Game Analysis on Ecological Compensation of Coal Resource in Jinzhong City

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Abstract. By using the game theory analysis method, this paper respectively from the perspective of compensation subject and compensation object, research on ecological compensation the stakeholders of the government, coal enterprises and residents, and analyzes the ecological compensation strategy choice and interest appeal of the three. Further exploration of the internal relationship between the three and the conclusion that the heavy penalty is better than the diligent supervision and high fees, the compensation net income is greater than the compensation cost and the compensation guarantee should be appropriate. In order to achieve sustainable progress of resources, environment and economy, accelerate the implementation of the scientific concept of progress, ecological compensation for coal resource progress has become an inevitable choice.

Keywords: Coal resources, Ecological compensation, Game.

1. Introduction

After long-term unreasonable mining, the ecological environment of the coal mining area in Jinzhong City has been seriously damaged, accompanied by serious water pollution, huge area of goaf, frequent geological disasters, desertification of land, declining cultivated land, and serious air pollution. The emergence of a series of ecological problems, the reduction of ecological carrying capacity, group incidents and social contradictions are also increasing. Therefore, the establishment and improvement of the ecological compensation mechanism of coal resources as soon as possible has become an urgent task for the sustainable development of Jinzhong City. It is already very important for improvement and protection. The fragile ecological environment has important practical significance.

2. Establishment of Ecological Compensation Game Model for Mineral Resources Development

1 Establishing a game model from the perspective of compensation subjects
(1)Game Model between Government and Coal Enterprises
Model description:In the coal ecological compensation mechanism, the government, as one of the compensation subjects, has certain compensation standards, collects compensation fees, and supervises the responsibility of enterprises; while coal enterprises, as part of the profitability, must pay compensation fees on time, improve equipment, improve efficiency, and reduce Pollution. Therefore, in order to reduce costs, enterprises should pay less compensation fees and reduce pollution. The government, as a public sector, represents the interests of the people and supervises coal enterprises, prompting enterprises to reduce pollution and protect the ecological environment. Therefore, the game between the two in the ecological compensation mechanism is generated.

Propose assumption:There are only two participants in the game: the government regulates and does not supervise the coal enterprises, and the coal enterprises implement pollution and non-polluting. When the information is complete, one party knows the other 's strategy, but does not know what action to take, participants. The payment is: the government's supervision is effective, regardless of the results of the supervision, and the cost is fixed, if the pollution is found, the fine is charged; if it is not regulated, the cost is 0. The compensation fee of the enterprise is fixed. If the government supervises and the enterprise is not polluted, the enterprise cost will not increase; if the government supervises and the enterprise pollutes, the penalty is added in addition to the compensation; if the

government does not supervise The cost of pollution and non-staining is only a fixed compensation fee. It is also assumed that the coal enterprise should pay the compensation fee A, the benefit before the payment is B, the environmental pollution penalty is C, and the government supervision cost is D. And the cost of supervision is less than the sum of the compensation payable and the fine of violation, that is, D < (A + C), otherwise the government will abandon supervision because of the high supervision cost, and build the game income matrix of the government and coal enterprises (Table 1)

Table 1. Game revenue matrix of government and coal enterprises

Government \ Enterprise	Pollution		No pollution	
Regulated	A+C-D	B-A-C	A-D	B-A
Not regulated	0	B	A	B-A

Model Equilibrium Strategy and Analysis:It can be seen from the above table that there is no pure strategy Nash equilibrium in the game (under the given information, the participant can only select a uniquely determined strategy in his policy space, and this strategy is the best strategy) because the government is assumed Choosing regulation, and the best choice for enterprises is not pollution; while the government chooses not to supervise, the best choice for enterprises is pollution; as far as enterprises are concerned, if enterprises choose pollution, the best choice for the government is supervision; Pollution, the government's best choice is not to regulate. Therefore, there is a mixed strategy Nash equilibrium in the game.Assume that the government supervises the probability of p , the probability of 1-p is not regulated; the probability of pollution of coal enterprises q , the probability of 1-q is not polluted, according to the above income matrix, the income when the enterprise chooses two different strategies is calculated.

The benefits of the company's choice of pollution are: $p < p^*$

The benefits that companies choose not to pollute are: $p(B-A)+(1-p)(B-A)$

According to the hybrid strategy Nash equilibrium principle, it is necessary to ensure that the benefits of each strategy selected by the enterprise are equal.

Then: $p(B-A-C)+(1-p)B = p(B-A)+(1-p)(B-A)$

Solving: the government's equilibrium supervision probability: $p^* = \dfrac{1}{1+\dfrac{C}{A}}$

When the government's regulatory probability $p > p^*$, the company's best strategy is not pollution; when the government's regulatory probability $p < p^*$, the company's best strategy is pollution, when the government's regulatory probability $p = p^*$, the company randomly chooses whether to pollute or not. It can be seen that the heavier the pollution penalty of the enterprise, the smaller the government's supervision may be; the higher the compensation payable by the enterprise, the higher the government's supervision rate.

on the other hand:

The government's choice of regulatory revenue is: $(A+C-D)q+(1-q)(A-D)$

The government's choice of non-regulatory benefits is: $0+(1-q)A$

The two benefits are equal, the probability of solving corporate pollution:

$$q^* = \frac{D}{C+A}$$

It can be known that when the company's pollution probability $q > q^*$, the government's best strategy is supervision; when the company's pollution probability $q < q^*$, the government's best

strategy is not to regulate; when the company's pollution probability $q = q^*$, the government will randomly choose to monitor or not. It can be seen that the pollution of enterprises is related to three variables: the government's supervision costs, the fines at the time of pollution, and the compensation fees of enterprises. The higher the government's regulatory cost, the higher the pollution rate of the enterprise; the heavier the pollution penalty, the lower the pollution rate of the enterprise; the higher the compensation payable by the enterprise, the lower the pollution rate of the enterprise.

(2)Game model between coal enterprises

Model Description: As one of the main bodies of ecological compensation, coal enterprises have a game and equilibrium because of the eternal contradiction between the pursuit of economic interests and ecological interests. Based on this, a game model is established.

Propose assumption:The economic benefit of two coal enterprises isα_1 , the ecological compensation cost is β, the economic benefit after ecological compensation is α_2, andα_2>β , that is, the economic benefit after compensation must be greater than the compensation cost, otherwise the compensation cost will be too high. To make the company abandon compensation, so build a game income matrix between enterprises (Table 2)

Table 2. Game income matrix between coal enterprises

A enterprise / B enterprise	compensation		no compensation	
compensation	α_1-β+α_2	α_1-β+α_2	α_1	α_1-β
no compensation	α_1-β	α_1	α1	α1

Model Equilibrium Strategy and Analysis: According to the results, there are two Nash equilibrium points, namely (compensation, compensation) and (no compensation, no compensation), and obviously the second strategy will benefit more than the first strategy, but the two coal enterprises are not completely opposite. The state of one party's gains will be damaged by the other party's non-compensation, so this is a non-zero-sum game; and in real life, because of the different missions and positioning of the enterprise and the complex external integrated environment, although they are all profitable For the purpose, but the actual choices will be different, some companies will choose compensation, some companies will choose not to compensate, so we can only use limited rational decision-making, so in order to pursue "win-win" or "win-win", will be limited Rational copying dynamics [in a group consisting of bounded rationality (the level of rationality can be very low), the strategy with better results than the average level will gradually be adopted by more players, so that the players in the group adopt various strategies. The ratio will change.]and evolutionary stability strategies.

For the coal enterprise group, the game can be played by means of random matching of members. Assume that the proportion of enterprises that choose compensation in the same mining area is M, and the proportion of enterprises that use non-compensation is(1-M), then the benefits of compensation and non-compensation are:

$$U = M\left(\alpha_1 - \beta + \alpha_2\right) + \left(1 - M\right)\left(\alpha_1 - \beta\right)$$
$$V = M\alpha_1 + \left(1 - M\right)\alpha_1$$

Average expected return of the entire coal enterprise group

$$U_{平均} = MU + \left(1 - M\right)V$$

It can be seen that the replication dynamic equation of the symmetric game

$$F\left(M\right) = \frac{dm}{dt} = m\left(U - U_{平均}\right) = M\left(1 - M\right)\left(M\alpha_2 - \beta\right)$$

Taking into account the situation, $\frac{dm}{dt} = 0$,Then got 3 solutions:

$$M = 0, M = 1, M = \frac{\alpha_2}{\beta}$$

Tue to: $F'(0) < 0, F'(1) < 0, F'\left(\frac{\alpha_2}{\beta}\right) < 0$ .According to the stability theory of differential equations,

both M=0 and M=1 are evolutionary stability strategies of the game, and when, $M = \frac{\alpha_2}{\beta}$ they are not

stable strategies.

Assuming that the probability of the two strategic equilibrium adopted by coal enterprises in the initial game falls at the same point at any point in the (0,1) interval, the possibility of better strategic

equilibrium (compensation, compensation) through replication dynamics is $1 - \frac{\alpha_2}{\beta}$,The chance of

achieving (no compensation, no compensation) poor strategy equilibrium is $\frac{\alpha_2}{\beta}$, so which strategy is

ultimately adopted is determined according to the size of β and α_2. At that time, $0 < \frac{\alpha_2}{\beta} < \frac{1}{2}$,the

(compensation, compensation) strategy takes precedence. At that time, $\frac{1}{2} < \frac{\alpha_2}{\beta} < 1$, (no compensation,

no compensation) The strategy is prioritized. At the time, $\frac{\alpha_2}{\beta} = \frac{1}{2}$ the priorities of the two strategies

were the same. This shows that to obtain a higher-yield (compensation, compensation) Nash equilibrium, on the one hand, we must strive to reduce the ecological compensation costs of enterprises, on the other hand, we must improve the economic benefits after compensation and increase the net income after compensation.

2 Establishing a game model from the perspective of compensation object

Game Model between Coal Enterprises and Residents in Mining Areas

Model Description: According to the definition of ecological compensation, the residents of the mining area are the objects of compensation. On the one hand, residents have abandoned supervision and protection because of the many benefits of coal development; on the other hand, they need to protect their own land in consideration of their own life and their generations; and coal enterprises need to make corresponding compensation, and the cost of ecological compensation will Directly increase costs and weaken the market competitiveness of enterprises, so less compensation or no compensation is the best choice for enterprises. Based on this, between the compensation and non-compensation, the residents begin the game between protection and non-protection.

Propose assumption: Assume that the residents are completely rational, and take the behavior of maximizing their own interests. The ecological compensation cost of the coal enterprise is set to C_1, the income before compensation is O_1, and the ecological protection cost of the mining area is C_2, the unprotected income. For O_2, only if both parties work together to obtain eco-efficiency E, and $E > (C_1 + C_2)$, only when the benefits of ecological compensation are greater than all costs, enterprises and residents will not give up compensation because they lose more than they lose. Protection, when unilateral efforts, the ecological benefit is 0, and the cost of one party will become the income of one party, and the income matrix between the coal enterprise and the residents of the mining area will be constructed. (table 3)

Table 3. Game income matrix of coal enterprises and mining area residents

Resident / Enterprise	protection		No protection	
Compensation	O_1-C_1+E	O_2-C_2+E	O_1-C_1	O_2-C_1
No compensation	O_1+C_2	O_2-C_2	O_1	O_2

Model Equilibrium Strategy and Analysis: According to the table, there are two Nash equilibrium points, namely (compensation, protection) and (no compensation, no protection), while the former is significantly more profitable than the latter, but the benefits of ecological compensation are difficult to achieve in the short term, so this matrix The game is ineffective, so you need to build a short-term return matrix (Table 4).

Table 4. Short-term game return matrix of coal enterprises and mining area residents

Resident / Enterprise	protection		No protection	
Compensation	O_1-C_1	O_2-C_2	O_1-C_1	O_2-C_1
No compensation	O_1+C_2	O_2-C_2	O_1	O_2

Model Equilibrium Strategy and Analysis: At this time, the only Nash equilibrium appeared in the table, that is (not compensated, not protected), which shows that enterprises and residents are arguing with each other, in order to maximize their own interests and neglect the ecological benefits, which leads to Shanxi Province. A series of ecological problems have emerged.

3. Conclusion

Based on the above game results, the following conclusions are drawn:

(1) Heavy penalties are better than diligent supervision and high fees. Through the analysis of the game results of the government and coal enterprises, the heavier the pollution punishment of enterprises, the smaller the government's supervision may be; the higher the compensation payable by enterprises, the higher the government's supervision rate. The higher the government's regulatory cost, the higher the pollution rate of the enterprise; the heavier the pollution penalty, the lower the pollution rate of the enterprise; the higher the compensation payable by the enterprise, the lower the pollution rate of the enterprise. Generally speaking, the heavier the penalties of enterprises, the lesser the government's supervision, and the lower the pollution rate of enterprises. Less government regulation, lower regulatory costs, and lower corporate pollution probability will help improve the effectiveness of ecological compensation.

(2) Ensure that the net compensation income is greater than the compensation cost. For the government, the cost of supervision is less than the sum of the compensation payable and the fine for violation, that is, $D<(A+C)$. Otherwise, the government will give up supervision because the supervision cost is too high; for coal enterprises, $\alpha_2>\beta$, That is, the economic benefit after compensation must be greater than the compensation cost. Otherwise, the enterprise will give up compensation because the compensation cost is too high. For the game between enterprises and residents, $E>(C_1+C_2)$, only when the ecological compensation income is greater than all When the cost is paid, the enterprise and the residents will not give up compensation and protection because they are not worth the loss.

(3) The guarantee of compensation should be appropriate. The compensation costs involved in the enterprise and the protection behavior of the residents. In the game analysis between coal enterprises, it can be seen that although enterprises choose actions that maximize their own interests, due to the complex external environment, enterprises choose limited rational behavior, which is determined by the size of β and α_2. That is, the cost of compensation and the actual benefits after compensation.

When $0<\alpha/2\beta<1/2$, the (compensation, compensation) strategy takes precedence. Therefore, in order to improve the compensation enthusiasm of the enterprise, the compensation standard should be appropriately determined. Otherwise, the enterprise will increase the economic burden because the compensation cost is too high. Reduce compensation behavior. However, if the standard is too low, it will not be able to compensate. For residents, high compensation fees may weaken their sense of self-protection. By establishing reasonable compensation standards, mutual cooperation between enterprises and residents can be achieved. Supervision and coordination.

Acknowledgments

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