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Green efficiency and environmental subsidy: Evidence from thermal power firms in China

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ABSTRACT

To achieve green development, ample environmental subsidies have been invested into many energy-intensive firms (such as thermal power firms) in China. Investigations of the effects of this kind of subsidy can help to provide specific and important implications for ongoing regulations. Unlike previous studies on the national, regional or sectoral level, this paper measures green efficiency and its compositions of thermal power firms and studies the impact of environmental subsidies on green efficiency by using the classical Slacks-based Measure and Tobit model. The results show that the average green efficiency ranges from 0.509 to 0.663 during 2010–2015, which is much lower than the general efficiency. The green scale efficiency is the main reason for the low green efficiency, thus indicating large room for improvement. Environmental subsidies negatively affect green efficiency and its decompositions from 2010 to 2013. The negative effect becomes weak and insignificant in 2014, and the environmental subsidies start to significantly promote green efficiency and its decompositions in 2015. According to our findings, some implications relating to improving green scale efficiency, increasing the intensity of environmental subsidies to firms and strengthening their supervision are proposed.

1. Introduction

The electric power industry is one of the top six energy-intensive industries in China according to the statistical report on national economic and social development issued by China's National Bureau of Statistics. As shown in Fig. 1 (a), coal consumption of the power sector accounts for approximately half of the entire industrial sector's coal consumption in China. Its share of pollutant emissions was still more than 30% in 2015, although it experienced a constant decrease from 2009 to 2015 because of the powerful environmental protection policies relating to desulfurization, denitration and dedusting. However, economic growth closely depends on the booming development of the power sector. According to the data from the World Bank shown in Fig. 1 (b), per capita electricity consumption in China grew rapidly from 2000 to 2014 and was even higher than the average level of upper middle-income countries after 2010. However, China still has a huge developmental space compared with high-income countries. Therefore, the power sector is a priority in achieving energy conservation and emission reductions.

Green development[1] is indispensable. However, it will increase the costs of firms, such as in environmental protection equipment purchases, the introduction of clean technologies, and penalties or suspensions because of environmental damage. Furthermore, green technology innovations will lead to market failures because of their externalities (Jiachen and Lihong, 2016; Ben Arfi et al., 2018). On the one hand, knowledge spillover (similar to general technology innovations) leads to firms paying the whole cost of green innovation but being unable to gain the whole consequent revenues. On the other hand, excessive pollutant emissions will be produced when the cost of pollution is less than the social costs because of the poor market pricing mechanism for pollutant emissions (Ding et al., 2014; He and Ou, 2017). The externalities will restrain the motivation of green technology innovations and increase environmental pollution (Dröes and Koster, 2016; Tian et al.,

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[1] Green development is a means to achieve sustainable development (Lin and Benjamin, 2017). According to the concept of green development proposed in the 12th and 13th Five Year plans in China, it refers to an innovative economic development model that takes environmental protection as one of its major focuses to achieve sustainable development with the constraints of environmental and ecological carrying capacity.

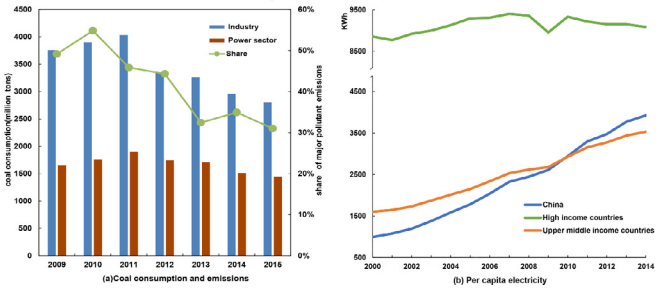

Fig. 1. The development status of power sector in China. **Source:** (a) authors' calculation based on Annual Statistic Report on Environment in China and China Statistical Yearbook. (b) authors' calculation based on the data from world bank. **Notes:** Pollutant emissions include sulfur dioxide, nitrogen oxides and smoke (powder) dust.

2017).

Public subsidies are considered an effective solution to externalities (Bi et al., 2016; Fogarty and Sagerer, 2016). The government encourages firms to adopt clean technologies, implement strategies for energy conservation and emission reductions and conduct green technology innovation activities through public subsidies in order to promote social welfare. In practice, many developed countries have adopted these kinds of environmental subsidies in order to address externalities (Endres et al., 2015; Heres et al., 2015).

At present, China is facing the dual pressures of energy shortages and environmental pollution (Chen and He, 2014). The extensive mode of economic growth with significant features of high energy consumption and high pollution is unsustainable (Ouyang and Sun, 2015). The Chinese government has to offer a large amount of financial support to many energy-intensive and pollution-intensive firms (such as thermal power firms) for several reasons. The energy-intensive industry is both the major pillar for current economic growth (Yang et al., 2018) and the main source of energy consumption and emissions in China. Moreover, environmental subsidies were allocated to energy-intensive firms for the introduction of energy-saving technologies, mergers and reorganizations among firms and the installment of energy-saving and emission reduction equipment to increase energy use efficiency and emissions abatement. Therefore, it is relevant to investigate the effects of environmental subsidies on energy-intensive firms in China. We address whether it can promote the green development of energy-intensive and pollution-intensive firms or mitigate their survival pressure, in other words, decrease their productivities.

Due to the difficulty of collecting the firm-level data related to emissions and green technology innovations, existing literature has mainly focused on green efficiency[2] at the national (Shen et al., 2017), regional (Tao et al., 2016, 2017) or sectorial (Li and Lin, 2015; Ghisetti and Quatraro, 2017) level to reflect its comprehensive strength. Few studies have measured green efficiency at the firm level. Little attention has been paid to the effects of environmental subsidies on green efficiency. However, firms are the actual entities that achieve cleaner production and sustainable economic development. The results at the firm level are more specific and practical.

From the perspective of firms, this paper uses a Slacks-based Measure (SBM), one type of data envelopment analysis (DEA) approach, to measure the green efficiency of thermal power firms by considering their energy consumption, emissions and green technology innovations based on corporate annual reports, social responsibility reports and patent information. Then, the impact of environmental subsidies on the green efficiency of thermal power firms is investigated.

The main possible contributions in this paper are from four aspects. First, most existing literature have studied the impacts of subsidies on renewable-energy firms (Zhang et al., 2014; Nie et al., 2016), farm firms (Sauer and Latacz-Lohmann, 2015; Minviel and De Witte, 2017), high-tech firms (Howell, 2017; Chen et al., 2018) and so on. However, at present, a large number of subsidies have to be injected into energy-intensive firms to promote cleaner production in China. Therefore, this paper verifies the impacts of subsidies on thermal power firms. Second, the effect of environmental subsidies on the green efficiency of thermal power firms is investigated in this paper, while most of the existing literature studied the relationship between comprehensive subsidies and general efficiency. In fact, the results of the impact of environmental subsidies on green efficiency are more specific. Third, due to the difficulty of collecting the firm-level data, existing studies have mainly measured green efficiency at the national, regional or sectorial level. Based on a firm-level dataset, this paper measures the green efficiency of thermal power firms and further studies the impact of environmental subsidies on the green efficiency of thermal power firms. The results from the firm-level study are more specific and practical because firms are the actual entities that achieve cleaner production and sustainable economic development. Fourth, considering the important role of green technology innovation in green development, we incorporate a green patents index into the SBM model as a desirable output to measure green efficiency, while most of the existing studies only focused on pollutant emissions as an undesired output when measuring green efficiency.

The rest of this paper is organized as follows. The subsequent section reviews the background of environmental subsidies for thermal power firms in China and the related literature. Section 3 describes the SBM method, the Tobit regression, the variables and the data sources. Section 4 reports the empirical results and provides a discussion. Section 5 presents robustness checks. Section 6 provides conclusions and implications, including future works.

2. Institutional background

2.1. Environmental subsidies for thermal power firms in China

Due to the coal-dominant energy structure, thermal power firms are the main component of the power sector in China. As shown in Fig. 2, the installed capacity of thermal power firms accounts for more than 60% of the power sector's total installed capacity, which reflects its dominant position in China. The thermal power sector is the fundamental industry that promotes the normal running of the economy and society, and it is the technology-intensive and capital-intensive industry that requires a lot of money to purchase and maintain automatic equipment in order to produce and deliver electricity. In addition, the thermal power firms have the notable features of high energy consumption, high emissions and low efficiency that bring great pressure to the ecological environment. Therefore, improving the green efficiency of thermal power firms plays a critical role in energy conservation and emission reductions. This paper focuses on the green efficiency of thermal power firms.

For the purpose of cleaner production, the Chinese government allocates a great deal of environmental subsidies to thermal power

[2] In this paper, green efficiency is the environmentally sensitive production performance that incorporates the dimensions of resources, green innovation, energy, and the environment into general efficiency to enhance productivity and environmental performance simultaneously to achieve overall socio-economic development (Zhang et al., 2018).