Preface

Frontier efficiency methodologies are classified into two types: *deterministic production frontier and stochastic production frontier*. *Frontier* refers to the maximum limit which represents the best-practice approaches to production. *Efficiency* is the use of maximum outputs produced from a given mix of inputs. *Stochastic production frontier* [i.e., Stochastic Frontier Analysis (*SFA*)] allows technical inefficiency effects, can account statistical noise in the measurement of efficiency, and also specifies a functional form for the production (e.g., cost function). *Deterministic production frontier*, such as *data envelopment analysis* (DEA), is a goal programming approach, which assumes that any deviations of decision-making units (DMUs) from the frontier are due to technical inefficiency. A key advantage of this approach over SFA is that it more easily accommodates both multiple inputs and multiple outputs and since it is a nonparametric approach prior aggregation of the inputs or outputs is not necessary. Further, a specific functional form for the production process does not need to be imposed on the model (as is required in the use of the SFA approach).

Since its introduction in 1978, DEA has become one of the preeminent nonparametric methods for measuring efficiency and productivity of DMUs. DEA is a linear programming technique which determines the best-practice frontier from a set of peers (DMUs) and measures efficiency between best-practice and observed units using multiple inputs and outputs. DEA models are now employed routinely in areas that range from assessment of public sectors such as hospitals and health care systems and schools and universities to private sectors such as banks and financial institutions. The advantage of DEA is to accommodate multiple inputs and multiple outputs for measuring the relative efficiencies of a set of homogeneous decision-making units without a priori assumption of profit maximization and cost minimization. DEA models are useful for performance evaluation and improvement of DMUs, including the multidimensional aspects of service efficiency issues and operations that can help managers improve service performance.

On the other hand, multi-criteria decision-making (MCDM) models require complex optimization problems using multiple objectives than using a single objective of either maximizing profit or minimizing cost. The multiple criteria

DEA and other goal programming models are examples wherein the decision maker can use multiple outputs and multiple inputs to examine service performance and improvement. This book also reveals how DEA is used in multi-criteria decision making and as a benchmarking tool.

Both DEA and MCDM have been frequently applied for measuring efficiency and productivity of service industries. Service sectors include financial services (banking, insurance, securities, fund management), professional services (accounting, legal, engineering, architecture), health services, education services, environmental services, energy services, logistics, tourism, information technology, telecommunications, transport, distribution, standards and conformance, audio-visual, media, entertainment, cultural, and other business services.

With the exception of some basic notions in DEA, this book is completely self-contained. Important concepts and applications in measuring efficiency of the service sector are carefully motivated and introduced. Specifically, we have excluded any technical material that does not contribute directly to the understanding of measuring efficiency with DEA. Many other excellent textbooks are available today that discuss DEA in much more technical detail than is provided here. This book is aimed at upper-level undergraduate as well as beginning graduate students who want to learn more about measuring and managing service productivity with DEA and other MCDM techniques, or who are pursuing research in DEA and its applications.

The main objective of this book is to provide the necessary background to work with existing DEA models. Once the material in this book has been mastered, the reader will be able to apply DEA models to his or her problems for measuring comparative efficiency of decision-making units in any service industry.

To facilitate this goal, the first chapter provides a literature review and summary of the current research in DEA with a focus on the service sector. In this introductory chapter we present a classification scheme with seven main primary categories in service industry, namely, education, hospital and healthcare, tourism, banking and finance, information technology and media services, transportations, and utilities. We discuss each classification scheme and group selected DEA papers published in the literature over the past three decades. Finally, we provide information on the use of Performance Improvement Management Software (PIM-DEA). A free limited version of this software and downloading procedure is also included in this book. This advanced DEA software enables you to make the best possible analysis of your data, using the latest theoretical developments in DEA. PIM-DEA software gives you the capacity to assess efficiency and productivity, set targets, identify benchmarks, and much more allowing you to truly manage the performance of any service industry. PIM-DEA is easy to use and powerful, and it has an extensive range of the most up-to-date DEA models, which can handle large sets of data.

This is followed by chapter "Development of Assessment Model for Research Efficiency of Universities," where **Jong-Woun Youn and Kwangtae Park** argue that the research in university is an essential part for national competitiveness and the foundation of knowledge and information of a society. This chapter assumes that the effective operation of limited resources by size of universities would be the plan for maximizing their effectiveness and suggests a grouping of similar universities by establishing a new classifying system. Based on the classifying system proposed in this chapter, four models including High Efficiency Expanding Model (HEEM), High Efficiency Stable Model (HESM), Low Efficiency Stable Model (LESM), and Low Efficiency Expanding Model (LEEM) are suggested through a practical analysis.

In the same content of education, **Dimitris Sotiros, Yannis G. Smirlis, and Dimitris K. Despotis** present an alternative method to assess the quality and extent of research in higher education in chapter "Incorporating Intra- and Inter-Input/Output Weight Restrictions in Piecewise Linear DEA: An Application to the Assessment of the Research Activity in Higher Education." They proposed an extension of Piecewise Linear DEA to value-based piecewise linear DEA that incorporates value judgments and allows common treatment for intra- and inter-input/output weight restrictions. Value-based piecewise Linear DEA further enables a better expression of individual preferences, enhances the model with the fully units invariance property, and also resolves the discontinuity issue that exists in the original Piecewise Linear DEA model.

The next two chapters are examples of use of DEA in health care efficiency. **Felix Masiye, Chrispin Mphukaa, and Ali Emrouznejad**, in chapter "Estimating the Efficiency of Healthcare Facilities Providing HIV/Aids Treatment in Zambia: A Data Envelopment Approach," discuss that many countries in Sub-Saharan Africa face a key challenge of sustaining high levels of coverage of AIDS treatment under prospects of dwindling global resources for *HIV/AIDS* treatment. Policy debate in *HIV/AIDS* is increasingly paying more focus on efficiency in the use of available resources. The aim of this chapter is to provide a framework to estimate short-term technical efficiency of HIV/AIDS treatment facilities using DEA. An application in Zambia shows the applicability of the proposed model.

In the same area of health efficiency, a benchmarking approach based on closest targets is given in chapter "Benchmarking in Healthcare: An Approach Based on Closest Targets" where **Juan Aparicio, Fernando Borras, Lidia Ortiz, and Jesus T. Pastor** examine the process of benchmarking in hospital performance. In particular, this chapter shows that the determination of closest targets as a benchmarking technique has significant advantages over traditional DEA methods for signaling keys for the inefficient hospitals to improve their performance. In doing so, this chapter uses a sample of hospitals, located in the eastern region of Spain. Further, some guidance in relation to determining potential improvement targets for each of the inefficient hospitals is given.

Services are becoming increasingly important to the developed and developing economies. However, evidence shows that as production moves from agriculture and manufacturing to service- and knowledge-based economies, productivity growth rates have declined. To date, there are no clear indicators for quantifying productivity for service and network based firms. This raises the question: *How can productivity be measured for service and network based firms*? **Moira Scerri and Renu Agarwal**, in chapter "Service Enterprise Productivity in Action (SEPIA)," present a systems view of productivity, which is organized into five sections: overview of productivity; current measures of productivity using KLEMS; existing service productivity models; service enterprise productivity in action (SEPIA) model; and new measures for service enterprise productivity. The key contribution of this chapter involves the operationalization of the SEPIA model and an illustration of the model through the use of an industry example.

This is followed by measuring good governance in chapter "Using Data Envelopment Analysis to Measure Good Governance" where **Rouselle Lavado, Emilyn Cabanda, Jessamyn Encarnacion, Severa de Costo**, **and Jose Ramon Albert** provide an estimate of good governance index using the DEA with evidence from Philippine provinces. This chapter illustrates how DEA can be used to provide insights on how provinces can improve on various indicators of governance. Aside from identifying peers, DEA is also able to estimate targets, which can serve as a guide for central governments in holding provinces accountable. This chapter shows that DEA is not used only for efficiency measurement but also applied to other applications in benchmarking and index generation, including nonprofit sectors such as public agencies.

A DEA-based methodology is developed in chapter "Measuring the Performance of Service Organizations and the Effects of Downsizing on Performance: Evidence from the Greek Citizen Service Centers" to measure the performance of not-for-profit and for-profit service organizations. **Panagiotis D. Zervopoulos** proposes a methodology that can incorporate endogenous and exogenous variables in the production process, which are directly or inversely related. This methodology always identifies reference units that are qualified in all of the dimensions of performance. In addition, it defines appropriate changes to the resources that are used by the low-performing units to enable them to become qualified in all facets of performance at the optimal condition. The methodology that is developed in this chapter is applied to public organizations, which are in charge of the provision of administrative services to citizens, in two instances: before and after the implementation of downsizing as part of the public management reform agenda. The results obtained from the assessment methodology are the basis for the analysis of the impact of structural reform, and particularly of downsizing, on the performance of public service organizations.

Luciana Yeung, in chapter "Measuring Efficiency of Courts: An Assessment of Brazilian Courts Productivity," develops a DEA framework for measuring efficiency in the Judiciary, specifically in State Courts with an illustration from Brazil. The chapter argues that both inefficient and unstable units could use DEA results to improve their management and to achieve better results in their efficiency, productivity, and effectiveness in the delivery of judicial services.

This is followed by an application of cost-efficiency and market power in chapter "Cost Efficiency and Market Power: A Test of Quiet Life and Related Hypotheses in Indonesian Banking Industry." **Viverita** investigates the relation between market power and cost-efficiency (the *quiet life hypothesis*), and the two competing hypotheses of the relationship between market power and efficiency as well as market concentration on profitability (*Structure Conduct Performance* and

Efficient Structure). This is illustrated with an application in the Indonesian banking industry from 2002 to 2011. Further to DEA and to capture the equilibrium dynamic of the Indonesian banking industry, the Lerner index method is used to measure the level of competition. Results of this chapter fail to reject both *Structure Conduct Performance* hypothesis and *Efficient Structure* hypothesis, but disapprove the existence of the *quiet life hypothesis* in the Indonesian banking market.

Internal structure of service organizations is important in service productivity. **Ming-Miin Yu and Li-Hsueh Chen**, in chapter "Internal Structure of Service Organization: From Multi-activity Financial Institutions to Network Structure Hotels," discuss that in recent years, based on characteristics that operational processes of financial institutions and hotels may jointly engage in multiple activities and multiple processes. This chapter is dedicated to describing internal structures of financial institutions and hotels as well as providing relative DEA models and applications. The chapter illustrates that in order to conform to real operational situations, the construction of DEA model should consider and match the internal operational characteristics of decision making units.

As another application **Michael L. Antonio** and **Ma. Socorro P. Calara,** in chapter "Application of DEA in the Electricity Sector: The Case of Meralco Distribution Sectors," present an application of DEA in the electricity sector with the Case of Meralco Distribution Sectors. The chapter seeks to (1) evaluate and compare the technical efficiency performance of Meralco Distribution Sectors using selected Performance-Based Regulation (PBR) indicators and other inputs, (2) determine which Meralco Distribution Sector achieved the highest technical efficiency performance, and (3) identify areas for improvement of each Meralco Distribution Sector. A linear monotone transformation was adapted to make use of an undesirable output in the DEA model. The chapter's findings imply that the management of Meralco or distribution sectors need to formulate strategies and policies that would further improve their performances.

Chapter "Improving Energy Efficiency Using Data Envelopment Analysis: A Case of Walnut Production" is an application of DEA for improving energy efficiency in farms with a case of Walnut Production. **Alireza Khoshroo and Richard Mulwa** discuss that Walnut is one of the most nutritive crops and modern production methods that can require large quantities of energy. Efficient use of these energies is a necessary step towards agricultural sustainability. Hence, this chapter focuses on optimizing energy consumption in walnut production by identifying and reducing excessive use of energy. DEA is used to model efficiency as an explicit function of human labor, machinery, fertilizers-chemicals, and irrigation energies. The result of DEA analysis shows a substantial inefficiency between the Walnut producers in the studied area, with the main difference between efficient and inefficient producers being in the use of chemicals, potash, machinery, and irrigation water.

Chapter "Service Productivity in IT: A Network Efficiency Measure with Application to Communication Systems" focuses on more advanced DEA models such as network efficiency measure with the application to communication systems. **Adeyemi Abel Ajibesin, Neco Ventura, H. Anthony Chan, and Alexandru**

Murgu introduce a network efficiency measure, which is a new kind of thinking for many evaluators in information technology and engineering. Efficiency measure involves going beyond knowledge (real or estimated) of program (nodes, algorithms, networks, etc.) impact and attempting to compare with other programs. In most cases, this knowledge leads to a decision as whether to replace the program with another more effective program. In this chapter, DEA is applied to extend the existing engineering method in computer networks and to evaluate the efficiency of communication networks.

In the same area of IT efficiency, **Geeta Sharma**, in chapter "Efficiency of Software Development Projects: A Case Study on an Information Technology Company in India," applies DEA to evaluate the relative efficiency of software development projects of a leading software company in India. In this chapter, projects are categorized as per their efficiency scores into highly efficient, moderately efficient, and less efficient companies through a process called Tier Analysis. The chapter also includes an improvement path for the projects with low efficiencies. Furthermore, through the application of Kruskal Wallis test, the software development project efficiency is compared with team size to determine whether efficiency varies across various team size categories, i.e., small, medium, large and extra-large.

The rest of this book is on the transport efficiency. **Darold T Barnum, John M Gleason**, **and Matthew G Karlaftis**, in chapter "Protocol for Comprehensive Efficiency Analysis of Multi-Service Metropolitan Transit Agency Operators," present a DEA protocol for analyzing the efficiency of metropolitan transit agencies that oversee multiple types of transportation services. The protocol is illustrated by applying it to United States transit agencies that can serve their cities with four types of subunits: self-operated motorbus, outsourced motorbus, self-operated demand-responsive, and outsourced demand-responsive. Using DEA models adapted for non-substitutable inputs and outputs, scores estimated for a focus agency include: (1) technical efficiency of the focus agency as a whole, (2) technical efficiency of each of the focus agency's subunit types when each subunit is compared only to others of the same type, (3) allocation efficiency of the focus agency in apportioning resources among its subunits, and (4) the effect of each subunit's technical efficiency on its parent agency's technical efficiency. Finally, a mathematical programming algorithm is illustrated that allocates the focus agency's resources to its subunits with the objective of decreasing the cost of transit in an urban area while holding total ridership constant. The protocol thereby is a comprehensive analysis and synthesis of a focus transit agency's efficiency in providing services to its metropolitan area.

Measuring the sustainability of air navigation services is subject of the chapter "Measuring the Sustainability of Air Navigation Services." **Vladimir Grigorov and Paula Rachel Mark** discuss that service productivity is synonymous with the organizational sustainability. It has applications that are broader than conserving the environment via agroindustrial innovation. The domain of Air Navigation Services is a classic example of a service industry, the sustainability of which can be determined using its organizational efficiency and effectiveness. It is a challenge to measure these organizational factors in this profession, because of insufficient data and the effect of random events such as inclement weather that cannot be quantified. A DEA caters for these restrictions and is thus an appropriate tool for determining the sustainability of Air Navigation Service Providers. The DEA results highlight the need for urgent attention to the organizational structure of Air Navigation Services and the reallocation of resources that will improve sustainability.

Sreekanth Mallikarjun, Herbert F. Lewis, and Thomas R. Sexton in chapter "Measuring and Managing the Productivity of U.S. Public Transit Systems: An Unoriented Network DEA" explain that the U.S. governments at all levels face budget shortfalls, and consequently public transit systems in the United States must compete with other public services for financial support. In order to depend less on public funding, it is critical that public transit systems focus on their operational performance and identify any sources of inefficiency. In this chapter, they present an unoriented network DEA methodology that measures a public transit system's performance relative to its peer systems, compares its performance to an appropriate efficient benchmark system, and identifies the sources of its inefficiency.

In the same area of public transport, **Thomas R. Sexton, Allan J. Jones, Andy Forsyth, and Herbert F. Lewis**, in chapter "Using DEA to Improve the Efficiency of Pupil Transportation," provide an example of use of DEA in Washington State that like many other states spends hundreds of millions of dollars annually to support the transportation of pupils to and from school. As with other state-funded activities, inefficiency increases costs and saps resources away from other critical state functions such as public and higher education, health care, transportation, and many others. In 2006, the state undertook a project to revise its pupil transportation funding formula and encourage its school districts to operate more efficiently. Together with Management Partnership Services, Inc., the state developed a DEA-based efficiency measurement system that it now uses to identify inefficient pupil transportation systems for management intervention. The system has identified potential first-year savings of roughly $33 million, with recurrent annual savings of at least $13 million.

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