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Evolutionary Game Analysis of Multiple Participation in Source Classification of Domestic Waste

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ABSTRACT

It's difficult to guarantee the effect of the source classification of domestic waste only by government, so it's necessary to rely on the participation of residents, social organizations and other forces. In this paper, by constructing the evolutionary game model of government, residents and social organizations, studies the evolutionary stability strategy, and uses matlab for simulation analysis. The results show that (1) When government loosely supervises and residents don't participate in the classification, the frequency of participation of social organizations is not high, which is not conducive to the classification of waste sources. (2) When government strictly supervises and residents do not participate in the classification, social organizations are more active in participating, but the government's management cost is too high. (3) When government loosely supervises and residents participate in classification, the participation rate of social organizations increases, and residents' awareness of independent participation in waste classification is increased, also can achieve the desired objective waste classification. (4) When government strictly supervises and residents participate in classification, social organizations participate actively at the highest level, this form of positive attitudes by all three parties is also the best way to efficiently carry out waste classification at source.

1. INTRODUCTION

With the acceleration of economic development and urbanization, the quantity of urban domestic waste is increasing year by year [1], the classification and recycling of domestic waste has become a serious problem faced by urban development. According to the "China Statistical Yearbook 2020" published by the National Bureau of Statistics, in 2019, the amount of urban domestic waste in China reached 242.062 million tons, with an average annual growth of about 6% in the past five years, domestic waste management has become a serious problem facing China's urban development. However, landfill and incineration, which are the main means of urban waste treatment, cannot keep up with the growth rate of waste production. Therefore, the fundamental way out lies in "reduction" and "resources", in which the source classification of waste is both the precondition and the key. It not only greatly improves the recycling rate of waste, but also reduces the transportation cost of waste and the difficulty in ending disposal [2, 3].

Since 1990s, China has been exploring an effective path of "front-end reduction and classification" of domestic waste, and has invested a lot of manpower and material resources. Take Beijing as an example: As early as 1993, Beijing issued the "Beijing City Appearance and Environmental Sanitation Regulations", which set requirements for the classified collection, treatment and utilization of domestic waste. In 2000, Beijing was listed as one of the "first batch of pilot cities for domestic waste classification." In 2017, the National Development and Reform Commission and the Ministry of Housing and Urban-Rural Development launched the "Implementation Plan for Domestic Waste Classification System", and Beijing was selected as the pilot city. According to the 2019 Beijing Municipal Waste Classification Satisfaction Survey Report, Beijing residents' awareness of household waste classification has initially formed, but the participation rate of household waste classification is only 43.4%. In terms of various administrative districts, only Dongcheng District, Xicheng District and Shijingshan District exceed 50%. The findings are similar to those found in previous studies [4]. The reasons are the imperfect supervision system in waste classification, the deviation between residents' awareness and behavior, and the low participation rate of social organizations, which all lead to the long-term in government-dominated, passive classification of residents and low participation rate of social organizations. Therefore, in order to truly realize the goal of recycling, reducing and harmless waste, it's necessary to actively explore the urban waste management mechanism coordinated by the government and the public, and clarify the respective roles of the government, enterprises, social organizations, and residents in the management of urban domestic waste [5].

Therefore, this paper hopes to discuss the behavioral strategy choices of the three parties in the source separation of waste by building an evolutionary game model between government, residents and social organisations, and to obtain the optimal way of cooperation between them, so as to make suggestions for improving the participation rate of source separation of urban domestic waste.

2. LITERATURE REVIEW

As the main generators of municipal waste, the participation of residents in waste separation at the front end is the key to the good operation of the municipal waste treatment system, therefore, in previous studies, many scholars have studied the issue of municipal waste separation governance with residents as the main body: At the macro level, most studies focus on the influence of external conditions such as environmental control policies, incentive policies, laws and regulations, and municipal waste separation and recycling systems on residents' waste separation behavior from the perspective of government regulation [6-10]. At the micro level, individual psychology, environmental knowledge, lifestyle habits, social structure, social capital, values, class identity, etc. are also the focus of discussion in most studies [11-14]. Some scholars have also combined micro and macro factors [15-17], and then led to various explanatory models of waste sorting behaviour: such as planned behaviour model [18], normative behaviour model [19], and A-B-C model [20].

Separation of domestic waste is a responsibility that needs to be shared by all members of the public, and there are relatively few studies that explore the interaction and cooperation between the government and residents from the perspective of multi-participant participation. In addition, social organisations are important participants in source separation of waste, forming a good partnership with the government by promoting separation policies and guiding residents to separate waste properly, thus reducing the cost of government oversight. However, there is a lack of discussion on the participation of social organisations in current research. For this reason, this paper attempts to conduct some useful exploration in this area.

Evolutionary games modify the assumption of perfect rationality of the participants in traditional games and introduce the concept of finite rationality. Due to this assumption premise, it has become an effective method for studying changes in the strategies of multiple players in the socio-economic field and has been widely used in the field of economic management where multiple players are involved [21-24].

Therefore, the paper is organised as follows: firstly, an evolutionary game model is constructed between the behaviour of residents and government, taking into account the participation of social organisations in the promotion and guidance of source separation of waste. Secondly, the evolutionary game model is solved to analyse the behavioural strategies of the three parties based on the local stability of the equilibrium point. Thirdly, the evolutionary process is visualised through Matlab software. Finally, suggestions are made to improve the participation rate of source separation of municipal waste.

3. ESTABLISH EVOLUTIONARY GAME MODEL

3.1 Definition of game subject

Source classification of domestic waste refers to the behavior of urban residents who separate and collect domestic waste according to specified categories, and put the collected waste into designated locations or selling them [25]. Through reading relevant literature and field investigations, when studying on the participation in the source classification, this paper selects the government, social organizations and residents as the participants in the behavioral strategy game process. The roles and relationships of each participant are defined as follows: The government is macro-controller whose work is to formulate and supervise the macro-policies. Social organizations are third-party non-governmental organizations invited by the government to participate. They are responsible for taking various non-compulsory measures to help and guide residents to participate in classification, and increase the participation rate and correct separation rate of residents. Residents are the main body of waste generation, and the most critical link who affects the effectiveness of waste classification. Whether or not to participate in classification directly affects the development of a series of subsequently work, as shown in Figure 1.

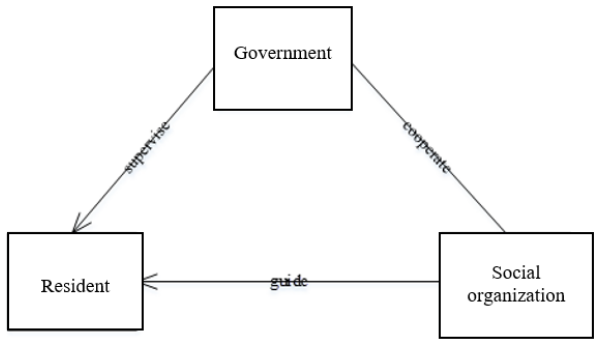

Figure 1. Relationship of participants in the game

Simplify the game framework: Social organizations are nonprofit organizations that voluntarily participate in the work of waste classification, and have a certain auxiliary and synergistic effect on government. In order to facilitate following study and don't affect the research conclusions, this paper put social organizations into model as the form of participation probability $p(0<p<1)$ to help reduce government's daily supervision costs, and improve the participation rate and correct rate of residents.

3.2 Hypothesis and model construction

3.2.1 Hypothesis

Assumption 1: The information of stakeholders of all parties isn't completely symmetric and all of them are bounded rationality. The strategy sets of the government and residents are{strict supervision; loose supervision};{ participate in classification; don't participate in classification}. Set the probability of choosing strict supervision in the government group as x, and the probability of choosing to participate in classification in the resident group as y, where $x, y \in [0, 1]$.

Assumption 2: The cost of strict supervision is a, which consists of fixed cost a_0 and marginal cost. Social organizations improve the participation rate of residents through publicity and education, and help government to reduce the cost of supervision. At this time, the cost of government supervision can be expressed as $a = a_0 + (1-p)/k$. The cost of loose supervision is b ($a > b$), and the government's subsidy to residents who participate in the classification work is c, and the fine to residents who don't participate in the classification work is d. Under strict supervision, the waste classification work maybe achieves good results, then the government's positive social utility is expressed as U_1. Loose regulation leads to the stagnation of waste classification and

the negative social utility is U_2.

Assumption 3: The cost of residents' participation in waste classification is e, which including time and physical cost, and the positive benefit of improving living environment is f; The administrative fine imposed on residents who do not participate in waste classification is g.

Model parameters were combined as shown in Table 1.

Table 1. Related parameter assumptions

Subject	Parameter	Meaning
Government	x	The government chooses the proportion of strict supervision.
	a	The cost of strict supervision
	a_0	Fixed costs when government are strictly supervising
	k	The regulatory capacity of government
	c	Incentive subsidies for residents to participate in the classification
	m	The cost of secondary classification by the government when residents are not classified
	u_1	Under strict supervision, when the classification work achieve good results, the government has received positive social utility.
	1-x	The government chooses the proportion of loose supervision.
	b	The cost of loose regulation
	u_2	Loose supervision leads to stagnation of classification and the negative social ulity received by government.
Resident	y	Proportion to join in waste classification
	e	Cost of waste sorting (including time and physical cost)
	f	When the residents participate in classification, the improvement of the environment will bring positive utility to them.
	1-y	Proportion not to join in waste classification
	d	fines for not participating in waste classification
Social organizations	p	Probability of participation in source classification, $0 < p < 1$

3.2.2 Model construction

According to relevant parameter settings and research assumptions, the income-payment matrix between government and residents is shown in the following Table 2:

Table 2. Return matrix

	Government	
Resid ents	Strictly supervise (x)	loosely supervise (1-x)
	participate u_1-a-c	-b-c
	(y) f-e+c	f-e
	not participate u_1-a-m+d	-b-u_2
	(1-y) -d	0

3.3 Solution and analysis of model

3.3.1 Expected revenue and replication dynamic equation

Suppose that the expected benefits of government's choice of strict and loose supervision are E_x and E_{1-x}, and the average expected benefits is $\overline{E_1}$, according to Table 2:

$$E_x=y(u_1\text{-}a\text{-}c)+(1-y)(u_1\text{-}a\text{-}m+d)=y(m\text{-}c\text{-}d)+u_1\text{-}a\text{-}m+d \quad (1)$$

$$E_{1-x}=y(-b-c)+(1-y)(-b-u_2)=y(u_2-c)-(b+u_2) \quad (2)$$

$$\overline{E_1}=xE_x+(1-x)E_{1-x} \quad (3)$$

The replication dynamic equation of the government's strategy is:

$$\frac{dx}{dt}=x\left(E_x-\overline{E_1}\right)=x(1-x)[y(m\text{-}d\text{-}u_2)+u_1\text{-}a\text{-}m+d+b+u_2] \quad (4)$$

Suppose that the expected benefits of residents' choice of participating in the classification or not are E_y and E_{1-y}, and the average expected benefits is $\overline{E_2}$, according to Table 2:

$$E_y=x(f\text{-}e+c)+(1-x)(f\text{-}e)=xc+f\text{-}e \quad (5)$$

$$E_{1-y}=-xd \quad (6)$$

$$\overline{E_2}=yE_y+(1-y)E_{1-y} \quad (7)$$

The replication dynamic equation of the residents' strategy is:

$$\frac{dy}{dt}=y\left(E_y-\overline{E_2}\right)=y(1-y)[x(c+d)+f\text{-}e] \quad (8)$$

Let $\frac{dx}{dt}=0$, $\frac{dy}{dt}=0$, Combining the replication dynamic equations of the government and resident, a two-dimensional dynamic system is obtained. Partial equilibrium points of the system are (0,0), (1,0), (0,1), (1,1) and (x *, y *) respectively.

Where:

$$x^*=\frac{e\text{-}f}{c+d}\ y^*=\frac{a+m\text{-}u_1\text{-}d\text{-}b\text{-}u_2}{m\text{-}d\text{-}u_2}$$

3.3.2 Local stability analysis of equilibrium point

If there are no strong shocks from the outside, the system itself will not deviate from the steady state and its strategy will not change; this equilibrium stable state is called evolutionary stable equilibrium and the corresponding strategy is called evolutionary stable strategy (ESS). The core idea of Evolutionarily Stable Stratery (ESS) is that "if an existing strategy is an evolutionarily stable equilibrium strategy, then there must be a positive intrusion barrier such that when the frequency of variation is lower than this barrier, the existing strategy is able to achieve higher returns than the variation strategy. "Equilibrium points obtained by the replication dynamic equation are not necessarily evolutionary stable strategy (ESS) of the system. According to the method proposed by Friedman [26], the evolutionary stability of these five equilibrium points can be determined by the eigenvalues of the Jacobian matrix corresponding to each equilibrium point. Jacobian matrix of the game system can be obtained by solving the partial derivatives of x and y for the replication dynamic equations of the government and resident strategies:

$$J=\begin{bmatrix}(1-2x)[y(m\text{-}d\text{-}u_2)+u_1\text{-}a\text{-}m+d+b+u_2] & x(1-x)(m\text{-}d\text{-}u_2)\\ y(1-y)(c+d) & (1-2y)[x(c+d)+f\text{-}e]\end{bmatrix}$$

Put these five equilibrium points into the Jacobian matrix:

When the equilibrium point is (0,0), Jacobian matrix can be

simplified as:

$$\begin{bmatrix} u_1\text{-}a\text{-}m\text{+}d\text{+}b\text{+}u_2 & 0 \\ 0 & f\text{-}e \end{bmatrix}$$

When the equilibrium point is (1,0), Jacobian matrix can be simplified as:

$$\begin{bmatrix} -(u_1\text{-}a\text{-}m\text{+}d\text{+}b\text{+}u_2) & 0 \\ 0 & c\text{+}d\text{+}f\text{-}e \end{bmatrix}$$

When the equilibrium point is (0,1), Jacobian matrix can be simplified as:

$$\begin{bmatrix} u_1\text{-}a\text{+}b & 0 \\ 0 & -(f\text{-}e) \end{bmatrix}$$

When the equilibrium point is (1,1), Jacobian matrix can be simplified as:

$$\begin{bmatrix} -(u_1\text{-}a\text{+}b) & 0 \\ 0 & -(c\text{+}d\text{+}f\text{-}e) \end{bmatrix}$$

When the equilibrium point is (x*, y*), Jacobian matrix can be simplified as:

$$\begin{bmatrix} 0 & \dfrac{(e\text{-}f)(c\text{+}d\text{-}e\text{+}f)(m\text{-}d\text{-}u_2)}{c\text{+}d} \\ \dfrac{(a\text{+}m\text{-}u_1\text{-}d\text{-}b\text{-}u_2)(u_1\text{+}b\text{-}a)(c\text{+}d)}{m\text{-}d\text{-}u_2} & 0 \end{bmatrix}$$

That is, the values of Jacobian matrix at these five equilibrium points are shown in the following Table 3:

Table 3. Matrix value at local equilibrium point

Equilibrium point	A_{11}	A_{12}	A_{21}	A_{22}
(0,0)	$u_1\text{-}a\text{-}m\text{+}d\text{+}b\text{+}u_2$	0	0	f-e
(1,0)	$-(u_1\text{-}a\text{-}m\text{+}d\text{+}b\text{+}u_2)$	0	0	c+d+f-e
(0,1)	$u_1\text{-}a\text{+}b$	0	0	-(f-e)
(1,1)	$-(u_1\text{-}a\text{+}b)$	0	0	-(c+d+f-e)
(x*,y*)	0	M	N	0

where:

$$M=\frac{(e\text{-}f)(c\text{+}d\text{-}e\text{+}f)(m\text{-}d\text{-}u_2)}{c\text{+}d},\ N=\frac{(a\text{+}m\text{-}u_1\text{-}d\text{-}b\text{-}u_2)(u_1\text{+}b\text{-}a)(c\text{+}d)}{m\text{-}d\text{-}u_2}$$

The stability of equilibrium point is judged by the eigenvalues of the five Jacobian matrices, and the results are shown in the following Table 4.

According to the results of evolutionary equilibrium, point (0,0) represents the government chooses loose supervision and resident not participate in classification, which is the worst evolutionary equilibrium state. Point (0,1) represents the government chooses loose supervision and resident prefer to participate in classification, which not only achieve the effect of waste classification but also reduce the cost of government, is the optimal evolutionary equilibrium state. Besides, point (1,0) and (1,1) represent the sub-inferior and sub-optimal state of system evolution.

According to above discussion, this paper will adjust the behavior parameters of the government, social organization and resident through numerical evolution simulation, so that the evolutionary game state between the government and resident can be maintained at the optimal point (0,1).

Table 4. Eigenvalue judgment of the matrix

Equilibrium point	Eigenvalue λ_1	Eigenvalue λ_2	Evolutionary stable strategy
(0,0)	$u_1\text{-}a\text{-}m\text{+}d\text{+}b\text{+}u_2$	f-e	$p<1\text{-}k(u_1\text{-}a_0\text{-}m\text{+}d\text{+}b\text{+}u_2)$ and f-e<0
(1,0)	$-(u_1\text{-}a\text{-}m\text{+}d\text{+}b\text{+}u_2)$	c+d+f-e	$p>1\text{-}k(u_1\text{-}a_0\text{-}m\text{+}d\text{+}b\text{+}u_2)$ and c+d+f-e<0
(0,1)	$u_1\text{-}a\text{+}b$	-(f-e)	$p<1\text{-}k(u_1\text{-}a_0\text{+}b)$ and $f-e>0$
(1,1)	$-(u_1\text{-}a\text{+}b)$	-(c+d+f-e)	$p>1\text{-}k(u_1\text{-}a_0\text{+}b)$ and c+d+f-e>0
(x*,y*)	Solution of Equation: $\lambda^2\text{-}(e\text{-}f)(c\text{+}d\text{+}f\text{-}e)(u_1\text{-}a\text{+}b)=0$		-

Note: $a = a_0 + (1-P)/K$

Table 5. Stability analysis of equilibrium point

Equilibrium point	Parameter value range	Stability	Strategy Selection of Game Subject
(0,0)	$p<p_0$, f<e	ESS	(loose supervision, not participate in classification)
(1,0)	$p>p_0$, e-f-c > d	ESS	(strict supervision, not participate in classification)
(0,1)	$p<p_1$, f > e	ESS	(loose regulation, participate in classification)
(1.1)	$p>p_1$, e-f-c < d	ESS	(strict supervision, participate in classification)
(x*,y*)	-	-	-

Note: $p_1=1\text{-}k(u_1\text{-}a_0\text{+}b)$, $p_0=1\text{-}k(u_1\text{-}a_0\text{-}m\text{+}d\text{+}b\text{+}u_2)$

4. SIMULATION ANALYSIS OF EVOLUTIONARY GAME

In order to verify the conclusions of theoretical analysis and to visualise the evolutionary path, simulations were carried out using Matlab software. At the same time, the simulation data of the model parameters are difficult to obtain and the relevant parameters cannot be quantified. We verify the evolutionary stabilisation strategy of the above game process by taking different values of the parameters according to the evolutionary stabilisation strategy constraints in Tables 4 and 5.

4.1 Two-side passive

When $p < p_0$ and f < e, the parameter values that meet the requirements are shown in Table 6. According to the results obtained from the simulation program, as shown in Figure 2, regardless of the initial strategies of government and resident, with increase of the number of evolutionary iterations, the

ratio of government supervision and resident' participation in classification will decreases continuously, and finally the stable point of their behavior evolution is (0, 0).

At this time, the enthusiasm of social organization to participate in source classification is not high, for the government, the cost of loose supervision is lower than strict supervision, meanwhile, the income of resident participating in classification is lower than the cost, so government prefer to choose loose supervision and resident choose not to participate in it. This state is not conducive to the continuous development of classification work.

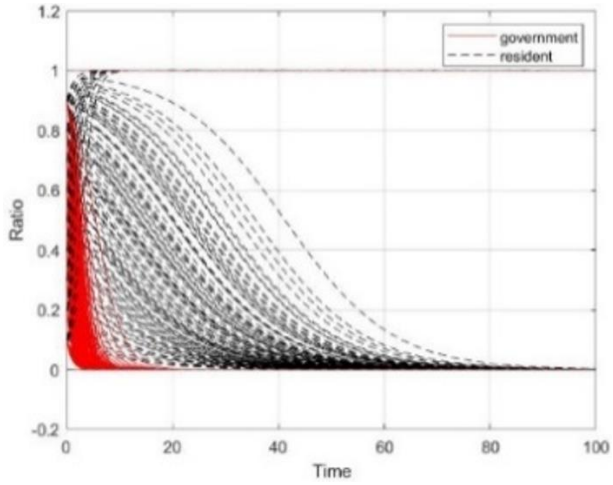

Figure 2. Simulation results of stable point (0,0)

Table 6. Parameter value corresponding to stable point (0,0)

Parameter	a_0	k	c	d	m	u_1
Assign value	0.5	0.5	0.5	0.4	0.4	1
Parameter	b	u_2	e	f	d	p
Assign value	0.2	0.7	0.3	0.2	0.4	0.2

4.2 Government initiative

When p>p_0 and e-f-c > d, the parameter values that meet the requirements are shown in Table 7. According to the results obtained from the simulation program, as shown in Figure 3, with increase of the number of evolutionary iterations, the ratio of government supervision will increase, but resident' participation in classification will decreases, and finally the stable point of their behavior evolution is (1, 0).

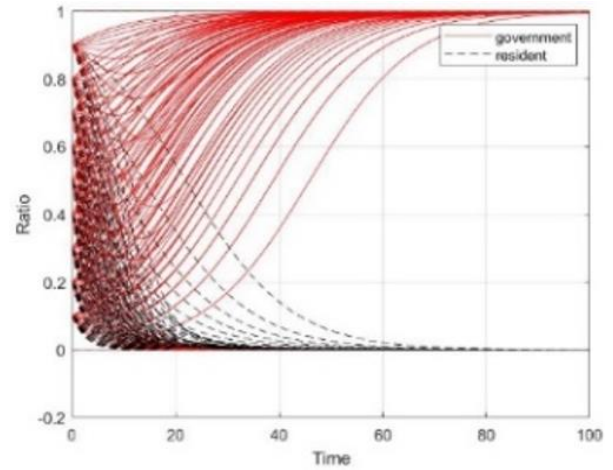

Figure 3. Simulation results of stable point (1,0)

Table 7. Parameter value corresponding to stable point (1,0)

Parameter	a_0	k	c	d	m	u_1
Assign value	0.5	0.5	0.2	0.4	0.4	1
Parameter	b	u_2	e	f	d	p
Assign value	0.2	0.7	0.6	0.2	0.1	0.5

At this time, the enthusiasm of social organizations to participate in the source classification improves, the cost of strict supervision has been reduced, and the difference between the cost of resident participating in waste classification and incentive subsidies received is bigger than the fines for not participating in classification, so government choose strict supervision and resident choose not to participate in classification. In this state, Although the government has invested a lot of energy in the compulsory management of waste source classification, the shortcomings are also very obvious. Due to the excessive financial pressure for government, the insufficient restraint on residents, and the low awareness of resident's participation, it is difficult to achieve the effect of waste source classification in the long run.

4.3 Resident initiative

When p <p_1, and f > e, the parameter values that meet the requirements are shown in Table 8. According to the results obtained from the simulation program, as shown in Figure 4, with increase of the number of evolutionary iterations, the ratio of government supervision will decrease, resident' participation in classification will increase, and finally the stable point of their behavior evolution is (0,1).

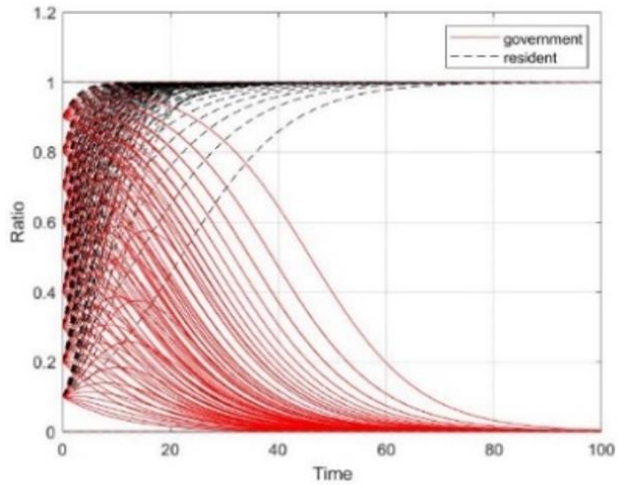

Figure 4. Simulation results of stable point (0,1)

Table 8. Parameter value corresponding to stable point (0,1)

Parameter	a_0	k	c	d	m	u_1
Assign value	0.5	0.5	0.5	0.4	0.4	1
Parameter	b	u_2	e	f	d	p
Assign value	0.2	0.7	0.2	0.3	0.4	0.6

At this time, the enthusiasm of social organizations to participate in the source classification of waste is further enhanced, the cost of government's loose supervision is lower than that of strict supervision, and the benefits of resident's participation in waste classification are bigger than the cost of classification, so government choose loose supervision and resident choose to participate in classification. In this state,

although the degree of government supervision will decline, however, due to the increasing participation rate of social organizations and increasing awareness of residents to participate in waste classification independently, the expected goal of waste classification can also be achieved, which highlights the importance of social organizations' participation.

4.4 Two-side initiative

When p>p_1, and e-f-c<d, the parameter values that meet the requirements are shown in Table 9. According to the results obtained from the simulation program, as shown in Figure 5, with increase of the number of evolutionary iterations, the ratio of government supervision and resident' participation in classification will increases continuously, and finally the stable point of their behavior evolution is (1, 1).

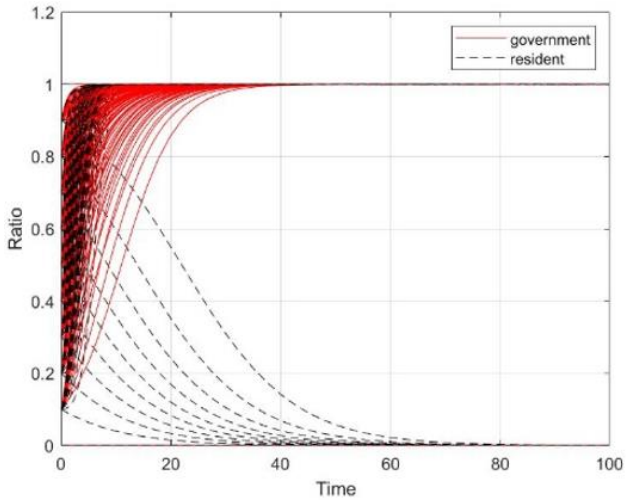

Figure 5. Simulation results of stable point (1,1)

Table 9. Parameter value corresponding to stable point (1,1)

Parameter	a_0	k	c	d	m	u_1
Assign value	0.5	0.5	0.5	0.4	0.4	1
Parameter	b	u_2	e	f	d	p
Assign value	0.2	0.7	0.3	0.2	0.4	0.75

At this time, the enthusiasm of social organizations to participate in waste source classification is higher than the first three simulation cases, the cost of strict supervision by the government is reduced, and the cost of residents participating in waste classification is less than the administrative fines for not participating in, so government prefer to choose strict supervision and residents choose to participate in classification. In this state, the increased participation rate of social organizations and government supervision will promote the attitude and behavior of residents to participate in waste classification, and this form of participation in which all three parties adopt a positive attitude is also the optimal way to realize the efficient implementation of waste classification at source.

The evolution simulation results of the above four scenarios show that, firstly, when government chooses loose supervision strategy, whether residents participate in waste classification depends on the time and physical cost of waste classification and the benefit of residents from environmental improvement, when the time and physical cost of participating in waste classification is higher than the benefit of residents from environmental improvement, residents tend to choose not to participate in classification; On the contrary, when residents get more benefits from environmental improvement, they tend to participate in classification. In this case, the increase of participation rate of social organizations can promote the willingness of residents to participate in waste classification. Secondly, when the government choose the strict supervision strategy, whether residents participate in waste classification depends on the cost of participating in classification and the administrative fine of not participating in classification. When the cost of participating in classification is higher than the administrative fine, residents are more inclined to choose not to participate in waste classification so as to bear a low administrative fine. On the contrary, when the administrative fines are greater if they do not participate in the classification, residents are more inclined to choose to participate in waste classification. In this case, the increase of the participation rate of social organizations also promotes the participation of residents in waste classification. Thirdly, the participation rate of social organizations has an important impact on the development of waste classification work, when government choose to loose supervision due to excessive financial pressure, through cooperation with social organizations, the financial pressure of government can be alleviated to a large extent, and the government can be urged to re-establish regulatory strategies. At the same time, the participation of social organizations is also one of the effective measures to promote residents' participation in classification.

5. CONCLUSIONS AND RECOMMENDATIONS

This paper introduces the evolutionary game into the source separation of waste. Based on the assumption of limited rationality, it considers the source separation of waste as a gradual dynamic learning process, and by constructing an evolutionary game model between government departments and residents in the source separation of waste when the participation rate of social organisations changes, it analyses the equilibrium point and stability of the evolutionary game and explores the behaviour of the government and residents under different circumstances The evolutionary stabilization strategies of government and residents' behaviours under different situations are discussed. The evolutionary game model is further illustrated by using Matlab 2020b software. Combining the above findings, this paper proposes the following recommendations for source separation of waste:

Firstly, at the macro level, stipulate the obligation of residents to separate domestic waste by formulating or amending relevant laws and regulations. At the micro level, strict penalties and monitoring measures should be established to strengthen the government's punishment and supervision of improper disposal of domestic waste.

Secondly, establish a sound incentive mechanism. The government should increase the benefits residents receive from waste separation efforts by improving the construction of waste separation infrastructure and increasing incentives for waste separation and recycling, so that residents can change from passive participants in waste separation to active promoters of waste separation.

Thirdly, the role of social organisations should be actively brought into play. The government's focus should shift to formulating policies and supervising and guiding public

participation in management. At the same time, guiding more social organisations to pay attention to and participate in waste separation work, and playing an active role in reaching out to communities to promote waste separation and guide residents in proper separation.

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