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Research on the coordinated development of environmental protection and industry in poverty alleviation under uncertainty

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ABSTRACT

With the promotion of sustainable development and the improvement of people's awareness of ecological environment protection, the focus of contemporary regional economic development has gradually changed to how to develop industries with local characteristics and optimize the construction of a regional industrial ecosystem on the premise of considering environmental protection. Based on the cumulative prospect theory, this research studies the synergistic effect of industrial development and environmental protection in the field of poverty alleviation. The initial state of the industrial revolution, the excess return, the cost, the tax policy, the reference point, and the uncertainty of revenue all affect the evolution of the industry. The results of this research provide a theoretical basis for local governments to formulate reasonable industrial policies and to promote the development of the regional economy.

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1. Introduction

As countries around the world steadily promote the strategy of rural revitalization, the focus of rural work in the new era is mainly on how to develop characteristic industries in poverty alleviation and form an optimized regional industrial ecosystem. Krugman points out that the accumulation of regional advantages is the basis of realizing the spillover effect in the future. However, among the great achievements of poverty alleviation literature, it is found that even with the help of developed areas, the poverty-stricken areas still lack a long-term awareness of industrial optimization and fail to form unique industries. Improving technologies, popularizing concepts, and cultivating characteristic and advantageous industries all help poverty areas to improve their regional strength.

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Some scholars believe that the local government's behaviour is closely related to industrial planning and development in poor areas (Jonathon, 2006; Bahmani-Oskooee & Oyolola, 2009). At this stage, the economic revenue obtained by the local government and the expected psychological benefits of local enterprises are the main factors affecting the precise positioning of the industry (Bank the world, 2010; Bhusal, 2011; Narain et al., 2008). In addition, attention should be paid to the role of environmental protection in poor areas for achieving sustainable development (Leonardo, 2016). The development of humans and society is one of the important components of sustainable development (Moonis, 2018). Therefore, the local government and enterprises entering the field of poverty alleviation are the main parts of pursuing the optimal allocation of resources. They also need to fulfil their environmental responsibilities and bear the penalties and aftercare costs caused by environmental pollution (Hasbek et al., 2016; Scheidel, 2013; Resnick & Birner, 2006). There are a series of contradictions and conflicts in the process of decision-making between enterprises and local governments (Pal & Saha, 2015; Xing et al., 2019). Finally, the balance of the region can be achieved, because the government takes environmental protection into account in the choice of leading industries. Therefore, it is essential to optimize the allocation of resources and take environmental protection as an external constraint to promote the development of industries in poverty-stricken areas (Stefan et al., 2008; Dogan & Seker, 2016a, Dogan & Seker, 2016b; Dong et al., 2011).

It is of great significance to study the location of the evolutionary game between local government and enterprises. In the field of poverty alleviation, the behaviour decision-making between the local government and leading local enterprises is a process of continuous game evolution. Based on the virtuous cycle of ecological protection, the boundary conditions for the optimization of the industrial structure are explored to improve the quality of industrial poverty alleviation. Behavioural economics research shows that continuous learning and self-awareness change will lead to a change in system entropy (Jianjun, 2005). Therefore, one of the focuses of industrial planning in the field of poverty alleviation is to observe the decision-making path of each actor.

2. Literature review

Scholars preliminarily use barter trade to analyse the industrial evolution process in poverty-stricken areas and propose that product demand promotes the transformation of the industrial layout (Ross, 1976; Murad & Nik Mustapha, 2010). However, endogenous power cannot completely solve the industrial upgrading in poor areas. Scholars believe that it is necessary to explore the main factors restricting the improvement of the lives of the poor. Based on this, they propose a variety of factors leading to poverty (Cynthia et al., 2004; Gangadharan & Valenzuela, 2001; Gustafsson & Sai, 2009; Hulme & Shepherd, 2003) and set up measures based on their capacity-building, external information, technology, and other groups' assistance to improve the lives of the poor (Figueroa, 2013; Xueguang & Hong, 2011; Ladman & Adams, 1978; Shi & Sai, 2013). Therefore, some scholars point out that an important innovative way to solve the problem of rural poverty is to combine the endogenous power

of the development of valuable regional resources. Samman and Santos (2013) present the completion of the industrial structure transformation of poor areas through external mechanisms such as rural support, social support, regional linkage, and industrial layout arrangement of surrounding areas. These paths fit the dynamic development law of path evolution under the cooperation of incentive mechanism, government, and foreign-funded enterprises.

Some researchers further note that small farm models in countries such as the Netherlands as well as the Federal Food Program and school meal program in Brazil can help improve the long-term stable income of poor areas. However, these measures are only aimed at individuals in poor areas, do not take into account the industrial-scale development of the area, and fail to help the poor areas fundamentally solve the problem of poverty (Rojas, 2012; Plotnick, 2009; Rojas, 2008; Ravallion, 2001; Rao, 1999; Snodgrass et al., 1992). Therefore, the researchers believe that improving the level of industrial-scale development in poverty-stricken areas can solve the problem of poverty.

Green poverty alleviation has been constantly proposed by researchers (He et al., 2012; Ravnborg Helle, 2003), who believe that a well-off society can be achieved in the form of small-world networks. In the strategy of implementing the policy of poverty alleviation and revitalizing rural development, the government can adopt a compound industrial mode, which is beneficial to environmental protection (Hongyan et al., 2010; Zarazúa & Angel, 2008; North Liisa & Cameron, 2000; Hermine, 1992). Poverty alleviation should also take into account the dependence of residents in rural and poor areas on the community and the natural environment, so that the protection of natural resources must be supported in poverty alleviation (Anguelovski & Alier, 2014). When the current development model in rural areas fails to combine the protection of the natural environment with material living conditions, social transformation can attempt to use materialistic approaches.

Scholars believe that the focus of achieving well-off goals in poor areas is sustainable development – that is, pursuing economic benefits while taking into account environmental protection (Gustafsson & Sai, 2009; Murad & Nik Mustapha, 2010; Gad & Yaron, 2007). EKC (Environmental Kuznets Curve) scholars suggest that developing countries should choose an economical route of environmental protection in their development (Takawira, 2019), while more environmental risks exist in low-income areas (Kremer, 2016). It is found that developed countries do not pay much attention to environmental protection in the process of economic development. In addition, the negative effect of environmental destruction is not immediate, which leads to the result of pollution first and treatment later. However, this method is not sustainable (Takawira, 2019). In terms of full and reasonable development of resources, the fundamental way to solve poverty is to develop a low-carbon industrial model (Butcher, 2011; Schilcher, 2007).

Although environmental improvements in poor areas conform to the inverted U-shape Kuznets curve, productivity declines in poor areas are mainly due to environmental pollution (Begum et al., 2015; Butcher, 2011; Dogan & Seker, 2016a; Lau et al., 2014). In other words, environmental problems improve when the unit capital-output reaches the inflection point. However, the impact of adverse factors such as

carbon emissions and environmental pollution are increasing (Dogan & Seker, 2016b; Khan et al., 2017; Ozcan & Filip, 2013). Although foreign direct investment (FDI) has brought innovative technologies for pollution treatment to developing countries, due to the influx of a large number of polluting enterprises via FDI, the environmental situation in poor areas is deteriorating. Environmental protection needs to rely on the progress of science and technology, and a lack of technological innovation will lead to the deterioration of pollution, such as in Vietnam and China (Dong et al., 2011; Gangadharan & Valenzuela, 2001; Imai et al., 2011; Lee, 2013; Qasim et al., 2011; Walle & Gunewardena, 2001; Resnick, 1970).

The private sector is a source of foreign investment and economic growth, but attracting investment in poor areas is not easy. For a local government, a mixture of non-economic and economic incentives must be designed to stimulate enterprises (Allan, 2001). For example, Iceland has a long history of economic success and has implemented strategies to encourage sustainable action (Gregory, 2016). The UN African Union's development focus is on the need for countries to improve resource management strategies and develop low-carbon economies ("Sustainable Development Goals", 2019). However, excessively inflated tax incentives reduce a country's funds for developing the national economy (Thomas, 2009). Economic growth should not be regarded as the effect of environmental protection (Karsch Nicole, 2019). A government should raise economic income while improving citizens' environmental awareness, implement environmental laws and regulations, adopt new technologies, and adjust industrial structure, such as transforming into information-intensive industries and service industries (Stern, 2017). The state should be committed to stabilizing the economy before it pays for the potentially high costs of environmental damage or introduce more modern and less polluting technologies (Özlem & Özokcu, 2017).

The reasons for environmental problems in poor areas are due to a lack of awareness in the sustainable development of local governments and the process of industrialization of enterprises. Scholars put forward the construction mode of a poverty alleviation industry to improve people's income and living standards in poverty-stricken areas. For example, some scholars put forward the small market economy model. Others propose to develop pollution-free industries in poverty-stricken areas to promote the sustainable development of the area, such as tourism having the greatest impact on Kenya's rapid economic growth. As one of the poorest countries in the world, about three quarters of its population live in rural areas. In addition to creating about 500,000 jobs directly through the development of the tourism industry in regional rural areas, there is a link between tourism and the local economy that helps reduce poverty and promote diversified industrial development that expands tourism while improving the competitiveness of other sectors and ensuring a better distribution of income (Njoya & Seetaram, 2018). This strand of current literature rarely discusses the impact of the decision-making process and the results on industrial evolution and environmental protection in poor areas. Therefore, compared with previous studies, the contribution of this research is as follows.

Under the guidance of environmental protection policy, we first explore the decision-making path of local government and poverty alleviation enterprises in the orientation of economic interest. While ensuring the revenue of local government

and enterprises, the coordinated development of industrial structure and natural ecological environment should be taken into account. Considering the uncertainty of tax revenue, initial state, and income, this research analyses their impact on industrial development in poverty-stricken areas. Second, this research investigates the influencing factors of industrial development in poverty-stricken areas and puts forward feasible countermeasures for the industrial development in poverty-stricken areas. Third, we introduce the evolution mechanism of industrial structure in the field of poverty alleviation and the game model of interval number payment matrix in section four. Section five is the numerical simulation. Section six is the conclusion.

3. Mechanism of industrial structure evolution in the field of poverty alleviation

Different participants have different interests, such as the local government starts from the public revenue and pursues the maximization of local economic revenue; while the purpose of enterprises is to realize the maximization of their benefits. Therefore, the path of industrial structure evolution of different participants varies. Due to the absolute advantage of local government in resource allocation and the dominant position in layout planning for a long time, government-led enterprises continue to emerge. In the later stage, a large number of high-quality enterprises join in due to vigorous investment promotion, so that the market demand determines the future industrial development direction of poverty alleviation areas. The economic function has been used to adjust for market failure in the continuous competitive development of enterprises. This tends to make the decision-making of the government and enterprises stable.

To realize the industrial value and scale effect, we should take into account the interests of the government and enterprises. We construct the optimal choice between the government and poverty alleviation enterprises under the uncertainty of income.

4. Under interval number payoffs for construction of the game model

In the process of industrial revolution in the field of poverty alleviation, there are two main participants. First, the local government not only considers the rapid acquisition of economic revenue, but also pays attention to the local ecological environment to a certain extent. The other participant is entry-oriented enterprises, which optimize the regional industrial structure and pay more attention to the full capture of economic interests. There is a particular coupling between the two participants, but there is also a big difference. Local governments not only care about the economic revenue brought by industrial construction, but also take positive environmental protection measures under the pressure of the central government. Entering enterprises think that the basis of the industrial cluster is the continuous growth of enterprise benefits. The industrial choice of the local government does not consider the influence of other external entities, which is the result of the game between local government and enterprises. To sum up, this research presents the following hypotheses.

Hypothesis 1: decision-makers. Local governments in poor areas not only undertake the task of optimizing industrial structure, but also contribute to environmental protection. Therefore, local governments and enterprises should choose the best among social, economic, and natural environment interests.

Hypothesis 2: behaviour selection process. There are different decision-making strategies for participants, local governments, and enterprises. On the one hand, the local government optimizes the industrial structure and exploits the industrial advantages by introducing advanced enterprises. However, under the pressure of the central government, local governments hope that enterprises will take measures to strengthen industrial ecological protection. On the other hand, the game with the local government sees whether the enterprises can take environmental protection measures of the technological process. Their decision-making process is not subject to external interference.

Hypothesis 3: fuzzy returns. Previous studies on evolutionary game assume that the benefits of each strategy are fixed. With the introduction of the cumulative prospect theory into the evolutionary game, the return is no longer fixed, but affected by the occurrence of small probability events. Therefore, the revenue matrix is replaced by the perceived cumulative prospect payment matrix. However, previous studies only consider the impact of limited circumstances, which means that the uncertainty is limited. The complexity of the objective world and the uncertainty of the individual subjective decision often lead to uncertainty of decision information. In many cases, players cannot provide any specific value in the decision-making process, but give an interval, which makes the return under each strategy present fuzzy characteristics – that is, the form of an interval number. We set R to be the real field number and $\tilde{a} = [a_L, a_U] = \{a | a_L \leq a \leq a_U\}$, $a_L, a_U \in R$ are interval numbers.

Hypothesis 4: game revenue. In the game, the local government's revenue lies in the difference between the value-added benefits and environmental investment costs produced by industrial optimization. The profit of enterprises lies in the difference between the value-added benefits of industrial layout and the environmental protection process cost of enterprises.

Hypothesis 5: prospect value. The strategic benefits of behaviour participants depend on the expected psychological benefits and loss value – that is, the expected value (V). According to the prospect theory, the cumulative prospect theory, the value function $v(x)$, and the weight function $\pi(p)$, V can be expressed as $V = \sum_i \pi(p_i) v(\Delta x_i)$, where p_i is the probability of event i , and Δx_i represents the difference between the actual income of each game object (x_i) and the REF point x_0 after event i occurs –that is, $\Delta x_i = x_i - x_0$, $v(\Delta x_i) = \{(\Delta x_i)^\alpha, \Delta x_i \geq 0; -\lambda(-\Delta x_i)^\beta, \Delta x_i < 0$, $\pi^+(p) = \frac{p^{\gamma_1}}{[p^{\gamma_1} + (1-p)^{\gamma_1}]^{1/\gamma_1}}$, and $\pi^-(p) = \frac{p^{\gamma_2}}{[p^{\gamma_2} + (1-p)^{\gamma_2}]^{1/\gamma_2}}$. Tversky and Kahneman are accorded $\alpha = \beta = 0.88$; $\lambda = 2.25$; $\gamma_1 = 0.61$; $\gamma_2 = 0.69$.

4.1. Construction of the payoff matrix

In the game between local government and enterprises, there are four pure strategies as follows.

Case 1: the local government adopts the industrial environmental protection strategy, and the enterprises entering into the industry adopt the ecological protection technology production strategy.

In this case, the local government needs to spend a specific cost C to execute an industrial environmental protection strategy, obtain ecological benefits M , and incur the cost of a specific subsidy K_1 . The enterprise enters using ecological protection technology production and obtains subsidies and profit, because of compliance with the local government's ecological and environmental policies. Enterprises and local governments share financial revenue, and local governments get a certain proportion from it, $k(0 \leq k \leq 1)$. However, there is significant uncertainty in the construction of industrial ecological protection measures, and the income of enterprises and government is divided into an interval range $[R_L, R_U]$. Therefore, in this case, the profit of the enterprise is $K_1 + (1-k)[R_L, R_U]$, and the income of the government is $-C - K_1 + M + k[R_L, R_U]$.

Case 2: the local government does not adopt the strategy of industrial ecological protection measures, and the entry enterprises do not adopt the production strategy of environmental protection technology.

In this case, the local government does not take industrial ecological protection measures, but rather only adopts preferential policies to attract investment. Enterprises enjoy subsidies. Enterprises and the government share the total income during their residence, and the government receives a certain proportion of subsidies $k(0 \leq k \leq 1)$. Similarly, in a new region, the income of enterprises is uncertain. The revenue sharing between enterprises and the government is also an interval $[S_L, S_U]$. Therefore, in this case, the income of the enterprise is $K_2 + (1-k)[S_L, S_U]$, and that of the government is $-K_2 + k[S_L, S_U]$.

Case 3: the local government adopts the strategy of industrial environmental protection measures, while the entry enterprises do not adopt the production strategy of environmental protection technology.

In this case, the local government needs to spend the cost C to implement the industrial environmental protection strategy. In contrast, the government only needs subsidies to adopt the industrial environmental protection strategy, while the government only needs subsidies K_2 to attract investment, because enterprises do not adopt environmental protection technology. The total income of investment promotion is shared by enterprises and the government, of which the government accounts for $h(h > k)$. The income distribution between the enterprise and the government is an interval $[P_L, P_U]$. Therefore, in this case, the income of the enterprise is $K_2 + (1-h)[P_L, P_U]$, and that of the government is $-C - K_2 + h[P_L, P_U]$.

Case 4: the local government does not adopt the strategy of industrial environmental protection measures, but adopts the production strategy of environmental protection technology in enterprises.

In this case, the local government does not adopt the strategy of industrial ecological protection, but only adopts preferential policies to attract investment K_2 . If the enterprises do not receive subsidies, then the total income during residence is shared by enterprises and the government, accounting for k . As a result of entering a new region, the income of enterprises is uncertain. The revenue sharing between

Table 1. Return matrix of the game.

Makers		Enterprises	
		Environment protection	Non- Environment protection
Governments	Using industrial ecological protection measures	$\begin{pmatrix} -C-K_1 + M + k[R_L, R_U], \\ K_1 + (1-k)[R_L, R_U] \end{pmatrix}$	$\begin{pmatrix} -C-K_2 + h[P_L, P_U], \\ K_2 + (1-h)[P_L, P_U] \end{pmatrix}$
	Not using industrial ecological protection measures	$\begin{pmatrix} -K_2 + k[T_L, T_U], \\ K_2 + (1-k)[T_L, T_U] \end{pmatrix}$	$\begin{pmatrix} -K_2 + k[S_L, S_U], \\ K_2 + (1-k)[S_L, S_U] \end{pmatrix}$

Source: MATLAB

enterprises and the government is an interval $[T_L, T_U]$. Therefore, in this case, the income of the enterprise is $K_2 + (1-k)[T_L, T_U]$, and that of the government is $-K_2 + k[T_L, T_U]$. To sum up, the income matrix of local governments and enterprises is as follows (Table 1).

4.2. Interval revenue evolutionary game based on the prospect theory

In the above-constructed payoff matrix, the payoffs of both sides are interval numbers due to uncertainty, making the stability of the evolutionary game difficult to realize. However, the cumulative prospect theory developed based on the prospect theory proposed by Kahneman and Tversky (1979) provides strong support for the decision-making process under uncertainty. In order to analyse the evolutionary stability behaviour of the game with an interval reward, the cumulative prospect theory is introduced to transform the interval number income matrix of industrial evolution into the perceived revenue matrix.

We set the return a to the interval number $[a_L, a_U]$, which means that the value may fall within the entire range. Therefore, the return can be regarded as a random variable, which is normally distributed in a large sample $a: N\left(\frac{a_L+a_U}{2}, \left(\frac{a_U-a_L}{6}\right)^2\right)$. The continuous interval is transformed into N the discrete interval, and the interval is $\Delta a = \frac{a_U-a_L}{N}$, and the return is $a_i = a_L + j * \Delta a$, ($j = 0, 1, \dots, N$). The REF point is a_0 , $x_j = a_j - a_0$, $x_j < 0$ for a loss and $x_j > 0$ for a return. Thus, the foreground value is $V = \sum_{j=1}^N v(x_j)\pi_j$, where $v(x_j) = \begin{cases} (x_j)^\alpha, & x_j \geq 0 \\ -\lambda(-x_j)^\beta, & x_j < 0 \end{cases}$, $\pi_j^+ = \omega^+(\sum_{l=j}^N p_l) - \omega^+(\sum_{l=j+1}^N p_l)$, $\pi_j^- = \omega^-(\sum_{l=1}^j p_l) - \omega^-(\sum_{l=1}^{j-1} p_l)$, $\pi_N^+ = w^+(p_N)$; $\pi_1^- = w^-(p_1)$. Therefore, the interval number payment matrix can be transformed into the following perceived payment matrix (Table 2).

4.3. Stability analysis

Assuming that the probability that the government chooses to take industrial ecological protection measures is x (in order to estimate the evidential strength and correctness, it is the ratio of the actual total area announced by the government of the tested area to the actual implementation), then the probability of not taking measures is $1-x$. The probability of enterprises choosing to adopt an environmental protection technology production strategy is y (in order to estimate the evidence strength and

Table 2. The perceived income matrix of industrial evolution.

Makers		Enterprises	
		environment protection	No taking-environment protection
Governments	Using industrial ecological protection measures	$\begin{pmatrix} -C-K_1 + M + kV_G^R \\ K_1 + (1-k)V_E^R \end{pmatrix}$	$\begin{pmatrix} -C-K_2 + hV_G^P \\ K_2 + (1-h)V_E^P \end{pmatrix}$
	Not using industrial ecological protection measures	$\begin{pmatrix} -K_2 + kV_G^T \\ K_2 + (1-k)V_E^T \end{pmatrix}$	$\begin{pmatrix} -K_2 + kV_G^S \\ K_2 + (1-k)V_E^S \end{pmatrix}$

Source: MATLAB

correctness, it is the ratio of the actual number of industry companies announced by the government of the tested area and the actual implementation), and the probability of choosing not to adopt environmental protection technology is $1-y$. Here, x, y are functions of time t . According to the perceived return matrix given in Table 2, we can get the dynamic replicator equation of the evolutionary game as follows.

The government's expected future values U_G and U_{NG} in the selection of industrial environmental protection measures and in the absence of industrial ecological protection measures, and the average expected prospect value \bar{U}_1 can be expressed as Equation (1):

$$\begin{cases} U_G = (-C-K_1 + kV_G^R)y + (-C-K_2 + hV_G^P)(1-y) \\ U_{NG} = (-K_2 + kV_G^T)y + (-K_2 + kV_G^S)(1-y) \\ \bar{U}_1 = xU_G + (1-x)U_{NG} \end{cases} \quad (1)$$

The expected prospect value $U_E U_{NE}$ and average expected prospect value \bar{U}_2 of enterprises using and not using an environmental protection technology production strategy are expressed as Equation (2):

$$\begin{cases} U_E = (K_1 + (1-k)V_E^R)x + (K_2 + (1-k)V_E^T)(1-x) \\ U_{NE} = (K_2 + (1-h)V_E^P)x + (K_2 + (1-k)V_E^S)(1-x) \\ \bar{U}_2 = yU_E + (1-y)U_{NE} \end{cases} \quad (2)$$

From Equations (1) and (2), the following kinetic equation of replicator can be obtained from Equation (3):

$$\begin{cases} \frac{dx}{dt} = x(1-x)(A_1 + B_1y) \\ \frac{dy}{dt} = y(1-y)(A_2 + B_2x) \end{cases} \quad (3)$$

Here, $A_1 = -C + hV_G^P - kV_G^S$; $B_1 = -K_1 + kV_G^R + K_2 - kV_G^T - hV_G^P + kV_G^S$; $A_2 = (1-k)V_E^T - (1-k)V_E^S$; $B_2 = K_1 + (1-k)V_E^R - K_2 - (1-h)V_E^P - (1-k)V_E^T + (1-k)V_E^S$.

Let $F(x) = \frac{dx}{dt}$, and $G(y) = \frac{dy}{dt}$. From $F(x) = 0$, we can obtain that when $x = 0, 1$ or $y = -\frac{A_1}{B_1}$, the selection behaviour of industrial environmental protection measures can achieve local stability; from $G(y) = 0$, we can conclude that when $y = 0, 1$ or $x = -\frac{A_2}{B_2}$ enters the enterprise, the adoption behaviour of ecological

Table 3. Parameters' meaning and initial value setting.

Symbol	Initial	Meaning
C	10	Cost of industrial environmental protection measures
K_1	10	Introduction subsidy of the environmental protection industry
K_2	5	Government subsidies for the introduction of general industries
M	30	Ecological spillover effect of a government building industrial ecosystem with the support of enterprises
k	0.2	Government's share after the introduction of enterprises
h	0.4	Government's share when enterprises are not environmentally friendly
R_L	30	Lowest public financial revenue in case 1
R_U	40	Highest public financial revenue in case 1
S_L	40	Lowest public financial revenue in case 2
S_U	50	Highest public financial revenue in case 2
P_L	40	Lowest public financial revenue in case 3
P_U	50	Highest public financial revenue in case 3
T_L	20	Lowest public financial revenue in case 4
T_U	30	Highest public financial revenue in case 4
T_0	20	Revenue reference of two maker

Source: MATLAB

protection technology reaches local stability. From $\begin{cases} F(x) = 0 \\ G(y) = 0 \end{cases}$, five possible equilibria of replicating dynamic systems are obtained: $O_1(0, 0)$, $O_2(1, 0)$, $O_3(0, 1)$, $O_4(1, 1)$ and $O_5\left(-\frac{A_2}{B_2}, -\frac{A_1}{B_1}\right)$.

This research proposes a new fuzzy payment matrix. When considering the expectation value of different game players, it is impossible to get the exact return matrix. Therefore, a numerical example is given based on the expected value of the interval return.

5. Numerical simulation

In order to simulate the evolution process of the industrial ecosystem and the influence of relevant parameters on the evolution of the system, this research applies MATLAB to simulate the dynamic evolution process of government and enterprises.

5.1. Parameters' settings

According to the actual meaning of the parameters, the initial values of each variable are set as follows (Table 3).

5.2. Simulation results

(1) The influence of the initial state on industrial evolution

On the premise of generality, the initial proportion of industrial ecological protection measures taken by local governments is set as $x = 0.5$. When both local governments and enterprises are risk-averse, Figure 1 shows that the system evolution converges to $(0, 0)$. If fewer enterprises start to adopt green technology, then it is $(1, 1)$ otherwise. When a few enterprises are adopting green technology, the government gradually gives up industrial ecological protection measures. The enterprises choose not to use environmental protection technology, and so the environment tends to deteriorate. When more enterprises adopt environmental protection technology according to the requirements of local governments, local governments will get more additional

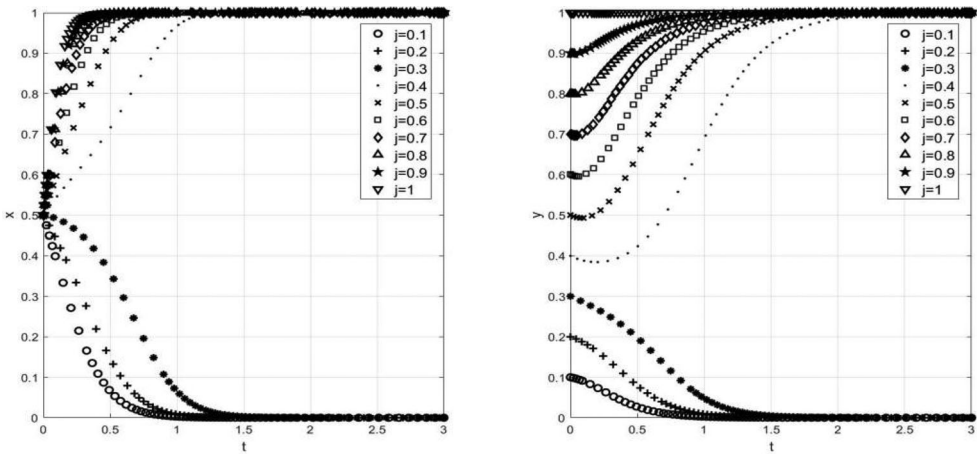


Figure 1. When $x = 0.5$, the influence of the initial state y on industrial evolution. Source: MATLAB.

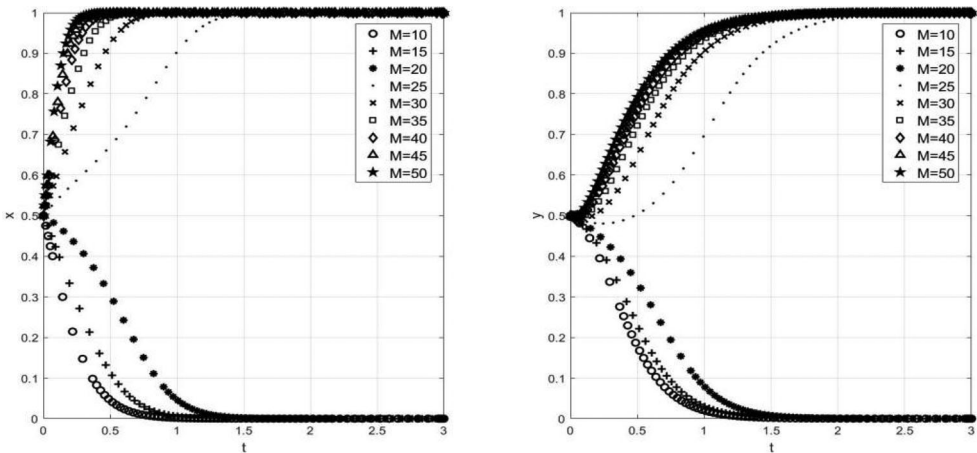


Figure 2. The impact of additional income M on industrial evolution. Source: MATLAB.

revenue due to the improvement of ecological benefits and production efficiency. Enterprises will also enjoy preferential tax policies and pay more attention to environmental protection production.

(2) The impact of excess revenue of local government industrial ecological protection measures on industrial evolution

Figure 2 mainly reflects the impact of the excess return of local government industrial ecological protection measures on industrial evolution. The results show that in the initial state $x = 0.5, y = 0.5$ (without loss of generality, the following simulation results are based on the initial state), the government implements industrial ecological protection measures with small revenue and high costs. It will then give up industrial ecological protection measures, and the ecological environment will deteriorate. On the contrary, when local governments can obtain more revenue from the implementation of industrial environmental protection measures, more local governments choose

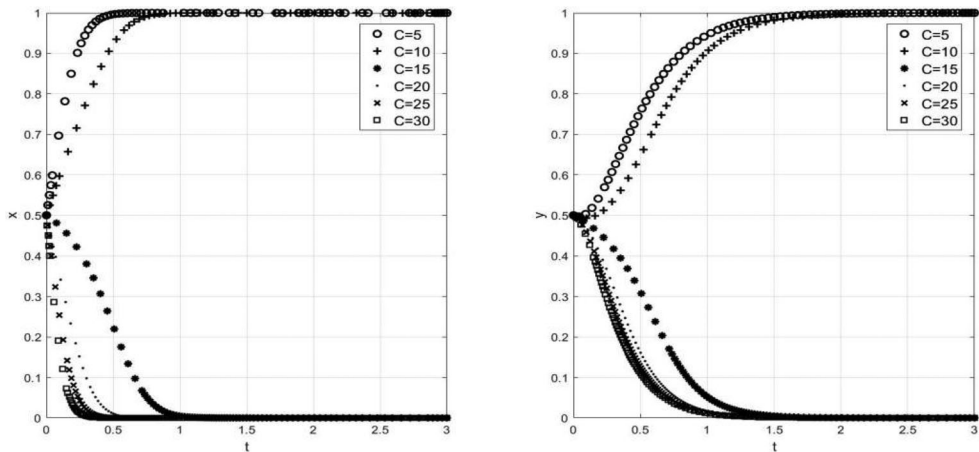


Figure 3. The impact of cost C on industrial evolution. Source: MATLAB.

industrial ecological protection measures to get additional benefits, and the system will eventually evolve into $(1, 1)$.

(3) The impact of the local government's cost of environmental protection measures on industrial evolution

Figure 3 shows that the cost of industrial environmental protection measures of a local government determines whether the local government takes industrial ecological protection measures and whether enterprises take environmental protection measures. When the cost of adopting ecological protection is high, the proportion of local governments adopting industrial environmental protection measures will gradually decrease, and the proportion of corresponding enterprises using environmental protection technology will also gradually decrease. Thus, the system evolves into $(0, 0)$. On the contrary, when local governments implement industrial environmental protection measures at a lower cost, the system will eventually evolve into $(1, 1)$.

(4) The impact of the local government's taxation on enterprises that do not adopt environmental protection production technology on industrial evolution

Figure 4 illustrates when the local government takes industrial ecological protection measures and the enterprises do not adopt environmental protection production technology that the local government's tax policy will affect the industrial evolution. When the local government has no environmental protection requirements, then it only considers the economic benefits of enterprises and adopts preferential tax policies. The enterprises will thus choose not to use environmental protection production technology to reduce costs.

When the local government designs preferential policies for enterprises composed of environmental protection technology and levies high taxes on enterprises, then the enterprises will not use environmental protection technology. The evolution path of enterprises and local governments will gradually tend to the direction of ecological protection. The system will eventually evolve into $(1, 1)$.

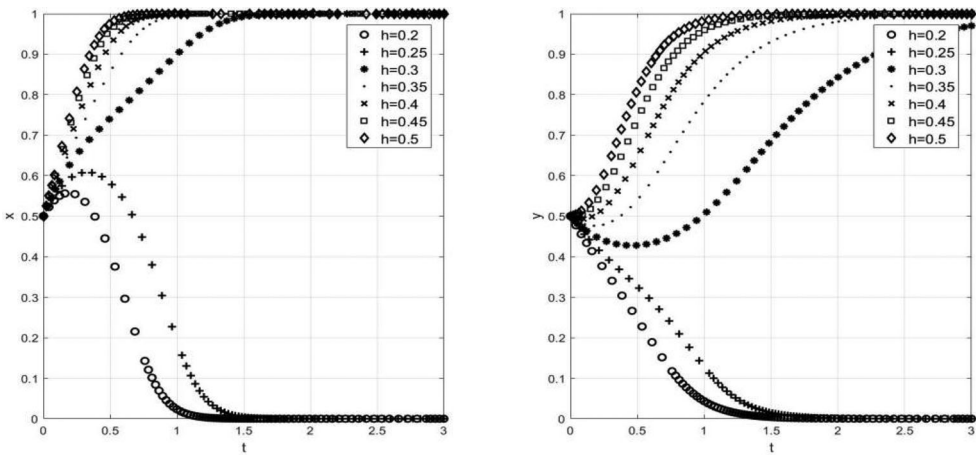


Figure 4. The influence of tax h on industrial evolution. Source: MATLAB.

(5) The influence of a reference point on industrial evolution

Because of uncertainty over whether the local government will take industrial ecological protection measures, the benefit of industrial ecological protection is an interval. As can be seen from [Figure 5](#), the reference points of both participants will affect the expected return. When the reference values of both participants are minimal, although there are some uncertainties, the perceived benefits of both participants are very high. Therefore, the system evolves into $(1, 1)$. When the reference value is high, the perceived value of both participants is low, and so the system evolves into $(0, 0)$.

(6) The influence of uncertainty on industrial evolution

[Figure 6](#) shows that the uncertainty of revenue has an important impact on the decision-making of different players. When the interest range is large, the uncertainty of local government and enterprise decisions will increase, and the system will gradually evolve to the initial state. When the range of return is small, the uncertainty is small, and the system will evolve into a benign state. In order to study the effect of income uncertainty on industrial evolution, we set the initial state of the system at $x = 0.3, y = 0.5$. As can be seen from [Figure 6](#), when uncertainty is small, the system will rapidly evolve to state $(1, 1)$. When the uncertainty is large, the system rapidly evolves to state $(0, 0)$.

6. Conclusions

(1) The initial state of poverty-stricken areas affects industrial development and environmental protection

[Figure 1](#) presents that the initial state of poverty-stricken areas restricts the effect of industrial development and environmental protection in the later stage. The local government sets the access threshold of ecological environment protection for urbanization, industrialization, and resource development, which include all kinds of ecological functional areas before attracting investment. It will help the enterprises to

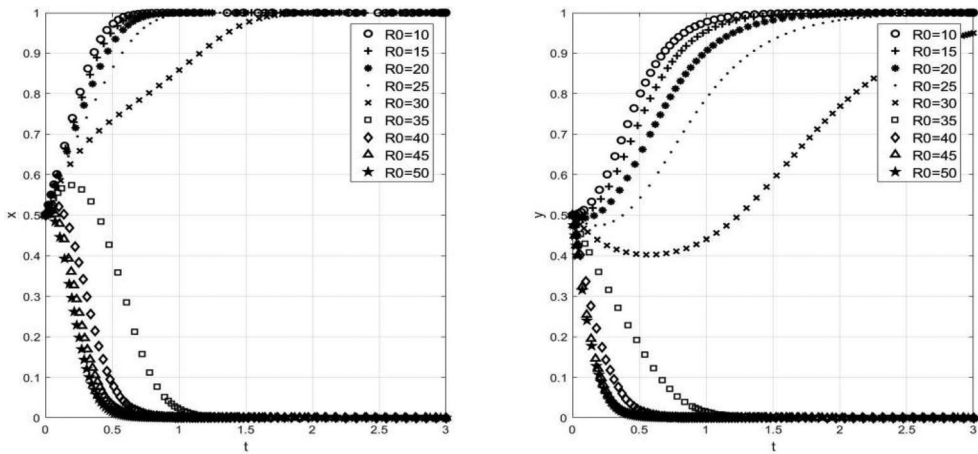


Figure 5. The influence of REF point R_0 on industrial evolution. Source: MATLAB.

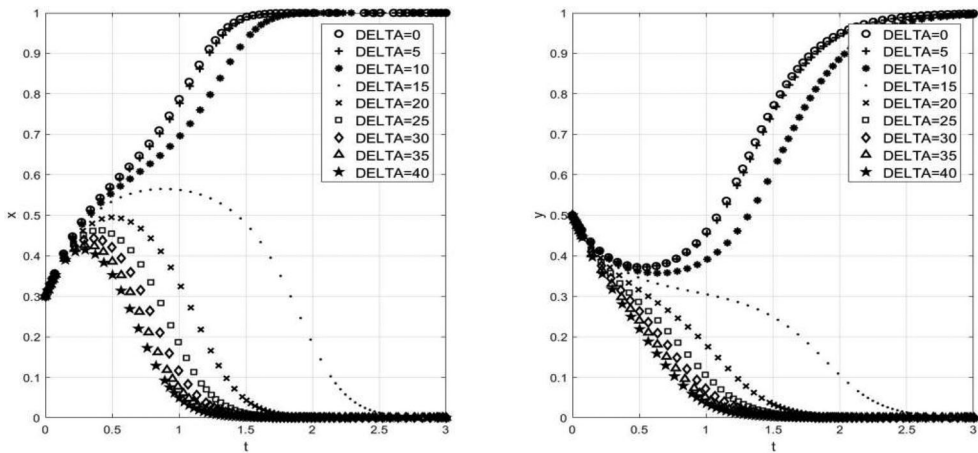


Figure 6. The influence of uncertainty on industrial evolution. Source: MATLAB.

take environmental protection measures and improve the virtuous circle of industrial development in this area. Therefore, promoting the sustainable development of industry should be guided by the best industrial environmental protection policy.

(2) The excess return and the costs of environmental protection by the local government restrict the industrial evolution.

Figures 2 and 3 show that local governments tend to pursue short-term economic benefits when the cost of environmental protection measures are high and the benefits are low. When the environmental protection costs are low and the economic benefits are high, the local governments will tend to choose the long-term sustainable development environmental protection policies. Therefore, one of the bottlenecks of green poverty alleviation lies in the financial problems of local governments. The central government can alleviate the contradiction between economic benefits and environmental protection in poverty alleviation areas by timely adopting subsidies and other policies.

(3) The guiding role of local government fiscal policy is conducive to environmental protection

Figure 4 shows that the change of tax policies will affect the choice of poverty alleviation enterprises for implementing a sustainable development strategy. Different tax policies are conducive to the coordinated development of the economy and environment. Therefore, local governments should give poverty alleviation enterprises the right of independent choice.

(4) The expected profits of local governments and poverty alleviation enterprises have different impacts on environmental protection effects

Figure 5 shows that local government and poverty alleviation enterprises can promote environmental protection measures when their expected benefits are low and their reference values are small. If the expected benefits of the enterprises are lower than the reference point, then the poverty alleviation enterprises will reduce industrial investment in the region.

(5) The level of environmental protection is subject to the uncertainty income of government and enterprises

As shown in Figure 6, the local government's responsibility for environmental protection depends on the degree of income uncertainty. Under the premise of relatively fixed expected benefits, local governments tend to coordinate the development of the environment and economy, pay attention to sustainable development, and have a high level of environmental protection. In contrast, when income uncertainty is large, local governments tend to reduce environmental protection standards. This research expounds the reasons for the differences in economy and environmental protection in different regions and takes into account income uncertainty, which affects the decision-making of local government and enterprises.

The China government in recent years has been actively learning from countries with high environmental protection and high income, especially those with low pollution and high income, such as Switzerland. In the face of the whole country's industrial upgrading and transformation, China is increasing the requirements for the environmental protection conditions of high pollution enterprises, enacting the mandatory requirement that environmental protection equipment be upgraded to international environmental protection standards, strengthening policy subsidies and financial support, and assisting in possible relocation and retransformation. In Fujian, for example, under the determination of environmental protection, local transformations and assistance to relocation are offered. After environmental improvement and possible income instability occurs during the process, a complete support scheme is initially given. It includes contact between manufacturers and manufacturers for equipment renewal, joint bargaining and capital subsidies, turnover subsidies for enterprises during downtime, and subsidies for employees' wages.

Some poverty-stricken areas may have to rely on industries with high pollution for their livelihood. In this regard, factories are being relocated and transformed, and

then new high-value and low-pollution industries (such as cultural industries) are introduced. The goal is to further enhance the overall economic value of the region and the level of environmental protection. Such cases can be seen everywhere throughout China, providing evidence that with consistent efforts of national policies, both economic growth and environmental protection can be carried out at the same time.

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