, which means that given that the SL firms are already competing for the switcher segment below this price, Firms *e*+ will never price at $p_{e+}^{\min}$. This key finding of the modeling effort will be treated in detail shortly. Before the discussion begins, however, also note that because only the SL firms can compete at $p_{e+}^{\min}$ and possibly above, as has just been shown, the cumulative distribution functions presented by Equation (5) will also remain valid above $p_{e+}^{\min}$. In fact, one can solve for the lowest price point above $p_{e+}^{\min}$ to which Firms *e*+ will ever reduce their price by solving the equation

$$n_{e+}r=n_{e+}p+\left[1-F\left(p\right)\right]^{(e+)-1}ps_{e+}. \tag{8}$$

The only solution to this equation that rises above $p_{e+}{}^{\min}$ is r. Given that the SL cluster firms are already competing for the switcher segment below $p_{e+}{}^{\min}$, Firms e+ will never price in the interval $[p_{e+}{}^{\min}, r]$. Rather, they will only price at r. Moreover, since the firms in other clusters, including those in LS, are no different from Firms e+ in response to the price competition between the SL cluster e firms, they too will not compete in any interval. Rather, they will price strictly at r. In other words, all the firms that fall into the group with relatively larger loyal segments will only price at their reservation prices. In any given interval, only the SL cluster e firms will have support, because they are the only firms that can offer the deepest discounts in an effort to capture the switcher segment.

The aforementioned conclusion is a critical result. The frequency and depth of discounts the e firms offer in order to steal the switcher segment from other firms are so significant that it does not pay for any other firm to even attempt to serve the switcher segment. That is, only the firms that have the least to lose by offering the deepest discounts will do so. In so doing, they will force the other firms to price at the reservation price. Hence, most firms delegate the price competition to the e firms that can profitably compete with each other in this equilibrium. Solving Equation (3) accordingly, the probability distribution functions are derived that represent the firms' equilibrium strategies.

$$f_i(p) = \begin{cases} 0 & p < r \\ 1 & p = r \\ 0 & p > r \end{cases} \qquad i \in LL, LS, SS \tag{9}$$

$$f_i(p) = \begin{cases} 0 & p < p_{SL}^{\min} \\ rS\dfrac{\left(\dfrac{(r-p)S}{pL}\right)^{(1/e-1)-1}}{p^2 Le} & p_{SL}^{\min} \le p < r \qquad \mathrm{i} \in SL. \\ 0 & p \ge r \end{cases} \tag{10}$$

Equations (9) and (10) demonstrate the two distinct promotional strategies that firms adopt in a market that consists of many asymmetrically positioned retailers. Firms with relatively large loyal segment sizes never promote in this market.

Figure 3 depicts the cumulative distribution functions that represent the mixed strategies firms adopt.

Next, one assumption regarding the reservation prices will be relaxed. To this point the discussion has assumed homogenous reservation prices for all firms, but now heterogeneity will be introduced.

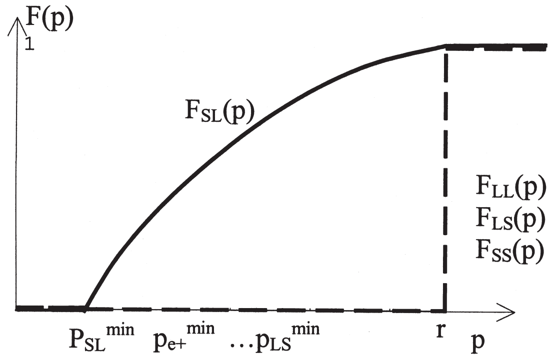

Figure 3. Cumulative Price Distribution Functions of the Firms, Where SL Firms Randomize Prices and All Other Firms Price at the Common Reservation Point

Heterogeneous Reservation Prices

The motivation for expanding the model with the introduction of heterogeneity is that different loyalty and switcher potentials may be characteristics of different positions that firms occupy within the market. For example, a firm that invests in providing better service levels and guarantees may increase the size of its loyal segment and may adopt a high-service, high-price strategy. Therefore, although reservation prices may be similar within clusters, it is possible that reservation price differences may exist between the clusters. That is, higher-service clusters, with potentially larger loyal segments, may quote higher reservation prices and still sell to their loyal customers. It is necessary to see whether the model can explain markets with differentiated clusters.

> *Proposition 4: The strategic reactions of all firms remain the same, even when cluster-specific reservation prices vary, as long as the reservation prices of all SL cluster firms are lower than those in other clusters.*

Proof: When $p_{SL}^{\min} = Sr_{SL}/(L + S)$ is lower than $p_{LL}^{\min}$, $p_{SS}^{\min}$, and $p_{LS}^{\min}$, the analysis for Proposition 3 holds, because only the SL firms with the lowest minimum prices can still offer discounts. Whereas the competition remains identical in the interval $[p_{LS}^{\min}, r_{SL}]$, the degenerate mixed-strategy responses of the SS, LL, and LS cluster firms will be given by the following formula:

$$f_i(p) = \begin{cases} 0 & p < r_i \\ 1 & p = r_i \\ 0 & p > r_i \end{cases} \qquad i \in LL, LS, SS \tag{11}$$

Therefore, because the competitive behavior in the lower intervals remains the same (i.e., fiercely competing firms with lower reservation prices, and probably lower levels of service, are already very aggressive), no other firm can offer sales in the upper intervals. Thus other clusters with higher levels of reservation prices sell to their loyal customers at their corresponding reservation prices. It is almost as if service levels play into the augmented product, and the resulting differentiated goods sell at different prices.

The principal finding of the model is that it can successfully explain the types of pricing behavior observed in today's on-line markets. The first panel in Figure 4 shows the theoretical cumulative distribution functions for all the clusters (for a random set of heterogeneous reservation prices for clusters SS, LL, and LS). The second panel in Figure 4 shows the corresponding theoretical average prices versus the standard deviation in prices for the four clusters. Note how closely this panel resembles the empirical scatter plots in Figure 2. Of course, if the reservation prices within the clusters were heterogeneous as well, the theoretical scatter plots would be similar to those in Figure 2.

Model Summary

The foregoing discussion asserts that when there are firms with relatively smaller loyal segment bases and larger price-comparing customer potential in any market, these firms have less to lose from offering discounts and effectively self-select themselves as actively price-promoting firms. Given the lower prices quoted by these firms (SL firms), all other firms (SS, LL, LS firms) are better off not engaging in price competition with them and resorting to their reservation prices. As a result, the observation can be explained in this way: There are many firms listed in price-comparison results pages whose prices remain constant over time, and only a handful of retailers offer varying levels of lower prices. This behavior matches the opening examples from homogenous goods markets as presented in Figure 2. The model yields firms' pricing behavior given asymmetrical loyal segment sizes for a homogenous product. The similarity of the empirical graphs found in Figure 2 and the theoretical scatter plot of Figure 4 provide some empirical evidence for the model.

Discussion

The objective in building a model of price competition in an oligopolistic market with asymmetrically positioned firms was to provide theoretical and empirical insight to markets in which price-comparison shopping was possible. From a theoretical point of view, the model demonstrates the existence of at least two distinct pricing strategies, thereby indicating the trade-offs different firms make in order to balance their desire to serve the price-comparing switcher segment with their desire to maximize the profit from their loyal segments. Moreover, the two distinct strategies also provide a theoretical explanation to the observed price dispersions in the homogenous goods markets.

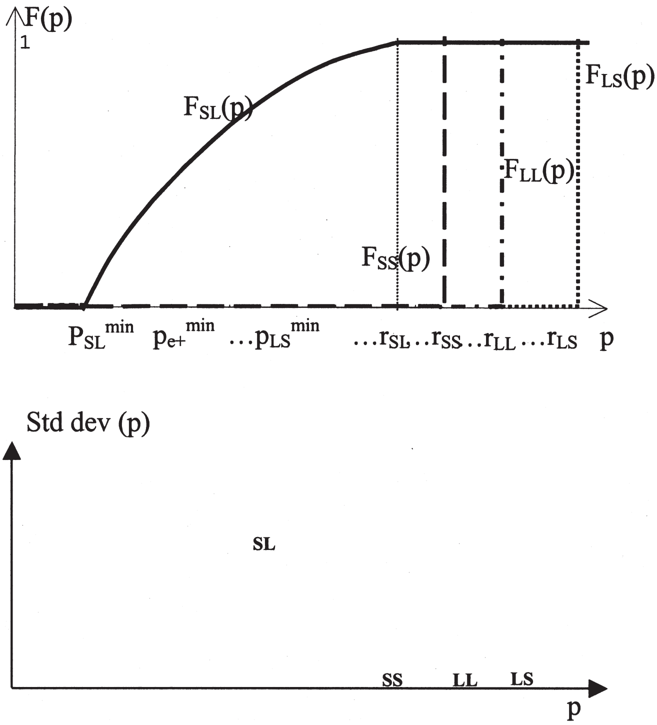

Figure 4. Cumulative Price Distribution Functions of the Firms and the Resulting Average Price Versus Promotion (standard deviation) **Scatter Plot When Cluster-Specific Reservation Prices Are Heterogeneous**

The central finding of the model demonstrates that only the firms that have the least to lose from offering the deepest discounts will do so, thereby forcing the other firms to price at the reservation price. This finding explains the typical price-comparison search-results page. Here, one would see most fringe players quoting lower prices that are more likely to change over time and more established retailers quoting higher and more stable prices. This finding also challenges the perception that all firms adopt mixed-pricing strategies in homogeneous product markets, which was mainly based on analysis of duopolies and symmetric oligopolies. However, as daily experience and the presented example data show, many firms with temporarily static prices can exist, and the model is unique in explaining this type of behavior.

The findings also provide an operational explanation for the observed price dispersion that has been studied by so many other researchers. Research streams in economics of information systems and marketing have reported and attempted to explain the sources of dispersed prices, where a one-price rule was expected to apply [2, 5, 6, 9, 11, 16, 20, 22]. The model shows that asymmetrically positioned firms may engage in competitive behavior that results in a variety of promotional patterns. Such patterns, in turn, display price dispersion for the homogenous product being examined.

Managerial Implications

The most significant managerial implication of the modeling effort pertains to the importance of establishing and maintaining loyalty by firms that are competing in today's information-rich markets. When information flows freely, as in on-line markets, where many firms coexist and compete for the business of customers, the lack of differentiation inevitably results in the zero-profit price of the Bertrand equilibrium. However, as the model demonstrates, positive profits are attainable for firms with loyal customers even in a market where customers search for better prices. Moreover, the profits are proportional to the size of the loyal segment size, indicating that higher profitability can be attained through the establishment of higher loyalty. The findings also make it obvious that firms with a large percentage of loyal customers should never attempt to use price promotion to attract switchers.

The model demonstrates that firms, especially those with virtually nonexistent loyal segment sizes, use sales as their only method of selling to at least some customers. Interestingly, this strategy cannot succeed in the long term, because the severity of the competition for the switcher customers forces firms to settle for zero profits. However, the difference between not selling at all and selling to switchers for zero profit is the chance to interact with switcher customers and perhaps retain them as future loyal customers. That is, even start-up companies with no existing loyal customer base have to make loyalty creation their first priority if they hope to break the vicious cycle of selling only to switchers at huge discounts and for zero profit. If a positive conversion rate can be attained with a desire to provide superior service, even at the low prices charged, a firm could hope to leverage its newly formed loyalty in the future so as to realize positive profits.

Conclusions and Limitations

A stylized model of price competition in an asymmetric oligopoly was developed to analyze emerging price competition in on-line markets. Cooperation, learning, reputation, and punishment may be issues that shape strategies in repeatedly played games, but the costs of including these complicated strategies by adapting a repeated-games framework would outweigh the benefits. As a result, a one-shot static game was used to demonstrate how, given the abundance of competition, firms classify themselves as price-promoters or regular-price stores.

One limitation of the model is that it does not capture the information structure of the market endogenously. Rather, it assumes that firms can correctly self-select themselves to be either price-promoters or static pricers. Even if there are non-SL firms that offer price discounts erroneously, they will incur negative profits because their minimum prices will be higher than SL minimum prices (i.e., the depth of some discounts to attract switchers will be insufficient to compete with SL firms that can offer much deeper discounts). Therefore, especially for oligopolies consisting of many firms (such as the markets for books, printers, and camcorders), the assumption that the group formation is an exogenous process enables a model that does not have to separately account for incomplete information at the expense of model simplicity.

The model represented a market with four clusters and at least three firms. Before concluding, it would be useful to clarify the choice of these numbers, because they may seem arbitrary. As mentioned before, the choice of three firms was made to satisfy the requirement to focus on an oligopoly. However, one can find dozens of retailers selling homogenous products in all the markets from which examples are offered. Therefore, the model's ability to support any oligopolistic number of firms is one of its desirable properties.

The modeling effort was presented with four clusters of firms. Although the findings remain intact, the model could as well have been presented in its alternative forms. In its most general form, a model with *k* asymmetric firms could be used. Using the same derivation, it could be shown that firms with the lowest loyal customer ratio will use mixed-pricing strategies to attract switchers if there is more than one firm with the same lowest loyal customer ratio. All other firms will charge reservation prices and avoid competing for switchers. If there is only one firm with the lowest loyal customer ratio, firms with the lowest and second-lowest loyal customer ratios will adopt mixed-pricing strategies to compete for switchers. All other firms stay away from the competition. Similarly, in its simplest form, a model with just two segments could be used, where using the same derivation it could be shown that firms with the lower loyal customer ratio will offer price promotions.[8]

Any choice of model exposition, whether the most general form, as selected for this paper, or the simplest form, has its advantages and disadvantages. The model exposition requires the complexity of a four-cluster setup but achieves a balance between reality and simplicity to successfully explain the five points summarized in the empirical regularity section. The most general form achieves robustness but trades reality for generalizability by ignoring the incompleteness of information and assuming that each firm is identifiable by all other firms. The simplest form achieves simplicity by reducing the number of clusters to just two but runs the risk of all firms behaving as price-promoters if there is just one firm with the lowest loyal customer ratio. Consecutively, it was decided to present the essence of the modeling effort with the current exposition in order to strike a balance between reality, simplicity, and generalizability. Fortunately, independent of the exposition, the contribution of the model remains intact: Firms with the greatest switcher-to-loyalty ratios price-promote for switchers, and all other firms prefer to have static prices at their own reservation points.

The discussion in this paper considers neither the heterogeneity in consumer willingness to pay nor promotions undertaken with traffic-building concerns. Incorporating the heterogeneity in consumer willingness to pay would be a direction for future research. An extension to cases where there may be many switcher segments, each comparing prices from a different set of retailers, could also lead to new insights. A comparison of traffic-generation strategies of price promotion with the present model would also be an important topic for future research.

NOTES

1. The data consist of daily prices on 1,388 books from 15 retailers, 112 printers from 20 retailers, and 95 camcorders from 53 retailers, collected over the course of one month, June 2002. These categories were chosen because the tendency to buy such items on-line is among the highest [13]. The retailers included in the study were compiled through MySimon (www.mysimon.com), which according to Allen and Wu covers the market best in terms of cross-sectional and longitudinal consistency [1]. MySimon achieves an estimated 14 million unique visitors (80 percent market share) in a market with a potential size of 35 million [16]. The prices of products are normalized across retailers and average prices are normalized across time and products for each retailer to calculate the average price. To calculate the average standard deviation across products (an indicator of price variability), the standard deviation of normalized prices was calculated for every product across time, and the average of those figures across products was taken within a category.

2. To illustrate this second point, consider a case where retailers have different strategies for different types of products (e.g., for textbooks vs. novels). Data aggregated over such a retailer's products might suggest that the retailer has medium levels of prices and promotional activity, whereas, in reality, it may be offering price promotions for some of its products (say, textbooks) while adopting a static price strategy for the others (say, novels). Therefore, observation at the product level may be less contaminated by this aggregation effect.

3. Cluster analysis is also used to see if the retailers can be grouped into two general groups such that retailers with smaller average prices will also have higher promotional activity. Using *K*-means cluster analysis and running independent sample *t*-tests based on the cluster memberships, it becomes apparent that for each category, the cluster with the higher price also has the lower level of promotional activity. The significance levels for price and promotional-activity differences between clusters, respectively, are camcorders (0.000, 0.053), books (0.000, 0.359), and printers (0.000, 0.111).

4. By formally presenting and analyzing a model of price competition, it is possible to provide an explanation for the first four items in the list at the beginning of this paper. An extension that considers heterogeneous reservation prices makes it possible to explain the fifth bullet point in the list.

5. Although two levels of switcher segment sizes are utilized, the results would not change even with a single switcher segment, because when the switcher segment is unique, the firms with the smallest loyal segment sizes will have the greatest desire to go after the switchers, as shown later in this paper.

6. This assumption is made to ascertain this conclusion: If firms in the SL cluster are the only ones competing for switchers by offering low prices (as the analysis shows in the section discussing the model), then these firms serve all the switchers in the given market.

7. If there were just one firm in the SL cluster, its reservation utility would be higher than Sr, as in Narasimhan's model [19]. However, recall that it was assumed, for simplicity, that there are at least two firms in the SL cluster.

8. We thank the two reviewers who emphasized the advantages of these alternative expositions.

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Appendix

Proof of Proposition 1

Assume that $(p_1^*, p_2^*, ..., p_k^*)$ is a pure-strategy equilibrium. In each of the cases below, there exists at least one p_i, $(i = 1, 2, 3, ..., k)$, so that $\pi_i(p_i, p_j^*, ..., p_k^*) > \pi_i(p_1^*, p_2^*, ..., p_k^*)$. Let us denote the jth lowest price as p^j. Note, though, that some of these quoted prices can be the same. Hence, $p^1 \leq p^2 \leq p^3 ... \leq p^k$. Now assume that there is a strategy set that is a pure Nash equilibrium. Two possibilities exist: Either $p^1 = p^2$ (i.e., the two lowest prices quoted are the same) or $p^1 < p^2$ (i.e., the two lowest prices are different). Let us assume the first possibility—that the two prices are the same. Let us denote the two firms with these prices as Firm z and Firm v, so that $p_z = p^1 = p_v = p^2$. Either Firm z or Firm v can undercut the price of its rival with an infinitesimal reduction in price, thereby capturing the entire switcher segment and increasing its profits. Also note that because switcher customers are shared when $p_z = p_v = p_z^{\min} = p_v^{\min}$, profits are strictly smaller than profits made at the reservation price. Hence, there cannot be a pure-strategy Nash equilibrium where $p^1 = p^2$.

Now assume the second possibility—that $p^1 < p^2$. Let us again denote the two firms with these two lowest prices as Firm z and Firm v, so that $p_z = p^1 < p_v = p^2$. If $p_z = p^1 < p_v = p^2 < r$, then Firm v can increase its price to r and profit from this move because it sells to its loyal segment at a higher price. On the other hand, if $p_z = p^1 < p_v = p^2 = r$, then Firm z can increase its price while still serving the switchers and can profit from the sale to both segments at a high price. Hence, there cannot be a pure-strategy Nash equilibrium where $p^1 < p^2$.

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