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A study of the operation efficiency and cost performance indices of power-supply companies in China based on a dynamic network slacks-based measure model

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ABSTRACT

This paper applies the dynamic network slacks-based measure model with free links and fixed links (hereafter referred to as DNSBM-Free and DNSBM-Fixed respectively) to evaluate the operational performance of 31 electric power-supply companies (hereafter referred to as EPCs) in China from 2010 to 2012. This approach allows for the consideration of the group heterogeneity of electric power transmission. This approach also considers the new structural reform in the power grid of China in the near future, i.e., the separation of the transmission division (hereafter referred to as T) and the distribution division (hereafter referred to as D). We extend several performance indices to measure the cost efficiency and technology gaps in electric power supply. We estimate the efficiencies of the EPCs under different policies. The results indicate that regional economic development level has a significant impact on the performance of the EPCs. Under the DNSBM-Free and DNSBM-Fixed models, while the efficiency of D was a slightly higher than that of T before separating T and D, however, the efficiency of D was significantly lower than that of T after separation. Conversely, divisional efficiencies of some companies show a significant gap between T and D. This suggests that policy-makers should seriously balance the pros and cons of separation policy before making decisions, and the EPCs in China focus on enhancing operating efficiency of D when deciding to separate T and D in the future. Furthermore, this paper speculates that the macro-economic environment influences the policy of separation of T and D.

1. Introduction

Since 2012, electric power construction in China has experienced exceptional success, and electric power production and supply capabilities have dramatically improved. In 2013, China's capacity for full-caliber power generation equipment reached 1.14676×10^9 kW, a 7.9% increase from the previous year. National full-caliber electric power output reached 4.9865×10^{12} kW, a 5.41% increase from the previous year. Additionally, the newly increased production capacity of the national electric power infrastructure was 8.315×10^6 kW. From an investment perspective, 739.3 billion Chinese yuan was invested into the national power engineering construction. However, although the electric power industry in China is experiencing large scale development, if invested resources are not properly used, this will result in inefficient use of financial, material and human resources. To avoid blind investment, we should devote our full attention to every electric power-supply company's operational efficiency. For companies with high operational inefficiencies, we should analyze the cause of the problem and find methods of improving efficiencies—this will increase the social and economic benefits of electric power supply enterprises.

From a production efficiency standpoint, numerous studies have contributed benchmark figures for the inputs and outputs of power companies. In order to assess the influence of electric reforms in Australia, Abbott [1] and Aghdam [2] both integrated data envelopment analysis (DEA) models with Malmquist Index (MI) to analyze the operational efficiency of Australian power grids from 1969 to 1999. The results revealed that the electric reforms have improved the productivity and efficiency performance of the industry. Wang et al. [38] used DEA to analyze the efficiency and performance of power utilities and its effects on price under the price-cap performance based regulation (PBR) model. Yadav [40,41] used DEA to analyze the efficiency of 29 electricity distribution divisions in India. The results revealed that most of the divisions are inefficient due to scale inefficiency rather than technical inefficiency. Thakur et al. [30] used DEA to evaluate the performance of 26 Indian electricity distribution utilities. The results indicate that there is a great potential

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for Indian electricity distributions to reduce staff costs. Edvardsen and Forsund [12] combined DEA with the MI to analyze the efficiency of large European electricity distributions, and proposed several different efficiency improving measures to these distributions. Tone and Tsutisui [35] proposed to decompose the cost efficiency into technical efficiency, price efficiency and allocative efficiency, and compared the electricity efficiencies of companies in Japan and America. The results revealed a large difference between the efficiency of Japanese power companies and American power companies. Goto et al. [22] examined the cost structure of the Japanese electrical power industry to investigate whether structural reform to the industry results in a cost-saving benefit to consumers. The results indicated that the functional separation between generation and transmission would increase total production cost in the industry. Azadeh et al. [6] presented an integrated DEA–COLS–SFA–PCA–NT algorithm for measuring the efficiency of 38 electricity distribution units in Iran. They also demonstrated the usability and reliability of the proposed algorithm. Pombo and Taborda [26] combined DEA and MI to investigate the performance of 12 power distribution units in Colombia from 1985 to 2001. The results revealed that the efficiency and productivity increased significantly after electricity reform in the country. Estellita Lins et al. [13] applied a two-stage DEA model to evaluate the performance of power distributions in Brazil. They also proposed that it is necessary to consider a further distinction between the two parties: the regulatory agency and the utility company, as they adopt different criteria to determine the efficient target. Li et al. [18] used a unified efficiency DEA model to analyze the performance of 24 power companies in China. The distinguishing factor of their research is that they considered the undesired outputs.

Scholars have analyzed the efficiency of different countries' electrical power supply enterprises and have achieved excellent results. However, there are very few studies of China's electrical power supply enterprises. There are two reasons for the lack of research in this field. First, the network function of T and D is separated even if they are vertically integrated and competitive divisions like generation (hereafter referred to as G) and retail sales freely compete with one another. Therefore, independent electric power companies can be used as evaluation samples for analysis and evaluation. In China, however, all power supply enterprises are state-owned; thus, it is impossible to separate power companies into completely independent samples. Moreover, in China, most power company data is unavailable to the public. Therefore, data acquisition creates an additional barrier in analysis. Thus, evaluating the efficiency of power companies in China has great significance.

In terms of the methodology, DEA is widely used to evaluate the performance of electricity distribution units. DEA was first proposed by Charnes et al. [9]. It is a method for evaluating and measuring the relative efficiencies of a set of decision making units (DMUs) that use multiple inputs to produce multiple outputs. After this pioneering study, the subsequent research work mainly focused on two aspects. The first focused on constructing different DEA models to compensate for the disadvantage of classical DEA models. For example the following models have been proposed to solve a variety of problems: the BCC model [7], the additive model [3], the SBM model [33], the hybrid model [34], the super-efficiency model [4], the cross-efficiency model [25], and the assurance region model [31]. The second focused on applying DEA models to solve the real-world problems. Statistics show that nearly 67% of the DEA related articles presented a real-world application, and banking [29,5,27,23,39], education [24], health care [16,17], and hospital efficiencies [8] were found to be the most popular application areas [20].

In recent years, the development of DEA has mainly focused on the two-stage DEA model and the network DEA model [37,21,19,11]. The basic feature of the two-stage DEA model is that outputs from the first stage become the inputs in the second stage. Seiford and Zhu [28] use the two-stage DEA model to measure the profitability and marketability of US commercial banks. Zhu [44] applies the same two-stage DEA model to Fortune Global 500 companies. The main limitations of the two-stage DEA model are that there are no additional independent inputs to the second stage. In more general situation, Färe and Whittaker [14], Färe and Grosskopf [15] proposed the network DEA model. Tone and Tsutsui [32] proposed a network slacks-based measure model, which was later seen to be the foundation for future research on network DEA. Tone and Tsutsui [35] proposed a dynamic network slacks-based measure model (hereafter referred to as DNSBM) to evaluate the performance of 21 US electricity distribution companies from 1991 to 1995. Furthermore, Tone and Tsutsui also proposed six new directions for future research.

In this study, we began by looking at the current situation of China's power companies and aim to provide EPCs with suggestions for a 'T and D separation' policy. To do so we use the DNSBM-Free model to evaluate present day China's EPCs and the DNSBM-Fixed model to assess those under the 'T and D separation' policy in the near future. We also analyzed the efficiency of 31 EPCs in China from 2010 to 2012. In addition, we proposed using the idea of performance index to inform this work. The provincial power companies were classified into two groups based on the economic development levels of their regions. The two groups' performance indices were calculated and compared. Based on the performance indices, we proposed suggestions for improving the operation efficiency of each company. The paper is structured as follows: Section 2 describes the current development situation of EPCs in China; Section 3 discusses the model and research methods used in this paper; Section 4 analyses the efficiency and performance indices of the EPCs in China; Finally Section 5 brings together the conclusions of this paper.

2. The current development situation of EPCs in China

In China, 90% of the power generation enterprises and 100% of the power supply enterprises are state-owned. Therefore, to accelerate the development of China's power industry and to introduce competition mechanisms, the State Council promulgated a power-system reform plan on February 10, 2002. Generally, the content of the reform plan includes the separation between G and T (note the separation between G and T is the ownership separation, and after separation, China had found two power grid companies, i.e., the State Grid and the Southern Grid, and five power generation companies, i.e., Huaneng, Datang, Huadian, Guodian and Zhong Diantou), the separation

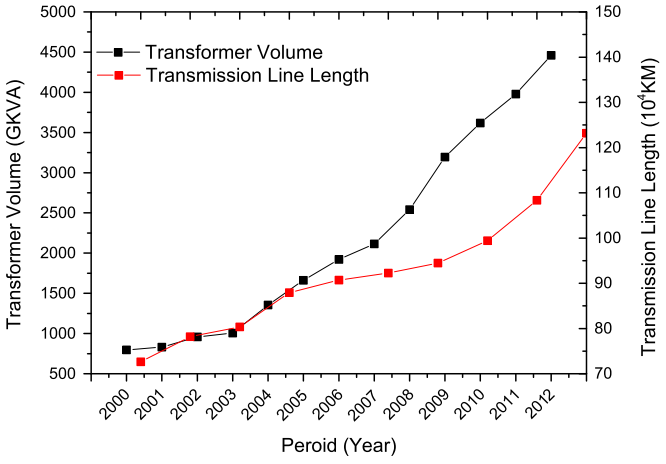

Fig. 1. Changes in length of transmission lines and capacity of transformers (35 kV and above), 2000–2012.