The Use of Super-Efficiency Analysis for strategy Ranking

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Abstract

The evaluation of strategic alternatives is particularly a difficult task. This difficulty is due to the complexities inherent in the evaluation process and the lack of structured information. Various analytical and normative models have helped decision makers in strategy selection; however, these models suffer from subjective judgments. This paper proposes an innovative method for ranking strategies without relying on weight assignment by decision makers. A numerical example demonstrates the application of the proposed method.

Keywords: Strategic Management, Strategy ranking, Super-efficiency analysis, Data envelopment analysis

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1. Introduction

The business environment is becoming more competitive and complex. Various factors have increased competitive pressures in markets, and made relationships between environmental factors more complex (e.g. global markets, faster technology transfers). Weaker firms are being driven from markets, with the more aggressive survivors having significant resources to exploit any strategic opportunity. In such an environment a competitive advantage is the ability to quickly and correctly interpret changes in the environment, and determine what strategies, if any, the firm should take (Weigelt and Macmillan, 1988).

Choosing among strategic alternatives is usually a difficult task. Managers encounter this difficulty because they lack perfect foresight. They must choose a strategy today, whose success depends on future conditions, without knowing exactly what the future looks like.

Managers should find this study helpful for a number of reasons.

- The study shows which strategy produces the optimal results.
- Since the study systematically evaluates strategies it can also illustrate to managers how changes in variables (i.e. inputs and outputs) affect the performance of strategies.
- By developing specialized software, managers can quickly evaluate the strategies.

Notice that, the proposed method should not be used by 'plugging-in' numbers and 'cranking' out optimal solutions. The complexity of the competitive environment requires any analytic model to be balanced on a set of assumptions. The study helps to evaluate the strategies, use it as a means of achieving that goal, not as the goal itself.

In summary, this paper provides a greater level than is provided by existing models. Initially, decision makers may be overwhelmed by the mathematical model that is presented in the paper. However, they could be convinced to use the proposed model through patient assistance and training by experts.

Many analytical and normative models have been developed to help a decision maker deal with the strategy evaluation process. Such models include strategic program evaluation (SPE) (King (1980)), quantitative strategic planning matrix (QSPM) (David (1986)), Electre II (EII) (Godet (1987)), the McKinsey matrix (Hill and Jones (1989)), competitive strength assessment (Thompson and Strickland (1983)), the scenario-strategy matrix (Naylor (1983)), and decision situation outcomes evaluation (Radford (1980)). These techniques have made definite contributions to the strategy evaluation process, but they suffer from subjective judgments.

Tavana and Banerjee (1995a) presented a multi criteria decision support system called Strategic Assessment Model (SAM). SAM uses the Analytic Hierarchy Process (AHP) for developing importance weights of the environmental factors, the entropy concept for developing intrinsic weights of the environmental factors, and an exponential utility function for calculating the risk-adjusted strategic value. Tavana and Banerjee (1995b) introduced an analytical method to support strategy evaluation which incorporates environmental analysis. Their AHP based method ranks strategic alternatives founded on expected risks and returns, which can be of significant help to corporate management. Tavana (2002) proposed a model that uses a series of intuitive and analytical methods including environmental scanning, AHP, subjective probabilities, and the theory of displaced ideal, to plot strategic alternatives on a matrix based on their Euclidean distance from the ideal alternative. Hastings (1996) provided a method for ranking strategy on quantitative, qualitative and intangible criteria based on AHP. Chiou et al. (2005) proposed a fuzzy AHP to derive the weight of considered criteria and the final synthetic utility values, and then ranked the importance of the criteria as well as the sustainable development strategies. Wind (1987) presented an AHP based application for corporate strategy for evaluating strategic options on multiple and interdependent objectives to ensure effective utilization of resources. However, AHP has two main weaknesses. First subjectivity of AHP is a weakness. Second AHP could not include interrelationship within the criteria in the model.

Carneiro (2001) presented a proposal of the functional architecture and the use of a group decision support system for helping groups of managers to select a strategy among several alternatives.

Chien et al. (1999) established a systematic approach that incorporates neural networks in conjunction with portfolio matrices to assist managers in evaluating and forming strategic plans. Based on the principle of dispersing risks, they also provided a linear integer programming model, which helps in allocating the annual budget optimally among proposed strategies. However, their proposed approach is computational burden. Meanwhile, their linear integer programming model considers just two factors including cost and profit of the strategy.

Kajanus et al. (2001) presented the principles of even swaps method and its use was illustrated by applying it to a case of strategy selection in a rural enterprise in Finland. Nevertheless, in the case of strategies abundance, the pairwise comparison between strategies is computational burden. In addition, their proposed method suffers from subjective judgments.

However, all of the abovementioned references suffer from subjective judgments. This limitation provided the motivation for introducing the proposed model. A technique not relying on weight assignment by decision makers is needed to better model such situation.

Recently, Farzipoor Saen (in press) presented an Imprecise Data Envelopment Analysis (IDEA) based method that allows strategy to be evaluated in the presence of both ordinal and cardinal data. However, his method is not based on super-efficiency analysis.

To the best of knowledge of authors, this paper is the first application of super-efficiency analysis to deal with strategy ranking. The objective of this paper is to propose a method for ranking strategies without relying on weight assignment. In summary, the approach presented in this paper has some distinctive contributions.

- The proposed model does not demand weights from the decision maker. Data Envelopment Analysis (DEA) obtains the optimal weights for all inputs and outputs of each Decision Making Unit (DMU) without relying on the subjective judgment of decision makers. In DEA formulations, the assessed DMUs can freely choose the weights or values to be assigned to each input and output in a way that maximizes its efficiency, subject to this system of weights being feasible for all other DMUs. This freedom of choice shows the DMU in the best possible light, and is equivalent to assuming that no input or output is more important than any other. The free imputation of input-output values can be seen as an advantage, especially as far as the identification if inefficiency is concerned. If a DMU is free to choose its own value system and some other DMU uses this same value system to show that the first DMU is not efficient, then a stronger statement is being made.
- The proposed model considers multiple criteria for strategy ranking.
- The paper makes a sufficient contribution to the practice of Operations Research. This paper is the first study which applies super-efficiency analysis for evaluating the strategies. The study contributes also to management literature because it points out the management use of its results.

This paper proceeds as follows. In Section 2, the method that ranks the strategies is introduced. Numerical example is discussed in Sections 3. Section 4 discusses concluding remarks.

2. Proposed method for ranking strategies

DEA proposed by Charnes et al. (1978) (CCR model) and developed by Banker et al. (1984) (BCC model) is an approach for evaluating the efficiencies of DMUs. Outcome of DEA models is an efficiency score equal to one to efficient DMUs and less than one to inefficient DMUs. So, for inefficient DMUs a ranking is given but efficient DMUs can not be ranked. One problem that has been discussed frequently in the DMUs ranking literature has been the lack of discrimination in DEA applications, in particular when there are insufficient DMUs or the number of inputs and outputs is too high relative to the number of DMUs. The research on ranking efficient DMUs can be divided into the following streams (Adler et al. (2002)):

In the first stream, the research was pioneered by Sexton et al. (1986). In their research, the ranking of DMUs was based on a cross-efficiency. In the second stream, the ranking of DEA-efficient DMUs is based on benchmarking, an approach initially developed by Torgersen et al. (1996). They concluded that a DMU was highly ranked if it was chosen as a reference by many other inefficient DMUs. In the third stream, researchers like Fridman and Sinuany-Stern (1997), who initiated the research in this direction, used multivariate statistical tools such as canonical correlation analysis and discriminate analysis to rank both efficient and inefficient DMUs. To increase discrimination between efficient DMUs, Farzipoor et al. (2005) introduced the correlation coefficient threshold that beyond which omission of one or more input vectors have no statistically significant effects on the efficiency mean. The threshold identification in terms of some of the DEA models was performed.

The last, yet the most popular, research stream in ranking DMUs is called super-efficiency. An advantage of super-efficiency method is the capability to rank both efficient and inefficient DMUs. Here, a concise review is presented:

The research in this area was first developed by Andersen and Petersen (1993). They proposed the idea of modifying the envelopment Linear Programming (LP) formulation so that the corresponding column of the DMUs being scored is removed from the coefficient matrix. For the input model this can result in values which are regarded as according DMU_o the status of being "super-efficient". These values are then used to rank the DMUs and thereby eliminate some (but not all) of the ties that occur for efficient DMUs.

Using a simple example with 5 fictitious products (A - E) that can be described by two inputs (price, running costs) and one output (quality), the advantages of the super-efficiency analysis vis-à-vis the efficiency estimation procedure of standard DEA are demonstrated (Staat and Hammerschmidt (2003)). 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.

In this 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 super-efficiency or with the standard DEA model. The difference between the standard and the super-efficiency 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 super-efficiency 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 super-efficiency index of, say 1.25 (equaling the ratio 0W/0B, see Fig. 1). The score reflects the maximum proportional increase in inputs preserving efficiency. The ability to differentiate the efficient products has several managerial implications for product policy. The super-efficiency 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 super-efficiency 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.

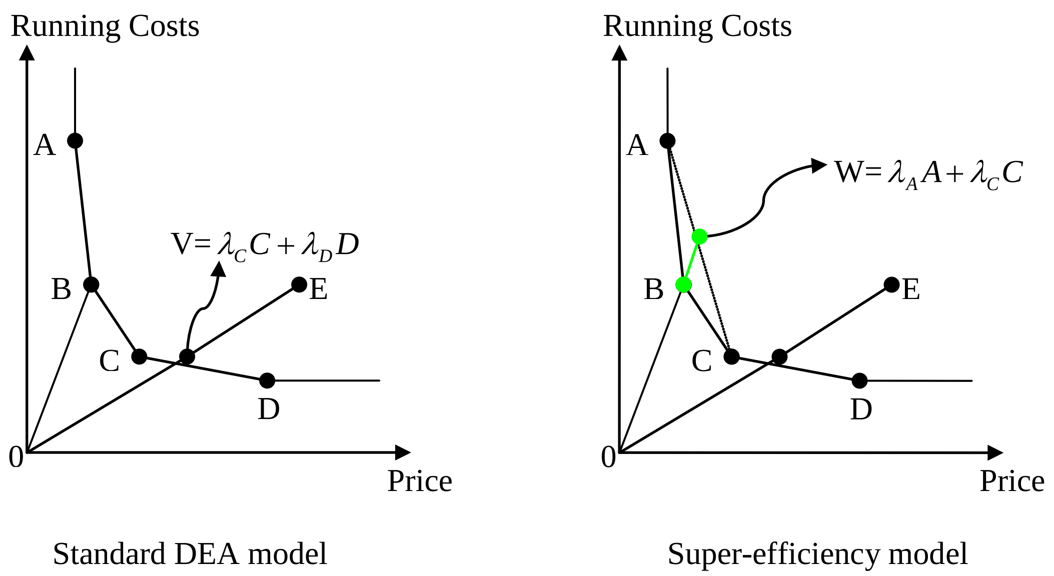

Figure 1. Standard DEA vs. Super-efficiency model

However, Thrall (1996) pointed out that the model developed by Andersen and Petersen (1993) may result in instability when some inputs are close to zero. Then, to avoid this problem, MAJ (Mehrabian et al. (1999)) and Slack-Based Measure (SBM) (Tone (2002)) models were proposed. Jahanshahloo et al. (2004) presented a method for ranking extreme efficient decision making units in DEA models with constant and variable returns to scale. They exploited the leave-one-out idea and l_1-norm. Jahanshahloo et al. (2005a) using Monte Carlo method, developed a method which is able to rank all efficient (extreme and non-extreme) DMUs. Jahanshahloo et al. (2005b) introduced a method for ranking of DMUs using Common Set of Weights (CSW). Jahanshahloo and Afzalinejad (2006) suggested a ranking method which basically differs from previous methods. In this ranking method, DMUs are compared against a full-inefficient frontier. This method can be used to rank all DMUs to get analytic information about the system, and also to rank only efficient DMUs to discriminate between them. Amirteimoori et al. (2005) described a new DEA ranking approach that uses l_2-norm. Jahanshahloo et al. (2006) showed that the technique used for rendering MAJ model unit-invariant causes the ranking to change when some inputs of some inefficient DMUs change, without causing any change in the new Production Possibility Set (PPS). They modified MAJ model so that this problem will not occur.

Saati et al. (2001) suggested a modification for MAJ model and proved that the modified version is always feasible and the ranking lies in (0, 1]. Unlike the previous models, this model is both input and output oriented, simultaneously. This model by decreasing inputs and increasing outputs of the DMU under consideration by equal sizes, project it on the frontier. The simultaneously changes in input and output are equal in size because otherwise due to giving different preferences to them, the problem becomes a multi objective programming one and hence yielding a complex situation.

Table 1 depicts the nomenclatures used in the paper.

Table 1. The nomenclatures

Problem parameters
$j = 1,. . . ,n$ collection of strategies (DMUs)
$r = 1,. . . , s$ the set of outputs
$i = 1,. . . ,m$ the set of inputs
y_{rj} = the rth output of jth DMU
x_{ij} = the ith input of jth DMU
y_{ro} = rth outputs of the DMU_o under investigation
x_{io} = ith inputs of the DMU_o under investigation
Decision variables
$\lambda =[\lambda_j]$ vector of DMU loadings, determining best practice for the DMU being evaluated
w_o radial input contraction factor (eventually to become efficiency measure)

In this paper strategy is considered as DMU. Suppose that there are n strategies (DMUs) to be evaluated. Each DMU consumes m inputs to produce s outputs. In particular, strategy j consumes amounts $X_j = \{x_{ij}\}$ of inputs (i=1, …, m) and produces amounts $Y_j = \{y_{rj}\}$ of outputs (r=1, …, s).

Omitting the column corresponding to DMU_o, the DMU under consideration, the ranking model is obtained as follows (Saati et al. (2001)):

$$
\begin{aligned}
\min \quad & w_o + 1 \\
\text{s.t.} \quad & \sum_{\substack{j=1 \\ j\neq o}}^{n} x_{ij}\lambda_j \le x_{io} + w_o \mathbf{1} \qquad i = 1,\dots,m \qquad (1) \\
& \sum_{\substack{j=1 \\ j\neq o}}^{n} y_{rj}\lambda_j \ge y_{ro} - w_o \mathbf{1} \qquad r = 1,\dots,s \\
& \lambda_j \ge 0 \qquad j = 1,\dots,n
\end{aligned}
$$

where w_o is a free variable and **1** is a vector of ones. Since the inputs and outputs are not homogeneous and scale of objective function in proposed model is depended on the units of measurement of input and output data, unit independence is obtained by normalization, e.g. dividing each input and output to the largest of them as one of the techniques for normalization.

Notice that efficient DMUs have super-efficiency score greater than or equal to 1, while inefficient DMUs have super-efficiency score less than 1.

If the optimal objective value of model (1) is greater than 1, DMU_o that is DEA efficient in the CCR model is super-efficient in the model (1). Otherwise, DMU_o is not super-efficient. Therefore, it is possible just solving super-efficiency model for ranking efficient DMUs without solving the CCR model. The super-efficiency scores of the DMUs obtained by the model (1) can be ranked in descending order. Note that the unity value in the objective function is kept just for the sake of comparability with the scores obtained by other super-efficiency models.

3. Numerical example

The data set for this example is partially taken from Farzipoor Saen (in press) and contains specifications on 27 strategies (DMUs). The inputs considered are Total Cost of strategy (TC)[2] and risk. Net Present Value (NPV) and payback time of the strategy will serve as the outputs. Table 2 depicts the strategy's attributes.

Table 2. Related attributes for 27 strategies

Strategy No. (DMU)	Inputs		Outputs		
	TC (10000$)	Risk	Payback time	NPV	Efficiency
1	7.2	.15	60	1.35	1
2	4.8	.05	6	1.1	.9
3	5	1.27	45	1.27	.53
4	7.2	.025	1.5	.66	1
5	9.6	.25	50	.05	.59
6	1.07	.1	1	.3	.48
7	1.76	.1	5	1	1
8	3.2	.1	15	1	.78
9	6.72	.2	10	1.1	.38
10	2.4	.05	6	1	1
11	2.88	.5	30	.9	.67
12	6.9	1	13.6	.15	.1
13	3.2	.05	10	1.2	1
14	4	.05	30	1.2	1
15	3.68	1	47	1	.61
16	6.88	1	80	1	.61
17	8	2	15	2	.41
18	6.3	.2	10	1	.37
19	.94	.05	10	.3	1
20	.16	2	1.5	.8	1
21	2.81	2	27	1.7	.85
22	3.8	.05	.9	1	.83
23	1.25	.1	2.5	.5	.69
24	1.37	.1	2.5	.5	.64
25	3.63	.2	10	1	.55
26	5.3	1.27	70	1.25	.58
27	4	2.03	205	.75	1

Table 3 shows the normalized data set of nine efficient strategies. In Table 4, the ranking results by using model (1), have been displayed. The strategies have been ranked in decreasing

[2] The inputs and outputs selected in this paper are not exhaustive by any means, but are some general measures that can be utilized to evaluate strategies. In fact, criteria that are critical to strategic choices concerning the future will vary from company to company and over time, and will emerge from different parts of the strategy analysis. In an actual application of this methodology, decision makers must carefully identify appropriate inputs and outputs measures to be used in the decision making process.

order of their objective values. As Table 4 shows, strategy 27 received the highest objective value and is the first candidate for selection.

Table 3. Normalized data

Strategy No. (DMU)	Inputs		Outputs	
	TC	Risk	Payback time	NPV
1	1	0.073892	0.292683	1
4	1	0.012315	0.007317	0.488889
7	0.244444	0.049261	0.02439	0.740741
10	0.333333	0.024631	0.029268	0.740741
13	0.444444	0.024631	0.04878	0.888889
14	0.555556	0.024631	0.146341	0.888889
19	0.130556	0.024631	0.04878	0.222222
20	0.022222	0.985222	0.007317	0.592593
27	0.555556	1	1	0.555556

Table 4. Final solution

Strategy rank	Strategy No.	Objective Value
1	27	1.576883
2	20	1.130326
3	7	1.04829
4	14	1.019749
5	13	1.003261
6	10	1.003173
7	1	1.00162
8	4	1.001199
9	19	1.000746

4. Concluding remarks

Strategic management is the process of aligning the internal capabilities of an organization with the demands from its environment to achieve an effective allocation of corporate resources. Effective strategic management requires effective strategy formulation, evaluation of alternative strategies, and implementation of the selected strategy. In this paper, an effective method for ranking strategies was introduced.

The problem considered in this study is at initial stage of investigation and much further researches can be done based on the results of this paper. Some of them are as follows:

Comparing the results of performance of proposed method with fuzzy DEA will be a research topic.

The model presented in this paper deals with the decision-making process of one decision maker. In reality, strategic decisions are rarely made by a single decision maker. The next step in enhancing the model will be to extend the capabilities of model to handle input from multiple decision makers and summarize their input for strategy selection.

Research on the influence of the different normalization techniques on the ranking results will be an interesting topic for the future studies.

Finally, using a robust mathematical model does not imply that the business environment is totally deterministic. Random events will always be part of the competitive environment. Therefore, developing a model which considers stochastic events will be an interesting research topic.

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