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Performance evaluation of Iranian electricity distribution units by using stochastic data envelopment analysis

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ABSTRACT

This paper introduces an approach based on stochastic data envelopment analysis (SDEA) for performance assessment of electricity distribution units. A new approach is applied for assessment of Iranian distribution units from 2001 to 2011 in this paper. There are usually incomplete and stochastic data or lack of data with respect to electricity distribution companies. Due to lack of information about some parameters, theory of probability is imported to the model. Different Iranian distribution units are considered as decision making units (DMUs). Network length, transport capacity and the number of employees are chosen as inputs while number of customers and total electricity sales are chosen as stochastic outputs. Then, the best electricity distributions units are selected with respect to efficiency scores in stochastic environment. Also, SDEA model is performed for each input, separately to identify the most important input indicators by comparing the results of associated efficiencies with SDEA model. The empirical results show that network length is the most important and influential input factor in this particular case study. To the best of our knowledge this is the first paper that examines stochastic outputs for assessment of electricity distribution units by SDEA in Iran.

Introduction

Energy is one of the basic concerns after starting the industrial revolution. Therefore, improving the efficiency of electricity distributions is an important issue around the word. There are different parametric and non-parametric methods for estimating efficiency scores of electricity distribution units. Also, different indicators for measuring the efficiency of electricity distributions such as price or revenue cap regulation schemes, sliding-scale, rate of return, partial cost adjustment, menu of contracts, and yardstick regulation are taken into account in previous studies such as Comnes et al. [7], Hill [13], Joskow and Schmalensee [15], Jamasb and Pollitt [14] and Hall [12].

Electricity industry plays an important role in the development of the countries. Assessment of the electricity distribution industry plays an important role in improving the performance. Therefore, in this study, a new approach is applied for assessment of Iranian distribution units over the period 2001–2011 to improve the performance. In this regards, 17 Iranian electricity distribution units are considered as the decision making units in this study. The main objective of this study is assessment of electricity distribution units with respect to five important indicators, which considered by Omrani et al. [18], including network length, transport capacity, number of employees, number of customers, and total electricity sales using SDEA approach. In addition, the most important input indicators are identified to enhance the performance of each electricity distribution unit.

The rest of this paper is organized as follows. The relevant literature has been reviewed in Section 'Literature review'. The proposed approach is presented in Section 'Methodology'. The implementation procedure of the approach for evaluation the performance of electricity distribution units is investigated in Section 'Case study' and the paper is concluded in Section 'Conclusion'.

Literature review

In the last decade, assessment of the power sector performance has been gained increasing attentions. Policy making, performance optimization and assessment of electricity distribution units are very important issues for regulators in the electricity restructuring and reform. Indeed, the efficiency levels of various methodologies are employed to set x-factors in the incentive regulation approaches such as revenue cap and price cap regulation. Debreu [8] and Farrell [10] introduced the concept of global technical efficiency and practical application of this theory had been established later in two

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category namely parametric and non-parametric approach. The parametric approaches apply statistical techniques whilst non-parametric approaches use linear and non-linear programming techniques such as data envelopment analysis (DEA) [9].

There are several studies about efficiency estimation electricity distribution units. Data envelopment analysis (DEA) is an ideal approach to evaluate the performance of various systems with multiple inputs and outputs. DEA is a popular optimization method for measuring the relative efficiency of decision making units (DMUs). Fallahi et al. [9] used DEA approach to assess the performance of power electric generation management companies. They considered installed capacity, fuel, labor, electricity used, average operational, time, and net electricity produced as key performance indicators (KPIs). In addition, the efficient company was identified in their study.

Azadeh et al. [2] presented a deterministic approach for performance assessment of electricity distribution units in Iran. They used DEA and principle component analysis (PCA) in their proposed approach. Network length, transformers capacity, number of employees, unit's delivery, and service area had been considered as major indicators in their study. In another study, Azadeh et al. [3] presented an approach based on DEA, corrected ordinary least squares (COLS), stochastic frontier analysis (SFA), and PCA methods for efficiency estimation of electricity distribution units. They selected the optimum DEA model for their particular case study. In addition, electricity distribution units had been evaluated and optimized through their proposed approach. They considered number of employees, operating costs, network length, transformer capacity, number of customers, size of service area, and unit's delivery as the most widely used indicators for evaluation of electricity distribution units.

DEA and window analysis (WA) were applied by Sözen et al. [24] for efficiency assessment of ten hydro-power plants. They used DEA with respect to the production and energy unit cost in order to optimize hydro-power plants. See et al. [21] presented SFA method for calculating technical efficiency levels of Malaysian thermal power plants. Fuel, labor, production indicator, and unit's delivery are chosen as input and output variables in their study. They demonstrated that plant size and fuel type have a significant impact on the performance.

An interactive robust data envelopment analysis (IRDEA) model was applied by Sadjadi et al. [20] to determine the input and output target values of electricity distribution companies. In their study, network length, transport capacity, number of employees, number of customers, and total electricity sales are considered for assessment by IRDEA. Also, Omrani et al. [18] considered these indicators to evaluate efficiency of Iranian electricity distribution units by using COLS and PCA. Lei and Feng [16] and Amina et al. [1] presented forecasting problems in flied of with respect to price and consumption in power generation units.

In terms of the impact of the most important contextual variables on efficiency scores in electricity industries, Zhang and Bartels [28] used DEA to study the effect of sample size on the mean productive efficiency of firms in electricity distribution in Australia, Sweden and New Zealand. By using Monte Carlo simulation, they showed that the mean efficiency is related to the sample size. Giannakis and Louis [11] presented a quality-incorporated benchmarking study of the electricity distribution utilities in the UK between 1991/92 and 1998/99. They found that cost-efficient companies did not necessarily exhibit high service quality and that efficiency scores of cost-only models did not show high correlation with those of quality-based models. Their results showed that integrating quality of service in regulatory benchmarking is preferable to cost-only approaches.

Pacudan and De Guzman [19] used DEA analyzed the productive efficiency and simulated the effect of the energy efficiency policy on the productive efficiency of the electricity distribution industry in the Philippines. They showed that the energy efficiency policy which benefits the overall economy and whole electricity supply industry results also in productive efficiency improvement in the distribution sector of the industry. Von Hirschhausen et al. [26] applied non-parametric (DEA) and parametric tests to evaluate the efficiency of electricity distribution industries in Germany. In this study, the inputs include capital, labor, and peak load capacity, and units sold and the number of customers are output. The data cover 307 German electricity distribution industries. The results indicate that returns to scale play but a minor role; only very small utilities have a significant cost advantage.

In estimating efficiency measures of the electric distribution industry in the previous studies, the different variables as inputs and outputs are adopted. The inputs which are frequently used in these studies include: actual number of employees (the number of employees); network losses (in GW h); and circuit of network line (in kilometers) [5,19]. The number of employees represents labor input. Circuit of network line and network loss denote capital inputs. Also the outputs variables include: actual number of customers (the number of customers); electricity sales (in GW h); and service area (in square kilometers). The number of customers shows the number of nodes the utility must supply. Many firms consist of geographically large distribution territories encompassing several cities, while others contain only a single city. The service area captures the effects of franchise area requirements and also consider the sparsely settled area. Both the km^2 of service area and the number of customers denote customer density. It should be noted that electricity sales contain all power deliveries to final consumer units.

In this paper, due to the lack of information about some parameters a stochastic DEA model is applied for evaluation shaping factor for performance assessment of electricity distribution units with respect to five important indicators including network length, transport capacity, number of employees, the number of customers, and total electricity sales. These indicators are frequently applied for assessment of electricity distribution units [14]. As mentioned before, network length, transport capacity, and the number of employees are controllable and deterministic indicators and are considered as inputs whilst number of customers and total electricity sales are uncontrollable and stochastic indicators and are chosen as outputs.

To the best of our knowledge, this is the first study that presents a novel approach for performance assessment of electricity distribution units with stochastic outputs. In addition, this study identifies important input indicators and weight of each input indicators have been achieved based on accurate mathematical modeling. The proposed approach is applied to Iranian distribution units from 2001 to 2011. The results of this approach can help managers and decision makers to improve the performance.

Motivation and significance

There are usually incomplete and stochastic data or lack of data with respect to electricity distribution units. This means data could not be analyzed by the deterministic models. Therefore, due to lack of information about some parameters, theory of probability should be imported to previous models. In this regard, new approaches for tackling such stochastic problems are required. This gap motivated the authors to develop a unique approach to handle such gaps for evaluating stochastic environment. Moreover, SDEA is developed and applied for evaluation of electricity distribution units.

In addition, five important indicators including network length, transport capacity, number of employees, number of customers, and total electricity sales are considered in this study to evaluate