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Evolutionary Analysis of Emission Reduction Strategies

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Abstract: *In recent years, the global climate problem has become increasingly prominent and has attracted great international attention, and the development of a low-carbon economy has become an inevitable choice at this stage. Carbon emissions trading is a market mechanism adopted to promote global greenhouse gas emission reduction and reduce global carbon dioxide emissions. By releasing uniform price information, the carbon trading market motivates enterprises to carry out energy saving and emission reduction, and optimizes the allocation of carbon emission resources, which is considered an important policy to reduce carbon emissions and control climate change. Based on this, this paper constructs the decision model and evolutionary game model of the government and enterprises on the basis of the existing ones, and analyzes the mixed strategy stability of the government and enterprises according to the replicated dynamic equation system to obtain the evolutionary stable strategies of the government and enterprises under different situations. Subsequently, the parameters of each situation are assumed and numerical simulation is performed using Matlab software to draw conclusions.*

Keywords: *Optimal emission reduction, Evolutionary games, Strategy stability, Numerical simulation*

1. Introduction

1.1. Background of the study

Industrialization and rapid economic growth have led to a dramatic increase in greenhouse gas emissions and huge consumption of fossil energy. Greenhouse [1] and Jingna Ji et al. [2] have found that the increasing in carbon emissions is having a important impact on our environment and society and is causing great concern worldwide. Hongfang Lu et al. [3] found that many countries have developed low-carbon policies such as cap-and-trade, carbon taxes, and low-carbon subsidies to address this issue. Among these, carbon trading policies use market mechanisms to promote global carbon emission reductions. There is evidence that achieving emissions reductions is an effective market-based policy. In the context of carbon trading policies, a salient question is whether enterprise will adopt abatement strategies while considering the cost-effectiveness of carbon abatement in the long run. Chen and Hu [4] argue that in practice, enterprise tend to be influenced by other players by imitating or learning from the behavior of others. Bin Wu et al. [5] show that to investigate the optimal strategies of enterprise under an aggregate control and trading policy, we apply evolutionary Game theory was used to analyze and predict the aggregate and dynamic behavior of enterprise, and the method has been successfully applied to investigate the dynamic effects of carbon reduction policies and the collective behavior of multiple players.

2. Problem description and assumptions

We consider two strategies that each company can adopt: a 'carbon reduction' strategy and a 'no reduction' strategy, and two strategies that the government can adopt: a carbon trading policy and a non-carbon trading policy. We develop the following model.

(1) NN model (no carbon trading policy by government, no emission reduction by enterprises)

(2) NR model (no government policy on carbon trading, companies reduce emissions)

(3) RN model (government implements carbon trading policy, companies do not reduce emissions)

(4) RR model (government implements carbon trading policy, enterprises reduce emissions)

Which π_G^{NN} ,π_G^{NR} ,π_G^{RN} , andπ_G^{RR} denote the benefits to the government under different strategies for the government and the enterprise, respectively; π_E^{NN},π_E^{NR},π_E^{RN},and π_E^{RR}denote the returns to the enterprise under different strategies of the government and the enterprise, respectively .

3. Evolutionary game model of carbon emission reduction by government and enterprises in the context of carbon trading

3.1. Assumptions of the evolutionary game model of carbon reduction by government and enterprises in the context of carbon trading

3.1.1. Behavioral strategies in the game

In the context of carbon trading, both governments and enterprises are rational participants in the reduction of emissions. The government can choose a "carbon trading" or "non-carbon trading" strategy, while enterprises can choose a "carbon emission reduction" strategy or a "no emission reduction" strategy. "Whether the government adopts a carbon trading strategy or not, and whether enterprises adopt a carbon reduction strategy or not, is considered to be the result of a game between the government and enterprises[6-7].

3.1.2. Probability of behavioral strategy adoption

In the initial stage of the game between government and enterprises, the probability of the government adopting a "carbon trading" strategy is assumed to be $x(0 \le x \le 1)$ and the probability of adopting a "non-carbon trading" strategy is $1-x$; The probability that a enterprise chooses to adopt an "emissions reduction" strategy is $y(0 \le y \le 1)$,and the probability of adopting a "no emission reduction" strategy is $1-y$.

3.2. Construction of an evolutionary game model for carbon reduction by government and enterprises in the context of carbon trading

3.2.1. The benefits of government and corporate behavioral strategies in the context of carbon trading

Table 1: Benefits of different strategies for government and business

Both sides of the game		Companies	
		Emission reduction y	No reduction in emissions $1-y$
Politics Government	Carbon trading x	$(\pi_G^{RR},\ \pi_E^{RR})$	(π_G^{RN},π_E^{RN})
	Non-carbon trading $1-x$	(π_G^{NR},π_E^{NR})	(π_G^{NN},π_E^{NN})

3.2.2. Construction of an evolutionary game model for carbon emission reduction by government and enterprises in the context of carbon trading

Based on the payoff matrices of the government and business games, replicated dynamic equations are constructed for the behavioral strategies of the government and business respectively, as shown in Table 1.

3.2.3. The replication dynamic equation for government behavioral strategies

Assuming that the expected benefits of a 'carbon trading' behavioral strategy are E_{11},the expected benefits of adopting a 'non-carbon trading' behavioral strategy are E_{12},the average expected return is E_1 and the expected benefits of adopting a 'carbon trading' behavioral strategy are

$$E_{11} = y\pi_G^{RR} + (1-y)\pi_G^{RN} \tag{1}$$

Expected benefits of a 'non-carbon trading' behavioral strategy for governments.

$$E_{12} = y\pi_G^{NR} + (1-y)\pi_G^{NN} \tag{2}$$

Average expected return to government.

$$E_1 = xE_{11} + (1-x)E_{12} \tag{3}$$

The replication dynamic equation for the government's behavioral strategy is:

$$F(x) = \frac{dx}{dt} = x(E_{11} - E_1) \tag{4}$$

$$= x(1-x)(E_{11}-E_{12})$$
$$= x(1-x)[y(\pi_G^{RR}-\pi_G^{NR}-\pi_G^{RN}+\pi_G^{NN})-(\pi_G^{NN}-\pi_G^{RN})]$$

Similarly, the replication dynamics equation for the enterprise's behavioral strategy can be obtained as

$$F(y)=\frac{dy}{dt}=y(E_{21}-E_2)$$
$$=y(1-y)(E_{21}-E_{22})$$
$$=y(1-y)[x(\pi_E^{RR}-\pi_E^{NR}-\pi_E^{RN}+\pi_E^{NN})-(\pi_E^{NN}-\pi_E^{NR})]$$

In summary the set of replicated dynamic equations that make up the dynamic system are

$$\begin{cases} F(x)=x(1-x)[y(\pi_G^{RR}-\pi_G^{NR}-\pi_G^{RN}+\pi_G^{NN})-(\pi_G^{NN}-\pi_G^{RN})] \\ F(y)=y(1-y)[x(\pi_E^{RR}-\pi_E^{NR}-\pi_E^{RN}+\pi_E^{NN})-(\pi_E^{NN}-\pi_E^{NR})] \end{cases} \tag{5}$$

4. Stability analysis of evolutionary game models

To maximize their own profits, the government and enterprises continuously adjust their respective strategies to achieve dynamic equilibrium, and the strategy obtained at this time is the evolutionary stable strategy. In this paper, we will analyze the evolutionary stability of the behavioral strategies of both governments and enterprises.

Replicating the dynamic system of equations (5) from the above equation, for ease of description, we write $H=\pi_G^{NN}-\pi_G^{RN}, M=\pi_G^{RR}-\pi_G^{NR}-\pi_G^{RN}+\pi_G^{NN}$

$H_E=\pi_E^{NN}-\pi_E^{NR}, M_E=\pi_E^{RR}-\pi_E^{NR}-\pi_E^{RN}+\pi_E^{NN}$, at which point the system of equations is

$$\begin{cases} F(x)=x(1-x)[yM-H] \\ F(y)=y(1-y)[xM_E-H_E] \end{cases} \tag{6}$$

$F(x)=0, F(y)=0$, when the five equilibrium points of the system can be found as (0,0), (0,1), (1,0), (1,1), $(\frac{H_E}{M_E},\frac{H}{M})$

According to the Jacobian matrix, the five equilibrium points are substituted to obtain the determinant and trace of the corresponding Jacobian matrix. Based on this, the stability analysis is carried out. The partial derivatives of the system of equations with respect to *x* and *y* are calculated, and the Jacobian matrix can be obtained as follows:

$$J=\begin{pmatrix} (1-2x)(yM-H) & x(1-x)M \\ y(1-y)M_E & (1-2y)(xM_E-H_E) \end{pmatrix} \tag{7}$$

Only if $det(J)>0$ and $tr(J)<0$ equilibrium point is the evolutionary stable strategy. The determinant of the Jacobi matrix J can be derived from equation(6) as

$$det(J)=(1-2x)(yM-H)(1-2y)(xM_E-H_E)-x(1-x)My(1-y)M_E \tag{8}$$

The trace of the Jacobi matrix J is:

$$tr(J)=(1-2x)(yM-H)+(1-2y)(xM_E-H_E) \tag{9}$$

The five equilibrium points are brought into Eq. (8) and Eq. (9) respectively, and the corresponding determinants and traces for the different equilibrium points can be found as follows.

(1) When the equilibrium point is (0,0), the $det(J)=HH_E, tr(J)=-H-H_E$

(2) When the equilibrium point is (0,1), the $det(J)=H_E(M-H), tr(J)=M-H+H_E$

(3) When the equilibrium point is (1,0), the $det(J)=H(M_E-H_E), tr(J)=H+M_E-H_E$

(4) The equilibrium point is (1,1) when $det(J)=(M-H)(M_E-H_E), tr(J)=H-M+H_E-M_E$

(5) The equilibrium point is $(\frac{H_E}{M_E},\frac{H}{M})$ when $det(J)=H_E(1-\frac{H_E}{M_E})H(1-\frac{H}{M}), tr(J)=0$

When $det(J)>0$ and $tr(J)<0$,the equilibrium point is the evolutionary stable strategy, so the equilibrium point $(\frac{H_E}{M_E},\frac{H}{M})$ is not an evolutionary stable strategy with $tr(J)=0$.Then we analyze each of the four stable points, combining the determinants of each of these points and their stability conditions, according to the notation of $M-H$ and M_E-H_E, we classified the discussion as follows.

Situation one: $M-H>0, M_E-H_E>0$

At this point, the equilibrium point (1,1) satisfies $det(J)|_{(x,y)=(1,1)}>0, tr(J)|_{(x,y)=(1,1)}<0$, so (1,1) is the evolutionary stabilization strategy.

For equilibrium points (0,0), (0,1), (1,0) need to be discussed by situations.

(1) $H>0, H_E>0$

$det(J)|_{(x,y)=(0,0)}>0, tr(J)|_{(x,y)=(0,0)}<0$, under which condition (0,0) is the evolutionary stable strategy.

$det(J)|_{(x,y)=(0,1)}>0, tr(J)|_{(x,y)=(0,1)}>0$, under which condition (0,1) is not an evolutionary stable strategy,$det(J)|_{(x,y)=(1,0)}>0, tr(J)|_{(x,y)=(1,0)}>0$,under which condition (1,0) is not an evolutionary stable strategy.

(2) $H>0, H_E<0$
$det(J)|_{(x,y)=(0,0)}<0$, under which condition (0,0) is not an evolutionary stable strategy.

$det(J)|_{(x,y)=(0,1)}<0$, under which condition (0,1) is not an evolutionary stable strategy.

$det(J)|_{(x,y)=(1,0)}>0, tr(J)|_{(x,y)=(1,0)}>0$, under which condition (1,0) is not an evolutionary stable strategy.

(3) $H<0, H_E>0$

$det(J)|_{(x,y)=(0,0)}<0$, under which condition (0,0) is not an evolutionary stable strategy.

$det(J)|_{(x,y)=(0,1)}>0, tr(J)|_{(x,y)=(0,1)}>0$, under which condition (0,1) is not an evolutionary stable strategy,$_{(x,y)=(1,0)}<0$, under which condition (1,0) is not an evolutionary stable strategy.

(4) $H<0, H_E<0$

$det(J)|_{(x,y)=(0,0)}>0, tr(J)|_{(x,y)=(0,0)}>0$, under which condition (0,0) is not an evolutionary stable strategy.

$det(J)|_{(x,y)=(0,1)}<0$, under which condition (0,1) is not an evolutionary stable strategy.

$det(J)|_{(x,y)=(1,0)}<0$, under which condition (1,0) is not an evolutionary stable strategy.

In summary, the equilibrium point (1,1) in case 1 satisfies $det(J)|_{(x,y)=(1,1)}>0, tr(J)|_{(x,y)=(1,1)}<0$, the equilibrium point (0,0) is in the case of case 1, which is an evolutionary stabilization strategy, where the government chooses to adopt a "carbon trading" policy and the enterprises chooses to adopt an "emission reduction" policy; the equilibrium point (0,0) is in the case of $M-H>0, M_E-H_E>0$ *and* $H>0, H_E>0$, under the condition that $det(J)|_{(x,y)=(0,0)}>0, tr(J)|_{(x,y)=(0,0)}<0$, the government chooses to adopt a "non-carbon trading" policy and the enterprise chooses to adopt a "no emission reduction" policy.

Situation two: $M-H>0$,$M_E-H_E<0$

At this point, the equilibrium point (1,1) $\det(J)|_{(x,y)=(1,1)}<0$, so under this condition (1,1) is not an evolutionary stable strategy; for equilibrium points (0,0), (0,1), (1,0) need to be discussed by cases.

(1) $H>0, H_E>0$

$det(J)|_{(x,y)=(0,0)}>0, tr(J)|_{(x,y)=(0,0)}<0$, under this condition (0,0) is an evolutionary stable strategy.

$det(J)|_{(x,y)=(0,1)}>0, tr(J)|_{(x,y)=(0,1)}>0$, under which condition (0,1) is not an evolutionary stable strategy.

$det(J)|_{(x,y)=(1,0)}<0$, none of the (1,0) is an evolutionary stable strategy under this condition.

(2) $H>0, H_E<0$

$det(J)|_{(x,y)=(0,0)}<0$, under which condition (0,0) is not an evolutionary stable strategy.

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$det(J)|_{(x,y)=(0,1)} < 0$, under which condition (0,1) is not an evolutionary stable strategy.

$det(J)|_{(x,y)=(1,0)} < 0$, under which condition (1,0) is not an evolutionary stable strategy.

(3) $H < 0, H_E > 0$

$det(J)|_{(x,y)=(0,0)} < 0$, under this condition (0,0) is not an evolutionary stable strategy.

$det(J)|_{(x,y)=(0,1)} > 0, tr(J)|_{(x,y)=(0,1)} > 0$, under which condition (0,1) is not an evolutionary stable strategy.

$det(J)|_{(x,y)=(1,0)} > 0, tr(J)|_{(x,y)=(1,0)} < 0$, under which condition (1,0) is the evolutionary stable strategy.

(4) $H < 0, H_E < 0$

$det(J)|_{(x,y)=(0,0)} > 0, tr(J)|_{(x,y)=(0,0)} > 0$, under which condition (0,0) is not an evolutionary stable strategy.

$det(J)|_{(x,y)=(0,1)} < 0$, under which condition (0,1) is not an evolutionary stable strategy.

$det(J)|_{(x,y)=(1,0)} < 0$, under which condition (1,0) is not an evolutionary stable strategy.

$det(J)|_{(x,y)=(1,0)} > 0, tr(J)|_{(x,y)=(1,0)} < 0$, under this condition (1,0) is an evolutionary stable strategy.

In summary: the equilibrium point (0,0) is at $M - H > 0, M_E - H_E < 0$,$H > 0, H_E > 0$,under the condition that $det(J)|_{(x,y)=(0,0)} > 0, tr(J)|_{(x,y)=(0,0)} < 0$,the equilibrium point (1,0) is an evolutionary stabilization strategy, where the government chooses to adopt a "non-carbon trading" policy and enterprise chooses to adopt a "no emission reduction" policy; the equilibrium point (1,0) at $M - H > 0, M_E - H_E < 0$, when $H < 0, H_E > 0$ *or* $H < 0, H_E < 0$,under the condition that $det(J)|_{(x,y)=(1,0)} > 0, tr(J)|_{(x,y)=(1,0)} < 0$,the equilibrium point (1, 0) is an evolutionary stabilization strategy, where the government chooses to adopt a "carbon-trading" policy and the enterprise chooses to adopt a "no-emissions" policy.

Situation three: $M - H < 0$,$M_E - H_E > 0$

At this point, the equilibrium point (1,1) satisfies $det(J)|_{(x,y)=(1,1)} < 0$, therefore conditionally (1,1) is not an evolutionary stable strategy; for equilibrium points (0,0), (0,1), (1,0) need to be discussed by case.

(1) $H > 0, H_E > 0$

$det(J)|_{(x,y)=(0,0)} > 0, tr(J)|_{(x,y)=(0,0)} < 0$, under which condition (0,0) is the evolutionary stable strategy.

$det(J)|_{(x,y)=(0,1)} < 0$, under this condition (0,1) is not an evolutionary stable strategy.

$det(J)|_{(x,y)=(1,0)} > 0, tr(J)|_{(x,y)=(1,0)} > 0$, under this condition (1,0) is not an evolutionary stable strategy.

(2) $H > 0, H_E < 0$

$det(J)|_{(x,y)=(0,0)} < 0$, under which condition (0,0) is not an evolutionary stable strategy.

$det(J)|_{(x,y)=(0,1)} > 0, tr(J)|_{(x,y)=(0,1)} < 0$, under which condition (0,1) is the evolutionary stable strategy.

$det(J)|_{(x,y)=(1,0)} > 0, tr(J)|_{(x,y)=(1,0)} > 0$, under this condition (1,0) is not an evolutionary stable strategy.

(3) $H < 0, H_E > 0$

$det(J)|_{(x,y)=(0,0)} < 0$, under which condition (0,0) is not an evolutionary stable strategy.

$det(J)|_{(x,y)=(0,1)} < 0$, under this condition (0,1) is not an evolutionary stable strategy.

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(4) $H < 0, H_E < 0$

$det(J)|_{(x,y)=(0,0)} > 0, tr(J)|_{(x,y)=(0,0)} >0$, under which condition (0,0) is not an evolutionary stable strategy.

$det(J)|_{(x,y)=(0,1)} > 0, tr(J)|_{(x,y)=(0,1)} < 0$, *under which condition (0,1) is the evolutionary stable strategy.*

$det(J)|_{(x,y)=(1,0)} < 0$,under this condition (1,0) is not an evolutionary stable strategy.

In summary : at $M - H < 0$,$M_E - H_E > 0$,$H > 0, H_E > 0$, the equilibrium point (0,0) is under the condition that$det(J)|_{(x,y)=(0,0)} > 0, tr(J)|_{(x,y)=(0,0)} < 0$ is an evolutionary stabilization strategy, where the government chooses to adopt a "non-carbon trading" policy and enterprises chooses to adopt a "no emission reduction" policy; at $M - H < 0$,$M_E - H_E > 0$,when $H > 0, H_E < 0 or\ H < 0, H_E < 0$,the equilibrium point (0,1) is under the condition that $\det(J)|_{(x,y)=(0,1)} > 0, \mathrm{tr}(J)|_{(x,y)=(0,1)} < 0$,the equilibrium point (0,1) is the evolutionary stabilization strategy, where the government chooses to adopt a "non-carbon trading" policy and the enterprise chooses to adopt an "emissions reduction" policy;

Situation four: $M - H < 0$,$M_E - H_E < 0$

At this point, the equilibrium point (1,1) satisfies $det(J)|_{(x,y)=(1,1)} < 0$, *t*herefore conditionally (1,1) is not an evolutionary stable strategy; for equilibrium points (0,0), (1,1), (1,0) need to be discussed by cases.

(1) $H > 0, H_E > 0$

$det(J)|_{(x,y)=(0,0)} > 0, tr(J)|_{(x,y)=(0,0)} < 0$, under which condition (0,0) is the evolutionary stable strategy.

$det(J)|_{(x,y)=(0,1)} < 0$, under this condition (0,1) is not an evolutionary stable strategy.

$det(J)|_{(x,y)=(1,0)} < 0$, under this condition (1,0) is not an evolutionary stable strategy.

(2) $H > 0, H_E < 0$

$det(J)|_{(x,y)=(0,0)} < 0$, under which condition (0,0) is not an evolutionary stable strategy.

$det(J)|_{(x,y)=(0,1)} > 0, tr(J)|_{(x,y)=(0,1)} < 0$, under which condition (0,1) is the evolutionary stable strategy.

$det(J)|_{(x,y)=(1,0)} < 0$, under this condition (1,0) is not an evolutionary stable strategy.

(3) $H < 0, H_E > 0$

$det(J)|_{(x,y)=(0,0)} < 0$, under which condition (0,0) is not an evolutionary stable strategy.

$det(J)|_{(x,y)=(0,1)} < 0$, under this condition (0,1) is not an evolutionary stable strategy.

$det(J)|_{(x,y)=(1,0)} > 0, tr(J)|_{(x,y)=(1,0)} < 0$, under this condition (1,0) is the evolutionary stable strategy.

(4) $H < 0, H_E < 0$

$det(J)|_{(x,y)=(0,0)} > 0, tr(J)|_{(x,y)=(0,0)} >0$, under which condition (0,0) is not an evolutionary stable strategy.

$det(J)|_{(x,y)=(0,1)} > 0, tr(J)|_{(x,y)=(0,0)} < 0$, under which condition (0,1) is the evolutionary stable strategy.

$det(J)|_{(x,y)=(1,0)} > 0, tr(J)|_{(x,y)=(1,0)} < 0$, under which condition (1,0) is the evolutionary stable strategy.

In summary: the equilibrium point (0,0) is at $M - H < 0, M_E - H_E <0$, $when\ H > 0, H_E > 0$,under the condition that $det(J)|_{(x,y)=(0,0)} > 0, tr(J)|_{(x,y)=(0,0)} < 0$,the equilibrium point (0,1) is an evolutionary stabilization strategy where the government chooses to adopt a "non-carbon trading" policy and enterprise choose to adopt a "no emission reduction" policy; the equilibrium point (0,1) at $M - H < 0$,$M_E - H_E < 0$,when $H > 0, H_E < 0$ $orH < 0, H_E < 0$ under the condition that $det(J)|_{(x,y)=(0,1)} > 0, tr(J)|_{(x,y)=(0,1)} < 0$ is an evolutionary stabilization strategy, where the government chooses to adopt a "non-carbon trading" policy and the enterprise chooses to adopt an "emissions reduction" policy; the equilibrium point (1,0) is at $M - H < 0, M_E - H_E < 0$,when $H < 0, H_E > 0$ or $H < 0, H_E < 0$,under the condition that $det(J)|_{(x,y)=(1,0)} > 0, tr(J)|_{(x,y)=(1,0)} < 0$,the equilibrium point (1,0) is an evolutionary stabilization strategy, where the government chooses to adopt a "carbon trading" policy and the enterprise chooses to adopt a "no emissions reduction" policy.

5. Numerical simulation analysis

This paper assigns appropriate values to the parameters and uses Matlab to conduct numerical simulations to obtain the probability change curves and their evolutionary trajectories for governmentand enterprises under different strategies, as follows:

Assumed parameters $\alpha = 50, \beta = 2, C_g = 20, p_g = 5, r = 1, n = 2, \sigma = 2, m + n = 4,$

$\theta = 1$. Let the revenue matrix of the enterprise beE , then E is:

$$E = \begin{pmatrix} \pi_E^{NN} & \pi_E^{NR} \\ \pi_E^{RN} & \pi_E^{RR} \end{pmatrix} = \begin{pmatrix} 312.5 & 3750 \\ 300 & 3250 \end{pmatrix} \tag{10}$$

Let the total social welfare size matrix beG , then G as

$$G = \begin{pmatrix} \pi_G^{NN} & \pi_G^{NR} \\ \pi_G^{RN} & \pi_G^{RR} \end{pmatrix} = \begin{pmatrix} 837.5 & 18650 \\ 1280 & 669.444 \end{pmatrix} \tag{11}$$

At this point we obtain the system of dynamic equations as

$$\begin{cases} F(x) = \frac{dx}{dt} = x(1-x)(-18423y - 442.5) \\ F(y) = \frac{dy}{dt} = y(1-y)(-487.5x - 12.5) \end{cases} \tag{12}$$

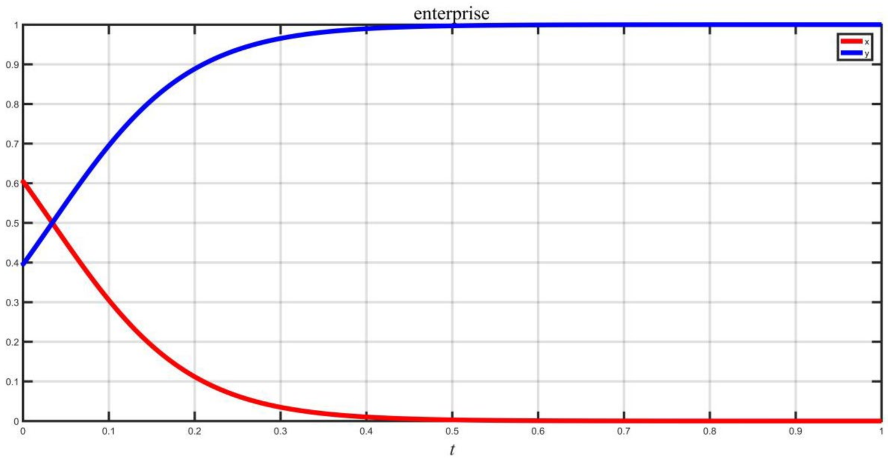

Figure 1: Enterprise game evolution trajectory

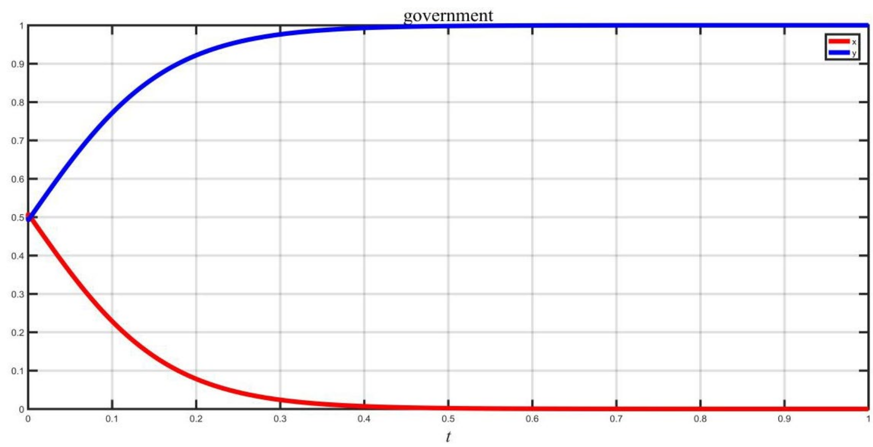

Figure 2: Government gaming evolution trajectory

Assuming that the probability of the initial state *x*=0.4, *y*=0.6, Matlab numerical simulation of enterprise and government decision-making, as shown in Figure 1: *y* is the probability that the enterprise adopts an emission reduction strategy, *x* is the probability that the enterprise does not adopt a carbon emission reduction strategy; as shown in Figure 2: *y* is the probability that the government adopts a carbon trading policy, *x* is the probability that the enterprise does not adopt a carbon trading policy[8-10].

From figure 1 and figure 2, it can be seen that in the process of evolving the game, the benefit of adopting carbon emission reduction strategy is higher than the benefit of not adopting carbon emission reduction strategy, and enterprises tend to adopt carbon emission reduction strategy, and the final equilibrium result of evolving the game: the government adopts carbon trading policy and enterprises adopt emission reduction strategy.

6. Conclusion

Based on the above analysis, this paper concludes the following:

(1) Whether an enterprise adopts a carbon reduction strategy or not depends on the cost of adopting a carbon reduction strategy, when the cost of adopting a carbon reduction strategy is lower than the overall benefits it brings, enterprises tend to adopt a carbon reduction strategy.

(2) When the cost of adopting carbon emission reduction strategy is higher, enterprises will prefer to adopt carbon emission reduction strategy when the government adopts carbon trading policy; when the comprehensive benefits of adopting carbon emission reduction strategy are higher than the cost of adopting carbon emission reduction strategy by enterprises, enterprises will also prefer to adopt carbon emission reduction strategy.

(3) In the case of enterprises adopting carbon reduction strategies, there is a strong relationship between whether the government adopts a carbon trading policy and the enterprises' carbon emissions. When the enterprises' carbon emissions exceed a certain threshold, the government tends to adopt a non-carbon trading policy; when the enterprises' carbon emissions are within a certain threshold, the government tends to adopt a carbon trading policy.

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