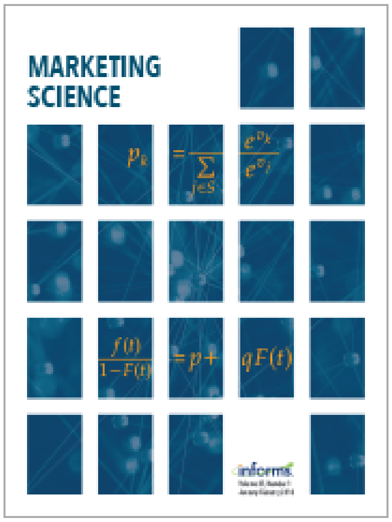

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Try It, You Will Like It—Does Consumer Learning Lead to Competitive Price Promotions?

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There is strong evidence that consumers learn from their brand consumption experiences and continuously update their brand purchase probabilities. However, in explaining why established competitive brands continuously compete through periodic price promotions, most of the existing theories do not attribute this phenomenon to underlying consumer learning. Yet, "try it, you will like it" is often the stated rationale of the practicing marketing manager in offering consumers a price promotion on a brand. This paper examines the connection between consumer learning and the offering of price promotions. The consumer model specified is Markovian in nature and encompasses in addition to consumer learning other empirical findings such as the increase in product class consumption in response to price reductions. The consumer models used in the existing game theoretic approaches to this problem are shown to be mostly special cases of the proposed model. It is demonstrated that for the commonly used price response functions the existence of consumer learning, at a level of intensity consistent with that identified in empirical works, makes it optimal for competing brands to periodically offer price promotions. Moreover, it is shown that the competing brands should promote in different periods as opposed to head to head.

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1. Introduction

Periodic price promotions are commonly offered by manufacturers of established national brands in frequently purchased product categories. Usually, the competing brands offer these promotions in different time periods. A puzzling question is: Why would established competing brands in mature markets persist in such behavior as opposed to settling in on some constant steady-state prices? If offering a price reduction in a particular period is optimal, why would it not be optimal in the next period and in all periods? To answer this question, one must first understand consumers' reactions to price promotions and then demonstrate the optimality of offering them by the competing brands.

The study of price promotions has been the most popular research topic in marketing science for the last two decades. The empirical works assessing consumers' response to price promotions have in general been done separately from the game theoretic models that attempted to explain why manufacturers offered them. One of the main aims of this paper is to strengthen the connection between these two streams of research and to have more of the empirical findings serve as foundations for the analysis of the optimal competitive behavior. To this end we will review the major empirical and analytical findings pertaining to promotions.[1]

The empirical works on the impact of price promotions are part of a general research stream attempting to explain consumers' brand switching behavior. In the prelogit era, Blattberg and Sen (1976), Givon and Horsky (1979), Jeuland et al. (1980), and Bass et al. (1984) examined individuals' diary panel data and specified stochastic brand switching models which did not include price promotion effects but allowed consumers to be heterogeneous in both the order of the stochastic process they followed as well as in the parameters of the process. These studies report, for most of the mature product categories examined, clear evidence of purchase reinforcement with either about half the population following the first order Markov process or the whole population the Linear Learning Model (LLM). That is, these individuals behaved as though they continuously learned about the brands they purchased. The shift to logit models and scanner panel data did not dampen the case for consumers' continuous learning. Guadagni and Little (1983), who were the first to introduce the logit framework to

[1] For a comprehensive review of research on price promotions, see Blattberg and Neslin (1990) and Neslin (2002).

the analysis of brand choice and the impact of price promotions, found that brand loyalty had a large impact. It was operationalized as a weighted average of past purchases, similar to the LLM. Similar findings of state dependence are reported in the many subsequent empirical studies of brand choice, including those that account for consumer heterogeneity in the parameters such as Keane (1997), Seetharaman et al. (1999), Seetharaman (2004), and Horsky et al. (2006). In terms of the magnitude of purchase reinforcement, Shoemaker and Shoaf (1977), Jones and Zufryden (1981), Guadagni and Little (1983), Neslin and Shoemaker (1989), Kahn and Louie (1990), and Gedenk and Neslin (1999) report that it is slightly diminished if the brand was previously bought on a promotion. Although there is widespread evidence on the existence of purchase reinforcement, the terminology used in conjunction with this type phenomenon is different in marketing and economics and within marketing depending on the literature and era. In the stochastic brand switching literature it is referred to as learning (of the first order for the Markov model and infinite order for the LLM) and inertia. In the logit framework it is referred to as brand loyalty (of different "orders") or state dependence. Other terms originating from economics, such as habit formation and switching costs, are related also.

A more general approach to examining the impact of price promotions has been taken in several studies which, while acknowledging that price promotions will lead to brand switching, also allowed them to cause an increase in the consumption of the product class. The latter is the obvious outcome of the economic notion of a downward sloping demand curve not only for the brand but also for the product category. These studies, such as those of Gupta (1988), Chiang (1991), Chintagunta (1993), and Bell et al. (1999), concluded that on average, in response to price promotion, 75% of the increased demand for a brand was because of brand switching, whereas about 25% was attributable to increased demand for the product class. More recently, van Heerde et al. (2004) argued that the latter effect plays a much larger role.

The firms' side in offering competitive price promotions has been addressed by another set of studies. In some game theoretic papers, the analysis is static. Shilony (1977) and Raju et al. (1990) consider a market in which only national brand loyal consumers exist. The brands compete by trying to attract all the consumers of another national brand by offering them a price discount greater than their common threshold switching level. In Varian (1980) and Narasimhan (1988), the national brand loyal consumers are totally loyal, but there exists an additional switchers segment who will all buy from the lowest-priced brand, and the national brands compete in getting this segment. In both types of study, consumers have price response functions with common discontinuities at both the category reservation price and the price premiums for brand switching. These latter discontinuities may lead in a static analysis to an optimal mixed pricing strategy that manifests itself in random prices. Several studies propose dynamic frameworks to assess the offering of price promotions by profit maximizing competitors. Lal (1990) and Rao (1991), who use a Varian and Shilony type framework, respectively, identify scenarios in which brands will be better off using two prices (regular and reduced), instead of one. Kopalle et al. (1996) show that if asymmetric reference price effects, in which a price reduction has a greater impact on demand than a price increase, exist, it may be optimal for oligopolists to offer price discounts. The value of competitive price promotions when these promotions also have, in addition to an immediate effect, a delayed effect is examined by Kopalle et al. (1999), and when these promotions increase stockpiling and consumption by Bell et al. (2002).[2]

The explanations forwarded for the optimality of competitive price promotions may partially explain the existence of this widespread phenomenon. However, none of the above studies encompasses all of the major empirical findings cited earlier on how consumers actually react to price promotions. For example, the evidence that price reductions also cause increased demand for the product class is usually unaccounted for. Moreover, the important empirical finding that consumers learn from their purchases of the differentiated brands is mostly ignored in this literature. Yet, discussions with marketing managers as to why they persist in offering deals on established national brands will often yield the explanation of "consumers will try it and like it."

In this paper we will examine whether it is optimal for competing national brands to offer periodic price promotions when faced with consumers who respond in a continuous manner to price changes both in terms of their decisions whether to buy and which brand to buy and, moreover, these consumers learn from their brand purchases. In this scenario it is quite possible that the brands may find it optimal to periodically reduce their prices to induce purchases by nonbuyers of their brands. These consumers may, because of learning about the characteristics and fit of the brands, decide to continue purchasing them even if their prices are later increased. To obtain insights into

[2] There is a wider set of studies that examines related issues. Some examine the optimality of price promotions by a monopolist. Others who model competition evaluate the impact of price promotions on long-run sales, as opposed to profits. Finally, others (e.g., Beggs and Klemperer 1992, Vilas-Boas 2004, Kopalle and Neslin 2003, and Che et al. 2007) pursue optimal competitive dynamic pricing policies not confined to price promotions.

the nature of the problem and its solution, we start in the next section by examining the case of a monopolist who offers a national brand and who is faced with both a segment of consumers who bought his brand in the last period and may buy again and another segment who did not buy his brand but is ready to buy, in particular if the monopolist lowers his price. We examine if the existence of consumer learning and its magnitude may determine whether it is optimal for the monopolist to offer price promotions or to always use a single-price strategy. We then proceed in the following section to the case of two competing national brands. In this case, there are consumer segments who bought in the last period from each of the national brands, as well as a segment of consumers who did not buy from them but are ready to buy, in particular if their prices are lowered. In this competitive case, a national brand that lowers its price attracts some consumers who bought from the other national brand and some who did not buy from either of them. We will demonstrate that many of the consumer models assumed in the static and dynamic game theoretic studies are special cases of our competitive model. We also examine for this case whether the existence of consumer learning and its magnitude provides an explanation for why competing brands are offering price promotions. Moreover, we try to trace to this framework other observable phenomena such as the competing brands dealing in different periods.

2. Price Promotions by a Monopolist in an Expandable Market

In this section we will examine whether it is optimal for an established price setting monopolistic national brand to offer price promotions when there are some consumers who do not always buy from him, but those who do buy learn from the brand consumption experience. Those consumers who do not buy from the national brand are assumed to buy from a price passive nonnational brand. This latter brand can be viewed as a passive store, local, or generic brand in the same product category; brands in a close substitute product class; a no purchase state; or a combination of all of these. We refer to the national brand as a monopolist, because in this scenario he is the only active price setting player. In fact, Blattberg and Wisniewski (1989) observe that when a national brand offers discounts, it attracts the consumers loyal to a store brand but not vice versa.[3]

As in past game theoretic studies that examine optimal pricing policies, we specify a market share model that describes the aggregate behavior of consumers. Our model relies on the results reported by Givon and Horsky (1978). They examine panel data on brands in several product categories and specify and estimate a composite heterogeneous model, which allows consumers to follow either the zero-order Bernoulli, the first-order Markov, or the LLM and to also be different in the magnitude of the process parameters. They further demonstrate that, provided that a part of the heterogeneous population of consumers is learning (via either the first-order Markov model or the LLM), the aggregate behavior of the population can be well approximated by a Markovian market share model. We define the Markovian transition matrix corresponding to the population's switching behavior among the national brand A and brand N (which represents all non-A alternatives) as

$$\begin{array}{c c} & \begin{array}{cc} A_t & \quad N_t \end{array} \\ \begin{array}{c} A_{t-1} \\ N_{t-1} \end{array} & \begin{bmatrix} F_t + a & 1 - F_t - a \\ F_t & 1 - F_t \end{bmatrix} \end{array}, \tag{1}$$

where, for example, $F_t + a$ is the probability of buying brand A in period t, given that it was bought in the previous period, $t-1$; a is the purchase feedback attributable to consumers' consumption experience with the brand; and F_t is a nonfeedback term. It is assumed (see, for example, Morrison 1966, Givon and Horsky 1978) that following the purchase of brand A there is a positive purchase reinforcement, $a > 0$. For (1) to define a transition matrix, all that is needed is that $F_t > 0$ and $F_t + a \leq 1$.

Throughout the paper we will mostly refer to the abovementioned phenomenon, in which consumers have, after purchase of brand A, a positive purchase reinforcement or a transient increase in the probability of its repurchase, as learning.

The aggregate market share model represented by transition matrix (1) specifies the market share of brand A in period t, m_t, as:

$$m_t = m_{t-1}(F_t + a) + (1 - m_{t-1})F_t = am_{t-1} + F_t, \tag{2}$$

where the learning coefficient, a, becomes the parameter of the lagged market share. Aggregate market share models of this nature, in which F_t is a function of marketing mix variables, have been widely used in econometric studies in both marketing and economics.[4] Givon and Horsky (1990) specified F_t to

[3] It should be noted that retailers and their store brands have become increasingly less passive (e.g., Narasimhan and Wilcox 1998 and Scott Morton and Zettelmeyer 2004). Although the role of the retailer is ignored at this stage, it will be examined later in the paper.

[4] As we already noted, the market we are describing behaves as though it were composed of homogeneous individuals, each governed by transition matrix (1). It should be emphasized, however, that estimation of market share model (2) with aggregate data will not identify learning when it does not exist at the individual level. The issue of spurious state dependence, the overestimation of the

be a function of advertising goodwill and price. In the context we are addressing here it will only be a function of price. The individuals who did not buy brand A in period $t-1$ may decide to buy it in period t. Based on matrix (1) the conditional probability that they will do so is F_t, which is dependent on the price brand A charges in that period, p_t, so that $F_t = F(p_t)$. The lower the price the monopolist charges, the higher the conditional probability that a nonbuyer will buy its brand, so $F'(p) < 0$.

The question we are addressing is: Should the established monopolistic brand A charge a fixed price over time, or should it, under certain conditions offer, once in a while, a price promotion? It is well known that new brands offer price promotions and even free samples in the initial stages after their introduction to induce trial, which may then lead to repeat purchases. This type of introductory pricing policy is often referred to as price penetration. Moreover, to totally new product class buyers, when they are about to make their first purchase, the established brand may appear as if it is new to the market place. If the number of such new buyers continuously entering the market is large (correspondingly, there may be some attrition in existing consumers), they may justify repeated price promotions to induce trial and learning. However, our interest here is different; we are interested in the optimal pricing behavior of an established national brand in a market composed of regular, price-sensitive consumers. Our analysis will therefore center on the long-term steady-state behavior of such a brand.

A Monopolist with a Single Price

We start our analysis with the optimal constant pricing behavior of a monopolist faced with consumers whose demand for his brand is defined by transition matrix (1). If the monopolist decides to charge a constant price p each period, then his steady-state market share, x, satisfies the equation

$$[x \quad 1-x]\begin{bmatrix} F(p)+a & 1-F(p)-a \\ F(p) & 1-F(p) \end{bmatrix} = [x \quad 1-x], \quad (3)$$

where $F(p)$ is the price response function, a is the learning coefficient, and $F(p) > 0, F(p)+a < 1$, $F'(p) < 0$. The steady-state market share solution to this equation is

$$x = \frac{F(p)}{1-a}. \quad (4)$$

degree of state dependence when heterogeneity is ignored (e.g., Frank 1962, Feller 1968, Massy et al. 1970, Heckman 1981), arises in a different type of analysis in which an individual level model is estimated cross-sectionally based on individual level diary or scanner data. Formal proofs of these assertions are provided in Givon and Horsky (1985).

It should be noticed that the steady-state market share is a continuous, strictly decreasing function of the price set by the monopolist.[5]

The monopolist's objective is to maximize profit. For simplicity we will assume unit marginal costs to be zero, and the long-run profit (and revenue) per period is thus

$$R(p) = px = \frac{pF(p)}{1-a}. \quad (5)$$

The monopolist's optimal constant price p^* needs to satisfy the first- and second-order conditions for the revenue function in Equation (5)

$$p^*F'(p^*) + F(p^*) = 0, \qquad p^*F''(p^*) + 2F'(p^*) < 0. \quad (6)$$

A Monopolist with Alternating Prices

The monopolist facing transition matrix (1) may decide to use two different prices, a "reduced" p_1 and a regular p_2. The frequency of using the reduced price may be every second period, in which case the prices follow the sequence of $\ldots p_1, p_2, p_1, p_2 \ldots$, or less frequently, such as every third period, in which case a sequence of $\ldots p_1, p_2, p_2, p_1, p_2, p_2 \ldots$, is followed. When the reduced price p_1 is used, $F(p_1) > F(p_2)$ and the monopolist's market share rises from the earlier market share obtained with the regular price p_2. We first examine the case when the monopolist reduces the price every second period. In steady state the monopolist's market share will alternate between a high share of x_1 obtained with the reduced price p_1 and the low market share of x_2 obtained with the regular price p_2. We realize that the term "steady state" is normally used to describe the convergence of a state variable to a single value. We take the liberty to use this terminology also for the case when the state variable converges to alternating repeated values as a result of alternating repeated control variable values.[6] The steady-state market shares, x_1 and x_2 (and then again x_1, followed by x_2, etc.) must satisfy the equations

$$[x_2 \quad 1-x_2]\begin{bmatrix} F(p_1)+a & 1-F(p_1)-a \\ F(p_1) & 1-F(p_1) \end{bmatrix} = [x_1 \quad 1-x_1], \quad (7)$$

$$[x_1 \quad 1-x_1]\begin{bmatrix} F(p_2)+a & 1-F(p_2)-a \\ F(p_2) & 1-F(p_2) \end{bmatrix} = [x_2 \quad 1-x_2]. \quad (8)$$

[5] If the price were increased to infinity, the conditional probability in the lower right corner of the transition matrix in Equation (3) would converge to 1, and the no purchase state N would become an absorbing state. At such a price, the steady-state share in (4) converges to zero.

[6] See Appendix A, "An Alternating Markov Chain," for the derivation in a general setting. Although this result may seem obvious, it does not currently appear in the stochastic processes literature.

The steady-state market shares solution to this system of equations is

$$x_1 = \frac{F(p_1) + aF(p_2)}{1 - a^2} \quad \text{and} \quad x_2 = \frac{F(p_2) + aF(p_1)}{1 - a^2}. \quad (9)$$

The monopolist's objective is to maximize the sum of the steady-state revenues over the two periods (which equals twice the long-run average profit per period)

$$R(p_1, p_2) = p_1 x_1 + p_2 x_2 = \frac{(p_1 + ap_2)F(p_1) + (p_2 + ap_1)F(p_2)}{1 - a^2}. \quad (10)$$

The monopolist's optimal reduced and regular prices must satisfy the first- and second-order conditions of the profits of Equation (10).

To Promote or Not to Promote

The key question for the monopolist is whether the reduced and regular prices can lead to a profitability that is higher than that obtained with the single optimal price. Put differently, our problem is to identify whether there exists some type of a reasonable price response function $F(p)$ that could lead to a two-price solution $p_1 \neq p_2$ to the maximization of revenue function $R(p_1, p_2)$ of Equation (10).

Theorem 1. *If $F''(p^*) \le 0$, then $p_1 = p_2 = p^*$ provides a strict local optimum to the monopolist's maximization problem* (10).

Proof. See Appendix B for proof of this theorem, as well as for all subsequent theorems.

Theorem 1 states that if the price response function $F(p)$ is not strictly convex at p^*, it is optimal for the monopolist to have a single price; if it is strictly convex at p^*, then it is possible that a two-price policy is better. Thus, the strict convexity of $F(p)$ at p^* is a necessary, but not a sufficient, condition for a two-price solution to be more profitable than a single-price solution. It turns out that most commonly used price response functions, such as the power and exponential functions, have a *positive* second derivative and may therefore lead to a two-price solution, which is better. We will further investigate under which conditions this happens for the exponential function.

An Exponential Price Response Function

A frequently used price response function is the exponential. In the context of transition matrix (1), it can be written as

$$F_{\text{exponential}}(p) = \alpha e^{-\beta p}, \quad (11)$$

where $0 < \alpha < 1 - a$ and $\beta > 0$ are parameters. The constraints on the magnitudes of the parameters ensure that this price response function adheres to the constraints set after Equation (3).

Theorem 2. *For the exponential response function* (11), *the maximization of the monopolist's problems* (5) *and* (10) *leads to the following results*:

(i) *If the monopolist charges a single constant price, $p = 1/\beta$ is the optimal one.*

(ii) *If $a < 1/3$, then $p_1 = p_2 = 1/\beta$ is optimal, and the monopolist should charge this single price.*

(iii) *If $a > 1/3$, then $p_1 = p_2 = 1/\beta$ is not optimal* (*it is only a saddle point*), *and the monopolist would do better to alternate between two prices.*

Theorem 2 illustrates that for the revenue function $R(p_1, p_2)$ of Equation (10) to have a maximum in two prices, not only must the specific $F(p)$ examined be strictly convex but also the purchase reinforcement parameter a has to be larger than a certain critical value. In the specific case of the exponential price response function, the critical value of a is $1/3$. Other critical values for a would result for other response functions. When a is smaller than the critical value, a constant price is optimal.

We have examined above the case in which the monopolist reduces his price every second period, but we can also conduct a similar analysis when the price is reduced less frequently. For example, every third period the price is reduced so that prices follow a sequence of $\ldots p_1, p_2, p_2, p_1, p_2, p_2, \ldots$ The steady-state market shares in this case will be of the nature: $\ldots x_1, x_2, x_3, x_1, x_2, x_3, \ldots,$ where $x_1 > x_2 > x_3$. That is, in the periods after a price promotion, the market share will steadily decline until the next price promotion bumps it back up. We show in Appendix A1[7] that, for the exponential response function when $a > 0.366$, the brand is better off promoting every third period, as opposed to not promoting at all. For promotions every fourth period to be worthwhile, in comparison to not promoting, we show in Appendix B1 that the required learning parameter is $a > 0.39$.

We saw that the condition for promotion every second period when an exponential price response function is assumed is that $a > 1/3$. A slightly larger learning parameter is required to justify less frequent promotions. It is important to note that the empirical works examining heterogeneous stochastic brand switching models at the individual level offer support for such a magnitude. In these studies, the mean of the learning parameter is usually double the needed 1/3 (e.g., Givon and Horsky 1978). Such a large learning coefficient at the individual level should come as no surprise; it is also found in econometric studies of aggregate data. In the many empirical studies that researchers have done with market share models of the type specified in Equation (2), $m_t = am_{t-1} + F_t$, they almost always find the parameter of the lagged share to be of considerable magnitude. For example, Clarke (1976), in his survey article of 69 different

[7] The Technical Appendices A1, B1, C1, and D1 are available at http://mktsci.pubs.informs.org.

published studies, several with multiple-product categories, reports a to be, on average, 0.591.

Reduced Reinforcement After Purchase on a Promotion

As reported in the Introduction there is empirical evidence that the magnitude of the purchase reinforcement is slightly diminished if the brand was previously bought on a price promotion, compared to when it was bought at a regular price.

The change in our analysis that would be caused by this type of phenomenon relates to the analysis of the monopolist using alternating prices. The market shares governed by matrices (7) and (8) would now change, in that the repeat purchase probability in matrix (8) for those who bought brand A in the previous lower price period will now be

$$F(p_2) + a - g(p_2 - p_1), \tag{12}$$

where g is some function of the discount level, $p_2 - p_1$. The repeat purchase probability in matrix (7) will remain $F(p_1) + a$, as the buyers of A in that period bought it on a regular price in the previous period.[8] In the empirical studies, g was estimated as a constant. However, it should stand to reason that its magnitude depends on the magnitude of the discount. The consumers who are only ready to buy at a very deep discount are the ones with the lower utility for the brand and are therefore less likely to repeat buy when the price rises. It is thus quite plausible that deepening the discount reduces the purchase feedback at an increasing rate. We thus specify g as a convex increasing function of the discount level

$$g(p_2 - p_1) = c(p_2 - p_1)^{\theta}, \quad \text{where } c > 0 \text{ and } \theta > 1. \tag{13}$$

In Appendix C1 we investigate the optimality of the monopolist offering price promotions in this case. By using the first- and second-order conditions analytically, in a fashion similar to that used in Theorem 2, we derive the region of the parameter space where the constant price is not optimal. This basically amounts to a restriction on the scalar c to be small in comparison to a. This result is quite intuitive because, if c becomes too large, the last term in conditional probability (12) negates the impact of the purchase reinforcement a, and there is no point in discounting. The empirical findings support the fact that the last term in (12) is only a fraction of a. For example, Guadagni and Little (1983) find g to be 0.21 of a. Next, for a specific set of parameter values in Equations (11), (12), and (13), we identify the graph of the two-price policies that lead to the same profit as the optimal single price. This amounts to a contour of a two-dimensional region in which alternating prices p_1 below p^* and p_2 above leads to profits that are higher than those associated with the best single price. We then search numerically the interior of that region and identify the values of the optimal alternating prices. These p_1^* and p_2^* are associated with a unique global maximum to the revenue function.

[8] Another somewhat related dynamic phenomenon that we do not pursue here is stockpiling. Interestingly, Ailawadi et al. (2007) find that stockpiling (purchase acceleration by loyals) is easily offset by increased consumption, preemptive switching, and additional repeat purchases (higher state dependence).

Discussion and Intuition

Some important conclusions can be drawn from examining this case of a single national brand in an expandable market. In particular, for it to be optimal for the monopolist to induce the "try it, you will like it" scenario by periodically offering price promotions, there should be learning on the part of consumers and it should be of a sufficient magnitude. If there is no learning (or only "weak" learning), the monopolist should use a single constant price.

This result—that for the brand to alternate prices the learning parameter, a, has to be larger than a certain critical value—is quite intuitive. In a multiperiod profit maximization, there would be reason to reduce the price in the first period and increase it in the second only if the payoff in the second period is enhanced enough to justify the loss in revenue incurred in the first period (vis-à-vis use of the optimal single price). The payoff is enhanced when a gets larger because a larger fraction of the increased number of brand buyers in the promotional period will buy it again at certain higher prices in the following period.

Put differently, the representative consumer, in deciding whether to purchase the brand, is trading off its utility against the asking price. Thus, if the monopolist reduces the price of the brand in the first period, its probability of purchase increases as does its share. In the following period, because of learning, the consumers who bought the brand have higher utility and probability of repurchase. The monopolist may decide to try to reap benefits from these higher utility consumers by charging them a higher price. The monopolist could increase that price to the level that would bring the share back to the initial pre-promotion market share, thereby creating a two-share steady state. The question we posed was: Would the monopolist's profits be higher with such a two-price strategy, as opposed to continuously charging the single optimal price? What we have shown is that if the utility after purchase increases enough (which is governed by the magnitude of a), the monopolist will be better off using two prices. In this case, in the second period the monopolist is able to reap enough "monopoly" profits from the higher utility consumers to overcome the decrease in profits in the lower-priced first period (vis-à-vis those obtained with an optimal single price).

3. Price Promotions by Duopolists in an Expandable Market

We now turn our attention to the more realistic and general case in which there are two competing price-setting national brands A and B that operate in a market in which there also exists, as in the previous section, a price-passive nonnational brand, N. When brand A decreases its price, it will attract some consumers from brand B and some from brand N. If both national brands increased their prices, some of their previous buyers will switch to brand N. The consumers who purchase the national brands learn about their quality and fit after their purchase. We will examine whether in this type market it is also optimal for the competing national brands to offer price promotions.

The purchases of the consumers in this market are governed by a 3×3 transition matrix

$$\begin{array}{c} \\ A_{t-1} \\ \\ B_{t-1} \\ \\ N_{t-1} \end{array} \begin{array}{c} \begin{array}{ccc} A_t & B_t & N_t \end{array} \\ \begin{bmatrix} F_A(p_A)+a_A & F_B(p_B)+b_B & 1-F_A(p_A)-a_A-F_B(p_B)-b_B \\ F_A(p_A)+b_A & F_B(p_B)+a_B & 1-F_A(p_A)-b_A-F_B(p_B)-a_B \\ F_A(p_A) & F_B(p_B) & 1-F_A(p_A)-F_B(p_B) \end{bmatrix} \end{array}. \quad (14)$$

For (14) to define a transition matrix, all that is needed is that $F_A(p_A) > 0, F_B(p_B) > 0$, $F_A(p_A) + a_A + F_B(p_B) + b_B \le 1$, and $F_A(p_A) + b_A + F_B(p_B) + a_B \le 1$. The price response functions, $F_A(p_A)$ and $F_B(p_B)$, allow each of the national brands to have its own parameters, for example, a different price elasticity. The lower the price a brand charges, the higher its probability of being bought, $F'_A(p_A) < 0$ and $F'_B(p_B) < 0$. The parameters a_A, a_B represent *learning* and are positive. Each brand may lead, depending on its quality, to a different magnitude of learning. The parameters b_A, b_B can be either positive or negative. Focusing on the left column of matrix (14), we observe that b_A relates to which segment of consumers is more likely to switch to brand A, those who last period bought brand B or those who bought brand N. If b_A is negative, those who bought B earlier are less likely to switch to A than those who bought N. This effect of a negative b can be viewed as some type of *stickiness* or *brand loyalty* of a national brand's consumers to their brand when faced with a lucrative offer, in the form of a price reduction from a competing national brand. Although theoretically b could be positive, we expect that in most markets with differentiated brands, b will be negative, indicative of the reluctance of national brand loyal consumers to switch.

Transition matrix (14) encompasses some of the findings of earlier studies. Aggregate market share models in which F_A and F_B are a function of marketing activities by the competitors, but without the no-purchase state N, have been empirically tested. Horsky (1977) and Chintagunta and Vilcassim (1992) do so in the context of advertising outlays,[9] and Kahn and Raju (1991) and Zhang et al. (2000) in the context of price promotions. The no-purchase state, or "outside good," is reported in several studies reviewed in the introduction, to be the source of 25% or even much more of the increased demand a promoting brand can expect.

Transition matrix (14) can also be viewed as a continuous generalization of the Varian and Shilony models. For example, the Varian-based studies assume that each national brand has a segment of hard-core consumers who do not switch from it and that there is an additional segment of switchers who all buy from that national brand which offers the lowest price. This framework is indicative of high a_A and a_B as well as negative b_A and b_B. That is, high repeat purchase rates for the national brands, as well as resistance to switching from them. In terms of the nonnational-brands segment, as can be seen from the last row of matrix (14), when the national brands lower their prices they will attract more switchers from brand N. If the price response functions are identical, $F_A = F_B$, the lower-priced national brand will attract more of them than the higher-priced one. In a similar manner, the parameters of model (14) can be set such that it approaches the Shilony-based studies in which the switching is only among the national brand loyal consumers.

The question we will ask here is the central question of this paper. Should the established competing national brands A and B charge fixed prices over time, or should they, under certain conditions, offer once-in-a-while price promotions? As in the case of the monopolist, we are not interested in some initial conditions but rather in the long-term steady-state behavior of such brands. Another issue of interest in this competitive case is if the two national brands do promote, should they do so in different periods or in the same period?

Two Competing National Brands with Constant Prices

We start our analysis with the optimal constant pricing behavior of the competing national brands faced with consumers whose demand for their brands is defined by transition matrix (14). If brands A, B always charge prices p_A, p_B, respectively, then the

[9] A notable early review of these types of Markovian advertising models is provided in Little (1979).

resulting steady-state market shares x_A, x_B satisfy the equation

$$\begin{aligned}&[x_A \quad x_B \quad 1-x_A-x_B]\\&=[x_A \quad x_B \quad 1-x_A-x_B]\\&\cdot\begin{bmatrix} F_A(p_A)+a_A & F_B(p_B)+b_B & 1-F_A(p_A)-a_A \\ & & -F_B(p_B)-b_B \\ F_A(p_A)+b_A & F_B(p_B)+a_B & 1-F_A(p_A)-b_A \\ & & -F_B(p_B)-a_B \\ F_A(p_A) & F_B(p_B) & 1-F_A(p_A)-F_B(p_B)\end{bmatrix}. \quad (15)\end{aligned}$$

The steady-state market share solutions to this linear system are:

$$x_A=\frac{(1-a_B)F_A(p_A)+b_AF_B(p_B)}{(1-a_A)(1-a_B)-b_Ab_B} \quad \text{and}$$
$$x_B=\frac{(1-a_A)F_B(p_B)+b_BF_A(p_A)}{(1-a_A)(1-a_B)-b_Ab_B}. \quad (16)$$

The steady-state market shares of Equation (16) provide further bounds on the values of the parameters that govern this type of competitive market. It is evident from (16) that both shares depend on the prices of both brands. The steady-state market share of a national brand is a continuous, strictly decreasing function of its own price. However, because in most regular competitive scenarios the share of a brand should also be a continuous, strictly increasing function of the price set by its competitor, we require that $b_A < 0$ and $b_B < 0$. This highlights the role of the b's as the basis of cross-price elasticities. Following (14), we required that $b < 1-a$. However, it is further evident in Equation (16) that, for the impact of the brand's own price to be larger than the impact of the competitor's price and, for the denominators to be positive $|b| < 1-a$, b needs to be negative and relatively small.[10]

Brand A chooses its constant price p_A to maximize its steady-state average revenue per period $R_A(p_A, p_B) = p_Ax_A$. Similarly, brand B chooses p_B to maximize $R_B(p_A, p_B) = p_Bx_B$. We assume that there exists a Nash equilibrium p_A^*, p_B^* satisfying the usual first- and second-order conditions:

$$\frac{\partial}{\partial p_A}R_A(p_A, p_B^*)=0, \qquad \frac{\partial^2}{\partial p_A^2}R_A(p_A, p_B^*)<0 \quad \text{when } p_A=p_A^* \quad (17)$$

$$\frac{\partial}{\partial p_B}R_B(p_A^*, p_B)=0, \qquad \frac{\partial^2}{\partial p_B^2}R_B(p_A^*, p_B)<0 \quad \text{when } p_B=p_B^* \quad (18)$$

[10] Note that if both competing brands increased their prices to infinity, the conditional probability in the lower right corner of the transition matrix in Equation (15) would converge to 1, and the no-purchase state N would become an absorbing state. With such prices the steady-state shares in Equation (16) converge to zero.

Two Competing National Brands with Alternating Prices

The competitive national brands may decide not to charge single prices but, rather, to each use two different prices, a reduced price and a regular price. The frequency of using the reduced prices may be every second period or less frequently. We will focus our analysis on the case in which the competing brands use the reduced prices every second period. In so doing, the brands will also need to decide if they both offer the price promotion in different periods or in the same period (at the same time).

If brands A, B decide not to charge a single price but rather to charge prices p_{A1}, p_{B1} and p_{A2}, p_{B2} in alternate periods, then the resulting steady-state market shares x_{A1}, x_{B1} and x_{A2}, x_{B2} must satisfy the two linear systems (see Appendix A for a general case derivation)

$$\begin{aligned}&[x_{A1} \quad x_{B1} \quad 1-x_{A1}-x_{B1}]\\&=[x_{A2} \quad x_{B2} \quad 1-x_{A2}-x_{B2}]\\&\cdot\begin{bmatrix} F_A(p_{A1})+a_A & F_B(p_{B1})+b_B & 1-F_A(p_{A1})-a_A \\ & & -F_B(p_{B1})-b_B \\ F_A(p_{A1})+b_A & F_B(p_{B1})+a_B & 1-F_A(p_{A1})-b_A \\ & & -F_B(p_{B1})-a_B \\ F_A(p_{A1}) & F_B(p_{B1}) & 1-F_A(p_{A1}) \\ & & -F_B(p_{B1})\end{bmatrix} \quad (19)\end{aligned}$$

and

$$\begin{aligned}&[x_{A2} \quad x_{B2} \quad 1-x_{A2}-x_{B2}]\\&=[x_{A1} \quad x_{B1} \quad 1-x_{A1}-x_{B1}]\\&\cdot\begin{bmatrix} F_A(p_{A2})+a_A & F_B(p_{B2})+b_B & 1-F_A(p_{A2})-a_A \\ & & -F_B(p_{B2})-b_B \\ F_A(p_{A2})+b_A & F_B(p_{B2})+a_B & 1-F_A(p_{A2})-b_A \\ & & -F_B(p_{B2})-a_B \\ F_A(p_{A2}) & F_B(p_{B2}) & 1-F_A(p_{A2}) \\ & & -F_B(p_{B2})\end{bmatrix}. \quad (20)\end{aligned}$$

These linear systems can be solved for the steady-state market shares $x_{A1}, x_{B1}, x_{A2}, x_{B2}$, which are detailed in Appendix C.

Brand A chooses its prices p_{A1}, p_{A2} and brand B chooses its prices p_{B1}, p_{B2} to maximize their respective steady-state revenues over the two periods (which equal twice their long-run average profit per period)

$$R_A(p_{A1}, p_{A2}, p_{B1}, p_{B2}) = p_{A1}x_{A1}+p_{A2}x_{A2}, \quad (21)$$
$$R_B(p_{A1}, p_{A2}, p_{B1}, p_{B2}) = p_{B1}x_{B1}+p_{B2}x_{B2}. \quad (22)$$

In- or Out-of-Phase Promotions

The prices brands A and B charge are a regular high (HI) price in the nonpromotional period and a reduced lower (LO) price in the promotional period. Suppose that $p_{AHI} > p_{ALO}$ and $p_{BHI} > p_{BLO}$ are the regular and reduced prices brands A and B decide to use. Then, when brands A, B charge prices p_{AHI}, p_{BHI} and p_{ALO}, p_{BLO} in alternate periods, we say they are price promoting *in-phase*. If, instead, they charge prices p_{AHI}, p_{BLO} and p_{ALO}, p_{BHI} in alternate periods, they are price promoting *out-of-phase*.

Theorem 3. *Brand A's profit when the brands price promote in-phase minus its profit when they price promote out-of-phase has the same sign as the parameter* b_A.

The implication of Theorem 3 is that if b_A and b_B are negative, that is, the stickiness consumers have to the national brands they had bought earlier is greater than that exhibited by the consumers who had bought brand N, then if they decide to promote, they will do so in different periods. It is important to note that the result of Theorem 3 is general and does not depend on a particular price response function, except that it needs to be downward sloping.

To Promote or Not to Promote

The key question for the competing national brands, which can obtain new consumers from each other and from the nonnational-brands segment, is whether the reduced and regular prices can lead to profitabilities that are higher than those obtained with the single optimal prices. We examine (as we did in the case of the single national brand) whether there exist reasonable price response functions that would lead each of the brands to use two different prices to maximize steady-state revenues (21) and (22).

Theorem 4. *For the competing national brands A and B, maximizing respectively revenues* (21) *and* (22),

$$\text{(i)}\begin{cases} \dfrac{\partial}{\partial p_{A1}} R_A(p_{A1}, p_{A2}, p_B^*, p_B^*) = 0 & \textit{when } p_{A1} = p_{A2} = p_A^* \\ \dfrac{\partial}{\partial p_{A2}} R_A(p_{A1}, p_{A2}, p_B^*, p_B^*) = 0 & \textit{when } p_{A1} = p_{A2} = p_A^* \\ \dfrac{\partial}{\partial p_{B1}} R_B(p_A^*, p_A^*, p_{B1}, p_{B2}) = 0 & \textit{when } p_{B1} = p_{B2} = p_B^* \\ \dfrac{\partial}{\partial p_{B2}} R_B(p_A^*, p_A^*, p_{B1}, p_{B2}) = 0 & \textit{when } p_{B1} = p_{B2} = p_B^* \end{cases}$$

$$\text{(ii)}\begin{cases} \text{(a)} & \textit{If } F_A''(p_A^*) \le 0 \textit{ then } p_{A1} = p_{A2} = p_A^* \textit{ is a strict local maximum for } R_A(p_{A1}, p_{A2}, p_B^*, p_B^*). \\ \text{(b)} & \textit{If } F_B''(p_B^*) \le 0 \textit{ then } p_{B1} = p_{B2} = p_B^* \textit{ is a strict local maximum for } R_B(p_A^*, p_A^*, p_{B1}, p_{B2}). \end{cases}$$

We can interpret this theorem as saying that if the hypotheses of part (ii) that the price response functions $F_A(p_A)$ and $F_B(p_B)$ are not strictly convex hold, then the prices $p_{A1} = p_{A2} = p_A^*$ and $p_{B1} = p_{B2} = p_B^*$ constitute a Nash equilibrium for the alternating price game.

Theorem 4 is the duopoly counterpart to Theorem 1 for the monopolist. It states that if the price response functions $F_A(p_A)$ and $F_B(p_B)$ are not strictly convex, the two national brands will be better off charging single prices. If these functions are strictly convex, then it is possible that two-price polices will lead to higher profits. Because the commonly used power and exponential price response functions have a *positive* second derivative, they may lead to two-price solutions being superior. We will further investigate under which conditions this happens for the exponential function.

An Exponential Price Response Function

In this section we will assume that the two national brands have, in transition matrix (14), exponential price response functions with the same parameters and also have identical parameters for learning and stickiness, such that

$$\begin{gathered} F_A(p) = F_B(p) = \alpha e^{-\beta p}, \quad \text{and} \\ a_A = a_B = a,\ b_A = b_B = b. \end{gathered} \tag{23}$$

The assumption of identical parameters is necessary if we are to obtain closed-form results.

Theorem 5. *When brands A, B charge constant prices,* $p_A^* = p_B^* = (1 - a + b)/(1 - a)\beta$ *is the Nash equilibrium.*

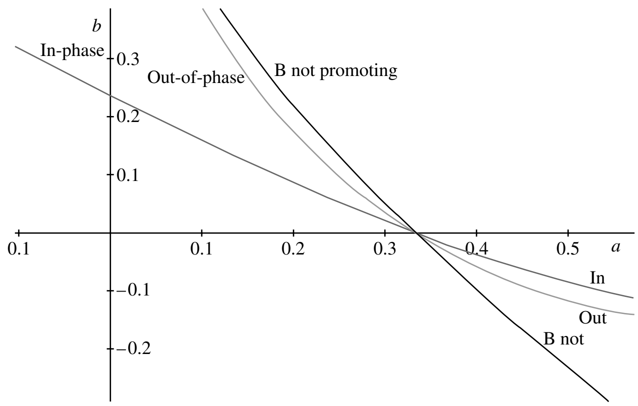
Theorem 5 is the duopoly counterpart to part (i) of Theorem 2. It is evident, as should be expected, that for negative values of b the optimal constant prices for the duopolists are lower than the optimal constant price for the monopolist. We will now pursue the duopoly counterpart to part (ii) of Theorem 2 and identify the conditions under which revenue functions R_A and R_B of Equations (21) and (22) will have maximums in two-price policies. As in the monopolistic case, the strict convexity of the exponential price response functions is a necessary condition for that to happen, but we also need to identify the sufficient conditions. If the two brands plan to use high and low prices it seems natural to consider HI and LO prices that are just above and just below their optimal constant prices $p_{AHI} = p_A^* + \delta$, $p_{ALO} = p_A^* - \delta$, $p_{BHI} = p_B^* + \varepsilon$, $p_{BLO} = p_B^* - \varepsilon$, where δ and ε are relatively small positive numbers.

Theorem 6. *In comparison to the case of brands A and B having constant prices* p_A^* *and* p_B^*:

(i) *The brands are better off price promoting out-of-phase if, and only if,*

$$a > \frac{2 - \sqrt{1 + 6b - 3b^2}}{3}.$$

Figure 1 Conditions for Competitive Price Promotions



(ii) *The brands are better off price promoting in-phase if, and only if,*

$$a > \frac{2 - b - \sqrt{1 + 8b + 4b^2}}{3}.$$

(iii) *If brand B is charging the constant price p_B^*, then brand A is better off alternating prices p_{AHI} and p_{ALO} if, and only if,*

$$a > \frac{-1 - b + 2\sqrt{1 - b + b^2}}{3}.$$

Figure 1 provides a graphical representation of Theorem 6 and the dependence of its three cases on the magnitudes of the two parameters a and b. It is important to examine this figure while keeping in mind that Theorem 6 relates to the conditions for promotions to be a better strategy than constant prices. The relevant regions of Figure 1, where the conditions associated with those three cases hold, are to the right of the respective curves. Moreover, it should be recalled that the general result of Theorem 3, that is, when b is negative the brands should promote out-of-phase, and vice versa, holds for any downward sloping demand curve. Although we have derived in Theorem 6, for analytical completeness, the case of a positive b and have included that region in Figure 1, the relevant range of b is only the negative one. Moreover, we expect, based on the discussion following Equation (16), the magnitude of b to be rather small. What we can see in Figure 1 is:

(i) When b is negative and the competitors are better off promoting out-of-phase, the brands will promote for a b close to zero if $a > 1/3$. The learning parameter a needs to become progressively bigger as b gets more negative. In other words, higher brand loyalty and stickiness of the national brands buyers to their brands makes it harder for learning to make promotions optimal.

(ii) When b is negative and the brands are best off promoting out-of-phase, if for some reason they chose not to promote out-of-phase they would still be better off promoting in-phase (as opposed to not promoting at all), but it would require a slightly greater magnitude of learning, a, than before (this can be seen by passing a horizontal line through $b = -0.1$).

(iii) If for some reason brand B decides not to promote, we can see (for example, by passing a horizontal line through $b = -0.1$) that for A to still be better off by promoting the needed magnitude of a is smaller and closer to $1/3$ than the magnitude required had B decided to promote also. Evidently, when brand B decides not to promote and keeps its price at the optimal constant steady-state price this case becomes closer to the case of the monopolist examined earlier. This result stands to reason because brand A actually "competes" against a passive brand N and a passive, at an optimal single-price level, brand B.

Reduced Reinforcement After Purchase on a Promotion

As reported earlier there is empirical evidence that the magnitude of the purchase reinforcement is slightly diminished if a brand was previously bought on a price promotion. In our competitive analysis, this phenomenon would cause a change in the transition matrices associated with Equations (19) and (20). Let us assume that brand B charged a reduced price, p_{BLO}, in the first period and a regular price, p_{BHI}, in the second period. The repeat purchase probability in Equation (20) for those who bought the brand in the first period, when its price was lower, will now be in line with Equations (12) and (13)

$$F_B(p_{BHI}) + a_B - c(p_{BHI} - p_{BLO})^{\theta}, \quad \text{where } c > 0 \text{ and } \theta > 1. \quad (24)$$

A similar change would apply to Brand A.

In Appendix D1 we demonstrate (along similar lines to those of Appendix C1) that we are able to identify, depending on the parameter values in Equations (19), (20), (23), and (24), the Nash equilibrium optimal alternating price policies for the two competing brands. At these prices both brands make higher profits than at the Nash equilibrium single price policies.

Discussion and Intuition

Several conclusions can be drawn from examining the two national brands in an expandable market case. First and foremost, if there is learning on the part of consumers and it is of large enough magnitude, the duopolists will be better off periodically promoting and inducing the "try it, you will like it" scenario, as opposed to keeping constant optimal prices. Consumer learning, as discussed in the monopolistic case, causes an increase in the utility of a brand after its purchase. Thus as we saw earlier the monopolist could use promotions to increase market share in the first period and then use his monopoly power to increase price in the second period. If the intensity of learning were high enough, the single national brand could in the second period more than recoup the lost profits of the first period. The intuition behind what makes promotions worthwhile in the competitive scenario is more complex.

When b is negative, a promoting national brand is more attractive to consumers who bought from brand N than to consumers who bought from the other national brand. In this case both brands find it advantageous to promote in different periods. As illustrated in Figure 1, the minimum required magnitude of learning, a, which makes the national brands better off promoting than not promoting, is higher here than the monopolist's critical value of $a = 1/3$. As b becomes more negative, the attractiveness of the promoting national brand to brand N buyers remains the same, but its attractiveness to the other national brand buyers diminishes. To overcome this diminished attractiveness to one segment of the market and still be better off promoting than not promoting, the critical magnitude of a has to become progressively larger, as b becomes progressively more negative. In the next period consumers who had bought the promoting national brand will mostly stick to it when it raises its price, provided that the increase in utility governed by a is large enough. Moreover, their inclination to cross over to the other national brand is diminished because the negative b implies high stickiness and brand loyalty. All in all, the reason behind the larger required magnitude of a in the competitive case versus the monopolistic one in the fact that the "monopoly" power of a competing brand is lower than that of a monopolistic brand. This reduced power was also borne out by the fact that the optimal constant price the competing brands could charge, as derived in Theorem 5, is lower than the optimal constant price of a monopolist.

Comparisons to Other Models of Competition

It is important to highlight some basic differences between the frameworks forwarded by the game theoretic papers published earlier on this topic, in particular the role that price promotions play in them, and the framework and role of promotions in our paper.

Lal (1990) constructs a market composed of two national brands with totally loyal segments and a price passive local brand regularly bought by a switching segment. If a national brand lowers its price enough, it will attract all of the latter segment. His model is thus an extreme case of our model with a high a and a negative b. He, too, demonstrates that in this case the brands will promote in different periods. One advantage that we have over Lal is that he assumes/conjectures that the two national brands will implicitly collude and deal in different periods and thereby divide the spoils gained from the local brand. We do not assume implicit collusion but rather prove in Theorems 3 and 6 that in this case out-of-phase promoting is the optimal behavior of two noncolluding competitors.

In the Shilony (1977) and Varian (1980) type papers, which end with a mixed strategy of randomized pricing, it is important to note that this pricing policy is a defensive mechanism. The brands need to find a way to hide their prices because the discontinuities in the demand curves create a "winner-take-all" situation in which they may lose all if the competitor undercuts their prices. On the other hand, our demand equation is continuously decreasing in price. Our framework has differentiated brands and the consumer learns about them after consumption. The purpose of price promotions in our multiperiod dynamic case is to build up market share and profits in comparison to a constant price strategy. Thus, while the single-period static mixed-strategy papers have to have competition to justify the defensive price promotions, in our multiperiod framework a monopolist in an expandable market may also find it optimal to promote and build share and profits. Moreover, if in the competitive scenario one of the competitors decides to stop promoting, the mixed-strategy papers will not be able to justify price promotions by the other competitor (no defensive strategy needed), whereas, as we saw in our framework, Theorem 6, part iii, the competitor may still find it optimal to price promote.

Generality of the Results

The generality of our results goes beyond providing a rationale for why two competing national brands will persist in offering price promotions in different periods.

In our analysis we do not consider retailers and treat the national brands as if they were vertically integrated or use exclusive channels. However, in the presence of independent retailers, our results hold if the national brands use consumer-directed coupons. In the case of trade promotions if the retailers are in a perfectly competitive market, they will not matter and the results will again hold. If, however, the retailers just like the national brands, are in a duopoly or oligopoly and maximize store/category profits the problem becomes much more complex. The problem of several manufacturers and several retailers (duopoly or oligopoly in both) is currently an unsolvable problem even for the most stylized formulations. However, in our case, if the retailer, which usually sets the promotional schedule jointly with the national brands way in advance, does not want them to promote in different periods, even when it is optimal for them we have shown that they would still be better off agreeing to promotions in the same period than not promoting at all, provided learning is large enough (larger than that required for the optimal out-of-phase promotions). Examination of retail promotional practices, for example for Coke and Pepsi, demonstrates that usually they are promoted in different weeks, but once in a while in the same one.

We further examined what happens if one of the national brands decided not to promote and to charge continuously the optimal constant steady-state price (below the regular HI price and above the promotional LO price of the two-price policy). A notable example is Procter and Gamble, which decided in the mid nineties to stop using promotions and to execute an EDLP (Every Day Low Price) policy. We have shown that the other national brand should still promote for values of learning which are actually smaller than those required for both brands to promote.

4. Summary

Firms in the United States spend annually higher amounts on price promotions than on advertising. In the last two decades with the increased availability of scanner panel data, price promotions have become the most studied topic in the academic marketing literature. Nevertheless, there exists a disconnect between the wealth of empirical findings describing the actual impact of promotions, on consumer brand switching and product category expansion, and the premises of the studies that try to explain the existence and optimality of promotions. In this paper we use the major empirical findings on how consumers respond to periodic price promotions as the foundation for an analysis of why such promotions are being offered by competing established national brands. We examine whether a possible explanation for the observed behavior of brands can be the fact that consumers learn from their purchases. The existence of such learning by consumers is well founded in many empirical works. In such a case it is possible that the national brands may periodically reduce their prices to induce purchases by nonbuyers of their brands—"try it, you will like it." These consumers may decide, due to learning about the brands, to continue purchasing them even if their prices are later increased.

We were able to demonstrate that if consumer learning exists and if its effects are strong enough, it will lead national brands to price promote. Surprisingly, this result seems quite robust. We were able to show that a monopolistic national brand facing an expandable market will find it worthwhile to periodically offer a reduced promotional price, at magnitudes of learning consistent with those found empirically in first order Markov brand switching models of us versus them. For this result to hold, the price response function needs to be decreasing at a decreasing rate as price increases, a property found in the most sensible and widely used response functions. In the case of duopolists in an expandable market, we specified a model that is consistent with empirical findings and encompasses the type of consumer segments assumed in earlier game theoretic approaches to this problem. In this competitive case a national brand that lowers its price attracts some consumers who previously bought from the other national brand and some who did not buy from either of them. The above results of the desirability of price promotions continued to hold. In addition, we were able to show that the practice of competing national brands promoting in different periods is optimal. Our framework can also explain promotions by a national brand when the other national brand chooses not to promote (for example, when it uses an EDLP strategy). Finally, although we did not formally analyze the case where the national brands are sold to the end consumer through retailers, we have shown that it is quite likely that also in this scenario if learning exists it will provide justification for the national brands to price promote.

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Appendix A. An Alternating Markov Chain

Let $\mathbf{P}, \mathbf{Q}$ be $\mathbf{n} \times \mathbf{n}$ stochastic matrices with all elements strictly positive. If we apply these alternatingly, then the state probability vector $\mathbf{u_n}$ evolves according to the equation

$$u_{n+1} = \begin{cases} u_n P & \text{if } n = 2m \text{ (i.e., when } n \text{ is even)}, \\ u_n Q & \text{if } n = 2m+1 \text{ (i.e., when } n \text{ is odd)}. \end{cases}$$

We define a new sequence of state probability vectors $\mathbf{y_m}$ by

$$\mathbf{y_{m+1}} = \mathbf{u_{2m+2}} = \mathbf{u_{2m+1}}\mathbf{Q} = \mathbf{u_{2m}}\mathbf{PQ} = \mathbf{y_m}\mathbf{PQ}.$$

Also, because $\mathbf{PQ}$ is a stochastic matrix with all elements strictly positive, we have

$$\mathbf{u_{2m}} = \mathbf{y_m} \to \mathbf{y} \quad \text{as } \mathbf{m} \to \infty,$$

where $\mathbf{y}$ is the unique probability vector satisfying $\mathbf{y} = \mathbf{yPQ}$. Similarly,

$$\mathbf{z_{m+1}} = \mathbf{u_{2m+3}} = \mathbf{u_{2m+2}}\mathbf{P} = \mathbf{u_{2m+1}}\mathbf{QP} = \mathbf{z_m}\mathbf{QP}$$

leads to

$$\mathbf{u_{2m+1}} = \mathbf{z_m} \to \mathbf{z} \quad \text{as } \mathbf{m} \to \infty,$$

where $\mathbf{z}$ is the unique probability vector satisfying $\mathbf{z} = \mathbf{zQP}$. Finally, taking limits in

$$\mathbf{u_{2m+1}} = \mathbf{u_{2m}}\mathbf{P} \quad \text{and} \quad \mathbf{u_{2m+2}} = \mathbf{u_{2m+1}}\mathbf{Q}$$

we obtain

$$\mathbf{z} = \mathbf{yP} \quad \text{and} \quad \mathbf{y} = \mathbf{zQ}.$$

Appendix B. Proofs of Theorems 1 to 6

Proof of Theorem 1.

Proof. Define the numerator of Equation (10) as $H(p_1, p_2) = (p_1 + ap_2)F(p_1) + (p_2 + ap_1)F(p_2)$.

It can be shown that the following hold[11]:

(i) If $p_1 = p_2 = p$ then both $\partial H/\partial p_1$ and $\partial H/\partial p_2$ equal $(1+a)(pF'(p) + F(p))$. By the equality in (6), this is 0 at $p = p^*$.

(ii) $\partial^2 H/\partial p_1^2 = d^2/dp_1^2(p_1F(p_1)) + ap_2F''(p_1)$. At $p_1 = p_2 = p^*$ the first term is negative by the inequality in (6), and the second term is nonpositive by assumption. A similar argument shows that $\partial^2 H/\partial p_2^2$ is negative at $p_1 = p_2 = p^*$.

(iii) At $p_1 = p_2 = p^*$ the determinant of the Hessian matrix of H can be shown through direct calculations to equal $4(1-a^2)F'(p^*)^2 + 4p^*(1+a)F'(p^*)F''(p^*) + (p^*)^2(1+a)^2F''(p^*)^2$. Because $F'(p^*) < 0$ and $F''(p^*) \le 0$, the first term is positive, and the remaining two terms are nonnegative.

Proof of Theorem 2.

Proof. For part (i)
$(d/dp)(pF_{\text{exponential}}(p)) = \alpha(1-\beta p)e^{-\beta p}$, which is 0 at $p = 1/\beta$, and $(d^2/dp^2)(pF_{\text{exponential}}(p)) = -\alpha\beta(2-\beta p)e^{-\beta p}$, which is negative at $p = 1/\beta$.

For part (ii) and (iii) let $H(p_1, p_2) = (p_1 + \alpha p_2)F_{\text{exponential}}(p_1) + (p_2 + ap_1)F_{\text{exponential}}(p_2)$. From the proof of Theorem 1 we know that $\partial H/\partial p_1 = 0$ and $\partial H/\partial p_2 = 0$ at $p_1 = p_2 = 1/\beta$. By direct calculation, the Hessian matrix of H equals:

$$\begin{bmatrix} -\alpha\beta(2-\beta p_1 - a\beta p_2)e^{-\beta p_1} & -\alpha\beta a(e^{-\beta p_1} + e^{-\beta p_2}) \\ -\alpha\beta a(e^{-\beta p_1} + e^{-\beta p_2}) & -\alpha\beta(2 - a\beta p_1 - \beta p_2)e^{-\beta p_2} \end{bmatrix}.$$

At $p = p_2 = 1/\beta$ this becomes

$$\begin{bmatrix} -\alpha\beta(1-a)e^{-1} & -2\alpha\beta a e^{-1} \\ -2\alpha\beta a e^{-1} & -\alpha\beta(1-a)e^{-1} \end{bmatrix},$$

with a determinant equal to $\alpha^2\beta^2(1+a)(1-3a)e^{-2}$. The determinant is positive in case (ii), which is consistent with a maximum, and is negative in case (iii), which is consistent with a saddle point.

Proof of Theorem 3.

Proof. The expression in question can be shown with the use of Equation (21) and the steady-state market shares of Appendix C to equal:

$$\begin{aligned} &R_A(p_{AHI}, p_{ALO}, p_{BHI}, p_{BLO}) - R_A(p_{AHI}, p_{ALO}, p_{BLO}, p_{BHI}) \\ &\quad = \frac{b_A(p_{AHI} - p_{ALO})(F_B(p_{BLO}) - F_B(p_{BHI}))}{(1-a_A)(1-a_B) - b_Ab_B} \end{aligned}$$

Because the response function $F_B(p)$ is a decreasing function of price, and b_A and b_B obtain small values so that $|b_A| < 1 - a_A$ and $|b_B| < 1 - a_B$, this expression has the same sign as b_A.

Proof of Theorem 4.

Proof. For part (i) a direct calculation shows that when $p_{A1} = p_{A2} = p_A$ then $(\partial/\partial p_{A1})R_A(p_{A1}, p_{A2}, p_B, p_B) = (\partial/\partial p_A)R_A(p_A, p_B)$ always holds. In particular, this is true when $p_A = p_A^*$ and $p_B = p_B^*$, so by the equality in condition (17) the first equality of part (i) holds. A similar argument proves the remaining three equalities.

[11] All the analytical solutions provided in this paper are either rechecked or derived using the computer algebra system DERIVE.

For part (iia), we need to show that the Hessian matrix

$$\begin{bmatrix} \dfrac{\partial^2}{\partial p_{A1}^2} R_A(p_{A1}, p_{A2}, p_{B1}, p_{B2}) & \dfrac{\partial^2}{\partial p_{A2}\partial p_{A1}} R_A(p_{A1}, p_{A2}, p_{B1}, p_{B2}) \\ \dfrac{\partial^2}{\partial p_{A1}\partial p_{A2}} R_A(p_{A1}, p_{A2}, p_{B1}, p_{B2}) & \dfrac{\partial^2}{\partial p_{A2}^2} R_A(p_{A1}, p_{A2}, p_{B1}, p_{B2}) \end{bmatrix}$$

is negative definite when $p_{A1} = p_{A2} = p_A^*$ and $p_{B1} = p_{B2} = p_B^*$. A direct calculation shows that when $p_{A1} = p_{A2} = p_A$ then

$$\begin{aligned} &\frac{\partial^2}{\partial p_{A1}^2} R_A(p_{A1}, p_{A2}, p_B, p_B) \\ &\quad = \frac{1 - a_B^2 - b_Ab_B}{(1-a_B)((1+a_A)(1+a_B) - b_Ab_B)} \frac{\partial^2}{\partial p_A^2} R_A(p_A, p_B) \\ &\qquad + \frac{p_A(a_A - a_Aa_B^2 + a_Bb_Ab_B)F_A''(p_A)}{((1+a_A)(1+a_B) - b_Ab_B)((1-a_A)(1-a_B) - b_Ab_B)} \end{aligned}$$

always holds. In particular, when $p_A = p_A^*$ and $p_B = p_B^*$ then by the inequality in condition (17) the first term is strictly negative, while the second term is nonpositive by the assumption in the theorem. A similar proof shows that the other diagonal element of the Hessian matrix is strictly negative. Finally, a direct calculation shows that when $p_{A1} = p_{A2} = p_A$ and $p_{B1} = p_{B2} = p_B$ then the determinant of the Hessian matrix equals

$$\begin{aligned} &\big((1-a_B)\{p_A^2(1-a_B)((1+a_A)(1+a_B) - b_Ab_B)(F_A''(p_A))^2 \\ &\qquad + 4p_A(1 - a_B^2 - b_Ab_B)F_A'(p_A)F_A''(p_A) \\ &\qquad + 4(1+a_B)((1-a_A)(1-a_B) - b_Ab_B)(F_A'(p_A))^2\}\big) \\ &\quad \cdot \big([(1+a_A)(1+a_B) - b_Ab_B][(1-a_A)(1-a_B) - b_Ab_B]^2\big)^{-1}, \end{aligned}$$

which is positive since $F_A'(p_A^*) < 0$ and $F_A''(p_A^*) \le 0$.

The proof of part (iib) is similar.

Proof of Theorem 5.

Proof. Under the assumptions in (23), the steady-state revenue for brand A is

$$R_A(p_A, p_B) = \alpha \frac{(1-a)p_Ae^{-\beta p_A} + bp_Ae^{-\beta p_B}}{(1-a)^2 - b^2}.$$

Direct calculation shows that

$$\frac{\partial}{\partial p_A} R_A(p_A, p_B)\bigg|_{p_A = p_A^*,\, p_B = p_B^*} = 0 \quad \text{and}$$

$$\frac{\partial^2}{\partial p_A^2} R_A(p_A, p_B)\bigg|_{p_A = p_A^*,\, p_B = p_B^*} = -\frac{\alpha\beta e^{-(1-a+b)/(1-a)}}{1-a+b} < 0.$$

A similar proof holds for brand B.

Proof of Theorem 6.

Proof. Under the assumptions in (23), the two-period steady-state revenue for brand A is

$$\begin{aligned} &R_A(p_{A1}, p_{A2}, p_{B1}, p_{B2}) \\ &\quad = \big(\alpha\{((1-a^2-b^2)p_{A1} + a(1-a^2+b^2)p_{A2})e^{-\beta p_{A1}} \\ &\qquad + (a(1-a^2+b^2)p_{A1} + (1-a^2-b^2)p_{A2})e^{-\beta p_{A2}} \\ &\qquad + (2abp_{A1} + b(1+a^2-b^2)p_{A2})e^{-\beta p_{B1}} \\ &\qquad + (b(1+a^2-b^2)p_{A1} + 2abp_{A2})e^{-\beta p_{B2}}\}\big) \\ &\quad \cdot \big(((1+a)^2 - b^2)((1-a)^2 - b^2)\big)^{-1}. \end{aligned}$$

We need to consider the behavior of $R_A(p_A^*+\delta, p_A^*-\delta, p_B^*+\varepsilon, p_B^*-\varepsilon)$, which for convenience we will denote by $R_A^*(\delta,\varepsilon)$, for small positive values of δ and

(i) small negative values of ε when the brands promote out-of-phase,

(ii) small positive values of ε when the brands promote in-phase, and

(iii) $\varepsilon=0$ when brand B is charging the constant price p_B^*. By direct calculation we find that

$$\frac{\partial}{\partial\delta}R_A^*(\delta,\varepsilon)\bigg|_{\delta=0,\,\varepsilon=0}=0 \quad\text{and}\quad \frac{\partial}{\partial\varepsilon}R_A^*(\delta,\varepsilon)\bigg|_{\delta=0,\,\varepsilon=0}=0.$$

The behavior of $R_A^*(\delta,\varepsilon)$ for small values of δ and ε is therefore determined by the second order terms

$$[\delta\quad \varepsilon]\begin{bmatrix} \dfrac{\partial^2}{\partial\delta^2}R_A^*(\delta,\varepsilon)\bigg|_{\delta=0,\,\varepsilon=0} & \dfrac{\partial^2}{\partial\varepsilon\partial\delta}R_A^*(\delta,\varepsilon)\bigg|_{\delta=0,\,\varepsilon=0} \\ \dfrac{\partial^2}{\partial\delta\partial\varepsilon}R_A^*(\delta,\varepsilon)\bigg|_{\delta=0,\,\varepsilon=0} & \dfrac{\partial^2}{\partial\varepsilon^2}R_A^*(\delta,\varepsilon)\bigg|_{\delta=0,\,\varepsilon=0} \end{bmatrix}\begin{bmatrix}\delta\\ \varepsilon\end{bmatrix}.$$

We evaluate this expression for the three cases under consideration.

(i) When the brands are promoting out-of-phase we set $\varepsilon=-\delta$. We find that brand A is better off when the two brands price promote out-of-phase if

$$\frac{2\alpha\beta(-3a^2+4a-(1-b)^2)e^{-(1-a+b)/(1-a)}}{(1-a)(1+a-b)(1-a-b)}$$

is positive. Because the parameters and variables are the same for both brands, brand B will also be better off. The above expression is positive when condition (i) of Theorem 6 holds.

(ii) When the brands are promoting in-phase we set $\varepsilon=\delta$. We find that brand A is better off when the two brands price promote in-phase if and only if

$$\frac{2\alpha\beta(-3a^2+(4-2b)a+b^2+4b-1)e^{-(1-a+b)/(1-a)}}{(1-a)(1+a+b)(1-a-b)}$$

is positive. Because the parameters and variables are the same for both brands, brand B will also be better off. The above expression is positive when condition (ii) of Theorem 6 holds.

(iii) If brand B is charging the constant price p_B^* we set $\varepsilon=0$. We find that brand A is better off price promoting if

$$\frac{2\alpha\beta(3a^2+2(b+1)a-(1-b)^2)e^{-(1-a+b)/(1-a)}}{(1-a-b)((1+a)^2-b^2)}$$

is positive. This leads to condition (iii) of Theorem 6.

Appendix C. Steady-State Market Shares for Two Competing National Brands

$$\begin{aligned}x_{A1}&=\big((1-a_B^2-b_Ab_B)F_A(p_{A1})+(a_A-a_Aa_B^2+a_Bb_Ab_B)F_A(p_{A2})\\&\quad+b_A(a_A+a_B)F_B(p_{B1})+b_A(1+a_Aa_B-b_Ab_B)F_B(p_{B2})\big)\\&\quad\cdot\big(((1+a_A)(1+a_B)-b_Ab_B)((1-a_A)(1-a_B)-b_Ab_B)\big)^{-1}\\x_{A2}&=\big((1-a_B^2-b_Ab_B)F_A(p_{A2})+(a_A-a_Aa_B^2+a_Bb_Ab_B)F_A(p_{A1})\\&\quad+b_A(a_A+a_B)F_B(p_{B2})+b_A(1+a_Aa_B-b_Ab_B)F_B(p_{B1})\big)\\&\quad\cdot\big(((1+a_A)(1+a_B)-b_Ab_B)((1-a_A)(1-a_B)-b_Ab_B)\big)^{-1}\\x_{B1}&=\big((1-a_A^2-b_Ab_B)F_B(p_{B1})+(a_B-a_A^2a_B+a_Ab_Ab_B)F_B(p_{B2})\\&\quad+b_B(a_A+a_B)F_A(p_{A1})+b_B(1+a_Aa_B-b_Ab_B)F_A(p_{A2})\big)\\&\quad\cdot\big(((1+a_A)(1+a_B)-b_Ab_B)((1-a_A)(1-a_B)-b_Ab_B)\big)^{-1}\\x_{B2}&=\big((1-a_A^2-b_Ab_B)F_B(p_{B2})+(a_B-a_A^2a_B+a_Ab_Ab_B)F_B(p_{B1})\\&\quad+b_B(a_A+a_B)F_A(p_{A2})+b_B(1+a_Aa_B-b_Ab_B)F_A(p_{A1})\big)\\&\quad\cdot\big(((1+a_A)(1+a_B)-b_Ab_B)((1-a_A)(1-a_B)-b_Ab_B)\big)^{-1}\end{aligned}$$

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