A Classification Approach for Competitive Pricing

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Abstract: Pricing strategies in marketing suffer from the problem that it is difficult to model interdependencies with respect to price decisions of competing enterprises. We present an approach which tries to tackle these shortcomings, allows for additional insights into the pricing structure of a market, enables a classification of different types of competitive pricing schemes and can be incorporated into a profit optimization framework.

1 Introduction and Selected Concepts of Representing Price Competition

An evaluation of price decisions has to take into account aspects of consumer behaviour and objectives of the enterprise under consideration as well as effects of competition (e.g., Gijsbrechts (1993)). With respect to the price dependent aspects of consumer behaviour, e.g., the incorporation of latitudes of price acceptance intervalls (e.g., Kalyanaram, Little (1994); Urbany et al. (1988)), cherry picking (e.g., Mulhern, Padgett (1995)) or multi-period patterns of purchase (e.g., Krishna (1994)) should be mentioned. Concerning the different objectives of the enterprise under consideration it is often recommended to extend pure profit maximization by additional goals, e.g., via constraints like lower bounds for market shares or rates of return (e.g., Sivakumar (1995)). The incorporation of competitor oriented effects aims at a more realistic description of the profitability of managerial decisions (Armstrong, Collopy (1996)). The necessity to consider competitive reactions in pricing strategies is uncontradicted (e.g., Mulhern (1997)) and a broad variety of different approaches has been suggested.

Subsequently some selected concepts are reviewed in more detail.

Reaction functions have already been used for a long time (e.g., Dolan (1981), Leeflang, Wittink (1996)) and can be described as something "which determines for a firm in a given time period its action (price and/or quality) as a function of the actions of (all) other firms during the preceeding time period" (Hanssens et al. (1990), p. 202). However, a deterministic relationship between the marketing mix variables (especially price) of competing enterprises may fail in practical applications (see, e.g., Natter, Hruschka (1996) for corresponding experiences with respect to reaction functions).

Reaction matrices represent percentual changes of own marketing mix instruments and those of competitors (e.g., Hanssens et al. (1990)) and are useful in differentiating competitive reactions. However, the use of elasticities imposes restrictions, e.g., to rely on single reaction values for different outcomes of changes in marketing mix variables.

Game theory models have been under consideration (see, e.g., Rao (1993)), but already at the beginning of the eigthies the opinion was hold, that such approaches are not directly useful for representing competitive behaviour in marketing mix optimization models (e.g., Dolan (1981)).

A recent suggestion is to model competitive price settings by empirical distribution functions of prices derived from given data via sampling within the framework of independent and identically distributed random variables (Natter, Hruschka (1996)). It allows to take into account competitive pricing close to the observed data but assumes independent settings of prices over time.

In the following, we analyze competitive pricing structures of markets, propose a classification for different types of competitive reactions, and use the results of an empirical example for further clarification.

2 A Parsimonious Description of Competitive Pricing Reactions

In order to tackle situations in which competitive pricing reactions occur, we structure the problem into four steps and use the following notation:

$\kappa \in K$	index/set of competing brands
b	brand under consideration
$l \in S_b$	index/set of price settings for brand b (e.g., $S_b = \{down, neglectable, up\}$)
$s \in S$	index/set of price tiers for competing brands (e.g., $S = \{low, medium, high\}$)
$t \in T$	index/set of time points for which pricing data have been collected, e.g., weekly data
$Q^{\kappa,l} = (q^{\kappa,l}_{s,j})$	observed matrix of transition probabilities between price tiers $s, j \in S$ for brand κ when the price setting for brand b is described by index l
$R^{\kappa,l} = (r^{\kappa,l}_{s,j})$	matrix of transition probabilities calculated by the constancy/change model
$(R^{\kappa,l})_s$	row s of $R^{\kappa,l}$

For reasons of parsimony we choose $S_b = \{down, neglectable, up\}$ and $S = \{low, medium, high\}$ and will present an empirical example to explain our findings later on.

In a first step, prices $p_{b,t-1}$ and $p_{b,t}$ for brand b at subsequent time points $t-1$ and t are used to derive the sets

$$\mathcal{M}^{down}_{\Phi^-} = \{t | p_{b,t} < p_{b,t-1} - \Phi^-\}, \quad (1)$$

$$\mathcal{M}^{neglectable}_{\Phi^-,\Phi^+} = \{t | p_{b,t} \in [p_{b,t-1} - \Phi^-, p_{b,t-1} + \Phi^+]\}, \quad (2)$$
$$\mathcal{M}^{up}_{\Phi^+} = \{t | p_{b,t} > p_{b,t-1} + \Phi^+\}, \quad (3)$$

where $\Phi^+, \Phi^- \geq 0$ describe bounds for a price range inside which it is assumed that price alterations for brand b are neglectable for the consideration of competitive pricing reactions (see, e.g., Mulhern, Leone (1995) for a similar argumentation).

In a second step, these sets $\mathcal{M}^{down}_{\Phi^-}$, $\mathcal{M}^{neglectable}_{\Phi^-,\Phi^+}$ and $\mathcal{M}^{up}_{\Phi^+}$, which differentiate between situations of price reductions ("*down*"), price increases ("*up*") and neglectable price changes ("*neglectable*") of brand b, are used to investigate the price movements of the competing brands $\kappa \in K$. Corresponding transition probability matrices $Q^{\kappa,l}$ can be empirically derived according to the given data. In order to realize a parsimonious representation for the competitive pricing behaviour, again, the price movements of the competing brands are modelled on a more aggregated level taking into account only changes within the three price tiers *low*, *medium*, and *high*. These price tiers are calculated by partitioning the observed price ranges into three intervals of approximately the same length.

In a third step, it is tried to explain the empirically derived transition probability matrices within a framework which models price settings as a mixture of two opposite types of pricing behaviour: a tendency to remain in the last chosen price tier ("constancy") and a tendency to vary price tiers over time ("change"). Such a differentiation is close to considerations concerning everyday low pricing and high/low-pricing as discussed in the most recent literature (e.g. Kopalle, Winer (1996); Lal, Rao (1997)).

Finally, in a fourth step, the empirically derived matrices are analyzed based on what we have called the constancy/change model. The results are used for a classification of the competitive pricing strategies under consideration according to some prespecified classes.

3 Classification Possibilities via the Constancy/Change Model

The idea of the constancy/change model is to describe competitive pricing behaviour via a convex combination of distribution functions where the "constancy" situation (i.e. a competing brand κ stays in state $s \in S$ independent of the behaviour of brand b) is represented by

$$\vec{\delta}_s' = (\ldots, \delta_{sj}, \ldots) \text{ with } \delta_{sj} = \begin{cases} 1, & s = j, \\ 0, & \text{otherwise} \end{cases}, \quad s \in S, \quad (4)$$

and the "change" situation by

$$(\vec{\pi}^{\kappa,l})' = \left(\ldots, \pi_j^{\kappa,l}, \ldots\right) \text{ with } \pi_j^{\kappa,l} \geq 0 \text{ and } \sum_j \pi_j^{\kappa,l} = 1. \quad (5)$$

Here, the competing brand κ reacts to the price setting strategy of brand b (denoted by l) according to the distribution $\vec{\pi}^{\kappa,l}$. Remember that for every row state of a transition probability matrix the corresponding row describes a probability distribution on the column states of that matrix. In the constancy/change model we use the expressions

$$\left(R^{\kappa,l}\right)_s = \left(1-\alpha_s^{\kappa,l}\right)\left(\vec{\pi}^{\kappa,l}\right)' + \alpha_s^{\kappa,l}\vec{\delta}_s', \text{ with } \alpha_s^{\kappa,l} \in [0,1], \ \forall s \in S, \tag{6}$$

to construct a matrix $R^{\kappa,l}$ that best fits the empirically derived matrix $Q^{\kappa,l}$. $\vec{\alpha}^{\kappa,l} = (\ldots, \alpha_s^{\kappa,l}, \ldots)$ describes the degree of the mixture of the just explained probability distributions. Dependent on the row state s the value of $\alpha_s^{\kappa,l}$ helps to interpret the tendency to vary prices over time or to remain in the last chosen price tier.

Formulation (6) includes interesting special cases. $\alpha_s^{\kappa,l} = 0$ leads to

$$\left(R^{\kappa,l}\right)_s = \left(\vec{\pi}^{\kappa,l}\right)'. \tag{7}$$

A situation in which formulation (7) is valid for all $s \in S$ is equivalent to the specification by Natter, Hruschka (1996) if $(\vec{\pi}^{\kappa,l})'$ is derived according to the empirical distribution of prices. $\alpha_s^{\kappa,l} = 1$ for all $s \in S$ leads to the identity matrix and reflects the pricing behaviour of a competitor which stays in the last chosen price tier.

The constancy/change model allows for a classification of competitive pricing strategies as depicted in Tables 1 and 2 where $\epsilon'_{\kappa,l}, \epsilon''_{\kappa,l} > 0$ are suitable chosen threshold parameters.

$\alpha_s^{\kappa,l} < \epsilon'_{\kappa,l}$	$\epsilon'_{\kappa,l} \le \alpha_s^{\kappa,l} \le 1-\epsilon''_{\kappa,l}$	$\alpha_s^{\kappa,l} > 1-\epsilon''_{\kappa,l}$
"change"	*"constancy/change"*	*"constancy"*
label for the competitive pricing situation of κ dependent on the indices l and s		

Table 1: Classification of pricing strategies

$\vec{\pi}^{\kappa,down} \overset{st}{<} \vec{\pi}^{\kappa,neglectable} \overset{st}{<} \vec{\pi}^{\kappa,up}$ "imitation"
$\vec{\pi}^{\kappa,down} \overset{st}{>} \vec{\pi}^{\kappa,neglectable} \overset{st}{>} \vec{\pi}^{\kappa,up}$ "contra-reaction"
$\vdots$

Table 2: Subclasses of pricing strategies

The two parameter vectors $\vec{\alpha}^{\kappa,l}$ and $\vec{\pi}^{\kappa,l}$ allow for insights concerning interactions of price settings. $\alpha_s^{\kappa,l}$ close to one determines the tendency to remain in the price tier of the last period ("constancy") while $\alpha_s^{\kappa,l}$ close to zero indicates variation with respect to the prespecified price tiers independent of prior price settings for brand b ("change"). Additional specifications of competitive pricing strategies are possible by $\vec{\pi}^{\kappa,l}$, $l \in \{down,\ neglectable,\ up\}$. In the case

$$\alpha_s^{\kappa,l} \leq 1 - \epsilon''_{\kappa,l} \quad \forall l,$$

a stochastic ordering according to $\vec{\pi}^{\kappa,down} \overset{st}{<} \vec{\pi}^{\kappa,neglectable} \overset{st}{<} \vec{\pi}^{\kappa,up}$ would indicate switches within the price tiers of brand κ which are in accordance with the price movements of brand b: the tendency to increase prices (i.e. to move from "*down*" to "*neglectable*" to "*up*") for brand b is accompanied by a "similar behaviour" of brand κ given by the probability distributions $\vec{\pi}^{\kappa,down}$, $\vec{\pi}^{\kappa,neglectable}$, and $\vec{\pi}^{\kappa,up}$ which put more probability mass on higher price tiers. This tendency of brand κ may be named as "imitation" within the "constancy/change" situation. The opposite behaviour could be labeled as "contra-reaction". Of course, there is a broad variety of possibilities to include additional stochastic relations with respect to $\vec{\pi}^{\kappa,down}$, $\vec{\pi}^{\kappa,neglectable}$, and $\vec{\pi}^{\kappa,up}$ into the classification scheme of Table 2.

4 Empirical Example

We illustrate our approach based on data of four brands, i.e., $K' = K \cup \{b\} = \{I, II, III,$ and $IV\}$, from the area of frequently purchased consumer packaged goods.

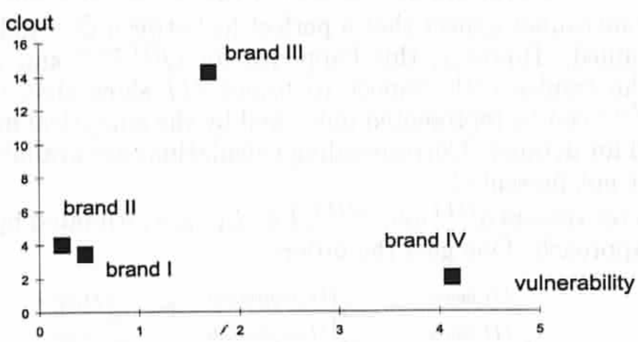

Figure 1: Competitive positioning of brands I, II, III, and IV.

The brands account on average for approximately 61% market share during the observation period of 101 weeks, i.e., $T = \{1, \ldots, 101\}$. Only market shares $ms_i(t)$ and corresponding brand prices $p_i(t)$ were available on a weekly basis, $i \in K'$, $t \in T$. In the observation period different types of pricing behaviour (leader/follower situations, cooperative/non-cooperative price settings) occured.

The competitive structure of the market can be illustrated using the clout and vulnerability values of the different brands as shown in Figure 1 where clout $c_i := \sum_{j\in K'\setminus\{i\}} \epsilon_{ji}^2$ and vulnerability $v_i := \sum_{j\in K'\setminus\{i\}} \epsilon_{ij}^2$ of brand i can be computed from the average cross price elasticities $\epsilon_{ij} := \frac{1}{101}\sum_{t=1}^{101}\epsilon_{ij}(t)$ with cross price elasticities $\epsilon_{ij}(t) = \frac{\partial ms_i(t)}{\partial p_j(t)}\frac{p_j(t)}{ms_i(t)}$ calculated on a weekly basis.
Brand IV has an interesting positioning: the *clout* of brand IV is very low and indicates only marginal opportunities to affect competitive market shares by own price settings. On the other side, the *vulnerability* of brand IV is relatively high which underlines that the market share of this brand may be influenced by competitive pricing decisions in a serious manner. Therefore, the following presentation of our classification approach will be illustrated with focus on brand IV, i.e., $b = \text{IV}$ and $K = \{I, II, III\}$.
Due to space limitations for this paper the application of the constancy/change model is discussed only for brand $\kappa = III$ which, too, has an interesting positioning in the competitive environment.

5 Results and Classification of Pricing Strategies

Although the above formulated approach allows for arbitrary non-negative Φ^+, Φ^-, in this paper -for convenience- we have chosen $\Phi^+ = \Phi^- = 0$. After having calculated the sets $\mathcal{M}_{\Phi^-}^{down}$, $\mathcal{M}_{\Phi^-,\Phi^+}^{neglectable}$ and $\mathcal{M}_{\Phi^+}^{up}$ in the first step, the transition probability matrices $Q^{III,l}$, $l \in S_{IV}$, and the corresponding matrices $R^{III,l}$, $l \in S_{IV}$, are determined in the second and third step.
Of course, one cannot expect that a perfect fit between $Q-$ and $R-$matrices can be obtained. However, this happened for $Q^{III,down}$ and $R^{III,down}$. In addition, the results with respect to brand III show that the empirical matrices $Q^{III,l}$ can be represented quite well by the analytical matrices $R^{III,l}$ (see Table 3 for details). Corresponding calculations are available for brands I and II but not presented.
The parameter vectors $\vec{\alpha}^{III,l}$ and $\vec{\pi}^{III,l}$, $l \in S_{IV}$, are estimated by a maximum likelihood approach. One gets the orders

$$\begin{array}{ccccc} \alpha_1^{III,down} & > & \alpha_1^{III,neglectable} & > & \alpha_1^{III,up}, \\ \alpha_2^{III,down} & > & \alpha_2^{III,neglectable} & > & \alpha_2^{III,up}, \\ & & \alpha_3^{III,neglectable} & > & \alpha_3^{III,up}, \end{array} \tag{8}$$

and the stochastic order

$$\vec{\pi}^{III,down} \overset{st}{>} \vec{\pi}^{III,neglectable} \overset{st}{>} \vec{\pi}^{III,up}. \tag{9}$$

According to the estimation results for $\vec{\alpha}^{III,l}$, $l \in S_{IV}$, given in Table 3, the pricing strategy of brand III as reaction to brand $b = IV$ belongs to the class of "*constancy/change*" (see Table 1).

$Q^{III,down}$	$Q^{III,neglectable}$	$Q^{III,up}$
$\begin{pmatrix} 1.000 & 0.000 & 0.000 \\ 0.000 & 0.889 & 0.111 \\ 0.000 & 0.056 & 0.944 \end{pmatrix}$	$\begin{pmatrix} 0.917 & 0.083 & 0.000 \\ 0.000 & 0.667 & 0.333 \\ 0.000 & 0.000 & 1.000 \end{pmatrix}$	$\begin{pmatrix} 0.909 & 0.091 & 0.000 \\ 0.091 & 0.818 & 0.091 \\ 0.000 & 0.080 & 0.920 \end{pmatrix}$
$R^{III,down}$	$R^{III,neglectable}$	$R^{III,up}$
$\begin{pmatrix} 1.000 & 0.000 & 0.000 \\ 0.000 & 0.889 & 0.111 \\ 0.000 & 0.056 & 0.944 \end{pmatrix}$	$\begin{pmatrix} 0.917 & 0.027 & 0.056 \\ 0.000 & 0.708 & 0.292 \\ 0.000 & 0.000 & 1.000 \end{pmatrix}$	$\begin{pmatrix} 0.909 & 0.082 & 0.008 \\ 0.076 & 0.841 & 0.083 \\ 0.007 & 0.073 & 0.920 \end{pmatrix}$
$\vec{\alpha}^{III,down}$	$\vec{\alpha}^{III,neglectable}$	$\vec{\alpha}^{III,up}$
$\begin{pmatrix} 1.000 \\ 0.876 \\ 0.460 \end{pmatrix}$	$\begin{pmatrix} 0.917 \\ 0.569 \\ 1.000 \end{pmatrix}$	$\begin{pmatrix} 0.902 \\ 0.000 \\ 0.913 \end{pmatrix}$
$\vec{\pi}^{III,down}$	$\vec{\pi}^{III,neglectable}$	$\vec{\pi}^{III,up}$
$\begin{pmatrix} 0.000 \\ 0.103 \\ 0.897 \end{pmatrix}$	$\begin{pmatrix} 0.000 \\ 0.322 \\ 0.678 \end{pmatrix}$	$\begin{pmatrix} 0.076 \\ 0.841 \\ 0.083 \end{pmatrix}$

Table 3: Results of the constancy/change model

Inequalities (8) indicate, that the "*constancy*" proportion of the competitive pricing strategy of brand III is decreasing when brand IV moves to "higher" price settings. The stochastic order of $\vec{\pi}^{III,l}$, $l \in S_{IV}$, as given in equation (9), allows for a more refined classification (see Table 2). Brand III obeys a pricing strategy of "contra-reaction" within the "constancy/change" class. This behaviour can be detected quite well from Figure 2 in which 26 weeks of the empirical price paths of brands III and IV from the middle of the observation period are depicted. Simple linear regression results proved to be not very useful: either the goodness of fit was dissatisfying or the estimated parameters were not statistically significant, although the regression results indicated a tendency for an interpretation which the classification approach of this paper has very clearly detected.

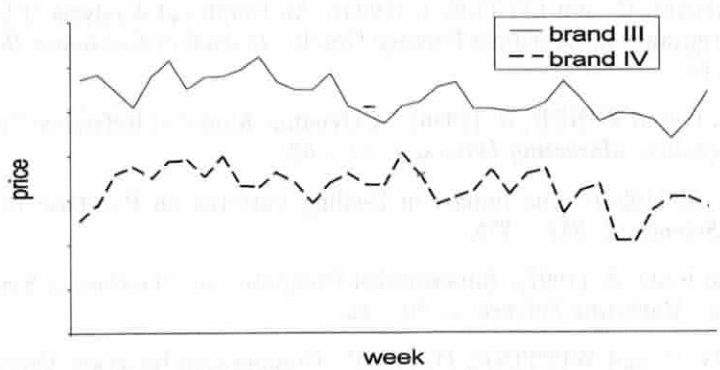

Figure 2: Price paths of brands III and IV (weeks 42 to 67).

6 Conclusion and Outlook

The presented contribution suggests a framework for analyzing and modelling competitive pricing behaviour. The incorporation of pricing interactions via an *a priori* classification of the price settings of the brand under consideration and the price tiers of the competing brands is of key interest. The decomposition of the pricing information within the presented constancy/change model allows for additional insights into the general pricing behaviour of competitors and enables a classification of different types of competitive pricing strategies.

The approach allows an anticipation of competitive pricing reactions within a well-based statistical framework. Extensive Monte Carlo-simulations for different planning horizons resulted in additional profit gains in the long run when taking into account competitive pricing reactions in the explained manner.

Of course, there are questions left for further research, e. g., the incorporation of multi product aspects or the consideration of product categories.

References

ARMSTRONG, J. and COLLOPY, F. (1996): Competitor Orientation: Effects of Objectives and Information on Managerial Decisions and Profitability. *Journal of Marketing Research, 5, 188 - 199.*

DOLAN, R. (1981): Models of Competition: A Review of Theory and Empirical Evidence. *Review of Marketing, 3, 224 - 234.*

GIJSBRECHTS, E. (1993): Prices and Pricing Research in Consumer Marketing. *International Journal of Research in Marketing, 10, 115 - 151.*

HANSSENS, D., PARSONS, L. and SCHULTZ, R. (1990): Market Response Models: Econometric and Time Series Analysis, in: Eliashberg, J. (Ed.), International Series in Quantitative Marketing. Kluwer Academic Publishers, Boston.

KALYANARAM, G. and LITTLE, J. (1994): An Empirical Analysis of Latitude of Price Acceptance in Consumer Package Goods. *Journal of Consumer Research, 21, 408 - 418.*

KOPALLE, P. and WINER, R. (1996): A Dynamic Model of Reference Price and Expected Quality. *Marketing Letters, 1, 41 - 52.*

KRISHNA, A. (1994): The Impact of Dealing Patterns on Purchase Behavior. *Marketing Science, 4, 351 - 373.*

LAL, R. and RAO, R. (1997): Supermarket Competition: The Case of Every Day Low Pricing. *Marketing Science, 1, 60 - 80.*

LEEFLANG, P. and WITTINK, D. (1996): Competitive Reaction Versus Consumer Response: Do Managers Overreact? *International Journal of Research in Marketing, 13, 103 - 119.*

MULHERN, F. (1997): Retail Marketing: From Distribution to Integration. *International Journal of Research in Marketing, 14, 103 – 124.*

MULHERN, F. and LEONE, R. (1995): Measuring Market Response to Price Changes– A Classification Approach. *Journal of Business Research, 33, 197 – 205.*

MULHERN, F. and PADGETT, D. (1995): The Relationship Between Retail Price Promotions and Regular Price Purchase. *Journal of Marketing, 11, 83 – 90.*

NATTER, M. and HRUSCHKA, H. (1996): Profit Impacts of Aggressive and Cooperative Pricing Strategies, in: Jørgensen, S., G. Zaccour (Eds.), Dynamic Competitive Analysis in Marketing, Lecture Notes in Economics and Mathematical Systems 444, Springer, Heidelberg, 71 – 83.

RAO, V. (1993): Pricing Models in Marketing, in: Eliashberg, J., G. Lilien, MarketingManagement Sciences , Vol. 5, North Holland, Amsterdam.

SIVAKUMAR, K. (1995): Quality-Tier Competition and Optimal Pricing. *Journal of Business Research, 33, 251 – 260.*

UBANY, J., BEARDEN, W. and WEILBAKER, D. (1988): The Effect of Plausible and Exaggerated Reference Prices on Consumer Perceptions and Price Search. *Journal of Consumer Research, 15, 95 – 110.*