Profitability of Price Promotions if Stockpiling Increases Consumption

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Abstract

Price promotions induce consumers to purchase higher-than-usual quantities, resulting in higher stocks that lead to increased consumption. We show for a stylized model with a single shop and a single loyal customer that because of this stockpiling effect, promotions can be profitable even if they do not attract extra customers.

1 Introduction

Researchers have spent several decades on investigating the effects of price promotions. Blattberg, Briesch and Fox (1995) review the marketing literature on a number of issues concerning price, and more general, sales promotions. As they report, some claims have been consistent and supported with empirical results, for instance that promotions result in a significant temporal and cross-sectional shifting of category demand. But for other important issues, few and conflicting results have been obtained. One of the unresolved key issues mentioned by Blattberg, Briesch and Fox (1995) is the effect of promotions on consumption through increased stocks that result from customers purchasing higher-than-usual quantities or accelerating their purchase occasion. In the last decade, it has been shown using experimental research (Chandon and Wansink 2002; Folkes, Martin and Gupta 1993; Wansink and Deshpande 1994) and econometric modelling (Ailawadi and Neslin 1998; Bell, Iyer and Padmanabhan 2002) that higher stocks indeed lead to increased consumption.

Why does this *stockpiling effect* occur? The main reason stated in the literature is that higher stocks reduce the concern about having to replace the product (Ailawadi and Neslin 1998; Assunção and Meyer 1993; Bell, Chiang and Padmanabhan 1999; Hoch, Drèze and

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Purk 1994), leading to a higher consumption rate. It has further been shown that the *flexibility of the consumption rate* differs across product categories. Another reason why higher stocks can lead to increased consumption, is that consumers face less stockouts and therefore have more opportunity to consume the product (Ailawadi and Neslin 1998).

If higher stocks indeed lead to increased consumption, then that effect should be taken into consideration when a firm chooses a retail format. The "everyday low price" (EDLP) format, which has recently received a lot of attention (Ailawadi, Lehmann and Neslin 2001; Bell and Lattin 1998; Hoch, Drèze and Purk 1994), does not benefit from the stockpiling effect, at least not in its pure form where the retailer charges a constant, low everyday price with no temporary price discounts. The alternative "high low" (Hi-Lo) retail format, which charges higher prices on an everyday basis but runs frequent price promotions in which the prices are below the EDLP level, does benefit. Of course, the EDLP retail format may be preferred for different reasons, such as restoring consumer credibility in retail pricing (Ortmeyer, Quelch and Salmon 1991) or lowering operating costs (Hoch, Drèze and Purk 1994). But the inability to benefit from the stockpiling effect may help explain why, in practice, most retailers have not adopted EDLP, and why those that claim to have adopted EDLP still use (occasional) price promotions (Hoch, Drèze and Purk 1994).

In this article we examine the effects of stockpiling on consumption and show that a retail format with price promotions can lead to higher profits than a constant pricing strategy, even if price promotions do not build more store traffic. The model developed by Bell, Iyer and Padmanabhan (2002) is the starting-point of this study. The authors develop a game theoretical model of price competition between shops in response to the stockpiling and subsequent consumption dynamics of consumers. The model is explained thoroughly in Section 2. It is based on a two-period planning horizon. The purchase and consumption behavior of consumers is as follows. A consumer can purchase either one or two units in the first period. Though he 'plans' to consume only one unit in the first period, price uncertainty can make him decide to purchase an additional unit and store it for consumption in the second period. But there is a probability that the additionally purchased unit is also consumed in the first period, and the consumer is aware of this stockpiling effect. The model makes use of several assumptions, one being that shops charge the same price in both periods. So, in a strict sense, Hi-Lo price strategies are not considered. However, shops can apply a randomized strategy, where the price that is charged is the outcome of a random choice between a high price and a low price. Bell, Iyer and Padmanabhan (2002) show that there are cases (i.e. parameter settings) for which the profit maximizing equilibrium solution is such that each shop applies a randomized price strategy rather than a constant price strategy. As we will point out in Section 2, however, the assumption that shops charge the same price in both periods leads to suboptimal strategies. Moreover, if that assumption is relaxed, then profit maximizing equilibrium solutions where shops apply a randomized price strategy no longer exist.

The model we propose is inspired by Bell, Iyer and Padmanabhan (2002) and uses the same purchase/consumption dynamics. But it differs on some key aspects. Several assumptions are relaxed: a firm does not have to charge the same price in each period; marginal consumption utility does not have to be constant. We consider a single shop, and hence there are no game theoretical elements. We consider a single loyal consumer, so that store traffic does not play a role. We study a long run planning horizon. The goal is to show that there are cases where Hi-Lo pricing is more profitable than charging a constant price.

The remainder of the article is organized as follows: The next section presents the model developed by Bell, Iyer and Padmanabhan (2002), summarizes their analysis and results, and provides some points of critique. We then describe our model in detail, determine the optimal pricing strategy, and present some examples of cases where Hi-Lo pricing is more profitable than charging a constant price. We conclude the article with a summary of the results and with directions for further research.

2 Bell, Iyer and Padmanabhan (2002): model, results, and critique

In this section, we present the model of Bell, Iyer and Padmanabhan (2002), summarize their analysis and results, and provide points of critique.

MODEL

A single type of product is considered, which is sold by n shops and for which there are T homogeneous consumers. Both shops and consumers have a two-period planning horizon, where a period can be interpreted as a time interval between two shopping trips. Consumers shop randomly, i.e. may purchase in each shop with equal probability $1/n$ on a shopping trip. Each consumer starts with zero stock at the beginning of period 1.

The consumption strategy of a consumer is independent of prices at which stocked products were purchased and independent of expectations about future prices. If two products are in stock at the beginning of a period, then at least one product is consumed and there is a probability θ that the second product is consumed. If there is one product in stock at the beginning of a period, then that product is consumed.

A consumer shops in a period if the stock at the beginning of that period is zero. The purchase behavior of a consumer is rational. His objective is to maximize the total expected utility over the two-period planning horizon. The utility in a period is equal to the value of the consumed products (u per product, measured in monetary units) minus the purchase cost (selling price per product) and holding cost (h per product that is in stock at the end of a period). Bell et al. remark that it is easy to also include a transaction cost per shopping trip. It is assumed that a consumer purchases at most two products in period 1 and at most one product in period 2.

The objective of a shop is to maximize the total profit over the planning horizon. Since purchase costs for a shop are ignored (they could easily be included, but that would not lead to additional insights), this is equivalent to maximizing total revenue. Clearly, a shop should not charge a price higher than u, since consumers will not purchase any products and hence no profit will be made. Moreover, it only makes sense to charge a price lower than u if that will make consumers purchase two products instead of one. Therefore, a shop should either charge the *high price* $p_h = u$ or the *low price* p_l, which is the price at which consumers are indifferent between purchasing one or two products. The exact value of p_l will be determined in the mathematical analysis below.

It is assumed that a shop charges the same price in both periods. So, actually, Hi-Lo strategies are not considered. However, a shop may apply a *randomized strategy* to determine the price, by choosing either the high price or the low price with certain positive probabilities. Alternatively, a shop may apply either a *fixed strategy* and charge the high price or the low price with probability 1.

An *equilibrium* is defined as a set of (fixed or randomized) strategies for each shop, where no shop can increase its expected profit by unilaterally altering its strategy. A *symmetric equilibrium* is an equilibrium where all shops apply the same strategy. Since all shops are identical, a symmetric equilibrium is sought. By λ, $0 \leq \lambda \leq 1$, is denoted the probability that a shop sets the high price.

MATHEMATICAL ANALYSIS AND RESULTS

First, a condition for p_l is derived based on the fact that consumers are indifferent between purchasing one or two products in the first period when that price is charged. The expected utility over both periods of purchasing one product in the first period is (using $p_h = u$)

$$\begin{aligned} E_1 &= 2u - p_l - (\lambda p_h + (1-\lambda)p_l)) \\ &= u - p_l + (1-\lambda)(u - p_l) \end{aligned}$$

and the expected utility over both periods of purchasing two products in the first period is

$$\begin{aligned} E_2 &= \theta(3u - 2p_l - (\lambda p_h + (1-\lambda)p_l)) + (1-\theta)(2u - 2p_l - h) \\ &= 2u - 2p_l - (1-\theta)h + \theta(1-\lambda)(u - p_l). \end{aligned}$$

The consumer is indifferent between purchasing one or two products if $E_1 = E_2$, which gives

$$(\lambda + (1-\lambda)\theta)(u - p_l) = (1-\theta)h. \tag{1}$$

Next, a second *equilibrium condition* for p_l is derived. Since each consumer starts with zero stock, all T consumers shop in period 1. An expected fraction $\lambda + (1-\lambda)\theta$ of consumers will return in period 2, since they consumed all (1 or 2) products purchased in the first period. Therefore, the total revenue for a shop that sets the high price $p_h = u$ is (recall that a consumer purchases in each shop with equal probability $1/n$)

$$R_h = \left(\frac{T}{n} + (\lambda + (1-\lambda)\theta)\frac{T}{n}\right) u$$

and the total revenue for a shop that sets the low price p_l is

$$R_l = \left(2\frac{T}{n} + (\lambda + (1-\lambda)\theta)\frac{T}{n}\right) p_l.$$

In equilibrium, it should hold that

$$R_h = R_l,$$

which can be rewritten as

$$(1 + \lambda + (1 - \lambda)\theta)\, u = (2 + \lambda + (1 - \lambda)\theta)\, p_l. \tag{2}$$

Combining (1) and (2) gives

$$p_l = \frac{u + h(1 - \theta)}{2}.$$

Given this low price, it is straightforward to determine the value λ^* for λ that maximizes total profit for a shop. Bell et al. show that, under a certain condition on the model parameters, $0 < \lambda^* < 1$, implying that a randomized strategy is optimal.

CRITIQUE

There are several unrealistic assumptions concerning consumer behavior in the model of Bell et al. All consumers are assumed to shop randomly, whereas many consumers have one or more favorite shops in practice. There is no decreasing marginal utility, since consuming a second product in a certain period brings the same utility as consuming the first product. However, these assumptions are acceptable since the objective of the model is not to approach a realistic setting, but to show that price promotions can be profitable in situations where stockpiling leads to increased consumption.

Our main critique concerns the restriction to strategies with constant prices over the planning horizon of two periods. This implies that if a shop charges the low price in the first period, it also has to charge the low price in the second period. But since shoppers never purchase two products in the second period, it is always better to charge the high price in that period. Therefore, all randomized (but with constant prices) strategies with $0 \leq \lambda < 1$ are sub-optimal. Therefore, it is better to consider the following strategies for a shop: charge the high price with probability λ, $0 \leq \lambda \leq 1$, in period 1; always charge the high price in period 2. But, as we will show below, an equilibrium for this class of strategies with $0 < \lambda < 1$ can never maximize profit.

So, we focus on the above mentioned modified strategies which always charge the high price in the second period. The total revenues then become

$$R_h = \frac{T}{n}\,(u + (\lambda + (1 - \lambda)\theta)u)$$

for a shop that charges $p_h = u$ in period 1, and

$$R_l = \frac{T}{n}\,(2p_l + (\lambda + (1 - \lambda)\theta)\, u)$$

for a shop that charges p_l in period 1.

The equilibrium condition $R_h = R_l$ now gives $p_l = u/2$. But it is obvious that selling two products for half the price in period 1 can never be profitable, since that will leave the profit in period 1 unchanged, but reduce the number of shoppers and hence the profit in period 2. So equilibria with randomized strategies never maximize profit.

3 Model with one shop and one loyal consumer

The objective of our model is not to give an accurate description of reality. The goal is to show that in situations where stockpiling leads to increased consumption, high-low pricing can be more profitable than charging a constant price, even if lower prices do not attract more consumers.

The model is inspired by the one of Bell, Iyer and Padmanabhan (2002), but differs from that model in the following key aspects. We consider a single shop and a single loyal consumer, and study a long run planning horizon. The utility of consuming a second product in a period may be less than that for the first product, i.e., there can be decreasing marginal utility. Both the shop and the consumer have an infinite period (long run) planning horizon, where a period can be interpreted as a time interval between two shopping trips.

The consumption strategy is independent of prices at which stocked products were purchased and independent of expectations about future prices. If two products are in stock at the beginning of a period, then at least one product is consumed and there is a probability θ that a second product is consumed. If there is one product in stock at the beginning of a period, then that product is consumed.

The purchase behavior of the consumer is rational. His objective is to maximize the expected utility per period. The utility in a period is equal to the value of the consumed products (u_1 for the first product and $u_2 \leq u_1$ for the second product, measured in monetary units) minus the purchase cost (selling price per product) and holding cost (h per product that is in stock at the end of a period). The consumer only shops in a period if there is no stock left at the end of the previous period, and purchases at most 2 products.

The objective of the shop is to maximize the expected total profit per period. Since purchase costs for the shop are ignored (they could easily be included, but that would not lead to additional insights), this is equivalent to maximizing total revenue. Clearly, a shop should not charge a price higher than u_1, since consumers will not purchase any products and hence no profit will be made. Moreover, it only makes sense to charge a price lower than u_1 if that will make consumers purchase two products instead of one. So, a shop should either charge the *high price* $p_h = u_1$ or the *low price* p_l at which consumers switch strategies, i.e., at which consumers are indifferent between purchasing one or two products. An expression for p_l will be determined in the next section. The probability that the shop charges the high price u_1 is denoted by λ, $0 \leq \lambda \leq 1$. Note that the shop uses constant pricing if $\lambda = 0$ (low price) or $\lambda = 1$ (high price), and Hi-Lo pricing if $0 < \lambda < 1$.

4 Analysis

We first determine an expression for p_l based on the indifference of the customer at that price between purchasing one or two products. Let E_1 denote the long-run expected utility per period if the consumer always purchases one product. Let E_2 denote the long-run expected utility per period if the consumer purchases two products when p_l is charged and one product when $p_h = u_1$ is charged.

It is easy to see (using $p_h = u_1$) that

$$\begin{aligned} E_1 &= \lambda(u_1 - p_h) + (1-\lambda)(u_1 - p_l) \\ &= (1-\lambda)(u_1 - p_l). \end{aligned}$$

In order to determine E_2, we first need to calculate the probability that the consumer shops in an arbitrary period, assuming that two products are purchased when the price is low. If the consumer shops in a certain period, then there is a probability $(1-\lambda)(1-\theta)$ that he will not shop in the next period. So the average time between two successive shopping trips is $1+(1-\lambda)(1-\theta)$ periods, and hence the probability that the consumer shops in a period is

$$\mathrm{Pr}_2 := \frac{1}{1+(1-\lambda)(1-\theta)}.$$

Consequently, the probability that a consumer shops *and* that the high price is charged is

$$\mathrm{Pr}_{2,h} := \frac{\lambda}{1+(1-\lambda)(1-\theta)},$$

and the probability that a consumer shops *and* that the low price is charged is

$$\mathrm{Pr}_{2,l} := \frac{1-\lambda}{1+(1-\lambda)(1-\theta)}.$$

If a consumer shops and the high price is charged, then one product is purchased. That product is consumed in the same period and the corresponding utility is

$$E_{2,h} := p_h - u_1.$$

If a consumer shops and the low price is charged, then two products are purchased. With probability θ, both products are consumed in that period giving total utility $u_1 + u_2 - 2p_l$. With probability $1-\theta$, one of the products is stocked and consumed in the next period giving total utility $2u_1 - 2p_l - h$. So, the expected utility corresponding with a low price shopping trip is

$$E_{2,l} := \theta(u_1 + u_2 - 2p_l) + (1-\theta)(2u_1 - 2p_l - h).$$

We therefore get (using $p_h = u_1$)

$$\begin{aligned} E_2 &= E_{2,h}\mathrm{Pr}_{2,h} + E_{2,l}\mathrm{Pr}_{2,l} \\ &= (1-\lambda)\frac{(2-\theta)u_1 + \theta u_2 - 2p_l - (1-\theta)h}{1+(1-\lambda)(1-\theta)}. \end{aligned}$$

The consumer is indifferent between purchasing one or two products for price p_l if $E_1 = E_2$, which gives

$$(1-\lambda)(u_1 - p_l) = (1-\lambda)\frac{(2-\theta)u_1 + \theta u_2 - 2p_l - (1-\theta)h}{1+(1-\lambda)(1-\theta)}.$$

This can be rewritten as

$$p_l = u_1 - \frac{\theta(u_1 - u_2) + (1-\theta)h}{1-(1-\lambda)(1-\theta)}. \tag{3}$$

Note from (3) that p_l is increasing in λ. So if the reduced price is charged more frequently, then a larger reduction is needed to make the consumer stockpile. This finding is in accordance with prior research on the relationship between promotional frequency and promotional response (Ailawadi, Lehmann and Neslin 2001; Assunção and Meyer 1993; Blattberg, Briesch and Fox 1995; Teunter 2002). It leads to the important managerial insight that price discounts should not be offered too frequently, since that reduces the incentive for the consumer to stockpile the product.

Using (3), it follows that the expected profit per period for the shop is

$$\begin{aligned} EP &= p_h \mathrm{Pr}_{2,h} + 2p_l \mathrm{Pr}_{2,l} \\ &= \frac{\lambda u_1 + (1-\lambda)2\left(u_1 - \frac{\theta(u_1-u_2)+(1-\theta)h}{1-(1-\lambda)(1-\theta)}\right)}{1+(1-\lambda)(1-\theta)}. \end{aligned}$$

By setting the derivative of EP with respect to λ to 0 and checking that the second derivative is negative, it is possible to derive a closed-form expression for the optimal value of λ and conditions for which it is between 0 and 1. However, there are two reasons for not presenting that expression and conditions here. First, they are very complex and not insightful. Second, they would have no direct practical use, since our model with a single customer that purchases at most two products is rather unrealistic.

Indeed, recall that the model was only designed to show that in situations where stockpiling leads to increased consumption, high-low pricing can be more profitable that charging a fixed price even if lower prices do not attract more consumers. In modelling terms: there are values of u_1, u_2, θ, and h for which the value of λ that maximizes EP is between 0 and 1. In the next section, we present some examples for which this indeed holds. For completeness, we also present examples for which the optimal value for λ is either 0 or 1.

5 Examples

Table 1 shows the low price and the associated profits for $\lambda = 0, 0.1, 0.2, \ldots, 1$ for four different examples. These examples are selected in order to show that both constant and Hi-Lo strategies can be optimal. For all examples, u_1 is set to 1 and can be interpreted as the unit of measurement for money/utility.

INSERT TABLE 1

First consider Example 1. If a constant high price $p_h = u_1 = 1$ is charged ($\lambda = 1$), then the profit is 1 in each period. The maximum constant price at which the consumer purchases two products is 0.75, which also leads to an expected profit per period of 1. But Hi-Lo strategies have the advantage that two products can be sold at a price higher than 0.75. In fact, as was proven in Section 4 and can be observed from Table 1, the lowest price p_l at which two units can be sold increases with the probability λ that the high price is charged. As Table 1 shows, the optimal value for λ is between 0.4 and 0.5 (0.46 to be exact) and the associated expected profit per period is 1.07.

For Example 2, similar arguments can be used to explain why a Hi-Lo strategy is optimal. Compared to Example 1, the value of p_l is lower for all values of λ, because the utility u_2 of consuming a second product is lower and the stocking cost is larger. But since the probability θ of directly consuming a second purchased product is large, offering price discounts can still be profitable. The optimal strategy is to charge the discount price 0.61 with probability 0.44. The profit for this optimal Hi-Lo strategy is 1.04, whereas the profit for applying the constant high or low price are 1 and 1.01, respectively.

Example 3 resembles Example 2 in that the stocking cost h is large and the utility u_2 of consuming a second product is small. So, again, a large discount is needed to sell two products. But the probability θ that selling two products increases consumption is much smaller, so that price discounts are no longer profitable. The optimal strategy is to always charge the high price.

Example 4 is the opposite from Example 3 with h small, u_2 large, and θ large. A small discount is sufficient to sell a second product, and the optimal strategy is to always charge the low price.

6 Conclusion

We analyzed a model with a single shop and a single loyal, utility maximizing customer. The customer normally purchases and consumes one unit of a product in each period. But a price promotion can induce the customer to purchase a second unit. That second unit is meant to be stored for the next period, but there is a probability that both units may be consumed in the same period once they are in stock. The consumer is aware of this *stockpiling effect*, but purchasing two products still maximizes his utility if the price cut is deep enough. It was shown that a deeper price cut is needed if promotions are more frequent, which supports the validity of the model. Aside from promotional frequency, the necessary price cut is also determined by other factors: the utility of consuming a second unit, the cost of holding a unit in stock, and the probability that a second stored unit is consumed. It was shown that for certain settings of these factors, price promotions can increase the shop's profit. So, because of the stockpiling effect, price promotions can increase the profit earned from the single loyal customer.

The more general implication of this result is that price promotions can increase profit, even if they do not attract extra customers. Therefore, the stockpiling effect should be considered in the analysis of price promotions, e.g. when comparing Hi-Lo and EDLP strategies. Future research should be directed towards finding the best way to incorporate the stockpiling effect in promotional models. The empirical testing of several inventory-consumption (rate) functions is very challenging, extending the work of Ailawadi and Neslin (1998). An indirect but perhaps more practical avenue for future research would be to investigate to which degree EDLP shoppers indeed exhibit less stockpiling effects than Hi-Lo shoppers.

	Example 1		Example 2		Example 3		Example 4	
	$u_1 = 1$		$u_1 = 1$		$u_1 = 1$		$u_1 = 1$	
	$u_2 = 0.8$		$u_2 = 0.6$		$u_2 = 0.7$		$u_2 = 0.9$	
	$\theta = 0.5$		$\theta = 0.85$		$\theta = 0.4$		$\theta = 0.6$	
	$h = 0.05$		$h = 0.1$		$h = 0.2$		$h = 0.05$	
λ	p_l	EP	p_l	EP	p_l	EP	p_l	EP
0.0	0.75	1.00	0.58	1.01	0.40	0.50	0.87	1.24
0.1	0.77	1.03	0.59	1.02	0.48	0.62	0.88	1.23
0.2	0.79	1.05	0.60	1.03	0.54	0.72	0.88	1.22
0.3	0.81	1.06	0.60	1.04	0.59	0.79	0.89	1.21
0.4	0.82	1.07	0.61	1.04	0.63	0.85	0.89	1.19
0.5	0.83	1.07	0.62	1.04	0.66	0.89	0.90	1.17
0.6	0.84	1.06	0.62	1.04	0.68	0.93	0.90	1.14
0.7	0.85	1.05	0.63	1.03	0.71	0.95	0.91	1.11
0.8	0.86	1.04	0.63	1.02	0.73	0.97	0.91	1.08
0.9	0.87	1.02	0.64	1.01	0.74	0.99	0.92	1.04
1.0		1.00		1.00		1.00		1.00

Table 1

Expected profit per period for $\lambda = 0.0, 0.1, 0.2, \ldots, 1$ for 4 examples.

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