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The Hierarchy and Transition of China's Urban Energy Efficiency

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Abstract

Urban energy efficiency has attracted lots of interests by city governors and researchers. Each city planner eagers to find effective ways to make city cleaner and more energy-efficient. The general approach of self-development is to learn from a model city or benchmark city. Thus, researchers are faced with the challenges of providing methods to identify such benchmark cities and paths to make improvement. This paper focused on urban energy efficiency hierarchy identification and level transition analysis by suggesting a novel application of multi-level frontiers DEA technique, using 49 China's environmental protection model cities data as example. Considering undesirable outputs such as PM2.5 and SO_2, this paper evaluates urban energy efficiency first. Accordingly, a four-grade city energy efficiency structure can be recognized. The outcome of multi-level frontiers DEA analysis has also uncovered energy efficiency improvement chain of each city in different hierarchy. By constructing a set of four Ordered Probit Models at the end, this paper indicates that such hierarchy attributes to several influential factors such as population and energy technology. Through the analysis of this paper, the detection of rich details of underlying urban energy efficiency would be the basal step toward energy-efficient city research. Moreover, this framework for efficiency hierarchy and transition analysis or its extension can be applied to other data sets or other efficiency research in future.

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Keywords: Urban energy efficiency; Multi-level frontiers; Data envelopment analysis (DEA); Undesirable outputs

1. Introduction

Urban energy efficiency is closely linked to city's environmental quality. Making city cleaner and more energy-efficient is a significant and everlasting social management issue. Top cities sorted by some

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evaluation systems or frameworks are always popular for automatically being visited or learned from by the non-top cities. Here is a real practical case in China. In recent years, haze pollution mainly caused by PM2.5, which is defined as tiny particles less than 2.5 micron in atmosphere, has severely polluted cities' environment in China. The Chinese government has taken a number of measures. For example, in February of 2012, the Ministry of Environmental Protection (MEP) of China promulgated a new "Ambient Air Quality Standards", which required all cities to implement the new air quality criteria in stages. In May 2012, the MEP announced a pilot project to monitor PM2.5 of 74 cities in China by the end of October 2015. The first monitor results listed environmental quality rankings from these 74 cities. Immediately, a media reported that mayor of *Zhengzhou* (Henan province) city leaded their administrative staffs to visit its neighbouring city *Shijiazhuang* (Hebei province) to learn their environmental management strategy and experience. Ironically, *Zhengzhou* ranked third from last while *Shijiazhuang* ranked fifth from last. Such a thought-provoking event caused widely discussions. Thus, there are three primary problems challenged the clean and energy-efficient city planner in China: (a) Which kind of city might become a model or a benchmark? (b) How to improve the condition and step into a higher efficiency level city? (c) What policies or strategies should be adopted to achieve the self-development? Such considerations can also be extended to other social development field where researchers are facing with similar challenges.

In this paper, we provide an analysis framework to identify benchmark cities and transition paths on urban energy efficiency. Using data from China's environmental protection model cities, we first introduce the urban energy efficiency evaluation methodology which contains undesirable outputs such as PM2.5 and SO_2. By putting forward a novel application of multi-level frontiers DEA technique, we get a four-grade city energy efficiency structure and design the energy efficiency hierarchy evaluation system. Meanwhile, the transition probability and trace path of each city can be recognized as well. To make the present policy implication more clearly, we choose several influential factors for the ordered probit regression, which is to analyze impacts on such a hierarchy. The idea of this article comes from the cross-fertilization of social reality and classical DEA theory, which is believed to become a discreetly empirical innovative analysis of urban energy efficiency in the further study.

2. Literature Review

As we all know that the pollution haze is a very serious problem in China. To the best of our knowledge, few studies focus on energy efficiency considering haze pollution. In view of the importance of the air pollution in China, this paper mainly focuses on the Chinese city's energy efficiency with air pollution instead of other pollutants. The performance of a city's energy efficiency is complex. Therefore, it is more suitable to grade those cities instead of fully ranking them. Grading system is a basic and useful approach for people to understand things. The DEA models can use input and output data to evaluate the relative efficiency or performance of DMUs without prior knowledge of input/output functions and of indicator weights (see, e.g. Cook et al. 2014). Yang et al. (2016) show that multi-level frontiers of classical DEA can be used to classify countries/territories into different grades, reflecting the level of performance of the selected countries/territories. This paper expands the method developing from Yang et al (2016) and to construct a multi-level efficient frontiers model applying in energy efficiency research , it also shows how to decompose those cities into different grades using multiple frontiers in DEA models.

3. Multi-level frontiers DEA Model

3.1. Classic DEA model

The classic DEA models include CCR model (Charnes et al. 1978) and BCC (Banker et al. 1984)