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Computational analysis of thermoelectric enterprises' environmental efficiency and Bayesian estimation of influence factors

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ABSTRACT

Research on the environmental efficiency of thermoelectric enterprises with high energy consumption and pollution emissions would contribute significantly to understanding regional ecological protection and sustainable economic growth. This study researches thermoelectric enterprises in China's Anhui Province and calculates their environmental efficiencies in 2009–2010. The Malmquist index method is used to resolve the variable trend of environmental efficiencies, and Bayesian estimation is conducted on the relevant influencing factors. The results of the quantitative analysis show that compared to 2009, the overall level of environmental efficiencies of thermoelectric enterprises in Anhui Province is lower, and there are great differences among thermoelectric enterprises. In addition, the variable trend of total factor productivity is highly consistent with technical progress, and the influencing degree of each factor on environmental efficiency varies. Finally, based on the empirical analysis, this study suggests how thermoelectric enterprises can improve environmental efficiency by, for example, introducing advanced production technologies and improving the coal quality and energy utilization ratios. It is important to focus first on how to protect the environment with treatment as assistant measures.

1. Introduction

With rapid economic development in China, environmental pollution concerns, such as dust and smoke accumulation that produces haze, are now an urgent issue. There is common agreement that the world must consider environmental protection when pursuing economic growth for sustainable development. Thermoelectric enterprises, an important part of the energy industry, have become the key driver of economic growth in Anhui Province alongside its continuous and stable socio-economic development. However, these enterprises have caused increasingly serious environmental pollution. Even though there are many environmental laws and regulations stipulated for thermoelectric enterprises, researchers have not yet evaluated actual enforcement properly. Such evaluation is urgent and necessary in order to improve policies and help enterprises find deficiencies.

Although there have been many achievements in research on economic growth and environmental protection, quantitative analysis dedicated to particular thermoelectric enterprises is rare. Environmental efficiency generally refers to the economic benefit created by one unit of environmental load, expressed by the ratio of economic value of product or service to environmental load. Thus,

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an enterprise can improve environmental efficiency only by reducing environmental load when pursuing economic benefits. Calculating environmental efficiency reveals the general performance of thermoelectric enterprises in terms of both economic benefits and environmental protection. In addition, evaluating the environmental efficiency of thermoelectric enterprises helps them to establish a balanced relationship between environmental protection and social responsibility in order to stimulate regional ecological protection and sustainable economic development.

This study examines ways that thermoelectric enterprises can both improve their profits and reduce pollution. The study examines these industries in China's Anhui Province from 2009 to 2011 using a slacks-based measure (SBM) model. The Malmquist index method is used to calculate and resolve the total factor productivity (TFP) of each enterprise. Importantly, the present analysis employs a Bayesian statistical method to understand the influencing factors of environmental efficiency better.

The paper is organized as follows: Section 2 contains a literature review. Section 3 presents the calculations and analyses of environmental efficiencies of relevant thermoelectric enterprises in Anhui Province in 2009–2010. A discussion of the dynamic analysis of environmental efficiencies and calculation of TFP values for each enterprise follows also in Section 3. Section 4 covers the Bayesian estimation of influencing factors. Finally, Section 5 offers conclusions and direction for further research.

The contribution of this paper is as follows. First, a quantitative evaluation is undertaken of the environmental efficiency of thermoelectric enterprises with high energy consumption and high pollution emissions in Anhui Province. This will help thermoelectric enterprises establish a balanced relationship between economic benefits and social responsibility and stimulate regional economic growth and sustainable environmental development. In addition, a Bayesian statistical method is applied to the research on influencing factors of environmental efficiency. Specifically, some important suggestions for thermoelectric enterprises are provided. Technical level, coal quality, and energy utilization ratios are important for the degree of coordination of the growth of thermoelectric enterprises across the province. In addition, enterprises should be enabled first to introduce advanced production technologies to protect the environment, and second, to treat using assistant measures.

2. Literature review

Researchers consider data envelopment analysis (DEA) an effective way to evaluate relative performance among a group of decision-making units (DMUs) that have the same properties (Färe, Grosskopf, Lovell, & Pasurka, 1989; Zhou, Ang, & Poh, 2008). Pre-selection and setting of each indicator's weight or form of production function are not required when using DEA, and this helps to avoid operator subjectivity. Furthermore, DEA has absolute advantages for handling multi-input and multi-output problems. As per the principles of linear programming, DEA can be used not only to judge whether corresponding points of DMUs are at effective production frontiers but also to gain a lot of useful management information (Sueyoshi & Goto, 2011).

Because of such advantages, a wide number of fields use the DEA method. In recent years, many scholars have carried out research on theories, methods, and applications of environmental efficiency evaluation. In the existing literature, Färe et al. (1989) are the first to use weak disposability of inputs and outputs to handle pollution variables. Thereafter, researchers have gradually extended this method to examine environmental efficiency evaluations. Yang and Pollitt (2009) use the data of Chinese coal-fired power plants to consider both undesirable outputs and uncontrollable variable, and propose six performance evaluation models based on DEA. Yang and Pollitt (2010) propose a model that can distinguish between weak and strong disposability among undesirable outputs to demonstrate its necessity in an efficiency model based on the empirical research of coal-fired power plants in China. Sueyoshi and Goto (2011), using a non-radial range-adjusted measure DEA model, measure scale return and loss under desirable output and discuss how to treat desirable and undesirable output problems in environmental evaluations. Rao, Wu, Zhang, and Liu (2012) analyze the energy efficiencies of 30 areas in China in 2000–2009 by using the slacks-based measure model of DEA, and conclude that areas in eastern China with fast economic growth have high energy efficiencies while areas in western China must still improve substantially. Sueyoshi and Goto (2012), using data from US coal-fired power plants, evaluate their environmental efficiencies and give a methodological comparison of radial and non-radial models. Li, Yang, & Liu (2013b) evaluate the environmental efficiencies of Beijing City in 2005–2009 and research their influencing factors using a two-stage DEA method. They deem Beijing's increasing rise of general environmental efficiency in that period is the result of its industrial structure, which is the most important influencing factor.

On measuring dynamic changes of DMUs, the Malmquist index is a generally used method to calculate input and output efficiency based on a ratio of distance function. Malmquist (1953) first puts forward the index, and then, Caves, Christensen, & Diewert (1982) apply it to measure changes of production efficiencies. Since then, many applications of the Malmquist index and variations thereof have been undertaken, as follows. Färe, Grosskopf, Norris, and Zhang (1994) combine the Malmquist index and DEA, which makes the method more widely applicable to measure changes of production efficiencies. Qazi and Yulin (2012) collect production and operation data of 15 high-tech industries in China in 2000–2010 and measure the variation index of each industry using the Malmquist index method. Pires and Fernandes (2012) investigate the changes of capital structures of 42 aviation companies from 25 countries by analyzing their financial efficiencies in 2001 and profit rates in 2002, measured by the Malmquist index. Zhang, Liu, Bressers, and Buchanan (2011) measure the total factor productivity (TFP) of each province in China in 1989–2008 by using the Malmquist–Luenberger index method; their results demonstrate that researchers frequently overestimate TFP growth that ignores undesirable