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China's Air Pollution Policy Evolution: Effectiveness, Governance Philosophy and Future Outlook — A Literature Review

Kaichen Zhang[1*†], Qinyi Luo[2†], Zhinan Wang[3†]

[1]The Ohio State University, Columbus, USA
[2]Olive Tree International Academy, Hangzhou, China
[3]Suffield Academy, Suffield, USA
**Corresponding Author. Email: Ryliez147@gmail.com*
[†]These authors contributed equally to this work and should be considered co-first authors.

Abstract: China's industrialization and rapid economic growth have led to severe air pollution, with significant impacts on public health and the economy. In response to these challenges, the Chinese government has adopted traditional top-down control policies. Over time, however, these policies have gradually demonstrated a limitation, which has led to a shift in national policy toward a more innovative bottom-up approach. The purpose of this paper is to review the effects and impacts of two important policies, the Air Pollution Prevention and Control Action Plan and the Dual Carbon Goal. By reviewing the relevant key literature, this study seeks to understand the shift from top-down policies to a more balanced governance model and how this will affect the future of air pollution governance in China. The analysis shows that top-down policies are only effective in the initial stages of pollution governance, but their lack of flexibility leads to implementation challenges at the local level. In contrast, bottom-up approaches, such as those used in China's low-carbon pilot cities, hold great promise for addressing region-specific needs and driving sustainable change. The paper concludes that China has developed a balanced approach to air pollution management that combines top-down and bottom-up elements. However, challenges remain, and future policy recommendations include further strengthening local innovation and public participation to achieve long-term improvements in air quality.

Keywords: Air Pollution, China, Control Action Plan, Dual Carbon Goals, Governance Philosophy

1. Introduction

Since China's industrialization and economic growth in recent decades primarily rely on fossil fuels, environmental pollution, especially the air pollution issue, has become more serious. The impact of air pollution on public health in China is significant. The average resident in China was exposed to a $PM_{2.5}$ concentration of 52.4 μg/m³, which corresponds to a decline in life expectancy by 4.6 years [1]. In areas with severe pollution, such as the Beijing-Tianjin-Hebei (BTH) region, extreme pollution incidents and environmental emergencies have triggered public health crises, leading to social instability. To address these concerns, the Chinese government has adopted a series of air pollution

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control policies and initiatives to promote sustainable development and reduce its industrial sector's environmental footprints. Among the recent year policies, the relatively early policy tends to emphasize the traditional top-down dominant approach. However, as the local air pollution issue intensified, the government has begun to explore the combination of top-down and more innovative and diverse approaches for better governance, for instance, experimenting with more bottom-up approaches and assisting with market-based tools. This is a sign of change in the philosophy of environmental governance in China. These policies have a significant and profound impact on the economies of China. Among all reviews focused on air pollution governance models, Part of the articles are analyzed from a single perspective of Top-down or Bottom-up, which may not be comprehensive enough. There are also reviews of air pollution governance based on Timeline. However, the analysis of each policy may be relatively limited, and thus a deeper understanding of the policy cannot be reached. In this paper, the authors discussed the effectiveness of the Air Pollution Prevention and Control Action Plan (2013) (APPCAP) and the Dual Carbon Goals (2020) (DCG) by reviewing the relevant literature over the past few years, analyzing the changes in China's concept of air pollution governance philosophy, and presenting a possible strategy for the future development on China's air quality governance.

2. Literature review

2.1. Top-down dominant approach: Air Pollution Prevention and Control Action Plan (2013) (APPCAP)

2.1.1. Air Pollution Prevention and Control Action Plan (2013)

In 2013, the state council released the Air Pollution Prevention and Control Action Plan(APPCAP), including goals to be achieved by 2017 [2]. 1) For cities at the prefecture level and above, reduce the concentration level of PM10 by 10% compared to 2012 levels. 2) Concentrations of PM2.5 In the Beijing-Tianjin-Hebei (BTH), Pearl River Delta (PRD), and Yangtze River Delta (YRD) should be reduced by 25 percent, 20 percent, and 15 percent, respectively. 3) Beijing's annual average PM2.5 concentrations should maintain 60 $\mu g/m^3$.

The APPCAP was the first air quality improvement plan in China, marking the strategic transition from reducing emissions of specific pollutants to comprehensive air quality improvement. Jin et al. [3] point out that, As PM2.5 pollution became more severe in 2013, air pollution policies in China changed significantly, including more multifaceted approaches. Lu et al., [4] also suggest that Control actions targeting multiple sectors have aimed to reduce PM2.5 concentrations since 2013. Increased ozone (O3) pollution requires a further integrated control strategy for O3 and PM2.5.

2.1.2. Vertical accountability in APPCAP: Top-Down dominant approach

The direct representation of the Top-Down governance model in APPCAP is vertical accountability. The idea is to ensure the effective implementation of policies through monitoring and feedback between hierarchical levels. It positively influences the governance effectiveness of the policy to a certain extent. Zeng et al. [5] suggest that the concentrations of major air pollutants of SO_2, NOx , PM2.5 and PM10 showed a decreasing trend in most parts of China. This significant emission reductions outcome is mainly due to robust administrative power, especially when emission reductions were tied to the performance evaluations and promotion of government officials. Vertical management structures in environmental governance can also be effective in enhancing incentives and coordination [6].

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2.1.3. Air Pollution Prevention and Control Action Plan: effectiveness and influence

Many scholars have discussed on effectiveness and influence of APPCAP from different views, including environment, health, and economies. Huang et al. [7] analyzed both the environmental and health impacts of APPCAP on air quality management by utilizing national air quality monitoring and mortality data from 74 key cities in China. Huang et al. [7] found that from 2013 to 2017, the annual average concentrations of PM2.5 in these cities decreased by 33.3%, PM10 decreased by 27.8%, sulfur dioxide decreased by 54.1%, and carbon monoxide decreased by 28.2%. However, the annual average concentration of nitrogen dioxide decreased by only 9.7%. The ozone concentration increased by 20.4%. In terms of health impacts, the significant improvement in air quality resulted in 47,240 fewer deaths and 710,020 fewer years of life lost (YLL) in 2017 compared to 2013. Huang et al. [7] conclude that APPCAP showed remarkable effectiveness in reducing mortality and life years loss related to air pollution, while future emission controls for ozone and nitrogen dioxide still need to be strengthened.

Furthermore, special attention has been paid to the BTH area due to severe air pollution conditions compared to the overall situation in China. As shown in Figure 1, Cai et al. [8] developed emission inventories for two different future scenarios starting from 2012 up to 2017 and 2020. based on APPCAP. The results of the study show that there will be a decrease in the emissions of sulfur dioxide (SO2), nitrogen oxides (NOX), PM2.5, non-methane volatile organic compound (NMVOC), and ammonia (NH3) in 2017 by36%, 31%, 30%,12%, and − 10% from the 2012 levels in BTH region, respectively. In 2020, the emissions of SO2, NOX, PM2.5, NMVOC, and NH3 will decrease by 40%, 44%, 40%, 22%, and − 3% compared to 2012 levels in BTH, respectively. The annual PM2.5 concentration for 2017 and 2020 will be 28.3% and 37.8% lower than PM2.5 concentration levels in 2012, respectively.

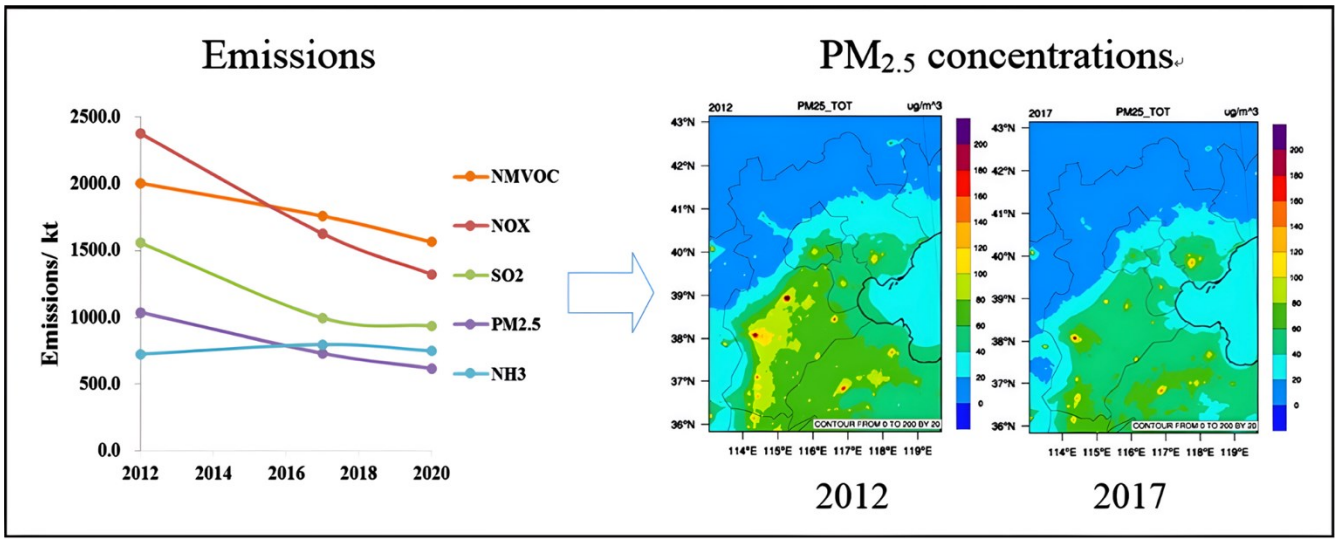

Figure 1: Emission inventories and PM2.5 concentration [8]

Wang et al. [9] used a different kind of approach and developed a quantitative analysis of air quality management in the Beijing-Tianjin-Hebei (BTH) region. Semi-structured expert interviews were also conducted with 12 stakeholders from different levels of government and research institutions who played vital roles in decision-making on air pollution control for the BTH region. The results show that air quality in the BTH region meets the objectives of the APPCAP under such strict air pollution control policies. Another scholar, Maji et al. [10], pointed out that as a result of APPCAP, PM2.5, PM10, NO2, SO2, and CO concentrations have significantly reduced by 7.4, 8.1,

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2.4, 1.9, and 80 μg/m^3/year respectively from 2014 to 2018. However, O_3 concentration increased by 1.3 μg/m^3/year. In terms of district-specific pollution (PM2.5 and O3) attributed mortality, PM2.5 and O3 were responsible for 29,270 and 3,030 deaths in 2014, respectively, but in 2018, the death rates for these emissions were reduced by 5.6 percent and 18.5 percent, respectively.

The Cost-Benefit Analysis for APPCAP confirms that the policy is economically effective. The health and economic benefits of improved air quality significantly exceed the cost of implementing the policy. Gao et al. [11] conducted a cost-benefit analysis on implementing policies in the Air Pollution Prevention and Control Action Plan in 31 provinces between 2013 and 2017. The results show that the total costs and benefits are 118.39 billion yuan and 748.15 billion yuan, with a benefit-cost ratio of 6.32, Indicating these policies are cost-effective in all scenarios. Gao et al. [11] also found that GDP and population were significantly correlated with the benefit-cost ratios. Sensitivity analyses suggest that the benefit-cost ratio is more sensitive to unit abatement cost, unit subsidy, GDP growth rate, and discount rate. Moreover, the success of APPCAP in economies is also reflected in the associated index. Yang et al. [12] developed a super-SBM model to measure the SERE of different cities. SERE refers to the extent to which the production process of a city reaches the overall frontier of all samples in this study. Capital, labor, and energy are selected as input indicators. GDP is chosen as the expected output indicator. The result shows that when a series of policies have been implemented in China, such as the revised APPCAP, specifying the need to strengthen the synergistic control of carbon and air pollutant emissions at the policy level. The SERE is growing rapidly, with an increase of 7.34% from 2013 to 2017, and reached the highest level in 2017.

2.2. Bottom-up dominant approach: Dual Carbon Goals (2020) (DCG)

2.2.1. China's Dual Carbon Goals: strategic framework and policy implementation

In 2019, the global total energy consumption emitted approximately 33 billion tons of carbon dioxide. In contrast, China is responsible for 9,869 million tons of total, representing over 28% of the total [13]. This has led China to recognize the necessity and urgency of implementing more effective policies to govern air pollution. A rising number of countries, including the United States and Japan, to solve the problems of excessive carbon emission, have developed policies and targets in the comprehensive areas. These policies contain many measures, such as green financing [14]. At the 75th United Nations General Assembly in 2020, China proposed the "Dual Carbon Goals" (DCG) officially, announcing the objectives that achieve a carbon peak by 2030 and carbon neutralization by 2060.

Generally, China will adopt the concept called "1+N" in "Dual Carbon Goals". "1" is the major policies the China central government published. Likewise, it is the constructive and dominating orientation of all actions in the future to abide by and enforce, and these policies from the central government will be the basis of implementing policies for local government. "N" could be divided into three proportions, encompassing the intensive fields, intensive industries, and support guarantees [15]. With regard to the intensive fields, the government would assign tasks and designate specific actions, with a particular focus on heavy industry, urban and rural construction, transportation, agriculture, and so on. Focusing on intensive industries, the central objective is the reduction of carbon emissions and making distinctive strategies for different industries. For supporting guarantees, the government would implement regulations in select areas, such as finance and innovative technology, to facilitate the "Dual Carbon Goals" initiative [16]

2.2.2. Low-carbon pilot cities: a bottom-up approach to achieving dual carbon goals

The concept of low-carbon pilot cities was first proposed in 2010. China has conducted 81 national low-carbon city pilots in three phases during 2010-2024. However, with the initiative of the "Dual

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Carbon Goals" in 2020, carbon peaking and carbon neutralization have become systematic and strategic endeavors. Therefore, this hat the designation of low-carbon pilot cities is becoming much more significant. [17]

Compared with other typical Chinese policymaking models, low-carbon pilot cities represent a "bottom-up" approach. This strategy allows pilot local governments to examine the policy before implementation by the central government independently. It provides these governments with greater autonomy in policy development and facilitates the utilization of more innovative policy tools. Once the attainment of certain success, the central government will integrate these policies into "Dual Carbon Goals", thereby consolidating the program's overall effectiveness [18].

2.2.3. Evaluating the impact and limitations of low-carbon pilot cities in China

The policy of low-carbon pilot cities has a number of implications for China. It is undoubtful that the policy has yielded considerable benefits. From an environmental standpoint, the Xiamen government has implemented measures to enhance solid waste management and optimize the water system, resulting in a notable reduction in the carbon intensity of solid waste [19]. The Beijing government has succeeded in curbing greenhouse gas emissions by improving transportation [20]. Overall, after adopting the low-carbon pilot cities policy, the carbon emission of the pilot city is 0.13% less than non-pilot cities and plays a leading role for nearby cities. [21]. From an economic perspective, the low-carbon pilot cities strategy has not only improved the energy mix to accelerate technological advancement in industrial sectors [22] but has also solved the dilemma of the economy in some regions [23]. From 2017-2022, the growth rate of the average annual GDP in pilot cities is 5.8%.

Nevertheless, the current policies are constrained by several limitations. Firstly, the innovative policies proposed by various local governments have proven ineffective. Song's study pays attention to the innovative and distinctive policies based on the country-level policies in 36 cities. However, there are only one-third of the original policies are actually available or efficient, which means that most of these city-level policies are not suitable or applied for real life. Secondly, successful local policies are not universally applicable to the whole country. The central policies from the central government have boundedness, including the diverse natural conditions, population, education level, competing officials' mechanism, etc. [18]. Furthermore, this policy exhibits economies of scale, with larger cities growing faster than smaller developments. This can exacerbate economic inequality [24]. With regard to the method of implementing policies, the policy instruments in the low-carbon pilot cities continue to privilege administrative measures over tax measures, and market-based policies remain underrepresented. For individuals, these market-based instruments are more conducive to encouraging people to adopt low-carbon lifestyles [25]. For companies, If the government can implement more market-based policies, such as environmental tax and green finance system, it will be efficient for firms to promote innovative technologies, finding a better method to balance the environment and economy [26].

2.3. China’s diverse governance: a combination of top-down and bottom-up

Externalities arise in the economic activities of industrial production and development. Air pollution is one of these negative externalities. This kind of externality is beyond the scope of market transactions and does not appear to react and compensate through the price mechanism. Thus, the operation mechanism of the market is not able to solve the air pollution issue. Therefore, it is necessary for the government to actively implement measures to control; top-down policy is very effective in the early stage of governance; it bridges the gap of environmental pollution awareness that cannot be filled by the market itself.

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Top-down policies issued by the central government are usually mandatory and targeted, emphasizing the development of uniform standards for top-down implementation. Vertical accountability is often applied in the process. A top-down approach helps to avoid delays and lack of direction in problem-solving. In addition, the central government has a strong ability to centralize and allocate resources, which is a strong protection for responding to urgent environmental problems on a national scale or serious air pollution incidents. It is also able to effectively allocate resources to support the promotion of pollution control in key areas such as the BTH region.

However, the disadvantage of the lack of flexibility of Top-down policies becomes apparent in the middle and later stages of policy implementation, especially at the local level. Policies that are excessively uniform might not be suitable for different regions, leading to poor implementation, lack of motivation, and even formalism in some cases. More specifically, some of the industrial cities in the North, like Tangshan, and service-oriented cities in the South, such as Shanghai, may require different governance approaches depending on local economic conditions.

Comparatively, the advantages of the bottom-up approach became obvious in the middle and late stages of the air pollution policy implement. Local governments and institutions can make certain adjustments when implementing policies, considering the characteristics of the local economic and industrial structure, which enables the policies to be implemented more smoothly. Moreover, bottom-up policies have a higher level of public support since it is most suitable to the local situation. However, local governments may struggle with insufficient motivation and implementation in governance, especially in the conflict between economic interests and environmental protection. Then, it is again necessary for the central government to monitor the implementation of air pollution control policies by local governments through the establishment of assessment mechanisms, rewards, and penalties.

From the perspective of dynamic equilibrium, different phases of governance require different types of governance. The Top-Down approach is more effective in responding to urgent environmental problems, while the Bottom-Up approach may be more efficient in implementing long-term community development programs.

Therefore, when considering the bottom-up approach and the top-down method, it is not necessary to divide them into a higher or lower value, and the top-down and bottom-up approaches are not opposites. Their advantages are relative, and their roles in solving the air pollution problem are supplemental. For China, a policy combination that fits the actual situation of China's political and economic structure is effective.

Combined with the review articles, it can be seen that the APPCAP issued in 2013 tends to be top-down dominant, while the dual-carbon policy proposed in 2020, especially in the pilot cities, combines a more bottom-up oriented approach. This implies the Chinese government's attempts at more diverse governance to air pollution, but overall, it is still top-down dominant. In air pollution management in China, the initial goal was to reduce emissions of specific pollutants; hence, the Top-Down model was adopted. However, when the goal was extended to comprehensive environmental quality improvement, local innovation, and broader social participation were required, which drove the adoption of more Bottom-Up elements.

When specifically reviewing articles related to the effectiveness and impacts of APPCAP, it can be seen that the results appear to be mostly effective but do not fully address the health and economic impacts of pollution. Combining DCG-related articles, we can find that although the pilot cities policy attempts had a good starting point, the result does not seem to have reached an expected effect. Therefore, both the top-down represented by APPCAP and the more bottom-up attempts in DCG have pros and cons, there is no single perfect choice, and a combination is the best way to go.

China's air pollution control policy has always been top-down dominant, which is determined by China's national conditions and system. China is a country with a highly centralized political system,

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and economic growth is usually given priority and environmental protection is neglected in the early stages of China's industrialization and urbanization. In addition, due to China's large geographical territory, air pollution often spreads across regions, and this complexity also determines that a central government-led, resource-integrated approach is better suited to propose effective solutions to the problem. Overall, a top-down dominant governance, combined with bottom-up approaches and assisted with market-based tools, is a possible direction of comprehensive governance that is in line with China's political and economic development and is suitable for China.

3. Conclusion

In conclusion, this paper reviewed the main research findings in air pollution management, including the effectiveness of APPCAP and DCG in environmental, economic, and health aspects, as well as the evolution of environmental governance philosophy in China. Existing studies have shown that the top-down dominant approach represented by APPCAP has been effective in improving air quality. However, the effectiveness of the more bottom Approach represented by DCG, especially in the pilot cities, has not been as effective as expected. Current research has mainly focused on the current state of air quality policy and the assessment of past environmental governance philosophy, but possible future governance strategies have rarely been explored and analyzed. Based on the characteristics of China, it is recommended that policymakers in future air pollution control combine top-down dominant governance with bottom-up approaches and assist with market-based tools. Overall, the studies reviewed in this paper provide systematic insights for understanding Top-down and Bottom-up models of governance in air quality management, providing important implications for further theory development and policy practice.

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