Game Analysis of Water Pollution Control in China's Watershed

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Abstract: Water pollution in the river basin is an important environmental management problem in China. At present, China's environmental governance has entered the policy game stage centered on related interests. There are two main focus areas. First, it aims to resolve the conflict between the central government, local governments, and enterprises in terms of the utilization of basin resources and the environment. Second, it is responsible for the implementation of environmental policy. By analyzing the relationships between the central government, local governments, and enterprises in the process of water pollution control in the river basin, this study examines the environmental regulation of the central government and the collusion between local governments and enterprises to pollute the environment. To achieve this, game theory is applied from the perspective of information economics. Lastly, the study proposes corresponding policy recommendations in order to get out of the "prisoner's dilemma".

1. Introduction

Since China's economic reform, the economy and society have improved dramatically, but the overall situation in terms of China's ecological environment remains poor. In particular, water pollution in the watershed shows a deteriorating trend, with important rivers subject to varying degrees of pollution. Because most of these rivers flow through a number of administrative regions, once pollutants are discharged upstream, cross-regional water pollution in the watershed occurs. This problem has severely restricted the sustainable development of the economy and society.

China has improved its watershed water pollution control to unprecedented levels, as one of the most important tasks of all levels of government. Owing to unremitting efforts, China's watershed water pollution control work has gradually entered the benign development track, with significant results. However, despite this, the water pollution in some parts of China's watershed has intensified, and the problem remains serious. The situation is related to collusion between local governments and enterprises, which are the main culprits responsible for the water pollution in the area. Therefore, it is of great theoretical and practical significance to examine the behavior of those involved in water pollution control.

2. The Relationships between the Main Bodies Responsible for Water Pollution in the River Basin

In recent years,although China has continued to strengthen its water pollution control investment and environmental legal system,the overall quality of the basin's water resources has not improved significantly.On the surface, it appears that China's frequent watershed water pollution incidents and dilemmas with regard to governance are due mainly to extensive economic development and an unreasonable industrial structure.However,the deeper reason behind the problem is the game played

between the central government,local governments,and enterprises.Therefore,clarifying the relationships between these bodies is important to formulating effective water pollution prevention and control policies.

Based on the planning and the willingness expressed by the central government,water pollution problems in the river basins can be controlled.However,the government departments focus primarily on the benefits to be gained from the relationships between them, followed by power relations, financial relations, and public administration relations [1].Since the country's economic reform,which has included the gradual establishment of China's market economic system and the reform of the government administrative system,the power of local governments has increased,which has helped to motivate all local governments.However,conflicts of interest in the various departments have emerged,local interests superseding overall interests.Because the river basin provides public water resources,relevant government departments and enterprises within the area lack incentives to take the initiative to control pollution.At the same time, the watershed water resources management system of segmentation and isolation,and the performance evaluation system with GDP at the core,influences local governments' development orientation.Furthermore,imperfect laws and regulations and China's fiscal decentralization inspire competition for growth among local governments, resulting in local corporates' environmental pollution behavior. In the face of economic development and environmental protection,the local governments tend to use economic development as a guide,choosing efficiency at the expense of fairness, and ignore social responsibility.Under the central government's supervision of environmental pollution,local governments often implement measures based on their own agenda, causing the central government's environmental policy to be distorted. Local governments focus on their respective region's rate of economic development, fiscal revenue, and personal interests, and are less enthusiastic about global interests such as water pollution control and other work. This inevitably leads to conflicts of interest between the central government and local governments and local government departments.

Enterprises are rational from an economic point of view, and pursue profit as their main objective. If there is no external intervention, enterprises lack the inherent power to control water pollution and protect the environment. Objectively, all levels of government should punish water pollution by enterprises and supervise their active water pollution control. However, because enterprises are local taxpayers and the main source of fiscal revenue, the interests of local governments and enterprises are highly relevant. Therefore, in the face of enterprises' water pollution behavior, local governments do not strictly implement the relevant policies of the central government, depending on the circumstances. Similarly, in order to maximize their own interests, enterprises also implement different preventive solutions. Whether enterprises and local governments conspire together against the central government's environmental regulations depends on the associated costs and benefits. In general, conspiracy is conducive to increasing the income of local governments and related officials, and saves enterprises' costs related to pollution control. Of course, once the conspiracy is perceived, both sides will be punished accordingly. However,because of the current imperfect laws and regulations, as well as previous environmental violations, the gains from collusion between enterprises and local governments are often greater than the associated costs. Coupled with the asymmetry of information, local governments are more willing to collude with enterprises, choosing economic interests over public interests, acquiescing to enterprises' sewage behavior. This further illustrates the importance and necessity of the central government strengthening its supervision of local governments and enterprises in the process of water pollution control.

3.   Game Analysis of Water Pollution Control

In terms of water pollution control, the central government, local governments, and enterprises are the main participants, and are closely connected. For a variety of reasons, a tripartite game is formed in the control of water pollution. The central government represents public interests, and does not cooperate with local governments and enterprises in the game relationship. However, their common interests mean local governments and enterprises do cooperate in the game relationship.

3.1 Hypothesis of the Mode

From the above analysis, it is clear that the central government, local governments, and enterprises are not able to judge the other participants' choices correctly, owing to incomplete information, among other reasons. The significant cost of supervision means the central government will implement supervisory measures with a certain probability. Similarly, local governments and enterprises will choose to conspire with a certain probability.

Assumptions: C represents the cost to the central government of supervising the conspiracy between local governments and enterprises; Y represents the central government's punishment of local governments for transgressions; R represents the central government's punishment of enterprises; π_1 represents the gain for a local government from conspiring with enterprises; π_2 represents the rent received by local governments from enterprises; and π_3 represents enterprises' gain from conspiring with a local government.

Then, $P(g)$ is the probability that the central government will implement supervisory measures; $P(s)$ is the probability of success of the central government's supervision; $P(d)$ is the probability of local governments and enterprises choosing to conspire; $E(g)$ is the central government's expected return; $E(d)$ is a local government's expected return; and $E(c)$ is an enterprise's expected return. Thus, we have a tripartite game matrix of the interaction between the central government, local governments, and enterprises describing the control of water pollution (see Table 1).

<div align="center">Table 1 Game Matrix Table</div>

		Central Government		Probability of Non-supervision $1-P(g)$
		Probability of Supervision $P(g)$		
		Probability of Success $P(s)$	Probability of Failure $1-P(s)$	
Local governments and enterprises	Probability of conspiracy $P(d)$	$\pi_1+\pi_2-Y$ $\pi_3-\pi_2-R$ $Y+R-C$	$\pi_1+\pi_2$ $\pi_3-\pi_2$ $-C$	$\pi_1+\pi_2$ $\pi_3-\pi_2$ 0
	Probability of Non-conspiracy $1-P(d)$	0 0 $-C$	0 0 $-C$	0 0 0

3.2 Model Analysis

Based on game theory and the data in Table 1, there is no pure-strategy Nash equilibrium in the game process. Thus, we solve for a mixed-strategy Nash equilibrium.

(A) The expected return of the local government is expressed as follows:

$$E(d)=p(g)p(d)[p(s)(\pi_1+\pi_2-Y)+(1-p(s))(\pi_1+\pi_2)]+p(d)(1-p(g))(\pi_1+\pi_2) \tag{1}$$

A local government pursues its own interests by maximizing:

$$\frac{\partial E(d)}{\partial p(d)}=p(g)[p(s)(\pi_1+\pi_2-Y)+(1-p(s))(\pi_1+\pi_2)]+(1-p(g))(\pi_1+\pi_2) \tag{2}$$

When the income of the local government is independent of the probability of conspiring with enterprises, we have $\dfrac{\partial E(d)}{\partial p(d)}=0$ .Then, we can derive the optimal supervision probability of the

government in the mixed-strategy Nash equilibrium, as follows: $P(\mathrm{g})_d{}^* = \dfrac{(\pi_1 + \pi_2)}{p(s)Y}$.

Thus, if the central government chooses to supervise with probability $p(g) = P(\mathrm{g})_d{}^*$,the benefits are the same, regardless of whether the local government and enterprises choose to conspire. If the central government chooses to supervise with probability $p(g) > P(\mathrm{g})_d{}^*$,then the local government will choose not to conspire with enterprises because of the high probability of being caught doing so, as well as the price to be paid under the central government's strict supervision and accountability policy. Thus, choosing not to conspire with enterprises will be more favorable to local governments. If the central government chooses to supervise with probability $p(g) < P(\mathrm{g})_d{}^*$,then the local government will tend to choose to conspire with enterprises, because the potential cost is low in this case. Not only does this increase the region's GDP and the capital of promotion, relevant officials can gain from enterprises, where this is clearly contrary to the will of the central government.

(B) The expected return of the enterprise is expressed as follows:

$$E(c) = p(g)p(d)[p(s)(\pi_3 - \pi_2 - R) + (1 - p(s))(\pi_3 - \pi_2)] + p(d)(1 - p(g))(\pi_3 - \pi_2)$$.   (3)

Thus,the enterprise pursues its own interests by maximizing:

$$\frac{\partial E(c)}{\partial p(d)} = p(g)[p(s)(\pi_3 - \pi_2 - R) + (1 - p(s))(\pi_3 - \pi_2)] + (1 - p(g))(\pi_3 - \pi_2)$$.   (4)

When the income of an enterprise is independent of the income of conspiring with the local government, we have $\dfrac{\partial E(c)}{\partial p(d)} = 0$ .Then, we have the following optimal supervision probability of the government in the mixed-strategy Nash equilibrium: $p(\mathrm{g})_c{}^* = \dfrac{\pi_3 - \pi_2}{p(s)R}$ .Under such conditions, if the central government chooses to supervise with probability $p(g) = P(\mathrm{g})_c{}^*$,then the benefits are the same, regardless of whether the enterprises and the local government choose to conspire. If the central government chooses to supervise with probability $p(g) > P(\mathrm{g})_c{}^*$,the enterprise tends not to conspire with the local government in order to maximize its own interests. The deterrence of the central government's strict supervision means that if they choose to continue to pollute the environment, doing so will lead to severe punishment by the central government and arouse strong opposition from the community. In addition, this will damage the corporate image and reputation in the eyes of consumers, and may have an adverse impact on the future development of the enterprise. If the central government chooses to supervise with probability $p(g) < P(\mathrm{g})_c{}^*$,the enterprise and the local government are likely to conspire owing to the lower probability of the incident being discovered and cost of punishment. The enterprise's best choice is to conspire with the local government to maximize their common interests. Similarly, from $P(\mathrm{g})_c{}^*$,we have that the probability of the central government's supervision is proportional to the total revenue obtained by the enterprise when it conspires with the local government and pollutes the environment. In addition, it is inversely proportional to the rent received by the local government from the enterprise and the probability of the central government's successful supervision and punishment of enterprises when the mixed-strategy game reaches the Nash equilibrium. This is because the enterprise behaves rationally from an economic perspective, and will pursue its own interests rather than actively assume responsibility for environmental protection. The more the enterprise benefits from conspiring with the local government, the greater is their level of environmental pollution. In this case, it is necessary for the government to strengthen its supervision. With regard to their reputation and future development, enterprises prefer to take the initiative to participate in pollution controls, rather than conspiring, when the rent they pay to the local government and the losses they incur as a result of the central government's controls are greater than the expected income from conspiring with the local government and polluting the

environment. In this case, the probability of central government supervision is low.

(C) The expected return of the central government is expressed as follows:

$$E(g) = p(g)p(d)[p(s)(Y+R-C)+(1-p(s))(-C)] + p(g)(1-p(d))[p(s)(-c)+(1-p(s))(-c)] \quad (5)$$

The central government pursues its own interests by maximizing:

$$\frac{\partial E(g)}{\partial p(g)} = p(d)p(s)(Y+R) - C \quad (6)$$

When the income of the central government is independent of its supervision probability $p(g)$, the optimal probability of a conspiracy between enterprises and local governments in the mixed-strategy Nash equilibrium is as follows: $p(d)_g^* = \dfrac{C}{p(s)(Y+R)}$.

At this point, if the probability of conspiracy between enterprises and a local government is $p(d) = p(d)_g^*$, the central government's income will not change, regardless of any supervision. The results of the central government's supervision or non-supervision is the same. In theory, the central government's best choice is not to supervise, because it can save on the cost of supervision, and the water pollution problems will be resolved. If the probability of enterprises and a local government conspiring is $p(d) > p(d)_g^*$, then the central government will choose to supervise, putting an end to the environmental pressure brought about by the conspiracy, in order to maximize the social welfare. If the probability of enterprises and a local government conspiring is $p(d) < p(d)_g^*$, the central government should choose not to supervise. Analyzing the conspiracy probability $p(d)_g^*$ in the mixed-strategy Nash equilibrium shows that it is proportional to the cost of the central government's supervision, and is inversely proportional to the cost of the central government's punishment and the probability of the central government's successful supervision when the mixed-strategy game reaches the Nash equilibrium. Obviously, the greater the cost of supervising environmental pollution controls, the less power the central government has, providing an opportunity for the enterprise and the local government to conspire.

In contrast, more effective central government supervision measures means the punishment is greater, and enterprises and local government are less likely to conspire.

4. Conclusions and Recommendations

In summary, we can see that the formulation and implementation of water pollution treatment policies in the basin is a game process between the three main bodies: the central government, local governments, and enterprises. The differences in the target orientation of the central government and the value orientation of local governments and enterprises affect their respective behaviors, leading to the dilemma of water pollution treatment in the basin. Therefore, in order to reduce their collusive behavior and improve the water pollution problem, we can strengthen the cost of environmental supervision by the central government, increase penalties for environmental pollution, and improve the political, reputation, and other non-material costs of local governments and enterprises when they are responsible for water pollution treatment in the basin. Accordingly, the conclusions of the game study on water pollution treatment in the basin are extracted, and relevant policy suggestions are put forward in order to provide scientific guidance for the improvement of the efficiency of water pollution treatment in the river basin.

4.1 Strengthening Technological Innovation

We need technological innovation to guide the fundamental treatment of water pollution. Technological innovation plays an important role in water pollution treatment. On the one hand, it can improve the production efficiency and resource utilization of enterprises, alleviating the pressure on the environment. On the other hand, it reduces the cost of pollution treatment by enterprises, improves the efficiency of pollution treatment, and can generate a profit for enterprises in sewage treatment. At

the same time, the progress of environmental monitoring technology has greatly reduced the regulatory costs and improved the efficiency of the government's environmental treatment.

4.2 Improving the Implementation of Environmental Policies

It is difficult to solve the problem of water pollution in China, mainly because of the failure of the government than that of the market. The lack of coordination and the interests of the sector within the watershed cannot solve the problem of water pollution effectively. Some local governments and law enforcers tend to ignore the national environmental protection policies, without strict enforcement of the law. They often adopt the attitude of acquiescence or even protection, allowing production by local polluters and taxpaying enterprises. Therefore, we must improve the implementation of environmental policies, constantly improve and perfect the law enforcement system, and raise the level of law enforcement to improve the effect of water pollution treatment in order to resolve the problem of the pollution of the water environment in the river basin.

4.3 Establishing and Improving Incentive and Restraint Mechanisms

From a government perspective the local government places a one-sided emphasis on economic growth and ignores the internal driving force of environmental protection under the current performance evaluation and environmental assessment systems. Therefore, we can change the performance evaluation system to use only GDP as the core index, integrate the indicators of resources and the environment into the scope of assessment, and implement a performance evaluation system based on GDP. These measures will greatly increase the cost of collusion between local governments, officials, and enterprises, and reduce the chances of conspiracy. At the same time, we should increase the punishment and achieve an "environmental performance one vote veto system." The relevant departments and personnel who are ineffective in water pollution treatment should be punished, and those who do well in preventing the treatment of water pollution should be rewarded. In this way, local government departments and related personnel will not be able to maintain the pollution of enterprises, and environmental pollution will gradually be improved. From the perspective of enterprises, those that pollute the environment should be punished by fines, forced production or rectification, and closure. On the other hand, we should reward enterprises that actively treat pollution and protect the environment, for example, by providing government priority procurement, low-interest loans or technical transformation funds, and other material incentives, as well as measures to enhance the reputation of enterprises through media praise and awarding environmental quality signs for products[2].In this way, a policy of positive incentives and reverse penalties can be adopted for sewage disposal to create a clear picture of reward and punishment, which will help to improve and maintain the environment[3].

4.4 Establishing and Improving the System and Mechanism of Environmental Supervision

At present, the local environmental protection department is subordinate to the local government in the administration, and also under the leadership of the relevant departments of the higher authorities. However, the appointment and office expenses of local environmental protection departments are directly under the control of local governments. This opens convenient paths for economic development at the expense of the environment and the interests of the public, as well as weakening the role of the environmental protection department of the local government. Therefore, it is considered that local environmental protection departments should be separated from local governments, and placed under the leadership of the central environmental protection administration to ensure that they can work independently and effectively. At the same time, relevant research shows that the supervision of public and social groups plays an important role in encouraging enterprises to comply with environmental regulations and in reducing collusion rent-seeking behavior between local governments and enterprises[4].Thus, we should establish an information disclosure mechanism for water pollution treatment, and establish a third-party supervision and restraint mechanism, consisting of the public, non-governmental environmental protection organizations, and the media. We should supervise how enterprises and governments treat the discharge of water pollution by mobilizing the power of society in order to reduce the asymmetry of information and the regulatory costs of the

higher government. This will contribute to the implementation of the central government's environmental protection policy.

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