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Two-level DEA approaches in research evaluation☆

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Abstract

It is well known that the discrimination power of data envelopment analysis (DEA) models will be much weakened if too many input or output indicators are used. It is a dilemma if decision makers wish to select comprehensive indicators, which often have some hierarchical structures, to present a relatively holistic evaluation using DEA. In this paper we show that it is possible to develop DEA models that utilize hierarchical structures of input–output data so that they are able to handle quite large numbers of inputs and outputs. We present two approaches in a pilot evaluation of 15 institutes for basic research in the Chinese Academy of Sciences using the DEA models.

Keywords: Hierarchical structures; Discrimination power; DEA; Research evaluation

1. Introduction

Nowadays, performance evaluation and benchmarking become routine practices in performance management. It has also been well recognized that a single indicator may not be sufficient for effective performance management, especially for the performance evaluation of research institutions, which often have multi-dimensional research activities. It is now a usual practice to set or select a set of performance indicators in the performance evaluations of research institutions.

For evaluation of decision making units (DMUs) with multiple-inputs and multiple-outputs in public sector, data envelopment analysis (DEA) is now one of the most widely accepted methods to measure the relative efficiency or productivity of research institutions. However, it is well-known that the discrimination power of DEA models will be much decreased if too many inputs or outputs are used. It is a dilemma if the decision makers (DMs) wish to select comprehensive indicators to present a relatively holistic evaluation using DEA. This is especially the case in the evaluation of research institutes in the Chinese Academy of Sciences (CAS), where usually many different outputs are measured in the evaluation in order to produce relatively comprehensive performance profiles of these institutes [1].

Intuitively, people may wish to use some statistical techniques to reduce numbers of indicators in order to improve DEA discrimination power. In practical applications, there have quite a few papers proposing different techniques on indicator reduction or aggregation, such as dropping highly correlated indicators [2–5], or selecting the main components by principle component analysis (PCA) [6], or aggregating indicators by analytic hierarchy process (AHP) [7–10].

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However, the standard DEA models are sensitive to indicator set changes. It was shown that even removal of a highly correlated output (or input) can greatly change the evaluation results [11]. Furthermore removal of highly correlated data may not be rational in the evaluations of research institutions, where it is well accepted that research institutions may have many outputs and their consequences like papers, citations of papers, awards, and invited talks, etc., which are complementary but often highly correlated. Often the DMs wish to include many such correlated indicators in order to present a relatively comprehensive evaluation. It may be difficult to justify removals of the indicators just due to data correlations.

It has been observed that in the evaluations of research institutions, often these indicators can be grouped hierarchically, where weights can be assigned to reflect the relative importance of different indicators in overall substitutions *within the groups, while no such substitutions can be easily decided among these groups* so that they are best considered to be no-substitutable. In this paper, we carry out a pilot study on DEA productivity evaluation of 15 institutes for basic research in the CAS by exploring multi-level data structures. The main purpose of this investigation is to explore the possibility of using DEA for efficiency evaluation of the CAS, where a large numbers of indicators were used so that the standard DEA models have not been able to be applied.

2. Inputs and outputs used in the evaluation of the CAS research institutes

One of the main missions of the CAS is "to *carry out top level research at the forefront of basic sciences*". Actually, the CAS is a major player in basic research in China. Following the process of Knowledge Innovation Program (KIP) of the CAS, which was launched in 1998, research quantity and quality of basic research have been steadily increased. In the evaluation of sustainability in the comprehensive evaluation system (CES) in 2002, research outcomes were measured from three aspects: objective achievements, quantitative measurements, and social and economic contributions [12]. Objective achievements were evaluated by peer review based on the pre-signed short-term (3 years) research contracts between the CAS administration and its research institutes. Quantitative measurements were based on the three sub-indicators: high quality publications—the number of publications in top research journals in different disciplines; invited talks in top international conferences; important national and international awards. Then patents commercialization, joint company numbers, rewarded invention patents, significant consultant reports and national standards setting-up were selected as the sub-indicators to social and economic contributions of the basic research. With these selected indicators and assigned weights, weighted sums of sub-scores of various indexes and volume data were used to produce the overall performance scores in the CES 2002. However, the rationality of the weights selection has always been questioned since the CAS evaluation system ever started. These provided us the initial motivations to apply DEA analysis on performance evaluation of the research institutes in the CAS, especially on research productivity evaluation. Since DEA allows some flexibility of weights selection, thus the problem of weights selection could be dealt with by using DEA.

In DEA applications, inputs and outputs need to be decided in advance. For research evaluation of basic research, usually the inputs are quite straightforward to decide. The number of research staff, the total research expenditures and the research equipment expenditures are the main hard research inputs for research activities. In this paper, the number of researchers is counted using the total permanent research staff plus post-doctors. Research expenditures exclude pensions of retired staff and equipment investment. The data of research equipment come from the CAS statistical annual report. Furthermore, there should also be some soft inputs that can benefit research outputs. However, data of this type are not available.

Research outputs are numerous, depending on different stakeholders' views. Nowadays, direct research outputs, research competitiveness and scientists cultivation are the three main aspects on performance evaluation of basic research in the CAS. Fig. 1 represents a view from the level of the Bureau of Basic Sciences on the most important performance indicators of the 15 institutes for basic research in the CAS. These indicators are direct research outputs, external research funding, and scientists cultivation, respectively [13]. They are also frequently used in performance evaluation of basic research in the world [14–18].

Meng et al. presented a questionnaire analysis in 2005, where AHP was used to judge relative importance for some research outputs of the 15 institutes for basic research in the CAS, and the selected research outputs were structured in three levels, as Fig. 1 shown [13]. Direct research outputs, external research funding and scientists cultivation are the first level. On the second level, direct research outputs can be further decomposed into five sub-indicators,