An Evolutionary Game Analysis on the Ecological Poverty Alleviation Industry

Haoyue Peng¹, Yao Xing^{1,*}

¹School of Business Administration, Shanxi University of Finance and Economics, Taiyuan, China

Abstract. Ecological poverty alleviation is a new idea that combines environmental protection and poverty alleviation, and the ecological industry poverty alleviation is an important part of it. The ecological poverty alleviation industry involves multiple bodies. Since different bodies have different strategic choices, there is a complex game relationship between them. From the perspective of evolutionary game, this article explores the game situation between local government and enterprises in the ecological poverty alleviation industry, and puts forward corresponding policy recommendations based on the results of game analysis.

1 Introduction

Ecological poverty alleviation, as a new way of poverty alleviation, links environmental protection in poverty-stricken areas with poverty alleviation and development. Compared with the traditional poverty alleviation model, ecological poverty alleviation organically combines poverty alleviation and environmental protection, which not only meets people's need to get rid of poverty, but also meets people's desire to protect the environment. It focuses on sustainable development, and it is a new way to help poor people get rid of poverty in a green way.

Ecological poverty alleviation methods include ecological compensation for poverty alleviation, poverty alleviation migration and ecological industry poverty alleviation, etc [1, 2]. Industry is the foundation and support for poverty alleviation. Industry can promote regional economic development. Stable industry support is an important guarantee for poverty alleviation [3]. Therefore, eco-industry poverty alleviation is one of the best ways to help the poor get rid of poverty. However, eco-industry poverty alleviation involves many different main bodies, for example, local governments and enterprises. And there are complex competition and cooperative relationships among the different bodies. In the actual poverty alleviation work, the central government is responsible for the top-level design in the poverty alleviation work, and the specific implementation depends on the local governments. However, some local governments have perfunctory attitudes. They may do not actively supervise poverty alleviation enterprises, do not care if the enterprises are actually involved in poverty alleviation, or only rely on the enterprises' conscious efforts to promote poverty alleviation and development. These behaviours have a negative effect on poverty alleviation and development. As far as poverty alleviation enterprises, because the ecological poverty alleviation model is still in the

exploratory stage and the management mechanism is not perfect, it is often the case that enterprises use projects to defraud poverty alleviation funds, or cannot actively participate in poverty alleviation projects [4]. Therefore, for the central government, how to make reasonable planning to help local governments and poverty alleviation enterprises to work together for poverty alleviation industry is very important. Based on these issues, this paper will use the evolutionary game method to research the game behaviour of the two main bodies and give corresponding policy recommendations.

2 Evolutionary game model between local government and poverty alleviation enterprises

2.1 Model assumption

In the evolutionary game model, the two bodies are limited rational local government and poverty alleviation enterprises. Under the condition of bounded rationality, the two bodies often cannot find their own optimal strategies from the beginning, but adjust their own strategies based on experience. The system composed of the two main bodies evolves on its own, and reaches the final game equilibrium through constant trial and error.

The strategies of local government are active supervision and negative supervision. The active supervision strategy mainly refers to punishing the poverty alleviation enterprises which have cheated compensation behaviours, and punishing the enterprises that have insufficient project operations. The negative supervision strategy mainly refers to the fact that the government does not intervene in whether poverty alleviation enterprises implement ecological poverty alleviation. The strategies of poverty alleviation enterprises are active poverty alleviation and negative

* Yao Xing: xingyao25@qq.com

poverty alleviation. Active poverty alleviation refers to the construction of production bases in strict accordance with project investment budgets, earnestly operating and managing industrial poverty alleviation projects, actively carrying out green technological innovations, and actively adapting to the new situation of poverty alleviation. Negative poverty alleviation refers to the fact that the actual investment of the enterprise is less than the nominal investment, the investment in the operation and management of the project is not enough, technical improvement is not carried out, and it is not actively adapted to the changing poverty alleviation situation [5]. Combining the actual situation and the above assumptions and drawing on previous related researches [6, 7], it is assumed that the probability ratio of local government adopting active supervision strategy is x , and the probability ratio of enterprise adopting active poverty alleviation strategy is y . The relevant parameters as follows in table 1.

Table 1. Nomenclature

Parameters	
A	The benefits of choosing an active supervision strategy to the local government.
B	The benefits for the enterprises when the local government chooses the active supervision strategy.
P	The basic benefits obtained when the government chooses the negative supervision strategy.
Q	The basic benefits for the enterprises when the local government chooses the negative supervision strategy.
K	The cost of active supervision.
L	The cost of active poverty alleviation.
M	Psychological loss of enterprises in active poverty alleviation under negative government supervision.
N	Indirect benefits obtained by enterprises when the government actively supervises.

2.2 Model framework

Based on the model assumptions, the payoff matrix for both players is shown in table 2.

Table 2. Payoff matrix

		Enterprises	
		Active poverty alleviation	Negative poverty alleviation
Local government	Active supervision	$(P+A-K, Q+B-L+N)$	$(-K, N)$
	Negative supervision	$(P, Q-M-L)$	$(0, 0)$

In this case, the expected income of the local government choosing the active supervision strategy is E_1 , the expected income of choosing the negative supervision strategy is E_2 , and the average income of the local government is E :

$$E_1 = y(P+A+K) + (1-y)(-K) \quad (1)$$

$$E_2 = yP \quad (2)$$

$$E = xE_1 + (1-x)E_2 \quad (3)$$

Therefore, local government's replicator dynamic equation is as follows:

$$F(x) = dx/dt = x(E_1 - E) = x(1-x)(yA - K) \quad (4)$$

The expected income of the enterprises choosing the active poverty alleviation strategy is U_1 , the expected income of choosing the negative poverty alleviation strategy is U_2 , and the average income of the enterprises is U :

$$U_1 = x(Q+B-L+N) + (1-x)(Q-M-L) \quad (5)$$

$$U_2 = xN \quad (6)$$

$$U = yU_1 + (1-y)U_2 \quad (7)$$

Enterprises' replicator dynamic equation is as follows:

$$R(y) = dy/dt = y(U_1 - U) = y(1-y)[(B+M)x + Q - L - M] \quad (8)$$

2.3 Model analysis

According to the equation (4) and equation (8), the first derivative of $F(x)$ and $R(y)$ are as follows:

$$F'(x) = dF(x)/dx = (1-2x)(yA - K) \quad (9)$$

$$R'(y) = dR(y)/dy = (1-2y)[(B+M)x + Q - L - M] \quad (10)$$

Firstly, for the local government, observing the equation (4), $x=0$, $x=1$ and $y=K/A$ are the roots of $F(x)=0$. And then, based on the stability theorem, if $F(x)=0$, $F'(x) \leq 0$, x will be the evolutionary stable strategy (ESS).

If $y=K/A$, then for any x , $F(x)=0$, $F'(x)=0$. In this situation, axis x is in a stable state. It is shown that when the enterprises actively alleviate poverty at the level of $y=K/A$, there is no difference in the benefits of the local government's choice of active supervision or negative supervision strategies. At this time, for all x , it is the stable state of the local government. When $y < K/A$, $F'(x=1) > 0$, $F'(x=0) < 0$, $x=0$ is the only ESS. This shows that when enterprises actively alleviate poverty at a level lower than $y=K/A$, local government gradually shift from an active supervision strategy to a negative supervision strategy. On the contrary, when $y > K/A$, $F'(x=1) < 0$, $F'(x=0) > 0$, $x=1$ is the only ESS. That means when enterprises actively alleviate poverty at a level higher than $y=K/A$, local government gradually shift from a negative supervision strategy to an active supervision strategy. And the active supervision strategy becomes a stable strategy of the local government in this situation.

Secondly, for the enterprises, from the equation (8), $y=0$, $y=1$, $x=(L+M-Q)/(B+M)$ are the roots of $R(y)=0$.

If $x=(L+M-Q)/(B+M)$, for any y , $R(y)=0$, $R'(y)=0$, all the y are in the stable state. It means that when the local government chooses the active supervision strategy at the level of $x=(L+M-Q)/(B+M)$, there is no difference in the benefits of the enterprise choosing to conduct ecological compensation or not to conduct ecological compensation. Similarly, when $x < (L+M-Q)/(B+M)$, $R'(y=0) < 0$, choosing a negative poverty alleviation strategy is a stable strategy for the enterprises. And when $x > (L+M-Q)/(B+M)$, $R'(y=1) < 0$, active poverty alleviation becomes the stable strategy for the enterprises.

3 Simulation analysis

In order to show the evolution trend more intuitively, this chapter will conduct numerical simulation analysis, and show the influence of different parameter changes on the evolution trend.

3.1 Influence of initial x , y

In order to research the influence of different x , y on the evolution result, this article first determine the values of other parameters. The initial values of parameters are shown in table 3.

Table 3. Values of parameters

P	Q	K	L	M	N	A	B
1	2.5	3	2	3	1	5	3

Set $x=0.3$, the values of y as 0.15, 0.3, 0.45, 0.6, 0.75, 0.9, the evolution trend of y is shown in figure 1. And set $x=0.9$, the values of y as 0.15, 0.3, 0.45, 0.6, 0.75, 0.9, the evolution trend of y is shown in figure 2.

Fig. 1. Evolution trend of y when $x=0.3$

Fig. 2. Evolution trend of y when $x=0.9$

From the figure 1 and figure 2, obviously, when the initial probability of the government's active supervision is greater, the enterprises' behaviour will be evolved into an active poverty alleviation state.

3.2 Influence of Q

Set the values of x as 0.15, 0.3, 0.45, 0.6, 0.75, 0.9, $y=0.5$, the values of Q as 2 and 4, and other parameters are consistent with table 3. The influence of different Q on the evolution result of x are shown in figure 3 and figure 4.

Fig. 3. Evolution trend of x when $Q=2$

Fig. 4. Evolution trend of x when $Q=4$

Figures 3 and figure 4 show that when Q increases, even if the local government chooses negative supervision, because the enterprises gain enough benefits to insist on active poverty alleviation, it will also affect the local government, and eventually the local government will tend to choose an active supervision strategy.

3.3 Influence of A

Set $x=0.5$, the values of y as 0.15, 0.3, 0.45, 0.6, 0.75, 0.9, the values of A as 4 and 10, and other parameters are consistent with table 3. The influence of different A on the evolution result of y are shown in figure 5 and figure 6.

Fig. 5. Evolution trend of y when $A=4$

Fig. 6. Evolution trend of y when $A=10$

With the benefits of active supervision by local government increase, local government are more willing to choose active supervision strategy. Figure 5 and figure 6 state that in this situation, under the influence of local government, the strategic choices of enterprises will be gradually evolved into active poverty alleviation.

4 Conclusion

This article studies the evolutionary game situation of the two main bodies of local government and enterprises in ecological poverty alleviation, and finds that enterprises' willingness for active poverty alleviation depends on the proportion of local government's active supervision and the benefits of local government's active supervision. Similarly, the government's willingness to actively supervise may also be related to the benefits of enterprises.

Based on this, the following suggestions should be considered: Firstly, the local governments should raise the willingness of supervision. From game results, when the probability of government's active supervision is high, enterprises will choose the active poverty alleviation strategy. Secondly, improving the quality of poverty alleviation industries is necessary. According to game analysis, it is shown that increasing the benefits of enterprises' ecological poverty alleviation will greatly

increase the enthusiasm of enterprises to participate in poverty alleviation. And increasing the income of local governments supervision will increase the probability of enterprises to participate in poverty alleviation as well. When the quality of the industry improves, both the two benefits will rise. Therefore, in order to improve the quality of ecological poverty alleviation, the enterprises and the local governments should set up a strict evaluation standard system to objectively evaluate the results of poverty alleviation.

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