Applied Mathematical Modelling 39 (2015) 4385–4404

Contents lists available at ScienceDirect

Applied Mathematical Modelling

journal homepage: www.elsevier.com/locate/apm

Distinctive data envelopment analysis model for evaluating global environment performance

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ARTICLE INFO

Article history:
Received 23 January 2013
Received in revised form 26 October 2014
Accepted 20 December 2014
Available online 31 December 2014

Keywords:
Data envelopment analysis
Global environmental performance
Imprecise data
Minimax regret-based approach
Non-discretionary factor
Undesirable factor

ABSTRACT

Evaluations of world environmental activities comprise an important research area when obtaining a better understanding of global efforts. However, some environmental criteria might include imprecise data. Environmental criteria can be classified according to four categories: discretionary, non-discretionary, desirable, and undesirable factors. The data envelopment analysis (DEA) technique has been applied widely to assess environmental performance. Classical DEA models evaluate performance of decision making units (DMUs) individually. However, the classical DEA models have some weaknesses. First, they focus on individual DMUs, where they freely assign weights to DMUs to obtain the best efficiency scores. Second, classical DEA models do not aggregate the performance of all DMUs to obtain an overall performance score. Finally, the calculations employed by classical DEA models are very long. To overcome these weaknesses, we propose DEA models for evaluating the individual and overall environmental performance of countries. The proposed models consider discretionary, non-discretionary, desirable, and undesirable factors simultaneously. Countries (DMUs) are ranked using a minimax regret-based approach (MRA). We provide a numerical example that illustrates the application of the proposed models.

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1. Introduction

Governments are now required to implement environmental practices to enhance their green image [1,2]. At present, people view their government as the savior of the environment. However, in contrast to popular belief, governments are not ultimate protectors of the environment. Indeed, different activities of governments may expose the environment to the dangers of global warming. Clear examples of public programs that destroy the environment were reported by Leal and Meiners [3]. The World Bank reported that cutting energy subsidies will reduce carbon emissions by 14%, 11%, 17%, 26%, and 49% in India, Indonesia, Russia, Venezuela, and Iran, respectively. Therefore, evaluating the environmental performance of countries is an important issue.

Environmental performance assessment is a multiple criteria decision-making problem and might include imprecise data, non-discretionary factors, and undesirable factors.

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http://dx.doi.org/10.1016/j.apm.2014.12.053
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Data envelopment analysis (DEA) is an appropriate technique for evaluating environmental performance. DEA is a nonparametric technique proposed by Farrell [4], which was later developed by Charnes et al. [5]. DEA is used to compute the relative efficiency of decision-making units (DMU), which consume multiple inputs to produce multiple outputs [6–10].

Classical DEA models assume that DMUs are evaluated individually. In particular, they focus only on individual DMUs, where weights can be assigned in a flexible manner to obtain DMUs with the highest efficiency score. However, classical DEA models have several problems. That is, efficiency evaluation based on DMU should employ a set of objectives in some cases. Achieving these objectives should require the coordinated action of all the DMUs. Therefore, obtaining individual DMUs with the best efficiency may not necessarily mean that the objectives have been satisfied. For example, in an insurance company, the aggressive competition between insurance agents (or brokers) may make customers unhappy in different ways. Specifically, in order to attract more clients, they may reduce the profit margin by lowering the insurance services rates below the adjusted limits determined by the company. As a result, the customer service quality is reduced (e.g., operations with low speed and delays). This strategy succeeds because customers are attracted to less expensive agents more than better customer service. The agents may also increase profitability by abusing a customer's lack of awareness by offering no regular discounts and/or providing unrequested ancillary services to reach a higher level of operating performance than other agents. Therefore, the destructive partnership between an insurance company and insurance agents can pose serious challenges for the company in the future or tarnish the reputation of the company. Similar problems may also effect environmental performance assessments. Ozone layer depletion, global warming, and climate change are consequences of the industrial activities of countries, but we cannot blame a particular country. Furthermore, a specific country is not responsible for improving the environment. Therefore, international collaborations are needed because the individual actions of countries are not sufficient.

In addition, the classical DEA models do not aggregate the performance of DMUs, so we cannot obtain an overall performance score based on all DMUs. Once again, we use the example of an insurance company. It is clear that the aggregated profitability of a company depends on the profitability of its individual agents. This implies that the inputs and outputs of the insurance company are the sum of the corresponding inputs and outputs of agents. Therefore, a company is efficient if and only if all the agents are efficient, whereas the inefficiency of agents leads to inefficiency in the insurance company. Thus, it can be concluded that a company's performance depends on the performance of its agents.

Furthermore, after solving J linear programming problems (where J represents the number of DMUs), the weights of the outputs and inputs vary among the DMUs. Therefore, for a given factor, there are J different weights. One weight may indicate a high degree of importance and another weight may denote a low degree of importance. Therefore, decision makers may be confused about the appropriate weights for factors. Finally, the calculations employed by classical DEA models are burdensome, i.e., to obtain the efficiency score for J DMUs, J problems must be solved. To overcome these weaknesses, we propose a new DEA model. The proposed model considers collaborative activities among DMUs. It determines the efficiency of individual DMUs but it also aggregates the efficiency scores of all the DMUs. Furthermore, the model assigns a unique weight to each factor. The number of calculations is reduced because the proposed model is run only once. Moreover, the new model can deal with imprecise data, desirable factors, undesirable factors, discretionary factors, and non-discretionary factors simultaneously.

The classical DEA models provide managerial information to facilitate performance improvement. In particular, the classical DEA models determine benchmarks for indentifying inefficient DMUs. Similarly, the proposed models indicate the degree to which reductions in amounts of inputs (or augmentations in amounts of outputs) of an inefficient DMU can make it efficient. Similar to the classical DEA models, during the dual formulation (i.e. the envelopment form) of the proposed models, if the variable that corresponds to DMU_j takes a positive value, the DMU_j is efficient and is referred to as the benchmark.

To the best of our knowledge, no previous studies have assessed environmental performance throughout the world using DEA method. In present study, we applied our proposed approach to evaluate the environmental performance of 163 countries (as individual DMUs). Moreover, we assessed their overall performance. Countries are ranked by a minimax regret-based approach (MRA).

The remainder of this paper is organized as follows. In Section 2, we present a review of previous studies. The proposed models are introduced in Section 3. Numerical example and policy implications are discussed in Sections 4 and 5, respectively. Finally, Section 6 gives some concluding remarks.

2. DEA and the environmental performance of countries

Due to the complexity of the environmental performance evaluation process, most eco-efficiency measures are either very limited or they depend on some subjective weighting scheme. Thus, decision makers must follow a convoluted assignment process to allocate the numbers to preferences in an accurate manner, where the weightings become more complex as the number of performance criteria increases. One application of the DEA technique is assessing the relative eco-efficiency of DMUs. The DEA does not require subjective judgments to allocate weights to criteria.

The DEA considers various substitution possibilities among different natural resources and emissions.In the conventional DEA framework [5], the inputs and the outputs are assumed to be strongly or freely disposable. However, this might not always be true in real production processes. In other words, reducing the undesirable outputs of a production process might

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