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REGULAR ARTICLE

A Stackelberg-Nash model for new product design

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Abstract Existing conjoint approaches to optimal new product design have focused on the Nash equilibrium concept to model competitive reactions. Whereas these approaches have treated *all* competing firms equally as Nash players, one firm may have an advantage over its rivals, e.g., more pre-experience on competitors' behavior and/or a first-mover advantage. This paper proposes a Stackelberg-Nash (leader-followers) model which can accomodate such information for decision making. The optimal product design problem is formulated from the perspective of a profit-maximizing new entrant (the leader) who wants to launch a brand onto an existing product market and acts with foresight by anticipating price-design reactions of the incumbent firms (the Nash followers). In the absence of closed-form solutions, we use a sequential iterative procedure to compute a Stackelberg-Nash equilibrium and to establish its uniqueness. The new conjoint model is illustrated under several competitive scenarios and price, design and profit implications are compared to a simple Nash equilibrium model. We find that a Stackelberg leader strategy may not only yield a much higher profit for the new entrant than a Nash strategy, but may also lead to strong profit asymmetries between competitors with still higher profits for the incumbent firms. In other words, the incumbent firms may also benefit strongly from a new entrant choosing a Stackelberg leader strategy.

Keywords Conjoint analysis · Optimal product design · Product competition · Game theory

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1 Introduction

Designing and pricing new products is one of the most important problem areas of a firm. In this field, conjoint analysis has turned out to be one of the most widely used techniques for measuring consumer preferences for product attributes (Green and Rao 1971; Johnson 1974). Based on a survey of US firms, Cattin and Wittink (1982) and Wittink and Cattin (1989) reported of about 1,000 commercial applications of conjoint analysis already in the 1970's and of about 400 applications yearly in the early 1980's. The increased commercial usage of conjoint analysis has also been documented for the European market by Wittink et al. (1994) and for the German market by Baier (1999). Reviews on theoretical advances of the conjoint methodology since its introduction into the marketing literature are provided by Green and Srinivasan (1978, 1990).

Substantial effort has further been devoted to the development of models and procedures for *optimally* designing new products using conjoint data (see, e.g., Albritton and McMullen 2007; Alexouda 2004; Alexouda and Paparrizos 2001; Balakrishnan and Jacob 1996; Camm et al. 2006; Chen and Hausman 2000; Dobson and Kalish 1988, 1993; Gaul et al. 1995; Green et al. 1981; Green and Krieger 1985, 1987, 1992; Kohli and Krishnamurti 1987; Kohli and Sukumar 1990; Nair et al. 1995; Steiner and Hruschka 2002, 2003; Zufryden 1977). Whereas most of these optimization approaches explicitly consider the current competitive scenario (i.e., competitors' existing products), retaliatory reactions of competitors which may occur after a new product has been introduced are neglected. As a consequence, product design decisions derived from these "traditional" approaches might be optimal only for the short term if incumbent firms are attacked in market shares or profits and therefore are likely to respond by redesigning (modifying) existing items or even by launching a new brand[1] for their part. To the best of our knowledge, only four conjoint models so far have accounted for this problem (Choi and DeSarbo 1993; Green and Krieger 1997; Gutsche 1995; Steiner and Hruschka 2000). In these approaches, the Nash equilibrium concept has been used to model competition treating *all* firms equally as Nash players.

In this paper, we propose a new conjoint-based approach to competitive new product design employing the Stackelberg-Nash leader-followers equilibrium concept (Sherali et al. 1983). Following Stackelberg (1934), each firm in a competitive market can be a leader or a follower. A follower is characterized as a firm which behaves according to a Nash (or Cournot) reaction function. Applied to the problem of optimal product design, a follower therefore tries to maximize its profit by setting price and design decisions under the assumption that brand offerings of its competitors remain unchanged. A leader, on the other hand, just works on the assumption that its rivals are followers, and incorporates this knowledge to find its profit-maximizing price-design strategy. For each feasible price-design strategy, a leader hence computes the expected outcome of the followers' reaction process, and chooses the one strategy which maximizes its profit after having taken into account those retaliatory responses. Depending on each competitor's behavior, different equilibrium concepts are available: (a) assuming that all competing firms are acting as followers leads to the well-known *Nash equilibrium*

[1] We use the terms 'brand' and 'product' interchangeably.

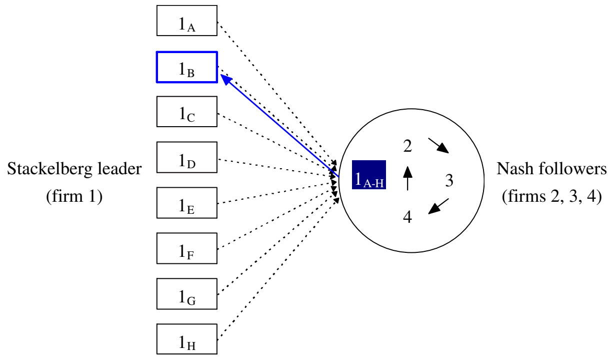

Fig. 1 An illustration of the Stackelberg-Nash equilibrium concept

concept which has been the dominating concept to model retaliatory reactions in previously proposed competitive product design models. (b) If, instead, one firm acts as a leader and its competitors as followers playing a Nash subgame among themselves, the resulting equilibrium is called a *Stackelberg-Nash equilibrium* (Sherali et al. 1983). This 'one leader-multiple followers' concept is exactly what we propose in this paper to consider retaliatory reactions for optimal new product design. Note that the so-called *Stackelberg* equilibrium (Friedman 1977), which applies to a duopoly with one leader and *one* follower, can be treated as a special case of the *Stackelberg-Nash equilibrium*. (c) The remaining concept, representing more than one firm in the role of a leader (usually referred to duopoly markets with two leaders, and known as Stackelberg disequilibrium (Aubin 1979)), has attracted only little attention in the economic literature and will not be considered in the following.

The opportunity to be a leader in a competitive scenario may emerge from asymmetries in the market structure, for example, if a firm has more resources to pre-commit, more information/pre-experience on the rivals' behavior and/or a first-mover advantage (see, e.g., Choi et al. (1990)). Being aware of such an advantage, it seems reasonable for a leader to take into account the likely responses of competing firms rather than to pursue a simple Nash strategy assuming that one's own decision has no impact on competitors. A leader can therefore act with foresight that followers will react afterwards according to their reaction functions. Since the followers have no way of influencing the leader's decision, the leader can do no better than incorporating the followers' inevitable behavior in its objective function (Friedman 1977). In the following, we assign the role of the leader to a new entrant who wants to enter an existing market and decides on price and design for a new brand to maximize its profit, while keeping to the assumption of profit-maximizing Nash behavior for the incumbent firms in response to the new entrant's brand launch (following existing approaches). This constitutes an asymmetric situation with a new entrant having a first-mover advantage and anticipating competitive reactions of the incumbent firms, whereas the incumbents do not expect the new brand launch or at least do not protect themselves against it (e.g., through an appropriate entry-deterrence strategy).

Figure 1 illustrates with a small example how the Stackelberg-Nash equilibrium approach works. Suppose that a new entrant (firm 1, the leader) faces the problem which one of eight feasible product profiles (A-H) to choose for its new brand. Being conscious of the reaction functions of the incumbent firms (the followers 2, 3 and 4), the new entrant is able to anticipate the outcome of the followers' reaction process (indicated by arrows) and to compute its own expected profit (as well as each follower's profit) at the resulting subgame Nash equilibrium. The profits are computed conditional upon each of the alternative brand concepts A-H, which are treated as an exogeneous factor (i.e., like an outside good) in the followers' subgame, respectively. Eventually, the new entrant chooses the one product profile with the highest expected profit representing the Stackelberg leader strategy. In this example, brand concept B may turn out as firm 1's best entry strategy (i.e., the Stackelberg leader strategy).

Two properties of the Stackelberg-Nash equilibrium concept are especially noteworthy in this introductory section: first, at a (subgame) Nash equilibrium, by definition, no one of the followers can increase its profit by changing its strategy unilaterally. Consequently, there is no incentive for any of the incumbent firms to deviate from its (subgame) Nash strategy regarding the other incumbent firms *and* the new entrant as committed to their "choices". But there is also no incentive for the new entrant to deviate from a Stackelberg leader strategy. Under the erroneous assumption that the incumbent firms would not change their current strategies, the new entrant could *perhaps* increase its profit by choosing another strategy (e.g., a different price level). However, in this case the new entrant would behave itself like a follower and would incur a profit collapse as soon as the incumbents do respond to its altered strategy. In fact, the leader knows that the followers would quickly adjust their strategies to the new situation in a predictable way, implying that any strategy different from the Stackelberg leader strategy leads to a less favorable profit position *after competitive reactions.* Playing a Stackelberg leader strategy does further not mean that the new entrant chooses an irreversible entry strategy (in the present context w.r.t. price and product design). Even if the new entrant has no more financial abilities to redesign its new product after the market entry (e.g., due to high costs to build up capacity), it could of course easily adjust the price of its brand at any time. However, all things being equal, this would cause retaliatory responses of the incumbent firms (which may also adjust their brand prices, for instance) leading to a lower profit for the new entrant than before.

The objective of this paper is twofold. First, we want to add to the body of knowledge with a new approach that is able to consider retaliatory reactions *and* to account for asymmetries between competitors. Existing approaches to optimal new product design based on conjoint data either have ignored price-design responses from competitors at all or cannot account for such asymmetries. Our approach therefore provides researchers in this field with a wider perspective of what is possible when competitors are "unequal" and offers another tool to predict competitive behavior. In the absence of closed-form solutions, we propose a numerical procedure (extending the procedure used by Steiner and Hruschka (2000)) to compute a Stackelberg-Nash equilibrium and to establish its uniqueness. Second, we compare the performance of the new approach under varying market conditions to a simple Nash equilibrium framework, i.e., to a situation where the new entrant not only considers competitive reactions but also behaves like a follower instead of a leader.

The paper is organized as follows: Sect. 2 first reviews the critical problem of how to derive competitive strategies in conjoint analysis. We then briefly discuss the main characteristics the previously proposed Nash equilibrium models have in common to provide the starting point for our own model formulation. Section 3 presents the new Stackelberg-Nash equilibrium model and describes the computational procedure for determining the Stackelberg leader strategy. In Sect. 4, we assess the performance of our new approach by picking up a series of market scenarios that were analyzed by Steiner and Hruschka (2000) for simple Nash equilibria. Under each scenario, we compare Stackelberg and Nash solutions with respect to implications on firms' profits as well as to the degree of differentiation between the new entrant's brand and the incumbents' brands. In Sect. 5, we propose some refinements of our model. Section 6 summarizes the most important contents of the paper, provides managerial implications and draws an outlook onto future research perspectives.

2 Deriving competitive strategies in conjoint analysis

As outlined in Sect. 1, only few conjoint models thus far have accounted for competitive reactions. Obviously, one of the main reasons for this deficiency is that competitive strategies cannot be derived analytically in conjoint models, as attributes used in conjoint studies are typically discrete. If, hence, an attacking firm wants to be provided with information on the consequences of its market attack after retaliatory reactions, one has to incorporate competitors' reaction functions into the conjoint simulator and to simulate competitors' moves explicitly.

Deriving a Nash equilibrium therefore requires to repeatedly find each competitor's best response to the latest price-design movements in the marketplace. Unfortunately, there is no possibility to prove theoretically that such an iterative adjustment process, also known as tatonnement process, always finds an existing Nash equilibrium (see Choi and DeSarbo 1993). However, results from a large-scale experimental study conducted by Steiner and Hruschka (2000) provide evidence that a *sequential* tatonnement do indeed always converge in discrete attribute spaces to a Nash equilibrium. In a sequential tatonnement, firms are assumed to move in turn according to a predetermined order. It is also well known that a simultaneous tatonnement which assumes that competitors decide simultaneously on their next "period's" strategies may cycle without ever finding an existing Nash equilibrium (see, e.g., Marks and Albers 2001). For this reason, we later focus on the sequential tatonnement procedure to compute a Stackelberg-Nash equilibrium. The tatonnement procedure to compute Nash equilibria has been introduced into the marketing literature by Choi et al. (1990, 1992) in a MDS-based context, and has first been used by Choi and DeSarbo (1993) to derive competitive product design strategies in conjoint analysis (i.e., in discrete attribute spaces).

While the existence of a Nash equilibrium is verified with tatonnement convergence, there is no guarantee that a numerically identified equilibrium is unique (see, e.g., Marks and Albers 2001). Depending on the starting configuration of the competitive marketing mix (i.e., initial brand designs, initial brand prices of competitors), a tatonnement sequence at best finds one equilibrium even if multiple equilibria exist.

Establishing the uniqueness of a Nash equilibrium or rather detecting all existing Nash equilibria with certainty in the absence of closed form solutions is therefore a much harder task and requires the application of the numerical equilibrium procedure to each possible starting configuration. To the best of our knowledge, only Steiner (1999) and Steiner and Hruschka (2000) have tackled this problem. We apply and extend their computational procedure, which contains a complete enumeration of tatonnement processes for all starting configurations, to identify multiple equilibria for the Nash followers in our Stackelberg-Nash model.

As a starting point for our model formulation, it is further important to know that the four competitive conjoint models yet proposed (Choi and DeSarbo 1993; Green and Krieger 1997; Gutsche 1995; Steiner and Hruschka 2000) are very similar in their core elements (besides the fact that they all represent Nash equilibrium models): first, it has been assumed that each competing firm decides simultaneously on price *and* design (i.e., the non-price attribute levels) for its brand(s) which is referred to as a simultaneous product-price game (see, e.g., Choi et al. 1992). Second, a consumer's utility of buying a brand has been represented by the linear-additive part-worth model which is the most widely used preference model in conjoint studies. Third, a probabilistic choice rule, either the (powered) Bradley-Terry-Luce share-of-utility rule or the logit choice rule, has been employed to model consumers' choices. Both probabilistic choice rules are known to be highly flexible in providing a realistic representation of consumer behavior (see, e.g., Albers and Brockhoff 1979; Gaul et al. 1995; Kaul and Rao 1995). The use of a probabilistic choice rule also agrees with the nonexistence results of a simultaneous product-price equilibrium under a deterministic, first choice rule (see, e.g., Choi et al. 1990; de Palma et al. 1985; Gabszewicz and Thisse 1986; Marks 1994). And fourth, the models have been formulated and illustrated as to consider profit contribution as the competitors' underlying objective for product design.

3 A Stackelberg-Nash model for new product design

To stay as close as possible in the research tradition on competitive product design, we adopt the well-established concept of a simultaneous product-price game, the use of the linear-additive part-worth utility model and of a probabilistic choice rule as well as the assumption of profit-maximizing firms for our model. Specifically, we follow Choi and DeSarbo (1993) and Steiner and Hruschka (2000) in formulating a firm's product design problem: like Choi and DeSarbo (1993), we assume single-brand competitors and use the logit rule to model consumers' choices; like Steiner and Hruschka (2000), who extended Choi and DeSarbo's work in several directions, we model consumer behavior at the segment-level. Prefering this segment level approach provides us with the opportunity to compare the final outcomes of a Stackelberg-Nash competitive scenario one-to-one with the Nash equilibrium results obtained by Steiner and Hruschka by replicating their study design. To the best of our knowledge, only this study has so far provided insights into competitive new product design that generalizes beyond the individual case.

Segment utility function. According to the linear-additive part-worth model, the utility of a consumer in segment i buying the brand of competitor j is given by the sum of part-worth utilities the consumer attaches to the individual attribute levels of this brand. Formally, with K attributes (including price) and L_k levels of attribute k, this compensatory conjoint utility function can be represented in the following way:

$$V_{ij} = \sum_{k=1}^{K} \sum_{l=1}^{L_k} \lambda_{ikl} x_{jkl} + \varepsilon_{ij}, \tag{1}$$

where

$i = 1, \ldots, I$ segments; $j = 1, \ldots, J$ competitors (or equivalently, brands);
$k = 1, \ldots, K$ attributes (with price as attribute K); $l = 1, \ldots, L_k$ levels of attribute k;
V_{ij}: segment i's utility for competitor j's brand;
λ_{ikl}: segment i's part-worth utility for level l of attribute k;
x_{jkl}: a (0,1) variable that equals 1 if brand j has attribute k at level l, and 0 otherwise;
ε_{ij}: a stochastic error term.

Product design problem. With the assumption of profit-maximizing firms, the optimal product design problem for competitor j can be stated as follows:

$$\max_{\vec{x}_j \in \vec{X}_j} \quad \Pi_j = \left(\mathrm{PR}_j - \mathrm{VC}_j\left(\vec{x}_j\right)\right) \cdot \sum_{i=1}^{I} \left(\mathrm{S}_i \cdot \mathrm{PROB}_{ij}\right), \tag{2}$$

subject to

$$\mathrm{PROB}_{ij} = \frac{\exp\left(\mu \cdot \hat{V}_{ij}\right)}{\sum_{m=1}^{J} \exp\left(\mu \cdot \hat{V}_{im}\right)}, \quad \mathrm{i} = 1, \ldots, I, \tag{3}$$

$$\sum_{l=1}^{L_k} x_{jkl} = 1, \quad k = 1, \ldots, K, \tag{4}$$

$$x_{jkl} = 0 \text{ or } 1, \quad k = 1, \ldots, K \text{ and } l = 1, \ldots, L_k, \tag{5}$$

where

$\vec{x}_j$: a (0,1) design-price vector for brand j in the feasible vector space $\vec{X}_j$ with elements x_{jkl};
PR_j: price of competitor j's brand;
$\mathrm{VC}_j(\vec{x}_j)$: competitor j's variable unit cost of producing brand profile $\vec{x}_j$;
S_i: size of segment i (segment sales volume);
PROB_{ij}: probability that a consumer in segment i chooses competitor j's brand;
μ: scaling parameter of the logit model ($\mu > 0$).

The composite utilities $\hat{V}_{ij}$ for any brand profile $\vec{x}_j$ constructable from the feasible attribute levels can be predicted after the part-worth utilities have been estimated from the underlying conjoint utility function (1). The parameter μ is absorbed by the other parameters of V_{ij} if maximum likelihood estimation is used, or otherwise may be calibrated explicitly in a second step using a predetermined conjoint utility function (see, e.g., Choi et al. 1990).

Objective function (2) maximizes the profit Π_j competitor j obtains from offering its brand. The profit is maximized with respect to brand price and brand design and is defined by unit contribution times the sum of units sold across segments. The probability PROB_{ij} that a consumer in segment i buys brand j is a function of all the competing firms' current brand prices and brand designs which are reflected by the respective conjoint utilities $\hat{V}_{im}$. Without loss of generality, any other probabilistic choice model than the logit choice rule (3) may be employed, as will be demonstrated in Sect. 5. Constraint (4) ensures that exactly one level of each attribute is assigned to brand j. The price PR_j assigned to brand j corresponds to price element x_{jKl} which is currently set on (= 1) in $\vec{x}_j$. Constraint (5) represents the binary restrictions with regard to the decision variables (attribute levels) of the optimization problem.

Following (Green and Krieger 1992, 1993, 1997), Dobson and Kalish (1993), Gaul et al. (1995) and again Choi and DeSarbo (1993) and Steiner and Hruschka (2000), firm j's unit cost function is assumed to be a linear-additive model of individual attribute level costs vc_{jkl}:

$$\text{VC}_j\left(\vec{x}_j\right) = \sum_{k=1}^{K} \sum_{l=1}^{L_k} vc_{jkl} x_{jkl} \tag{6}$$

Individual attribute level costs are usually available from the cost accounting system of a firm or otherwise can be estimated along with the preceding conjoint study (see Gaul et al. 1995). Assessing the costs of competitors for product profiles is a much harder task. However, Choi and DeSarbo (1994) have demonstrated that optimal product profiles are by far less sensitive to absolute cost levels than to the relative magnitude across cost levels, thus relieving the difficult task of accurate cost measurement to estimating at least relative cost levels of competitors. Finally, following the models of Choi and DeSarbo (1993), Green and Krieger (1997) and Steiner and Hruschka (2000), and particularly in order to compare our study results with those obtained by Steiner and Hruschka (2000), we assume the fixed cost of a brand j not to depend on its profile $\vec{x}_j$.

Stackelberg-Nash equilibrium model. We state our Stackelberg-Nash model from the point of view of a new entrant (denoted by firm 1) who wants to introduce a new brand onto an existing competitive market. To stay consistent with the assumption of rational behaving firms, we assume that the incumbent firms (firms 2 to J) have reached a Nash equilibrium before the new entrant attacks. The incumbent firms are now assumed to *react* as followers (as before the market entry) to the new entrant's brand launch by changing price and/or non-price attribute levels in a way that they move to a new Nash equilibrium (the followers' subgame equilibrium). The new entrant, on the other hand, *acts* as a leader with more foresight and decides on price and design for its new brand anticipating the incumbents' competitive responses. Stated more formally, the new entrant tries to maximize its profit with respect to its new brand's price and design subject to the reaction functions of the incumbent firms[2]:

$$\max_{\vec{x}_1 \in \vec{X}_1} \quad \Pi_1 = (\mathrm{PR}_1 - \mathrm{VC}_1(\vec{x}_1)) \cdot \sum_{i=1}^{I} (S_i \cdot \mathrm{PROB}_{i1}) \tag{7}$$

subject to

$$\vec{x}_j = \arg\max_{\vec{x}_j} \ \Pi_j = \left(\mathrm{PR}_j - \mathrm{VC}_j(\vec{x}_j)\right) \cdot \sum_{i=1}^{I} \left(Q_i \cdot \mathrm{PROB}_{ij}\right), \quad j = 2, \ldots, J. \tag{8}$$

$\vec{x}_j$ $(j = 2, \ldots, J)$ in Eq. (8) represents the solution to incumbent j's profit maximization problem (2)–(5) resulting from the Nash subgame the incumbents (the followers) play conditional upon the leader's current strategy.

Computing the subgame Nash equilibrium requires the simultaneous solution of model (2)–(5) for all incumbent firms. Since we do not have closed-form solutions, we take the numerical approach to compute Nash equilibria and employ the sequential tatonnement procedure (compare Sect. 2). In order to establish the existence of multiple Nash equilibria in the followers' subgame, we adopt the computational procedure used by Steiner and Hruschka (2000). Accordingly, we enumerate all possible starting configurations for the incumbents and apply one tatonnement to each.[3] Finally, to identify the profit-maximizing (Stackelberg) leader strategy and, thereby, the Stackelberg-Nash equilibrium, we have to solve the Nash followers' subgame with respect to each feasible product profile the new entrant can choose. In general, if the new entrant does not face any technological constraints for new product design, the number (N) of feasible product profiles and therefore the number of subgames to solve depends on the number of attributes (K) and attribute levels (L_k):

$$N = \prod_{k=1}^{K} L_k \tag{9}$$

The problem of how to proceed if multiple Nash equilibria exist in at least one of the Nash followers' subgames is discussed in Sects. 4.1 and 4.3. We will see that the solution to this problem is unequivocal under all market scenarios analyzed and that a unique Stackelberg-Nash solution exists even in the case of multiple Nash equilibria in the followers' subgame. It is also important to note that the Stackelberg-Nash equilibrium model reduces to a Stackelberg equilibrium model in the case of only one single incumbent firm (compare Sect. 1). The solution to this latter model is much easier, as only the best response of the single incumbent to any of the leader's strategies needs to be computed and no numerical equilibrium procedure is required.

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[2] We assume that the new entrant's brand launch does not have a primary demand effect which is a realistic premise for many markets. Consequently, we hold segment volumes constant before and after the market entry. In Sect. 5, however, we also investigate the impact of an outside good on equilibrium results.

[3] For more details on this computational procedure, see Steiner and Hruschka (2000).

We illustrate the simpler Stackelberg equilibrium model relevant for duopolies (one new entrant, one incumbent firm) in Sect. 4.2, and then proceed in Sect. 4.3 with applications of our model to triopoly scenarios.

4 An illustration

4.1 Data and previous findings on Nash equilibria in conjoint attribute spaces

In this section, we illustrate the proposed new model using a conjoint data set published by Steiner and Hruschka (2000). The data refer to the product category 'sneakers' and consist of

- part-worth utilities for up to four segments and two attributes (1. *Price* with feasible levels 90, 110, 130, 150 and 170 in DM; 2. *Cushioning System* with feasible levels STA=Base System, AIR=Air-cushioning, HEX=Hexalite-cushioning, GEL=Gel-cushioning and SEL=Self-adjustment),
- individual attribute level costs for the non-price attribute *Cushioning System,* assumed to be identical across competitors.

The data are represented in Table 1. For comparison of results, we keep prices and costs in DM monetary units. Figure 2 shows clearly the differences in consumer preferences across the four segments (A, B, C and D) which are reflected by the corresponding part-worth utilities.

As for most product categories, consumers are price-sensitive which is expressed by higher part-worth utilities for lower price levels. Consumers of segment B are least sensitive to price changes, while consumers of segment A show a comparably high price sensitivity yet for low and medium price levels. The price sensitivity of segment D consumers is intermediate and consistently lower (higher) than for consumers of segment A (segment B). Consumers of segment C are less price-sensitive for levels up to 130 DM but highly price-sensitive for price levels beyond 130 DM. Concerning the cushioning system, different segments prefer different levels: consumers of segment A

Table 1 Segment-level part-worth utilities and individual attribute level costs

Attributes	Price (in DM)					Cushioning System				
Levels	90	110	130	150	170	STA	AIR	HEX	GEL	SEL
	Segment-Level Preferences (Part-Worths)									
Segment A	0.000	-1.186	-1.927	-2.611	-3.119	1.082	0.896	0.634	0.377	0.000
Segment B	0.000	-0.237	-0.441	-0.675	-0.878	0.000	0.495	0.792	1.045	1.760
Segment C	0.000	-0.316	-0.643	-2.651	-3.319	0.000	0.893	1.344	0.779	0.137
Segment D*	0.000	-0.450	-0.958	-1.786	-2.536	0.000	1.474	1.582	1.636	0.977
	Individual Attribute Level Costs									
	--	--	--	--	--	52	86	89	92	114

* The preference data with respect to segment D are only reported in Steiner (1999)

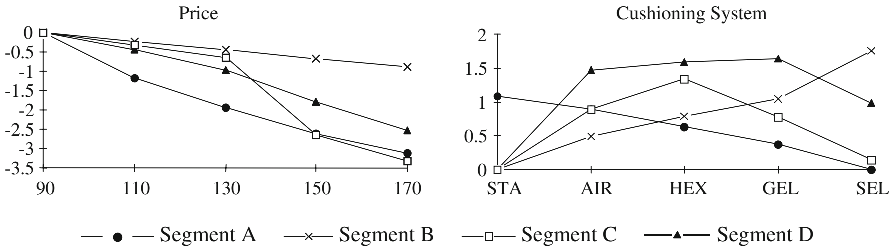

Fig. 2 Representation of segment-level part-worth utilities

prefer the level STA the most, whereas consumers of segments B, C and D show the highest preference for the levels SEL, HEX and GEL, respectively. In addition, the entire part-worth preference structures within segments are very different from each other. Overall, we observe a high degree of heterogeneity in consumer's price and quality preferences across the four segments.

Using these data, we focus in the following on duopoly markets (1 new entrant, 1 incumbent firm) and triopoly markets (1 new entrant, 2 incumbent firms). We follow Steiner and Hruschka (2000) with respect to the selection of product market scenarios for our study. They considered markets with homogeneous consumer preferences (by treating each of the segments separately as own market) and with heterogeneous consumer preferences (represented by markets composed of each two of the segments, for example by segment combinations AB or CD, assuming equal segment sizes). Replicating these market scenarios enables us to benchmark the Stackelberg leader strategies resulting from our model against the Nash solutions obtained by Steiner and Hruschka (2000) under corresponding market conditions and at the same time to study the results from our model under varying market conditions.

Two results Steiner and Hruschka (2000) have revealed from their study on Nash competition in conjoint attribute spaces are particular important. First, although in duopoly and triopoly markets multiple Nash equilibria may coexist, always exactly one *efficient* Nash equilibrium exists. A Nash equilibrium is characterized to be an efficient one, if no one of the competing firms could increase its profit at any other coexisting Nash equilibrium. Therefore, even if multiple Nash equilibria exist, a unique prediction on the competitive behavior of firms can be made, and the efficient Nash equilibrium can be treated as it were unique. Second, Steiner and Hruschka have found the efficient Nash equilibrium in duopoly and triopoly markets always to represent a minimally differentiated brand configuration. Thus, competitors offer homogeneous brands and share markets/segments and profits at equilibrium. This holds independent whether all competitors are incumbent firms or one of the firms is a new entrant. We will see in Sect. 4.3 that the property of *exactly one efficient Nash equilibrium in the case of multiple equilibria* also holds without exception for the followers' subgame of two incumbent firms in our Stackelberg-Nash equilibrium framework. Consequently, we can give a unique prediction on the final outcome of the competitive reaction process between two incumbents under any of a new entrant's feasible price-design strategies, which in turn represents a sufficient condition for the uniqueness of a Stackelberg-Nash equilibrium.

Tables 3 and 5 (left part, respectively) summarize the efficient Nash equilibrium solutions[4] found by Steiner and Hruschka (2000) under the duopoly and triopoly scenarios we replicate for our study. Particularly, the minimally differentiated equilibrium brands as well as the corresponding equilibrium profits for the competing firms under these scenarios are reported. For example, assuming a triopoly situation under market scenario AD, the new entrant (firm 1) as well as both incumbents (firms 2 and 3) would offer the same brand profile 90 STA at the Nash equilibrium. Hence, the three firms would share segments one third each (i.e., 33% market share in segments A and D, respectively) and profits (2.533×10^5 DM, respectively) at equilibrium (compare Table 5).[5] We will discuss these tables in more detail in Sects. 4.2 and 4.3 when we compare Nash and Stackelberg solutions.

4.2 Stackelberg versus Nash equilibrium solutions on duopoly markets

In this subsection, we present and discuss the results from the application of our model on duopoly markets. In the duopoly case, as mentioned in Sect. 3, the Stackelberg-Nash equilibrium model reduces to the Stackelberg equilibrium model which is much easier to solve for two reasons: first, the followers' subgame simplifies to determining just a single best response for the one incumbent firm rather than playing a Nash subgame with multiple incumbents. Second, the best response of the one incumbent conditional upon a leader's strategy is always unique (except in the very unlikely case that two or more alternative retaliatory strategies of the incumbent would be profit-maximizing). We illustrate the computation of the Stackelberg equilibrium under one selected market scenario (scenario AD) in detail and then summarize the results and the most important findings across all other duopoly scenarios.

With two attributes at five levels each, as given in our data set, each competitor can choose one out of 25 feasible brand profiles for its brand. Table 2 shows the whole game matrix for a new entrant and one incumbent firm leading to $25 \times 25 = 625$ different leader-follower configurations. For each of these brand configurations, we have computed the respective profits the two firms would earn under market scenario AD, where the upper number in each cell corresponds to the profit of the new entrant and the lower number to the profit of the incumbent firm. Profits are given in DM $\times 10^5$ monetary units and have been calculated assuming segment sales volumes of 10,000 (following Steiner and Hruschka 2000). For example, if the new entrant launches brand profile 150 AIR and the incumbent currently offers and carries on to offer 170 STA (the monopolistically profit-maximizing brand design), the associated profits for the new entrant and the incumbent firm would be 9.486×10^5 and 6.110×10^5 DM.

The decision process of the entrant firm acting as a leader can now be described as follows: in a first step, it computes for each of the 25 candidate profiles it can choose for its brand (90 STA, 110 STA, . . ., 170 SEL) the best response of the incumbent firm. For

[4] In the following, we will call an efficient Nash equilibrium the profit-maximizing Nash equilibrium.

[5] For market scenario A, it is clear in advance that firms will offer the cushioning system STA, as it offers the highest utility to consumers *and* can be realized at the lowest cost. Of course, this must hold at a Stackelberg-Nash equilibrium, too.

Table 2 Game matrix for a new entrant and one incumbent firm under duopoly scenario AD

New entrant / leader strategies	Incumbent firm / follower strategies																								
	90 STA	*110 STA*	*130 STA*	*150 STA*	*170 STA*	*90 AIR*	*110 AIR*	*130 AIR*	*150 AIR*	*170 AIR*	*90 HEX*	*110 HEX*	*130 HEX*	*150 HEX*	*170 HEX*	*90 GEL*	*110 GEL*	*130 GEL*	*150 GEL*	*170 GEL*	*90 SEL*	*110 SEL*	*130 SEL*	*150 SEL*	*170 SEL*
90 STA	3.800 **3.800**	5.231 3.615	6.063 3.154	6.794 2.078	7.160 1.365	2.784 0.507	4.035 2.251	4.811 3.230	5.776 3.073	6.489 2.456	2.967 0.122	4.106 1.931	4.802 3.019	5.723 3.013	6.439 2.475	3.163 -0.23	4.191 1.615	4.825 2.776	5.709 2.886	6.420 2.421	3.877 -2.35	4.854 -0.29	5.503 0.883	6.337 1.197	6.884 1.056
110 STA	3.615 5.231	5.800 **5.800**	7.549 5.448	9.268 3.940	10.23 2.795	2.299 0.642	4.250 3.042	5.754 4.435	7.535 4.486	8.939 3.855	2.548 0.156	4.528 2.561	5.923 4.013	7.573 4.236	8.925 3.736	2.856 -0.30	4.827 2.102	6.113 3.595	7.652 3.948	8.955 3.558	3.872 -3.20	5.918 -0.39	7.226 1.207	8.778 1.752	9.890 1.651
130 STA	3.154 6.063	5.448 7.549	7.800 **7.800**	10.61 6.267	12.45 4.767	1.794 0.708	3.789 3.634	5.715 5.576	8.179 6.089	10.33 5.673	2.018 0.174	4.191 3.072	6.089 4.999	8.394 5.635	10.43 5.374	2.318 -0.34	4.648 2.527	6.492 4.437	8.648 5.169	10.57 5.031	3.328 -3.78	5.999 -0.49	7.959 1.567	10.27 2.460	12.11 2.506
150 STA	2.078 6.794	3.940 9.268	6.267 **10.61**	9.800 9.800	12.78 8.219	1.159 0.753	2.758 4.125	4.596 6.737	7.181 8.111	9.735 8.456	1.337 0.186	3.183 3.518	5.132 6.053	7.651 7.438	10.05 7.893	1.578 -0.37	3.686 2.923	5.720 5.382	8.157 6.773	10.42 7.310	2.328 -4.23	4.950 -0.60	7.247 2.017	10.00 3.527	12.49 4.065
170 STA	1.365 7.160	2.795 10.23	4.767 12.45	8.219 **12.78**	11.80 11.80	0.807 0.773	2.078 4.377	3.692 7.423	6.110 9.486	8.646 10.65	0.953 0.192	2.473 3.760	4.281 6.712	6.767 8.702	9.212 9.877	1.148 -0.38	2.952 3.150	4.947 6.007	7.473 7.927	9.821 9.108	1.703 -4.45	4.058 -0.66	6.427 2.329	9.330 4.354	12.04 5.486
90 AIR	0.507 **2.784**	0.642 2.299	0.708 1.794	0.753 1.159	0.773 0.807	0.400 0.400	0.551 1.496	0.638 1.779	0.715 1.357	0.754 0.972	0.415 0.096	0.558 1.272	0.640 1.641	0.716 1.286	0.754 0.923	0.435 -0.18	0.567 1.048	0.644 1.484	0.717 1.198	0.756 0.864	0.533 -1.60	0.644 -0.16	0.702 0.393	0.751 0.438	0.775 0.357
110 AIR	2.251 4.035	3.042 **4.250**	3.634 3.789	4.125 2.758	4.377 2.078	1.496 0.551	2.400 2.400	3.124 3.073	3.835 2.573	4.232 1.990	1.556 0.135	2.492 2.020	3.193 2.746	3.882 2.335	4.268 1.796	1.658 -0.26	2.608 1.644	3.275 2.414	3.933 2.096	4.304 1.612	2.255 -2.55	3.197 -0.27	3.766 0.689	4.255 0.818	4.498 0.706
130 AIR	3.230 4.811	4.435 **5.754**	5.576 5.715	6.737 4.596	7.423 3.692	1.779 0.638	3.073 3.124	4.400 4.400	5.987 4.092	7.023 3.393	1.827 0.159	3.226 2.660	4.568 3.944	6.129 3.703	7.144 3.048	1.947 -0.31	3.446 2.190	4.781 3.471	6.291 3.308	7.267 2.717	2.858 -3.24	4.558 -0.39	5.860 1.069	7.125 1.371	7.824 1.242
150 AIR	3.073 5.776	4.486 7.535	6.089 **8.179**	8.111 7.181	9.486 6.110	1.357 0.715	2.573 3.835	4.092 5.987	6.400 6.400	8.343 5.851	1.395 0.178	2.746 3.299	4.338 5.421	6.644 5.867	8.568 5.356	1.502 -0.35	3.012 2.753	4.670 4.827	6.954 5.298	8.827 4.842	2.359 -3.92	4.304 -0.53	6.213 1.647	8.524 2.405	10.11 2.354
170 AIR	2.456 6.489	3.855 8.939	5.673 **10.33**	8.456 9.735	10.65 8.646	0.972 0.754	1.990 4.232	3.393 7.023	5.851 8.343	8.400 8.400	1.014 0.188	2.172 3.657	3.690 6.399	6.187 7.707	8.721 7.791	1.111 -0.37	2.446 3.076	4.092 5.749	6.631 7.022	9.127 7.125	1.788 -4.29	3.623 -0.63	5.711 2.112	8.676 3.482	11.19 3.741
90 HEX	0.122 **2.967**	0.156 2.548	0.174 2.018	0.186 1.337	0.192 0.953	0.096 0.415	0.135 1.556	0.159 1.827	0.178 1.395	0.188 1.014	0.100 0.100	0.138 1.309	0.160 1.658	0.179 1.293	0.188 0.937	0.105 -0.19	0.141 1.068	0.161 1.480	0.180 1.184	0.189 0.859	0.130 -1.68	0.160 -0.16	0.176 0.392	0.188 0.437	0.194 0.360
110 HEX	1.931 4.106	2.561 **4.528**	3.072 4.191	3.518 3.183	3.760 2.473	1.272 0.558	2.020 2.492	2.660 3.226	3.299 2.746	3.657 2.172	1.309 0.138	2.100 2.100	2.733 2.864	3.356 2.453	3.703 1.919	1.385 -0.27	2.206 1.709	2.819 2.499	3.415 2.170	3.745 1.689	1.899 -2.63	2.730 -0.28	3.257 0.719	3.699 0.859	3.917 0.755
130 HEX	3.019 4.802	4.013 5.923	4.999 **6.089**	6.053 5.132	6.712 4.281	1.641 0.640	2.746 3.193	3.944 4.568	5.421 4.338	6.399 3.690	1.658 0.160	2.864 2.733	4.100 4.100	5.578 3.901	6.544 3.272	1.743 -0.32	3.052 2.260	4.307 3.609	5.755 3.459	6.687 2.878	2.575 -3.30	4.090 -0.40	5.331 1.120	6.544 1.454	7.216 1.344
150 HEX	3.013 5.723	4.236 7.573	5.635 **8.394**	7.438 7.651	8.702 6.767	1.286 0.716	2.335 3.882	3.703 6.129	5.867 6.644	7.707 6.187	1.293 0.179	2.453 3.356	3.901 5.578	6.100 6.100	7.951 5.642	1.365 -0.36	2.663 2.814	4.194 4.987	6.407 5.508	8.233 5.072	2.175 -3.94	3.885 -0.55	5.685 1.709	7.931 2.519	9.473 2.503
170 HEX	2.475 6.439	3.736 8.925	5.374 **10.43**	7.893 10.05	9.877 9.212	0.923 0.754	1.796 4.268	3.048 7.144	5.356 8.568	7.791 8.721	0.937 0.188	1.919 3.703	3.272 6.544	5.642 7.951	8.100 8.100	1.003 -0.38	2.130 3.127	3.608 5.907	6.049 7.269	8.508 7.407	1.649 -4.31	3.237 -0.64	5.170 2.179	8.062 3.617	10.53 3.919
90 GEL	-0.23 **3.163**	-0.30 2.856	-0.34 2.318	-0.37 1.578	-0.38 1.148	-0.18 0.435	-0.26 1.658	-0.31 1.947	-0.36 1.502	-0.37 1.111	-0.19 0.105	-0.27 1.385	-0.32 1.743	-0.36 1.365	-0.38 1.003	-0.20 -0.20	-0.28 1.122	-0.32 1.537	-0.36 1.230	-0.38 0.903	-0.25 -1.80	-0.32 -0.17	-0.35 0.410	-0.37 0.460	-0.39 0.385
110 GEL	1.615 4.191	2.102 **4.827**	2.527 4.648	2.923 3.686	3.150 2.952	1.048 0.567	1.644 2.608	2.190 3.446	2.753 3.012	3.076 2.446	1.068 0.141	1.709 2.206	2.260 3.052	2.814 2.663	3.127 2.130	1.122 -0.28	1.800 1.800	2.343 2.654	2.876 2.332	3.174 1.848	1.548 -2.74	2.254 -0.30	2.729 0.774	3.130 0.941	3.329 0.844
130 GEL	2.776 4.825	3.595 6.113	4.437 **6.492**	5.382 5.720	6.007 4.947	1.484 0.644	2.414 3.275	3.471 4.781	4.827 4.670	5.749 4.092	1.480 0.161	2.499 2.819	3.609 4.307	4.987 4.194	5.907 3.608	1.537 -0.32	2.654 2.343	3.800 3.800	5.170 3.709	6.065 3.151	2.283 -3.36	3.601 -0.42	4.758 1.197	5.922 1.589	6.578 1.505
150 GEL	2.886 5.709	3.948 7.652	5.169 **8.648**	6.773 8.157	7.927 7.473	1.198 0.717	2.096 3.933	3.308 6.291	5.298 6.954	7.022 6.631	1.184 0.180	2.169 3.415	3.459 5.755	5.508 6.407	7.269 6.049	1.230 -0.36	2.332 2.876	3.709 5.170	5.800 5.800	7.560 5.433	1.980 -3.98	3.460 -0.56	5.114 1.789	7.263 2.692	8.767 2.736
170 GEL	2.421 6.420	3.558 8.955	5.031 **10.57**	7.310 10.42	9.108 9.821	0.864 0.756	1.612 4.304	2.717 7.267	4.842 8.827	7.125 9.127	0.859 0.189	1.689 3.745	2.878 6.687	5.072 8.233	7.407 8.508	0.903 -0.38	1.848 3.174	3.151 6.065	5.433 7.560	7.800 7.800	1.508 -4.34	2.869 -0.65	4.618 2.253	7.368 3.800	9.767 4.188
90 SEL	-2.35 **3.877**	-3.20 3.872	-3.78 3.328	-4.23 2.328	-4.45 1.703	-1.60 0.533	-2.55 2.255	-3.24 2.858	-3.92 2.359	-4.29 1.788	-1.68 0.130	-2.63 1.899	-3.29 2.575	-3.94 2.175	-4.31 1.649	-1.80 -0.25	-2.74 1.548	-3.36 2.283	-3.98 1.980	-4.33 1.508	-2.40 -2.40	-3.30 -0.25	-3.83 0.647	-4.29 0.763	-4.52 0.648
110 SEL	-0.29 4.854	-0.39 5.918	-0.49 **5.999**	-0.60 4.950	-0.66 4.058	-0.16 0.644	-0.27 3.197	-0.39 4.558	-0.53 4.304	-0.63 3.623	-0.16 0.160	-0.28 2.730	-0.40 4.090	-0.55 3.885	-0.64 3.237	-0.17 -0.32	-0.30 2.254	-0.42 3.601	-0.56 3.460	-0.65 2.869	-0.25 -3.30	-0.40 -0.40	-0.52 1.118	-0.64 1.447	-0.71 1.327
130 SEL	0.883 5.503	1.207 7.226	1.567 **7.959**	2.017 7.247	2.329 6.427	0.393 0.702	0.689 3.766	1.069 5.860	1.647 6.213	2.112 5.711	0.392 0.176	0.719 3.257	1.120 5.331	1.709 5.685	2.179 5.170	0.410 -0.35	0.774 2.729	1.197 4.758	1.789 5.114	2.253 4.618	0.647 -3.83	1.118 -0.52	1.600 1.600	2.177 2.302	2.554 2.262
150 SEL	1.197 6.337	1.752 8.778	2.460 **10.27**	3.527 10.00	4.354 9.330	0.438 0.751	0.818 4.255	1.371 7.125	2.405 8.524	3.482 8.676	0.437 0.188	0.859 3.699	1.454 6.544	2.519 7.931	3.617 8.062	0.460 -0.37	0.941 3.130	1.589 5.922	2.692 7.263	3.800 7.368	0.763 -4.29	1.447 -0.64	2.302 2.177	3.600 3.600	4.693 3.900
170 SEL	1.056 6.884	1.651 9.890	2.506 12.11	4.065 **12.49**	5.486 12.04	0.357 0.775	0.706 4.498	1.242 7.824	2.354 10.11	3.742 11.19	0.360 0.194	0.755 3.917	1.344 7.216	2.503 9.473	3.919 10.53	0.385 -0.39	0.844 3.329	1.505 6.578	2.736 8.767	4.188 9.767	0.648 -4.52	1.327 -0.71	2.262 2.554	3.900 4.693	5.600 5.600

instance, continuing the example above, the new entrant would expect the incumbent to move from 170 STA to 130 STA if he really launches 150 AIR, thus leading to the maximum profit of 8.179×10^5 DM for the incumbent conditional upon this leader strategy and to a profit of 6.089×10^5 DM for the new entrant. The incumbent's respective profit-maximizing response to each of the possible leader strategies is highlighted in red colour (bold and underlined) in each row of the game matrix. From the remaining 25 leader-follower configurations (the ones including the red-marked best response of the incumbent), the new entrant chooses in a second step the brand profile which maximizes its profit. Accordingly, under market scenario AD, we obtain brand profile 170 STA as the Stackelberg leader strategy and thereby 170 STA/150 STA as the Stackelberg equilibrium configuration with respective profits of 8.219×10^5 DM and 12.78×10^5 for the new entrant and the incumbent (see the red-framed cell in the game matrix). In contrast, the profit-maximizing duopoly Nash equilibrium under this scenario would be 130 STA/130 STA leading to a lower equilibrium profit of 7.800×10^5 DM for both the new entrant and the incumbent (compare Table 3).[6,7]

Table 3 compares Nash and Stackelberg solutions (equilibrium brands and profits for the new entrant and the incumbent firm) for all duopoly scenarios analyzed. We see that Nash and Stackelberg equilibria may coincide in duopoly markets, as is the case under scenarios B and C (homogeneous preferences) and under scenarios AB, AC, BC, BD and CD (heterogeneous preferences). This implies that it does not pay for the new entrant to play a Stackelberg leader strategy rather than a simple Nash strategy under these scenarios, and that the new entrant cannot do better than share sales and profits with the incumbent firm through minimum differentiation. However, under market scenarios A, D as well as under market scenario AD (as illustrated above), Nash and Stackelberg equilibria are different and the Stackelberg leader strategy leads to a higher absolute profit for the new entrant than he could realize at the minimally differentiated profit-maximizing Nash equilibrium. This increase in profit is strongest under scenario A, where the new entrant could more than double its profit (from 1.900×10^5 DM at the Nash equilibrium to 4.433×10^5 DM at the Stackelberg equilibrium). Interestingly, under these scenarios, the incumbent firm also benefits (in terms of a higher absolute profit) from a new entrant playing a Stackelberg leader, and can make even more profit than the new entrant. Consequently, if Stackelberg and Nash solution do not coincide, a leader strategy leads to higher absolute profits for the new entrant, but a Nash entry strategy to a better profitability position relative to the incumbent firm. We attribute the higher profit levels of both firms at the Stackelberg equilibrium to the lower competitiveness of the two brands which is reflected by a higher degree of differentiation (as under scenario D) or by considerably higher price levels of both firms (i.e., less aggressive pricing, as under scenarios A and AD) as compared to the respective Nash configurations.

[6] We note that the simple duopoly Nash game under market scenario AD has two further minimally differentiated, albeit inefficient, Nash equilibrium solutions (90 STA/90 STA and 110 STA/110 STA).

[7] Importantly, it does not pay for the new entrant to deviate from the Stackelberg leader strategy (170 STA) because he knows, by definition of being a leader, that the incumbent firm would react to the new situation. Specifically, if the new entrant would lower its price to 130 (leading to a maximum profit increase all things being equal), the incumbent would quickly respond likewise with a price cut from 150 to 130, resulting in a suboptimal solution for the new entrant.

Table 3 A comparison of Nash and Stackelberg solutions in duopoly markets

	Profit-Maximizing Nash Equilibrium [a] Brand | Profit				Stackelberg Equilibrium Brand | Profit			
Scenario	New Entrant (Firm 1)		Incumbent Firm (Firm 2)		New Entrant (Firm 1)		Incumbent Firm (Firm 2)	
A	90 STA	1.900	90 STA	1.900	170 STA	4.433 [b]	150 STA	6.119
B	170 STA	5.900	170 STA	5.900	170 STA	5.900	170 STA	5.900
C	130 STA	3.900	130 STA	3.900	130 STA	3.900	130 STA	3.900
D	150 HEX	3.050	150 HEX	3.050	150 STA	3.199	170 AIR	5.657
AB	170 STA	11.800	170 STA	11.800	170 STA	11.800	170 STA	11.800
AC	130 STA	7.800	130 STA	7.800	130 STA	7.800	130 STA	7.800
AD	130 STA	7.800	130 STA	7.800	170 STA	8.219	150 STA	12.774
BC	130 STA	7.800	130 STA	7.800	130 STA	7.800	130 STA	7.800
BD	170 GEL	7.800	170 GEL	7.800	170 GEL	7.800	170 GEL	7.800
CD	130 STA	7.800	130 STA	7.800	130 STA	7.800	130 STA	7.800

[a] Compare Steiner and Hruschka (2000). The duopoly Nash equilibrium solutions under market scenarios comprising segment D preferences are only reported in Steiner (1999)

[b] Profits (in DM $\times 10^5$ monetary units) are computed assuming equal segment volumes of 10,000 (following Steiner and Hruschka (2000))

4.3 Stackelberg-Nash versus simple Nash equilibrium solutions on triopoly markets

In this subsection, we summarize the results we obtained from the application of our model to triopoly markets. In the triopoly case, the derivation of a Stackelberg leader strategy is computationally more demanding than in the duopoly case: first, for any leader's strategy, we have to compute the best responses for *two* incumbents as the final outcome of a Nash subgame between them. Second, a followers' subgame may have multiple Nash equilibrium solutions which all have to be identified in order to give a sound prediction of the expected competitive behavior of the incumbent firms. Fortunately, as already mentioned in Sect. 4.1, the solution to the Nash followers' subgame is as it were unique even in the case of multiple Nash equilibria, as we then without exception found exactly one efficient Nash subgame equilibrium to exist (see the illustration below). In this point, our findings confirm those of Steiner and Hruschka (2000) for simple duopoly and triopoly Nash games. We next again provide some more details on the computation of the Stackelberg leader strategy under one selected market scenario and subsequently give an overview of our results across all other triopoly scenarios.

As before, with two attributes at five levels, each competitor can choose 1 out of 25 feasible brand profiles for its brand. However, we here dispense with a representation of the whole game matrix for the new entrant and the two incumbents. Instead, considering as example again market scenario AD, we present in Table 4 the final outcomes

Table 4 Subgame Nash equilibria for two incumbent firms under triopoly scenario AD

		Incumbent firms / followers' Nash equilibrium strategies [a]																	
		90 STA	110 STA			90 STA	110 STA			90 STA	110 STA			90 STA	110 STA			90 STA	110 STA
New entrant / leader strategies	90 STA	2.533 2.533			90 AIR	0.392 1.939			90 HEX	0.095 1.994			90 GEL	-0.184 2.056			90 SEL	-1.717 2.441	
	110 STA	2.171 3.089			110 AIR	1.667 2.480			110 HEX	1.463 2.476			110 GEL	1.244 2.487			110 SEL	-0.203 2.835	
	130 STA	1.785 3.365	**3.305** **4.571**		130 AIR	2.256 2.826			130 HEX	2.161 2.798			130 GEL	2.018 2.791			130 SEL	0.579 3.113	**0.830** **4.295**
	150 STA	1.105 3.586	**2.191** **5.152**		150 AIR	1.904 3.235	**2.915** **4.479**		150 HEX	1.907 3.206	**2.814** **4.462**		150 GEL	1.848 3.194	**2.662** **4.469**		150 SEL	0.700 3.431	**1.073** **4.936**
	170 STA	0.705 3.687	**1.486** **5.435**		170 AIR	1.390 3.486	**2.268** **5.017**		170 HEX	1.421 3.467	**2.237** **4.999**		170 GEL	1.402 3.458	**2.155** **4.999**		170 SEL	0.575 3.605	**0.927** **5.320**

[a] Note that all subgame Nash equilibria are minimally differentiated such that equilibrium brands and profits are the same for both incumbent firms. Across leader strategies, only two different subgame Nash equilibria are observed (90 STA/90 STA and 110 STA/110 STA).

of the Nash followers' subgame between the two incumbents under each possible leader strategy the new entrant can play (90 STA, 110 STA, ..., 170 SEL). For each of these final leader-followers brand configurations, we provide the respective profits of the three competitors, where the upper number in a cell of the table corresponds to the profit of the new entrant and the lower number to the individual profit each of the two incumbents could realize. Equilibrium profits for the two incumbents are the same at any one time, as we found all existing Nash equilibria in the 25 followers' subgames to be minimally differentiated (i.e., the two incumbents offer homogeneous brands at any subgame equilibrium). For example, if the entrant firm would choose 130 AIR as its new brand, the noncooperative profit-maximizing response of each of the two incumbent firms would predicted to be 90 STA from the Nash subgame, leading to a profit of 2.256×10^5 DM for the new entrant and to equal individual profits of 2.826×10^5 DM for the two incumbents.

We also see from Table 4 that for some leader strategies (for example, 90 STA or 130 AIR), only *one* solution in the followers' subgame exists, while for some other candidate items (for example, 130 STA or 150 AIR), the Nash subgame has two equilibrium solutions. In the latter cases, however, there always exists exactly one efficient subgame Nash equilibrium at which both incumbents (and interestingly, as a result, also the new entrant) can realize more profit than at the second subgame equilibrium.[8] Consequently, we can give a unique prediction of the incumbents' best responses under each leader strategy. For example, if the new entrant would launch 150 AIR, the two incumbents cannot do better than both move to 110 STA if they want to maximize their individual profits. For subgames with two equilibria, we have indicated the profit-maximizing subgame equilibrium solution in bold in Table 4. Across the 25 leader strategies, we observe only two different subgame Nash equilibria for the two incumbents (90 STA/90 STA and 110 STA/110 STA).

With Table 4, the computation of a Stackelberg-Nash equilibrium is now easily understood: in a first step, the new entrant determines for each of the 25 feasible candidate profiles it can choose for its brand the final outcome(s) of the Nash followers' subgame. If a subgame has multiple Nash equilibrium solutions, the new entrant needs only to consider the profit-maximizing one. There remain 25 leader-followers configurations (one under each leader strategy accounting for the incumbents' best responses) from which the new entrant selects in a second step the brand profile which maximizes its profit. Accordingly, we now obtain brand profile 130 STA as the Stackelberg leader strategy and thereby 130 STA/110 STA/110 STA as the Stackelberg-Nash equilibrium configuration, with an associated profit of 3.305×10^5 DM for the new entrant and respective individual profits of 4.571×10^5 DM for both incumbent firms (see the red-framed cell in Table 4). For comparison, the profit-maximizing triopoly Nash equilibrium configuration under market scenario AD would be 90 STA/90 STA/90 STA yielding a lower equilibrium profit of 2.533×10^5 DM for both the new entrant and the two incumbents (compare Table 5).

Table 5 contrasts Stackelberg-Nash solutions with simple Nash solutions across all triopoly scenarios we analyzed. As it turns out, nearly all insights we gained on duopoly

[8] In the following, we will call an efficient subgame Nash equilibrium the profit-maximizing subgame equilibrium.

Table 5 A comparison of Nash and Stackelberg-Nash solutions in triopoly markets

	Profit-Maximizing Nash Equilibrium [a] Brand | Profit				Stackelberg-Nash Equilibrium Brand | Profit			
Scenario	New Entrant (Firm 1)		Incumbent Firms [b] (Firms 2 and 3)		New Entrant (Firm 1)		Incumbent Firms [b] (Firms 2 and 3)	
A	90 STA	1.267	90 STA	1.267	90 STA	1.267 [c]	90 STA	1.267
B	170 SEL	1.867	170 SEL	1.867	170 SEL	1.867	170 SEL	1.867
C	130 HEX	1.367	130 HEX	1.367	130 HEX	1.367	130 HEX	1.367
D	130 HEX	1.367	130 HEX	1.367	130 HEX	1.367	130 HEX	1.367
AB	130 STA	5.200	130 STA	5.200	130 STA	5.200	130 STA	5.200
AC	90 STA	2.533	90 STA	2.533	130 STA	3.568	110 STA	4.473
AD	90 STA	2.533	90 STA	2.533	130 STA	3.305	110 STA	4.571
BC	130 STA	5.200	130 STA	5.200	130 STA	5.200	130 STA	5.200
BD	170 GEL	5.200	170 GEL	5.200	170 GEL	5.200	170 GEL	5.200
CD	130 HEX	2.733	130 HEX	2.733	170 HEX	3.652	130 STA	6.042

[a] Compare Steiner and Hruschka (2000). The triopoly Nash equilibrium solutions under market scenarios comprising segment D preferences are only reported in Steiner (1999)

[b] Note that both triopoly Nash equilibria and duopoly subgame Nash equilibria are minimally differentiated such that equilibrium brands and profits are the same for both incumbent firms

[c] Profits (in DM×10^5 monetary units) are computed assuming equal segment volumes of 10,000 (following Steiner and Hruschka (2000))

markets also apply to triopoly markets: First, Stackelberg-Nash equilibria and simple Nash equilibria may coincide, as is the case under scenarios A, B, C and D (homogeneous preferences) and under scenarios AB, BC and BD (heterogeneous preferences). Hence, the principle of minimum differentiation also holds for a Stackelberg-Nash equilibrium under these scenarios, leading to equal market shares and profits for the three competitors. Second, if Stackelberg-Nash and simple Nash solutions are different from each other, as under market scenarios AC, AD and CD, then a Stackelberg leader strategy always yields a higher profit for the new entrant than its Nash counterpart. This increase in profit for the new entrant is comparable across these three scenarios and varies from +30 to +40% (for example, 30.48% under scenario AD). Again, the incumbents as well benefit if the new entrant acts as a Stackelberg leader rather than a simple Nash player. Not only can they improve their individual profits (for example, under scenario AD from 2.533×10^5 DM at the Nash equilibrium to 4.571×10^5 DM at the Stackelberg-Nash equilibrium), but they also can realize a higher profit than the new entrant. Consequently, under scenarios AC, AD and CD, a leader strategy results in higher absolute profits for the new entrant, whereas a Nash strategy reduces profit differences to the incumbent firms at a lower absolute profit level. The higher absolute profit level of all three firms at the Stackelberg-Nash solution is the result of a less stronger competition between the new entrant and the two incumbents as compared to the respective Nash configurations: the new entrant either differentiates its brand to a higher degree from those of the minimally differentiated incumbents (as under scenario CD) or competitive pricing is much less aggressive allowing all three competitors to offer their brands at higher price levels (as under scenarios AC and AD).

Interestingly, under all triopoly scenarios, the two incumbents offer homogeneous brands at the Stackelberg-Nash equilibrium. And, as opposed to duopoly markets, there is obviously not enough scope for a Stackelberg leader strategy to be superior to a simple Nash entry strategy in case of homogeneous consumer preferences (i.e., under scenarios A, B, C and D).

5 Refinements

In this section, we present some refinements of our approach. First, we analyze how sensitive our findings on duopoly and triopoly markets are concerning the use of the logit choice rule as probabilistic choice model. For example, is our finding that the leader makes a lower profit than the follower(s) if Stackelberg (respectively Stackelberg-Nash) and simple Nash equilibria do not coincide valid only under the selection of the logit choice simulator? Secondly, we enhance our model by including an outside good in the choice rule to be capable of category demand effects, and present associated equilibrium results for a market scenario with four consumer segments. Our conjecture here is that the existence of an outside good may provide competitors an incentive for product differentiation and welfare creation.[9] Implications from considering an outside good can also be derived from our findings presented in Sect. 4, as we will illustrate below.

5.1 Bradley-Terry-Luce share-of-utility rule

To assess whether our findings on profit implications (e.g., profit asymmetries) and degree of product differentiation of competitors also hold under a different probabilistic choice model, we replicated our study using the Bradley-Terry-Luce (BTL) share-of-utility rule instead of the logit choice rule. The BTL model has been widely used for optimal/competitive product design based on conjoint data and has been employed in commercial conjoint simulators, too (see Green et al. 2004). According to the BTL model, the probability PROB_{ij} that a consumer in segment i buys brand j is calculated as (compare Eq. (3) for the logit choice rule):

$$\text{PROB}_{ij} = \frac{\hat{V}_{ij}}{\sum_{m=1}^{J} \hat{V}_{im}}, \quad i = 1, \ldots, I \tag{10}$$

The BTL choice rule, by definition, requires composite utilities $\hat{V}_{ij}$ to be non-negative (i.e., $\hat{V}_{ij} \geqslant 0, i = 1, \ldots, I, j = 1, \ldots, J$). We therefore rescaled the segment-specific part-worth utilities λ_{iKl} $(l = 1, \ldots, 5)$ for the *price attribute levels* (compare Table 1) by the following transformation so that the lowest part-worth utility

[9] We thank an anonymous referee for these important suggestions.

is upscaled to zero, respectively:

$$\lambda^*_{iKl} = \lambda_{iKl} - \min_l \lambda_{iKl}, \quad i = 1, \ldots, I, \tag{11}$$

with index K denoting the price attribute. Importantly, using the "new" transformed part-worth data leaves our simulation results under the logit choice rule unchanged, as adding an arbitrary constant to each alternative's composite utilitiy $\hat{V}_{ij}$ does not affect the logit choice probabilities (e.g., see Hruschka et al. 2004).

Table 6 reports the Nash and Stackelberg solutions (equilibrium brands and profits) obtained for the *duopoly scenarios*. The results confirm our previous findings and can be summarized as follows: (1) Nash equilibria are minimally differentiated and may coincide with Stackelberg equilibria, as under all one-segment scenarios (homogeneous preferences) and under scenarios AC, BC, BD and CD (heterogeneous preferences). Here, the new entrant does not benefit from being a leader and cannot do better than share sales and profits with the incumbent firm. (2) Under market scenarios AB and AD, however, Stackelberg leader and Nash follower strategies differ from each other, with the new entrant offering a more expensive cushioning system at a higher price (170 HEX) than the incumbent firm (150 STA). Just as under the logit choice rule, both leader and follower can increase their profits as compared to the minimally-differentiated Nash equilibrium, with the incumbent firm benefitting even stronger than the new entrant.

Comparing Nash and Stackelberg equilibria across the Luce and logit versions of our model (Table 3 vs. 6), we can hardly recognize regularities. Some Nash equilibria

Table 6 A comparison of Nash and Stackelberg solutions in duopoly markets (Luce version)

	Profit-Maximizing Nash Equilibrium Brand | Profit				Stackelberg Equilibrium Brand | Profit			
Scenario	New Entrant (Firm 1)		Incumbent Firm (Firm 2)		New Entrant (Firm 1)		Incumbent Firm (Firm 2)	
A	170 STA	5.900	170 STA	5.900	170 STA	5.900 [a]	170 STA	5.900
B	170 GEL	3.900	170 GEL	3.900	170 GEL	3.900	170 GEL	3.900
C	130 STA	3.900	130 STA	3.900	130 STA	3.900	130 STA	3.900
D	170 AIR	4.200	170 AIR	4.200	170 AIR	4.200	170 AIR	4.200
AB	130 STA	7.800	130 STA	7.800	170 HEX	8.756	150 STA	9.006
AC	130 STA	7.800	130 STA	7.800	130 STA	7.800	130 STA	7.800
AD	130 STA	7.800	130 STA	7.800	170 HEX	7.804	150 STA	10.158
BC	170 HEX	8.100	170 HEX	8.100	170 HEX	8.100	170 HEX	8.100
BD	170 GEL	7.800	170 GEL	7.800	170 GEL	7.800	170 GEL	7.800
CD	130 STA	7.800	130 STA	7.800	130 STA	7.800	130 STA	7.800

[a] Profits (in DM×10^5 monetary units) are computed assuming equal segment volumes of 10,000 (following Steiner and Hruschka (2000))

change (scenarios A, B, D, AB, BC) and some not (scenarios C, AC, AD, BD, CD). Stackelberg equilibria may shift from minimum differentiation to a stronger degree of differentiation (scenario AB) or vice versa (scenarios A and D), or may change not at all (scenarios C, AC, BD, CD). There is further no tendency that equilibrium profits are higher or lower under the Luce or logit choice rule.

Table 7 shows the simulation results under the BTL choice rule for the *triopoly scenarios*. Again, many of our previous findings are confirmed: (1) the two incumbent firms always offer homogeneous brands at both Nash equilibria and Stackelberg-Nash equilibria and therefore realize equal market shares and profits. (2) For 9 out of 10 market scenarios, Nash and Stackelberg-Nash equilibria coincide and are minimally differentiated leading to equal market shares and profits for all three competitors. Under these scenarios, it does not pay for the new entrant to "play" a Stackelberg leader strategy compared to a simple Nash strategy.

Under market scenario BC, however, we observe a completely new equilibrium pattern: Nash and Stackelberg-Nash equilibria coincide but the new entrant offers a different brand (130 STA) than the minimally differentiated incumbent firms (170 HEX). Moreover, the new entrant can make a higher profit than an incumbent firm. In other words, we found no difference between Nash and Stackelberg-Nash equilibria under all triopoly scenarios, and a profit advantage for the new entrant when equilibrium brands are not minimally differentiated. Quite contrary to our results on duopoly scenarios, there is the tendency that equilibrium profits are higher under the Luce choice

Table 7 A comparison of Nash and Stackelberg solutions in triopoly markets (Luce version)

	Profit-Maximizing Nash Equilibrium Brand | Profit				Stackelberg-Nash Equilibrium Brand | Profit			
Scenario	New Entrant (Firm 1)		Incumbent Firms [a] (Firms 2 and 3)		New Entrant (Firm 1)		Incumbent Firms [a] (Firms 2 and 3)	
A	150 STA	3.267	150 STA	3.267	150 STA	3.267 [b]	150 STA	3.267
B	170 GEL	2.600	170 GEL	2.600	170 GEL	2.600	170 GEL	2.600
C	130 STA	2.600	130 STA	2.600	130 STA	2.600	130 STA	2.600
D	170 HEX	2.700	170 HEX	2.700	170 HEX	2.700	170 HEX	2.700
AB	130 STA	5.200	130 STA	5.200	130 STA	5.200	130 STA	5.200
AC	130 STA	5.200	130 STA	5.200	130 STA	5.200	130 STA	5.200
AD	130 STA	5.200	130 STA	5.200	130 STA	5.200	130 STA	5.200
BC	130 STA	5.578	170 HEX	5.204	130 STA	5.578	170 HEX	5.204
BD	170 GEL	5.200	170 GEL	5.200	170 GEL	5.200	170 GEL	5.200
CD	130 STA	5.200	130 STA	5.200	130 STA	5.200	130 STA	5.200

[a] Note that the two incumbent firms' always offer the same brands at both triopoly Nash equilibria and Stackelberg-Nash equilibria implying equal profits for them

[b] Profits (in DM$\times 10^5$ monetary units) are computed assuming equal segment volumes of 10,000 (following Steiner and Hruschka (2000))

rule than under the logit choice rule (Table 5 vs. 7). This can be attributed to higher prices or a less expensive cushioning system (w.r.t. variable costs) of the brands at equilibrium.

5.2 Category demand effects

To accommodate possible category demand effects, we extended our model by the option to incorporate an outside good in the choice simulator. Formally, this is accomplished by adding the outside alternative to the denominator of the respective choice rule. Taking the logit choice rule as example, expression (3) changes to:

$$\text{PROB}_{ij} = \frac{\exp\left(\mu \cdot \hat{V}_{ij}\right)}{\sum_{m=1}^{J} \exp\left(\mu \cdot \hat{V}_{im}\right) + \exp\left(\mu \cdot \hat{V}_{i,\text{outside}}\right)}, \quad i = 1, \ldots, I, \quad (12)$$

with $\hat{V}_{i,\text{outside}}$ reflecting the composite utility of the outside good. The inclusion of an outside good is reasonable, if consumers do not consider buying a brand with a utility below a certain threshold level ("status quo utility").

In a first step, we analyzed the implications from considering an outside good for a duopoly situation under market scenario ABCD, which comprises all four consumer segments (compare Table 1). We specified the outside good in terms of a generic product choosing as brand designs 170 HEX and 90 STA, alternatively; 170 HEX represents a brand high in price and with the cushioning system that is on average most preferred across segments, while 90 STA is the brand with the lowest (and most preferred) price level but also with the least preferred cushioning system across segments.

Table 8 reports the simulation results under both the logit and Luce versions of our model including the basic scenario without an outside good: (1) As expected, equilibrium profits for the firms significantly decrease with the existence of an outside good, and are lowest if 90 STA represents the outside alternative. (2) Equilibrium solutions w.r.t brand designs seem to be much more sensitive under the logit choice rule rather than under the Luce choice rule. Here, equilibrium brands do not vary at all under the Luce version, independent of whether an outside good is considered or not. In contrast, under the logit choice rule, Nash and Stackelberg equilibria may change in the presence of an outside good: in such cases, firms offer higher quality brands (i.e., a more expensive cushioning system concerning variable costs) or set lower prices, thereby increasing consumers' welfare. (3) There is no evidence that the presence of an outside good drives firms to differentiate their brands: the principle of minimum differentiation holds for all Nash equilibria, and we see no unique tendency in the variation of the Stackelberg equilibria towards more or less differentiation (e.g., the Stackelberg equilibrium shifts to minimum differentiation under the logit choice rule with the introduction of an outside good with profile 170 HEX).

Implications from including an outside good can further be derived from our findings presented in Sects. 4 and 5.1 when considering the Stackelberg leader strategy to be an outside alternative. Remembering that a leader's strategy is set exogeneously

Table 8 A comparison of Nash and Stackelberg solutions in 4-segment duopoly markets considering different probabilistic choice rules (logit vs. Luce) and an outside good at different status-quo utility levels

Scenario ABCD							
Profit-Maximizing Nash Equilibrium Brand | Profit				Stackelberg-Nash Equilibrium Brand | Profit			
New Entrant (Firm 1)		Incumbent Firm (Firm 2)		New Entrant (Firm 1)		Incumbent Firm (Firm 2)	
Logit choice rule, no outside good							
130 STA	15.60 [a]	130 STA	15.60	170 STA	17.52 [a]	150 STA	24.65
Logit choice rule. outside good with profile 170 HEX							
130 STA	11.87	130 STA	11.87	130 STA	11.87	130 STA	11.87
Logit choice rule, outside good with profile 90 STA							
130 HEX	5.097	130 HEX	5.097	170 GEL	5.123	110 STA	7.023
Luce choice rule, no outside good							
130 STA	15.60	130 STA	15.60	130 STA	15.60	130 STA	15.60
Luce choice rule, outside good with profile 170 HEX							
130 STA	11.18	130 STA	11.18	130 STA	11.18	130 STA	11.18
Luce choice rule, outside good with profile 90 STA							
130 STA	8.542	130 STA	8.542	130 STA	8.542	130 STA	8.542

[a] Profits (in DM×10^5 monetary units) are computed assuming equal segment potentials of 10,000

and a follower reacts conditional upon the leader's choice (compare expressions (7) and (8)), we can in fact treat the Stackelberg brand as it were an outside good. We can therefore gain related insights by comparing the Nash equilibrium solutions on duopoly markets (2 firms, no outside good) to the subgame Nash equilibrium solutions on triopoly markets (2 firms, 1 outside good).[10] Interestingly, all findings obtained under the four-segment market scenario ABCD are confirmed: equilibrium profits always decrease; equilibrium positions are much more stable under the Luce choice rule (only the equilibrium solutions under scenarios A and D change) rather than the logit choice rule (equilibria remain unchanged only w.r.t. scenarios A, BC, BD and CD); if equilibrium solutions are affected by the outside good, then firms either increase

[10] Please compare Table 3/Table 5 (left-hand side) with Table 6/Table 7 (right-hand side, column 'incumbent firms') for the results under the logit and Luce choice rules, respectively.

brand quality (by offering a more costly cushioning system) or demand lower prices; and finally, firms keep to the principle of minimum differentiation and offer identical brands even if an outside good is present. Summing up, allowing category expansion seems to provide an incentive for welfare creation but not for product differentiation under a probabilistic choice rule.

5.3 A note on the discreteness of the price attribute

Like in many conjoint models on optimal product design, we have treated the price attribute in our study at discrete levels, too (e.g., compare Choi and DeSarbo 1993; Gaul et al. 1995; Green and Krieger 1992, 1997; Gutsche 1995). However, in order to accommodate the (more realistic) case that firms may want to charge an arbitrary price level in the price range between 90 and 170 for their sneakers, our study could further be refined by using related part-worths for intermediate price levels obtained by interpolation. One way of interpolation is to generate a piecewise linear price response function from the part-worth utilities by *linearization* between each two adjacent utility levels. From the assumed linear relationship between the utility levels, we could then derive a sufficient number of intermediate price utility “coordinates”, which amounts to covering the price attribute dimension with a much finer “grid” of points. Future research should explore to what extent our results carry over if, for example, linearly interpolated utility levels at intermediate price steps of 1 DM (i.e., for price levels 90, 91, 92,. . ., 168, 169, 170) are additionally used for optimization.

Linear interpolation between part-worth utilities is exactly what many descriptive conjoint studies implicitly assume when usually depicting part-worth functions as piecewise linear curves. It is important to note that the part-worth model thereby provides high flexibility to represent nonlinearities in the preference function, as far as quantitative attributes such as price (for which interpolation is reasonable) are considered (Green and Srinivasan 1978). As can be seen from Table 1 and Fig. 2, at least three of the four segments (segments A, C and D) exhibit a nonlinear price-preference relationship. Using a vector model for prices instead would impose a linear relationship in advance with the consequence that existing nonlinearities cannot be captured at all. Moreover, the cost of having to estimate a larger number of parameters for the part-worth model (for L_K price levels $I(L_{K-1})$ parameters compared to I parameters for a vector model) should pose no statistical problems, if estimation of part-worths is carried out at the segment level.

6 Conclusions

This paper presents a new model for competitive new product design based on conjoint data employing the *Stackelberg-Nash equilibrium concept.* We assign the role of the Stackelberg leader to a new entrant (the leader) who wants to introduce a new brand onto an existing product market, while keeping to the assumption of Nash behavior for the incumbent firms (the followers). The new approach is illustrated under several duopoly and triopoly scenarios and price, design and profit implications for competitors are compared under different probabilistic choice rules to corresponding results from a simple Nash equilibrium model.

Our results agree with previous findings that Stackelberg and Nash solutions *may* become the same in discrete strategy spaces (see, e.g., Choi et al. 1990). In this case, it does not pay for the new entrant to act with more foresight as a leader as compared to playing a simple Nash strategy. On the other hand, we also saw both on duopoly and triopoly markets that a Stackelberg leader strategy can yield a much higher profit for a new entrant than he could achieve with a simple Nash strategy. In that case, the profit asymmetry between the new entrant (the leader) and the incumbents (the followers) always is in favor of the incumbents who not only can as well increase profits as compared to a simple Nash equilibrium but also can realize higher profits than the new entrant. It is, however, hard to derive generalizations from our simulation study under what conditions Stackelberg and Nash equilibria do or do not coincide. Obviously, the answer to this question depends on the interaction of several individual factors: part-worth preference structures within segments, the trade-off between utility (part-worths) and costs across individual attribute levels, the number of competing firms and the type of probabilistic choice model used. We briefly discuss this issue in the following.

From Table 3 (logit choice rule, duopoly markets), we observe that Stackelberg and Nash equilibria differ under market scenarios A, D and AD. Consumers in these segments are rather price-sensitive which is reflected by a strong decrease in part-worth utilities whenever price is increased to the next higher level. Price sensitivity therefore seems to be an important driver for price differentiation at a Stackelberg equilibrium. In addition, the trade-off between utility and costs for the cushioning system attribute is very distinct in segment D allowing firms to differentiate their brands with respect to this quality attribute. Table 4 (logit choice rule, triopoly markets) further reveals that the number of competitors may also be an influential factor. While increasing the number of competitors from two to three firms seems to leave no more scope at all for product differentiation on markets with homogeneous preferences (market scenarios A to D), the opposite can be observed on markets with heterogeneous preferences. Here, the followers achieve a higher profit than the leader at the Stackelberg-Nash equilibrium under market scenarios AC, AD and CD. Going to the simulation results under the luce choice rule (Tables 6 and 7), things entirely change. Stackelberg and Nash equilibria do coincide under all market scenarios except under duopoly scenarios AB and AD. Equilibrium results therefore seem to be very sensitive to the type of probabilistic choice rule used, too.

The simulation study provides several other new findings: (1) the principle of minimum differentiation for Nash equilibria apparently holds for duopolies but need not hold on triopoly markets when using the BTL share-of-utility rule to model consumers' choices (as shown under market scenario BC). Steiner and Hruschka (2000) previously found that duopoly and triopoly Nash equilibria were minimally differentiated under the logit choice rule. (2) The presence of an outside good may provide an incentive for the competing firms to increase consumers' welfare, either by setting lower prices or by increasing brand quality. There is, however, no evidence that the existence of an outside alternative creates an incentive for product differentiation.

The results from our study provide the following managerial implications: first, although we cannot prove the uniqueness of a Stackelberg-Nash equilibrium analytically due to the discrete nature of the product design problem, we found a unique solution under all market scenarios analyzed. Strategically, uniqueness of an equilibrium is a highly desirable property, as it allows the decision-maker a unique prediction of competitive behavior. Otherwise, it would be difficult to justify which one of multiple solutions the competing firms should choose independently from each other. Second, our results show that it is important to compare different strategies for market entry and that no overall recommendation in favour of Stackelberg *or* Nash can be given for a new entrant. Rather, knowing absolute and relative profit implications of a Stackelberg leader versus a simple Nash strategy, a new entrant should weight up the *possible* trade-off between higher absolute profit but stronger profit asymmetry with a leader strategy and lower absolute profit but also reduced profit differences to the incumbent(s) with a Nash strategy. Our results also indicate that this trade-off may turn out very differently across scenarios. Importantly, in the one single case under the BTL choice rule where we found the new entrant to make a higher profit than the incumbent firms through product differentiation, Nash and Stackelberg-Nash solutions were identical.

To give a concrete recommendation for a Stackelberg leader strategy to be played, a new entrant could, for example, announce its new brand(s) in time. If the incumbent firms quickly respond to the announcement by optimally repositioning their existing brands (e.g., by cutting prices and or redesigning quality attributes) and moving into a new market equilibrium, the new entrant cannot do better than eventually introduce the new product design corresponding to the leader strategy. If the incumbents would not react immediately to the announcement *and* the new entrant is able to redesign a new product profile once launched, a traditional optimal new product design strategy (ignoring retaliatory responses) may be superior in the short term. In this case, however, the new entrant is prepared to move to the Stackelberg leader position as soon as the incumbents do respond to its market entry.

Another important point with practical relevance is our experience that the Stackelberg-Nash equilibrium could be derived much more easily than by solving each of N followers' subgame problems (compare expression (9)) *explicitly* for multiple equilibria. Under each of the triopoly scenarios we analyzed, it proved to be sufficient to start out *in each subgame* from the profit-maximizing duopoly Nash equilibrium for the two incumbents (i.e., before the new entrant's attack), therefore requiring only one single tatonnement per subgame starting just from this duopoly equilibrium configuration. If this property generally holds, the computation of a Stackelberg-Nash equilibrium would become really simple.

Our model has also some limitations. When there is less knowledge (experience) about the entering market or when the incumbent firms are expecting the introduction of a new brand, it seems unlikely that a new entrant's decision has a big impact on the incumbents' decisions. For such situations, a framework that treats incumbents as leaders and new entrants as followers should be preferred. In contrast, one reason for a substantial first-mover advantage of a new entrant would be the existence of vertical relationships among firms, as existent in manufacturer-retailer relations. To accommodate interactions in those vertical relationships, one could think about an extension of our model where a retailer launches a private label brand and anticipates both the reactions of its competitors (the upstream firms) and the impact on its own profit by deriving higher or lower markups. In addition, more experiences have to be gained—with respect to, e.g., a higher number of competitors, different cost structures of competitors and/or a higher number of conjoint attributes—to further generalize our findings. Keeping these limitations of our study in mind, we hope that this paper stimulates further research on competitive new product design.

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