Performance assessment of Iranian electricity distribution companies by an integrated cooperative game data envelopment analysis principal component analysis approach

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Highlights

- •

We combine bargaining game, PCA and DEA model to obtain the efficiency scores.

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The integrated approach is applied to electricity distribution companies in Iran.

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PCA is combined with DEA to reduce the number of variables.

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The bargaining game is combined with PCA–DEA to obtain more realistic results.

Abstract

This paper introduces an integrated approach to evaluate efficiency of electricity distribution companies. It combines bargaining game theory, principal component analysis (PCA) and data envelopment analysis (DEA) to obtain more realistic results with higher resolution power. In real world case studies, classical DEA models often identify too many decision making units (DMUs) as efficient. It also occurs when the number of DMUs under evaluation are not large enough compared with the total number of inputs and outputs. To overcome this problem and reduce the number of the variables, PCA technique is combined with the conventional DEA model. Then, the bargaining game model is combined with the PCA–DEA model in order to discriminate among the DMUs. To illustrate the performance of the proposed approach, thirty-seven Iranian electricity distribution companies are evaluated. The results indicate the abilities of the proposed approach to evaluate the DMUS in a competitive environment.

Introduction

In real world, it is often necessary to rank a group of peer decision making units (DMUs) which produce multiple outputs by consuming multiple inputs such as schools, hospitals, banks, enterprises, regions, electricity companies and so on (Bian and Li [8]). Performance measurement of electricity distribution companies is considered as one of the most important issues among regulators. In fact, regulators compare the electricity distribution companies and adjust different factors such as price and revenue in the incentive-based schemes. The incentive based schemes are designed to provide a measurement scheme to compensate the efficient companies versus inefficient ones. There are several methods for efficiency estimating of DMUs such as DEA, PCA and Stochastic Frontier Analysis (SFA). DEA is one of the most important and common models for efficiency estimation and ranking of the DMUs. DEA was proposed by Charnes et al. [12] and extended by Banker et al. [5].

Suppose there are n DMUs where each DMU_j ($j = 1, 2, \dots, n$) produce s outputs y_{rj} ($r = 1, \dots, s$) by utilizing m inputs x_{ij} ($i = 1, \dots, m$). DEA uses the following measure to evaluate of DMU_o's performance:Unfortunately, the power of the conventional DEA model in the presence of the large number of the inputs and outputs is weak. In the other words, if the number of DMUs increases in the model (1), DEA introduces most of the DMUs as efficient units. In this paper, to overcome the mentioned weakness of the DEA, PCA and game theory approaches are combined with the DEA to get more realistic results. First, PCA model is combined with the DEA to reduce the number of the variables. Then, the approach based on the DEA and bargaining game model is used to compare the DMUs in the competitive environment. The rest of the paper is organized as follows: 'Literature review' provides a literature on electricity distribution companies, proposed approaches and methods used in this article. 'Methodology' introduces the methodology of the proposed model. In 'Case study', the case study is presented. The results and analyses of the case study are provided in 'Results and discussion'. Finally, the conclusion is summarized in 'Conclusion'.

Section snippets

Literature review

As mentioned before, performance evaluation of the electricity distribution companies is one of the most important issues for the researchers and regulators, especially in the last years. Sadjadi et al. [45] have evaluated Iranian electricity distribution companies by using an interactive robust data envelopment analysis (IRDEA) model. They have proposed the novel model to determine the input and output target values of electricity distribution companies with considering the existence

PCA model

According to the Zhu [57], Premachandra [40] and Liang et al. [32], PCA is applied to evaluate and rank the performance of *n DMUs* (j = 1, 2, … , n) with m inputs (i = 1, 2, … , m) and s outputs (r = 1, 2, … , s) which the ratio between every output and every input is as follows:Obviously, the bigger the , the better the performance of DMU_j in terms of the rth output and the rth inputs. Now let , e.g., k = 1 corresponds to i = 1, r = 1 and k = 2 corresponds to i = 1, r = 2, etc.,

Case study

In order to have a better understanding of the performance of the proposed model, the proposed method is implemented by using some actual data of year 2010 for Iranian electricity distribution companies. There are some studies for efficiency estimating of electricity distribution companies. Goto and Tsutsui [23] used DEA model to measure overall cost efficiency and technical efficiency between Japanese and US electricity utilities. They showed that Japanese utilities were more efficient than US

Results and discussion

In order to demonstrate the performance of the proposed PCA–DEA–Bargaining game model, the dataset of 37 Iranian electricity distribution companies are used and an efficiency measures and ranks are calculated for each company in 2010. The results of the standard input-oriented DEA model are shown in the third column of Table 3. As shown, 31 companies are efficient and lay on frontier. Other companies are inefficient and need to improve their performance. Obviously, the efficiency scores from

Conclusion

In this paper, an approach based on the PCA, DEA and game theory introduced and applied for the Iranian electricity distribution companies in order to measure their relative performances in the competitive environment. 37 electricity distribution companies with six inputs and eight outputs considered for the purpose of this study. All of these inputs and outputs are important for the decision makers and top managers of the companies. But, because of the large number of the inputs and outputs,

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The efficiency of the distribution subsystem is higher than in two other subsystems, which may be due to the privatization of these subsystems resulting in more competition among the companies. Also, these results are in line with (Omrani et al., 2015; Sadjadi et al., 2011) (Fig. 9). While our findings of the electricity generation subsystems are opposite to (Jahangoshai Rezaee et al., 2012), which is probably due considering the thermal power plants only in (Jahangoshai Rezaee et al., 2012) while all types of electricity generation sources were considered here.

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