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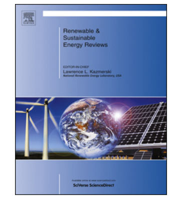

The impacts of provincial energy and environmental policies on air pollution control in China

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ABSTRACT

In recent decades, China has witnessed substantial progress in urbanization and industrialization and has become the manufacturing center of the world, but has suffered from severe environmental deterioration, especially air pollution. National and provincial governments have adopted a series of policy tools aiming at energy conservation and emission reduction, varying from energy saving regulations to cleaner production policies. This paper investigates provincial energy saving and emission reduction policies by evaluating their effectiveness on local air pollution control. Relying on a panel data regression analysis on a sample of 26 provinces and four centrally-controlled municipalities over a ten-year period from 2002 to 2011, we find empirical support for the positive impacts of provincial energy saving regulations and two environmental standards on the improvement of local air quality.

Contents

1. Introduction

China has witnessed dramatic economic growth during the last few decades, with an annual gross domestic product (GDP) growth rate of approximately 10% [1]. However, China's outstanding economic performance is achieved at the cost of environmental degradation. A number of environmental problems arise as byproducts of rapid industrialization and urbanization [2], and air pollution is the one that has received considerable public attention. The negative impacts from air pollution are posing significant threats to China's long-term sustainability [3]. The World Bank estimated that the annual economic loss generated by air pollution could be as much as 1.2% of China's GDP based on cost-of-illness valuation and 3.8% based on willingness to pay [4].

The fast-growing economy in China is accompanied by a rapidly increasing demand for energy and resources [5]. Different

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from a few developed countries, such as Germany and France, where clean energy technologies have been widely adopted and utilized, China still highly depends on traditional energy sources. In 2011, 69% of the country's total energy consumption came from coal, followed by oil (18%), hydroelectric sources (6%), natural gas (4%), nuclear power (1%) and other renewables (1%) [1].

Over reliance on fossil fuels has led to serious air quality degradation [6]. Emissions from coal combustion act as major anthropogenic contributors to air pollution in China [7]. As a result of a coal-dominated energy structure, urban air in China has been heavily polluted by high concentrations of sulfur dioxide (SO_2) and total suspended particles [8]. The other two pollutants strongly associated with fossil-energy use are NO_x and CO_2, which contribute to the formation of acid rain, smog, particulates and tropospheric ozone, and lead to serious air quality deterioration [9].

To control for air pollution, both central and provincial governments in China have employed various energy saving regulations, emission reduction policies and environmental standards. Nevertheless, extant literature on air pollution control policies mainly focuses on central government's activities and policies [10,11]. Studies on provincial policies are relatively rare, and they mainly draw conclusions from case studies, which are difficult to generalize. This study is designed to fill this gap by providing insight into the effectiveness of these energy and environmental policies via quantitative methods. Specifically, this paper will quantify energy saving policies, emission reduction policies and environmental standards in Chinese provinces, and evaluate the influence of these policies on air quality in China.

We will provide an extensive review of the literature on China's air quality and energy policies in the next sections. A detailed description of research methods and data collection strategies will be demonstrated, followed by results and discussions of the analysis. Policy implications will be summarized at the end of the paper.

2. Air quality in China

According to a report published by the Ministry of Environmental Protection (MEP) [12] in China, only three out of seventy-four cities were in compliance with the Grade II requirements of the *National Ambient Air Quality Standards* (NAAQS) in 2013, while the other seventy-one cities were experiencing air pollution to varying degrees. Particularly, cities in the Yangtze River Delta, Pearl River Delta, and Beijing–Tianjin–Hebei regions suffer from worst air pollution, with $PM_{2.5}$ (particles with an aerodynamic diameter less than 2.5 μm) concentration two to four times above the standards stipulated in *World Health Organization* (WHO) guidelines.

Accused of a major cause for negative human health effects, $PM_{2.5}$ has been heatedly discussed as an important public issue by scholars, government officials and the general public in China in recent years. It acted as a tipping point for China's clean air movement in 2012, incentivizing the MEP to implement the new *Air Quality Index* (AQI). AQI signals a notable shift from its previous version as the *Air Pollution Index* (API), a score between 0 and 300 calculated based on three key pollutants (SO_2, NO_2, PM_{10}) to measure local air quality.

Although AQI is a better indicator of local air quality than API, AQI had not been widely applied in most cities in China until 2013. Thus it is currently impossible to collect AQI information and conduct statistical analyses on Chinese cities. Compared with AQI, API does not account for CO, O_3 and $PM_{2.5}$ emissions. As a result, API illustrates that air quality is getting better in China in recent years, creating a discrepancy between governments' air quality report and the general public's personal experience. However, API is still an accurate indicator measuring the emissions of SO_2, NO_2 and PM_{10}, and is the best available data to track environmental performance over the last decade.

Fig. 1 demonstrates the trend of the annual average API of 26 provinces and four direct-controlled municipalities by geographic region from 2002 to 2011. Hong Kong, Taiwan, Macao and Tibet were excluded from our sample due to lack of data.

As illustrated in Fig. 1, despite fluctuations and variations in trend among provinces, the annual average API experienced a decrease in most provinces during the period of 2002 to 2011, indicating an overall downward trend of emissions from SO_2, NO_2 and PM_{10}. The variation in API among provinces has dropped significantly from 2002 to 2011, showing a trend of convergence in API scores across China. This convergence is exemplified by many provinces with high API scores in 2002, such as Gansu, Henan and Chongqing, experiencing significant improvement over time, and other provinces with low API scores in the same year, such as Hainan, Guangxi and Yunnan, experiencing moderate deteriorations.

Different regions also exhibit varying patterns in API trend between 2002 and 2011. Northeast China and North China regions show overall trends for API improvement, while East China experiences stagnation during the same period. API scores in Northwest China experience much fluctuation over time in several provinces, compared with a moderate convergence in Mid-South and Southwest China.

The above trend analysis is consistent with previous finding that ambient SO_2, NO_x and inorganic aerosol concentrations had been controlled during the 11th Five-Year Plan (FYP) and 12th FYP periods [11]. During these periods, provincial governments in China implemented administrative targets to achieve the national energy conservation and emissions reduction targets [13]. In the next section, we will discuss provincial level energy and environmental policy designs, and examine their influence on air quality across Chinese provinces.

3. Reviews on energy and environmental policies for air quality control

As policy responses to concerns over air quality deterioration, the national government of China issued multiple laws and regulations as well as comprehensive plans in recent years. For instance, the 12th FYP set up a target to reduce SO_2, NO_x and industrial fume and dust by 12%, 13% and 10% respectively by 2015 [14]. In correspondence to central government's environmental protection activities, a number of provincial governments are taking increasingly leading roles in shaping policy outcomes via their own actions, through adoptions of cleaner production, energy saving and comprehensive resource utilization policies, and through revisions of local standards for emissions reduction. Whether or not these policies have actually contributed to air quality improvement has received growing attention from researchers and policy makers, due to their theoretical importance and policy relevance.

As for studies focusing on national policies, Xue et al. predicted that the implementation of *National Total Emission Control* (NTEC) during the 12th FYP will lead to reductions in the average SO_2 and NO_2 concentrations across all Chinese cities by 9.28% and 10.61% respectively by 2015 [10]. Similar conclusions were reached by Wang et al. [11], who found that the 11th FYP and the 12th FYP have effectively controlled the emission of ambient SO_2, NO_2 and inorganic aerosol concentrations, leading to an improvement in air quality in China's metropolitan areas [10,11].

At the sub-national level, Wang and Hao indicated that many challenges, such as ensuring a sustained high local GDP growth rate for provinces located in western China, thwarted China and its provinces in achieving energy intensity reduction [8]. These provinces resorted to energy efficiency improvement and carbon-neutral energy development when designing their energy policies. Similarly, Li et al. suggested that local governments in China should