INSTITUTE FOR MARKET-ORIENTED MANAGEMENT
UNIVERSITY OF MANNHEIM, GERMANY

A Super Efficiency Model for Product Evaluation

Matthias Staat [1] and Maik Hammerschmidt [2]

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[1] *School of Economics, University of Mannheim, L 7, 3-5, 68131 Mannheim, Germany*

[2] *School of Business Administration, University of Mannheim, L 5, 1, 68131 Mannheim, Germany*

Abstract

This study applies a Super Efficiency Data Envelopment Analysis model to evaluate the efficiency of cars sold on the German market. Efficiency is conceptualized from a customers' perspective as a ratio of outputs that customers obtain from a product relative to inputs that customers have to invest. The output side is modeled as a set of customer-relevant parameters such as performance attributes but also non-functional benefits and brand strength. More than 60% of the cars are efficient but the analysis shows marked differences regarding their degree of Super Efficiency. Super Efficiency indicates the extent to which the efficient products exceed the efficient frontier formed by other efficient units. Based on the parameter weights, segments of cars with a particular mix of characteristics can be identified; cars with a comparative advantage relative to their competitors who provide the same mix are characterized as the reference points within a given segment.

1 Introduction

Frequently, i.e. in consumer reports, products are evaluated by applying a fixed set of weights to a number of product attributes. For cars, these may be quality, durability, engine performance and others. This type of evaluation typically results in a ranking of products, which informs consumers about the "best buys" in some product category. This method of product evaluation has the advantage of being simple but may not be equally informative for all consumers. The weights applied to the product attributes are, even if developed by experts, somewhat arbitrary. For instance, products with a good performance on attributes with relatively high weights will be rated as "best buys" (Norman and Stoker 1991). These weights may be a misrepresentation of the preferences of a large number of consumers, however. Some consumers, for instance, may care almost exclusively about the durability of a product and consider all other product attributes as being of minor importance. Any weighting scheme that views durability as one among many important attributes and assigns durability an average weight, will generate a ranking that is of little relevance to these consumers.

Over the past decade, several authors (see the literature cited below) have applied Data Envelopment Analysis (DEA) to evaluate products. DEA assigns individually optimized attribute weights to each product in the sense that no other weights exist that will lead to a better ranking for a given product. The most durable product e.g., will be given a maximal weight for durability and no other product will be able to dominate it. However, this will render a ranking with a potentially large number of undominated or "efficient" products which are all placed at the top of the ranking.

The purpose of our analysis is twofold. First, we will demonstrate how the so-called SE model (SE) of DEA introduced by Andersen and Petersen (1993) solves the problem of standard DEA, namely that many products are rated as efficient and tie for the top position in the ranking. The SE model was developed specifically for the purpose of ranking efficient units in DEA.

The second important objective of our analysis is to link DEA studies on product evaluation to the marketing literature on product choice. Up to the present, DEA analyses have been presented simply as a more flexible or "smarter" approach to product evaluation. The DEA results, however, can be closely tied to marketing concepts and have more to offer than a ranking or the detection of "best buys". In fact, they can be used for the purpose of market segmentation which renders them informative not only for the consumers but also for the suppliers of the product.

This paper is organized as follows: First, we will discuss the concept of efficiency and more specifically product efficiency in the marketing context. Next, the concept of customer value will be linked to DEA-based product efficiency evaluations. We then discuss the advantages of the SE model vs. the standard DEA approach for the purpose of product evaluation. Results for the evaluation of middle class cars will illustrate the usefulness of our approach. A final section provides a summary of our findings.

2 Efficiency in Marketing

The literature on assessing marketing performance has long advocated the use of productivity or efficiency measures. On the basis of an extensive survey, Bonoma and Clark (1993) conclude that the most popular measure of marketing performance is efficiency, defined as an output to input ratio. Such productivity measures can be based on physical, non-monetary metrics (as for instance sales volume per salesman-hour or orders divided by calls) or monetary metrics (e.g., channel revenues to channel costs). The widespread use of the ratio concept of efficiency for assessing the performance of marketing functions is documented in Murthi, Srinivasan, and Kalyanaram (1996) and Parsons (1994). Virtually all the marketing performance research has concerned the managerial efficiency of marketing processes like selling (Mahajan 1991; Athanassopoulos 1998, Horsky and Nelson 1996), marketing channel design (Coughlan and Flaherty 1983; Ratchford and Stoops 1988), advertising (Achenbaum 1992, Luo and Donthu 2001) and promotion (Abraham and Lodish 1993) or - on an aggregated level - the efficiency of the overall marketing function of a firm or branch (Murthi, Srinivasan, and Kalyanaram 1996; Hershberger, Osmonbekov, and Donthu 2002).

The efficiency concept has, however, less frequently been applied to assess the performance of products. This is surprising because products represent the tangible, marketable outcomes which reflect all marketing processes. Therefore, the optimization of products from a customer's perspective is to be seen as a crucial task. Thus, "marketing economists" should consider efficiency not only a supply-side but also a demand-oriented concept (Doyle and Green 1994; Parsons 1996). A prerequisite to establish profitable customer relationships is that products have to create superior value to customers (Srivastava, Shervani, and Fahey 1999; Staat, Bauer and Hammerschmidt 2002). The more efficient a product provides a set of demanded characteristics (outputs) for given expenditures (inputs) the higher is its economic value to customers. Providing high product efficiency *for* customers may in the long run result in a higher economic value *of* the customers for the supplier. Despite this, the efficiency construct has not been employed comprehensively to conceptualize and analyze the customer value of products.

3 Product Efficiency Analysis with DEA

3.1 The Concept of Product Efficiency

From an economics 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). When selecting products consumers consider both quality and non-quality related dimensions within an economically oriented decision concept of "higher-order-abstraction" (Sinha and DeSarbo 1998; Zeithaml 1988). As a first simple definition, product efficiency can be conceptualized as quality-price-ratio or a performance-price-ratio in the sense of value for money (Despotis et al. 2001).

Instead of viewing efficiency merely 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. Further studies that call for such a multi-faceted conceptualization of customer value are, e.g., Sinha and DeSarbo (1998) and Huber, Herrmann, and Braunstein (2000). In line with these requirements, product efficiency or customer value (*CV*) may be measured as a ratio of some function *f* of the outputs and some function *g* of the inputs of a product:

(1) $$CV = \frac{f\left(\text{Outputs}\right)}{g\left(\text{Inputs}\right)} = \frac{\sum_r^R u_r y_r}{\sum_i^I v_i x_i}$$

Inputs x and respective weights v are indexed by i. They represent the customer's "investments" made in order to obtain and use a good. 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). Frequently, these functions take the form of a fixed weighting scheme for the product characteristics. The largest German association of car drivers (ADAC), for instance, regularly tests new cars and ranks them according to their performance on several parameters in this way. A multitude of single output-input ratios have to be aggregated into an overall measure. The resulting product efficiency score can be seen as a measure of customer value of a product. It is the customer's economic value derived from the product and can be understood as the return on customer's investments. However, if the weights are fixed, this may not reflect the preferences of many consumers.

An alternative to product evaluation with a fixed weighting is DEA, non-parametric method to determine the relative efficiency of multiple input-multiple output-structures. The few studies that have dealt with product efficiency analysis using DEA can be divided into two groups. The first stream of approaches measures efficiency only by technical-functional parameters and may be referred to as "*technical approaches*" (Doyle and Green 1991, 1994; Odeck and Hjalmarsson 1996; Papagapiou, Mingers, and Thanassoulis 1997; Papahristodoulou 1997; Bulla et al. 2000; Despotis et al. 2001). These approaches neglect that non-technical attributes also - and in some product categories predominantly - affect consumer choice. These studies do not employ the concept of product efficiency within the comprehensive perspective of consumer theory which represents the dominant framework for marketing research.

The second stream follows the theoretical requirement that the product efficiency in the sense of customer value must consist of a multitude of purchase-relevant components where qualitative attributes have to be included (Fernandez-Castro and Smith 2002; Zeithaml 1988). These studies aim at a *market-oriented product evaluation*. The customer view is assured by integrating all characteristics from which utility is derived. Very few empirical attempts have been made to make such a broad construct of product efficiency operational and to assess products accordingly (Staat, Bauer, and Hammerschmidt 2002; Fernandez-Castro and Smith 2002; Bauer, Staat, and Hammerschmidt 2003).

All studies cited above, whether technical or market-oriented, have applied DEA to measure and analyze product efficiency. Because several DEA applications exist in this field of research the principles and implications of this method are discussed rather briefly. The basic DEA model is used as the starting point to develop an extended approach for product evaluation drawing on the market-oriented perspective mentioned above.

3.2 DEA as a method of product efficiency analysis

The use of DEA for the purpose of product evaluation is consistent with the characteristics approach to consumer theory widely established in the literature. It considers goods not as desirable by themselves, i.e. as "entities" but as bundles of qualitative and quantitative characteristics which create utility for the consumer (Lancaster 1966; Fernandez-Castro and Smith 2002). According to this understanding we consider products as bundles of output and input parameters on which product efficiency analyses should be based. In the perspective of this paper, evaluating and selecting competing products is seen essentially as a problem of multi attribute decision making whose solution requires the use of weightings (Doyle and Green 1994).

DEA simultaneously integrates multiple input- and output attributes, still yielding a single efficiency score. No a priori specifications of the input and output weights are required, however. Thus, DEA avoids the problem that a product performs best on one parameter but is inefficient in terms of another and only the choice of the weights determines how the product is rated. It is in the nature of marketing that alternative value-creating product concepts (parameter-mixes) exist to serve consumer segments with corresponding preferences. Therefore, the plethora of different product strategies needs to be considered when evaluating product efficiency. The relevance of DEA is obvious, because it achieves product evaluation by assigning individual weights to all output-input- parameters for each product. Thus, different products can be rated as efficient representing a set of multiple benchmarks. Out of this set DEA assigns customized benchmarks to each inefficient product adjusted to their specific characteristics mix.

The degree of (in)efficiency of a product is determined by measuring its relative distance to a product frontier which is made up of all identified efficient products. At a specific scale level, each of these demand the lowest inputs for given output characteristics compared to all other observed units and therefore create a maximum customer value. Inefficient units are located off the frontier. Thus, the efficiency yielded by a DEA represents the *relative* product efficiency. In the sequel, we present a formal discussion of DEA which we limit to the interpretation of DEA results as indicators of customer values and as a means of market segmentation.

The right hand side of (1) can be extended by a side condition which results in a normalization of the customer value or efficiency score to yield the ratio form of the DEA program. This in turn can be transformed into an easily solvable linear programming equivalent (see Charnes, Cooper, and Rhodes 1978). The primal maximization program (2) is often referred to as the *multiplier form*.

$$(2) \qquad \begin{aligned} &\max_{\mu,\nu} w_0 = \mu \ Y_0 \\ &s.t. \ \ \mu Y - \nu X \leq 0 \\ &\qquad -\mu \leq -\varepsilon \\ &\qquad -\nu \leq -\varepsilon \end{aligned}$$

In the multiplier version the program selects the weights μ and ν that are most favorable for the unit under investigation. The weights contain important information about the efficiency contributions of the parameters. Efficiency drivers (i.e. strength) of a product – observations in DEA data are generally referred to as DMUs - are those parameters that have been assigned high weights. Obviously, by maximizing the equation the highest possible efficiency value is assigned to all products.

The following minimization problem (3) is the so called *envelopment form* of the DEA LP and is the dual of the multiplier version. In contrast to the literature cited above, we use a variable returns to scale specification (VRS) of the DEA model introduced by Banker, Charnes, and Cooper (1984). The middle class car market comprises a wide range of models (see table 1 below) for which the assumptions implied by a constant-returns to scale (CRS) specification does not seem warranted. Since we estimate a variable returns to scale model, the condition $e\lambda = 1$ needs to be added, yielding the following LP

$$
\begin{aligned}
&\min_{\theta,\lambda,s^+,s^-} z_0 = \theta - \varepsilon s^+ - \varepsilon s^- \\
&\text{s.t. } Y\lambda - s^+ = Y_0 \\
&\theta X_0 - X\lambda - s^- = 0 \\
&e\lambda = 1 \\
&\lambda, s^+, s^- \geq 0,
\end{aligned} \tag{3}
$$

where e is a vector of ones of a suitable dimension. In (3) the efficiency score indicates the maximum proportional reduction that could be achieved simultaneously in all inputs without decreasing actual outputs. When achieving this maximum reduction the product reaches the corresponding benchmark on the frontier. The efficiency score in the envelopment LP (3) is determined by comparing actual parameter values of the product that is evaluated, the so-called DMU_0, which are denoted X_0 for inputs and Y_0 for outputs with the corresponding values 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 (3) denote the weights of the efficient peers in the reference unit. For all parameters with non zero slack variables (s^- and s^+) the proportional reduction does not suffice to reach an efficient position. The non-Archimedean ε 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.

Products with $\lambda_j > 0$, where j is an index for the observations, are part of the reference product for a given inefficient product. DEA allows the detection of market partitions by identifying different benchmarks as well as similar inefficient products. Each product, whose efficiency is estimated through the same set of efficient peers, must offer a comparable mix of characteristics (input-output-structure). For products with different proportions of attributes, different benchmarks are identified as reference points. Consequently, all products benchmarked through the same efficient peers can then be aggregated – together with their peers - to one sub-market (Staat, Bauer, and Hammerschmidt 2002).

The DEA model that has been applied in nearly all previous studies on product efficiency analysis is the original model developed by Charnes, Cooper and Rhodes (1978). This standard specification is therefore referred to as CCR-model and implies the CRS assumption.

Even with a CRS-technology, a considerable proportion of observations are characterized as efficient. This holds especially in cases where the number of observations is small relative to the dimension of the parameter space. The phenomenon of "specialization" in form of product differentiation adds to this effect, i.e. a large number of units are typically rated as efficient only because they have singular input-output combinations. In 13 empirical investigations on product efficiency using the standard formulation of DEA the authors found that the median percentage of efficient products was at 40%. This amount renders basic DEA less useful for a comprehensive investigation of a complete product market.

3.3 Basic Principles of Super Efficiency

In the remainder of this section we will briefly introduce an extended approach of product evaluation based on the SE model that overcomes the above mentioned limitation of the standard model. We suggest that the discriminatory power of the SE model provides insights that cannot be gained with standard DEA. To our knowledge no study exists that employs the SE model for product evaluation.

Using a simple example with 5 fictitious products (A - E) that can be described by two inputs (price, running costs) and one output (quality) we demonstrate the advantages of the SE analysis vis-à-vis the efficiency estimation procedure of standard DEA. To allow a two-dimensional depiction the inputs are standardized on the output (see the left graph in figure 1). As products A, B, C and D are not dominated they are their own reference points and are assigned an efficiency score of 1.0 (100%) when employing the standard DEA approach. Therefore, products A to D represent the efficient peers. They form the reference set for all inefficient products that are located off the frontier. Because each efficient unit serves as its own reference point the basic DEA model assigns identical efficiency scores equal to one to all efficient units.

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 secures the similarity between inefficient products and benchmarks that are used as reference points for estimating their efficiency scores. The identification of reference points in terms of benchmark product(s) has valuable implications for product design. Evidence that competitive benchmarks in sense of target positions affect the choice and the modification of product strategies is provided in Shoham and Fiegenbaum (1999).

In our example, only product E is dominated. An inefficient product (like E) is compared to a reference point on the frontier representing an efficient product or linear combination of such products that demand not only the same level of inputs but also the same inputs mix from customers. The reference product indicates how an inefficient product would have to improve (lower) its inputs in order to be considered one of the "best buys". In the case of E, the corresponding reference point is a so-called virtual reference product V, a linear combination of the observed efficient products C and D, which are the nearest neighbors of E on the frontier (see the intersection of the ray of origin and the frontier in fig. 1). The efficiency score of E is calculated as the ratio of the distances 0V and 0E which is less than one. The score reflects the minimum proportional decrease in inputs yielding efficiency.

The results for inefficient products are the same when evaluated with the SE or with the standard DEA model. The difference between the standard and the SE approach lies in the treatment of efficient units. Consider an evaluation of Product B in detail. According to the standard model the reference point of B is B itself, the efficiency score equals 0B/0B = 1.0. The degree of SE of product B can, however, be determined by excluding B from the reference set. The elimination of B implies that B is compared to that input frontier spanned by the remaining set of efficient observations (in our case A, C and D). As can be seen from the right graph of fig. 1, the reference point in the evaluation of efficient B is W as a linear combination of A and C. Thus, B is assigned a SE index of, say 1.25 (equaling the ratio 0W/0B, see fig. 1). The score reflects the maximum proportional increase in inputs preserving efficiency.

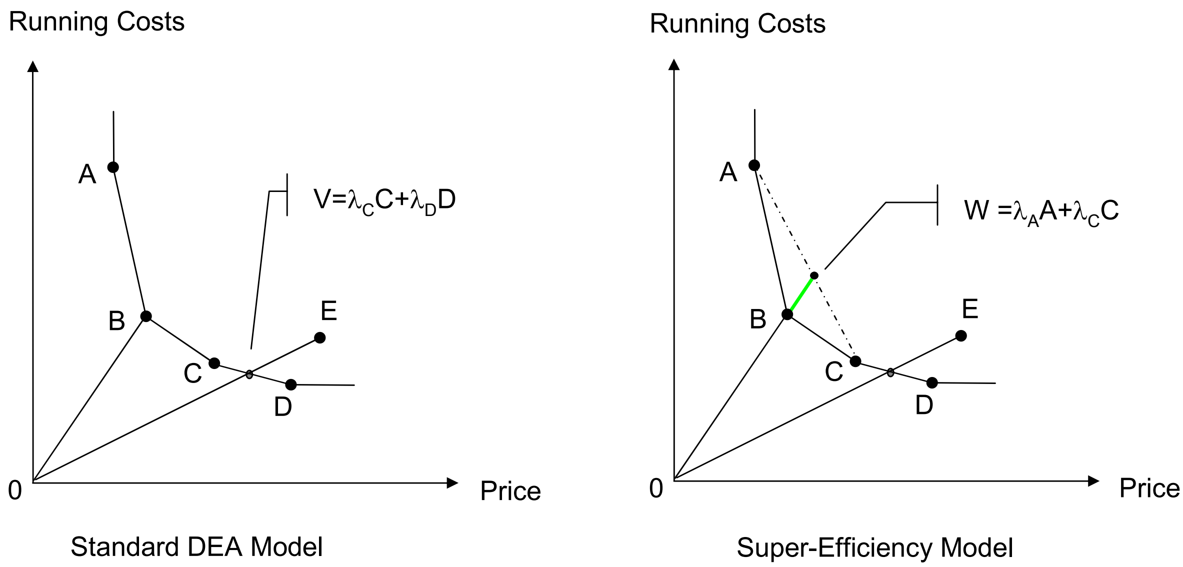


Figure 1. Standard DEA vs. Super Efficiency Model

The ability to differentiate the efficient products has several managerial implications for product policy. The SE score of 1.25 for product B implies that even if consumers had to pay

25 % more inputs for product B it would remain efficient, i.e. it offers maximum customer value relative to inefficient competitors. By using the SE procedure a ranking of the total set of products can be obtained. Consequently, influential units that push out the frontier can be identified and the degree of competitive advantage of efficient products can be assessed.

The mathematical formulation of the SE model requires a reformulation of the linear program of the original DEA model (3) presented above. This can be demonstrated with the dual LP (4) (Andersen and Petersen 1993)

$$
\begin{aligned}
\min_{\theta,\lambda,s^+,s^-} z_0 &= \theta - \varepsilon s^+ - \varepsilon s^- \\
\text{s.t. } Y\lambda - s^+ &= Y_0 \\
\theta X_0 - X\lambda - s^- &= 0 \\
\lambda_0 &= 0 \\
e\lambda &= 1 \\
\lambda, s^+, s^- &\geq 0,
\end{aligned}
\tag{4}
$$

In order to obtain individual reference functions for the efficient observations as well, the column of the unit being scored (DMU_0) has to be removed. Note, however, that the results for the standard model can always be recovered from the SE scores by setting all scores greater than one to unity.

4 Empirical Application

4.1 Data

The DEA approach of product evaluation is now applied to data from the market for middle class cars in Germany. Our analysis includes 48 variants of 17 the best selling models of 16 different brands. In order to ensure comparability between all products in the data set not all models of the middle class segment are included, e.g. vehicles with Diesel engines and convertibles were excluded.

Automobiles are infrequently purchased items bearing some financial risk. This implies that a substantial fraction of consumers is likely to show high cognitive involvement seeking for a rational decision making (Papahristodoulou 1997). Technical and cost parameters can be assumed to be important choice criteria. Most related studies use price as the only input (see Doyle and Green 1991, 1994; Papagapiou, Mingers, and Thanassoulis 1997; Papahristodoulou 1997; Despotis et al. 2001; Fernandez-Castro and Smith 2002;) although other costs that are relevant for the purchase decision - e.g. running costs - have to be included. In addition to technical features, non-technical parameters have to be considered in order to meet the requirements of a comprehensive performance evaluation. Modeling product efficiency only with technical features, which is typical in most related studies, contradicts the reality of purchase behavior (Lancaster 1966; Bearden and Etzel 1982). The value of middle class cars arises not only from technical parameters but to a significant extent from psycho-emotional or social attributes like brand image (Grubb and Grathwohl 1967; Bearden and Etzel 1982).

Mason et al. (2001) claim that in addition to rational considerations affective elements play a role for the purchase decision of a car as well. The majority of consumers shows high emotional involvement when buying a car. Cars can, according to a study by Bearden and Etzel (1982), be considered as symbolic products which are used to demonstrate status and the ability to afford luxury.

We use comfort, safety features and engine power (HP) as technical outputs. The data are taken from car tests conducted by the ADAC. Comfort and safety are evaluated, i.e. by crash tests, and are rated on a scale from 0 to 5 and 0 to 1, respectively. As an important safety feature, the number of airbags is used as a separate output. Non-technical outputs include special equipment, “Gimmicks” (symbolic attributes that signal uniqueness and differentiation of an individual) and brand strength. The latter is measured as an index of brand awareness, image, sympathy and recognition. The German Automobile Club (ADAC) suggests a similar operationalization of automobile brand equity (see ADAC 2001). Special equipment like air conditioning or gimmicks like a surround sound stereo system are added to an index. Price and running costs (exclusive depreciation) serve as inputs.

Table 1

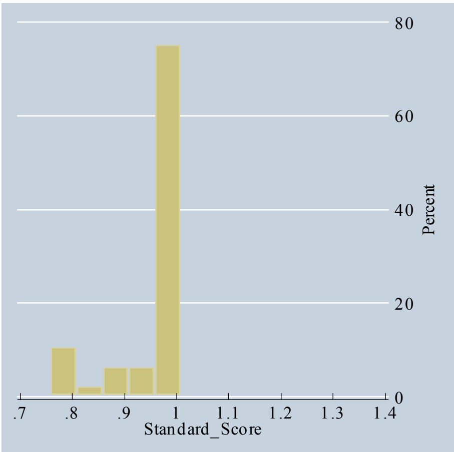
Descriptive Statistics for input and output parameters

	Price €	Running costs €	Comfort	Airbags	Safety	Engine power	Special equipment	"Gimmicks"	Brand strength
Mean	16,045	287.85	2.33	4.71	0.52	106.04	1.42	2.79	3.03
Standard deviation	4129	30.53	0.79	0.97	0.50	26.09	0.54	0.94	0.73
Maximum	27,027	364.00	3.00	6.00	1.00	172.00	2.00	5.00	4.55
Minimum	9694	246.00	0.00	4.00	0.00	74.00	0.00	1.00	2.13

We use the street price of the cars charged by re-import retailers, which we believe is more realistic than the fictive list price of authorized dealers. The latter is hardly ever paid by the customer. Compared to the previous studies on car efficiency the multitude of employed parameters conceptualizes the customer value of cars in a more adequate way. The outputs selected are deemed by most commentators to be the purchasing-relevant characteristics of a car in Germany (ADAC 1997; ADAC 2001; Fernandez-Castro and Smith 2002). The descriptive statistics of the selected variables can be found in table 1.

4.2 Results

The distribution of efficiency scores is shown in fig. 2. Applying the standard model results in a spiked distribution of efficiency scores (see the histogram to the left in fig. 2). Standard DEA leaves 66.6% (32/48) of the cars with an undifferentiated score of unity, which is obviously not helpful for assessing the competitive position (relative performance) of the efficient cars themselves. Moreover, for the majority of the investigated products only limited marketing implications and almost no support for consumer decision making can be derived.



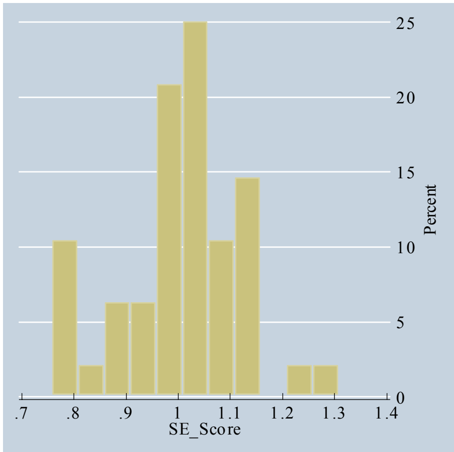


Figure 2. Distributions of efficiency scores

In contrast, the SE model enables a more differentiated ranking of all cars, including the efficient ones (see the histogram to the left of fig. 2). This adds more information about the properties and functioning of the efficient cars. Out of the 32 efficient cars 27 are super efficient obtaining a score exceeding unity. Only 5 cars have an index value of exactly 1.0.

Table 2

The five most efficient and inefficient cars

Position in Ranking	Model	Efficiency Score (reference set)
1	RENAULT LAGUNA1.8 16V DYNA	1.31 (17)
2	BMW 318 I	1.22 (1)
3	BMW 330 I	1.15 (11)
4	HYUNDAI ELANTRA 2.0 GLS	1.15 (4)
5	BMW 316 TI COMPACT	1.14 (0)
	…	
44	ROVER 75 CONNOISSEUR	0.89
45	ALFA ROMEO 156	0.87
46	MAZDA 626 1.8 CC COMFORT	0.86
47	ROVER 75 CLUB	0.78
48	ROVER 75 CLASSIC	0.77

To conserve space, we only list the five most efficient and the five most inefficient cars according to our ranking. With standard DEA, where the first 5 models in Table 2 are assigned a score of unity, no further information could be derived for these models. In contrast, the SE results show considerable differences concerning the extent of value creation to customers. The Renault Laguna provides maximum customer value and represents the "best buy" in the middle class market. The SE score of 1.31 implies that even if customers would have to pay 31 % more inputs (price, running costs) for the Renault they still would make an efficient purchase decision (i.e. get maximum value in relation to the observed alternatives). Contrarily, Rover 75 variants provide poorest value in the market and are the "worst buys". When buying the reference cars of Rover's models customers would receive the same outputs for less than 80% of the respective inputs. Thus customers could improve their purchase efficiency significantly by not buying a Rover 75.

DEA results provide further useful information for product marketing in form of the variables generated by the two linear programs. First we consider the virtual multipliers given by the primal solution (see (2) above). The product-specific multipliers indicate the parameters on which the product performs strongly relative to its immediate competitors, i.e. the parameters with the highest contribution to the product's efficiency. Thus the multiplier patterns provide information about the particular product strategies (parameter mix) employed in order to create customer value. Zero multipliers indicate that from the corresponding attributes no benefits are derived (Fernandez-Castro/Smith 2002).

Table 3

Self Evaluators

Model	Score	Price €	Running costs €	Comfort	"Gimmicks"	Special Equipment	Airbags	Safety	Power	Brand strength
BMW 316TI COMPACT		14,733	247	1	1	1	4	0	85	4.55
HYUNDAI SONATA 2.0 GLS X.		11,627	288	3	3	1	4	1	96	2.13
JAGUAR X-TYPE 3.0 EXEC.		27,027	348	3	2	1	6	1	172	2.5
Multipliers										
BMW 316TI COMPACT	1.15	0.98	0.02	0	0	0	0	0	0	1.15
HYUNDAI SONATA 2.0 GLS X.	1.11	1	0	0.48	0.17	0	0	0.11	0.34	0
JAGUAR X-TYPE 3.0 X.	1.03	0	1	0.29	0	0	0	0	0.73	0

For a detailed interpretation of the results we focus first on a set of so-called self evaluators, i.e. cars that are never part of the reference unit of any other car like the BMW 316 Ti Compact (see table 3). It is interesting to observe that this BMW, which is one of the smallest models in the BMW product line, derives its efficiency on the output side exclusively from its high value for brand strength. It seems intuitive that the BMW, a rather high priced middle class car, will appeal to customers who value its brand more than any other aspects of it. Likewise, the Jaguar X-Type derives its efficient position from a combination of comfort and engine power. This fits with Jaguar's marketing strategy and the fact that over the past two decades the brand has lost much of its once considerable strength. The Hyundai Sonata instead derives its efficiency from a combination of a low price and a number of positive multipliers on its output parameters. Given Hyundai's strategy of offering fully equipped cars at a very reasonable price, this result has an intuitive appeal. These self evaluators have a unique positioning within the market and fit with typical niche models referring to common market opinion (W&V 2003). This may serve as an indicator for the validity of our methodological approach.

Table 4

Data and super efficiency results for selected models

			Multipliers								
	Efficiency score	Weight λ	Price €	Running costs €	Com-fort	"Gim-micks"	Special Equipment	Airbags	Safety	Power	Brand
MAZDA 626 2.0 EXCL.	0.98		1.00	0	0	0.13	0,57	0.05	0	0.24	0
MITSUBISHI CARISMA 1.6 C.	1.11	0.53	1.00	0	0.43	0.14	0,54	0	0	0	0
TOYOTA AVENSIS 1.8 TERRA	1.06	0.47	0.53	0.47	0	0.07	0,60	0	0	0.39	0
Targets			11,924	264	2.05	3.00	2.00	4.00	0	85	2.63
Slacks											
MAZDA 626 2.0 X.			0	10	2.05	0	0,00	0	0	0	0,13
Data											
MAZDA 626 2.0 X.			12,182	280	0	3.00	2.00	4.00	0	85	2.50
MITSUBISHI CARISMA 1.6 C.			11,617	266	3.00	3.00	2.00	4.00	0	76	2.50
TOYOTA AVENSIS 1.8 TERRA			12,269	261	1.00	3.00	2.00	4.00	0	95	2.78

Next, we will discuss how markets can be segmented with DEA. To this end, we investigate an inefficient car and its efficient peers (see data and SE results in table 4). Through the λ-weights from the dual solution - see LP (4) - individual benchmarks are assigned for the inefficient cars that serve as target positions for efficiency improvements. As table 4 shows, the inefficient Mazda 626 is benchmarked by other Japanese cars, namely the Mitsubishi Carisma and Toyota Avensis. In contrast to the self-evaluators, these models compete strongly with other models in their segment. They are assigned as the most comparable reference products to the Mazda and form its virtual reference unit. The relevance of both peers for assessing the relative efficiency of the Mazda is nearly the same (with $\lambda_{\text{Mitsubishi}} = 0.53$ and $\lambda_{\text{Toyota}} = 0.47$).

As outlined above, the combined reference unit must offer a similar and therefore comparable mix of characteristics (i.e. a similar product concept), otherwise these peers would not have been assigned as benchmarks. Consequently it seems legitimate to cluster all products that try to maximize customer value with similar product strategies in the same "value segment". Thus, DEA makes it possible to partition the overall market into product sub-markets based on their input-output-structure.

Integrating the explanations stemming from the results of the two LPs we can infer the following: The efficient peers Mitsubishi and Toyota represent the benchmarks for that sub-market of cars that position themselves by offering superior power and special equipment at a very reasonable price. Providing brand strength and safety is clearly not the focus of their product concepts. Thus the Mitsubishi and the Toyota reach their efficient position by providing that specific mix of product characteristics and at the same time demanding lowest inputs from customers relative to the alternatives in that segment. Interestingly, this market partition which is derived endogenously by the SE model corresponds with the "typical" classification of cars based on the country of origin criterion ("Japanese segment").

5 Conclusions

Several studies have been devoted to the development of efficiency measures for products using DEA. The main weakness of standard DEA is that it leaves the efficient units of the product set undifferentiated. Virtually all previous approaches are liable to suffer from presenting a high fraction of efficient products. Thus the implications of these studies on product evaluation are limited. Drawing on previous studies in the field we have introduced an extended model of product evaluation that maintains the desirable properties of the original DEA-model but adds more information allowing a ranking of the total set of observations. Thus, further insights into the efficiency properties of the products that span the frontier can be extracted. The SE model avoids the dilemma to either obtain a differentiated ranking by using possibly fixed weights or to avoid exogenous constraints on the weights and loose a differentiated ranking by the same token. Now differences in the superiority of the efficient units can be identified. At the same time, the DEA results can be used for endogenous market segmentation.

By applying the SE procedure, we evaluate the efficiency of the 48 best selling cars of the German middle class market. In contrast to other studies in this field, we conceptualize the efficiency value not as a technical measure but from the customer's perspective. We interpret the efficiency score as a measure the customer oriented product efficiency (customer value), i.e. as a ratio of outputs that customers obtain from a product relative to inputs (price, running costs) that customers have to invest. On the output side we integrate a number of customer relevant attributes such as non-functional benefits (status attributes, brand equity) which go beyond the pure technical features. The employed parameters conceptualize the customer value in a comprehensive way.

The SE analysis demonstrates that efficient cars show significant differences in their degrees of SE. With standard DEA for 66% of the cars no further insight can be derived. Instead, the SE scores allow for the identification of leading (influential) cars among the efficient ones, i.e. cars that push out the frontier and have high competitive ledges. Such cars could afford a high increase in customer inputs while preserving the provision of a maximum customer value. At the same time, it is possible to derive a market segmentation endogenously by identifying niche products and clusters of cars with a similar product strategy. We provided examples that underscore the intuitive appeal of our approach. We were able to demonstrate that the usefulness of DEA as a tool for marketing decisions has not been fully exploited in previous studies.

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