Resource and Energy Economics 43 (2016) 14–32

Contents lists available at ScienceDirect

Resource and Energy Economics

journal homepage: www.elsevier.com/locate/ree

Environmental technical efficiency, technology gap and shadow price of coal-fuelled power plants in China: A parametric meta-frontier analysis

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ARTICLE INFO

Article history:
Received 17 May 2014
Received in revised form 29 October 2015
Accepted 3 November 2015
Available online 12 November 2015

JEL classification:
Q52
Q54
Q58

Keywords:
Chinese power plant
Meta-frontier
Parametric estimation
Environmental technical efficiency
Shadow price

ABSTRACT

In this paper, we propose a new meta-frontier estimation method to investigate the environmental technical efficiency and carbon abatement cost of power plants in China taking the technological heterogeneities into consideration. This study is based on a plant-level cross-sectional data set comprising 648 observations for the year 2008. Results show that, state-owned power plants are least efficient relative to the meta-frontier. A further 44 percent of total CO_2 emissions can be cut if all power plants are completely efficient. Additionally, the group of state-owned power plants is faced with the lowest cost to marginal CO_2 abatement.

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http://dx.doi.org/10.1016/j.reseneeco.2015.11.001
0928-7655/

1. Introduction

China has become one of the main greenhouse gas emitters in the world because of its rapid economic growth and accompanying growth in energy consumption. In terms of its contribution to total emissions, the power sector is a major pollution source. According to statistics, CO_2 emissions from electricity and heat production account for almost 50 percent of total emissions from combustion in 2011 in China (IEA, 2013). Though clean energy, such as hydropower, wind and solar power, has developed rapidly during the past decade, thermal power (especially coal-fuelled power) remains at present China's dominant form of energy generation (Xie et al., 2012).[1] Thus it is extremely important to investigate the environmental efficiency, the marginal abatement cost and the abatement potential of China's power sector.

The importance of the power sector in environment protection has long been emphasized by previous studies. Multi-input/multi-output production theory combined with the directional (or Shephard) output distance function method is widely used to estimate the environmental efficiency and the marginal abatement cost for power plants.[2] Examples include Murty et al. (2007) for India, Färe et al. (2005), Lee (2005), Sueyoshi et al. (2010), Sueyoshi and Goto (2013a, 2013b) for the US, Yang and Pollitt (2009), Wei et al. (2013) for China, Zhou et al. (2012) for a panel of 129 countries, etc. In spite of its widespread acceptance, one weakness of this method is that it does not consider plant heterogeneity while it assumes that plants share a common production frontier. Actually, the production sets of different firms may differ due to differences in physical, human and financial capital stocks, economic infrastructure, resource endowments and any other characteristics of the physical, social and economic environment in which production takes place (O'Donnell et al., 2008). If these differences are neglected, results from any estimation may be biased.

One possible way to consider plant heterogeneity is to implement a meta-frontier analysis. The typical procedure for this type of analysis is to proceed in two steps. The first step is to classify the plants into different groups according to their characteristics (such as region, ownership, industry, etc.) and to estimate the group-specific production frontier for each group respectively. The second step is to estimate the meta-frontier – i.e. the envelope of the group-specific frontiers (Battese et al., 2004; Chiu et al., 2012; Oh, 2010). Only very few studies have considered group heterogeneity in an analysis of the power sector.[3] Zhang et al. (2013) propose a meta-frontier non-radial directional distance function to model energy and carbon emissions performance of Korean electricity generation plants. This approach considers group heterogeneities, non-radial slacks and undesirable outputs simultaneously. Zhang and Choi (2013) further propose a meta-frontier non-radial Malmquist carbon emission performance index for measuring dynamic changes of total-factor carbon emission performance over time. Applying this new method, they examined the dynamic changes in carbon emissions performance of fossil-fuel power plants in China.

In this paper, we intend to propose a new meta-frontier estimation method, and then apply this newly proposed method to estimate the environmental efficiency and marginal abatement cost of CO_2 emissions for China's coal-fuelled power plants. Our paper makes two key contributions. First, almost all the previous studies estimating environmental meta-frontier efficiency are based on the non-parametric Data Envelopment Analysis (DEA) approach, while our approach is based on parametric linear programming. The merit of our approach is that the estimated parametric directional output distance functions are differentiable, thus allowing us to estimate the marginal CO_2 abatement cost of the plants. Second, our empirical analysis covers a wider range of China's power plants than in previous studies. Yang and Pollitt (2009) examine the environmental performance of 221 Chinese power plants, Wei et al. (2013) investigate 124 power plants located in Zhejiang Province of China, Zhang and Choi (2013) focus on 259 large (exceeding 1GW) state-owned fossil-fuel power plants in China. Our

[1] By 2011, the installed capacities of hydropower and wind power in China are 233 GW and 46 GW respectively, corresponding to 22 percent and 4 percent of the total installed power capacity.

[2] This method is also widely used for environmental efficiency studies in other industries, such as agriculture (Färe et al., 2006), manufacturing (Lee and Zhang, 2012), and container glass industry (Boyd et al., 2002), etc.

[3] The method of meta-frontier analysis has been widely used in other fields, such as Lin and Du (2013) on energy efficiency, Chen and Song (2008) on agriculture, Moreira and Bravo-Ureta (2010) on dairy farms, etc.