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The effects of electricity reforms on productivity and efficiency of China's fossil-fired power plants: An empirical analysis

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ABSTRACT

This paper investigates the effects of electricity reforms on productivity and efficiency of China's generation plants, based on the third industrial census data and the first economic census data. Partial factor productivity (PFP) analysis indicates that the productivity improvements in labor and capital inputs associated with the reforms are approximately 26% and 45% respectively. The effect of the reforms on fuel expense is weakly significant, but there is evidence of significant productivity improvement in fuel usage. Further total factor productivity (TFP) analysis shows that the efficiency gain from the reforms is still significant when the substitution effect of labor and capital inputs are considered, though the magnitude is much lower than that of the PFP analysis. The effect of the reforms on technical efficiency becomes weakly significant when fuel expense is further included in TFP analysis, but a significant positive effect is expected if fuel input is measured in physical quantity.

1. Introduction

In the past three decades, China has introduced a series of market-oriented deregulation reforms in its electricity industry, which have significantly altered the market structure and institutional framework of the industry. The reforms mainly focused on the involvement of private investment, exit of the government's role in the management of enterprises, and vertical unbundling of generation and transmission sectors. One of the main objectives of the electricity reforms in China is to improve the productivity and efficiency of the industry.

Economic theories have long argued that market-oriented reforms will generate important efficiency gains for an economy. X-inefficiency theory points out that for lack of competition plants will not operate on an outer-bound production possibility surface consistent with their resources because many people will trade the disutility of greater effort for the utility of feeling less pressure. By contrast, in situations with high competitive pressures, it is possible to improve productivity by increasing X-efficiency (Leibenstein, 1966). Agency theory also argues that regulation may induce efficiency distortion because of asymmetric information, while market competition makes plants residual claimants to cost-savings, thus increasing incentives for efficiency-enhancing efforts (Laffont and Tirole, 1993). However, whether market-oriented reforms will ultimately improve production efficiency of the electricity industry remains an empirical question.

A number of studies have attempted to measure the ex-post efficiency gains from electricity deregulation reforms in the world, such as Steiner (2000) and Hattori and Tsutsui (2004) on OECD countries, Nagayama (2007) and Zhang et al. (2008) on developing countries, Hiebert(2002), Knittel (2002) and Fabrizio et al. (2007) on the United States, Abbott (2006) on Australia, Pombo and Taborda (2006) on Columbia, Sen and Jamasb (2012) on India, and so on. These researches find evidences of efficiency gains in generation and distribution sectors associated with the electricity deregulation reforms.

The possible impact of China's electricity reforms also has been widely discussed. While most studies focused on market structure and pricing system of the industry, few studies addressed the quantitative measure of the ex-post operating efficiency gains from the reforms, possibly due to the problem of data availability. For the studies that did measure such efficiency gains quantitatively, there is still room for improvement.

Du et al. (2009), in assessing the impact of electricity reforms on labor, fuel and material inputs in generation sectors based on two-year plant-level census data, find that the net efficiency improvements in labor and material inputs are significant, while those of fuel input are not. Gao and Van Biesebroeck (forthcoming) also find deregulation

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to be associated with a reduction in labor input and material use in their study of the effects of electricity reforms on the performance of generation plants based on a plant-level census dataset covering the years 1998–2007. Zhao et al. (2012) find that the implementation of "operation period price" in 1996 promoted power plants to be more responsive to electricity demand and price signals, while the implementation of "yardstick power price" in 2003 led electric capacity to increase tremendously. Kahrl et al. (2013) evaluate the effects of the transition from "equal shares dispatch" to "energy efficiency dispatch" based on a case study of Guangxi Autonomous Region, and they find that the energy and cost savings from this transition are small. The problem with these studies is that the substitution effect of inputs is ignored, and thereby the overall effect of the reforms may be overestimated or underestimated.

Taking the effect of factor substitution into consideration, Ma et al. (2011) investigate the impact of the reforms on total factor productivity (TFP). They find a positive TFP growth during the period 2000–2008 for China's generation plants largely due to a significant technological change. At the same time, they also find that the unbundling reform has made the previously less efficient state-owned plants converge to more efficient private plants. However, the study of Ma et al. (2011) is based on a dataset of only 40 large scale power plants while the smaller ones are ignored because of data availability. This may lead to estimation bias. Barros et al. (2013) estimate the cost efficiency of 12 Chinese hydroelectric companies based on stochastic frontier analysis, and they find that the main cause of the inefficiency is the mismatch between inputs and outputs.

In this paper, we further investigate the impact of the electricity reforms on productivity and efficiency of China's generation sector. Our research is based on the third industrial census data and the first economic census data, which are both plant-level datasets including almost all the generation plants in China. Thus, our estimation results are more representative and reliable. Considering the possibility of factor substitution, we compare the effect of the reforms on both partial factor productivity (PFP) and TFP. The significance of our research is that it captures the advantages of both large sample estimation and TFP analysis, thus adds to the understanding of China's electricity reforms.

PFP analysis shows that the market-oriented electricity reforms have improved labor productivity and capital productivity of China's generation plants by 26% and 45% respectively. Although the improvement of fuel productivity is only weakly significant, there is evidence of performance improvement in fuel usage measured in physical quantity. Further TFP analysis shows that the performance improvement from the deregulation reforms is still significant when the substitution effect between labor and capital is considered. When fuel expense is further included in TFP analysis, the efficiency-improving effect of the electricity reforms becomes weakly significant, but evidence of improvement in technical efficiency is found when fuel input is measured in physical quantity. Our research is of direct policy relevance to the government in contemplating their further electricity restructuring schemes and contributes to the broad economic debate on the role of market in the economy.

The remainder of the article is organized as follows. Section 2 reviews the process of China's electricity industry reforms. Section 3 presents the econometric model and identification strategy. Section 4 describes the data. Section 5 presents the estimation results. Section 6 discusses the robustness of the results. The last section concludes the article.

2. China's electricity industry reforms

After the foundation of the People's Republic of China, the electricity industry was incorporated into the central planning system because of its special importance, fully funded by the central government. The Ministry of Electricity Power (MEP) was responsible for usage of funds, management of electricity assets and dispatching of electricity power. The sectors of generation, transmission and distribution were vertically integrated. The electricity investments from local governments, private investors and foreign investors were forbidden.[1]

After the start of the general market-oriented economic reforms in 1979, the electricity demand of China increased dramatically, but the development of the electricity industry was relatively slow because of lack of electricity construction funds. Large-scale blackouts and brownouts were frequent, holding back the rapid economic growth. In order to relieve the problem of power shortage and attract more construction funds, in 1985, the State Council enacted a policy document, *Interim Provision on Promoting Fund-raising for Investment in the Electricity Sector and Implementing Different Electricity Tariffs*, which indicated the beginning of a new period of power sector development in China (Ma, 2011). The local governments, private investors and foreign investors were allowed to invest in the generation sector, but the transmission and distribution sectors were still monopolized by the MEP. The policy resulted in the emergence of a large number of independent power plants (IPPs) under the rate-of-return regulation.

In order to improve the productivity and efficiency of the electricity industry, the government carried out the second round of reform in 1997. The MEP was abolished with all its electricity assets taken over by a newly established public utility, the State Power Company (SPC), while its administrative functions were transferred to the State Economic and Trade Commission (SETC). Still vertically integrated, the SPC was responsible for the daily operation of the electricity system. After the reform, the state-owned electricity plants gained more freedom in daily operation and management, and were able to better allocate resources, thus further improving the productivity and efficiency of the plants.

In 2002, the third round of electricity reform began. The vertically integrated SPC was dismantled in order to realize equal access to the transmission grid for all the plants.[2] Its generation assets were allocated into five large generation corporations, while its transmission and distribution assets were inherited by two large grid companies.[3] With the generation and transmission sectors vertically separated, the grid companies kept only a few peaking generation plants. In 2003, a new independent regulatory agency, the State Electricity Regulatory Commission (SERC) was established to supervise the electricity market operation (Pittman and Zhang, 2008). At the same time, the government attempts to implement wholesale competition in the generation sector. The SERC established some experimental regional wholesale markets, but the experiments were soon suspended because of nationwide power shortage and the problem of market power.[4] After the unbundling reform and competition experiments, all the generation plants have the same priority in accessing to the transmission grid, which gives some competition pressure or at least competition expectation to the state-owned plants, and thus has possibly helped improve their productivity and efficiency.

3. Econometric model and identification strategy

The method of difference-in-differences (DID) estimation is widely used in policy evaluation (Bertrand et al., 2004). DID estimations

[1] More detailed introduction of China's electricity reforms can be found in Andrews-Speed and Dow (2000), Xu and Chen (2006) and Yang (2006).

[2] Before the unbundling reform, the state-owned generation plants usually had priority over the other plants to access to the grid, especially when the electricity power was redundant.

[3] The five large generation corporations are China Huaneng Group, China Datang Group, China Huadian Group, China Guodian Group and China Power Investment Group. The two large grid companies are the State Grid Corporation of China and China Southern Grid Corporation.

[4] The regional wholesale competition markets were experimented in Northeast (including Jilin, Liaolin and Heilongjiang) and Eastern China (including Shanghai, Zhejiang, Jiangsu, Anhui and Fujian).