Literature Review on Game Analysis for Air Pollution Prevention and Control

Xiaohong Sun*
Shandong Jiaotong University, Jinan, Shandong, China
*Corresponding Author.

Abstract: As a serious environmental issue toward all over the world in recent years, pollution has restricted the high-quality growth of the economy and people's life satisfaction. Focusing on the current situation of air pollution prevention in our country, government departments and pollutant discharge enterprises are the core of the prevention and control work. However, above parties generate interactive games because of different interests and demands in the practice of prevention, which always presents a situation of lack of responsibility or deviation from responsibilities. Through combing the literature at home and abroad, this paper concludes various kinds of theoretical game analysis in air pollution prevention and control, combining period characteristics of China's specific prevention work arrangement and governance objectives. We look forward to achieving the path of pluralistic co-governance and carrying out the major decision of air pollution prevention through exploring the difference of interests among each subject.

Keywords: Air Pollution Prevention; Game; Pluralistic Co-governance

1. Introduction

Western countries have started relevant research about atmospheric gaming since the 1970s and our country's has started since the 1990s. The beginning of gaming study in China mainly focuses on the discussion of the basic game theory of our country and the lack of methodological research. The reason for the current situation is that scholars can't obtain relevant data about air pollution prevention and are difficult to conduct empirical analysis due to a lack of support from external conditions, which affects the development process of theory and practice of air pollution prevention in our country. In 2013, "Ten Measures for Air Pollution Control" is released. Theoretical research also entered a transitional period, the research perspective appeared to "Blowout" phenomenon, and research results bloomed.

2. Origins and Development of Game Theor

Game theory is based on the rational man hypothesis. Different from decision-making, a game means a decision based on guessing each other's decision, which is an interactive decision actually. The game theory can be traced back to the 18th century and the development of the main theory started in the 1930s. Emile Borel proposed the "Minimax Theorem of Finite Form", and John von Neumann and Oskar Morgenstern proposed three kinds of presentation forms and two kinds of solutions of the game in their book Theory of Games and Economic Behavior, which established the cornerstone of the field of game theory. In 1950-1951, Nash made a distinction between cooperative games and non-cooperative games, and defined "Nash equilibrium". In the 1980s, relevant publications of game theory have already reached more than 6000 kinds internationally. Research on gaming started in the 1990s, the game research in China experienced the research process from the static game with perfect information to the dynamic game with perfect information, and then to the static game with imperfect information and the dynamic game with imperfect information.

3. Review of Relevant Foreign Theoretical Literature

Most foreign research involved transboundary environmental issues of multiple countries initially (1970s), considered water resources, air environmental pollution, and solid waste

contamination as the core and tried to build an effective reward system to facilitate international cooperation. After the 1970s, under the influence of environmental federalism theory (which mainly focuses on the rational allocation of environmental management functions among multiple levels of government), foreign scholars started from the perspective of game theory between governments, discussed what influence the same- level financial competition made in the work of government pollution control. Relevant research after the 21st century focused on constructing game models and behavior analysis of expanding game subjects from governments to related entities such as enterprises and citizens. Foreign relevant literature is classified into transboundary environmental issues, the game between governments, and the game between governments and enterprises according to their research direction. This paper summarizes as follows.

3.1 Transboundary Environmental Issues
Kucukmetmetoglu & Guldmann (2002) [1] used cooperative game theory to study river allocation in three countries. Frisvold (2015) [2] used the idea of game theory to study the regulation and enforcement of environmental policies for water treatment projects along the U.S.-Mexico border.

3.2 Games between Governments
Some scholars believe that fiscal competition has a negative impact on governments' choice of environmental governance decisions. Levinson (2003) [3] pointed out that governments tend to develop the economy and deregulate, resulting in a race to the bottom (in environmental enforcement, governments will develop economic development at the expense of the ecosystem, resulting in weak enforcement).
Some scholars believe that fiscal competition positively affects governments' choice of environmental governance decisions. Oates &Schwab (2006) [4] constructed a model of government fiscal competition and concluded that governments must provide more effective environmental protection policies based on voter preferences as a means of attracting residents and resources. Porter &Linde (1995) [5] proposed that when the three conditions of

strong government investment in environmental governance, high cost of enterprise illegal emissions, and high environmental preferences of residents are present, there will be a " benign competition" among governments (fiscal competition will lead to the improvement of the environmental governance behavior of the government, and improve the quality of the environment). Kunce & Shogren (2005) [6] argued that assessment indicators provide incentives for governments to strictly enforce environmental regulations, leading to environmental improvements.

3.3 Games between Governments and Enterprises
It means the game behavior of government regulation and enterprise emissions in environmental governance. Kennedy (1994) [7] explains the reasons for governments to choose non-cooperative game. Damania (2001) [8] constructs the government-enterprise game model to provide a theoretical basis for realizing the win-win situation of environmental protection and economic development.

4. Review of relevant domestic theoretical literature
Searching subjects of "Air" and "Game" in the CNKI database, with SCI、EI、CSSCI, and core journals as sift standard, we found a total of 228 articles related to atmospheric games from core journals such as Chinese Management Science and Systems Science and Mathematics from 2004 to 2022. One of the earliest articles from the journal Economic Management, Exploring the "Same House Game" and Global Environmental Management Strategies [9], constructed an air game model between developed and developing countries, and analyzed that only when both sides of the game chose the "real cooperation" strategy could the current environmental problems be solved. The year and keyword statistics of the sample literature on atmospheric gaming in China and the overall distribution is shown in Figure 1 and Table 1.
From the view of published time of papers, relevant research about air game has developed from scratch from 2004 to 2022, and has presented a rapid growth trend on the

whole. China proposed the strategic goals of "carbon peaking" and "carbon neutrality" in "The Fourteenth Five-Year Plan" It is predicted that relevant research results will continue to grow in the coming years. Therefore, it is very necessary to conclude relevant research results about the air governance game.
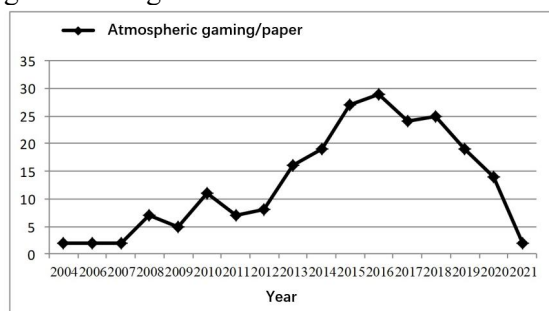

Figure 1. Annual Statistics of Chinese Air Game Literature

Table 1. Keyword Statistics of Air Game Literature in China

Types	Number
Government departments	127
Collaborative governmence	34
Beijing,Tianjin,Hebei	32
Enterprises	35

According to research directions, domestic relevant literature is classified into four categories—games between different levels of governments, games between different regional governments, games between governments and enterprises, and games between international organizations. The summary is as follows.

4.1 Games between Different Levels of Governments
Ma&Shi (2016) [10] introduced a new perspective of vertical compromise by lower governments (shifting financial power upwards and administrative power downwards ", which is a compromise induced by the financial imbalance between different levels of governments), pointed out that lower governments create extra-budgetary income and develop the economy through hidden means. Nie&Zhang (2019) [11] first constructed a tripartite game between the different levels of governments and

enterprises. Ding&He (2020) [12] combined social networks with evolutionary games to analyze the internal and external driving mechanisms of different levels of governments in controlling air pollution.

4.2 Games between Different Regional Governments
It refers to the research on Air Collaborative Governance in Specific Cities of Beijing Tianjin Hebei. Yue&Huo (2017) [13] used a game model to obtain incentives for different regional governments to carry out joint prevention and control measures. Xue et al (2014) [14] believed that a reasonable allocation mechanism for governance costs is the key to effectively implementing regional cooperation.

4.3 Games between Governments and Enterprises
Xie&Sun (2015) [15] believe that there are multiple pollution control states between governments and enterprises, and the efficiency of pollution control can be maximized when information is symmetrical. Chen et al (2016) [16] elaborated on the dilemma of government inefficiency in air pollution and proposed the implementation of an air pollution tax strategy. Xu (2019) [17] suggested introducing a third-party regulatory mechanism to increase the probability of illegal pollution discharge by enterprises being discovered.

4.4 Games between Countries
Zhou et al (2018) [18] believed that China should promote cooperation in environmental governance in Northeast Asia, strengthen cooperation with Japan and South Korea, and consolidate the role of cooperation mechanisms, such as the North-East Asian Subregional Programme for Environmental Cooperation (NEASPEC).

5. Phase Division of Practical Work on China Air Pollution Prevention and Control

5.1 Phase Division of Air Pollution Prevention and Control
The work of air pollution prevention and control includes two parts. One is the work of air pollution prevention, which means

reasonably planning the city's industrial layout, relocating key regulatory enterprises for exhaust gas pollution to industrial parks, staying away from public living areas, and implementing ultra-low emission transformation for key pollutant discharge enterprises to eliminate the phenomenon of "pollution before treatment" from the source. The other is the work of air pollution control, which means increasing government supervision efforts, carrying out regional joint prevention and control, promoting green production vigorously, strengthening source utilization, and improving air quality effectively.

Air pollution prevention and control is an important cornerstone of China's sustainable development, which is more and more imperative with socioeconomic development. Air pollution prevention and control in our country can be traced back to the 1970s, and the process of prevention can be divided into four stages:

Firstly, initial phase (before 2013): In 1972, our country sent a delegation to participate in the first United Nations Conference on the Human Environment in Sweden, proposing to integrate environmental protection into the national agenda, which uncovered the prelude of environmental protection work in China. In 1973, the government held the first National Conference on Environmental Protection, discussed outstanding issues about current situation of ecological environment in our country, made the first ecological environment protection law of China--Several Provisions on Protecting and Improving the Environment (Trial Draft) and the 32-character Environmental Protection Work Guidelines (layout reasonably, utilize comprehensively, turn harm into good, depend on the masses, work together, protect the environment, and benefit people), pioneered the use of legal force to protect the ecological environment in China. In 1978, the goverment carried out the "Three-North Shelterbelt Program" Project, building an ecological barrier for windbreak and sand fixation in northwest China, which became the milestone of the construction of an ecological environment system in China. In 1988, the goverment approved to implement Air Pollution Prevention and Control Law of the People's Republic of China, clarified the

regulatory responsibilities of governments, regulations on the prevention and control of smoke as well as dust pollution, and measures for illegal actions, and promoted the actual implementation of air pollution monitoring and control work in China. In 2002, China published Technical Policies for Pollution Prevention and Control of Sulfur Dioxide Emissions from Coal Combustion and provided technical support and guidance of for the clean use of coal and the construction of flue gas desulphurization facilities. In 2008, for the first time, China conducted regional joint prevention and control operations to protect the air quality of Beijing Tianjin Hebei and surrounding areas during the Olympic Games. In 2012, our country released the "12th Five Year Plan for Energy Conservation and Emission Reduction", and clarified the main tasks and ten key energy-saving and emission reduction projects during the "12th Five Year Plan" period.

Secondly, phase of emission reduction (from 2013 to 2017): In 2013, China implemented Air Pollution Prevention and Control Action Plan (also " Ten Measures for Air Pollution Control "), and set goals of improving national air quality in 2017 and ten protective measures. In 2015, China carried out an ecological environment protection superintends and made experiments in Hebei first. In 2016, our country published a new revision of the Air Pollution Prevention and Control Law of the People's Republic of China, significantly increased the number of laws, clarified a series of environmental regulations to check out and supervise governments' effectiveness of the air environment governance within administrative regions, and regulated that the public should consciously fulfill their environmental obligations. In 2017, SO_2 emissions of China decreased to $875.4×10^4$ t, and NOx emissions decreased to $1258.83×10^4$ t (above data is sourced from the official website of the National Bureau of Statistics, http://www.stats.gov.cn/）, the comprehensive control of multiple sources of pollution and multi-pollutant synergistic emission reduction measures have been effective. . According to the 2017 China Ecological Environment State Bulletin, the data shows that PM2.5 and PM10 all over our country decreased significantly, the proportion of excellent days

increased, and goals as well as key work tasks formulated in "Ten actions" have been succeeded comprehensively.

Third, critical stage (from 2018 to 2020): In 2018, the government published the Three-Year Action Plan to Fight Air Pollution to formulate specific goals of improving air quality, resolute to win the battle of blue-sky defense, and increasing the masses' sense of blue-sky happiness. In 2019, the Ministry of Ecology and Environment printed and distributed annual work highlights, formulated key work of carrying out the work of strengthening supervise of important regions and targeted assistance actions deeply, and promoted all places to revise the emergency plan for heavily polluted weather. In 2020, after launching a pilot project, the Ministry of Ecology and Environment implemented to rectify national fixed pollution sources, issue pollution discharge permission and register pollution discharge information, which is in order to realize fixed pollution sources permission coverage fully. During "The thirteenth Five-Year Plan", the phased goals of the pollution prevention and control campaign and the goals of the blue-sky defense campaign in improving air quality have been successfully achieved, and have provided conditions for continuous improvement of air quality during the "Fourteenth Five-Year Plan" period.

Fourthly, phase of transformation (after 2020): Air pollution has already become a global issue, and the work of air pollution prevention and control needs the concert of nations. In September 2020, China proposed that all countries need to promote green transformation and global mutual assistance vigorously at the 75th general debate of the United Nations General Assembly; China promised that we will reach a carbon peak before 2030, realize carbon neutrality before 2060, and contribute Chinese strength to build a beautiful Earth. The "14th Five Year Plan" formulated in October 2020 aims to achieve comprehensive green transformation and harmonious coexistence between humans and nature. In February 2021, Minister Huang Runqiu claimed that we must conduct cooperation about global pollution control and build a community of all life on Earth at the 5th United Nations Environment Conference.

Since 2013, the whole country has promoted air pollution prevention and control work steadily, the sense of responsibility of controlling pollution all over the society has run high, and the effect of air governance has succeeded obviously. London UK spent 28 years (from 1952 to 1980) governing air pollution, and Los Angeles US spent 64 years (from 1943 to 2007). Our country spent less than developed countries in Europe and America and obtained rich governance experience in air pollution prevention and control. However, there are a series of issues that appeared in the practice of governing, for example, district (county) level government contradicted the superior government in terms of interests because of the constraints of quantitative accountability mechanism when carried out law and regulations of air pollution prevention and control. The superior government put excessive emphasis on assessment results while district (county) level government facing faces enormous pressure between economic development and ecological governance; or enterprises continuously reduce production costs and governed pollution negatively in order to ensure maximum profit, which brought difficulties and troubles for the law enforcement work of district (county) Bureau of Ecology. So far, China still faced severe challenges of air pollution, especially secondary pollution.

5.2 Governance Goals of Air Pollution Prevention and Control

Governance goals of air pollution prevention and control include two parts. One is the decrease in the average concentration of PM2.5. In 2014, the Ministry of Environmental Protection signed a responsibility letter with 31 provinces (district, city) of our country to formulate annual average concentration decrease index of PM2.5 and PM10, for example, Beijing Tianjin Hebei, Shandong, and Chongqing have respectively set targets for a 25%, 20%, and 15% reduction in annual average concentration of PM2.5. The other is the increase in the average proportion of excellent days. In 2019, the Ministry of Ecology and Environment formulated the proportion of excellent days nationwide and the annual target for total exhaust gas emissions. The Ministry of Ecology and Environment

conducts annual assessments of the fulfillment of indicators in various regions all over the country. According to the requirement of air pollution prevention and control, Provincial Departments of Environmental Protection carry out programs based on the actual situation of each province, clarifies the responsibility and work of each relevant department, decompose and implement goals to basic-level governments, to make sure the annual objective tasks of local air pollution prevention and control could be completed on time, and improves air quality effectively.

6. Conclusion

The practical process of air pollution prevention and control concerns interest distribution of all actors, different actors will have game in the process of governance because of interests. Using game theory to discuss the decisions of actors has already become one of the important theory methods of environmental governance. Since then, game theory has been evolving in the field of environmental pollution governance. This paper referred to domestic and foreign relevant scholars' research methods and results, combed and concluded game relationships between different actors and Chinese air pollution prevention and control in recent years in order to improve diversified governance of air pollution prevention and control.

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