

Preface

The topic of production efficiency has attracted attention since Adam Smith's pin factory and even before. However, a rigorous analytical approach to the measurement of efficiency in production originated with the work of Koopmans (1951) and Debreu (1951), empirically applied by Farrell (1957). Farrell's seminal work gave rise to a considerable amount of studies.

The basic idea of efficiency analysis is to make a comparison among a group of firms or branches or among Decision Making Units (DMUs), in order to evaluate how the resources (or inputs) are used to obtain (produce) the products (services or outputs). This evaluation process is based on the estimation of a benchmark frontier against which the DMUs are assessed, using DMUs' inputs and outputs. The level of efficiency of each DMU is gauged as the distance from the estimated ('efficient') frontier.

In literature on efficiency analysis, the nonparametric approach has received a considerable amount of interest, both from a theoretical and an applied perspective. This mainly because it does not require many assumptions and particularly because it does not need the specification of a functional form for the frontier. Hence, the parameters of the functional form of the frontier do not have to be estimated in this approach, from which the name 'nonparametric' approach derives, whereas in the parametric approach, the parameters of the efficient frontier must be estimated. Data Envelopment Analysis (DEA) and Free Disposal Hull (FDH) are among the most known and applied nonparametric techniques for the measurement of the efficiency in production and service activities (see *e.g.*, Cooper, Seiford and Tone, 2000, for about 1,500 references of their applications). Nevertheless, this traditional nonparametric approach (DEA/FDH based) presents some severe limitations that are not always taken into account by researchers who apply it in empirical works. These limits should be carefully considered in order to provide a correct interpretation of the obtained results.

To summarise, the main drawbacks of the traditional nonparametric approach are known to be:

- Deterministic and non-statistical nature;
- Influence of outliers and extreme values;
- Lack of parameters for the economic interpretation;
- Unsatisfactory techniques for the introduction of environmental or external variables in the measurement (estimation) of the efficiency.

The main objective of this book is to provide a systematic and comprehensive treatment of recent developments in efficiency analysis in order to overcome these drawbacks.

In Part I of the book (Methodology), we introduce a complete set of tools for measuring the efficiency of firms (or production units, or Decision Making Units) and for explaining the observed efficiency differentials. This is a general and flexible toolbox that does not make any assumption on the behaviour of the units under analysis. Therefore, it can be used in theories that generalise the neoclassical theory of production as well as alternative ones (as is the case of the evolutionary theory of production).

The Methodology presents, in an intuitive, rigorous and self-contained way, the state-of-the-art on ‘advanced’ frontier models based on techniques that do not impose any functional specification of the frontier (nonparametric methods) and are not affected by extremes and outliers in the data (robust methods).

The following issues are dealt with in detail and further developed:

- *Statistical inference in nonparametric frontier estimation.* Here, we introduce stochastic elements in nonparametric frontier models, and we present the application of the bootstrap in efficiency analysis (Simar and Wilson, 1998, 2000b, 2006a), including: estimation of bias and confidence intervals of efficiency estimates; hypothesis testing; comparison of groups’ efficiency.
- *Robust estimators of frontiers.* Order- m frontiers (Cazals, Florens and Simar, 2002; Daraio and Simar, 2005a) and α -quantile frontiers (Daouia and Simar, 2004), do not envelop all data points and for that are not influenced by extreme values. They are also characterised by useful statistical properties and interesting economic interpretations.
- *Parametric approximation of nonparametric and robust frontiers.* These approximations, introduced by Florens and Simar (2005) and Daouia, Florens and Simar (2005), provide ‘robust’ estimates of parameters usable

for economic interpretation. These techniques are extended, in this book, to the full multi-input multi-output setup.

- *Nonparametric and robust conditional frontier models.* These models, recently introduced by Daraio and Simar (2005a, 2005b), are able to capture and measure the effect of external environmental variables on the efficiency, in a way that overcomes most drawbacks of previous methods.

This book has been specifically designed for applied economists who have an interest in the advantages of traditional nonparametric methods (DEA/FDH) for efficiency analysis, but are sceptical about adopting them because of the drawbacks they present.

In Part II of the book (Applications), we propose three empirical illustrations taken from different economic fields: insurance sector, scientific research and mutual funds industry. These applications perfectly illustrate how the tools we propose can be used to analyse economies of scale, economies of scope, dynamics of age and agglomeration effects, trade-offs in production and service activities, groups comparison as well as help explain efficiency differentials. These extensively treated empirical applications, based on real data, show the usefulness of our approach in applied economics. Through these applications we illustrate how various statistical tools can be combined to shed light on the key features of the studied production process.

Moreover, this book has also been written for researchers with a background in Operations Research (OR) and/or Management Science (MS), who would like to deepen their knowledge of these new robust and nonparametric techniques, which have been recently presented at specialised conferences and have appeared on the scientific journals in recent years. In this book they will find a readable, synthetic but also accurate presentation of these recent advances - without the burden of technicalities and formal demonstrations - together with an extensive illustration of their use in empirical works.

Advanced Robust and Nonparametric Methods in
Efficiency Analysis

Methodology and Applications

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