Value Based Benchmarking and Market Partitioning

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Abstract: The paper offers an analytical approach for an integrated treatment of market partitioning and benchmarking within a Data Envelopment Analysis (DEA) framework. Based on an empirical example from the automotive industry we measure product efficiency from the customer's perspective. This is interpreted as customer value, i. e., as a ratio of outputs that customers obtain from a product (e. g., resale value, reliability) and inputs that customers have to invest (e. g., price, running costs). Products offering a maximum customer value relative to all other alternatives represent efficient peers, which constitute benchmarks for different sub-markets. All products benchmarked via the same efficient peer(s) constitute a sub-market including the benchmarks.

1 Introduction

A major tenet of marketing theory is the inclusion of benchmarking into the competitive advantage paradigm. Competitive benchmarks used by firms and managers as reference points evidently affect the choice, direction and implementation of performance-enhancing strategies (Shoham, Fiegenbaum (1999)). The strongest theoretical support for the use of benchmarking is given by strategic reference point theory, which is an extension of prospect theory. In this context the content and risk of marketing decisions are viewed to depend on whether managers perceive their firms as above, below or equal to some given reference point. Arguably, if for example a firm's product position is below the standards set by leading competitors, improvements or strategic action in general may be triggered. Success is viewed as something depending on the position of firms or products relative to competitors.

The reasons that account for the popularity in competition driven companies are twofold: first, with benchmarking performance is evaluated only with regard to other products in the market (relative performance evaluation). Second, benchmarks are real objects (”observed successes”) not hypothetical or prescriptive ideals.

Despite these advantages standard benchmarking tools suffer from several deficiencies (Staat, Hammerschmidt (2000)): When benchmarking in a multiple criteria setting a consistent ranking of products necessitates a simultaneous integration of all criteria. Otherwise, it may well happen that a product performs best on one parameter but is inefficient in terms of another. When applied in a multi-criteria setting the results generated by benchmarking exclusively depend on the weights assigned to the parameters. But applying the same vector of parameter weights to all products exogenously would essentially apply one and the same global benchmark to all units. This may lead to extreme performance differences, which are not caused by product inefficiency but by the fact that they may not be comparable to the benchmark.

In addition, with a fixed weighting scheme only one strategy for optimizing products would be rated efficient. In this case, the possibility of alternative approaches (parameter-combinations) to the generation of product value is neglected and at the same time the existence of different consumer segments is implicitly ignored. By using DEA, we develop an approach to derive product reference points to assess and improve product performance in a theoretically and methodologically sound way.

DEA is an exploratory data mining approach, which can be interpreted as a generalized form of benchmarking. The data mining aspect of DEA is given by the fact that the method reveals data structures by grouping observations around efficient units without the necessity of prior knowledge about the factors which determine efficiency. Related studies by Papahristodoulou (1997), Doyle, Green (1991) as well as Kamakura et al. (1988) also use DEA to evaluate product efficiency but not in a marketing context. Bauer et al. (2000) provide a DEA of the car market cast in a marketing context but do not introduce the concept of value based market structuring.

In this paper the efficiency value is measured as an input-output-ratio from the customer's perspective. We show that, in addition to this, DEA achieves market partitioning endogenously. By assigning individual weights to the input-output-parameters different products can be rated as efficient, i. e. serve as benchmarks. All inefficient products located next to the same benchmark(s) have a similar input-output-structure and are clustered in the same market partition. The identification of different benchmarks jointly with similar inefficient products DEA allows us to find "natural" market partitions (product segments). The according segment specific benchmarks are used to assess intra-partition efficiency. Based on an empirical application to the market for compact cars the DEA approach for benchmarking and market partitioning is illustrated.

2 Customer Value as a Basis for Benchmarking and Market Partitioning

Within a value based perspective consumers do not search for products with maximum quality or minimum price but seek to maximize the quality-price-ratio in the sense of value for money (Rust, Oliver (1994)). While forming their judgements about products consumers jointly consider both quality and non-quality related dimensions within an economically oriented decision concept of "higher-order-abstraction" (Sinha, DeSarbo (1998)). This embodies a return to cost trade-off, defined as customer value. This type of sophisticated, two-dimensional purchasing behavior can be expected especially in electronically mediated markets with information driven consumers.

Instead of viewing value solely as a quality-price trade-off, a more systematic, multi-attribute operationalization of customer value is needed (Huber et al. (2000)). Along with these requirements we conceptualize the two basic value dimensions in a more multi-faceted way by measuring customer value as a ratio of weighted outputs and inputs. The principle of modeling the customer value (CV) of a product, which we develop, can be represented as follows:

$$\mathrm{CV} = \frac{\text{Outputs}}{\text{Inputs}} = \frac{\sum_r u_r y_r}{\sum_i v_i x_i} \tag{1}$$

Inputs x and respective weights v are indexed by i. They represent an "investment" by the customer necessary to obtain and use a good. In addition to out-of-pocket costs such as price, insurance or running costs inputs could also be non-monetary sacrifices such as time, risk or search costs. Outputs y and respective weights u are indexed by r and represent "outcomes" from a product, i. e. performance attributes from which the customer derives his utility (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 in a customer‘s perspective. It can be understood as the return on customer‘s investment.

The analogy of CV and economic efficiency is obvious since products are chosen that offer maximum outputs for given inputs or that demand minimum inputs for a particular output level. This general concept models the customer's trade-off between all received outputs (positive consequences, utility, results) and all inputs (sacrifices, costs) across the entire process of purchasing and using the product. The single input-output-ratios are aggregated into an overall value measure. As a result, we obtain a generalized, broadly applicable measure of customer value because all kinds of customer relevant input and output parameters can be included in our analysis, independent of scale level or dimensionality.

Customer value has often been defined as a higher-order construct to evaluate products, containing much more choice relevant components than one-dimensional approaches do (Sinha, DeSarbo (1998) and Huber et al. (2000)). In spite of this, no empirical attempt has been made to structure product markets on grounds of the customer value. To this end, a market partition is interpreted as a cluster of products that are similar with regard to certain criteria and thus can be considered close substitutes (Bauer, Herrmann (1995)).

Conventionally, only utility or quality related attributes are used as such criteria (see Day et al. (1979)) without connecting them to price-variables within an input-output-function. Typical methods for sub-market identification are MDS, hierarchical cluster analysis or forced switching-methods (DeSarbo et al. (1998) and Day et al. (1979)). Such methods enable researchers to infer, which products belong to one sub-market in terms of similarity w. r. t. particular quality criteria.

Furthermore, these conventional methods do not provide information about which product represents reference units in each of the several sub-markets. We are not aware of any study that jointly treats both market partitioning and benchmarking. Our method enables us to partition the product market and to identify benchmarks for each partition endogenously within a value based view.

3 DEA-based Market Partitioning and Benchmarking

3.1 Basic Principles of DEA

DEA is introduced as a technique which enables the analyst to assess the efficiency value measured in the way described above. It is a non-parametric approach to measure the efficiency of observed output-input-structures or decision making units (DMUs), which can be companies, processes or like in this paper products. Thus, we refer to market partitioning in the generic sense as partitioning the product market in several segments (see Bauer, Herrmann (1995)). Product market partitions as well as intra-partition benchmarks and efficiency scores are estimated on grounds of customer value. Thus, results can be transformed in strategy advice for a customer value management (CVM) of products. DEA supports the development of customer value maximizing strategies, i. e. gives directions for the variation of the input and output parameters.

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. Efficient products offer a particular level and combination of desired outputs demanding the minimum inputs compared to all other products. All products creating a maximum customer value are rated "efficient". This reflects that customers choose the product from which they receive maximum customer value in relation to the relevant alternatives. Thus the efficiency yielded by a DEA is the *relative* customer value. The customer value estimation of a particular DMU_0 is represented in the following expression:

$$\max_{u,v} \mathrm{CV}_0 = \frac{\sum_r u_r y_{r0}}{\sum_i v_i x_{i0}} \quad \text{s.t.} \quad \frac{\sum_r u_r y_{rj}}{\sum_i v_i x_{ij}} \leq 1, \;\; j = 1, ..., J \qquad (2)$$

In the expression input weights are denoted v_i and output weights u_r with index i for inputs and index r for outputs whereas index j runs over the products. DEA assigns an individual vector of weights to each product, optimally adjusted on each specific input-output-structure. High weights are placed on those variables where a product compares favorably, low weights are placed on those variables where it compares unfavorably. These weights give CVM important information about the customer value drivers; these are the parameters that have been assigned high weights by the optimization algorithm.

The sum of the weighted output to input ratios, CV, is maximized under the restriction that no other product achieves a score greater than 1 if the weights that maximize the CV of the product being evaluated are applied to it. Thus, all products with a CV of 1 offer a maximum relative CV in the context of the relevant competition. With a DEA, CV is estimated specifically in relation to the competitive situation in the market, allowing an effective support of competitive advantage management.

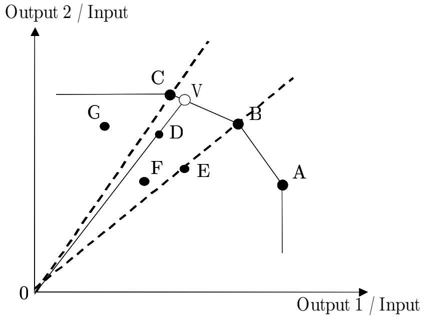
3.2 Market Partitioning and Benchmarking: An Overview

We will now illustrate the principle of CV determination in figure 1. It depicts an overall market with seven products (A to G) and two outputs (which can be thought of as comfort, safety) normalized by one input (price). When benchmarking with fixed exogenous weights only one product (A, B or C) could be ranked first. In this case, the ranking would exclusively depend on the relative weights assigned to the outputs. But because all three products create maximum CV in a different way of combining outputs and inputs each product can be considered efficient within a unique value segment. They constitute the efficient frontier of the market as a whole reflecting the best value offered to customers with regard to their specific preferences.

This frontier is extended by two lines branching off horizontally from point A and vertically from point C. This can be justified by the fact that points left to 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 points that are observed. This applies analogously to points below A.

The figure shows that each ray from the origin which intersects with an efficient product forms a boundary of a sub-market. In this example we can partition the overall market into three sub-markets. For each market partition, relative customer value is estimated. Products D, E,

Figure 1: Illustrating sub-market boundaries



and F are all benchmarked against reference units made up of B and C because these are the efficient neighbors. Hence, products B to F belong to one market partition. This is the essence of intra sub-market efficiency evaluation and implies that the efficiency value of D, E, and F is calculated only in comparison to B and/or C. It would result in a quite meaningless comparison 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 to F with their more balanced output structure.

The degree of inefficiency for a product is measured by 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 efficient frontier. Therefore the inefficiency is calculated as the ratio of the distances of the two output combinations to the origin, i. e. $\overline{\mathrm{OE}}/\overline{\mathrm{OB}}$.

Assuming the distance ratio as 0.8 means 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. For D, no existing product is located on the corresponding intersection with the efficient frontier. Hence, the benchmark used to assess the relative value of D is a so called "virtual DMU" V, a linear combination of the efficient peers B and C. The efficiency score is calculated as $\overline{\mathrm{OD}}/\overline{\mathrm{OV}}$.

3.3 The Formal Model

Continuing the formal discussion of DEA, the optimization problem (2) can be transformed into a linear programming problem. Formula (3) is the primal program of the linearized version of formula (2) above (see Cooper et al. (2000), p. 43). In this input-oriented formulation efficiency is measured as the proportional input reduction an inefficient product would be able to achieve if it applied the same input-outputtransformation (strategy) for value creation as the corresponding benchmark on the efficient frontier.

$$\begin{aligned} \max_{\theta,\lambda,s^+,s^-} \quad & z_0 = \theta - \epsilon s^+ - \epsilon s^- \\ \text{s.t.} \quad & Y\lambda - s^+ - Y_0 = 0 \\ & \theta X_0 - X\lambda - s^- = 0 \\ & \lambda, s^+, s^- \geq 0 \end{aligned} \tag{3}$$

The above problem has to be solved separately for each DMU in the sample. It has a number of side conditions that corresponds to the number of input and output parameters ($I + R$). In contrast, the dual problem (2) in ratio form has a number of side conditions equal to the number of DMUs. The efficiency score θ is augmented by input slacks s^- and output slacks s^+ multiplied by a non-Archimedian ϵ. It is thereby transformed into the so called slack-augmented score z_0. It 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. In an input-oriented model such as the one in (3) z_0 measures the input reduction possible for DMU_0 when compared to a reference unit.

This unit consists of a linear combination of efficient peers. Inputs x and outputs y of all DMUs are stacked in the vectors X and Y. The factors λ in (3) denote the weights of the efficient peers in the reference unit. It is characterized by outputs $X\lambda$ equal to or greater than outputs Y_0 of DMU_0 and inputs $X\lambda$ less than or equal to X_0.

To recur to figure 1 the input-oriented formulation implies that the value of product E could also be maximized by reducing necessary customer inputs by 20%. That is, the benchmark product B offers the same outputs for only 80% of the inputs (price to be invested) of E. This fraction is denoted by θ. It is equal to CV in formula (2). In the case of product E, the reference unit consists solely of the real product B and therefore $\lambda_B = 1$ and $\lambda_{-B} = 0$. The reference unit V relevant for product D consists of two efficient products, namely B and C. Because V is closer to C the factor λ_C is greater than λ_B.

Non-zero slacks, s^+ and/or s^-, exist for all parameters for which a variation by the proportional factor $1-\theta$ does not suffice to reach the position of the value benchmark. These parameters are weaknesses of the product because on those parameters small variations do not suffice to reach the position of maximum CV. Parameters with zero slacks do contribute to the efficiency of a product and thus indicate strengths of the product.

4 Applying DEA to Data

DEA-based market partitioning and benchmarking is now applied to data from the compact car market. Our analysis includes 30 variants -our observational unit- of the 11 best selling models in the German market in 1994. Compact cars are bought with little emotional involvement. On the output side the value of compact cars arises from technical-functional components (i. e. from basic utility). Thus, we can assume rational, cognitively involved buyers (Papahristodoulou (1997)) at least in a substantial segment of the compact car market.

Our analysis applies to this buyer segment, the data are based on interviews with ADAC-members (German Automobile Drivers Association) that show e. g. an above average road performance. Hence, it is justifiable 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 serve as inputs. Instead of reporting on all 30 variants we show only minimum, maximum and average values of these parameters. It is possible, however, to analyze the efficiency of products with higher emotional involvement by means of DEA. As a prerequisite, data on parameters which adequately describe the product features connected with to emotional involvement, must be available.

40 % of the analyzed model variants are efficient. They create maximum relative value to customers and thus form the efficient frontier. Due to space limitations, we cannot list the results for all 30 variants (available from the authors upon request). We limit our illustration to a few particular models, which suffices to understand the method. The Toyota Corolla, for example, offers below average or average outputs but requires the lowest investments (price, running costs) from customers. Instead, for the VW Golf a customer has to invest above average inputs but receives "market leading" performance on resale value and comfort in return. Both models create maximum value in terms of the output-input-ratio, which is maximal in relation to the market but with different value creating strategies.

In contrast, the Peugeot 306 is dominated by other car models (Corolla, Honda Civic) w. r. t. this ratio provided, thus it does not achieve a CV of 1. The Corolla and the Civic are identified as the nearest efficient neighbors for the Peugeot 306. They serve as benchmarks, from which the reference unit (virtual DMU) is combined. The Corolla and the Civic enter the reference unit with factors $\lambda_{Corolla} = 0,97$, $\lambda_{Civic} = 0,07$. The Corolla is located much closer to the Peugeot therefore it has a much higher importance for the benchmarking of the Peugeot than the Civic. θ is estimated at 0.9, implying that the Peugeot could create maximum CV when reducing price and running cost by 10% $(1 - \theta)$ provided that

Table 1: Descriptive Statistics, ADAC Member Survey, 1996

Parameters	Min.	Max.	Mean
resale value in % of purchase price	0.30	0.56	0.38
reliability on a scale from 0.2 to 1	0.89	0.99	0.95
safety on a scale from 0.2 to 1	0.37	0.45	0.40
comfort on a scale from 0.2 to 1	0.30	0.50	0.40
road performance in km p. a.	15.470	29.200	20.364
advanced catalytic converter (E3 Norm)	0	1	0.57
price in DM	23.100	36.980	26.766
running costs in DM p. a.	2.509	4.727	3.202

no slacks exist. But we have non-zero slacks for 5 parameters (price, resale value, reliability, E3 norm, safety). By means of the slacks s^+, s^- and the efficiency score θ DEA provides direct implications for deriving value enhancing strategies. A CVM obtains exact indications of how much any parameter have to be varied to close revealed value gaps.

All other inefficient car models, whose reference point is made up by the Corolla and the Civic are partitioned in the same sub-market.

5 Conclusion

With DEA we propose a method to structure product-markets based on customer value. Since the method measures customer value in a relative way it provides sub-market specific value benchmarks, which has two main advantages. First, DEA estimates intra partition costumer value. An overall market can thus be structured into product segments. Each sub market represents an own, specific approach of creating customer value. Second, target positions are provided for each identified sub-market. On these targets a CVM should be aligned in order to create maximum value for customers. DEA assigns an individual value function to each product, indicating a way to improve (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. Also, several extensions of the DEA specification used in this paper are available which could be applied to our data. For instance, the bootstrap provides a statistical foundation of the DEA approach (for an application, see Staat (2000)).

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