



Impact of environmental regulations on the efficiency and CO₂ emissions of power plants in China



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HIGHLIGHTS

- An empirical study with 137 power plants in China.
- Market based regulations help improve efficiency and reduce CO₂ emission.
- Government subsidies help improve efficiency and reduce CO₂ emission.
- Command and control regulations do not have a clear impact.
- China should utilize more market based regulations in its power industry.

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ABSTRACT

The power industry is the largest air polluter in China, contributing nearly 40% of CO₂ emissions and 60% of SO₂ emissions. Under mounting pressure to improve standards of environmental protection, it is imperative that the industry increases the efficiency and environmental performance of power plants in China. We investigate the impacts of three different environmental regulations on efficiency improvement and CO₂ reduction: command and control regulations (CCR), market-based regulations (MBR), and government subsidies (GS). We find that MBR and GS have a positive impact on efficiency improvement and CO₂ reduction. However, CCR have no significant impacts. This finding has important implications since CCR dominates China's environmental policy. We discuss the policy implications of these findings, such as China should further release the potential of MBR in the power industry, instead of solely relying on CCR; and pay more attention to the coordination of different policy instruments.

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1. Introduction

In response to the economic and environmental challenges posed by energy use, Chinese policy makers have formulated targets for reducing energy consumption and CO₂ emissions in terms of not only intensity, but also amount. Besides the target set for China at the Copenhagen International Climate Change Conference in 2009, in 2011 the State Council issued *The Twelfth Five-year Energy Saving and Emissions Reduction Comprehensive Plan* and set a goal of reducing energy consumption by 16% per 10,000 Yuan GDP by 2015 from 2010 levels and 32% from 2005 levels. Furthermore, the plan established goals based on absolute amounts: for example, saving 670 million tonnes of coal equivalent (TCE) during the five-year period 2010–2015, reducing chemical

oxygen demand (COD) and SO₂ emissions by 8%, and reducing ammonia and nitrogen oxide emissions by 10% during the same period.

Without question, it will require significant policy intervention to achieve these environmental goals. Chinese policy makers face a critical question: should they fall back on the traditional command and control approach, or intensify the use of environmental economic instruments? Research has shown that firms behave differently under different policy regimes, which in turn determines policy outcomes [1,2]. Our central task is to study how different types of regulations affect Chinese power plants' operational efficiency and environmental performance. We chose the power industry for the following reasons. First, it is a primary pollution source, accounting for around 40% of total CO₂ emissions and 60% of total SO₂ emissions in China in the past thirty years. Second, relative to other energy sectors the power industry is flexible when it comes to fuel choices and technological solutions for

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environmental problems, and as a result, shows wide variation between firms in terms of environmental improvement. Third, power plants are relatively concentrated and thus easy to regulate [3].

We created a plant-level database based on data collected from China Electric Power Statistical Compilation (CEPSC) (2011 and 2012) and surveys of power plant managers. Based on this database, we analyzed the impact of various environmental policies on the operational efficiency and CO₂ emissions of power plants. The policy variables are captured by the perception of plant managers. We found that power plants that perceive a stronger influence from market-based regulations (MBR) perform better on operational efficiency and CO₂ emissions than the plants that perceive a stronger influence from command and control regulations (CCR)¹. In contrast, power plants that perceive a stronger influence from CCR do not perform significantly better or worse in terms of operational efficiency and CO₂ emissions.

The rest of our paper proceeds as follows. In Section 2 we review the related literature, before going on to describe the Chinese environmental regulations that affect the power industry in Section 3. We discuss our data collection, measurement, and analytical models in Section 4, and in Section 5 we present and discuss our empirical findings. In Section 6, we conclude our paper.

2. Literature review

2.1. CO₂ mitigation in China

Because of China's prominent role in combating global warming, factors affecting CO₂ emissions in China have recently become an actively researched topic [4–8]. Some of the literature has explored the link between CO₂ emissions and China's economic growth [4,6,7], however, these papers found mixed results. For example, Zhang and Cheng [6] argued that neither CO₂ emissions nor energy consumption affect economic growth. However, Bloch et al. [7] found that energy consumption affects economic growth positively. Su and Ang [8] investigated the impact of inter-regional trade and international trade on CO₂ emissions.

Some other papers have studied CO₂ emissions in specific sectors, for instance, electricity generation [5,9,10,11], transportation [12], construction [13], cement production [14], and iron and steel sector [15,16]. Xu et al. [17] investigated the changes of energy-related GHG emissions in five sectors in China (agricultural sector, industrial sector, transportation sector, commercial & service sector, and the residential sector). To the best of our knowledge, only four papers have examined CO₂ reduction in the sector of electricity generation in China. Gnansounou et al. [5] analyzed the strategic technology options for mitigating CO₂ emissions in Shanghai's power sector. Cong and Wei [9] studied the impact of carbon emissions trading (CET) on China's power sector. Zhao et al. [10] studied the major factors that have influenced CO₂ emissions within China's power industry from 1980 to 2010. Zhou et al. [11] studied the impact of CDM on the carbon emission in power industry in the city of Shenzhen in China.

In contrast to these previous studies of CO₂ mitigation in China, this study explores how to promote CO₂ reduction in China's power sector based on a plant-level database. Specifically, we investigate the role of environmental regulations, which are an important instrument in motivating power plants to save energy and reduce emissions.

2.2. Environmental regulations and operational efficiency

The relationship between environmental regulations and operational efficiency is important because firms are unlikely to voluntarily comply with and exceed environmental regulations unless they can simultaneously achieve efficiency gains by doing so. Two radically different views exist on the relationship between environmental regulation and corporate performance. The classical school [18]; 1992; [19] argues that economic and environmental goals often conflict with each other and environmental regulation may negatively impact corporate efficiency. In contrast, the revisionist school, notably the “Porter hypothesis”, considers environmental regulation to have a positive impact on technological innovation and, therefore, on corporate efficiency [20,21].

Scholars have investigated whether the impact of environmental regulation on corporate performance is contingent upon the type of environmental regulations and the type of firms. Zerbe [22] argued that a pollution tax seems to have the most positive impact on corporate innovation, while a production tax has the weakest. Downing and White [23] found that, compared to CCR, MBR promote corporate innovation and thus efficiency more effectively. Milliman and Prince [24] concluded that direct controls usually provide the fewest incentives to promote technological change; on the other hand, market-based measures, such as emissions taxes and permit auctions, can offer the greatest incentive to promote technological change. Williams [25] pointed out that MBR create more incentives to enhance efficiency than command-and-control regulation. These studies are all based on theoretical analysis. Some other studies explored the issue from an empirical perspective. Testa et al. [26] found that direct regulation has the most effective role on corporate performance improvement, while MBR (economic instruments) has negative effects on business performance.

Several researchers have investigated empirically the impact of environmental regulations on corporate performance in China [28,27,29]. However, most of these studies are built on industry- or provincial-level data [27,29]. Such data neglect variation across firms, the primary units that face environmental regulation and make decisions on efficiency and environmental management [30]. Zhang et al. [28] based their study on firm-level data, but the sampled firms were from Wujin county of the Jiangsu province, which limits our ability to generalize the findings of the study.

2.3. Environmental regulations and environmental performance

Scholars have also investigated the impact of different types of environmental policy on corporate environmental performance. For instance, Ellerman et al. [31] reported that SO₂ emissions in the U.S. fell dramatically relative to previous levels and also relative to levels that likely would have been obtained in the absence of a cap and trade program. Knoar and Cohen [32] found that firms with the largest stock price decline on the day that the Toxic Release Inventory became public subsequently reduced emissions more than their industry peers, providing evidence that a mandatory information disclosure program is an effective instrument for environmental management. Cui et al. [33] explored the cost-saving effect of China's emission trading scheme on CO₂ emission reduction. They argued that the cost-saving effects of the eastern and western provinces are more pronounced than the central provinces. Zhou et al. [10] concluded that CDM effectively facilitates the development of renewable energy and CO₂ emission reduction.

More closely related to our study, several scholars compared the impact of different types of regulations on corporate environmental performance. Mao et al. [11] examined and compared the impact of various environmental policies – carbon tax, energy tax, clean

¹ We classify the perceived influence of environmental regulations (for example, CCR) by power plants into 7 levels (1–7), with 7 for the strongest influence and 1 for the least.

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