William W. Cooper, Lawrence M. Seiford, Joe Zhu, Handbook on Data Envelopment Analysis, International Series in Operations Research and Management Science, Kluwer Academic Publishers, 2004, ISBN 1-4020-7797-1

1. Introduction

Data Envelopment Analysis (DEA) is non-parametric approach, based on linear programming, which has grown in the last two decades into a widely used set of quantitative analytical tools for measuring and evaluating performance of decision making units (DMUs). These are (hopefully homogeneous) entities that perform the same activity in a (relatively) similar operating environment, possessing a certain degree of autonomy, and which "consume" inputs to "produce" outputs, which are in general non-commensurable. The abundant DEA literature (books, journal and conference papers, research reports and thesis) reveals a wide range of (worldwide) applications to evaluate the efficiency and productivity of distinct kinds of entities in several activity domains such as hospital departments, bank branches, university departments, secondary schools, electricity distribution companies, power plants, etc., and even countries regarding their performance in aspects such as environmental issues, telecommunication services, sports, etc. One of the main advantages of DEA lies on its empirically-oriented nature, that is, based on the observed data, thus not requiring strong assumptions regarding functional forms of linking the outputs to the inputs (as is required by other approaches to efficiency evaluation). DEA aims at identifying an efficient frontier (in the Koopmans–Pareto sense), which is different according to distinct models and the underlying returns to scale assumptions, consisting of the efficient DMUs and a measure of inefficiency for the DMUs that do not belong to the frontier. That means that for the inefficient DMUs, which do not display the "best practice" for the combination of inputs and outputs, it is possible to identify the DMUs belonging to the efficient frontier they should compare with. This amounts to a mechanism of projection of the inefficient DMUs onto the efficient frontier revealing the corresponding percentages of reduction in the consumption of inputs and/or of augmenting the production of outputs to achieve efficiency.

The origins of DEA go back to the works of Farrel (1957) on methods for productivity evaluation, in which the need of global indicators was recognized in order to overcome the restrictive nature of factor productivity indexes (that is, global efficiency indicators resulting from the combination of multiple inputs rather than mere factor productivity indicators). The seminal DEA model, assuming constant returns to scale, resulted from the work of Charnes et al. (1978), which was motivated by the need to evaluate educational programs in public schools in the USA. The main characteristic of this model (known as the CCR or engineering ratio model) is the transformation, for each DMU, of the situation multiple output/multiple input into a ratio virtual output/virtual input. This ratio yields an efficiency measure that is a function of a set of multipliers, which are the decision variables of a fractional programming model (then transformed into a linear programming model). The extension of the CCR model for the case of variable returns to scale was proposed in Banker et al. (1984) (the BCC model), in which an additional constraint guarantees that each DMU under evaluation is compared with a convex combination of the other DMUs.

The recognition of DEA as a powerful tool (with its advantages and shortcomings) to model operational processes, its empirical nature and the fact of not requiring excessive assumptions, has transformed it into one of Operational Research/Management Science techniques showing more vitality and witnessing an enormous basic and applied research effort. From the seminal paper by Charnes et al. (1978), thousands of documents can be referenced either concerning theory and methodology or application studies in the public, private and regulated sectors.

This handbook on data envelopment analysis, edited and authored by some of the most prominent researchers in the field of DEA, aims at being a comprehensive reference for researchers, students and practitioners, and a milestone in the DEA progression. The handbook is organized into

three main parts. The first one covers the basic DEA models as well as some extensions, including sensitivity analysis, the incorporation of value judgments in DEA models, the use of distance functions, the consideration of qualitative data, the identification and management of congestion within DEA models, the efficiency change over time captured through the Malmquist index, chance constrained models, the performance of bootstrap techniques, and statistical tests based on efficiency scores. The second part consists in application-oriented papers in the areas of education, banking, engineering, sports, retailing and health care. The last part is a state-of-the-art survey of DEA software tools.

The book has about 600 pages and it is priced at EUR 154. The editors are William W. Cooper (University of Texas at Austin), Lawrence M. Seiford (University of Michigan at Ann Arbor), and Joe Zhu (Worcester Polytechnic Institute).

2. Content of the book

The book comprises 18 chapters written by 29 contributors. In chapter 1, authored by the editors, the background and history of DEA are revisited and the various models and methods for treating allocative and overall efficiency are covered. The CCR model is presented in detail as well as extensions to deal with non-discretionary and categorical inputs and outputs, incorporation of judgments and a priori knowledge, and window analysis. A new additive model is also presented aimed at dealing with allocative and overall efficiency, which can be used whenever the usual ratio form of the efficiency measure gives unsatisfactory or misleading results. This model requires unit prices (associated with output slacks) and unit costs (associated with input slacks) to assess "profit efficiency".

The topic addressed in chapter 2, by Banker, Cooper, Seiford and Zhu, is returns to scale (RTS) in DEA models. The discussion is centred on the relationships between DEA models and methods and the qualitative RTS characterizations they produce (such as whether RTS is identified as increasing, decreasing or constant). The RTS approaches within BCC and CCR models are revisited, extending them to models other than radial measure models.

In chapter 3, by Cooper, Li, Seiford and Zhu, methods for studying the sensitivity of DEA results to changes in the data are presented. The focus is the sensitivity of DEA efficiency evaluation, namely regarding the stability of the classification of the DMU status into efficient and inefficient. Global data changes are considered, in the sense that the stability of results is assessed when inputs and outputs change simultaneously for all DMUs.

The incorporation of value judgments in DEA models is addressed in chapter 4, by Thanassoulis, Portela and Allen. The important issue of the role and meaning of weights is revisited, and the main reasons for including value judgments in DEA models are described (generally motivated by real-world applications). Methods for incorporating value judgments and reducing the flexibility of DMUs in choosing their "value system" are presented, which are categorized in two broad classes: weight restrictions (absolute restrictions, assurance regions, and restrictions on virtual inputs and outputs) and changing the data set (transforming the data and adding new DMUs). The authors also discuss the changes that the incorporation of value judgments may introduce on the efficient frontier and its RTS characteristics.

Chapter 5, by Fare, Grosskopf and Whittaker, deals with distance functions and their duality relations. DEA estimations of various distance functions are presented and it is shown that their support functions (profit, revenue and cost) also may be estimated via DEA.

In chapter 6, Cook discusses the treatment of qualitative data in DEA models. The radial projection DEA model in the presence of ordinal data is examined and then applied to the efficiency evaluation of R&D projects and a telephone office. It is shown that by introducing the concept of rank position data within the DEA structure, the resulting model can be transformed into a VRS type model. The linking of the ordinal DEA model to multiple criteria decision making with ordinal data and criteria importance is also mentioned.

Cooper, Deng, Seiford and Zhu, in chapter 7, present various approaches to identify and manage

congestion (understood as a form of technical inefficiency) with DEA models. It is illustrated how the DEA models can be used to determine the effects of congestion, namely the amount of congesting inputs, the output reduction due to congestion and the points where technical inefficiency gives way to congestion.

Chapter 8, by Tone, is a comprehensive study of the Malmquist productivity index to evaluate the productivity change of a DMU between time periods. This index includes a catch-up (recovery) term and a frontier-shift (innovation) term to capture the effects of both efficiency and technology changes. Three different approaches for the measurement of the Malmquist index are presented: radial, non-radial and non-radial and non-oriented. It is shown that the oriented radial models suffer from the neglect of slacks and infeasibility.

Chapters 9, 10 and 11 are devoted to probabilistic and statistical characterizations of the main efficiency evaluation models. In chapter 9, Cooper, Huang and Li deal with chance constrained programming extensions of the deterministic DEA formulations, thus making it possible to use characterizations such as "probably efficient" and "probably not efficient". Expected value formulations are used to discuss DEA efficiency and its relationship with sensitivity analysis in stochastic situations. Other types of chance constrained programming models incorporate Simon's satisficing concepts to extend the potential uses of DEA to cases in which full efficiency can be replaced by the attainment of aspiration levels of performance.

Chapter 10, by Simar and Wilson, presents bootstrap methods for statistical inference within non-parametric efficiency estimation. It is shown, via Monte Carlo experiments, that the iterated bootstrap offers a convenient approach for evaluating the performance of the bootstrap and providing corrections in a given applied context.

Chapter 11, by Banker and Natarajan, is devoted to statistical tests based on DEA efficiency scores, showing that the DEA estimator of the production frontier has desirable statistical properties enabling to develop a wide range of formal statistical tests. These can be used to test hypotheses of interest and relevance in the application of DEA such as existence of scale economies, separability and substitutability of inputs in production system, comparison of efficiency of groups of DMUs, etc.

Six DEA application chapters follow. In chapter 12, Ruggiero deals with DEA applications in education, one of the public sector activities in which a large amount of funds is invested and has witnessed a growing trend towards the consideration of accountability and efficiency issues. A discussion of the treatment of non-discretionary variables is also provided.

Chapter 13, by Paradi, Vela and Yang, discusses the DEA application to banking and provides a comprehensive review of the literature on bank branch performance DEA models (which describes variables, sample, type of RTS and model-orientation).

Chapter 14, by Triantis, presents the issues that researchers face when applying DEA to engineering problems, and proposes an approach for the design of an integrated DEA based performance measurement system. Moreover, it summarizes studies that have focused on engineering applications of DEA, and suggests systems thinking concepts that are appropriate for future DEA research in engineering. A bibliography of DEA applications in engineering is also provided.

Chapter 15, by Anderson, shows how DEA can be used to assess the player who had the most dominant baseball batting season, using the concept of super-efficiency. The adjusting capability of DEA to the changing circumstances of the game was recognized as one of its main strengths.

Chapter 16, by Athanassopoulos, provides a discussion on the performance of for-profit retail service industries. The study focus on the development of a unified methodological framework for assessing the operating efficiency of real networks (512 retail outlets in banking, sales forces, restaurants and betting shops). The monitoring of marketing and cost efficiency of service chains contributes to enhance the accountability of the marketing function and the decision making ability to improve the performance of individual branches.

Chapter 17, by Chilingerian and Sherman, focuses on health care applications of DEA. It offers a brief history of case studies in health sector (from hospitals to physicians) and discusses some of the

models and motivations behind the applications. An eight-step procedure for DEA health application is provided with emphasis on the need for including quality measures of the services delivered.

Chapter 18, by Barr, presents a critical survey of DEA software packages, both commercial and non-commercial. Besides descriptions of eight individual packages, comparisons of their features and capabilities are provided, as well as links to further information on each of them.

3. Discussion

The handbook is intended for researchers, students and practitioners. It aims at reflecting the state-of-the-art as well as representing a milestone in DEA advancing. I found this handbook a valuable reference for researchers, graduate students, and consultant analysts. However, it requires a relatively important degree of familiarity with the main DEA models and extensions to be used as an introductory door to this field. For this purpose (for instance, for classroom use in undergraduate classes) other references by the same authors are more appropriate (Charnes et al., 1994; Cooper et al., 2000), mainly because the topics unfolding in more comprehensive, self-contained and written in a didactic way.

In this scope, I found all the chapters on the first part of the book, covering methodological issues, quite interesting and useful, in particular those devoted to the incorporation of value judgments and sensitivity analysis in DEA models. The chapters exploring the links with statistics, devoted to the performance of bootstrap techniques and statistical tests based on efficiency scores, also unveil important research directions. However, these chapters require from the reader a level of expertise on DEA models (as well as other topics), which cannot be acquired in the handbook itself. The chapter dealing with the consideration of qualitative data is the only one where the links between DEA and multiple criteria decision making are briefly explored. This is a relevant research and application topic and it would have been useful to have a whole chapter devoted to it.

The second part of this handbook, regarding application studies, left me with a sense of "incompleteness". Of course, it will be impossible to include chapters, or even mention, all the areas in which DEA applications have been reported in the literature. Therefore, I believe a more judicious selection of material to be included should have been done to reflect state-of-the-art and relevance in DEA applications. The chapters included in the handbook are interesting and indeed lessons can be learned therein that can be replicated in studies in other areas. However, the handbook would have benefited from the inclusion of chapters describing studies in other (perhaps more relevant) areas, such as, for instance, energy, agriculture, environment, or telecommunications. Also, there is some imbalance in the treatment of applications in the chapters in the second part of the handbook. Some chapters enter into the details of model description (input and output factors, type of RTS, etc.) whereas other chapters merely do a survey of the literature. It goes without saying that both types can be useful for researchers and practitioners, but a higher consistency on this specific issue could have been pursued.

Nevertheless, this handbook provides an important value-added regarding DEA monographs, even though I think the editors could have organized it more under the perspective of a valuable complement to the other two books already mentioned above. This handbook constitutes, namely regarding some methodological chapters in the first part, an encouraging research agenda for further developments and uses of DEA. In this scope it is a valuable tool for researchers, graduate students and experienced practitioners. Moreover, up-to-date references are provided in most chapters that enable the reader to develop further his/her own specific interests in this continuously advancing area.

As other book reviewers already noted elsewhere, Kluwer books are too expensive (other publishers also suffer from this sin too). With the affordability of production means why are not camera-ready books more reasonably priced for single individuals and not just libraries (and perhaps not all)? It would be interesting Kluwer, and other scientific publishers, could lead a

performance analysis of the consequences of this price policy on sales!

References

Banker, R.D., Charnes, A., Cooper, W.W., 1984. Some models for estimating technical and scale inefficiencies in Data Envelopment Analysis. Management Science 30 (9), 1078–1092.

Charnes, A., Cooper, W.W., Rhodes, E., 1978. Measuring the efficiency of decision making units. European Journal of Operational Research 2, 429–444.

Charnes, A., Cooper, W.W., Lewin, A.Y., Seiford, L.W., 1994. Data Envelopment Analysis: Theory, Methodology and Applications. Kluwer Academic Publishers.

Cooper, W.W., Seiford, L.M., Tone, K., 2000. Data Envelopment Analysis: A Comprehensive Text with Models, Applications, References and DEA-solver Software. Kluwer Academic Publishers.

Farrel, M.J., 1957. The measurement of productive efficiency. Journal of the Royal Statistical Society, Series A 120, 253–281.

Carlos Henggeler Antunes
Department of Electrical Engineering and Computers
University of Coimbra
Polo II-Pinhal de Marrocos
3030 Coimbra, Portugal
E-mail address: ch@deec.uc.pt

Available online 23 September 2005

doi:10.1016/j.ejor.2005.07.017

Lech Polkowski, Rough Sets. Mathematical foundations, Physica-Verlag, Heidelberg, ISBN 3-7908-1510-1, XX, 534 p. 20 illus., Softcover ISSN: 1615-3871. Euro 79,95

The book of Polkowski presents the mathematical basis of rough set theory. I believe that to review the book, it is necessary to start recalling the basic ideas of rough set theory. Rough set theory has been proposed by Pawlak in the early 80s (for the first article in a journal see Pawlak 1982; for a complete exposition of the theory see Pawlak 1991). From a logical point of view, rough set theory is a new approach to vagueness implementing the Frege's idea that vague concepts are characterized by a boundary region that consists of all elements which cannot be classified neither to a concept nor to its complement. Within rough set theory, knowledge is related to the ability of classifying objects from given universe of the discourse U; this knowledge gives us basic information about the elements in U. For example, let us suppose that the universe of the discourse is given by a set of patients and the information is related to their symptoms. All patients described by the same data (i.e. all the patients having the same symptoms) are indiscernible. These groups are called elementary sets and are the building blocks of our knowledge. Let us suppose that we have information also about the different illness of the patients. Now we can relate the classification with respect to symptoms with the classification with respect to illness. To each given set of patients having the same illness Y we can associate two sets:

- the lower approximation, that is the set of all the building blocks included in Y,
- the upper approximation, that is the set of all the building block having a non-void intersection with Y.

In simple words the lower approximation is composed of all the patients presenting symptoms which univocally are associated with illness Y, while the upper approximation is composed of all the patients presenting symptoms which are associated with illness Y but not necessarily univocally. In a sense, the lower approximation consists of patients having symptoms suggesting surely presence of illness Y, while upper approximation consists of patients having symptoms suggesting possibly presence of illness Y. The set difference between the upper and the lower approximation is composed of patients having symptoms associated with illness Y but also to other classes of illness. Let us observe that this type of analysis