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Energy-saving and emission-abatement potential of Chinese coal-fired power enterprise: A non-parametric analysis

Chu Wei [a,*], Andreas Löschel [b,c], Bing Liu [d]

[a] Department of Energy Economics, School of Economics, Renmin University, Beijing 100872, China
[b] Center of Applied Economic Research Münster (CAWM), University of Münster, 48143 Münster, Germany
[c] University of International Business and Economics, Beijing 100029, China
[d] China Academy of Social Management, Beijing Normal University, Beijing 100875, China

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ABSTRACT

In the context of soaring demand for electricity, mitigating and controlling greenhouse gas emissions is a great challenge for China's power sector. Increasing attention has been placed on the evaluation of energy efficiency and CO_2 abatement potential in the power sector. However, studies at the micro-level are relatively rare due to serious data limitations. This study uses the 2004 and 2008 Census data of Zhejiang province to construct a non-parametric frontier in order to assess the abatement space of energy and associated CO_2 emission from China's coal-fired power enterprises. A Weighted Russell Directional Distance Function (WRDDF) is applied to construct an energy-saving potential index and a CO_2 emission-abatement potential index. Both indicators depict the inefficiency level in terms of energy utilization and CO_2 emissions of electric power plants. Our results show a substantial variation of energy-saving potential and CO_2 abatement potential among enterprises. We find that large power enterprises are less efficient in 2004, but become more efficient than smaller enterprises in 2008. State-owned enterprises (SOE) are not significantly different in 2008 from 2004, but perform better than their non-SOE counterparts in 2008. This change in performance for large enterprises and SOE might be driven by the "top-1000 Enterprise Energy Conservation Action" that was implemented in 2006.

1. Introduction

The expansion of China's power sector raises worldwide concerns due to its significant role in global greenhouse gas (GHG) emissions. In 2011, China's power sector produced about 3981 million tons of CO_2 equivalent ($MtCO_2e$), accounting for almost 50% of China's and about 13% of the worldwide emissions from fuel, respectively (IEA, 2013). China's booming power generating capacity — 950 gigawatt (GW) in 2010, and expected to hit 1760 GW by 2020, still can't keep up with its rapidly increasing electricity demand (Reuters, 2011). Given the rapid expansion of the power sector in China, problems might be further exacerbated in the future.

To reverse this trend, China has made great efforts to reduce its energy intensity by 19.1% during the 11th Five-Year Plan (FYP) from 2006 to 2010 (NDRC, 2011). New targets for reducing its energy intensity and carbon intensity by 16% and 17% relative to its 2010 levels by 2015 were set in the 12th FYP (2011–2015), respectively (Zhang, 2011). To achieve this national goal, a key program is the Top-1000 Enterprises Energy Conservation Action launched by the National Development and Reform Commission (NDRC), the National Bureau of Statistics (NBS), the State-owned Assets Supervision and Administration Commission, the Office of National Energy Leading Group and the General Administration of Quality Supervision, Inspection and Quarantine in 2006 (Price et al., 2010). The aggregated energy consumption for these top-1000 enterprises accounts for 47% of total industrial sector and 33% of total national energy consumption in 2005. Whether these top-1000 enterprises can achieve their energy-saving targets, i.e. 100 Mtce (Millions of tons of coal equivalent) by 2010, is thus crucial for achieving the national goal. To create strong incentives for decision-makers, large-scale enterprises, mostly state-owned enterprises (SOE) with a minimum of 180,000 t of coal equivalents (tce) energy consumption from nine major energy-intensive sectors,[1] must sign an energy conservation agreement with local governments. To meet the program's requirement, the top-1000 enterprises are required to establish an energy-saving organization, set up an energy-saving target, submit their quarterly fuel utilization information online to NBS directly, invest in energy efficiency improvements and conduct energy auditing and training. Additionally, the enterprise managers and local officials cannot be promoted without achieving their goal. Under this strict regulation,

* Corresponding author at: Depart of Energy Economics, School of Economics, Renmin University, No. 59 Zhongguancun Street, Haidian District, Beijing 100872. Tel.: +86 10 82500322.
E-mail address: xiaochu@ruc.edu.cn (C. Wei).

[1] These nine sectors include: iron and steel, chemical, electricity power generation, petroleum, construction materials, non-ferrous metals, coal mining, paper, textile.

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the top-1000 enterprises reached its target at the end of 2008. However, the cost-effectiveness of the program is unclear. There exists neither a bottom-up analysis nor an evaluation of energy-saving and emission-reduction potentials at the enterprise level in China (Price et al., 2011; WorldBank, 2009). Hence, the distribution of energy-savings and emission-abatement potential among large enterprises or SOEs is unknown.

Given this background, one question we are interested in is whether a large power enterprise has greater energy-saving potential and associated CO_2 abatement potential than a smaller enterprise. The existing literature does not provide a clear linkage between firm size and energy (in)efficiency. On the one hand, large firms can benefit from economies of scale and the formalization of procedures, which allow them to gain superior performance relative to smaller ones. On the other hand, large firms might be characterized by complex hierarchical management structures, failure to minimize production costs and lack of competition, which lead to X-inefficiency (Leibenstein, 1975). Empirical studies are also equivocal. For example, some studies support a positive relationship between efficiency and firm size (Kalaitzandonakes et al., 1992; Lundvall and Battese, 2000; Pagano and Schivardi, 2003). Contrarily, Page (1984) finds little evidence of a systematic relationship between firm size and efficiency. Majumdar (1997) offers the opposite evidence and finds larger firms to be less productive than small ones.

As for ownership, the debate on relative efficiency of public versus private enterprises also has a long history in economics. The property rights view suggests that publicly owned enterprises perform less efficient than privately owned enterprises since the public ownership attenuates property rights and reduces the manager's incentive to minimize costs. Consequently, state-owned enterprises (SOE) perform less efficiently and hence have a higher abatement potential than private firms. However, the existing empirical evidence provides weak support for this hypothesis. For example, Atkinson and Halvorsen (1986) find no significant difference between publicly and privately owned electric utilities in the U.S.

Given the crucial role that the power sector plays in climate change mitigation and the debates on current practices, several important questions naturally arise: How large are coal-fired power enterprises' reduction potential of energy usage and associated CO_2 emission in China? Are these potentials associated with enterprise scale and ownership? This paper attempts to respond to these questions by analyzing data from coal-fired power enterprises in China's Zhejiang province of the years 2004 and 2008. Since the energy-saving regulation for these enterprises was implemented in 2006, this unique firm-level data also provides an opportunity to examine whether the energy reduction potential and its associated CO2 abatement potential changed.

The non-parametric approach of data envelopment analysis (DEA) has been widely used in the literature. A key advantage of DEA over other approaches is that it does not need a specific pre-assumed functional form and can easily accommodate both multiple inputs and multiple outputs. This technique has been applied to evaluate, e.g., the relative energy and environmental efficiency of U.S. power plants (Färe et al., 1989, 2007; Pasurka, 2006; Tyteca, 1997). Zhou et al. (2008) and Zhang and Choi (2014) provide a comprehensive overview on the use of DEA model in energy and environmental studies. Recently, DEA has been used with increasing frequency in studies of the Chinese power sector: Choi et al. (2012) apply a non-radial slacks-based DEA model to estimate the energy efficiency and shadow price of energy-related CO_2 emissions at the province level for the period 2001 to 2010. Xie et al. (2012) use a two-stage network DEA model to evaluate the provincial environmental performance in China and explore the linkage between the environmental efficiency and generation forms. Yang and Pollitt (2009) apply three multiplicative DEA models to 582 Chinese coal-fired power plants in 2002 to gauge their environmental performance. They also employ an unbalanced panel of 796 power plants during 1996–2002 to calculate the Malmquist TFP indices (Yang and Pollitt, 2012). Using an output-oriented DEA technique, Zhao and Ma (2013) estimate the technical and scale efficiency score of 34 power plants during 1997–2010 and then examine the impact of de-regulation on performance.

Apart from these previous studies, this paper applies the non-radial Weighted Russell directional distance function approach to measure the energy-saving potential index and CO_2 emission-abatement potential index for coal-fired power enterprises in 2004 and 2008. This approach is first developed by Chen et al. (2011) which mirrors the strategy employed by Chung et al. (1997) and extended the work of Fukuyama and Weber (2009). It recently has been applied for Japanese banks (Barros et al., 2012), Indian banks (Fujii et al., 2014) and Korean power plants (Zhang et al., 2013). One advantage of this methodology is that it provides the specific-factor efficiency (such as energy efficiency and CO_2 emission efficiency) in addition to the overall efficiency score in the radial directional distance function (DDF) model (Sueyoshi and Goto, 2011). Moreover, it can avoid the overestimation the efficiency value as it takes account the nonzero slacks, which are ignored in the

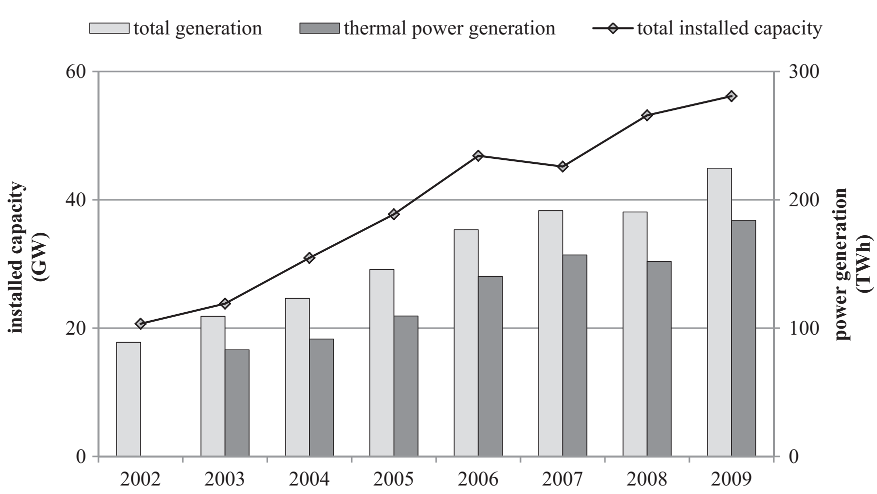

Fig. 1. Power generation and installed capacity in Zhejiang (2002–2009).
Source: The power generation data is taken from the China Energy Statistical Yearbook (NBS, 2009); the installed capacity data is taken from the White Paper of Energy in Zhejiang (Zhejiang Province Economic and Information Commission and Zhejiang Provincial Bureau of Statistics, 2011).