Game Analysis of Establishing Ecological Compensation Mechanism of Mineral Resources Development in China

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Abstract Increasingly serious environmental issue due to mineral resources development essentially peaking is the result of game among interest subjects of ecological system. Ecological compensation as a systematic arrangement between adjusting damage and environment protectors, remains an effective measure of environmental conservation. This paper discussed the interest distribution problem of each part from the perspective of game theory, and builds a game mode of ecological compensation. between protector and compensator The result indicates to solve the problem, our country should build a long—term ecological compensation goal with socialized supervision and evaluation mechanism. Under the condition of clear definition of ecological property rights, ecological system can be optimized through rational evaluation of ecological value and guiding personnel's behaviors.

Key words Game theory; Mineral resources; Ecological compensation; Mechanism

1 Introduction

Large-scale mineral resources development can satisfy national economic constructions, but meanwhile, it brings forth a series of echo-environmental issues. For a long time, China has implemented unbalanced development model as follows. The eastern regions with geographical superiority have preferential policies; while under long-term energy-subsidies, the central and western regions output raw materials to the eastern areas in low prices. Thereby, large-scale mining and irrational resource consumption in the central and western regions are always underway while there is no echo-environmental compensation. In 1980s, China carried out an unsustainable policy called "a mineral should be exploited immediately once discovered". In the guidance of that policy, robbed development of minerals has began, which not only caused huge wastes but also destroyed the echo-environment near minerals. Moreover, a wrong idea that the echo-environment is valueless was prevalent and the ecosystem service value has not been aware of. Thus the eco-system has not been recovered in time with ecological damage scale ever-expanding and ecological damage extent ever-deepening. In the end, local eco-system functions have degenerated or even were lost. In recent years, though several measures of strengthening eco-environment have be adopted to improve ecological situations of mining areas, several indispensable policies are absent in practice. Thereby, ecological benefits and related economic benefits are distributed unfairly between protectors and beneficiaries, between destroyers and sufferers. In other words, twisted ecology situations in China are as follows. Beneficiaries can occupy ecologic benefits without compensations; protectors cannot obtain due economic incentives; destroyers do not have to assume required responsibilities; sufferers cannot get appropriate economic compensations [1]. Ecological compensation is an incentive measure of protecting eco-environment which can adjust the distribution relationships of ecologic benefits and economic benefits while game theory Game theory attempts to mathematically capture behavior in strategic situations, in which an individual's success in making choices depends on the choices of others. Thereby, this paper attempts to explore ecological compensation mechanism of mineral resources exploitation from the perspective of game theory. It then constructs an optional consequence mechanism in order to achieve an optimal ecological system.

2 Ecological Compensation in Terms of Game Theory

Seeing from the viewpoint of economics, ecological compensation is designed to make sure the regions and industries that benefit most from the exploitation of natural resources pay for the damages caused to the environment[2]-[4]. Ecological compensation mechanism can internalize external costs with economic motivation features. The mechanism can, on one hand, improve, maintain and recover the ecology system functions; and on the other hand, it can adjust the distribution relationships of ecologic benefits and economic benefits[5]-[6]. Since tactics and benefits of every party involved are interacting, ecological compensation is a game between each party.

2.1 The concept of game theory

Game theory can be defined as the study of mathematical models of conflict and cooperation between intelligent rational decision-makers. Game theory provides general mathematical techniques for analyzing situations in which two or more individuals make decisions that will influence one another's welfare[7]. One of the principal aims of game theory is to determine the optimum strategy for dealing with a given situation or confrontation. This can involve such goals as maximizing one's gains, maximizing the probability that a specific goal can be reached, minimizing one's risks or losses, or inflicting the greatest possible damage on adversaries. Thereby, ecological compensation analyses based on game theory can reveal the conflict between individual reason and collective reason and help to achieve collective rationality.

Most researches in game theory focus on how groups of people interact and that whether a binding agreement is achieved is essential. There are two main branches of game theory: cooperative and non-cooperative game theory[8]. Non-cooperative game theory deals largely with how intelligent individuals interact with one another in an effort to achieve their own goals while cooperative game theory emphases collective rationality containing efficiency, equity and justness.

Ecological compensation pertains to cooperative game theory, requiring every party's efficiency, equity and justness. However, since ecological system possesses public goods attributes and externality, overdevelopment, market malfunction and hitchhike emerge during ecology system exploitation. Therefore, all parties are likely to face the following problems when picking tactics.

2.2 The Problem of "Chicken Game" in ecological compensation

Mineral resources can be viewed as the game of the overall socio-economic systems and natural ecosystems[9]. Local governments as Game participants seek the goal for maximize public support, whether or not the financial health of the local operating conditions is one of the important indicator .However, when the development of mineral resources increase local tax , it also bring significant effect of negative externalities . Facing the local taxes and the negative external effects brought by the development, local Government will make the decision develop or not. Local governments should strive to seek the transfer of such externalities to maximize their own interests if they want to develop; however, the practitioners whose objective is to maximize profit development will have to decide whether to accept the government's shift. Thus, the key of solution to the "chicken game" is which party burden effects of negative externalities by development.

3 The Game Model of Ecological Compensation

The above analysis shows that the root of problems of ecosystems "chicken game" causes in its individual rationality is not the rational constraints of collective values .Lacking of individual acts of restraint mechanism will result in a lack of active cooperation with scattered individuals and fall into contradiction of individual rationality and collective rationality [10]. From the view of game point, a system or institutional arrangement to be effective must be Nash equilibrium. Therefore, how to give full play to the enthusiasm of stakeholders and to seek best collective interests of the Nash equilibrium solution is the key to solving these problems. Thus, according to the above analysis, we establish a game model.

3.1 The game model

Assumptions in the protecting the environment behavior of returning farmland to forest and pasture, the establishment of ecological and environmental protection zones , X and Y are the two stakeholders in eco-system. According to the principle of "Who compensates when he uses, who pays when he benefits (damages)". As a protector of the environment, X's response to the ecological environment should have two strategies: protection and lacking of protection. As a regional ecological benefit, Y also has two strategies to the ecological environment: compensation and no compensation. Payment matrix formed by X and Y is in Table 1.

In Table 1 of payment matrix, L is a protection strategy chosen by X, the protection of ecological environment; you can get long-term ecological output and basic meet logical growth curve model. $Lt = k / (1 + ae\text{-}bt)$ (Lt said the output of ecological environment in t year, k is the maximum value of Lt, a, b are constants); C_1 is the cost of ecological protection paid by the protector X; S is the short-term gains when protector X select no protection strategy; F_1 is the punishment when the protector X does not protect ecological behavior is found, α is the probability of punishment is discovered; U_1 is external positive effect of ecological enjoyed by Y when X chose ecological protection strategy (U_1 is an increasing function of time ,U_1 increase over time); U_2 is external positive effect of ecological enjoyed

by Y when X chose ecological no protection strategy (U_2 is a decreasing function of time, as time goes by, U_2 decreasing even negative);C_2 is the protector X's compensation of ecological effects compensated by Y; F_2 is the punishment when the behavior of Y does not compensate is found; β is the probability of punishment is discovered.

Let's discuss the solutions of the game under the following two conditions.

3.2 Game solutions

3.2.1 When α and β equal to zero

When the probability of the punishment that Y do not compensate and the probability of the punishment that X do not protect is same, the payoff matrix of two players is showed in Table 2.

Table 1 The Pay-off Matrix of Protector *X* and Compensator *Y*

		Compensator Y of Ecological Compensation	
		compensation	not-to-compensate
Protector *X* of Ecological Environment	protection	$L-C_1+C_2$ U_1-C_2	$L-C_1$ $U_1-\beta\cdot F_2$
	not-to-protect	$S-\alpha\cdot F_1+C_2$ U_2-C_2	$S-\alpha\cdot F_1$ $U_2-\beta\cdot F_2$

Table 2 When *α* and *β* Equal to Zero, the Pay-off Matrix of Protector *X* and Compensator *Y*

		Compensator Y of Ecological Compensation	
		compensation	not-to-compensate
Protector *X* of Ecological Environment	protection	$L-C_1+C_2$ U_1-C_2	$L-C_1$ U_1
	not-to-protect	$S+C_2$ U_2-C_2	S U_2

When $L-C_1>S$, the game's solution is(X, Y) = (protection, not-to-compensate).

When $L-C_1<S$, the game's solution is(X, Y) = (not-to-protect, not-to-compensate).

When $L-C_1=S$, the game has two solutions, namely:

(X, Y)= (protection, not-to-compensate)

(X, Y)= (not-to-protect, not-to-compensate)

The above two solutions, which appears to be a mixed strategy. We suppose that the probability that Protector X protect the environment is X, not protect is $(1-A)$. When Compensator Y choose not to compensate, the expected profit is

$$A\cdot U_1+(1-A)\cdot U_2$$

When the mixed strategy get to Nash equilibrium, the expected profit Compensator Y choose to compensate and the expected profit Compensator Y choose not to compensate should be the same, then we can get

$$A\cdot U_1+ (1-A)\cdot U_2=A\cdot(U_1-C_2) +(1-A)\cdot(U_2-C_2)$$

Thus $A=C_2/0$. Then, the game has no solution, which means that as long as $L-C_1=S$, both parties have no best choice.

From the above solution we can see, as long as the behavior that compensator Y not to compensate and protector X not to protect will not be punished, compensator Y would choose not to compensate in any case. Meanwhile, whether the protector X chooses to protect the environment or not depends on the comparison of $(L-C_1)$ and S. If $(L-C_1)$ >S, Protector X will protect the environment, otherwise, he will not choose to protect the environment.

3.2.2 When α and β are not equal to zero($0<\alpha<1$， $0<\beta<1$)

According to table 1 and Methods of solving solution in game theory, we can obtain

When $\begin{cases} 1>\alpha>\dfrac{C_1+S-L}{F_1} \\ 1>\beta>\dfrac{C_2}{F_2} \end{cases}$, the solution of the game is (X,Y)=(protection, compensation)

When $\begin{cases} 1 > \alpha > \dfrac{C_1 + S - L}{F_1} \\ \dfrac{C_2}{F_2} > \beta > 0 \end{cases}$ the solution of the game is (X,Y)=(protection, compensation)

When $\begin{cases} \alpha = \dfrac{C_1 + S - L}{F_1} \\ \beta = \dfrac{C_2}{F_2} \end{cases}$, no solution or two solutions

The first situation：X chooses to protect the environment, Y chooses to compensate; X choose not to protect the environment, Y choose not to compensate. The two cases, which will appear is a mixed strategy. We suppose the probability that Protector X protect the environment is A, not protect is (1-A), the probability compensator Y choose to compensate is B, not compensate is (1-B).

(1)When Compensator Y choose to compensate, the expected profit is

$$A\cdot(U_1-C_2)+(1-A)\cdot(U_2-C_2)$$

When Compensator Y choose not to compensate, the expected profit is

$$A\cdot(U_1-\beta\cdot F_2)+(1-A)\cdot(U_2-\beta\cdot F_2)$$

When the mixed strategy get to Nash equilibrium, the expected profit Compensator Y choose to compensate and the expected profit Compensator Y choose not to compensate should be the same, then we can get

$$A\cdot(U_1-C_2)+(1-A)\cdot(U_2-C_2) =A\cdot(U_1-\beta\cdot F_2)+(1-A)\cdot(U_2-\beta\cdot F_2)$$

Resolving the equation, we can get:

$$A=(C_2-\beta F_2)/0$$

Then the equation has no solution.

(2) When Protector X choose to protect the environment, the expected profit is

$$B\ (L-C_1+C_2)+(1-B)(L-C_1)$$

When Protector X choose not to protect the environment, the expected profit is

$$B(S-\alpha F_1+C_2)+(1-B)(S-\alpha F_1)$$

When the mixed strategy get to Nash equilibrium, the expected profit Protector X choose to protect the environment and the expected profit Protector X choose not to protect should be the same, then we can get

$$B\ (L-C_1+C_2)\ +\ (1-B)(L-C_1)=B(S-\alpha F_1+C_2)+(1-B)(S-\alpha F_1)$$

Resolving the equation, we can get:

$$B=（C_1+S-L\alpha F_1）/0$$

Then the equation has no solution.

The second situation: X chooses to protect the environment, Y chooses not to compensate; X choose not to protect the environment, Y choose to compensate. The process of solving the mixed strategy and the results are completely same with a.

The third situation: no solution, but still includes the following categories (table 1 and table 2).

When $\alpha=(C_1+S-L)/F_1$, $\beta=C_2/F_2$, no solution.

When $\alpha=(C_1+S-L)/F_1$, $\beta=C_2/F_2$, no solution.

The game has no solution, which means both of the players have not the best choice.

When $\begin{cases} 0 < \alpha < \dfrac{C_1 + S - L}{F_1} \\ 0 < \beta < \dfrac{C_2}{F_2} \end{cases}$,the solution of the game is (X,Y)=(protection, not-to-compensate)

When $\begin{cases} 0 < \alpha < \dfrac{C_1 + S - L}{F_1} \\ \dfrac{C_2}{F_2} < \beta < 1 \end{cases}$ the solution of the game is (X,Y)=(protection, compensation)

According to the solution, as long as the probability of Protector X being punished is $1>\alpha>\frac{C_1+S-L}{F_1}$ and the Punishment F_1 is in line with $F_1>C_1+S-L$, then whether Compensator Y implements ecological compensation, Protector X will definitely choose to protect eco-environment.

As long as the probability of Compensator Y being punished is $1>\beta>\frac{C_2}{F_2}$ and the Punishment F_2 is in line with $C_2>F_2$, then whether Protector X protects eco-environment, Compensator Y will definitely choose to not to carry out ecologic compensations.

In order to guarantee that Protector X protects eco-environment and Compensator Y implements ecological compensation, the following prerequisites should be satisfied. Firstly, the probability of Protector X being punished is $\alpha>\frac{C_1+S-L}{F_1}$ and the Punishment F_1 is in line with $F_1>C_1+S-L$; secondly, the Probability β of Compensator Y being punished is $\beta>C_2/F_2$ and the Punishment F_2 is in line with $F_2>C_2$.

That is to say, only when

$$\begin{cases}\alpha>\dfrac{C_1+S-L}{F_1}, F_1\geq C_1+S-L\\ \beta>\dfrac{C_2}{F_2}, F_2\geq C_2\end{cases}$$

Protector X will protect the eco-environment and Compensator Y will implement ecological compensations.

Therefore, a sound consequence mechanism is center to an ecological compensation mechanism, and then Protector X will be punished if he does not protect eco-environment and Compensator Y will get punished if he does not implement ecological compensations. At the meantime, the Probability α of Protector X being punished meets $\alpha>(C_1+S-L)/F_1$ and the Punishment F_1 is in line with $F_1>C_1+S-L$; the Probability β of Compensator Y being punished is $\beta>C_2/F_2$ and the Punishment F_2 is in line with $F_2\geq C_2$.

Since the Probability α, the Probability β, the Punishment $F_1$and the Punishment F_2 rely on the followings: S, which is a short-term gain when Protector X chooses not to protect the environment; L, which is a long-term gain when Protector X chooses to protect the environment; C_1, which is the cost of protecting the eco-environment; C_2, which is the ecological compensation. Meanwhile, L is the function of eco-environment input. In long run, L is determined by the local economic development level and self-development ability; the decrease of C_1 is dependent on the improvement of input conversion rate, which is the result of technology advancement. C_2 is the evaluation of eco-environment value when property rights are defined clearly.

4 Conclusions and Suggestions

According to the above analysis, ecological compensation for mineral resources development should establish long-term environmental protection investment mechanisms, which rely on four parameters S, L, C_1 and C_2, namely China's ecological compensation should establish long-term goals and social supervision and evaluation mechanisms, and reasonably evaluate the value of eco-environment on the premise of clearly defined property rights.

4.1 Clarifying the property rights of ecosystem services

The principle "compensate for use and pay for benefit" is a re-balancing institutional arrangement based on rights, obligations and responsibilities among many stakeholders. However, nowadays China's laws and regulations related to ecological protection and ecological construction haven't make explicit stipulations on whom to make the compensation and whom to receive it, also specific rights and obligations in eco-environment are limited to principle norm, as a result, stakeholders cannot define their relationship among responsibilities, rights and profits in eco-environmental protection by law, and the goal that change ecological compensation from compulsory to voluntary is difficult to achieve according to rewards and punishment mechanisms. Therefore, to change the current situation of "virtual" natural resources ownership and unclear property right, we should define property rights in natural environment and ecological field in a creative way, further improve ownership system, strictly define ownership, management right as well as development and use right, change promotion reliance on administrative pattern and so on. Ownership must be effective in a long enough time period, so the

owner would be concerned with the conservation and sustainable use of natural resources and output improvement in ecological benefits, for protracted nature changes resources into producer' s assets, which can bring benefits from the investment to improve and maintain resources productivity.

4.2 Strengthening study on method of value-based ecosystem services

To solve the contradiction between individual rationality and collective rationality in ecosystem, rewards and punishment system should be introduced into the construction of ecological compensation rewards and punishment mechanisms. How to define ecological compensation standard and rewards and punishment volume scientifically are core of whether ecological compensation mechanisms can be implemented effectively or not. To determine compensation standard by the value of ecosystem services is more reasonable in fairness and science. However, achievements in value-based ecosystem services are difficult to provide evidences for the development of ecological compensation standards in the short term, subject to such factors as availability of current achievements in the value of ecosystem services and so on. Therefore, making ecological compensation standards by opportunity cost is still a first choice in the near future. Since opportunity cost not only related to regional eco-environment, but also change with economic development, namely opportunity cost has dynamic feature. However, corresponding scientific research and data accumulation is still lacking at present. Therefore, the key of strengthening research in valued-based ecosystem services is to overcome technical problems (value-based method mainly) and improve the science and rationality of ecological compensation standard making.

4.3 Establishing third-party supervision and evaluation institutions

For a long time, China's eco-environment construction implements that higher authorities of the department supervise and evaluate the work of lower authorities, thus effective supervision and evaluation of ecological environment construction by independent third-party supervision and evaluation institutions are lacking, so there are differences between supervision and evaluation results and actual situation, which lead rewards and punishment mechanism to lose practical significance. The main defects are such problems as targets distortion, inaccurate of evaluation and supervision standards, neglect of heterogeneity and so on, caused by starting from departmentalism. To ensure the fairness and rationality of ecological compensation policies and effectively implementation of rewards and punishment mechanisms, it's necessary to establish a socialized team of ecological compensation policy supervision and evaluation institutions. The team can either be reformed from some scientific research institutions, or evolves from some non-profit environmental protection organizations, whose basic qualification requirements is that its members should be multidisciplinary professionals, so that omnidirectional evaluation can be conducted on eco-environment benefits, economic benefits and social benefits. Meanwhile, relevant policies should be draw to regulate that all future acceptances, daily maintenance and so on of eco-environment construction projects be conducted by third-party independent supervision organizations. Third-party independent supervision institutions can not be administrative affiliation of executors and vindicators of project construction, so as to ensure the fairness of supervision and evaluations as well as the effective implementation of rewards and punishment mechanisms.

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