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Sulfur dioxide control in China: policy evolution during the 10th and 11th Five-year Plans and lessons for the future

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HIGHLIGHTS

► This paper assesses China's SO_2 reduction policies between 2000 and 2010.
► Government used a variety of policy instruments to achieve emission targets.
► Experience shows that accountability, incentives, and political support were key.
► The policy lessons can aid future policies for SO_2, NO_x, and CO_2 reductions.

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ABSTRACT

China's Central government established national goals to reduce sulfur dioxide (SO_2) emissions by 10% in both the 10th and 11th Five-year Plan periods, 2001–2005 and 2006–2010, respectively. But the early policies were unsuccessful at reducing emissions—emissions increased 28% during the 10th Five-year Plan. After adapting a number of policies and introducing new instruments during the 11th Five-year Plan, SO_2 emissions declined by 14%. We examine the evolution of these policies, their interplay with technical and institutional factors, and capture lessons from the 11th Five-year Plan to guide future pollution control programs. We find that several factors contributed to achievement of the 11th Five-year Plan SO_2 reduction goal: (1) instrument choice, (2) political accountability, (3) emission verification, (4) political support, (5) streamlined targets, and (6) political and financial incentives. The approach integrated multiple policy instruments—market-based, command-and-control, and administrative instruments specific to the Chinese context. The evolution of SO_2 reduction policies and programs has implications for further SO_2 reductions from power plants and other sources, as well as control of other atmospheric pollutants such as nitrogen oxides (NO_X) and carbon dioxide (CO_2) in China.

1. Introduction

Rapid industrialization and urbanization have pulled millions of Chinese citizens out of poverty (Baldinger and Turner, 2002; World Bank, 2011), but as incomes rise, people migrate to urban areas, and exports increase, the demand for energy grows. China is now the world's largest energy consumer (BP, 2011a) and energy demand is expected to continue growing rapidly through 2030 (BP, 2011b). As a result of urbanization, industrialization, and increased energy consumption, ambient air quality in many Chinese cities exceeds both national standards and international guidelines (Hao et al., 2007; Yi et al., 2007; Chan and Yao, 2008; Millman et al., 2008; Huang et al., 2009). In an effort to improve air quality, China's Central, provincial, and local governments have implemented a suite of evolving policies and programs to reduce emissions that contribute to the air quality problems.

Many of the governments' efforts are focused on sulfur dioxide (SO_2) emissions—a key pollutant that contributes to both ambient air pollution and acid rain. As part of the 10th Five-year Plan (2001–2005), the Central government established national objectives to control SO_2 emissions. The goal called on provincial

Abbreviations: CEMS, continuous emissions monitoring system; CO_2, carbon dioxide; EIA, environmental impact assessment; EPB, environmental Protection Bureau; FGD, flue gas desulfurization (a.k.a. scrubbers); GDP, gross domestic product; MEP, Ministry of Environmental Protection (State Environmental Protection Agency); MOF, Ministry of Finance; NDRC, National Development and Reform Commission; NPC, National People's Congress; NO_X, nitrogen oxides; PM, particulate matter; RMB, Chinese Renminbi (approximately 0.16 USD); RSCs, regional supervision centers; SO_2, sulfur dioxide; TEC, total emissions control; USD, U.S. dollar (approximately 6.4 RMB)

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Table 1
SO_2 reduction goals, results, and role of flue gas desulphurization (FGD) technology.

Element	10th Five-year Plan (2001–2005)	11th Five-year Plan (2006–2010)
Goal	Reduce SO_2 emissions 10% below 2000 levels	Reduce SO_2 emissions 10% below 2005 levels
Result	Emissions 28% above 2000 levels	Emissions 14% below 2005 levels
Diffusion of FGD technology	FGD installed on 14% of thermal power plant capacity by the end of 2005	FGD installed on 86% of thermal power plant capacity by the end of 2010

governments to reduce SO_2 emissions an average of 10% below 2000 emission levels. However, during this period SO_2 emissions increased by approximately 28% (NBS, 2004, 2010). In the 11th Five-year Plan (2006–2011), the government again set a goal to reduce SO_2 emissions by 10%, this time below 2005 emission levels. This second attempt was successful—although the economy grew rapidly and electricity generation increased by nearly 80% (CEC, 2006, 2011), total SO_2 emissions declined by more than 14% by the end of 2010 (see Table 1) (NBS, 2010; Wen, 2011). In this case study, we examine the evolution of policy instruments and the effect of political pressures to reduce SO_2 emissions. In doing so, we identify a variety of political and economic tools that proved successful in reducing China's SO_2 emissions and suggest lessons for future pollutant reduction efforts.

Several recent papers review environmental progress during the 11th Five-year Plan. These papers examine the development of emission targets (Xu, 2011a), role of control technologies (Steinfeld et al., 2009; Xu, 2009, 2011b; Xu et al., 2009), and energy efficiency measures including closure of small, inefficient boilers (Price et al., 2010, 2011; Wang and Chen, 2010; Zhang et al., 2011). Other papers assess the economic benefits of achieving the SO_2 emission reduction target (USEPA and MEP, 2007; Cao et al., 2009; Wang et al., 2010). In this paper, we focus on the evolution of policy instrument choice (Stavins et al., 1998) and the interplay between technology, policy, and institutional factors to explore distinctive policy tools for Chinese environmental management. We examine key environmental policies within the larger context of economic and political conditions. In doing so, we trace the evolution of SO_2 control policies and draw lessons to inform development of policies and measures to achieve the 12th 5-year plan (2011–2015) goals to further reduce SO_2 emissions, reduce nitrogen oxides (NO_X) emissions, and decrease carbon dioxide (CO_2) intensity (8%, 10%, and 17% below 2010 levels, respectively). We first review the impacts and sources of SO_2 emissions, summarize the literature on policy instrument choice, discuss key SO_2 control policy instruments and the evolution of those policies, and highlight lessons that may aid future emission reduction efforts. We focus largely on efforts in the electric sector because it is responsible for a majority of SO_2 emissions and was a target of pollution prevention and control efforts in both the 10th and 11th Five-year Plans.

2. Sulfur dioxide emission impacts and sources

Atmospheric SO_2 emissions are a major contributor to $PM_{2.5}$ in China. In several major Chinese cities, sulfates constitute 20–35% of ambient $PM_{2.5}$ (Li et al., 2009; Pathak et al., 2009; Tan et al., 2009) resulting in serious health impacts. Zhang et al. (2008) estimate total PM concentrations in 111 key Chinese cities contributed to more than 280,000 premature deaths and 680,000 cases of chronic bronchitis at a cost to the economy of more than 187.7 billion RMB (29.2 billion USD) annually. Sulfates also contribute to acid deposition, a serious problem across much of the country that impairs lakes and streams, damages materials (e.g., paints, buildings, infrastructure, cultural resources), and harms forests and other vegetation. In 2004, the Ministry of Environmental Protection (MEP)[1] – the Central government's environment agency – estimated the economic costs of acid rain at more than 83 billion RMB (13 billion USD) per year (Hao et al., 2007).

During the 10th Five-year Plan period, economy-wide SO_2 emissions increased at an average rate of 5.5% annually, but the SO_2 intensity (emissions per unit of GDP) and coal-fired power sector's average emission rate (emissions per unit of electricity generated) decreased by 4–5% annually as plants improved efficiency (NBS, 2001, 2002, 2003, 2004, 2005, 2006, 2010; IMF, 2011). During the 11th Five-year Plan period, economy-wide SO_2 emissions rose in the first year before beginning a steady decline to 22 million tons in 2010—a 14.3% reduction from 2005 levels. Economy-wide emissions declined by an average rate of 2.8% annually while SO_2 intensity and coal-fired power plants' emission rates both declined by an average of 10% annually (see Fig. 1). While there is uncertainty about the accuracy of emission data, observations from the Ozone Monitoring Instrument (OMI) aboard NASA's Aura satellite corroborate the SO_2 emission trends through 2009 (Li et al., 2010; Lin et al., 2010; Wang et al., 2011; Yang et al., 2011).

Industrial SO_2 emissions in China largely originate from six key sectors responsible for 67% of 2009 emissions: electricity, iron and steel, cement, chemicals, non-ferrous metals, and petroleum/coking coal (NBS, 2010). Between 2005 and 2010, emissions from iron and steel production and non-ferrous metal smelting grew by 24% and 14%, respectively, while all other major sectors saw emission declines, including a 23% decline by the power sector (see Table 2).

3. Policy instrument choice

The literature on choice of policy instruments to meet environmental goals recognizes both the importance of instrument choice (Sterner, 2002; Goulder and Parry, 2008) as well as the gaps between economic theory and political practice in choosing policy instruments (Stavins et al., 1998). The tools normally available to meet environmental goals range from market-based instruments and performance standards to technology mandates and research subsidies (Stavins et al., 1998; Sterner, 2002; Stavins, 2003). The appropriateness and efficiency of a policy tool is based on a complex calculation of perceived economic benefits and costs, as well as a calculus of political feasibility, which often are at odds with one another (Stavins et al., 1998). While this research on instrument choice and market-based instruments for environmental policy originated in Europe and North America, there is a growing body of scholarship exploring policy instruments to implement environmental policies in other regions of the world (Eskeland and Jimenez, 1992; Blackman and Harrington, 2000; Sterner, 2002; Greenspan Bell, 2004; Kruger et al., 2004). However, tool deployment and effectiveness is

[1] MEP was known as the State Environmental Protection Agency, or SEPA, until 2008 when it was elevated to a ministerial level agency. To avoid confusion, we use the name MEP throughout the paper.