Classification of Pricing Strategies in a Competitive Environment

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Abstract: The general structure of multiperiod price paths mainly depends on consumer characteristics, competitive reactions and restrictions which describe additional salient features of the underlying pricing situation. We present an approach which generalizes well-known price response functions in the area of reference price research and discuss price paths for important classes of competitive pricing strategies.

1 Reference price concept

There is intense research focussing on the concept of reference prices and managerial implications. A concise definition concerning reference prices is given by Kalyanaram, Winer (1995, p. G161): "The concept of a reference price is that it is an internal standard against which observed prices are compared." Reference prices can be understood as consumer specific, internal anchoring levels which are used to evaluate the actual market prices of products or services. A market price exceeding the corresponding reference price is perceived as loss and may on the aggregate level lead to an reduction in sales volume. The opposite effect is to be expected if a market price is below the corresponding reference price. The reference price concept and its different foundations are discussed in more detail, e.g., by Monroe (1990) and Nagle, Holden (1995).

In spite of the many different reference price operationalizations and formulations of price response functions there are some recommendations frequently mentioned as further research opportunities (see, e.g., Kalyanaram, Winer (1995)). Most of all it is suggested to incorporate more than one reference price in the description of pricing situations, to consider the possibility of a region of reduced price sensitivity, to allow for asymmetric gain resp. loss effects according to prospect theory (see Kahneman, Tversky (1979)), and to account for the other different behavioural theories underlying the reference price concept. An additional relevant aspect is that the formulation of pricing situations should allow for normative implications and managerial recommendations in the area of multi-period pricing decisions.

2 Example of a modified price response function

In the situation of a duopolistic market a price response function that considers the suggestions just mentioned is given by

$$\begin{aligned} q_n &= q_n(p_n^{(r)}, \bar{p}_n^{(r)}, p_n, \bar{p}_n) = a - b \cdot p_n - c \cdot \bar{p}_n \\ &\quad - d_1 \cdot 1\{p_n \leq p_n^{(r)} - \delta_1\}(p_n - p_n^{(r)} + \delta_1) \\ &\quad - d_2 \cdot 1\{p_n > p_n^{(r)} + \delta_2\}(p_n - p_n^{(r)} - \delta_2) \\ &\quad - e_1 \cdot 1\{p_n \leq \bar{p}_n - \epsilon_1\}(p_n - \bar{p}_n + \epsilon_1) \\ &\quad - e_2 \cdot 1\{p_n > \bar{p}_n + \epsilon_2\}(p_n - \bar{p}_n - \epsilon_2) \\ &\quad - f_1 \cdot 1\{\bar{p}_n \leq \bar{p}_n^{(r)} - \gamma_1\}(\bar{p}_n - \bar{p}_n^{(r)} + \gamma_1) \\ &\quad - f_2 \cdot 1\{\bar{p}_n > \bar{p}_n^{(r)} + \gamma_2\}(\bar{p}_n - \bar{p}_n^{(r)} - \gamma_2), \quad n = 0, 1, \ldots, N, \end{aligned} \tag{1}$$

with parameters a, b, c, d_1, d_2, δ_1, δ_2, e_1, e_2, ϵ_1, ϵ_2, f_1, f_2, γ_1, $\gamma_2 \in I\!R$, where

$$1\{x \geq y\} := \begin{cases} 1, & \text{if } x \geq y, \\ 0, & \text{otherwise,} \end{cases} \tag{2}$$

is the notation for the indicator function. q_n is the sales volume and p_n resp. $p_n^{(r)}$ are used for the market price resp. reference price of the product of the interesting enterprise in period n, where N denotes the planning horizon. The market price resp. reference price of the product of the competing enterprise is given by $\bar{p}_n$ resp. $\bar{p}_n^{(r)}$. The reference prices $p_n^{(r)}$, $\bar{p}_n^{(r)}$ and the market prices p_n, $\bar{p}_n$ are used in a prospect theory context (see Tversky, Kahneman (1991) for the multiattributed case). In addition, formulation (1) accounts for regions of reduced price sensitivity due to the parameters δ_1, δ_2 and γ_1, γ_2. Following a suggestion of Rajendran, Tellis (1994) the competitive price $\bar{p}_n$ is captured in the manner of a contextual reference price for p_n. Equation (1) is a piecewise linear price response function (as, e.g., the approach of Greenleaf (1995)). Note that q_n can be interpreted as attraction of the products under consideration and incorporated into an MCI-approach (MCI is the abbreviation for Multiplicative Competitive Interaction, see, e.g., Hruschka (1996)).

Formulation (1) is very flexible and incorporates some recently published contributions as special cases (see, e.g., Greenleaf (1995) with $c = 0$, $\delta_1 = 0$, $\delta_2 = 0$, $e_1 = 0$, $e_2 = 0$, $f_1 = 0$, $f_2 = 0$, Kopalle et al. (1996) with $\delta_1 = 0$, $\delta_2 = 0$, $e_1 = 0$, $e_2 = 0$, $f_1 = 0$, $f_2 = 0$, or Kopalle, Winer (1996) with $c = 0$, $\delta_1 = 0$, $\delta_2 = 0$, $e_1 = 0$, $e_2 = 0$, $f_1 = 0$, $f_2 = 0$). Most of these approaches do not take into account regions of reduced price sensitivity or ignore the fact, that the competitive price may serve as an anchor of price judgement and, therefore, has to be modelled adequately.

3 Classification of pricing strategies based on dynamic programming

In order to model the pricing situation described so far, dynamic programming was applied to a markov decision process formulation. A short description of the basic methodology is given in the appendix. Additional constraints, incorporated in the optimization via dynamic programming and discussed subsequently, can be used for classification issues. The following restrictions were considered:

$$\sum_{n=0}^{N-1} 1\{p_n \leq \sigma_{1,n}\} \leq \kappa_1, \tag{3}$$

$$\sum_{n=0}^{N-1} 1\{p_n \leq \sigma_{2,n}\} \geq \kappa_2, \tag{4}$$

$$\sum_{n=0}^{N-1} 1\{|p_n - p_{n-1}| \geq \sigma_{3,n}\} \leq \kappa_3, \tag{5}$$

$$\sum_{n=0}^{N-1} 1\{|p_n - p_{n-1}| \geq \sigma_{4,n}\} \geq \kappa_4. \tag{6}$$

In restriction (3), it is tried to cope that consumers often assume a positive correlation between the price of a product and its quality (see, e.g., Erevelles (1993)). For high-quality products it may be desirable to establish a quality category by means of a unique price tier. By inequality (3) it can be avoided to set more than κ_1 prices below the lower limit of this price tier, denoted by $\sigma_{1,n}$ in period n.

As the intention of price promotions is often to increase store traffic or to support the price image of underlying products (see, e.g., Monroe (1990)) a specified number κ_2 of promotional prices, i.e. prices which are lower than a lower price bound $\sigma_{2,n}$ in period n, can be prescribed by restriction (4).

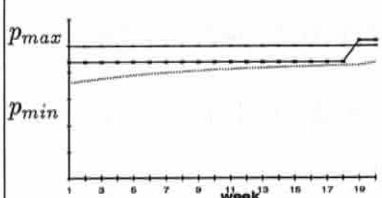
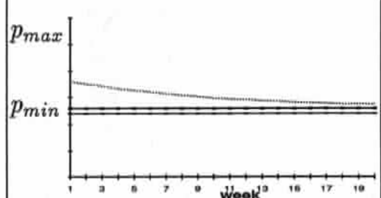
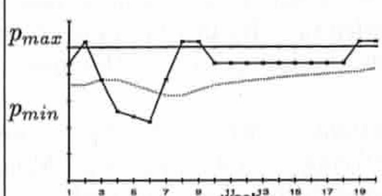
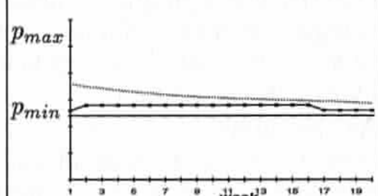
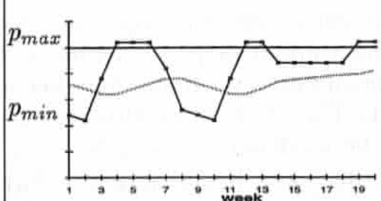
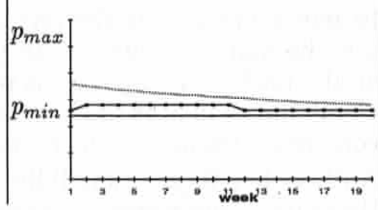
If prices are reduced too often, consumers may not be willing any more to buy a product at the regular price (see, e.g., Kalwani, Yim (1992)) or may be unable to appreciate the amount of price reduction (e.g., Urbany et al. (1988)). If a product is perishable, consumers may become suspicious about the quality of the product. Therefore, price alterations should not be conducted too often, which can be modeled by inequality (5).

Authors like Rajendran, Tellis (1994) and Krishnamurthi, Raj (1991) stress the point to reach consumer segments of different price sensitivity by promotional activities. If it is intended to address different consumer segments, the number of price changes κ_4 should be large enough so that price alterations can be recognized as deal occasions by consumers with low price awareness or reduced willingness to switch the product. Constraint (6) can be used to tackle such a situation.

Together with the following three different classes of competitive pricing behaviour this opens a magnitude of possibilities for describing pricing situations.

In class 1, it is assumed that the competitor sets an everyday relatively high price near to p_{max}, a behaviour which is close to the pricing decisions of national brands. In class 2, the competitor is assumed to be very price aggressive and to set an everyday low price close to p_{min}, which is quite characteristic for private label brands or store brands. In class 3, the competing firm is assumed to directly copy the price settings of the profit maximizing enterprise. Pricing decisions of this kind are often observable (see, e.g., the recent price war in the area of forthnightly tv-magazines discussed by Rosenfeld (1996)).

Table 1: Classes of pricing strategies

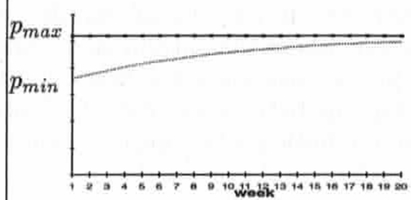
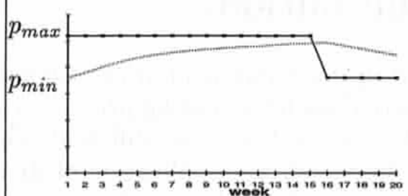
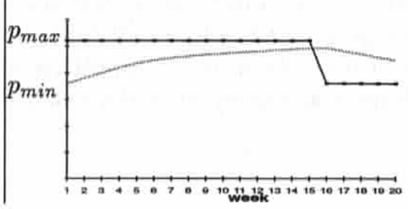
	pattern of competitive behaviour	
constraints	*class 1: everyday high price*	*class 2: everyday low price*
without price promotions		
with 5 price promotions		
between 5 and 10 price promotions		

reference price — optimal price — competitive price

For all presented classes of competitive pricing behaviour profit maximization without additional constraints results in paths of nearly constant prices. Such optimal price paths are depicted by bold black dots in Tab. 1 together with reference and competitive prices.

In cases where exactly five or between five and ten price promotions are forced by the restrictions the results change significantly for class 1. In the situation of five to ten feasible price promotions, the price path is splitted into a phase with high price promotional activity at the beginning of the overall planning interval and a phase of relatively constant prices at the end. In periods 1, 2, and 3 and during periods 7 to 11 the profit maximizing enterprise conducts price promotions, i.e., selects a price which is lower than $\sigma_{2,n}$. Additionally, more than the minimum number of five price promotions are performed. Between these periods with price promotions the enterprise selects higher market prices in order to increase its reference price (periods 4 to 6) and to take advantage of a high reference price level in subsequent periods. At the end of the overall planning interval the profit maximizing enterprise selects prices which are near to p_{max} and therefore close to the price of the competing firm.

Table 1: Classes of pricing strategies (cont.)

	pattern of competitive behaviour
constraints	*class 3: price follower*
without price promotions	
with 5 price promotions	
between 5 and 10 price promotions	
reference price	optimal price — competitive price

In class 2 of our scenario of competitive pricing behaviour the competitor is assumed to set an everyday low price. In cases with price promotions a comparison with the optimization results without constraints shows that the price paths change only slightly. In the first weeks of the overall planning interval the profit maximizing enterprise selects a market price which is below its reference price and close to the price of the competing firm. Accordingly, the reference price declines over time. In the last periods of the overall planning interval the profit maximizing enterprise lowers the market price. This increases the difference between its reference price and market price and, at the same time, decreases the difference between the prices of the competing brands, resulting in a last push with respect to the sales volume. During the overall planning interval the profit maximizing enterprise only sets the minimum number of price promotions. We observe a clear reluctance to set high market prices and to increase the own reference prices. The effects due to competitive prices seem to be more important than the effects due to reference prices.

A similar effect is observable in class 3. As the competitor selects the same market price as the profit maximizing enterprise, it is quite unfavourable to lower the market prices. Therefore, in the case of exactly five price promotions as well as in the situation, where the enterprise is allowed to conduct between five and ten price promotions, only the minimum number of promotional activities is selected. In both cases (exactly 5 price promotions resp. between 5 and 10 price promotions) the optimization with constraints results in identical optimal multiperiod price paths.

4 Conclusion and outlook

An extension with respect to the formulation of price response functions was presented. Additionally, restrictions for modeling pricing situations were introduced and the impact of such constraints on different classes of competitive pricing strategies was discussed. By application of dynamic programming to a markov decision process formulation remarkable changes of the structure of optimal multiperiod price paths could be observed.

Dependent on the information concerning the underlying class of pricing behavior, results of the kind mentioned before will influence the price setting behavior of enterprises in markets whose competitive structure can be described in terms of restrictions as exemplarily demonstrated in this contribution.

Appendix: Formulation of the pricing situation as markov decision process

Based on the above mentioned price response function a markov decision process is defined in order to derive optimal price paths for different classes of competitive pricing reactions. We need specifications for the state space S, the action space A, the reward function r, the transition probability law $\mathbf{p}$, the planning horizon N, and the terminal reward v_0.

Let p_{min}, p_{max} resp. $\bar{p}_{min}$, $\bar{p}_{max}$ denote thresholds for the underlying pricing situation and $s_n := (p_n^{(r)}, \bar{p}_n^{(r)})$ all possible combinations of reference prices of the two enterprises under consideration with

$$s_n \in S \;:=\; \Big\{[p_{min}, p_{max}] \cap \{0, 1/100, 2/100, \dots\}\Big\} \tag{7}$$

$$\times\Big\{[\bar{p}_{min}, \bar{p}_{max}] \cap \{0, 1/100, 2/100, \dots\}\Big\}. \tag{8}$$

Possible actions $a_n := p_n$ are the price settings of the interesting enterprise with

$$a_n \in A := \Big\{[p_{min}, p_{max}] \cap \{0, 1/100, 2/100, \dots\}\Big\}. \tag{9}$$

In order to specify the reward function r, we interpret q_n of equation (1) as attraction of the brand of the interesting enterprise and define in a similar manner $\bar{q}_n$ as attraction of the product of the competing enterprise. Using an MCI-approach, the market share of the interesting enterprise is given by

$$ms = ms(s_n, a_n, \bar{p}_n) = f(x) = \frac{q_n(x)}{q_n(x) + \bar{q}_n(x)} \tag{10}$$

with $x = (p_n^{(r)}, \bar{p}_n^{(r)}, a_n, \bar{p}_n)$. Now, the reward function r is specified as $r(s_n, a_n) := ms(s_n, a_n, \tilde{pr}_2(s_n)) \cdot mv_n \cdot (a_n - c_n)$ for the first and the second class and as $r(s_n, a_n) := ms(s_n, a_n, a_n) \cdot mv_n \cdot (a_n - c_n)$ for the third class of competitive pricing strategies. Here, c_n denotes the cost per unit of the product of the interesting enterprise, mv_n the volume of the market in period n, and $\tilde{pr}_2(s)$ the projection on the second component of a state $s \in S$.

In the example, the planning horizon N consists of 20 periods, the terminal reward v_0 is set equal to zero.

With an adequately specified transition probability law $\mathbf{p}$ one can define a density function on $(S^N, \mathcal{P}(S^N))$, where $\mathcal{P}(S^N)$ denotes the power set of S^N, see, e.g., Puterman (1994).

With the settings

$$\zeta_\nu := pr_\nu : S^N \to S, \quad \nu = 1, \dots N, \tag{11}$$

$$\phi_0, \dots, \phi_{N-1} \in F := \{f : S \to A\}, \tag{12}$$

$$\eta := (\zeta_\nu)_{\nu=1}^N, \quad \zeta_0 := s_0 \in S, \tag{13}$$

and the abbreviation pr_ν for the projection on component ν of S^N, the random N-period profit is given by

$$R_{(\phi_0,\dots,\phi_{N-1})}(s_0, \eta) := \sum_{\nu=0}^{N-1} (1+\beta)^{-\nu} r(\zeta_\nu, \phi_\nu(\zeta_\nu)) + (1+\beta)^{-N} v_0(\zeta_N), \tag{14}$$

where β is the discount factor (in the example $\beta := 10\%$ p.a.).

With the notation mentioned before the profit maximizing enterprise has to solve

$$\max_{(\phi_0,\dots,\phi_{N-1}) \in F^N} \leftarrow ER_{(\phi_0,\dots,\phi_{N-1})}(s_0, \eta) \tag{15}$$

subject to restrictions (3) to (6).

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