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Analyzing Product Efficiency-
A Customer-Oriented Approach

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Abstract

The purpose of this study is to provide a broader, economic perspective on customer value management. By developing an efficiency-based concept of customer value we aim at contributing to the presently underrepresented research field of marketing economics. The customer value concept is utilized to assess product performance and eventually to determine the competitive market structure and the product-market boundaries.

Our analytical approach to product-market structuring based on customer value is developed within a microeconomic framework. We measure customer value as the product efficiency viewed from the customer's perspective, i.e., as a ratio of outputs (e.g., resale value, reliability, safety, comfort) that customers obtain from a product relative to inputs (price, running costs) that customers have to deliver in exchange. The efficiency value derived can be understood as the return on the customer's investment.

Products offering a maximum customer value relative to all other alternatives in the market are characterized as efficient. Different efficient products may create value in different ways using different strategies (output-input-combinations). Each efficient product can be viewed as a benchmark for a distinct sub-market. Jointly, these products form the efficient frontier, which serves as a reference function for the inefficient products. Thus, we define customer value of alternative products as a relative concept.

Market partitioning is achieved endogenously by clustering products in one segment that are benchmarked by the same efficient peer(s). This ensures that only products with a similar output-input structure are partitioned into the same sub-market. As a result, a sub-market consists of highly substitutable products.

In addition, value-creating strategies (i.e., indications of how to vary inputs and outputs) to improve product performance in order to offer maximum customer value are provided. The impact of each performance parameter on customer value is determined, identifying the value drivers among them.

This methodological framework is applied to data of the 1996 German Automobile Club (ADAC) survey.

Contents

1 Efficiency in Marketing

As the concept of value based management becomes more and more established as a holistic managerial framework affecting all functions and organizational processes, the assessment of marketing performance gains new momentum. This implies a wider scope and content in understanding marketing within business processes. Now, more attention is paid to sustaining and enhancing shareholder value through marketing activities (Srivastava, Shervani, and Fahey 1999). For this reason, the task is no longer to simply attract and retain customers but to do so efficiently. To focus on profitable customer relationships that generate a maximum cash flow return on investments is a key prerequisite to augmenting shareholder value.

The literature on assessing marketing management performance has long advocated the use of productivity or efficiency measures. On the basis of a survey of more than 50 studies from the past 30 years, Bonoma and Clark (1993) conclude that the most popular measure of marketing performance is efficiency, defined as an output to input ratio. Obviously, management is convinced that good marketing skills are reflected in productivity gains, defined through the benefits and costs of marketing activities.

Productivity measures vary from physical units (as for instance sales volume per salesman-hour or orders divided by calls) to monetary values (e.g., channel revenues to channel costs). The widespread use of the ratio concept of efficiency for assessing the performance of marketing functions or technical product efficiency is well documented in Murthi, Srinivasan, and Kalyanaram (1996) and Parsons (1994). Virtually all the systematic marketing productivity research has concerned the functions retailing (Ratchford and Stoops 1988, Ingene 1983), wholesaling (van Dalen, Koerts, and Thurik 1990), selling / distribution (Mahajan 1991; Sujan, Weitz, and Sujan 1988), advertising (Achenbaum 1992; Jagpal 1999, p. 165-176), promotion (Abraham and Lodish 1992), R&D (Pappas and Remer 1989), and marketing network investments (Coughlan and Flaherty 1983). Researchers in the field of marketing efficiency may be characterized as “marketing economists”.

Although the ratio concept has been put to extensive use for the assessment of technical or productive efficiency it has not yet been applied in marketing to assess the efficiency of the product as such. This is surprising because to optimize products from a customer’s perspective ought to be the first priority for marketing. If this is to be achieved, “marketing economists” should not consider efficiency a supply-side concept only but rather a demand-oriented one. In order to accelerate and enhance cash flows from customer relations, which are necessary to generate shareholder value, a product has to create superior value to customers compared with current or potential rivals. The more efficient a product provides a set of demanded characteristics (outputs) for given expenditures (inputs) the higher its economic value for customers.

Although this linkage seems clear, the efficiency construct has not been employed comprehensively to conceptualize and analyze customer value. It is worth emphasizing that work within the customer value perspective, traditionally based on behavioral or psychological approaches, has so far conceptualized customer value in terms of satisfaction or perceived quality. This line of research does not consider the more fundamental, economic determinants of the consumer's product decision as in the field of microeconomic preference theory. Furthermore, no effort has been made to use an efficiency-based customer value concept to analyze product-markets, let alone to determine the competitive market structure and product-market boundaries.

The purpose of this study is to develop a broader economic perspective on customer value management. We aim to contribute to the presently underrepresented research on marketing economics. Our main objectives are to develop an efficiency-based concept of customer value, to utilize this customer value concept in order to assess product performance and finally to structure product-markets from a competition-oriented point of view.

2 Product Efficiency and Market Structuring

2.1 Customer Value as a Measure of Product Efficiency

From an economics- and value-based perspective consumers do not search for products with maximum quality or minimum price but seek to optimize on the quality-price-ratio (Rust and Oliver 1994). As a first simple rule, value can be conceptualized as quality-price-ratio or a performance-price-ratio in the sense of value for money (Vinson, Scott, and Lamont 1977; Johnson 1996; Zeithaml and Bitner 1996).

While forming their judgments about products consumers jointly consider both quality and non-quality related dimensions within an economically oriented decision concept of "higher-order-abstraction" (Sinha and DeSarbo 1998; Zeithaml 1988). This type of sophisticated, value sensitive purchasing behavior can be expected in competitive, especially in electronically mediated markets with rational, information driven consumers. Intelligent software agents, bargain finders like www.priceline.com or www.autoweb.com, locate the lowest price for specified product characteristics and therefore reduce search costs for buyers to virtually zero. In turn, product-marketing has to combine, as shown in figure 1, the previously more one-sided strategic focuses of quality-management ("the best or nothing") and cost-management ("the cheapest or nothing") into a concept of customer value management.

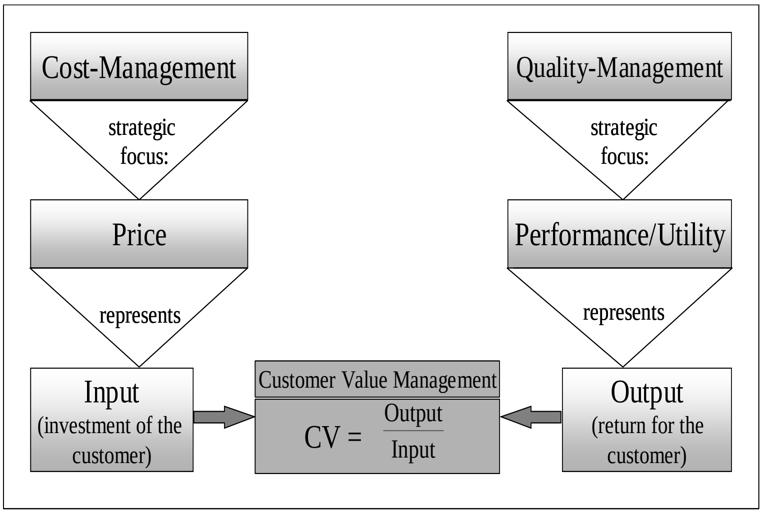

Figure 1: Modeling customer value as an efficiency measure

Instead of viewing value solely as a quality-price trade-off Sinha and DeSarbo (1998) emphasize that value is a more complex construct in which all "get" and "give" components of a product should be embedded. Numerous authors request a more systematic, multi-attribute implementation of customer value (Sinha and DeSarbo 1998; Huber, Herrmann, and Braunstein 2000; Holbrook and Corfman 1985). In line with these requirements, we conceptualize the two basic value dimensions by measuring customer value (CV) as an efficiency ratio of weighted outputs and weighted inputs. This implements CV in a multi-faceted way.

(1) $$CV=\frac{\text{Outputs}}{\text{Inputs}}=\frac{\sum_{r}^{R} u_r y_r}{\sum_{i}^{I} v_i x_i}$$

Inputs x and respective weights v are indexed by i. They represent the customer's "investments" in order to obtain and use a good. In addition to out-of-pocket costs such as price, search costs or running costs, inputs could also be non-monetary sacrifices such as time or risk. Outputs y and respective weights u are indexed by r and represent “outcomes” of a product, i.e. performance attributes from which utility is derived (e. g., reliability, comfort, safety). CV is the customer’s economic value derived from the product in the sense of an output to input efficiency value. It can be understood as the return on customer’s investment.

The analogy of CV and economic efficiency is obvious since products are chosen which offer maximum outputs for given inputs or that demand minimum inputs in order to obtain a particular output level. The maximization of the output value that can be achieved at alternative input levels is the underlying rationale of preference formation and finally of consumer choice behavior (Lovelock 1991; Rust and Oliver 1994).

This general concept models the customer’s trade-off between all received outputs (positive consequences, utility) and all inputs (sacrifices, cost) for the entire process of purchasing and using the product. All single output-input ratios are aggregated into an overall value measure. We obtain a generalized, broadly applicable measure of customer value, because every output and input parameter relevant for customers can be included in our analysis, independent of scale level or dimension of the problem.

In spite of the theoretical requirement that the customer value must consist of a multitude of choice-relevant components, no empirical attempt has been made to operationalize such a construct for means of market structuring. Our approach does apply a multi-dimensional construct in an empirical analysis on market structure.

2.2 The Concept of Customer Value-Based Market Structuring

Accurate market structuring is an essential prerequisite for both strategic and tactical marketing decisions. Questions like “What is our relevant sub-market?”, “Who are our competitors?” and “Which are our benchmarks?” need to be answered. By structuring markets one can gain considerable insight into the pattern of competition within the market and into the question of which products can and should be compared to each other and which not. To structure a market implies to identify the composition and the contours of product subsets, which in turn requires drawing boundaries between them (Bauer and Herrmann 1995). This aim necessitates a market partitioning method.

Market partitioning is based on the assumption that an entire sales market is not made up of homogenous products but rather of separate product segments (sub-markets) where products differ with regard to certain criteria. The idea of partitioning is to group a pre-specified set of products in a way that products within a group compete more intensely with one another than products belonging to different segments (Grover and Srinivasan 1987). The majority of the relevant body of literature holds that the underlying criteria used for market partitioning should reflect demand-relevant product characteristics (Day, Shocker, and Srivastava 1979; Elrod 1991; MacKay, Easley, and Zinnes 1995).

According to a widely accepted definition, sub-markets are groups of products that are similar with regard to certain attributes and thus can be considered close substitutes (Bauer and Herrmann 1995). Several analytical methods have been proposed in order to derive product-market structures directly from choice data (DeSarbo et al. 1998; Ramaswamy and DeSarbo 1990; Grover and Srinivasan 1987). Such techniques typically utilize panel purchase data, which do not contain product attribute ratings or measures of similarity. A large part of this work treats products as uni-dimensional entities when in reality they are not.

The consensus in the marketing and economics literature is that consumers do not decide to purchase “a product” but bundles of characteristics (Hjorth-Andersen 1984; Lancaster 1966; Rosen 1974). Obviously, product features should be the underlying criteria when it comes to dividing the market into product segments relevant for marketing.

Other approaches of defining market boundaries incorporate product characteristics but focus on either quality- or performance-related attributes, still others focus on price-related attributes (Day, Shocker, and Srivastava 1979; Rao and Sabavala 1981; DeSarbo and Wu 2001; Lefkoff-Hagius and Mason 1993) without integrating them into a higher order measure. Standard methods for sub-market identification are methods such as multidimensional scaling, which represents products in an attribute space or hierarchical cluster analysis, which derives hierarchical choice patterns by product-market trees (DeSarbo et al. 1998, DeSarbo and Wu 2001, Green, Krieger, and Zelnio 1989; MacKay, Easley, and Zinnes 1995). They are based solely on quality or utility related attributes and enable researchers to infer which products belong to the same sub-market only in terms of similarity with respect to particular quality criteria.

In contrast, recent research in marketing has compiled strong evidence that consumers do not separately optimize on either quality or price, but search for a favorable ratio of the dimensions discussed above (for an overview of empirical studies of this kind, see Huber, Herrmann, and Braunstein 2000). The quality-price-ratio or, more generally, the output-input-ratio provided by a given product affects the quality of a consumer's choice and in turn reflects the degree of consumer efficiency of the purchasing act (Ratchford et al. 1996). Hence, of customer value should be incorporated when estimating product-market structures.

Market partitioning as defined above is only one element of insightful market structuring. In order to determine the reference units in a sub-market and thereby to gain information useful for product design, benchmarking is needed in addition to partitioning. In order to be instructive for marketing decisions, reference points in terms of benchmark product(s) must be identified. Competitive benchmarks used by firms and managers as reference points evidently affect the choice, direction and implementation of performance-enhancing strategies (Shoham and Fiegenbaum 1999; Day and Nedungadi 1994). There is also strong theoretical support for the use of benchmarking by the strategic reference points theory, which is derived from the prospect theory, as well as by the institutional theory, game theory and industrial organization economics (Shoham and Fiegenbaum 1999; Kahneman and Tversky 1979; Meyer and Rowan 1977; Tirole 1989; Porter 1980). In this context, success is seen as depending on the position of firms or products relative to competitors.

As outlined above, we define products as bundles of output and input parameters. Benchmarks (best practices) are represented by products that offer the best ratio of outputs to inputs creating a maximum efficiency value to customers, relative to the remaining products of the relevant sub-market. Therefore, to identify best practice bundles and to assess all other products of the respective sub-market relative to this best practice is what benchmarking is about. Only by examining segment benchmarks, strengths and weaknesses can be identified from a competitive point of view.

To put the above into a simplified formula we propose market structuring as a concept that combines market partitioning and benchmarking. To our knowledge, there is no study that jointly treats these two aspects. Building upon previous work, we introduce an integrative approach to market partitioning and benchmarking based on customer value and use a nonparametric technique known as Data Envelopment Analysis (DEA) as the methodological framework. Based on consumer ratings of several value relevant input and output attributes, we empirically apply our approach to the market for compact cars illustrating its potential for the analysis of competitive market structures.

Our work extends existing DEA studies related to product efficiency (e.g., Doyle and Green 1991; Kamakura, Ratchford, and Agrawal 1988; Murthi, Srinivasan, and Kalyanaram 1996;

Papahristodoulou 1997). In these studies, unlike in our approach, the DEA score is interpreted as a measure of technical or market efficiency rather than a measure of efficiency-based customer value. Furthermore, these studies do not apply the DEA concept in the context of marketing. Bauer, Staat, and Hammerschmidt 2000 have employed DEA as a marketing research method for product positioning but did not introduce the framework for market structuring.

3 An Integrated Approach to Market Structuring

3.1 Methodology

DEA is a non-parametric approach to measure the efficiency of observed output-input-structures (in DEA parlance: decision making units - DMUs), which can be companies or other organizations, processes, brands or, as in our case, products. Efficiency scores, measured on the basis of customer-relevant value parameters, are used as criteria for deriving partitions of the product-market as well as for deriving intra-partition benchmarks.

In a setting with multiple criteria, a consistent analysis of product value necessitates a simultaneous integration of all relevant parameters. Otherwise, it may well happen that a product performs best on one parameter but is inefficient in terms of another and only the choice of the parameter determines how the product is rated. Thus, a weighting scheme is necessary to cope with this problem. But with weighting the results generated by benchmarking exclusively depend on the weights assigned to the parameters.

A rationale for choosing a nonparametric technique is the fact that it does not project the observed data into an inflexible scheme of fixed weights. Exogenously applying the same vector of parameter weights to all products - which is generally the case in alternative approaches - would essentially apply one and the same global benchmark to all units (Bauer, Staat, and Hammerschmidt 2000). We consider the idea of a single proper benchmark to be misleading in our context because in that case only one strategy for optimizing products would be assumed in the analysis. Instead, the plethora of different marketing strategic possibilities needs to be considered when evaluating product efficiency. It is in the nature of marketing that alternative value-creating product concepts (parameter-combinations) exist to serve consumer segments with corresponding preferences. Consequently, if a concept of efficiency analysis is to be useful, it needs to calculate segment-specific efficiency scores.

In the sequel, we demonstrate that DEA is a powerful tool suited for the purpose structuring markets in a systematic and differentiated way. Our approach achieves benchmarking and market partitioning endogenously by assigning individual weights to all output-input-parameters. Thus, different products can be rated as efficient, i.e. represent best practice benchmarks.

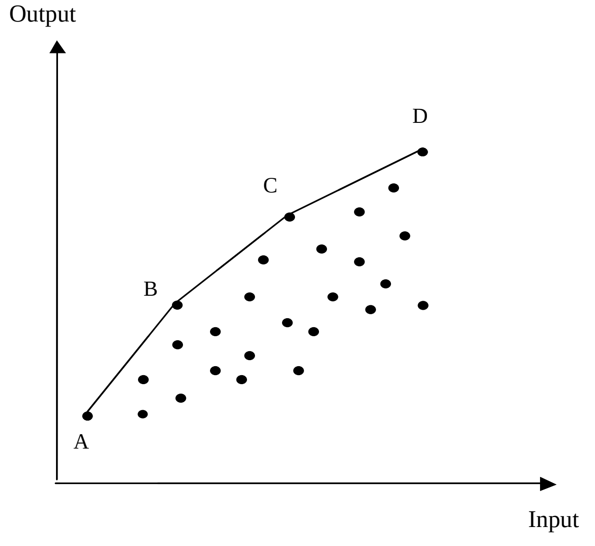

Figure 2: Constructing the efficiency frontier in the input-output-space

DEA determines the degree of (in)efficiency of a product by measuring its relative distance to an efficient frontier. This frontier (best value line) is made up of all identified “efficient” products, as for example products A to D in figure 2. At a specific scale level, each of these demands the lowest combination of inputs for given output characteristics in comparison to all other products and therefore creates a maximum customer value. These so-called efficient peers represent best-practice benchmarks. Inefficient units are located off the frontier depicted as the cluster of dots below the solid line connecting A, B, C and D in figure 2. This principle of estimating the value frontier of a product cluster adequately reflects consumer preference formation. Consumers choose the product from which they receive a maximum value in relation to the comparable alternatives. Thus, the efficiency yielded by a DEA represents the *relative* customer value.

A maximum relative customer value is not necessarily the maximum customer value in an absolute sense, i.e. it may be possible to further increase the customer value even of the efficient peers. Thus, the efficiency estimates for all DMUs can be characterized as upper bounds on their theoretical efficiency.

The estimation of the customer value of a particular product (indexed with subscript “0”) is formulated as a fractional programming problem:

Maximize

$$CV_0 = \frac{\sum_{r=1}^{R} u_r y_{r0}}{\sum_{i=1}^{I} v_i x_{i0}}$$

subject to

(2)
$$\frac{\sum_{r=1}^{R} u_r y_{rj}}{\sum_{i=1}^{I} v_i x_{ij}} \leq 1 \; ; \; j = 1, ..., J$$

and

$$u_r, v_i > 0; r = 1, ..., R; i = 1, ..., I,$$

where

J = number of products in the data set

R = number of outputs

I = number of inputs

y_{rj} = the value of the r^{th} output for the j^{th} product

x_{ij} = the value of the i^{th} input for the j^{th} product

u_r, v_i = positive weights given by the solution.

The sum of the weighted output to input ratios (CV) is maximized under the restriction that no other product attains a score exceeding 1 if the weights that maximize the CV of the product being evaluated (the DMU_0) are applied to it. The efficiency of each product is evaluated through comparison with all products. The number of optimization problems equals the number of products. Thus, all products with a CV of 1 offer a maximum relative customer value in the context of the investigated products. The CV is estimated with regard to the specific competitive situation in the market, allowing for an effective support of competitive advantage management.

Instead of applying the same vector of weights to the entire sample of products, as would be the case with standard approaches, DEA assigns an individual vector of weights to each product, which is optimally adjusted to each specific output-input-structure (non-parametric approach). Maximum weights are attached to those parameters on which a product compares favorably and minimum weights to those on which it compares unfavorably. The weights contain important information about the customer value drivers; these are the parameters that have been assigned high weights by the optimization algorithm.

Obviously, by maximizing the equation the highest plausible efficiency value is assigned to the inefficient DMUs. By comparing the inefficient products to their respective efficient peers, i. e. to the efficient units on the frontier located next to them, the inefficiency (the distance to the frontier) is minimized. This “nearest neighbor”-logic of DEA guarantees the similarity between inefficient products and benchmarks that are used as reference points for estimating their efficiency value.

Each product, whose efficiency is estimated through the same set of efficient peers, must have a comparable input-output-structure; for products with a different structure, different benchmarks are identified as reference points. All products benchmarked through the same efficient peers can then be aggregated - with their peers - to one sub-market. The identification of different benchmarks as well as similar inefficient products allows us to detect “natural” market partitions and associated benchmarks simultaneously.

The results of the proposed integrative modeling of market partitioning and benchmarking are in several ways useful for the management. New products can be targeted to those specific input-output-combinations that are value maximizing in the sub-market to which the product belongs. Furthermore, existing products can be evaluated and modified in order to improve performance. The closer a product is to the benchmark, the higher the consumer’s preference for the respective product will be.

3.2 Overview of the Approach

We will now illustrate our approach by mapping sub-markets onto the point on the best practice function (see figure 3) with the exact same output-input structure. For merits of simplicity, we assume an overall market made up of seven products (A to G) that can be described by two outputs (comfort, safety) and one input (price). To allow a two-dimensional depiction the outputs are standardized on the input.

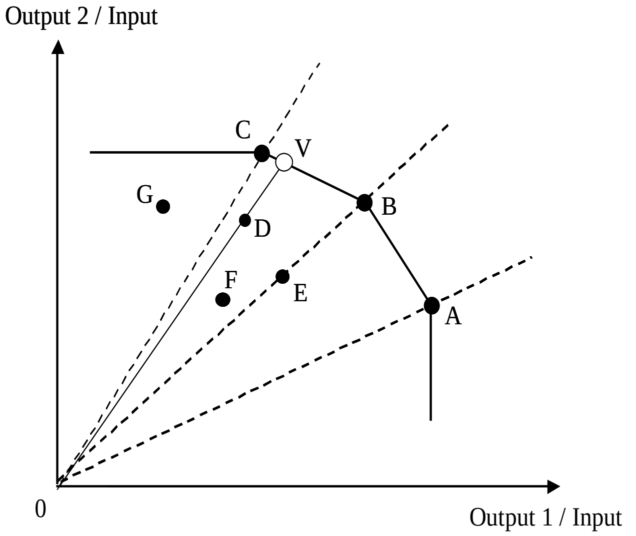

Figure 3: Illustrating sub-market boundaries

When considering either one or the other isolated value dimension (output), only one product - the one with the maximum level for the given dimension - could be in top rank. Obviously, more than one dimension will play a role in customers' preferences. This makes rankings based on single dimensions a moot exercise. In order to consider both (in general: more than one) value dimensions simultaneously, a weighting scheme is needed. We argued before that applying exogenous weights the identification of the best value products depends solely on the vector of weights assigned (Staat and Hammerschmidt 2000). By estimating an optimal vector of weights for each product endogenously this weighting dilemma disappears. Now, different parameter value combinations may be rated as efficient (A, B and C in figure 3), including combinations that do not contain a maximum value for either parameter (product B).

In our example all three products A, B, and C create superior customer value with a unique combination of outputs and inputs. Each of them can be interpreted as a specific value-benchmark (efficient peer), each representing a unique market-segment from a customer value point of view. Offering an undominated quality mix in relation to the price, they constitute the efficient frontier[1] of the market as a whole, offering the best value to customers with regard to

[1] Two lines branching off horizontally from point A and vertically from point C extend the frontier. This can be justified by the fact that points to the left of C offer as much of output 2 and less of output 1 than C and therefore can be considered a conservative approximation of the frontier beyond the points observed in the sample. The frontier below A is constructed analogously.

their specific preferences. In contrast, product F represents the relatively worst value within the reference set.

As in our stylized market in figure 3 shows, each cone that is formed by rays from the origin intersecting with an efficient product, forms a sub-market, the rays being the sub-market boundaries. Products D, E, and F are located in the same direction as products B and C, i.e. they create value in a similar way. Consequently, these three products belong to the same sub-market. But, for instance, F is less successful in creating value because it is dominated by a combination of B and C on both dimensions. Thus, for consumers whose preferences are reflected by parameter weights similar to those that are assigned to B, C and F, product F should not be their first choice. Consumers receive a higher value when buying products B or C.

In this simple example, we can partition the overall market into three sub-markets. Homogeneity within a sub-market is not merely defined through to the absolute levels of the single parameters, but rather with respect to the structure of value creation. The value structure is the proportion of the output parameters, which is similar for all products located in the same area. For example, the value of C and G derives mainly from output 2, which is offered in a high amount relative to output 1 when compared to the relevant sub-market. A's value structure is just the mirror image of C's. Hence, the 3 sub-markets derived in figure 3 define three different value segments.

Relative customer value is now estimated by DEA for each market partition. For example products D, E, and F are all evaluated through comparison with B and C because these are their efficient neighbors, which is the essence of intra partition efficiency evaluation. The efficiency value of D, E, and F is calculated only in comparison to B and/or C but not, for instance, to A. It would not make much sense if one were to use A as a benchmark for this segment since A with its high level of output 2 and its relatively low output 1 is qualitatively different from products B and F, which have a more balanced output structure.

The degree of inefficiency of a product is calculated by measuring its distance to the origin relative to that of an efficient benchmark. For instance, the benchmark for E is product B as the nearest point on the frontier. The inefficiency is calculated as the ratio of the distances of the two output combinations, i.e., $\overline{OE}/\overline{OB}$. The use of this ratio of distances aligns the above discussion with the following formal description: "Because the ratio is formed relative to the Euclidian distance from the origin over the (…) possibility set, we will always obtain a measure between zero and unity. We can also interpret the results for managerial (…) uses in a relatively straightforward manner. … Because we are concerned with output, however, it is easier to interpret (…) in terms of its reciprocal." (Charnes, Cooper, and Tone 2000, p. 10). The ratio $\overline{OB}/\overline{OE}$, the percentage of additional output required to obtain efficiency can be directly derived by subtracting 1.

Assuming the distance ratio to be 0.8 implies a relative CV for E of 0.8. This value can be interpreted as follows: for the same input (price) that has to be invested for B, product E offers only 80% of B's outputs. In other words, for the same price the customer receives 25% more comfort and safety from product B. To reach the position with a maximum value, E would have to increase the outputs to $1/0.8 = 1.25$ of the original level without increasing price.

Neither for D nor for F a single dominant product exists on the corresponding intersection with the efficient frontier. Hence, the benchmark used to assess the relative value of, say D, is a so-called "virtual DMU" V (see figure 3), a linear combination of the efficient peers B and C. The inefficiency score is calculated as $\overline{OD}/\overline{OV}$.

3.3 Formal Description

Having developed the intuition behind our approach in section 3.2 we now discuss the formal model. The fractional programming problem (2) is transformed into a more tractable linear programming equivalent (see Charnes, Cooper, and Rhodes 1978 and Cooper, Seiford and Tone, 2000, p. 23f). This is yielded if the denominator and the numerator of the objective function and the side conditions in (2) are divided by the aggregated inputs of DMU_0. The primal maximization program (3) is the linearized formulation of equation (2):

$$(3) \qquad \begin{aligned} &\max_{\mu,\nu} w_0 = \mu\, Y_0 \\ \text{s.t.}\quad &\mu Y - \nu X \le 0 \\ &-\mu \le -\varepsilon \\ &-\nu \le -\varepsilon \end{aligned}$$

The input-oriented model of the same problem is given by the dual minimization program:

(4)
$$
\begin{aligned}
\min_{\theta,\lambda,s^+,s^-} \; z_0 &= \theta - \varepsilon s^+ - \varepsilon s^- \\
\text{s.t.} \; Y\lambda - s^+ &= Y_0 \\
\theta X_0 - X\lambda - s^- &= 0 \\
\lambda, s^+, s^- &\geq 0
\end{aligned}
$$

In (4) the efficiency score is measured as the maximum proportional input reduction achievable for an inefficient product if it applied the same input-output-transformation (strategy for value creation) as the corresponding benchmark on the frontier.

The above mentioned problem has to be solved for each DMU in the sample. It has a number of side conditions, which are determined by the number of input and output parameters (I + R). In contrast, the primal problem (2) in ratio form has a number of side conditions equal to the number of DMUs. The efficiency score θ is transformed into the so-called slack augmented score z_0 by adding input slacks s^- and output slacks s^+ multiplied by an infinitesimal non-Archimedean ε. This non-Archimedean is usually a constant smaller than any positive real number and ensures that no segment of the frontier function has a zero or infinite slope.

The efficiency score is determined by comparing actual parameter values of DMU_0, which are denoted X_0 for inputs and Y_0 for outputs with the corresponding values X and Y of the reference unit. This unit consists of a linear combination of efficient peers in the market offering the highest amount possible of each characteristic $Y\lambda$ (equal or higher than Y_0) at the lowest inputs $X\lambda$ (equal or less than X_0). The factors λ in (4) denote the weights of the efficient peers in the reference unit.

To recur to the example in the previous section, the input-oriented formulation implies that the value of product E could also be maximized by reducing necessary inputs by 20%. Product B offers the same outputs with only 80% of the inputs required for E. This fraction of inputs is denoted by θ. It corresponds to our CV concept as defined in formula (2). In the case of product E, the reference unit consists solely of product B and therefore $\lambda_B = 1$ and $\lambda_{-B} = 0$. Thus, $1-\theta$ is the reduction of inputs necessary if E were to be efficient keeping its own value strategy, which is the same as B's.

The reference unit V relevant for product D is made up of B and C. Because V is closer to C, i.e., its structure is more like C's, we have $\lambda_C > \lambda_B$.

Slacks, s^- and/or s^+, exist for all parameters for which an adjustment by the proportional factor 1-θ would not suffice to reach a value-efficient position. An input slack indicates the additional reduction necessary for the parameter in question to match the corresponding value of the benchmark. Parameters with slacks of zero contribute to the efficiency of a product and indicate its strengths. Parameters with non-zero slacks signify the weaknesses of the product because small variations of these parameters would not immediately improve the value position a product. By assessing strengths and weaknesses DEA indicates individual strategies to improve the product efficiency for customers.

4 Empirical Application

DEA-based market partitioning and benchmarking is now applied to data from the compact car market. Our analysis includes 30 variants - our observational units - of the 11 best selling models –each from a different brand- in the German car market in 1994. These are (in alphabetical order) the Citroën ZX, the Ford Escort, the Honda Civic, Hyundai Lantra, the Mazda 323, the Nissan Almera, the Opel Astra, the Peugeot 306, the Renault Mégane, the Toyota Corolla and the Volkswagen Golf (Rabbit).

Automobiles are infrequently purchased items bearing some financial risk. This implies that a substantial fraction of consumers is likely to show high cognitive involvement leading to rational decision making (Kamakura, Ratchford, and Agrawal 1988; Papahristodoulou 1997). Moreover, compact cars are bought with little emotional involvement. On the output side the value of compact cars arises only to a minor extent from psycho-emotional or social attributes and to a major extent from technical and functional components (i.e., from basic utility).

Our analysis applies to this rational buyer segment: the data are not representative but taken from interviews with ADAC (German Automobile Club) members. Participation in these interviews required a meticulous documentation of a three-year period of car use, which proves the high informational involvement of the participants. Therefore, it is feasible to model customer value by technical parameters only. We use resale value after 4 years, reliability, safety, comfort, road performance and sufficiency of the catalytic converter as outputs. Price and annual running costs function as inputs. Instead of reporting on each single parameter value for all variants, we select a few exemplary cars and list only the minimum, the maximum and the average values of the sample.

Table 1: ADAC Member Survey 1996, Descriptive Statistics

Model / Brand	Price in DM	Running cost	Resale value	reli-ability	Road per-formance	E3Norm	comfort	safety
Honda Civic	23690	2899	.37	.98	20050 km	yes	.32	.37
Peugeot 306	29000	3392	.36	.94	21070 km	no	.40	.38
Toyota Corolla	23990	2815	.38	.99	19310 km	no	.38	.41
VW Golf	25700	2912	.56	.94	18280 km	no	.45	.41
mean	26766	3202	.38	.95	20364 km	.57	.40	.40
Maximum	36980	4727	.56	.99	29200 km	yes	.50	.45
Minimum	23100	2509	.30	.89	15470 km	no	.30	.37

Of the 30 analyzed model variants 40 % are efficient. They generate maximum relative value to customers and thus form the efficient frontier. These efficient peers represent value bench-marks for different sub-markets because they reach their position with a specific structure of the value-determining parameters mentioned above. We find that 8 of the 11 brands have at least one efficient variant in their line. Neither the Citroën or the Hyundai nor the Nissan has an efficient variant on offer.

To keep the presentation manageable we will not list the entire set of results, i.e., θ, λ, μ and ν for all 30 variants. Instead, we focus on a few particular models, which suffices to illustrate the approach developed above.

The Toyota Corolla, for example, is an efficient peer that offers below average or average outputs but requires lowest investments (price and running costs) from customers (see table 1). The Volkswagen Rabbit, on the other hand, requires above average inputs but provides “market leading” performance on resale value and comfort. Both models create maximum value in terms of the output to input ratio but with entirely different value creating strategies. Therefore, both models represent benchmarks of different sub-markets (“value clusters”).

In contrast, other car models like the Peugeot 306 are inefficient, i.e. they are dominated by a reference technology. The Peugeot 306 achieves less than the maximum CV of 1 (see table 2). The Corolla and the Civic are identified as the nearest efficient neighbors for the Peugeot 306. They form its reference unit.

The importance of the efficient peers for the reference technology of the Peugeot 306 is reflected in weights λ_i. The peers enter the reference unit with factors $\lambda_{Corolla} = 0.97$ and with $\lambda_{Civic} = 0.07$. Since the Corolla is located much closer to the Peugeot, i.e. it is much more similar to it (see table 1), it is much more important for the reference unit than the Civic. The efficiency score θ is estimated at 0.9, which implies that the Peugeot could create maximum customer value by reducing price and running costs by 10% (1-θ) provided that no slacks exist. But non-zero slacks have been calculated for 5 out of the 8 parameters (see table 3), which means that the Peugeot would have to improve its performance even more in order to become competitive.

Table 2: Efficiency score θ und weights λ w. r. t. to the virtual technology (for selected cars)

Model	θ	Civic	Corolla65	GolfS55
Honda Civic	1.000	1.000		
Toyota Corolla 65	1.000		1.000	
VW Golf S55	1.000			1.000
Peugeot 306	0.900	0.076	0.976	

For these slack-parameters, variation by the common factor 1-θ (10%) does not suffice to reach the efficient frontier. To calculate the variation required for a slack-parameter in order to reach an efficient level from a customer's perspective, the value for the slack has to be added to the 10% reduction. Slack-parameters represent critical value factors and can be interpreted as parameters whose performance is lagging especially far behind the value benchmark.

By means of the slacks, s^+ and s^-, and the efficiency score θ, DEA provides exact evidence of the magnitude by which any parameter must be reduced (inputs) or increased (outputs) in order to close revealed value gaps.

Table 3: Virtual Multipliers (for selected cars)

Model	Price	Running costs	Resale value	Reliability	Road performance	E3Norm	Comfort	Safety
Honda Civic	-0.372				0.299	0.127		
Toyota Corolla 65		-0.355		0.790		0.109		
VW Golf S55		-0.343	0.363			0.398		
Peugeot 306		-0.295			0.368		0.309	

According to the customer value criterion, the Honda Civic, the Toyota Corolla, the Nissan Almera and the Peugeot 306 belong to the same sub-market. A second value segment derived is made up of the Mazda 323, the Hyundai Lantra and again the Toyota Corolla. The Opel Astra and the VW Golf variants form a third segment. Like unit B in figure 1, the Corolla is located in a position where several sub-markets overlap.

Hence, the competitive market structure is determined by overlapping groups of products corresponding to different sub markets. The competitive intensity for a product can be estimated by the number of sub-markets a product is assigned to. The higher the dimensionality, the more segments possibly overlap. For example, the Corolla is located in the intersection of several sub-markets, i.e., it is comparable to the corresponding car models of these sub-markets. If comparability implies substitutability, the Corolla is exposed to much more competitive pressure than for instance the Ford Escort, whose variants are all located within only one sub-market. While the Ford Escort can be considered to be a successfully differentiated niche model, the Corolla is an “all purpose”-car, which has to compete almost against the entire compact car market.

By means of a DEA we structured the 30 compact car variants into three significant value-based sub-markets, whose benchmarks each reflect a successful strategy of maximizing value to customers. In addition to the three major sub-markets described above, six models successfully established themselves as efficient products in proper niches.

5 Conclusion

With DEA we propose a method to structure product-markets by using the criterion of customer value. Since the method measures customer value in a relative way it provides sub-market specific value benchmarks. This has two main advantages. First, DEA estimates intra-partition customer value. By means of the benchmarks sub-market boundaries can be identified. An overall market can thus be structured into product segments. Each segment represents its own specific approach towards the creation of customer value. Second, target positions are provided for each identified product-market. On these targets customer value management needs to focus in order to create maximum value for customers and in turn for business.

DEA is a non-parametric technique estimating individual results for each product. The method does not operate with aggregated measures, i.e., it does not use an average value function that is identical for all units. Instead, DEA assigns an individual value function to each product, indicating the way to maximize customer value.

Of course, a better description of the specific advantages of the variants is desirable, including non-technical output parameters like design or brand image. An integration of those parameters into a DEA model is easily handled, provided the data are available. The reason why in this particular study those criteria were not employed is due to the nature of the respective ADAC survey data.

The present analysis could be extended in various ways. First, it would be desirable to have some information on the image of the brands. However, we argued above that our analysis is concerned with the rational sub-segment of car users. Therefore, the lack of this type of information is not critical for our results. Second, weight restrictions (Cooper, Seiford, and Tone 2000, p. 151ff) could be used to incorporate a priori knowledge about the relative importance of some parameters. At last, it would be of interest to check the results for their statistical significance. The bootstrap provides a statistical foundation of the DEA framework (Simar and Wilson 2000, for an application, see Staat 2002).

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