Analysis of the Prevention and Control of Inner lake Pollution in China
Based on the Game Between the Government and Enterprises

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Abstract. With the rapid development of industrialization, the pollution problem of Inner lakes have become increasingly prominent. Enterprises do not consider environmental costs to pursue profit maximization, and government regulation becomes inevitable. The pollution control process of Inner Lake is actually a game process between enterprises and the government. In the current game analysis, there is a major defect of ignoring the political cost and reputation cost caused by environmental pollution to the government and enterprises, which makes the theory unable to explain the real world. This paper analyzes the static game and mixed strategy game between local government and enterprises, and draws the conclusion that the extra benefit, reputation cost, government supervision cost and political cost of enterprises’ pollution of Inner lake all affect the choice of their behaviors. In addition, this paper introduces discount factor, analyzes multi-stage dynamic repeated game, and finds that the enterprise's future choice is closely related to the size of discount factor. Finally, the author puts forward policy Suggestions to promote and improve their behaviors from three aspects. Firstly, the third party constraint mechanism is introduced to increase the political cost of the government and the cost of corporate reputation. Secondly, actively carry out technological innovation to reduce the cost of pollution treatment. Finally, it is necessary to increase the punishment for negligence of government supervision and strengthen the responsibility of government supervision.

1. Introduction

As China's economic development has entered a state of rapid rise, the problems of environmental pollution and the continuous deterioration of ecological quality have also come along. Among them, the internal lakes with the nature of "public ponds" bear a heavy burden in the process of urbanization and industrialization, and the pollution problem is prominent. According to the state of China's Ecological Environment Bulletin 2018, of the 55 major lakes that monitor water quality in China, mild and moderate eutrophication accounts for 45.5 percent, or nearly half. Although in recent years, under the guidance of theory of "two mountain", and the background that the central Committee has attached unprecedented importance to environmental and ecological issues since the 18th CPC National Congress, pollution in China's Inner lakes has improved. However, because of the lake resources have stronger externalities, and each person is "economic man", which makes the treatment effect is not stable and appeared again and again. This template includes specific instructions for the papers submitted to the conference.

For example, the three most polluted lakes (Taihu lake, Chaohu Lake and Dianchi Lake) are the
focus of China's annual State of the Ecological Environment Bulletin. In recent ten years (2009-2018), except that the water quality of Taihu Lake has been improved and basically stabilized in the state of mild IV pollution, the water quality of Chaohu Lake and Dianchi Lake has not been fundamentally improved. Most of the time, the water quality of Chaohu Lake and Dianchi Lake has been in the state of eutrophication with severe V pollution, and it may slip into the inferior V water at any time if it is slightly relaxed. It can be seen that it is difficult to solve the problem of free riding in the utilization of internal lake resources only by government policy.

In the context of environmental regulation, enterprises will not cooperate with policies in pursuit of profit maximization or for various reasons, and the government is also an "economic man" in pursuit of profit maximization. As a result, there is a conflict of interest between the two sides, and the game between them is inevitable. Only when enterprises take the initiative to protect internal lake resources and reduce opportunistic behaviors, and the government effectively plays the supervisory role, can the effective governance of Inner lake pollution be realized.

2. Game Model Construction

2.1. The Assumptions and Parameters

2.1.1. The Assumptions of the Model

The game parties in this paper are local governments and enterprises, and the model has the following assumptions:

(1) Assuming that all enterprises in a certain place are polluters and the main income of local governments comes from this enterprise. They are all rational people, and the government aims to maximize social welfare while the enterprise aims to maximize its own interests;

(2) Assuming that the enterprise has two alternative strategies: pollute the environment or do not pollute the environment. Local governments have two options: regulation or indulgence;

(3) Assuming that enterprises will pay corresponding costs for environmental pollution, including fines and reputation losses;

(4) Assuming that local governments choose to indulge, there will be political costs.\[1\]

2.1.2. Parameters

Let the economic income of the enterprise be R, which is dependent on the output Q, namely R = R(Q). Q is positively correlated with the amount of pollution emitted. The revenue T of local government is a function of output Q, that is, T = T(Q).

(1) If the enterprise conducts pollution and pollution treatment, its output is Q₁ and profit is R₁. The government's tax revenue is T₁.

(2) When an enterprise conducts opportunistic behavior to pollute the Inner lake, its output is Q₂, its profit is R₂, and its government tax revenue is T₂.

\[ Q_2 > Q_1, \quad R_2 > R_1, \quad T_2 > T_1 \]

In addition, enterprises can obtain higher economic benefits when they choose not to treat
pollutants, but it will cause pollution to local environment and harm to residents' health. The loss caused by the decline of reputation and loss of competitiveness is called reputation cost, denoted as $H$. After taking reputation cost into account, the income of polluters is $R_2 - H$. The cost of government supervision is $C$, and the benefit of punishment (such as fine or levy of pollutant discharge tax) on polluters is $F$. If the local government ignores the harm of lake pollution to ecology and residents in pursuit of economic growth, then the government will face public criticism and affect the performance and image of the local government and the official career, which is called political cost $H$.

2.2. Static Game Analysis

We first set up the game under complete information, the game only lasts for one period, both sides act simultaneously. The income matrix of local government and enterprises under different strategies is obtained (as shown in Table 1):

|               | government         | enterprise     |
|---------------|--------------------|----------------|
|               | Supervision        | pollution      |
|               | ($R_2 - F - h, T_2 + F - C$) | ($R_2 - h, T_2 - H$) |
|               | indulgence         | no pollution   |
|               | ($R_1, T_1 - C$)   | ($R_1, T_1$)   |

(1) When $R_2 - R_1 > F + h$, if the cost saved or the benefit gained by the enterprise in polluting the Inner lake is greater than the fine $F$ and reputation cost $H$ borne by the enterprise, whether the local government conducts supervision or not will not affect the choice of "free rider" of the enterprise, and the optimal strategy of the enterprise is pollution.

(2) On the premise that enterprises choose to pollute the environment, when $F - H < C$, that is, if the cost of government regulation is greater than the difference between the fine and reputation loss received, the government will choose not to regulate.

To sum up, in the context of complete information, there are two Nash equilibria between enterprises' environmental pollution and local government regulation. For enterprises, both (regulation, no pollution) and (indulgence, pollution) are equilibrium solutions. However, in real life, there is not complete information symmetry between government and enterprises, and they cannot know the choice of each other. Moreover, at present, the government regulation cost in China is relatively high, and the reputation cost of enterprises is also relatively small. Therefore, the unique equilibrium solution (pollution, indulgence) of the static game model above is obviously inconsistent with the current national policy of green and sustainable development in China. The next step is to analyze the probability distribution of the mixed strategy Nash equilibrium of the game.[2]

2.3. Mixed Strategy Game Analysis

Suppose the probability that the enterprises do not pollute the Inner lake is $P$, and the probability of pollution is $1-P$. The probability of government regulation is $Q$, and $1-q$ is the probability that the government does not implement regulation.
When enterprises pollute the Inner lake, enterprise income: 
\[ E_1 = q(R_2 - F - h) + (1-q)(R_2 - h) \]

When the Inner lake is not polluted, the enterprise's income is: 
\[ E_2 = q R_1 + (1-q) R_1 \]

When selecting supervision, local government revenue: 
\[ U_1 = p (T_2 - F - C) + (1-p) (T_1 - C) \]

When indulgent is chosen, local government benefits: 
\[ U_2 = p (T_2 - H) + (1-p) T_1 \]

When the mixed strategy Nash equilibrium is realized, the enterprise and the local government get the same income when they make two choices. In this case, \( E_1 = E_2, U_1 = U_2 \). Thus obtained \( p^* = \frac{C}{F + H} \), \( q^* = \frac{R_2 - R_1 - h}{F} \).

When the probability of non-pollution and government regulation is \( P^* \) and \( Q^* \) respectively, the mixed game model reaches Nash equilibrium. And the following conclusions can be obtained: When \( p < p^* \), the government's best option is indulgence; When \( p > p^* \), the government's best choice is regulation; When \( q < q^* \), the optimal choice of the enterprise is to pollute the environment; When \( q > q^* \), the optimal selection strategy of the enterprise is not to pollute the environment. In this game, the Nash equilibrium depends on factors such as expected earnings from pollution and non-pollution, loss of corporate reputation, government fines and the cost of government regulation.

### 2.4. Multi-stage Dynamic Repeated Game Analysis

Next, increase the number of game periods to construct a dynamic multi-stage game model. Suppose in the process of repeated game, the two sides decide to cooperate at the beginning. If the enterprise chooses not to pollute the Inner lake, the cooperation between the two sides will not be interrupted, but will be repeated. Once the enterprise pollutes the environment, the government will find out at the end of the period, and the enterprise will pay the penalty of \( F \) at the beginning of the next period and terminate the cooperation from then on. Now introduce discount factor, once the enterprise chooses to implement opportunistic behavior in a certain period to obtain temporary additional benefits, it must consider the present value of all benefits.

Assuming that the enterprise did not pollute the environment before the \( t \) period, the income of the enterprise in each period was \( R_1 \). In the stage \( t+1 \), if an enterprise chooses to pollute the Inner lake, it will get extra income \( R \) and reputation cost \( H \). At the beginning of the next period, the enterprise shall also pay the penalty \( F \), and the game shall be terminated. At this point, the present value of the total earnings of the enterprise:

\[
y_1 = R_1 (1 + \delta + \delta^2 + \cdots + \delta^{t+1}) + \delta^t (R_2 - F - h) = \frac{R_1}{1 - \delta} (1 - \delta^t) + \delta^t (R_2 - F - h)
\]

If the enterprise does not carry out opportunistic behavior and does not pollute the Inner lake, then the cooperation between the government and the enterprise will continue forever, and the present value of the enterprise's earnings is:

\[
y_2 = R_1 (1 + \delta + \delta^2 + \cdots + \delta^t) = \frac{R_1}{1 - \delta}
\]

Since the enterprise pursues profit maximization, as long as it meets \( y_2 > y_1 \), the enterprise will not choose pollution. At this time:

\[
\frac{R_1}{1 - \delta} \geq \frac{R_1}{1 - \delta} (1 - \delta^t) + \delta^t (R_2 - F - h)
\]
When \( y_2 = y_1 \), \( \delta = \frac{R_1}{R_2 - F - h} \). When \( r > F + h \), \( \delta \approx 0 \). When \( r < F + h \), \( \delta \approx 1 \).

3. Conclusion of Model and Policy Suggestions

3.1. Conclusion of Model

In the static game, we can see that it is impossible for enterprises to actively deal with pollutants under the condition of tax regulation by the government. Because the measures taken by enterprises also require a lot of costs. In addition, even if the government will punish enterprises for polluting, as long as there is profit space, enterprises will take the risk. Therefore, in order to control the pollution in Inner lake, we should not only ensure the implementation of the government's supervision role, but also ensure certain pressure and incentive for enterprises to promote better cooperation between the two sides.

In the mixed strategy game analysis, the level of income affects the decision-making behavior of both sides. The higher the cost of government supervision, the heavier the punishment for enterprises to pollute the Inner lake and the less opportunistic behaviors they will suffer. The lower the cost of supervision, the lower the political cost of condoning corporate pollution, and the more the government will increase its supervision.

In the multi-stage dynamic repeated game, the enterprise will compare the present value of current benefit and future benefit at the same time. The choice of enterprises in the future is closely related to the size of discount factor, which is determined by the additional benefits obtained from environmental pollution. When the extra income \( R \) is greater than the sum of penalty \( F \) and reputation cost \( H \), the discount factor tends to zero, and the short-term income that enterprises attach importance to will choose to pollute the environment at the beginning of cooperation. When the extra income \( R \) is less than the sum of penalty \( F \) and reputation cost \( H \), the discount factor tends to 1. In this case, the future income will be greater than the short-term income, and the enterprise will choose not to pollute the environment.

3.2. Policy Suggestions

Introduce a third-party restraint mechanism to increase government political costs and enterprise reputation costs. Reputation incentive mechanism is used to restrain the behavior of both players. The government should give full play to the role of the news media, associations and groups as well as the public. By adopting this mechanism, enterprises will face higher social constraints (enterprises will bear high reputational costs when they pollute), so as to consciously reduce pollution. At the same time, public and media supervision will also lead to more direct constraints on the government, which means that local officials will face higher political costs if they do not regulate polluting enterprises. In addition, by mobilizing the power of social groups to assist government departments to supervise enterprises' emissions, information asymmetry between government and enterprises will be alleviated, and the cost of government supervision will be reduced, which will all help the government to strengthen environmental management.

Actively carry out technological innovation to fundamentally solve the problem of excessive cost. At present, the performance of enterprise competitiveness is not only price, quality, packaging, brand and other external forms, environmental competitiveness is also a form of enterprise competitiveness. Because this kind of competitiveness is a kind of intangible assets,
which can play a role in the long-term competition. Although technological innovation and improvement of production equipment will lead to the increase of cost and the decrease of competitiveness in the short term, in the long run, technological progress will reduce the cost of environmental protection, conform to the national policy of green development, and improve their competitiveness in the future. As a long-term development enterprise, it should not only focus on the immediate interests, but also have a long-term vision and take sustainable development as its own goal.

Increase penalties for government oversight negligence and strengthen government oversight responsibilities. At present, the local development view and achievement view are the fundamental factors affecting the government's ineffective environmental supervision. Some local governments still regard GDP as a hard indicator and the environment as a soft one, seeing only economic benefits rather than environmental and social ones. Therefore, internal inspections of environmental supervision and environmental protection administrative law enforcement inspections should be strengthened, and the investigation and punishment of inactions in environmental supervision should be strengthened. Once the negligence of government supervision is found, severe penalties shall be imposed in accordance with the law.

4. Conclusion

Since the government and enterprises are both economic people, the externality of the pollution of the Inner Lake is difficult to solve only by the market mechanism. Through the above game analysis, it is found that the development of environmental governance needs the joint efforts of the government and enterprises, the government should play the role of guidance and supervision, and the enterprises should improve the sense of social responsibility to carry out pollution control voluntarily. Reducing the government's income from enterprises' pollution, reducing the cost of government supervision and increasing the punishment on enterprises' pollution are conducive to the improvement of environmental quality. Establishing a system to increase the reputation cost of corporate pollution and increase the non-material cost of local governments to indulge pollution is an important direction for improving environmental quality.

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