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Game Analysis on the Problem of the Pollutant Emissions in Chinese Neighboring Province

Ziwei Deng[1,a,*]

[1]*School of Economics, Jinan University, Guangzhou, China*
a. dengziwei@stu2021.jnu.edu.cn
**corresponding author*

Abstract: With the continuous development of Chinese economy, the accompanying environmental problems have become a matter of great concern. Due to the spatial connection of neighboring provinces in China, pollution from one province can easily be discharged into the jurisdiction of the other province, which will inevitably cause interest damage of the later province. China's provincial governments have limited jurisdictional areas, the game exists between different provincial governments due to different interest demands. This paper analyzed the conflict of interests between local governments in Chinese neighboring provinces due to the emission problem, constructed a game model, analyzed the impact of the cost of pollutant treatment and economic compensation for pollutants on the emission decision made by neighboring provincial governments, and propose reference suggestions for Chinese neighboring provincial governments to deal with the pollution emission problem by combining the results of game analysis. The results of the study show that the two sides of the game can reach a synthetic win-win decision when the right to discharge is clear.

Keywords: cross-region, environmental regulation, government cooperation, game theory

1. Introduction

The development of the industrial economy has led to increasingly severe environmental problems and a series of environmental pollution problems were caused by factory emissions. The protection of the environment is related to the sustainable development of the economy and will have a profound impact on future generations. China's decentralization reform and the competition among Chinese provincial governments to promote local development together with the negative externalizations of the environment itself as a public good will lead to a "market failure" in which the market cannot allocate resources efficiently, resulting in a fragile horizontal relationship among local governments. Local governments in China focus on immediate short-term interests, and in order to seek near-term development and enhance their own development, there are different interests among local governments, so the cooperation of horizontal local governments is weak [1]. If one government discharges pollution into the jurisdiction of the other government, there will be a game between the two governments regarding the environmental discharge [2]. In cross-regional cooperation, local governments always adopt the speculative behavior of free-riding due to rationality and information asymmetry, leading to the final "prisoner's dilemma", ignoring the collective rationality[3].In this paper, the decisions made by neighboring provincial governments in China based on their own interests are mod-

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eled to analyze the corresponding decisions made by local governments under the condition of maximizing the interests of their own provinces, and based on this condition, reference suggestions are made to better solve the pollution emission problems between neighboring provinces.

2. Literature Review

2.1. Existing Research on Local Government Cooperation in Cross-Area Environmental Governance

Environmental problems cannot be solved by one local government independently and effectively. Cross-administrative environmental governance is a category of regional public goods and public affairs. Regional public goods need to be jointly provided by two or more local governments, and their consumption will generally spill out of their territorial boundaries, and other administrative regions will benefit or suffer as a result. Therefore, cross-administrative environmental governance, as a public pond resource, is characterized by both non-exclusivity and competition [4]. Environmental resources within a fixed area are limited, and when one user uses a portion of the resources, the available resources for other users are reduced. The polluting province pollutes the environment of the receiving province, and the resources of the polluted area are occupied by the polluting area, and the resources available to it are thus reduced, and its own interests will be damaged as a result.

The interaction between the two sides of the game can be either betrayal or cooperation. In the case of local government relations, the inter-regional environmental governance is also characterized by either conflict or coordination. Conflict, in the case of limited allocation of environmental resources, means that if each local government believes that other local governments will take care of pollution, they can discharge pollution from their own region to other regions and let other governments take care of it for them. Coordination means that the local governments can communicate and reach an agreement to deal with the regional environmental pollution problem together. In cross-regional environmental management, local governments are reluctant to invest high costs in environmental pollution due to information asymmetry and opportunistic considerations for their own interests [5].

The further development of fiscal decentralization has made local governments as independent interest subjects, and in the current economic performance appraisal system, GDP is very important, because of the high cost and long payback period of environmental pollution treatment, and has a great negative impact on the development of pollution-intensive industries, and has a certain inhibitory effect on economic growth, so local governments mostly prefer to choose to reduce the investment in environmental treatment and choose rapid Therefore, most local governments prefer to reduce investment in environmental management and choose rapid economic development to meet the performance aspirations of local officials. The lack of effective constraints among local governments often leads to speculation [6]. The administrative district administrative model has cut the common interest structure among local governments and presented the independent local interest situation. "The pursuit of self-interest, especially direct economic interest, has become a fundamental motivation for local governments' behavioral choices [7]. The main manifestations are the differences in regional environmental governance goals of local governments, the differences in local governments' perceptions of collaboration, and the asymmetric information and insufficient trust in environmental governance among local governments. Uneven economic development leads to differences in environmental governance goals among local governments in the region, which is reflected in the differences in environmental governance capital investment and environmental management efforts among local governments. In actual pollution control, local governments still take local economic development as their main priority, and each of them will be willing to transfer pollution to other regions as long as the pollution does not occur in their own regions. In cross-regional environmental governance,

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the trust between local governments is greatly reduced due to differences in the perceived benefits and costs of collaboration and the impact of information asymmetry, and the lack of trust also affects the sustainable development of local government collaboration [6].

2.2. Existing Analysis of the Game of Economic Compensation Arising from Environmental Pollution

Many studies of games are based on an optimization basis, in which they assume that the marginal benefits and marginal costs of pollution control are known, proving that full cooperation should be the optimal solution in terms of the overall welfare of the big picture. At this point, the cost of controlling environmental pollution and the damage caused by pollution are minimal. However, when the overall welfare is optimal, it does not mean that the welfare of each region is optimal, and some regions will have their welfare reduced accordingly due to pollution control. Therefore, the fully cooperative solution proposed by Samuelson will hardly be an equilibrium solution [8]. Consequently, the beneficiary regions should compensate financially for the regions whose welfare is impaired. However, such economic compensation is for the polluted region to compensate the source region financially, which is contrary to the polluter pays principle. Furthermore, the payment of financial compensation from the polluted region to the source region will alleviate the costs and expenses required to treat the pollution in the source region and increase its tendency to release more pollutants to other regions, which will not achieve the initial purpose of reducing pollution emissions.

3. Introduction of the Game Model

In the first place, in the game model, the government of the polluting province A and the government of the polluted province B are established. n represents the cost that the government of province B needs to pay to deal with the pollution in its jurisdiction, r is the benefit that the government of province a will gain by discharging the pollution to the neighboring province nearby, i is the cost of coordination and cooperation between governments (the amount of cooperation cost is less compared with the economic compensation), p_1 is the economic compensation from the polluting province to the polluted province under the cooperation condition, and p_2 is the economic compensation from the polluting province to the polluted province under the non-cooperation condition (assuming that p_1 is much larger than p_2), q is the benefit obtained by the environment when the polluted province is not polluted or q is the economic loss caused by pollution.

3.1. Basic Assumptions

First, the two provincial governments (provincial government A, provincial government B) are allowed to pollute emissions according to their own interest claims, the other provincial government has no right to interfere.

Second, the emissions from province A to province B will cause economic interests damage to province B.

Third, the governments of both provinces are rational participants, and the goal of each participant is to minimize the cost of pollution control and the damage to economic interests suffered by the province. Because the regions are connected, the emissions are convenient, and there is no need to solve environmental pollution by themselves, etc., the cost of discharging pollutants from province a to province b is much smaller than that of treating pollutants by province a itself [9].

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3.2. Modeling and Analysis

According to the assumptions, it can be concluded that, as a rational participant, the provincial government A is bound to discharge pollution to province b in order to minimize the cost of pollution control and the economic benefits suffered by the province. Thus, according to the set parameters, the benefit functions of the two provincial governments under different combinations of strategies are determined, and the game process between the two provincial governments can be analyzed, resulting in the game matrix in Table 1.

Table 1: Game matrix between the provincial government A and the provincial government B.

		Provincial Government B	
		Cooperation	No cooperation
Provincial Government A	Compensation	$(r-i-p_1,n-i+p_1-q)$	$(r-p_2,n+p_2-q)$
	Non-compensation	$(r-i,n-i-q)$	$(r,n-q)$

3.3. Solution of Pure Strategy Nash Equilibrium

By analyzing the game matrix, for province government B, when province government A chooses to make corresponding financial compensation for polluting the environment of province B, province government B will choose to cooperate because the cost of cooperation is smaller in amount for financial compensation and p_2 is much smaller than p_1. When province government A chooses not to compensate, province government B will choose not to cooperate.

For province government A, province government A will choose not to compensate no matter what decision province government B makes. Based on the choice of province government A, province government B will choose not to cooperate, then the analysis yields a Nash equilibrium in which province government a does not compensate province B financially and province government B does not cooperate with province government A.

The analysis shows that the final decision of province A and province B is essentially the classic "prisoner's dilemma". Each local government, in pursuit of maximizing its own interests without considering the interests of others or the whole, will eventually choose not to cooperate or make concessions. The premise of this conclusion is that province B has no right to interfere with province A's pollution emissions in its own province, as assumed earlier. The conclusion of the analysis proves that if province B does not have the means to effectively stop province A's emissions, province A will make the convenient and effective decision of directly discharging pollution to another province out of concern for maximizing its own interests. In order to get out of the "prisoner's dilemma" problem and make the two sides move toward a cooperative outcome, the following assumptions can be made.

If province government B has a proven means of preventing province government A from freely discharging pollutants into province B, so that province government a has to spend m to dispose of its pollutants under the condition that province government A does not cooperate, i.e., under the condition that province government B does not cooperate, the benefit function of province government A is $(r - p_2 - m)$ under the compensation condition and $(r - m)$ under the non-compensation condition. And the provincial government B can make the pollutant of province A cannot be discharged to province B by this means under the condition that the provincial government A does not make financial compensation, i.e., the provincial government a need to treat the discharge of the province by itself. According to the assumptions listed in Table 2 game matrix [10].

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Table 2: Game matrix between the provincial government A and the provincial government B.

		Provincial Government B	
		Cooperation	No cooperation
Provincial Government A	Compensation	(r-i-p_1, n-i+p_1-q)	(r-p_2-m, n+p_2-q)
	Non-compensation	(r-i-m, n-i-q)	(r-m, n-q)

Analyzing the game matrix in Table 2, for province government A, if province government B chooses to cooperate, when $m>p_1$,since the two provinces are adjacent to each other, the cost of discharging from province A to province B is much smaller than the cost of treating its discharge by province A due to the convenience of discharge and the small repair work required, province government A will choose to compensate province government B; if province government B chooses not to cooperate the choice to not compensate is conditional on the province government B choosing not to cooperate. For province B, province B chooses to cooperate when province A chooses to compensate, and chooses not to cooperate when province A chooses not to compensate. At this point, there are two Nash equilibrium outcomes, namely (Compensation, Cooperation) and (Non-compensation, No cooperation).

When $m>p_1$, assumed that i is relatively small and can be roughly ignored, (r-i-p_1)>(r-m), so province government A will choose to cooperate with province government B and compensate province government B financially, while province government B will choose to cooperate with province government A under the condition that province government A chooses to compensate. Therefore, both sides will choose the strategy of (Compensation, Cooperation).

4. Suggestions

Based on the above assumptions and the analysis of the game, in order to promote cooperation between local governments in neighboring provinces, two proposals are proposed for different subjects.

In the case of the central government, it should implement the innovation of administrative policies. Foster a consensus on cooperation among local governments and improve the operation mechanism of local government cooperation. Increase the share of environmental protection in the performance evaluation of local officials, so as to encourage local government officials to pay attention to the promotion of environmental protection and increase the investment in environmental protection while trying to develop the regional economy. Only when local governments pay attention to local environmental protection will they solve the speculative behavior of local governments and fundamentally solve the problem of environmental pollution.

For the local governments, each local government should adopt a policy of economic compensation. The province that emits pollutants should pay the corresponding economic compensation to the polluted province. The pollutant-emitting province pays a certain amount of money to the polluted province to compensate for the loss of the polluted province when it discharges pollutants into the polluted area, causing economic loss to the polluted area and environmental damage to the area. In the long run, if a polluting province feels that the amount of money needed to discharge to a neighboring province and pay financial compensation for the countermeasure is more than the cost of upgrading its own emission technology and applying it to the province's emission treatment, the polluting government will make efforts to upgrade its own pollution emission treatment technology to reduce emission and promote environmental protection out of consideration of long-term interests.

5. Conclusion

As people's awareness of environmental protection increases, the issue of regional pollution emissions is becoming more and more important. In dealing with the pollution emission problem between

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two regions, the best outcome is undoubtedly the cooperation between the two governments towards a win-win situation. The purpose of this paper is to investigate the conditions for cooperation between neighboring provincial governments in China on the issue of environmental pollution emissions, and to establish a game matrix under two different assumptions to explore the conditions for the two governments to move from non-cooperation to cooperation. Through the analysis of the model, it is found that the problem is essentially a "prisoner's dilemma", and further study reveals that it is possible to "get out of the dilemma" by determining the ownership. Ultimately, the key to cooperation is the importance of local environmental issues in the region. This study provides a simulated game analysis of local government departments in two neighboring provinces with pollution emission problems, and makes recommendations for the relevant government departments to refer to when making decisions. The shortcoming of this study is that the research on this issue is still superficial and has not explored the deeper causes to give more constructive suggestions. In the future, by understanding the factors influencing the environmental game between local governments and combining more knowledge of game analysis, we can further analyze the fundamental conditions that enable the cooperation between the two governments and promote environmental protection.

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