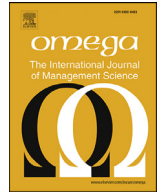




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Hierarchical network systems: An application to high-technology industry in China[☆]

Linyan Zhang*, Kun Chen*

College of Auditing and Evaluation, Nanjing Audit University, Nanjing 211815, PR China

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ABSTRACT

In real world situations, there is a hierarchical structure exists in a specific organization and each component has its network process. However, such hierarchical network system has not been well studied in previous literature, and misleading results often are produced. The current paper discusses a data envelopment analysis (DEA) modelling technique for a network structure where a hierarchical system consists of components having two-stage series processes. An additive network DEA is proposed to evaluate the performance of this type of network structure. The overall and divisional efficiencies of the system and each component can be derived, and the relationship between system efficiency, divisional efficiency and the ones of components is discussed. The newly developed additive network DEA is nonlinear and cannot be converted into a linear program. A semidefinite programming (SDP) approach is developed for effectively solving this model and the global solution can be guaranteed. Another linear multiplicative network DEA also developed for this hierarchical system. The two newly developed models are illustrated with a case of the performance evaluation of high-technology industry in China.

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1. Introduction

Data envelopment analysis (DEA) is a technique for measuring the relative efficiency of a set of decision making units (DMUs) applying multiple inputs to produce multiple outputs [4,9]. DEA has been applied to an enormous number of practical problem settings, and its modelling structure has been extended in many directions (see, e.g. [15,42,43]). In many real-world cases, DMUs may consist of internal or network structures with intermediate measures or links. Compared with the standard DEA model where the internal structure of DMUs is not taken into account, the network DEA refers to applying the DEA technique to DMUs of multistage processes composed of a number of divisions operating interdependently with each other. See for example, Färe and Grosskopf [21], Tone and Tsutsui [46], Fukuyama and Weber [24], Cook and Zhu [17], An et al. [2], Fukuyama and Matousek [23] and Kao [33].

Usually, almost all organizations have a hierarchical structure. An organization has several levels and each level consists of a number of subunits. A unit at the higher level is divided into several subordinate units at the lower level. At the first level, for ex-

ample, there are several units, under which some subunits are located at the second level. Some larger units in the second level sometimes maybe further divided into several subordinate units with different functions at the third level, and so on (see also [31]). It is noted that each component in each level usually has a multistage operational process. In other words, a multistage network process is embedded in each component of hierarchical system. However, such hierarchical network structure has attracted relatively little attention. How to evaluate the performance of the hierarchical network system to identify the efficiency relationship in such cases is a valuable research issue in DEA.

Some approaches in DEA are developed for the hierarchical structure. For example, a distance function model is developed by Färe and Primont [20] to measure the efficiency of multi-plant firms, which is applied by Kao [28] to measure the efficiency of 8 forest districts in Taiwan, with a total of thirty-four subordinate working circles. Cook et al. [13] and Cook and Green [14] propose a CCR-type model to measure the efficiency of ten Canadian power plants, with forty subordinate power units. Castelli et al. [7] propose two models to measure single-level and two-level hierarchical structures where the units at the first level can have common subunits at the second level. However, the operation of each component is treated independently in Castelli et al.' [7] models for two-level systems. The relationship among these components is not considered in their models, which only measure the whole DMU.

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* Corresponding authors.

E-mail addresses: linyanzhang@yeah.net (L. Zhang), kunchen@nau.edu.cn (K. Chen).

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