

## Research Article

# Analysis of Smooth Implementation of Industry Poverty Alleviation considering Government Supervision

Haifeng Yao <sup>1</sup> and Jianguye Fu<sup>2</sup>

<sup>1</sup>Department of Business Administration, Chongqing College of Finance and Economics, Chongqing, China

<sup>2</sup>Department of Management, Guizhou University, Guiyang, China

Correspondence should be addressed to Haifeng Yao; yhf1533@163.com

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Vigorous implementation of industrial poverty alleviation is the fundamental path and core power of poverty alleviation in impoverished areas. Enterprises and poor farmers are the main participants in industry poverty alleviation. Government supervision measures regulate their behaviors. This study investigates how to smoothly implement industry poverty alleviation projects considering government supervision. A game model is proposed based on the evolutionary game theory. It analyses the game processes between enterprises and poor farmers with and without government supervision based on the proposed model. It is shown that poverty alleviation projects will fail without government supervision given that the equilibrium point  $(0, 0)$  is the ultimate convergent point of the system but will possibly succeed with government supervision since the equilibrium points  $(0, 0)$  and  $(1, 1)$  are the ultimate convergent point of the system, where equilibrium point  $(1, 1)$  is our desired results. Different supervision modes have different effects on the game process. This study considers three supervision modes, namely, only reward mode, only penalty mode, and reward and penalty mode, and investigates the parameter design for the reward and penalty mode. The obtained results are helpful for the government to develop appropriate policies for the smooth implementation of industry poverty alleviation projects.

## 1. Introduction

Poverty is a permanent problem in human history. China, the largest developing country in the world, has a severe poverty problem. Nevertheless, after decades of great effort, China is the first country to achieve the United Nations Millennium Development Goal, reducing the people living in poverty by half [1, 2].

Poverty alleviation methods are mainly divided into two categories: inclusive poverty alleviation and targeted poverty alleviation, as shown in Figure 1, in which industry poverty alleviation is the fundamental method to eliminate poverty. Industry poverty alleviation is market- and economy-oriented. It aims to establish and breed a characteristic agriculture industry project through accurate selection and support of leading enterprises, promoting the development of poverty areas and increasing farmers' income. The main

participants in industry poverty alleviation are enterprises and poor farmers, constructing the long-term benefit connection mechanism.

The production of agricultural products with regional characteristics or geographical indications by playing the advantages of geographical resource endowment and developing characteristic industries is critical to implement industry poverty alleviation. Implementation has multiple forms, such as scale agriculture, featured industries, and small farmer production. The development of scale agriculture and featured industries is the main form, and the development of small farmer production is an important complement. The specific poverty alleviation mode includes "key enterprises+," "agricultural cooperatives+," "resource industries+," "financial institution+," and "tourism resources+." However, given the spatial differences in the distribution of agricultural resources, industry poverty

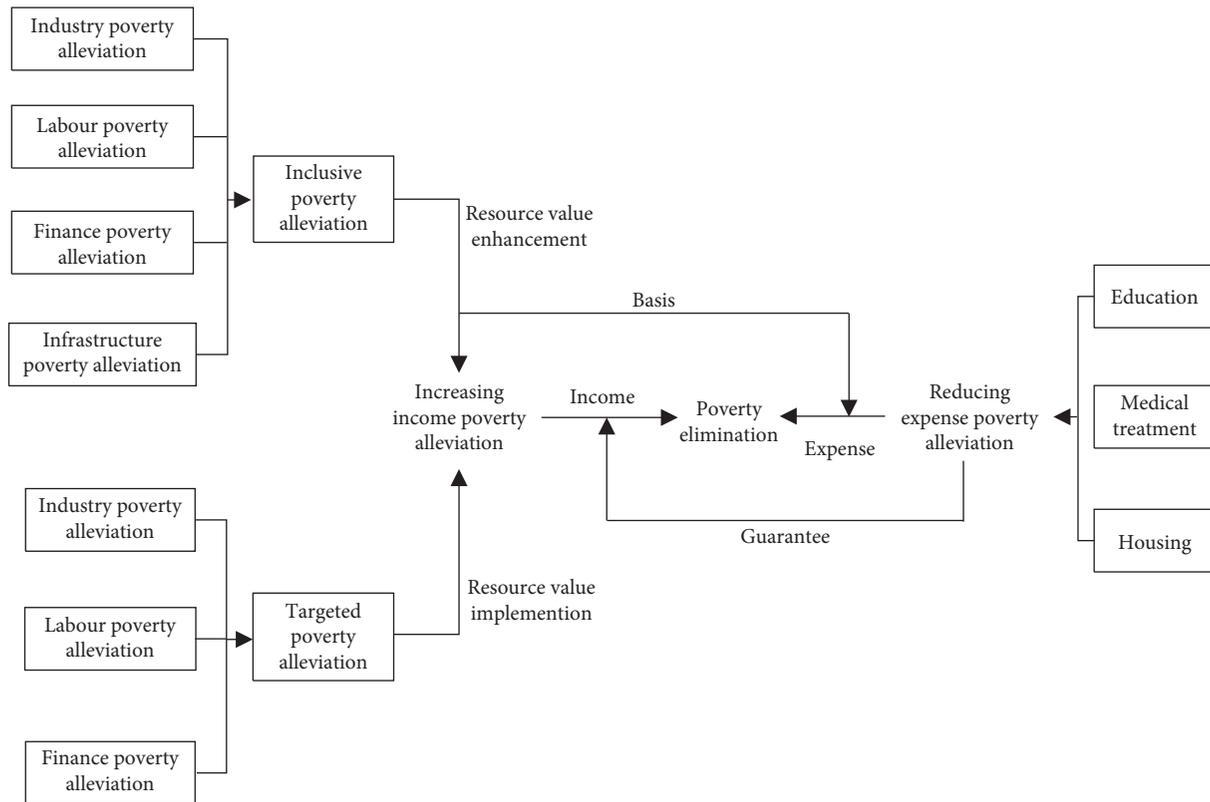


FIGURE 1: Common poverty alleviation methods.

alleviation possesses a strong regional nature. Therefore, differences in condition, standard, scale, and path aspects for different regions may be significant. Thus, different regions should explore the appropriate industry poverty alleviation mode according to their actualities [3, 4].

With the government's attention to industry poverty alleviation, academic research on the related issues of industry poverty alleviation is also increasing. Liang et al. analyze the function mechanism and constraints of local governments, poverty alleviation enterprises, and poor farmers in improving industry poverty alleviation based on the sustainable livelihood analysis framework [5]. The influence mechanism of market uncertainty and participation in industrialization projects to poverty reduction is discussed in [6]. Reference [7] demonstrates that labor movements from the rural to urban sectors have played an essential role in industrialization with global value chains. Many developing East Asian countries have achieved rapid economic growth and poverty reduction by effectively utilizing global value chains. Alvarez et al. investigate main poverty reduction approaches worldwide and consider that international industrialization has had a more significant impact on poverty reduction, which has been proven by industry poverty alleviation practices from China and India [8].

According to the antipoverty history and data from Odisha of India and Congo, particularly in the low urbanization and less nonagricultural industry region, Sahoo and Badibanga et al. [9, 10] consider the vigorous

development of agricultural industrialization as the primary approach of rural poverty reduction. Morris et al. [11] discuss entrepreneurship as a source of empowerment for the economically disadvantaged; they think that poverty is multidimensional and complex, and the agricultural industry is effective for poverty reduction. Reference [12] analyzes the moderating effect of firm size on the influence of corporate social responsibility actions on the economic performance of micro-, small-, and medium-sized enterprises, which are critical in industry poverty alleviation. The sustainable development capacity of small- and medium-sized enterprises participating in industrial poverty alleviation is explored in [13]. The study in [14] investigates the spatio-temporal evolution characteristics of the coupling coordination relationship between industrial structure transformation and upgrade and tourism poverty alleviation efficiency by the SBM model, improved entropy method, and coupling coordination model. With the combination of quantitative and qualitative analysis, a description framework is built in [15] to compare the performance of different industry organization models in poverty alleviation regarding the performance of utilizing poverty alleviation funds, the benefit affiliating mechanism, and project targeting.

The four frequently used poverty-reduction pathways are industrialization, rural development, social welfare, and employment. The study in [16] analyses 15 systematically selected national cases of demonstrated rapid poverty reduction, seeking insights into practical approaches to

reducing poverty. Page et al. studied the influence of aid and employment on poverty reduction in Africa and proposed a method to aid and poverty in Africa, which focuses on supporting structural change for job creation [17]. The study in [18] discusses the relevance of the numerous theoretical perspectives on network formation and network management to the newly emerging cooperative sectors in the developing world. The results show that cooperation brings great benefits of development to the rural poor. By applying the instrumental variable, propensity score matching, and Rosenbaum bounds methods on survey data from five rural villages in frankincense woodland areas of Northern Ethiopia, the effects of membership in the rural frankincense firms on income and poverty are examined in [19], the results of which indicate that frankincense cooperatives have a significant positive impact on poverty reduction.

The study in [20] explores the interactive relationship between the main participants of industry poverty alleviation and its influencing factors and explains the theoretical mechanism of industry poverty alleviation and rural revitalization. Based on the field survey data in recent years, the practices, effects, and existing problems of the “targeting the poor households” industry poverty alleviation policy are analyzed in [21]. The study in [22] shows that production poverty alleviation by small farmers is an essential supplement to industry poverty alleviation. Only by establishing a nested market that embeds the production and consumption relations of small farmers into social relations can the production of poverty alleviation by small farmers be sustained.

The previously mentioned references have made in-depth research on the paths, modes, and problems in industry poverty alleviation, but few references have focused on the game process between participants. However, taking part in poverty alleviation projects by enterprises and poor farmers is also a mutual game process. Thus, the game theory can be used to investigate their behaviors in industry poverty alleviation.

The main participants in industry poverty alleviation are enterprises and poor farmers. The government must supervise and regulate the behaviors of enterprises and poor farmers to implement poverty alleviation projects smoothly. This study uses evolutionary game theory to investigate the game process between enterprises and poor farmers in industry poverty alleviation. A game model with the government supervision is proposed. Based on the proposed model, the behavioral processes between enterprises and poor farmers in industry poverty alleviation are analyzed by simulation. Furthermore, this study explores the effect of different supervision modes and parameters design. The results indicate that the industry poverty alleviation project does not continue without government supervision, no matter how high the initial willingness of enterprises and poor farmers to participate in the project is. Therefore, government supervision is indispensable to implement the poverty alleviation project. The obtained results are helpful for the government to develop an appropriate policy for the industry poverty alleviation.

## 2. Evolutionary Game Model

*2.1. Model Assumptions.* Two major participants in the industry poverty alleviation project are enterprises and poor farmers. They have bounded rationality. The government regulates their behaviors by developing some measures.

According to the general framework of game and behavior [23], enterprises have two behavior strategies: active poverty alleviation and negative poverty alleviation. In the “active poverty alleviation” behavior strategy, enterprises actively establish and manage agricultural product production base according to poverty alleviation project requirements. In the “negative poverty alleviation” behavior strategy, the management of poverty alleviation project is inactive, and the investment is insufficient. In the poverty alleviation project, poor farmers can work at the agricultural product production base. Similarly, poor farmers also have two behavior strategies: active participation and negative participation. In the “active participation” behavior strategy, poor farmers put themselves to work. In the “negative participation” behavior strategy, poor farmers negatively participate in the poverty alleviation project and do not work hard.

The symbol “ $x$ ” represents the probability of choosing the “active poverty alleviation” behavior strategy for enterprises, whereas the symbol “ $y$ ” represents the probability of selecting the “active participation” behavior strategy for poor farmers. The range of their variation is from 0 to 1. Accordingly, the probabilities of choosing “negative poverty alleviation” and “negative participation” behavior strategies for enterprises and poor farmers are “ $1-x$ ” and “ $1-y$ .” Thus, the four behavior strategy combinations between enterprises and poor farmers are as follows: active poverty alleviation and active participation, active poverty alleviation and negative participation, negative poverty alleviation and negative participation, and negative poverty alleviation and negative participation, as shown in Table 1.

The local government determines the poverty alleviation project in impoverished areas. Through open tendering, the government introduces some enterprises related to the poverty alleviation project. Two parts constitute the needed project funds. One part is from the self-financing of enterprises, and the other part is from government supporting funds. The government provides means of production to poor farmers, and poor farmers put them as an asset into the project, which will obtain a certain percentage of profit earned by the project according to predetermined proportion. Furthermore, poor farmers can also earn some income through working on the project.

To implement the poverty alleviation project smoothly, the government regulates enterprises’ and poor farmers’ behaviors by developing some supervision measures. Enterprises will gain some rewards from the government if they select the “active poverty alleviation” behavior strategy but will be penalized by the government if they choose the “negative poverty alleviation” behavior strategy. Poor farmers who prefer the “negative participation” behavior strategy will also obtain some rewards from the government. The related parameters in the model are displayed in Table 2.

TABLE 1: Four behavior strategy combinations between enterprises and poor farmers.

Game participants		Poor farmers	
		Active participation $y$	Negative participation $1 - y$
Enterprises	Active poverty alleviation $x$	Active poverty alleviation, active participation	Active poverty alleviation, negative participation
	Negative poverty alleviation $1 - x$	Negative poverty alleviation, negative participation	Negative poverty alleviation, negative participation

TABLE 2: Model parameters.

Parameters	Implications
$z_1$	Total investment of enterprises choosing "active poverty alleviation" behavior strategy
$z_2$	Total investment of enterprises choosing "negative poverty alleviation" behavior strategy
$g$	Supporting funds to poverty alleviation project provided by the government
$s$	Means of production provided by the government to poor farmers
$r_1$	Project profits of choosing "active poverty alleviation" behavior strategy and "active participation" behavior strategy for enterprises and poor farmers
$r_2$	Project profits of choosing "active poverty alleviation" behavior strategy and "negative participation" behavior strategy for enterprises and poor farmers
$r_3$	Project profits of choosing "negative poverty alleviation" behavior strategy and "active participation" behavior strategy for enterprises and poor farmers
$r_4$	Project profit of choosing "negative poverty alleviation" behavior strategy and "negative participation" behavior strategy for enterprises and poor farmers
$q$	Predetermined proportion of the profit, $q = z_1/(z_1 + s)$
$r_5$	Working income of poor farmers under "active poverty alleviation" behavior strategy for enterprises
$r_6$	Working income of poor farmers under "negative poverty alleviation" behavior strategy for enterprises
$c$	Labor cost of poor farmers working at the production base
$j_1$	Rewards to enterprises from the government when they choose "active poverty alleviation" behavior strategy
$j_2$	Rewards to poor farmers from the government when they choose "active participation" behavior strategy
$f$	Fines to enterprises penalized by the government when they choose "negative poverty alleviation" behavior strategy
$p$	Probability discovered by the government when enterprises choose "negative poverty alleviation" behavior strategy, $0 \leq p \leq 1$

According to these parameters, the income matrix of enterprises and poor farmers can be calculated as shown in Table 3.

$$\begin{cases} a_1 = q \cdot r_1 - z_1 + g + j_1, \\ a_2 = q \cdot r_2 - z_1 + g + j_1, \\ a_3 = q \cdot r_3 - z_2 + g + (1 - p) \cdot j_1 - z \cdot f, \\ a_4 = q \cdot r_4 - z_2 + g + (1 - p) \cdot j_1 - z \cdot f, \\ b_1 = (1 - a) \cdot r_1 + r_5 - c + j_2, \\ b_2 = (1 - a) \cdot r_2, \\ b_3 = (1 - a) \cdot r_3 + r_6 - c + j_2, \\ b_4 = (1 - a) \cdot r_4. \end{cases} \quad (1)$$

2.2. *Modeling.* The symbols " $u_{1x}$ " and " $u_{2x}$ " represent the expected revenues of choosing "active poverty alleviation" and "negative poverty alleviation" behavior strategies for enterprises, which can be written as

$$\begin{cases} u_{1x} = y \cdot a_1 + (1 - y) \cdot a_2, \\ u_{2x} = y \cdot a_3 + (1 - y) \cdot a_4. \end{cases} \quad (2)$$

Their average revenue is calculated as

$$\bar{u}_x = x \cdot u_{1x} + (1 - x) \cdot u_{2x}. \quad (3)$$

Based on evolutionary game theory [24], the replicator's dynamic equation of enterprises choosing behavior strategies is shown as

$$\begin{aligned} F(x) &= \frac{dx}{dt} \\ &= x(u_{1x} - \bar{u}_x) \\ &= x \cdot (1 - x) \cdot ((a_1 - a_2 - a_3 + a_4) \cdot y + a_2 - a_4). \end{aligned} \quad (4)$$

Similarly, we can obtain the expected revenues of choosing "active participation" and "negative participation" behavior strategies for poor farmers, which are replaced using the symbols " $u_{1y}$ " and " $u_{2y}$ ."

$$\begin{cases} u_{1y} = x \cdot b_1 + (1 - x) \cdot b_3, \\ u_{2y} = x \cdot b_2 + (1 - x) \cdot b_4. \end{cases} \quad (5)$$

The average revenue is given as

$$\bar{u}_y = y \cdot u_{1y} + (1 - y) \cdot u_{2y}. \quad (6)$$

The replicator's dynamic equation of poor farmers choosing behavior strategies is written as

TABLE 3: Income matrix of enterprises and poor farmers.

	Participants	Poor farmers	
		Active participation	Negative participation
Enterprises	Active poverty alleviation	$a_1, b_1$	$a_2, b_2$
	Negative poverty alleviation	$a_3, b_3$	$a_4, b_4$

$$\begin{aligned}
 F(y) &= \frac{dy}{dt} \\
 &= y(u_{1y} - \bar{u}_y) \\
 &= y \cdot (1 - y) \cdot ((b_1 - b_2 - b_3 + b_4) \cdot x + b_3 - b_4).
 \end{aligned} \tag{7}$$

Consequently, we obtain a two-dimensional dynamic system according to (4) and (7), which describe the evolutionary game process between enterprises and poor farmers as follows:

$$\begin{cases} \frac{dx}{dt} = x \cdot (1 - x) \cdot ((a_1 - a_2 - a_3 + a_4) \cdot y + a_2 - a_4), \\ \frac{dy}{dt} = y \cdot (1 - y) \cdot ((b_1 - b_2 - b_3 + b_4) \cdot x + b_3 - b_4). \end{cases} \tag{8}$$

### 3. Equilibrium Points

When (8) is equal to 0, five equilibrium points can be obtained: point (0, 0), point (0, 1), point (1, 0), point (1, 1), and point  $(x_d, y_d)$ , where  $x_d = (b_4 - b_3)/(b_1 - b_2 - b_3 + b_4)$ ,  $y_d = (a_4 - a_2)/(a_1 - a_2 - a_3 + a_4)$ .

Based on the method proposed by Friedman [25], the stability of equilibrium points is decided by the stability of the Jacobi matrix, which is shown in (9). According to the Jacobi matrix, we can obtain Jacobi traces replaced by symbol “tr(J)” and determinants replaced by symbol “det(J)” of every equilibrium point revealed in Table 4. If  $\text{tr}(J) < 0$  and  $\text{det}(J) > 0$ , the corresponding equilibrium point is considered to be the evolutionary stability strategy (ESS) point of system.

$$J = \begin{bmatrix} \frac{\partial F(x)}{\partial x} & \frac{\partial F(x)}{\partial y} \\ \frac{\partial G(y)}{\partial x} & \frac{\partial G(y)}{\partial y} \end{bmatrix} = \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{bmatrix}, \tag{9}$$

where

$$\begin{cases} \alpha_{11} = (1 - 2x)((a_1 - a_2 - a_3 + a_4)y + a_2 - a_4), \\ \alpha_{12} = x(1 - x)(a_1 - a_2 - a_3 + a_4), \\ \alpha_{21} = y(1 - y)(b_1 - b_2 - b_3 + b_4), \\ \alpha_{22} = (1 - 2y)(b_1 - b_2 - b_3 + b_4). \end{cases} \tag{10}$$

### 4. Results Analysis

The initial values of model parameters are shown in Table 5. In the analysis, the remaining parameters remain unchanged except for the analyzed parameter.

*4.1. Evolutionary Game Process without Government Supervision.* Parameters  $j_1, j_2,$  and  $f$  are set to 0. The Jacobi traces and determinants of equilibrium points can be obtained as shown in Table 6. Only one equilibrium point (0, 0) is an ESS point, indicating that the final selected strategies for enterprises and poor farmers are “negative poverty alleviation” and “negative participation,” respectively.

For initial probability  $x$  of active poverty alleviation for enterprises, we consider three situations: high, medium, and low, which are represented by the values of 90%, 50%, and 10% in simulation. Similarly, the initial probability  $y$  of active participation for poor farmers is also divided into these situations. Figure 2 displays the evolutionary game process for enterprises and poor farmers at  $x = 90\%$ , 50%, and 10% and  $y = 50\%$ , where Figure 2(a) is the variation tendency of probability of active poverty alleviation for enterprises and Figure 2(b) is that of active participation for poor farmers.

From Figure 2, although the initial probability of active poverty alleviation for enterprises is different, no matter how high or low,  $x$  and  $y$  ultimately converge to 0 point. However, the convergence rates are different; the lower the value of initial probability, the faster the convergence rate. Furthermore, as shown in Figure 1, the probability of active participation for poor farmers firstly increases and then decreases to 0 point at  $x = 90\%$ .

Figure 3 shows the evolutionary game process at  $x = 50\%$  and  $y = 90\%$ , 50%, and 10% without government supervision, where Figure 3(a) shows the variation tendency of the probability of active poverty alleviation for enterprises and Figure 3(b) shows that of active participation for poor farmers. The different initial values of  $x$ , and  $y$  decrease and ultimately converge to 0 point. Compared with Figure 1, the effects of the initial values of  $y$  on the game process are less significant than that of  $x$ .

Figures 2 and 3 reveal that no matter how high initial  $x$  and  $y$  for enterprises and poor farmers, the equilibrium point (0, 0) is their ultimate convergence point. This evolutionary game process is a reasonable explanation for the fact that if the government only provides financial assistance to enterprises without supervision, it leads enterprises to only care about immediate interests and defraud poverty

TABLE 4: Jacobi traces and determinants of equilibrium points.

Equilibrium points	$\text{tr}(J) (\alpha_{11} + \alpha_{22})$	$\text{det}(J) (\alpha_{11}\alpha_{22} - \alpha_{12}\alpha_{21})$
(0, 0)	$-(a_4 - a_2 + b_4 - b_3)$	$(a_4 - a_2) (b_4 - b_3)$
(0, 1)	$a_1 - a_3 + b_4 - b_3$	$(a_1 - a_3) (b_4 - b_3)$
(1, 0)	$b_1 - b_2 + a_4 - a_2$	$(b_1 - b_2) (a_4 - a_2)$
(1, 1)	$-(a_1 - a_3 + b_1 - b_2)$	$(a_1 - a_3) (b_1 - b_2)$
$(x_d, x_d)$	0	$(b_4 - b_3) (a_4 - a_2) (b_1 - b_2) (a_1 - a_3) / [(b_1 - b_2 - b_3 + b_4) [a_1 - a_2 - a_3 + a_4]]$

TABLE 5: Initial values of model parameters.

Parameters	Values
$z_1$	7.5
$z_2$	1.5
$g$	3
$s$	1.5
$r_1$	10.5
$r_2$	7.5
$r_3$	6
$r_4$	4.5
$r_5$	4.5
$r_6$	0.75
$c$	3
$j_1$	3
$j_2$	0.75
$f$	3
$p$	0.5

alleviation funds using the name of the project in poverty alleviation, causing enterprises to reduce poverty negatively and poor farmers to partake negatively. The industry poverty alleviation project will ultimately fail. Thus, to better use limited poverty alleviation funds and sustain poverty alleviation, introducing government supervision in the poverty alleviation process is necessary.

#### 4.2. Evolutionary Game Process with Government Supervision.

According to the previously mentioned analysis, the implemented project would not continue if government supervision is not considered in the industry poverty alleviation project. In general, government supervision is enforced by rewards and penalties. When enterprises actively support the poverty alleviation project, that is, enterprises selecting “active poverty alleviation” strategy, they will gain some rewards from the government, such as subsidies and tax incentives. When enterprises negatively support poverty alleviation project, that is, enterprises selecting the “negative poverty alleviation” strategy, they will incur some penalties, such as fines and canceling subsidies. Poor farmers who actively participate in the poverty alleviation project will gain some rewards, such as subsidies. Given the unfavorable position of poor farmers, they will not incur any penalty when choosing the “negative participation” strategy. The three supervision modes are only rewards, only penalties, and rewards and penalties. The only rewards mode means that the government only uses the policy of rewards to enterprises and poor farmers. The only penalties mode means that the government only adopts the

penalties policy for the enterprises and poor farmers. The rewards and penalties mode means that the government simultaneously employs the rewards and penalties for the enterprises and poor farmers.

For the only rewards supervision mode, parameters  $j_1, j_2$ , and  $f$  are set to 3, 0.75, and 0, respectively. For the only penalties supervision mode, parameters  $j_1, j_2$ , and  $f$  are set to 0, 0, and 3, respectively. Table 5 reveals their Jacobi traces and determinants results of every equilibrium point. It is shown that equilibrium point (0, 0) is only one ESS in the previously mentioned two modes. Figures 4(a) and 4(b) exhibit their game results for these two supervision modes, where (1) variation tendency of probability of active poverty alleviation for enterprises at initial values  $x = 90\%$ , 50%, and 10% and initial value  $y = 50\%$ ; (2) the variation tendency of the probability of active for poor farmers; (3) the variation tendency of probability of active poverty alleviation for enterprises at initial value  $x = 50\%$  and initial value  $y = 90\%$ , 50%, and 10%; (4) the variation tendency of the probability of active participation for poor farmers initial value  $x = 50\%$  and initial value  $y = 90\%$ , 50%, and 10%.

As shown, the final point of convergence of  $x$  and  $y$  is point (0, 0) for enterprises and poor farmers as well as that without government supervision. However, the convergence rate is slower.

In the rewards and penalties mode, parameters  $j_1, j_2$ , and  $f$  are set to 3, 0.75, and 3, respectively. The Jacobi traces and determinants results of every equilibrium point are shown in Table 5. The two equilibrium points as ESS are (0, 0) and (1, 1). Compared with Figures 4(a) and 4(b), another ESS (1, 1) appears. Figure 4(c) indicates the game results. The final results closely depend on the initial values of  $x$  and  $y$ . As shown in (1) and (2), when the initial probability of active poverty alleviation for enterprises is high and medium ( $x = 90\%$  and 50%), the final point of convergence of  $x$  and  $y$  is point (1, 1) for enterprises and poor farmers. For the low initial probability of active poverty alleviation for enterprises ( $x = 10\%$ ), point (1, 1) is the final point of convergence for enterprises and poor farmers. For the different initial state of probability of active participation for poor farmers, the final results are similar as in (3) and (4).

It is concluded that although there are three supervision modes, the effect of every mode on the game process of enterprises and poor farmers is different. At the only rewards supervision mode and the only penalties supervision mode, the equilibrium point (0, 0) is the ESS point. Therefore, enterprises and poor farmers ultimately select “negative poverty alleviation” and “negative participation,” respectively. As a result, the poverty alleviation project would fail.

TABLE 6: Jacobi  $\text{tr}(J)$  and  $\text{det}(J)$  of every equilibrium point without and with government supervision.

Equilibrium points	Without government supervision		With government supervision					
			Only rewards		Only penalties		Rewards and penalties	
	$\text{tr}(J)$	$\text{det}(J)$	$\text{tr}(J)$	$\text{det}(J)$	$\text{tr}(J)$	$\text{det}(J)$	$\text{tr}(J)$	$\text{det}(J)$
(0, 0)	-5.5	7	-3.25	2.5	-4	4	-1.75	0.63
(0, 1)	-0.25	-4.5	0.5	-0.94	1.25	-1.5	2	0.94
(1, 0)	5.5	7	4.75	5.5	4	4	3.25	1.37
(1, 1)	0.25	-4.5	-2	-2.06	-1.25	-1.5	-3.5	2.06
$(x_d, x_d)$	0	6.3	0	1.03	0	1.2	0	-0.26

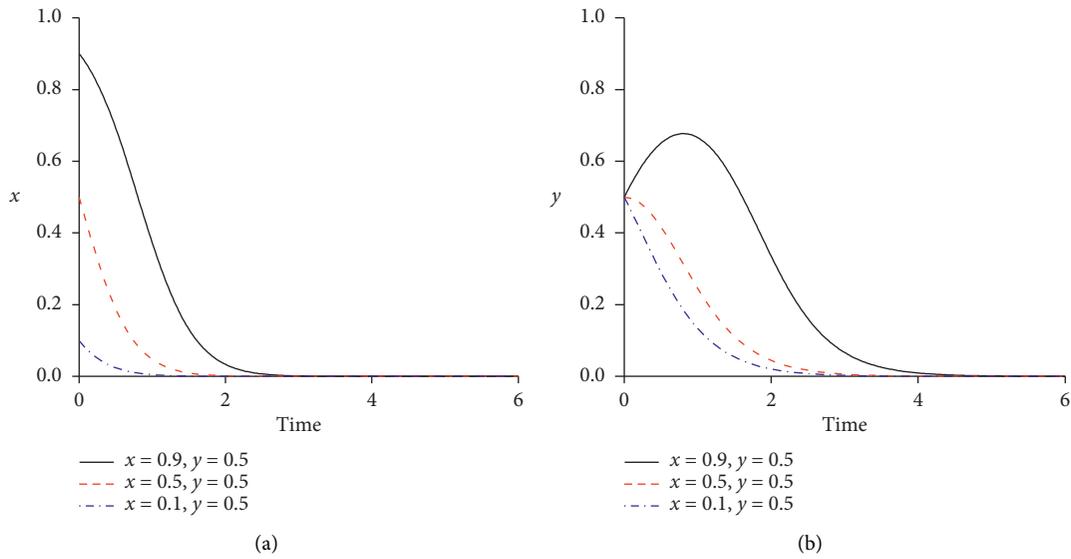


FIGURE 2: Evolutionary game process without government supervision at initial value  $x = 90\%$ ,  $50\%$ , and  $10\%$  and initial value  $y = 50\%$ : (a) variation tendency of probability of active poverty alleviation for enterprises and (b) variation tendency of probability of active for poor farmers.

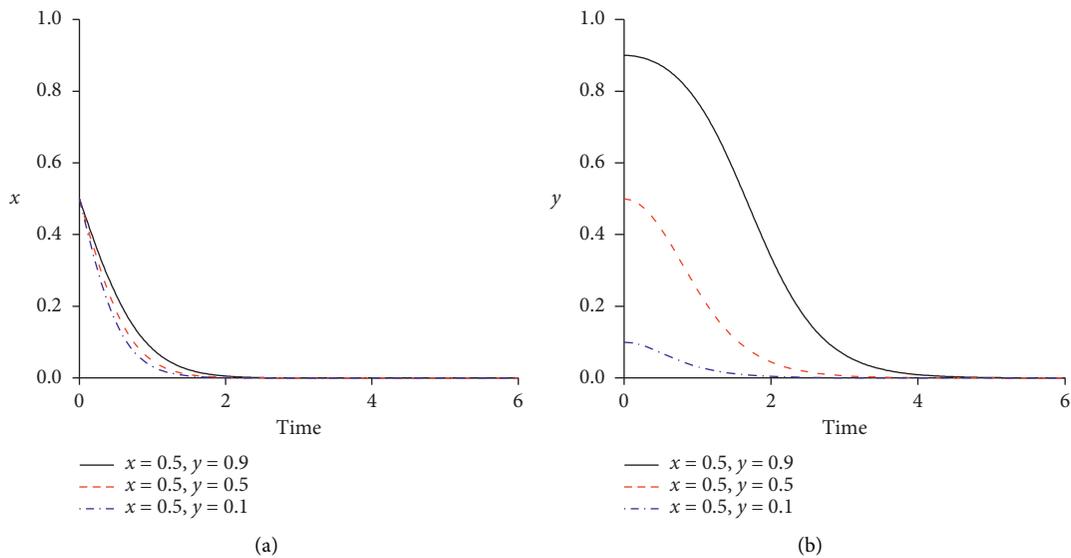


FIGURE 3: Evolutionary game process without government supervision at initial value  $x = 50\%$  and initial value  $y = 90\%$ ,  $50\%$ , and  $10\%$ : (a) variation tendency of probability of active poverty alleviation for enterprises and (b) variation tendency of probability of active participation for poor farmers.

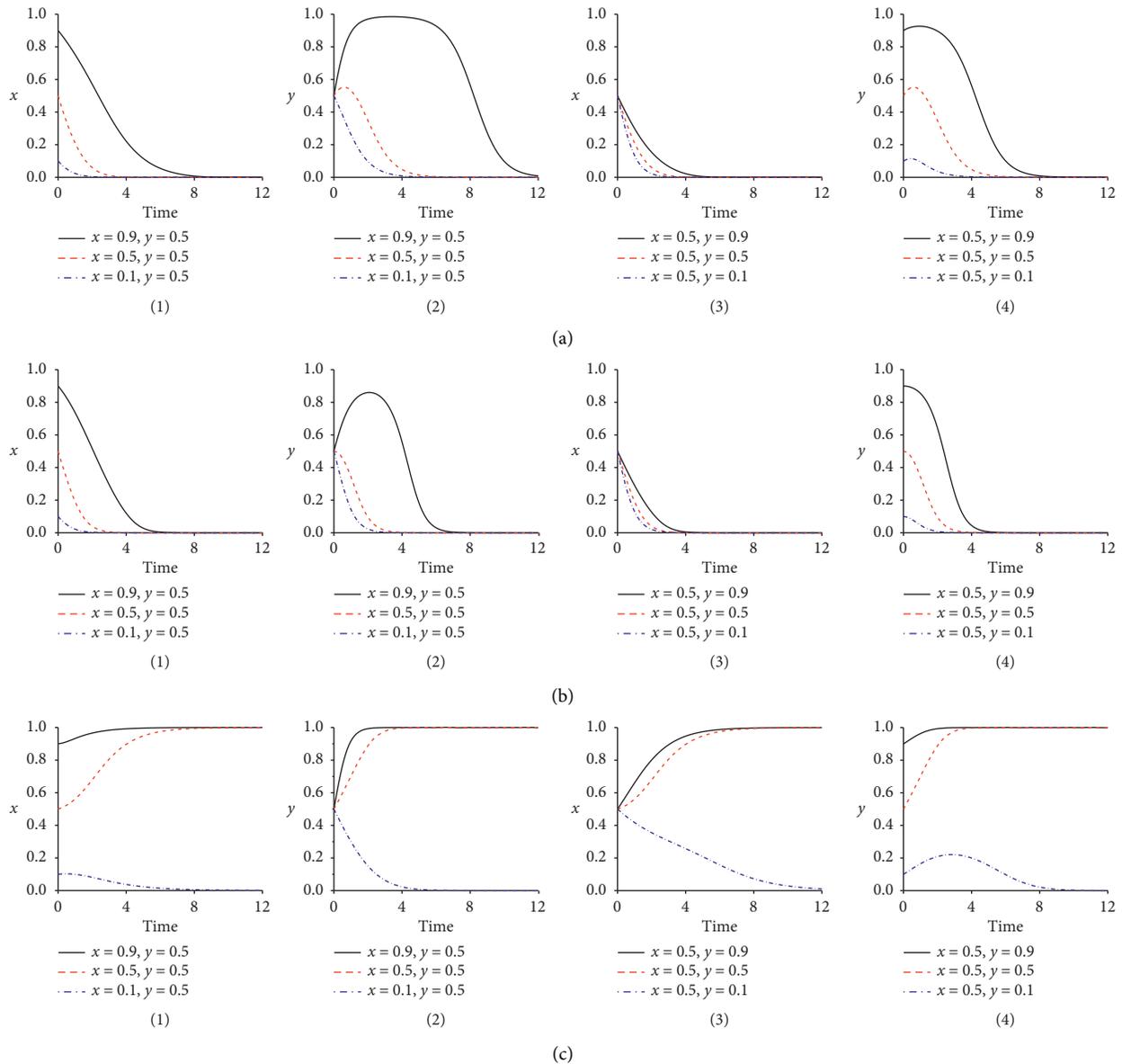


FIGURE 4: Evolutionary game process under different supervision modes used by the government: (a) only rewards mode, (b) only penalties mode, and (c) rewards and penalties mode, where (1) is the variation tendency of probability of active poverty alleviation for enterprises at initial value  $x = 90\%$ ,  $y = 50\%$ , and  $10\%$  and initial value  $y = 50\%$ ; (2) is the variation tendency of probability of active participation for poor farmers; (3) is the variation tendency of probability of active poverty alleviation for enterprises at initial value  $x = 50\%$  and initial value  $y = 90\%$ ,  $50\%$ , and  $10\%$ ; and (4) is the variation tendency of probability of active participation for poor farmers initial value  $x = 50\%$  and initial value  $y = 90\%$ ,  $50\%$ , and  $10\%$ .

The two equilibrium points  $(0, 0)$  and  $(1, 1)$  are the ESS points for the rewards and penalties supervision mode. Under the state of  $x$  or  $y = 90\%$  and  $50\%$ , the equilibrium point  $(1, 1)$  is their ESS point. This means enterprises and poor farmers ultimately select “active poverty alleviation” and “active participation,” which are the desired results. Thus, poverty alleviation project would continue and succeed. For the state of  $x$  or  $y = 10\%$ , the equilibrium point  $(0, 0)$  is the ESS point. Final selected strategies for enterprises and poor farmers are similar to that at the only rewards and penalties supervision modes. Poverty alleviation project would also fail. Thus, the results of the third mode are the

best in three supervision modes and should be considered in the implementation of the industry poverty alleviation project.

### 5. Effects of Design Parameters of Rewards and Penalties on the Game Process

The previously mentioned analysis shows that the third mode, the rewards and penalties supervision mode, possibly results in the success of the poverty alleviation project. However, many parameters must be carefully considered in its specific implementation process. The main parameters

are as follows: the probability  $p$  of government discovery and fines  $f$  penalized by the government when enterprises negatively take part in poverty alleviation project and ultimately select “negative poverty alleviation” strategy, rewards  $j_1$  to enterprises awarded by the government when enterprises ultimately select “active poverty alleviation” strategy, and rewards  $j_2$  to poor farmers awarded by the government when poor farmers ultimately select “active participation” strategy. Moreover, the different initial values for  $x$  are only considered in this part since enterprises possess a dominant position in the industry poverty alleviation project.

**5.1. Effects of the Probability  $p$  of Government Discovery on the Game Process.** Figure 5 exhibits the evolutionary game process under different probabilities of government discovery, such as  $p = 0.1, 0.5,$  and  $0.9$  at initial value  $x = 90\%, 50\%,$  and  $10\%$ , where Figure 5(a) shows the variation tendency of probability of active poverty alleviation for enterprises and Figure 5(b) shows the variation tendency of probability of active for poor farmers.

Parameter  $p$  will change the convergence direction.  $x$  and  $y$  likely converge to point 1 under a larger parameter  $p$ . When the probability  $p$  of government discovery increase is equal to  $0.5$  and  $0.9$ , point  $(1, 1)$  is also their final point of convergence. When the probability  $p$  of government discovery is equal to  $0.1$ , point  $(0, 0)$  is their final point of convergence. Although the initial value  $x$  is low, such as equal to  $0.1$ ,  $x$  and  $y$  ultimately converge to point  $(1, 1)$  at a high probability  $p$  of government discovery, such as equal to  $0.9$ . It is concluded that the high probability  $p$  of government discovery is helpful to implement the poverty alleviation project.

**5.2. Effects of Parameters Rewards  $j_1$  on the Game Process.** Figure 6 shows the effects of rewards  $j_1$  to enterprises awarded by the government on the game process at  $j_1 = 1.5, 3,$  and  $4.5$ , where Figure 6(a) shows the variation tendency of probability of active poverty alleviation for enterprises and Figure 6(b) shows the variation tendency of probability of active for poor farmers.

It is shown that  $x$  and  $y$  converge to 1 with an increase of  $j_1$ . When  $j_1$  decreases from 3 to 1.5,  $x$  and  $y$  ultimately converge to point  $(0, 0)$  at the initial value  $x = 50\%$  and  $10\%$ , and they ultimately converge to point  $(0.86, 1)$  at the initial value  $x = 90\%$ . At a high reward condition, such as equal to 4.5, although the initial value of  $x$  is small, such as equal to 0.1,  $x$  and  $y$  ultimately converge to point  $(1, 1)$ , which is our desired result.

Thus, a suitable reward is important. If the reward is excessively low, the incentive function to enterprises is little; if the reward is enough, even though initial probability  $x$  of active poverty alleviation for enterprises is low, the ultimate results are our desired results, and the industry poverty alleviation project is ongoing.

**5.3. Effects of Parameter Fines  $f$  on the Game Process.** Figure 7 displays the effects of fines  $f$  to enterprises penalized by the government on the game process when enterprises select the “negative poverty alleviation” strategy at initial value  $x = 90\%, 50\%,$  and  $10\%$  and initial value  $y = 50\%$ , where Figure 7(a) is the variation tendency of probability of active poverty alleviation for enterprises and Figure 7(b) is the variation tendency of probability of active for poor farmers.

From Figure 7, whether fines  $f$  increase from 3 to 4 or decrease from 3 to 2,  $x$  and  $y$  ultimately converge to point  $(1, 1)$  at initial value  $x = 90\%$  and  $50\%$ . However, for initial value  $x = 10\%$ , the condition is different. Point  $(1, 1)$  is the final point of convergence with fines  $f$  increasing from 3 to 4, and point  $(0, 0)$  is their final point of convergence with fines  $f$  decreasing from 3 to 2. For the medium initial probability of active poverty alleviation for enterprises and low fine  $f$ , although  $x$  and  $y$  ultimately converge to point  $(1, 1)$ , the process is different.  $x$  decreases and then slowly increases and converges to point 1, whereas  $y$  directly converges to point 1. For low initial value  $x = 10\%$  and large fines  $f = 4$  condition,  $x$  directly converges to point 1, and  $y$  shows a decreasing trend and then rapidly increases to point 1.

Consequently, fines  $f$  to enterprises penalized by the government also bring a significant impact on the game process. Large fines will regulate the behavior of enterprises and make them positively participate in the industry poverty alleviation project.

**5.4. Effects of Parameter Reward  $j_2$  on the Game Process.** In this case, the parameter rewards  $j_2$  to poor farmers awarded by the government when poor farmers ultimately select the “active participation” strategy is increased to 1.25 and decreased to 0.25 from the initial value of 0.75, respectively. Figure 8 indicates the effects of rewards  $j_2$  on the game process at initial value  $x = 90\%, 50\%,$  and  $10\%$  and initial value  $y = 50\%$ , where Figure 8(a) shows the variation tendency of probability of active poverty alleviation for enterprises and Figure 8(b) shows the variation tendency of probability of active for poor farmers.

As shown in Figure 8, some rewards awarded by the government will motivate poor farmers to participate in the poverty alleviation project. For the medium and high initial probability of active poverty alleviation for enterprises, whether rewards  $j_2$  increase or decrease,  $x$  and  $y$  ultimately converge to point  $(1, 1)$ . For initial value  $x = 10\%$ ,  $x$  and  $y$  ultimately converge to point  $(0, 0)$ .

By all accounts, the introduction of government supervision will constrain the behaviors of enterprises and poor farmers in the industry poverty alleviation project. Unlike when there is no government supervision, another equilibrium point  $(1, 1)$ , which is our desired result, will appear under suitable parameters. Therefore, suitable parameter designs with government supervision are important and helpful to promote the smooth implementation of the industry poverty alleviation project.

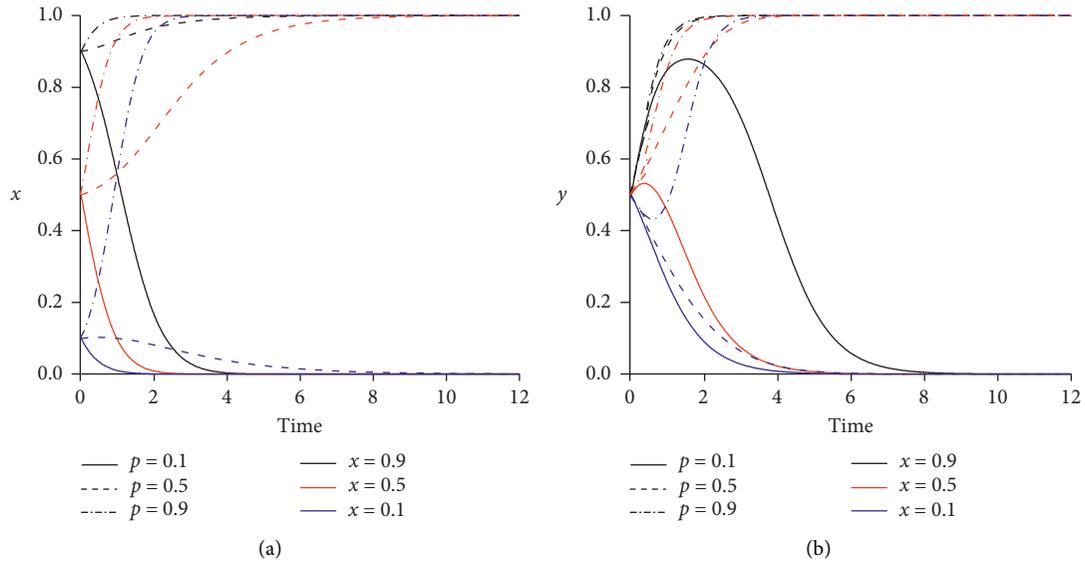


FIGURE 5: Effects of probability  $p$  of government discovery on the game process when enterprises negatively alleviate poverty at initial values  $x = 90\%$ ,  $50\%$ , and  $10\%$  and  $y = 50\%$ : (a) variation tendency of probability of active poverty alleviation for enterprises and (b) variation tendency of probability of active participation for poor farmers.

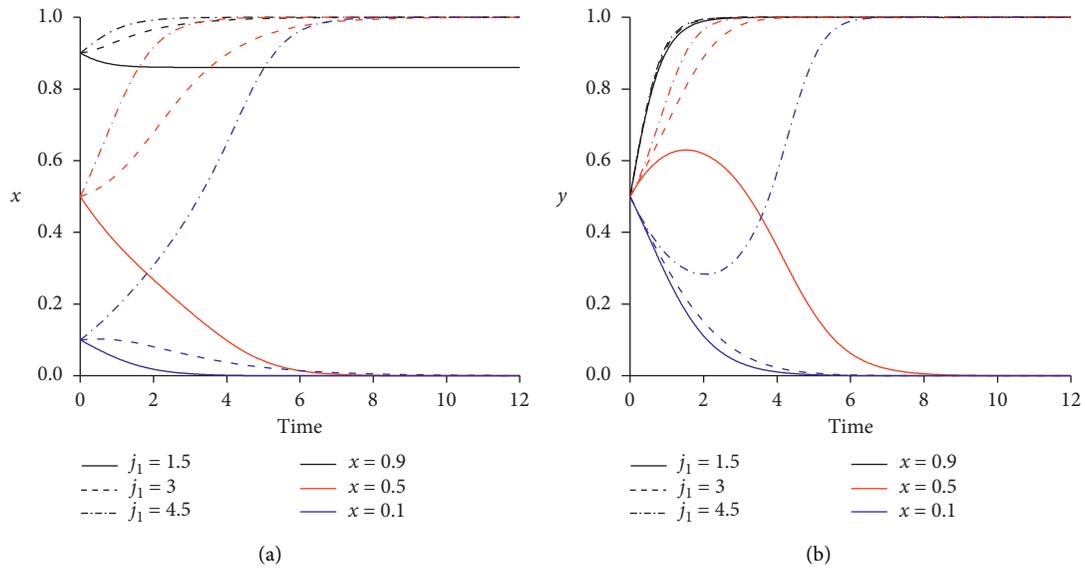


FIGURE 6: Effects of rewards  $j_1$  to enterprises on the game process when enterprises select “active poverty alleviation” at initial value  $x = 90\%$ ,  $50\%$ , and  $10\%$  and  $y = 50\%$ : (a) variation tendency of probability of active poverty alleviation for enterprises; (b) variation tendency of probability of active participation for poor farmers.

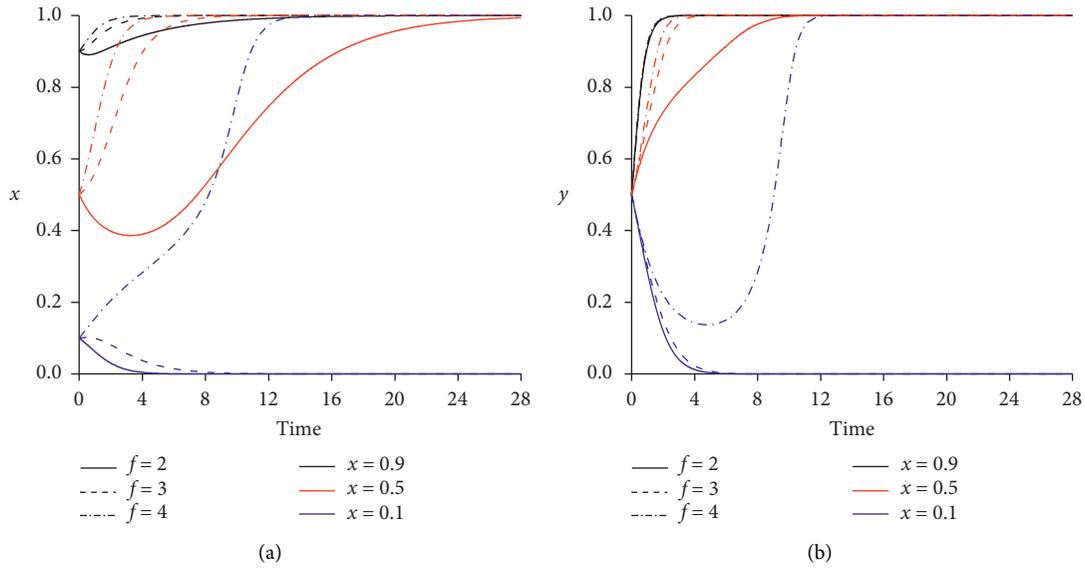


FIGURE 7: Effects of fines  $f$  to enterprises on the game process when enterprises select “negative poverty alleviation” strategy at initial value  $x = 90\%$ ,  $50\%$ , and  $10\%$  and  $y = 50\%$ : (a) variation tendency of probability of active poverty alleviation for enterprises; (b) variation tendency of probability of active participation for poor farmers.

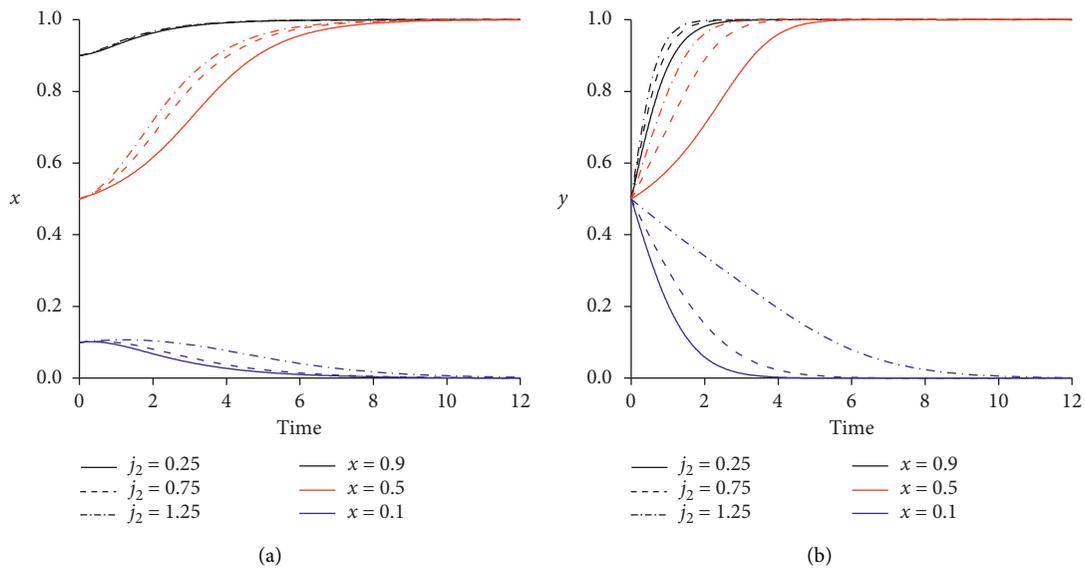


FIGURE 8: Effects of rewards  $j_2$  to poor farmers awarded by the government on the game process when poor farmers select the “active participation” strategy at initial value  $x = 90\%$ ,  $50\%$ , and  $10\%$  and  $y = 50\%$ : (a) variation tendency of probability of active poverty alleviation for enterprises; (b) variation tendency of probability of active participation for poor farmers.

## 6. Conclusions

Poverty is a global problem. Poverty alleviation and eradication are important ways for human beings to achieve sustainable development. The fundamental path and core power of poverty alleviation in poor areas are implementing industry poverty alleviation vigorously.

This study investigates the game processes of participants in industry poverty alleviation according to the evolutionary game theory and analyses the smooth implementation of industry poverty alleviation considering

government supervision. The equilibrium point  $(0, 0)$  is the ultimate convergent point of the system without any supervision measures for enterprises and poor farmers from the government. Therefore, the poverty alleviation projects will fail. To promote the good implementation of industry poverty alleviation, introducing government supervision is necessary.

Different supervision modes have different effects. This study considers three supervision modes. In the only reward mode or only penalty mode, the system has the only equilibrium point  $(0, 0)$  as ESS, which indicates that the

poverty alleviation projects ultimately fail. In the reward and penalty mode, another equilibrium point (1, 1) appears as ESS. The ultimate result depends on the original state of the system. The ESS (1, 1) is the desired result and predicates that poverty alleviation projects will continue. Thus, the reward and penalty mode is a recommended strategy for government supervision.

In addition, the parameter design is also investigated for the reward and penalty mode. The convergence direction of the game process can be changed by the adjustment of parameters. The game process likely converges to point (1, 1) under higher reward and penalty to an enterprise. If the parameters are chosen reasonably, we can obtain our desired results. Consequently, it is necessary to consider reasonable parameters in government supervision.

### Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

### Additional Points

JEL classification: Q12 and Q18.

### Conflicts of Interest

The authors declare that they have no conflicts of interest.

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