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Sources of production inefficiency and productivity growth in China: A global data envelopment analysis

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ABSTRACT

The current mode of production in China is extensive and inefficient and has caused great stress on both resources and the environment. This paper focuses on analyzing the sources of production inefficiency and productivity growth in China. Here, a developed slacks-based measure is utilized to decompose production inefficiency into three components: input inefficiency, economic output inefficiency, and environmental inefficiency. Furthermore, by applying a method based on global data envelopment analysis, we take a further step to analyze the key factors responsible for the change of environmental productivity during 2003–2011 from the point of view of technical progress, productive scale, and management level. The results show that, redundancy in energy and labor inputs, and excessive emission of sulfur dioxide, chemical oxygen demand, and ammonia nitrogen, are the main sources of production inefficiency in China. During the sample period, the efficiency in all inputs and environmental emissions has improved (except for capital input efficiency, which had a decreasing trend). Further analysis shows that the overall environmental productivity in China has begun to follow an ascending path. Technical progress is the most powerful contributor to China's productivity growth, while the decreases in scale and management efficiency are the two main obstacles preventing productivity improvement.

1. Introduction

In recent decades, China's national economy has been steadily growing at a remarkable speed. However, this rapid development has also had high cost in terms of resources and environment. According to the statistics, China's gross domestic product (GDP) in 2010 accounted for 8.6% of global economic output, while China has the largest population in the world and its energy consumption accounted for 20.3% of global level. Besides the problem of high resource consumption, the challenges associated with expansion of environmental pollution are also very severe in China and tended to worsen in recent years. In 2010, the chemical oxygen demand (COD) and sulfur dioxide (SO_2) emissions in China were as high as 12.38 and 21.85 million tons, respectively. The air pollutions in many big cities became more serious in 2012 and 2013[1]. It is reported that 90% of the groundwater in China has been polluted to varying degrees, and as much as 60% of all underground water is classified as undrinkable shallow groundwater[2]2See http://news.hefei.cc/2013/0327/021565436.shtml.. Obviously, China's productivity is at a relatively low level, and its current economic growth model with extensive and inefficient resource consumptions is unsustainable.

Construction of a resource-saving and environment-friendly society has currently become a mutually recognized ambition of everyone in China. The Chinese government has already taken note of the severity of the situation and has begun to take measures to improve resource utilization and environmental efficiency. These measures adopted include implementing the energy-saving and emission reduction targets set in the "11th five year plan" (2006–2010), adjusting industrial structure, and eliminating excess capacity. Fortunately, the Chinese government's initial efforts have already achieved some positive results. During 2003–2011, China's energy consumption per unit of GDP and total emissions of two main environmental pollutants have already been in a decreasing trend (as shown in Fig. 1). However, on the whole, China's performance with respect to environmental productivity is still at a relatively low level. In this context, China's State Council announced in August 2012 that in order to make a further step in resource-saving and improving environmental efficiency, China aimed to reduce the energy consumption per unit of GDP and the total emissions of three main environmental pollutants respectively by 16% and 8% by the year 2015 based on the 2010 level. In this way, learning from China's successes as well as failures in resources-saving and improving environmental efficiency over the past years will certainly provide significant reference for China's

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[1] The toxic fog that covered a large area of Eastern China for a long time in the beginning of 2013 was a latest example of serious environmental pollution in China. As a reference, see http://www.chinadaily.com.cn/china/2013-01/13/content_16109839.htm.

[2] See http://news.hefei.cc/2013/0327/021565436.shtml.

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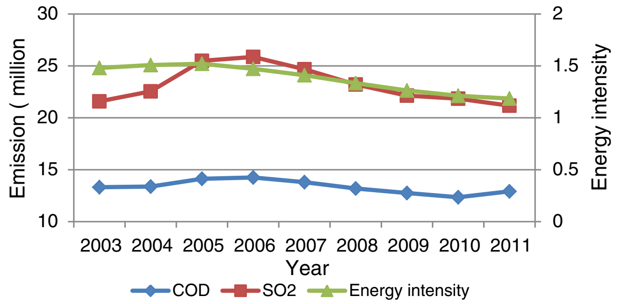

Fig. 1. Energy intensity and emission of COD and SO_2 during 2003–2011. Source: China Statistical Year (2004–2011).

policy making in the future. Therefore, analysis and calculation of the historical performance of China's environmental productivity is also a target of this study.

Data envelopment analysis (DEA), a relatively new non-parametric approach to efficiency evaluation, has been widely used for measuring environmental and energy productivity (Zhou et al., 2008a). Hu and Wang (2006) defined the first total-factor energy efficiency index with DEA for assessing provincial total-factor energy efficiency in China. So far, the total-factor framework has been widely utilized to explore total-factor productivity and total-factor energy efficiency in different countries and regions (Chen et al., 2008; Honma and Hu, 2008, 2009; Wang, 2007; Wang et al., 2012; Wei et al., 2007, 2009). Generally, three key input factors (energy, capital and labor) as well as the economic output factors (GDP) are all included in the conventional total-factor frameworks.

Halilu and Veeman (2000) argued that the conventional total-factor frameworks only took desirable outputs (such as economic outputs) into consideration and simply ignored the undesirable outputs (such as environment pollutants). As a result, evaluation of social welfare and economic performance is distorted in these studies. In recent years, progressively greater numbers of researchers have realized that the early estimates of productivity are, to some extent, biased as they only took economic efficiency into account and ignored the undesirable outputs like environmental pollution (Watanabe and Tanaka, 2007). In response, some scholars have tried to incorporate environmental factors into the total-factor framework (Bian and Yang, 2010; Chen and Golley, 2014; Chiu and Wu, 2010; Färe et al., 2007; Guo et al., 2010; Li and Hu, 2010; Lin et al., 2011; Meng et al., 2013; Shi et al., 2010; Wang and Feng, 2014; Wang et al., 2011, 2013, 2014; Wu et al., 2012; Yeh et al., 2010; Zhou et al., 2006, 2007, 2008b, 2010). In these studies, the maximum economic benefits as well as the best optimal environmental performances are considered. Therefore, evaluations which consider these undesirable outputs can provide more reasonable and more accurate estimation results.

Nevertheless, there are still some problems remaining in the existing studies. First of all, in the practice, productivity growth and technical progress are both continuous over time. However, most of the existing researches utilize single-phase benchmark technologies to construct single-phase reference production sets. These are subsequently used for calculating productivity growth and technical progress. As a result, estimation results from these studies lack stability and may deviate from the actual production activity (Oh, 2010; Oh and Heshmati, 2010). Secondly, in a complete production process, a variety of inputs (such as energy, capital and labor) are essential. At the same time, a variety of outputs (such as economic output and environmental pollutant emissions) are also produced. Therefore, production inefficiency could be decomposed into three components: input inefficiency, economic output inefficiency and environmental inefficiency. Following this, more detailed information about productivity inefficiency could be obtained. However, most of the existing studies only conduct empirical studies on the productivity as a whole — very few of them take the further step to analyze its components in more detail. Hence, these studies have certain limitations.

In order to obtain continuous productivity growth and technical progress, we carry out our evaluations by applying a global DEA-based method in our analysis. And by utilizing an improved slacks-based measure (SBM) proposed by Wang et al. (2010), we also focus on analyzing the components of productivity inefficiency at a more detailed level.

The rest of this paper is organized as follows. In Section 2, the DEA-based methods utilized in our analysis are briefly introduced. Section 3 presents the regional panel data used in the empirical study. Section 4 presents the results of our research and necessary discussion. Section 5 gives the conclusions and some policy implications.

2. DEA-based methodology

DEA is proposed by Charnes et al. (1978) and is a mathematical procedure using linear programming technique to assess the efficiencies of decision-making units (DMUs). In this paper, it is used for measuring the sources of production inefficiency and productivity growth in China. According to the main purpose of this article, we focus on analyzing China's environmental productivity by applying a global DEA method. Hence, before introducing our empirical DEA models, brief introductions to environmental technology and the global DEA method are first given in Sections 2.1 and 2.2, respectively. In Sections 2.3, 2.4, and 2.5, the empirical models utilized in this paper are then introduced.

2.1. Environmental technology

Initially, the Chinese government and society did not realize the harm caused by environmental pollution. Hence, there used to be almost no environmental regulations on production activities in China. As a form of negative externality, environmental pollution and its social price have not been reflected in the cost of enterprise. As a result, enterprises have been free of environmental constraints while pursuing economic benefits. However, in recent years environmental pollution has become a serious social and public issue. In order to solve this problem, the Chinese government has gradually enhanced its environmental regulation of the production activities of enterprises. In this way, enterprises are being forced to realize the environmental targets. Obviously, it has become costly for enterprises to reduce these undesirable outputs (i.e. environmental pollutant emissions in this paper). In a word, China's current environmental productivity is specifically consistent with the environmental technology proposed by Färe et al. (1989), in which environmental indicators are weak disposability.

Let $x = (x_1, \ldots, x_N) \in \Re^N_+$ represents the inputs, and $y = (y_1, \ldots, y_M) \in \Re^M_+$ and $b = (b_1, \ldots, b_J) \in \Re^J_+$ represent the desirable and undesirable outputs, respectively. $P(x)$ represents the production possibility set: $P(x) = \{(x, y, b) : x \text{ can produce } (y, b)\}$. Suppose that there are K DMUs. As the input and economic output in the paper are both strong disposability, they meet the condition as follows: if $(y, b) \in P(x)$ and $y' \leq y$ or $x' \geq x$, then $(y', b) \in P(x)$, $P(x') \in P(x)$. And if environmental indicators are also strong disposability, they will meet the same condition as the economic output does. In this scenario, undesirable output can be generated within a certain scope without subsequent cost (Chen, 2012). In this case, we can formulate $P(x)$ as follows:

$$P(x) = \left\{ \begin{array}{l} (x, y, b) : \sum_{k=1}^{K} z_k x_k \leq x; \sum_{k=1}^{K} z_k y_k \geq y; \\ \sum_{k=1}^{K} z_k b_k \geq b; z_k \geq 0 \; for \; k = 1, \ldots, K \end{array} \right\}. \quad (1)$$

However, if the environmental indicator is weak disposability, that is to say, if $(y, b) \in P(x)$ and $0 \leq \theta \leq 1$, then $(\theta y, \theta b) \in P(x)$. This hypothesis suggests that a decrease in quantity of b has a certain cost. A reduction in environmental indicator b must be accompanied with a decrease in economic output with a given input. As Färe et al. (1989), Boyd and