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Chapter 1

A Review of Air Pollution Control Policy Development and Effectiveness in China

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Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.74928

Abstract

Upon economic booming and rapid urbanization, China has been suffering from severe air pollution problem. While the Chinese government strives to reduce emissions through numerous laws, standards and policy measures, rapid economic and social changes challenge policy design and implementation. Over time, control policies have been largely ineffective and air quality in the majority of the nation has not been significantly improved and even worsened in many urban areas. This chapter reviews the development of the air pollution control policies in China's nearly 70 years' history and discusses some political and institutional factors that have resulted in the ineffectiveness of policy implementation. We examined the pollution charge system, a key policy measure used in air pollution regulation between 1980s and 2000s, and highlighted some major changes in control policies since 2000s. A comparison of pollution control policies between China and the United States is also presented. The purpose of this chapter is to inform decision makers, particularly in the developing world, with some insights of improving policy designs and environmental governance in the control of air pollution.

Keywords: air pollution, control policy, effectiveness, China

1. Introduction

Upon economic booming and rapid urbanization, China has been suffering from severe air pollution problem. A recent study based on satellite observations reported China as one of the regions with the highest long-term concentrations of fine particulate matter ($PM_{2.5}$, particulates with an aerodynamic diameter of less than or equal to 2.5 μm) [1]. The population-weighted average $PM_{2.5}$ concentration reached 59 $\mu g/m^3$ in 2010, with more than 80% people

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living in areas where air quality did not meet China's annual average $PM_{2.5}$ standard of 35 μg/m^3 [2].[1] Air pollution has caused serious public health and environmental damages in China, resulting in enormous economic loss. For instance, a recent evaluation estimated that the health-related economic loss in China's 74 cities caused by PM_{10} and sulfur dioxide (SO_2) ranged from 1.63 and 2.32% of the GDP [3].

While China is confronted with one of the highest levels of air pollution in the world, rapid economic and social changes challenge policy design and implementation for the endeavors to reduce pollution. The problem of regulating air pollution is complex, not only because it involves many different pollutant emitters, but also because regulations involve many institutions that cut across domains of environment, energy, natural resource, public health, and economic policy [4]. Policies that work well in western developed countries can fail in a less developed country for any economic, social, and institutional reasons [4]. In China, the central government has been addressing this issue since late 1970s and has promulgated a series of laws, regulations as well as programs to mitigate pollution. However, although China has worked diligently for more than three decades to address its air pollution issue, the current pollution levels are still severe across the country. This has raised the questions that how successful the air quality policies have been in terms of policy design, enforcement and effectiveness. This chapter reviews the development of the air pollution control policies in China's nearly 70 years' history, focusing on its basic structure and distinct features, addressing some political and institutional factors that have resulted in the ineffectiveness of policy implementation. A comparison of control policies between China and the USA is conducted to highlight their similarities and differences, followed by a few conclusion remarks for future air pollution designs and implementations in China. The purpose of this chapter is to inform decision makers, particularly in the developing world, with some insights of improving policy designs and environmental governance in the control of air pollution.

2. China's air pollution control policy development and effectiveness

2.1. Environmental policies before China's 1979 economic reform a brief history[2]

For many years before China's reform of the economic system in 1979, pollution was a so-called nonissue in China [5]. For example, only a few regulatory standards (largely oriented to occupational health) based on Soviet practice were promulgated in 1956 and revised in 1962 but were almost ineffective [6]. For almost two decades (1950s and 1960s), China's economic sector paid very little attention to pollution control because it was neither included in enterprise norms and received state investment funds, nor did it receive public concerns [5].

[1]The World Health Organization (WHO) recommended annual PM2.5 level is 10 μg/m^3.
[2]Historical issues in this section were heavily informed by [5].

China's lack of pollution control, both ideologically and practically, both by governmental actions and by general public demand, was because of several reasons: first, during that period China placed the policy priority exclusively on economic development, particularly the development of heavy industries, so as to fulfill rapid industrialization in this country; second, China's political isolation from the western world made this nation slow in understanding and participating in the world's increasing concerns about pollution in 1960s, which was even aggravated by the anti-intellectual ferment of the Cultural Revolution from 1966 through 1976 [5]; third, because of the poor income levels and living conditions in general, Chinese people were the most concerned with basic life demands such as food and clothes, and therefore little heed had been taken of environmental issues. However, the development of heavy industries in this period and the ubiquitous use of "dirt" technologies as well as abuse of natural resources, along with the expansion of population had gradually caused severe threats to China's environment as well as natural resources.

The United Nations Conference on the Human Environment, held in Stockholm, Swedish in 1972 motivated China to address the increasingly serious environmental problems in this country, and significantly improved China's understanding of this issue. A conference on stack dust removal was held in Shanghai in 1972 that led to a pilot emission control project in Shenyang, one of China's most air-polluted cities located in Eastern-north part [5]. Perhaps this was China's first formal air pollution control project.

In 1973, the State Planning Commission convened a national conference on environmental protection. The conference led to China's first State Council Directive on environmental protection, named "Some Regulations on Protecting and Improving the Environment," which signified the beginning of official environmental protection work in China, and included some industrial emissions standards for air pollutants such as particles. It covered only power plants, boilers, steel-smelting furnaces, and cement plants, which were arguably the most significant point sources in urban areas [4]. When China first began to develop regulations for air pollution control in late 1970s, China did not adopt the technology-standard approach that was then popular in the USA and some other OECD countries [4]. The main guideline of the Directive was to incorporate environmental considerations into planning while not retarding economic development [5]. The idea of pollution control, however, was not clearly indicated in the document. Following the conference, China began to establish a bureaucratic structure to deal with environmental problems: in October 1974, a leading group for environmental protection under the State Council was set up with a small staff of 20, and following that, similar units were also formed at the provincial level in many parts of China.

McElroy argued that the US air pollution legislation had a problem-trailing character because it addressed only problems that were already apparent, many of them unanticipated when the responsible technologies were first introduced [7]. In this regard, China was without exception, or even in a worse situation than the USA. Over the history, China's environmental decision-making seemed to mainly pay attention to environmental damages when the problems were already fairly obvious, risking serious long-term environmental and resource destruction, which can be very expensive to cure later.

2.2. China's major air quality regulations during 1980s and 1990s

As discussed in previous section, before the 1978 political and economic reform, China's environmental governance had been relatively inert, and compared with the western countries such as the USA, who began to nationalize pollution control soon after the publication of Rachel Carson's influential book *Silent Spring*, the government responded to accumulating environmental issues more than one decades behind. Once the Chinese government began to respond, how effective it has been to improve environmental quality and protect natural resource? It seems that it had not been fairly effective during the decades of 1980s and 1990s, at least in terms of stopping the deterioration of environmental quality. With regard to air quality, no significant improvement was observed in major air-polluted cities. For instance, the annual mean concentrations of TSP and SO_2 for five large Chinese cities (Beijing, Shenyang, Xi'an, Shanghai, and Guanzhou) during 11 years (1981–1991) did not change apparently and continuously violated the WHO recommending limit to a large extent [8]. Deng Xiaoping's political and economic reform in 1979 is a turning point for China's environmental protection. As China was infused with the idea of sustainable development, and more importantly, as the government became increasingly concerned with and better understanding the environmental destruction resulting from economic development during 1970s, they started issuing measures of pollution control and natural resources protection.

A salient characteristic of China's air pollution issue is that, like many developing countries, the early stages of industrial growth were pursued without much investment in environmental protection, leading to heavy air pollution in urban areas [4]. Brandon and Ramankutty called it "grow first, clean up later" environmental strategies and argued that they had resulted in serious environmental problems such as exceedingly polluted air [9]. The essential problem is, arguably, that a fairly significant gap has existed between the goals embodied in China's environmental laws and regulations and actual levels of environmental quality [10].

2.2.1. China's air pollution regulation: an overview

Since the government began responding to environmental issues at the national level in late 1970s, they became increasingly active in promulgating environmental laws and issuing legally binding administrative regulations, as well as organizing regulatory agencies at different levels of governments. Two types of environmental statutes exist in China: a "basic law," namely, *People's Republic of China National Environmental Law*, and specific environmental laws to direct particular issues such as air pollution, water pollution, natural resources and ecosystem protection, and so forth [10]. With regard to air pollution, the special environmental law is *People's Republic of China Air Pollution Prevention and Control Law*, which was first enacted in 1987, and then was subsequently revised twice in 1995 and 2000, respectively, and most recently in 2015 in response to the urgent air pollution in China.[3] Besides laws, regulations on air pollution include the National Ambient Air Quality Standards (NAAQSs) and various

[3]Source: The website of the National People's Congress of the People's Republic of China, http://www.npc.gov.cn/npc/xinwen/2015-08/31/content_1945589.htm. Accessed December 1, 2017.

emission standards targeting industrial facilities (particularly coal-fired power plants) and motor vehicles (refer to **Table A1** in the Appendix).

Despite of about 30 environmental laws and hundreds of regulations, standards and programs and agencies that provide a foundation for curtailing further degradation, it seems that China's environmental quality has not been considerably improved for decades. Scholars have argued that a significant gap exists between the goals embodied in China's environmental laws and regulations and their actual effects [10, 11]. In the succeeding section, this problem will be discussed by investigating the design, implementation and effectiveness of China's pollution levy system, one of the major national programs targeting industrial emissions.

2.2.2. China's pollution levy system

First promulgated in 1979, China's Environmental Protection Law established national and local Environmental Protection Bureaus (EPB),[4] required polluters to comply with waste discharge standards, and directed enterprises to assess environmental impacts of proposed projects and ensured that new projects satisfied applicable environmental standards [10]. For the first time, it formally stipulated the polluter pays principle and based upon this, authorized the creation of a pollution levy system to assess fees on all enterprises for pollution emissions that exceed standards, and it also required that new facilities demonstrate design compliance with emissions standards as a condition of obtaining a construction permit [12].

2.2.2.1. The development of the pollution levy system[5] and monitoring network

Preliminary discussion of a possible pollution charge system (pollutant discharge fees) began in China after the Stockholm Human Environment Conference in 1972. The idea was formally adopted by the central government in 1978, when the Leaders Group for Environmental Protection in the State Council provided a work report to the Central Committee of the Chinese Communist Party. The report stated "Pollution source control should be an important component of environmental management; fees should be charged against pollution discharge; and environmental protection authorities, in cooperation with other departments, should set up a detailed levy schedule." Several local governments immediately began experimenting with charges, and by the end of 1981, 27 of China's 29 provinces, autonomous regions and municipalities had established programs of some type. After studying these local experiences, the central government issued an "Interim Procedure on Pollution Charges" in February, 1982. The procedure defined the system's objectives, principles, levy standards, levy collection methods, and principles for fund use. Under the pollution levy system, enterprises must pay fees for releases on air-borne and water-borne pollutants that violate standards on emissions and effluents, and typically, fees are based on the pollution indicator that exceeds the discharge standard by the greatest amount [10].

[4]Environmental Protection Bureaus (EPB) is China's main government agency created under China's basic environmental law in charge of environmental protection tasks. All levels of governments (e.g. central, provincial, municipal, and county) have their own EPB as one of the government agencies.

[5]Unless noted, information on China's pollution levy system development in the succeeding paragraph was cited from [13].

Monitoring compliance is a key step of implementing pollution levy system. To what extent industrial firms obey the rules heavily depends on their beliefs in how likely their emission activities would be monitored and discovered. Article 23 of People's Republic of China Air Pollution Prevention and Control Law authorizes the state and local environmental agencies to design standard monitoring methods and direct to set up environmental monitoring networks and release the information on air quality to the public.[6] Based on this, the EPBs at all levels organize their affiliates of local environmental monitoring stations. Monitoring stations are responsible for checking up on polluters' activities, and EPBs are authorized to penalize enterprises that fail to meet emission standards [10]. To determine the actual pollution levels, on the one hand, enterprises are often required to monitor their waste releases (a process called "self-monitoring"), and to report results to environmental agencies ("self-reporting"), and on the other hand, state and local EPBs conduct periodic facility inspections to gauge the reliability of self-reported data [10]. Specifically, staffs of the environmental monitoring station regularly collect samples outside a facility, analyzes the samples, and submits results to the environmental inspection station, which are another affiliate of a local EPB [10]. The inspection station then determines the total pollution charges and report to their affiliated local EPBs. Ma and Ortolano argued that the Chinese system for self-monitoring differs from the one in the USA in that US permit holders that falsify data are subject to severe penalties under both civil and criminal law [10]. However in China, there were many cases that the self-reported data were not reliable. Therefore, regulators often rely on their own monitoring information to determine the levies.

After a few years' discussion, preparation, and experimenting, nationwide implementation of the pollution levy system rapidly followed in 1982, which has turned out to be one of the Chinese government's major responses to the deteriorating environmental problems since 1980s. During the 1980s and 1990s, almost all of China's counties and cities have implemented the levy system. As a national environmental regulatory program, the pollution levy system was originally created both to penalize industrial polluters who exceed emission standards and to fund local environment bureaus [4].

China's environmental regulation in the 1980s and 1990s was largely a "direct regulation" or "command-and-control" system: the required behavior of enterprises was spelled out and sanctions were imposed if requirements were violated [4]. Although the pollution levy system can be considered as a market-like policy instrument, it still heavily relied on government regulations [14]. The levy system is based on a discharge standard system, and only discharges exceeding the standards are subject to a fee. However, management options look good on paper may fail in reality. In China's pollution control practice, regulatory behaviors were confronted with resource obstacles, institutional conflicts as well as budget limits, which were not anticipated while designing policies. In the next section, some specific issues in the implementation of China's pollution levy system will be reviewed and critically analyzed.

[6]Source: The website of the National People's Congress of the People's Republic of China, http://www.npc.gov.cn/npc/xinwen/2015-08/31/content_1945589.htm. Accessed December 1, 2017.

2.2.2.2. Conflicts between economic and environmental goals

Andrews argued that the creation of environmental policy often involves conflicts among exclusive preferences, and "such conflicts are far less amenable to political compromise or compensation than other policy issues" [15]. As China is in the stage of rapid industrialization, the conflicts between economic development and environmental protection often become salient, whereas it seems that environmental policy design has not adequately considered these inherent conflicts. Case studies in [10] indicated that typically the Mayor's Offices in China try to balance their obligations for both economic development and environmental protection, and they usually favors industrial growth over pollution abatement when both goals conflict, although China's fundamental environmental protection law explicitly stipulates that governments at all levels (national, provincial, municipal, county, etc.) are responsible for environmental protection within their jurisdictions. Their case studies found that work can be intervened by upper level government or other government agencies. For instance, mayor's offices asked local EPBs to approve a new project even though it failed to satisfy environmental regulations, or forced EPBs not to enforce any penalties when environmental regulations were violated. An example that higher level governments were involved in the enforcement of pollution levy is: the mayor's office forced the local EPB to return the pollutant discharge fees that they had collected from a noncompliant plant because the office argued that the facility had financial problems and the penalty fees had made its economic position even worse. Eventually the local EPB had to return the fees. As a result, the polluting facility was implicitly allowed to continue with their emissions that violated the standard. In some other cases, for the purpose of their own prestige, the government leaders just offset the EPB's penalty on an industrial enterprise by giving the enterprise a tax break proportioned to the size of the fee. Ma and Ortolano concluded from their extensive case studies in China that "the instances in which a mayor's office interfered with an EPB's work are common" [10]. This kind of "government failure" phenomena happened for two main reasons: first, China's post-1978 decentralization policies gave local officials strong financial incentives to expand their economies—as a consequence of decentralization, much municipal government revenue comes from enterprises in the form of taxes, and thus often favor industrial development over pollution control [10]; second, apart from producing revenue, for a long time in China, creation of jobs (lower unemployment rate), income of residents as well as other economic indexes have been the indicators of government accomplishment. Consequently, government leaders have strong incentives to improve these evidence in order to have more reputation, perhaps seeking for promotions. To tackle this problem, Jahiel argued that China would have to "significantly weaken the regional economic interests that make environmental inter-jurisdictional co-ordination so complex and contentious" [16]; third, China's environmental protection apparatus (such as EPBs) had suffered from insufficient authority and lack of co-ordination between institutional actors [16]. In the government administrative hierarchy, EPBs stay at the same level as other agencies such as economic commission, planning commission, industrial bureaus, etc., but they are all at a lower level than central leaders such as Mayor's Office of a city. In most cases, local EPBs (at provincial, city, or county levels) do not have sufficient authority or independent roles for environmental regulation; fourth, because China's environmental laws are general and often intentionally ambiguous, they allow the State Council, national

agencies, and local governments to add details that influence implementation [10]. Most day-to-day implementation of a national environmental law occurs at the local level [10]. Typically, local governments respond to national edicts by producing their own versions of national regulations, notices, etc.; and due to the ambiguity of the national laws, local government has a big opportunity to design local environmental regulations to their own interests whereas not visibly inconsistent with national legal enactments [10]. All these lingering problems seem to facilitate government's self-interests against environmental goals, particularly at local levels. As the highest administrative government official has enormous incentives to promote local economic development, and they have more powerful jurisdiction than environmental protection apparatus, it is very likely that they would intervene local EPBs' work when preference conflicts are involved in decision-making process [10]. Andrews discussed this kind of "intrinsic hazards of governance processes" as "government decisions are routinely designed to promote the short-term self-interests of public officials, perhaps at the price of long-run environmental damage," and "governments tend to externalize the environmental costs of their decisions" [15]. Not surprisingly, these shortcomings of government behaviors are responsible for China's environmental deterioration in the past despite of the extensive efforts to address the issues.

2.2.2.3. Revenue-driven environmental regulators

Not only the governmental agencies other than environmental regulators can unfavorably affect the implementation of policies targeting pollution control, but also the environmental regulators (in most cases local EPBs) themselves would favor some other preferences over environmental goals. In practice, this damages the effectiveness of environmental policies. EPBs may act as self-interested politicians whose decisions can lead to environmental costs to the society. With regard to China's national pollution levy program, examples include that the regulators simply collect fees to maximize their own revenues, irrespective of the ultimate purpose of pollution abatement; they may act inconsistently with the laws, or strategically to their own preferences. Public choice theory argues that politicians, just like people who act in the free market, are motivated by self-interest. Using public choice theory, Schneider and Volkert argued that an incentive-oriented environmental policy has hardly any chance of being implemented, and pure environmental interest groups are difficult to organize [17].

Under China's pollution levy system, local EPBs are supposed to respond to violations of environmental rules through several enforcement options including issuing warnings, imposing fees, revoking emission permits (which are issued to each industrial facilities under the pollution levy system), and gaining court assistance to collect fees, in the order from the least to the most severe degrees in terms of EPBs' enforcement actions [10]. Although as mentioned before, the primary purpose of pollution levy is to provide incentives to industrial pollutants to mitigate their emissions, and a supplementary intension is to fund local environment bureaus. However, in many cases, the latter has become regulators' essential goal. Ma and Ortolano, through their case studies in six large industrial cities, concluded that what EPB actually did were often different from what they were authorized to do [10]. For instance, in some cases they imposed heavy penalties, and in others they helped enterprises resolve their noncompliance problems and imposed no sanctions at all, and usually the decisions were made for their own benefits. Examples include calculating the pollution discharge fees not based on what is set by

laws, but on the criteria to maximize their own revenues. Not surprisingly, due to regulators' rent-seeking behaviors, the pollution levy system works less effective than expected in terms of emission control.

The transit from planned to market economy had substantial influence on China's air quality, and policy designs and implementation to control air pollution as well. One issue of concern has been the impacts of China's state-owned enterprise (SOEs) on the environment upon their changes resulting from China's economic reform. For instance, upon the reform, SOEs had become increasingly depended on bank loans and retained profits to finance investment other than on government funds as previous [10]. It resulted in disincentives for SOEs to invest on environmental projects, since these projects had to compete for capital against factory renovation and expansion projects [10]. Furthermore, since late 1980s, the fraction of SOEs incurring net losses had increased rapidly: For example, the percentages of industrial SOEs losing money rose from 13% in 1986 to 44% in 1995 [18]. Money-losing SOEs pose serious environmental concerns. Local EPBs tended to avoid requiring these enterprises to satisfy environmental requirements because the money to pay for environmental facilities would generally have to come from the state. Moreover, local government leaders would be unlikely to support an EPB that imposed demand on a money-losing SOE supporting large numbers of workers or retirees [10].

However, on the other hand, China's rapid economic growth, particularly since 1990s, also has positive impacts on air quality. Although economic growth has increased the variety and magnitude of emission-generating activities, which result in more emissions, it also generates the wealth needed to build a stronger infrastructure for environmental management of industry [4]. Likewise, in the household sector, economic growth has helped households move up the energy ladder, replacing dirty fuels with cleaner ones [4]. With respect to SOEs, the bankruptcies and mergers resulting from the on-going program of SOE reform since 1990s have shut down many old industrial facilities that were large, inefficient consumers of energy (mainly coal, China's most important fuel) [19], which implies a significant contribution to the decrease of emissions from these sections [4].

In the preceding discussion, several factors were examined that have resulted in significant gap between the goals and effects of China's pollution levy system. While they are still far away from indicating all the reasons attributable to ineffectiveness of the system, they do shed light on some government failure problems and institutional barriers common in China's environmental regulation during the decades of 1980s and 1990s. Jin et al. summarized four major limitations of air pollution control policies during that early time period as follows: (1) the general absence of environmental rights and interests; (2) lack of regional co-ordination in air quality management; (3) lack of monitoring capacity; and (4) weak laws and regulations [11].

2.3. New air pollution concerns and some major changes in control policies since 2000s

2.3.1. A brief overview of the air quality trend in China's major cities over the past two decades

Since the 1990s, China has seen some improvement in ambient air quality in major cities, particularly the levels of SO_2. **Figure 1**, adopted from [11], summarizes the annual average levels of SO_2, PM_{10}, and NO_2 in China's seven megacities between 1996 and 2014. Although the levels

of SO_2 have been improved, the concentrations of two air pollutants of the greatest health impacts, that is, $PM_{2.5}$ [20] and ground-level ozone [21], have been worsened in recent years.

2.3.2. Some major changes in control policies since 2000s[7]

This section briefly summarizes some major changes in China's air pollution control policies since the beginning of the twenty-first century.

1. Air pollution regulation executed more stringent emission standards for coal-fired boilers and power plants, and motor vehicles, and the NAAQSs (**Table A1** in the Appendix). The emission and air quality standards in China were initially established early between 1980s and 1990s, and since then has been significantly revised several times and tightened over time, particularly after the "$PM_{2.5}$ crisis" that happened between 2012 and 2013 [11]. These standards are generally in line with international ones, and some of them (for instance, emission standards for power plants) are even more stringent than those used by western developed countries such as the USA [11]. Example of specific policy measures include use of low-sulfur and low-ash coal or more advanced pollution control equipment, installation of central heating to replace individual coal boilers, banning the use of coal stoves for cooking in urban areas, shutdown or relocation of coal-fired power plants in urban areas, restricting vehicle purchase and use, enhancing public transportation system, and regulating dust from construction sites.

2. Mass-based emission control took the place of concentration-based control. Concentration-based emissions standards have the disadvantage that emission standards can be met by diluting the waste gas stream with air, rather than by reducing the mass of pollutant discharged [4]. During 2006–2012, China implemented the "total emission control on SO_2" and an "energy saving" policy: A 10% reduction in SO_2 and a 20% reduction in energy consumption per unit of GDP from the 2005 levels were set as the national targets [11]. These targets were decomposed among provinces and local governments were required to fulfill the "assigned" target. The 10% SO_2 reduction goal was achieved [11].

3. Stronger political will to prevent pollution, instead of generating pollution and then treating it. Based upon previous experiences and research, the central government has realized that the costs to the entire society could be much higher to use the so-called end-of-pipe strategy than to prevent emissions. The 2014 government work report stated that "China shall punch hard to strengthen the prevention and control of pollution, and resolutely declare war against pollution" [11].

4. Market-based instruments started to be utilized in air pollution control. Market-based environmental policies are generally considered by economists to have the advantages over traditional command-and-control approaches in terms of cost-effectiveness and dynamic incentives for technology innovation and diffusion [22]. In early 2000s, China learned market-based tools for air quality regulation from western developed countries, and began to

[7]This section was heavily informed by [11].

http://dx.doi.org/10.5772/intechopen.74928

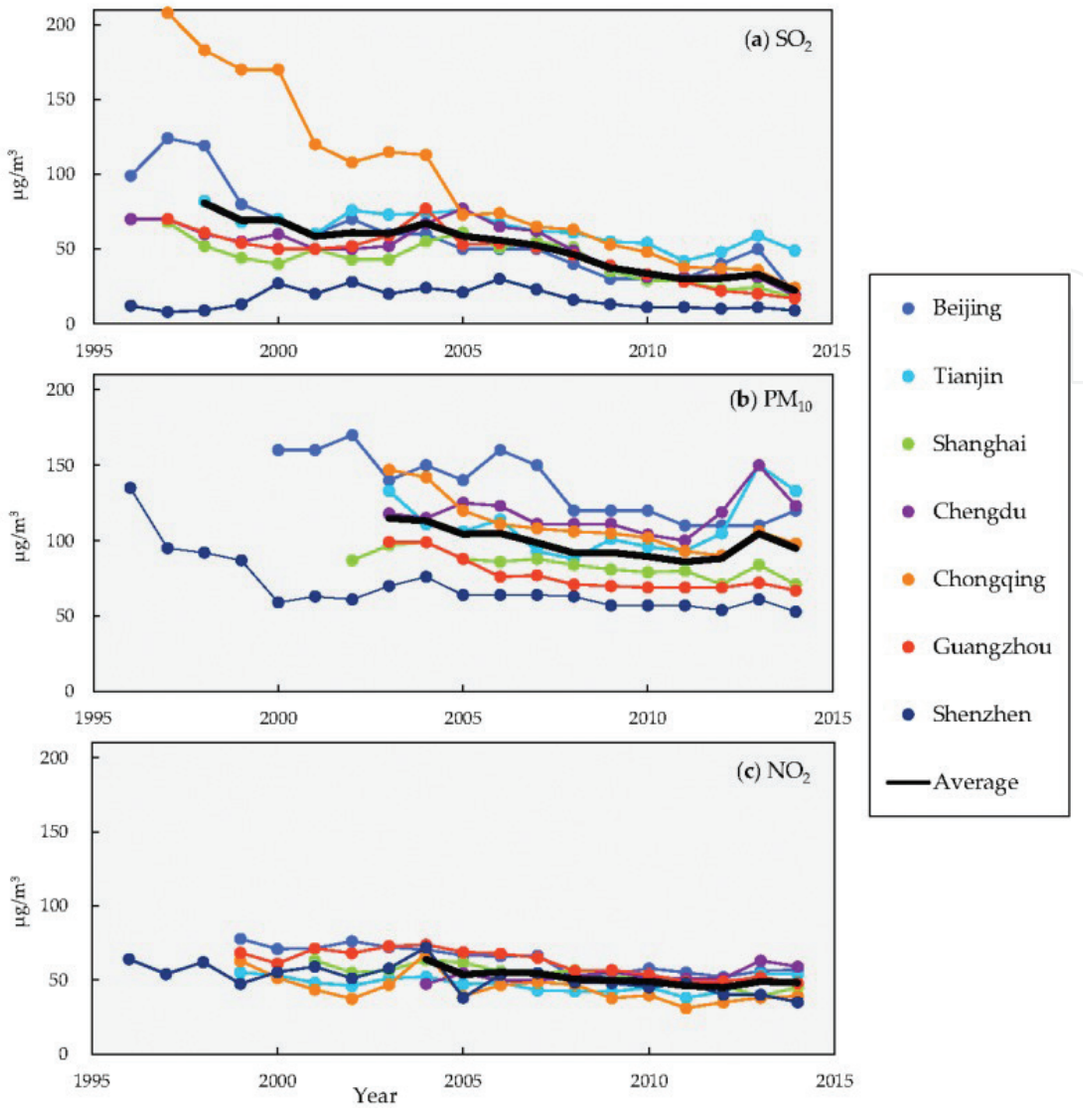


Figure 1. Trends of SO_2 (a); PM_{10} (b), and NO_2 (c) annual concentrations of seven China megacities in 1996–2014 (adopted from [11]).

experiment and demonstrate these policy tools through pilot projects. Examples include tradable pollutant permits that are currently being tested in pilot provinces and cities [11]. Florig et al. argued that some of China's emission standards do not consider source-to-source variations in the unit costs of emission abatement, and thus impose higher compliance costs on some polluters than others for the same amount of abatement [4]. Therefore, emission trading program seems to be promising in terms of reducing abatement costs. Experiences in the USA illustrate that the emissions trading program, which created a nationwide market for emissions reductions, has resulted in greater reductions in SO_2 emissions at much lower cost than would have been required under the technology-based approach of the past [23]. However, due to China's distinct political and institutional system, and immature development of market economy, as well as a strong tradition of

command-and-control environmental regulation, the success of emissions trading system requires new administrative departments to be set up and the actual effect is still rather uncertain [11]. Beside the trading program, a carbon tax policy is under consideration by the government.

5. Increasing public participation and civil society's role in combating air pollution. Chinese citizens, particularly urban residence demand better air quality as the income increase and living standard improvement [11]. Real-time air quality monitoring data have become more available to the general public, particularly in the most polluted megacities. Some data on emission sources and penalties on polluters have also been disclosed to the public [11].

Despite of the major reforms of regulations, air quality improvements remain insignificant in most cases. Jin et al. discussed some reasons for policy ineffectiveness: emission data reported by local government were unreliable; failure of inter-regional cooperation in abatement efforts (regional transboundary pollution issue); "campaign style" regulations that temporarily occur during some major international events such as the 2008 Olympics in Beijing—the effects of those temporary regulations diminished after the event; lastly, some argued that the current total control measures should be completely revoked [11].

2.3.3. Changes in energy system in response to air pollution

Coal is the primary energy source in China due to it abundance and has been the largest contributor to air pollution in China's history. Over the past three decades, coal has been accounted for approximately two-thirds of China's primary energy consumption [24]. In contrast, in the US coal accounts for less than 20% of the nation's energy production[8]. Despite the decrease in the percentage share of coal in China's total energy consumption since the 1950s, the total consumption of coal has been rising dramatically due to the soaring demands [25]. For instance, the total consumption was 1.5 billion tons in 2000 and rose to 3.8 billion tons in 2011[9]. Natural gas consumption generates much less pollution than coal and thus it is often regarded as a cleaner energy [24]. Natural gas currently accounts for about 6% of China's primary energy supply, which is considerably lower than the global average of 24% [24]. In response to the severe ambient air pollution problem, the Chinese government has listed the switch from coal to gas as a key part of China's sustainable energy system transformation strategy [24]. The switch from coal to natural gas in power plants, particularly over winter as part of the efforts to cut concentrations of $PM_{2.5}$ that causes smog, was first implemented in the capital city Beijing, and quickly adopted by other provinces [11]. However, many provinces suspected or canceled the "coal to gas" initiative soon mainly due to natural gas shortages and soaring heating cost in China [11]. For instance, in early December 2017, the Beijing city government ordered an immediate restart to coal-fueled generators to ease the shortage of natural gas in northern China, which had caused numerous freezing homes and schools[10]. Despite the challenges facing China, it is

[8]Data in 2016. Sources: U.S. Energy Information Administration, https://www.eia.gov/energyexplained/?page=us_energy_home. Accessed January 23, 2018.
[9]Data source: U.S. Energy Information Administration, https://www.eia.gov/todayinenergy/detail.php?id=9751. Accessed January 23, 2018.
[10]Source: China Daily Online, http://en.people.cn/n3/2017/1211/c90000-9302785.html. Accessed January 23, 2018.

expected that China's move away from coal to cleaner energy sources will happen quickly in the near future. In December 2017, China released the nation's five-year plan (2017–2021) to convert northern Chinese cities to clean heating during the winter [26]. The plan sets the goal of converting half of northern China to clean heating (mainly natural gas and electricity heating) and reducing coal burning by 74 million tons by 2019 [26]. By the end of the five-year period in 2021, the goal is to achieve 70% cleaning heating and reduce coal burning by 150 million tons [26]. Overall, as part of China's national strategies to control the impacts of energy system on air quality, a national campaign to replace traditional, dirty coal with cleaner energy sources is under way, but it is likely to encounter many challenges. The government needs to develop strategies to ensure energy supply without boosting prices and hurting the economy.

3. Comparing air pollution control policies in China and in the USA[11]

China, in particular in the past two decades, learned a lot of policy tools from western industrialized countries such as the USA, which are considered to be more advanced in policy designs and implementations, and which in general has a much better air quality thus implying more successful in curbing air pollution. However, as mentioned before, policies work well in developed countries may fail in a developing country such as China, due to the differences of political and institutional systems, situations of economic development as well as many other social and cultural factors. Compared to the USA, China has a much more concentrated population, resulting in a much greater demand for energy consumption to survive its residents, which perhaps makes the air quality regulation issue even more complicated.

3.1. Centralization and decentralization of air pollution regulation

Regarding the historical path, China responded to air pollution almost a decade behind the USA. For instance, as mentioned in the previous section, China's first formal air pollution control project was initiated after a conference on stack dust removal held in 1972, whereas the very first air pollution statutes in the USA, designed to control smoke and soot from furnaces and locomotives, were passed by the cities of Chicago and Cincinnati in 1881 [23]. This is not surprising due to China's slowness in industrialization (started in 1950s but only began to develop rapidly after the 1979's economic reform) compared to the USA's early industrial revolution. One significant difference between China and the USA with regard to the features of the evolution of environmental governance particularly the air and water pollution issues perhaps is, that they followed an opposite path on the centralization and decentralization of pollution control. In the USA, the states, cities, and countries' governments first reacted to pollution problems by enacting their own ordinances targeting pollution control. Examples include the first air pollution statutes by Chicago

[11]The information about the US draws heavily on [23].

and Cincinnati governments and increasingly air pollution laws by other states, cities, and counties. By 1980, there were already 50 state, 81 municipal, and 142 county air pollution control jurisdictions with statutes in the USA [23]. The US federal government entered the control efforts for the first time with the passage of the Air Pollution Control Act in 1955 [23]. Until the 1970, the federal role in environmental protection had been greatly enlarged, indicated by federal minimum standards and regulations as primary policy tools [15]. In China, on the contrary, the central government first responded to the issue by promulgating national level environmental laws, regulations, and programs, and then instructing the local government (province, municipal, county, etc.) to be responsible for the implementation of them, or to outline their own measures in response to the regulations. This difference between China and the USA is heavily rooted in the USA's federalism political system and China's traditional centralized governmental system. While the decentralized regulations may involve problems such as conflicts, debates, negotiations between federal and local government, China's major problem in the past seemed to be the compliance by local regulators to the national statutes. In very recent years, following China's political reform, which is characterized by the trend of governance system decentralization in particular regarding economic development issue, the environmental governance has also indicated some evidence of decentralized regulations. This trend is expected to gradually become more apparent, but the change may be slow.

3.2. Some features of the basic air pollution control law

Regarding the national air pollution control law (For China, Air Pollution Prevention and Control Law and for the USA, the Clean Air Act first passed in 1963 and followed by the 1970 amendments), there are a couple of similarities. For example, both laws provides support from central government for air pollution research, and for the development of local pollution control agencies; both laws' initial focus was industrial and residential sources of air pollution, and later the regulation of emissions from mobile sources was added together with vehicle emissions standards, when the problem became more apparent (an exception in the USA was the state of California, who took on the air quality problems associated with motor vehicle exhausts when it first passed its air pollution ordinances [23]). Technological innovations and the adoption of "best available technology" are strongly encouraged in under both laws. Both countries' laws execute so-called new source performance standards, that is, newly constructed (or substantially modified) plants are subject to stricter emissions standards than currently existing factories. In the USA, "federal controls on new sources, but state controls on existing sources" [23]. On the other hand, Florig et al. argued that China's grandfather rules (similar to the USA policy toward existing factories) may have the unintended consequence of extending the time that older facilities are kept in service, to avoid having to incur the additional operating costs or pollution levy fees associated with a new replacement facility with more stringent emissions requirements, and the more stringent emissions requirements for use of more advanced pollution control technologies provides a disincentive to adopt these measures [4]. One distinct feature of the US law that is not seen in China's law is that the US Clean Air Act addressed the federal government's assistance to the states when cross-boundary air pollution problems arose [23]. Although China's national

control law is silent about cross-boundary air pollution issue, this problem might still rise in practice, because despite of China's strong tradition of "centralized regulation," the actual day-to-day implementations of laws are authorized to local governments.

3.3. National ambient air quality standards and emission performance standards

Both China and the USA have national level ambient air quality standards. **Tables A1** and **A2** in the Appendix list both countries' NAAQSs. **Tables A1** and **A2** illustrate that both countries focus on the six common (or criteria) air pollutants in regulation. While the USA has been using primary standards for human health and secondary standards for the environment (primary and secondary standards are the same in most cases except for SO_2 and the annual standard for $PM_{2.5}$), historically China had been using three categories of standards that applied to different types of land. The latest one (GB3095–2012, see **Table A1**) revoked the Grade III standard. Although the complexity of China's NAAQSs allowed more flexibility in regulation based on the demand for air quality or variations of costs to control at different types of regions, it may involve more debates, dispute, negotiations, or even conflicts in determining which standard to apply, resulting in more difficulties in regulations. Comparably, the US 1977 amendments also established three classes of "already clean" areas: in Class I areas (which include national parks, forests, and wilderness areas, and other areas that states elect to include), very little additional deterioration in air quality is permitted, even if current concentrations are far below the NAAQSs; somewhat more pollution is permitted in Class II areas (which make up most of the remaining clean air regions); in Class III areas, air quality is permitted to deteriorate up to but not beyond the level of the NAAQSs [23]. Generally, China's Grade II standards (which applies to regular living areas) is comparable to the USA's primary standards. Taking $PM_{2.5}$ as an example, China recently started the nation's $PM_{2.5}$ standard in 2016. China's Grade II $PM_{2.5}$ annual average standard is 35 $\mu g/m^3$, which is less stringent than the USA primary standard of 15 $\mu g/m^3$. At present, it may not be economically and politically feasible for China to adopt the standards as stringent as those used in the USA, due to the possible high costs resulting from emission reduction. Nevertheless, a ubiquitous problem in China is nonattainment. For example, a review of $PM_{2.5}$ concentration in major Chinese cities during 2005–2016 reported that nearly 90% of the pollution levels exceeded the annual limit of 35 $\mu g/m^3$ [20].

4. Conclusion remarks

Due to the severity of China's air pollution issue, the nation's economic growth may have been offset by the economic loss due to adverse health impacts and environment damages attributable to air pollution. As stated in Rock "the human health costs of environmental degradation and growing spontaneous public pressure have made it increasingly difficult for all levels of Chinese government to ignore the environmental degradation attending high-speed urban-industrial growth" [24]. The government is currently confronted with an onerous challenge to better design and implement policies to clean the ambient environment.

This chapter reviews the development of air quality policies since 1950s in China's political and economic development context, focusing on the period since China's reform of the economic system in 1979. Over time, environmental policy designs and implementations were rooted in China's broad institutional development, agenda settings and policy processes, and today's policies have been strongly shaped or influenced by past policies. It was found that both China's central government and the local EPBs had a strong will to clean the environment and had been seriously addressing this issue since the initiation of China's national environmental regulation in late 1970s. However, they had experienced great difficulty in enforcing emissions standards not only on individual pollutants, but also on the industrial bureaus that control them, and the economic commissions and mayors that depend on them to deliver income and employment [27]. As the daunting result, there had been a huge gap between the set goals and the actual outcomes. With regard to environmental governance, Rock argued "the focus in China is how a nascent environmental agency learned how to take advantage of the rules of economic governance to influence powerful economic actors" [24]. As for policy design and implementation, China has to significantly strengthen government's interests at all levels in environmental objectives.

Since China still needs to substantially balance the costs of pollution reduction, market-based policies seem to be very promising as China's market economy becomes more mature. While market-based policy instruments such as the cap-and-trade system have been arguably successful in the USA in term of emission reduction and cost-effectiveness, their actual effects in China are still uncertain. China should definitely learn the experience established in developed nations, but may not simply follow their practice. The uniqueness and distinctiveness of China's political and institutional characteristics requires it to be very prudent when referring to policies developed in other countries.

A common problem in China's past environmental policy designs is, arguably, policy and regulations may be not politically or economically feasible or enforceable, and the goals are sometimes unrealistic. China's future environmental policy designs should systematically and thoroughly evaluate the feasibility through comprehensive policy analyses, and address the effectiveness issue, and dynamically adjust policies based on evaluation of past effects and problems.

By and large, China, in the stage of rapid industrialization and urbanization, is now facing an arduous challenge to tackle its air pollution problem: For instance, requiring the use of "clean" energy would result in a fundamental change in China's energy consumption structure, whereas China's energy shortage problem, particularly shortages of cleaner fuels such as natural gas, is still a substantial issue; emission control of transportation system may dauntingly conflict with the rapidly increasing demand for automobiles; and changes in urban infrastructure for better emission control would impose an enormous costs on cities. However, huge health and environmental damage attributable to air pollution has made regulation targeting pollution abatement imperative. Therefore, China has to seriously balance its interests on economic growth with the risk of inexorable increase in the damage to human health and environment in the

development of future economic and energy policies. Revolutionary change is very likely and air quality management based on health risk is primary direction [11]. In this regard, the government is incumbent on developing a wiser course that protects the environment in order to improve the welfare of its citizens and ensure a sustainable development.

Acknowledgements

We would like to sincerely thank Dr Richard Andrews, Professor Emeritus of Environmental Policy in the Department of Public Policy, University of North Carolina at Chapel Hill, United States, for his inspiration of this research, and his insightful comments on an early version of this chapter.

A. Appendix

See **Tables A1** and **A2.**

Year	No. of standard	Grade[2]	SO_2	TSP	NO_2	CO[3]	O_3[4]	PM_{10}	$PM_{2.5}$[5]
1982	GB3095–82	I	50	150	50	100	120	50	—
		II	150	300	100	100	160	150	—
		III	250	500	150	200	200	250	—
1996	GB3095–1996	I	20	80	40	100	120	40	—
		II	60	200	40	100	160	100	—
		III	100	300	80	200	200	150	—
2000	Amended GB3095–1996	I	20	80	40	100	160	40	—
		II	60	200	80	100	200	100	—
		III	100	300	80	200	200	150	—
2016	GB3095–2012	I	20	80	40	100	160	40	15
		II	60	200	40	100	200	70	35

[1]Unless specified, all standards are in the unit of μg/m^3, 24-h average.
[2]Grade I standard applies to places like national park or forests, where stricter requirements for air quality are needed; Grade II applies to usual urban industrial, residential and commercial areas and rural areas; Grade III applies to heavy or special industrial areas.
[3]CO: mg/m^3, 1 h average.
[4]O_3: μg/m^3, 1 h average.
[5]$PM_{2.5}$: μg/m^3, annual average.

Table A1. National Ambient Air Quality Standards[1] (NAAQSs) table, China (adopted from Jin et al. [11]).

Pollutant	Primary standards	Averaging times	Secondary standards
Carbon monoxide (CO)	9 ppm	8 h	None
	35 ppm	1 h	None
Lead (Pb)	0.15 μg/m^3	Rolling 3 month average	Same as primary
Nitrogen dioxide (NO_2)	100 ppb	1 h	None
	53 ppb	1 year	Same as Primary
Ozone (O_3)	0.070 ppm	8 h	Same as Primary
Particulate matter ($PM_{2.5}$)	12.0 μg/m^3	1 year	15.0 μg/m^3
	35 μg/m^3	24 h	Same as primary
Particulate matter (PM_{10})	150 μg/m^3	24-h	Same as primary
Sulfur dioxide (SO_2)	75 ppb	1 h	
		3 h	0.5 ppm

*Source: the USEPA official website: https://www.epa.gov/criteria-air-pollutants/naaqs-table, [Accessed December 8, 2017].
Note: *Primary standards* set limits to protect public health, including the health of "sensitive" populations such as asthmatics, children, and the elderly. *Secondary standards* set limits to protect public welfare, including protection against decreased visibility, damage to animals, crops, vegetation, and buildings.

Table A2. National Ambient Air Quality Standards (NAAQSs) table, United States*.

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