Research on the Ecological Protection of Trans-Regional Lake Water Resources from the Perspective of Game Theory

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***Abstract*—Lake Water resources is public goods in the usage property, the ecological protection process of trans-regional lake water resources is actually the supply process of public goods. According to the economic strength of the administrative regions around a lake, we use the method of game theory to divide the trans-regional lake resources ecological protection activities in China into three types, such as the game between weak regions, the game between strong regions and the game between strong region weak region, analyze the behavior of the participants in the three games, reveals the dilemma of lake resources ecological protection in China, and puts forward the corresponding strategies and suggestions.**

Keywords—Game Theory; Public Goods; Ecological Protection

I. INTRODUCTION

The lake is an important freshwater resource, accounting for more than 90% of the surface water resource. China has 24000 natural lakes, whose total area is 8.3 square kilometers. The Dongting Lake, Poyang Lake, Taihu Lake, Hongze Lake and Chaohu are representatives of the five great lakes in China. Lake ecological protection is the focus of the prevention and control of water pollution in China, and it is the key to ensure the safety of drinking water sources. Because there are usually different administrative regions and interest subjects around each of the lake, there are some problems, such as the management system is not smooth, the implementation of responsibility is not sufficient, the development of lakes is excessive, the overall coordination is weak, the investment of lake protection is insufficient, etc. At present, the problem of lake water pollution is very serious in China. The protection work of trans-regional water resources has not made substantial progress, which has been hovering at a low level [1, 2, 3, and 4]. Some experts and scholars attributed these phenomena to regional monroeism, lack of overall situation consciousness, but didn't make in-depth analysis of inherent institutional reasons [5, 6, 7, 8, 9, and 10].

With the perspective of game theory, the more and more serious dilemma of the ecological protection of trans-regional lake water resources is the result of repeated game among the interest subjects around the lake. We view the lake water resources as public goods, and take the ecological protection process of trans-regional lake water resources as the supply process of public goods. According to the economic strength of the administrative regions around a lake, we use the method of game theory to divide the trans-regional lake resources ecological protection activities in China into three types, such as the game between weak regions, the game between strong regions and the game between strong region and weak region, analyze the behavior of the participants in the three games, reveal the dilemma of lake resources ecological protection in China, and put forward the corresponding strategies and suggestions.

II. THE GAME BETWEEN WEAK REGIONS

First, assume that the cost of the ecological protection of lake resources is 4, and income of each region is 3.The relationship that income is lower than the investment reflects the true situation of the weak region, the more investment of ecological protection is, the less enthusiasm the weak region has, the worse profit the weak region has.

We assume that the game has two participants such as weak region A and weak region B, whose strategies are as "positive" and "negative". So, there are four cases as follows.

If both of weak region A and weak region B takes the ecological protection measures, their share of the ecological protection cost is 2, the gross income of weak region is 3; the net income of each weak region is 1. If only the weak region A takes the ecological protection measures, the weak region A will bear all of the ecological protection cost 4, his gross income is 3, and his net income is -1, meanwhile the net income of weak region B is 3. Similarly, If only the weak region B takes the ecological protection measures, the weak region B will bear all of the ecological protection cost 4, his gross income is 3, and his net income is -1, meanwhile the net income of weak region A is 3. If neither of weak region A and weak region B takes the ecological protection measures, then there is no cost of ecological protection, there is no income, the income of each participant is 0.

Based on the above description, the game's payoff matrix is shown in TABLE 1.

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TABLE I. THE GAME'S PAYOFF MATRIX BETWEEN WEAK REGION A AND WEAK REGION B

		weak region B	
		positive	***negative***
weak region A	***positive***	1,1	-1,3
	negative	3,-1	0,0

According to the above game payoff matrix, we discuss the strategy choice of weak region A and weak region B respectively.

First, consider the strategy choice of weak region A in the game between weak region A and weak region B. If weak region B chooses "positive" strategy, then the profit of weak region A in choosing "positive" strategy is 1 and the profit of weak region A in choosing "negative" strategy is 3, the choice of "negative" strategy is optimal reaction of weak region A under weak region B taking "positive" strategy; If weak region B chooses "negative" strategy, then the profit of weak region A in choosing "positive" strategy is -1, and the profit of weak region A in choosing "negative" strategy is 0, the choice of "negative" strategy is optimal reaction of weak region A under team leader taking "negative" strategy. So, no matter what kind of action strategy teacher B chooses, the optimal reaction of weak region A is to choose "negative" strategy. Therefore, the dominant strategy of weak region A is a "negative" strategy in the game between weak region A and weak region B.

By considering the strategy choice of weak region B with the same way as the above, we can know that the dominant strategy of weak region B is also "negative" strategy.

Therefore, the game structure is the classic "prisoner's dilemma" model, which has a pure Nash equilibrium ("negative", "negative"), that is to say, neither of weak region A and weak region B will choose "negative" strategy, although both of weak region A and weak region B choosing "negative" strategy is not conducive to the individual, but also not conducive to the collective. In this game, the weak region A and weak region B fell in the famous "prisoner's dilemma", each of them chose the most advantageous strategy based on their individual rational, however, they finally got a bad result which do harm to both their individual interest and their collective interest.

III. THE GAME BETWEEN STRONG REGIONS

Assume that the cost of the ecological protection of lake resources is 4, and income of each region is 5. The relationship that income is higher than the investment reflects the true situation of the strong region, the more investment of ecological protection, the better profit of strong region.

We assume that the game has two participants such as strong region A and strong region B, whose strategies are as "positive" and "negative". So, there are four cases as follows.

If both of strong region A and strong region B takes the ecological protection measures, their share of the ecological protection cost is 2, the gross income of strong region is 5; the net income of each strong region is 3. If only the strong region A takes the ecological protection measures, the strong region a will bear all of the ecological protection cost 4, his gross income is 5, and his net income is 1, meanwhile the net income of strong region B is 5. Similarly, If only the strong region B takes the ecological protection measures, the weak region B will bear all of the ecological protection cost 4, his gross income is 5, and his net income is 1, meanwhile the net income of strong region A is 5. If neither of strong region A and strong region B takes the ecological protection measures, then there is no cost of ecological protection, there is no income, the income of each participant is 0.

Based on the above description, the game's payoff matrix is shown in TABLE 2.

TABLE II. THE GAME'S PAYOFF MATRIX BETWEEN STRONG REGION A AND STRONG REGION B

		strong region B	
		positive	***negative***
strong region A	***positive***	3,3	1,5
	negative	5,1	0,0

According to the above game payoff matrix, we discuss the strategy choice of strong region A and strong region B respectively.

First, consider the strategy choice of strong region A in the game between strong region A and strong region B. If strong region B chooses "positive" strategy, then the profit of strong region A in choosing "positive" strategy is 3 and the profit of strong region A in choosing "negative" strategy is 5, the choice of "negative" strategy is optimal reaction of strong region A under strong region B taking "positive" strategy; If strong region B chooses "negative" strategy, then the profit of strong region A in choosing "positive" strategy is 1, and the profit of strong region A in choosing "negative" strategy is 0, the choice of "negative" strategy is optimal reaction of strong region A under team leader taking "negative" strategy. So, strong region A has no dominant strategy in this game, whose optimal reaction depends on the strategy chosen by the other side. If strong region B chooses "positive" strategy, then strong region A had better to choose "negative" strategy; if strong region B chooses "negative" strategy, then strong region A had better to choose "positive" strategy.

By considering the strategy choice of strong region B with the same way as the above, we can know that strong region B also has no dominant strategy in this game, whose optimal reaction depends on the strategy chosen by the other side.

Therefore, the game structure is a classic "chicken game" model, which has no pure Nash equilibrium, but has two mixed strategy Nash equilibriums such as (positive, negative) and (negative, positive), that is to say, one side will choose "negative" strategy if the other chooses "positive" strategy, and vice versa.

In the chicken game both of the two sides has no common interests, if one side insists on playing game, the other side is difficult to exit the game, thus generating a dilemma.

Both participants as a rational person, they wish each other to take "positive" strategy, but he takes "negative" strategy, so that he can be free to share the achievements for the other side to invest on the ecological protection.

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At this time, the side, who takes adventure "negative" strategy to win the game, is to establish his happiness on the "pain" of the other side.

However, in the real environment, because strong region has a very strong need for the ecological protection, superior leaders have high expectations on the strong region, the environmental protection requirements of the people in the strong region is also very high, and strong areas have an abundant capital, can invest considerable funds in the ecological protection, strong region will is likely to take the ecological protection measures. So, theoretically mixed strategy Nash equilibrium is often not the real choice in reality.

However, for a region to invest on the ecological protection, if the achievements of ecological protection made by the region are shared by other regions with no charge, the ecological protection enthusiasm of the region will gradually decrease over time. Finally it will make no one to be willing to invest in the protection of lake resources. Hence, the ecological protection of lake resources has become an empty slogan.

IV. The Game between Strong Region and Weak Region

Assume that the cost of the ecological protection of lake resources is 4, and income of strong region is 5, and the income of weak region is 3. The relationship that income is higher than the investment reflects the true situation of the strong region, the more investment of ecological protection, the better profit of strong region. The relationship that income is lower than the investment reflects the true situation of the weak region, the more investment of ecological protection is, the less enthusiasm the weak region has, the worse profit the weak region has.

We assume that the game has two participants such as strong region and weak region B, whose strategies are as "positive" and "negative". So, there are four cases as follows.

If both of strong region and weak region takes the ecological protection measures, their share of the ecological protection cost is 2, the gross income of strong region and weak region are 5 and 3 respectively, the net income of strong region and weak region are 3 and 1 respectively. If only the strong region takes the ecological protection measures, the strong region will bear all of the ecological protection cost 4, his gross income is 5, and his net income is 1, meanwhile the net income of weak region is 3. Similarly, If only the weak region takes the ecological protection measures, the weak region will bear all of the ecological protection cost 4, his gross income is 3, and his net income is -1, meanwhile the net income of strong region is 5. If neither of strong region and weak region takes the ecological protection measures, then there is no cost of ecological protection, there is no the income, the income of each participant is 0.

Based on the above description, the game's payoff matrix is shown in TABLE 3.

TABLE III. The game's payoff matrix between strong region and weak region

		weak region	
		positive	***negative***
strong region	***positive***	3, 1	1, 3
	negative	5, -1	0, 0

According to the above game payoff matrix, we discuss the strategy choice of strong region and weak region respectively.

First, consider the strategy choice of strong region in the game between strong region and weak region. If weak region chooses "positive" strategy, then the profit of strong region in choosing "positive" strategy is 3 and the profit of strong region in choosing "negative" strategy is 5, the choice of "negative" strategy is optimal reaction of strong region under weak region taking "positive" strategy; If weak region chooses "negative" strategy, then the profit of strong region in choosing "positive" strategy is 1, and the profit of strong region in choosing "negative" strategy is 0, the choice of "negative" strategy is optimal reaction of strong region under weak taking "negative" strategy. So, strong region A has no dominant strategy in this game, whose optimal reaction depends on the strategy chosen by the other side. If weak region chooses "positive" strategy, then strong region had better to choose "negative" strategy; if weak region chooses "negative" strategy, then strong region had better to choose "positive" strategy.

Second, consider the strategy choice of weak region in the game between strong region and weak region. If strong region chooses "positive" strategy, then the profit of weak region in choosing "positive" strategy is 1 and the profit of weak region in choosing "negative" strategy is 3, the choice of "negative" strategy is optimal reaction of strong region under strong region taking "positive" strategy; If strong region chooses "negative" strategy, then the profit of weak region in choosing "positive" strategy is -1, and the profit of weak region in choosing "negative" strategy is 0, the choice of "negative" strategy is optimal reaction of weak region under strong taking "negative" strategy. So, the choice of "negative" strategy is a dominant strategy of weak region in this game.

Therefore, the game structure is the classic "boxed pig game" model, which has a pure Nash equilibrium ("positive", "negative"), that is to say, weak region inevitably choice "negative" strategy, and strong region has to choose to "positive" strategy, who acts as the role of "big pig", and bears the responsibility for the ecological protection of lake water resources, and meanwhile weak region freely share the achievements of the ecological protection made by strong region, just like a "little pig" to take the free ride of a "big pig" in "boxed pig game".

As a rational person, weak region has little interest in ecological protection, and has lower enthusiasm. Strong region has greater interest in ecological protection, and has high enthusiasm. Because of his need, strong region has to bear all the responsibility of ecological protection of lake water resources. With no charge, weak region can enjoy the results of ecological protection. It is very common phenomenon for weak region to take a free ride in the early stage of ecological protection. From its own work requirements, strong region has to undertake the responsibility of ecological protection, is

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willing to take measures for ecological protection of lake resources, and also is willing to let weak region take a free ride. However, because there is no reasonable ecological protection compensation mechanism, the achievements of ecological protection made by strong region are shared by weak region for a long time, and without any effective compensation, the ecological protection enthusiasm of strong region will gradually decrease over time. Finally the strong region will also be not willing to invest in the ecological protection. As time passes, the teaching team gradually exists in name only.

V. CONCLUSIONS AND SUGGESTIONS

We have analyzed the behavior of various interest subjects in the process of the ecological protection of trans-regional lake water from the perspective of the supply of public goods, According to the economic strength of the administrative regions around a lake, we applied the method of game theory to divide the lake resources ecological protection activities in China into three types, such as the game between weak regions, the game between strong regions and the game between strong region weak region, analyzed the behavior of the participants in the three games, revealed the dilemma of lake resources ecological protection in China,

Whether a prisoner's dilemma, a chicken game, or a boxed pigs game, it is the result for administrative subjects to make rationally choice under the realistic environment, which is in accordance with the essence of market competition and cooperation.

In order to change the problems that exist in the ecological protection of trans-regional lake resources, we should manage to change the payoff function of the game payoff matrix. For example, government at higher level can take incentive measures to change the profit what participate interest subjects get from the ecological protection, make the Nash equilibrium of game converges to the ideal state of win-win, so as to make the interest subjects have intrinsic motivation to actively participate in the ecological protection. Incentive policies can be encouraging mechanism of the ecological protection, cost sharing mechanism, sharing effect evaluation mechanism, ecological compensation mechanism and so on. Only really arouse the inner motivation of different interest subjects, the noble goal to protect of lake resources, which is good for the whole society, will gradually become a reality.

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