Hindawi
Complexity
Volume 2021, Article ID 6567902, 14 pages
https://doi.org/10.1155/2021/6567902

Research Article

Promotion Strategy of Policy against Food Waste (PAFW): The Perspective on Evolutionary Game between Local Government and Large Supermarkets

Xichun Luo [1] **and Honghao Zhao** [2]

[1]School of Intelligent Manufacturing, Dongguan City College, Dongguan, Guangdong 523000, China
[2]Department of Decision Sciences, School of Business, Macau University of Science and Technology, Taipa, Macao 999078, China

Correspondence should be addressed to Honghao Zhao; hhzhao@must.edu.mo

Received 29 April 2021; Accepted 18 August 2021; Published 7 September 2021

Academic Editor: Miguel Fuentes

The implementation of PAFW is an important way to reduce food waste. Discussing how to more successfully implement PAFW to reduce food waste is of great significance in achieving sustainable development. Different from the previous literature, this paper uses evolutionary game theory to establish a strategic interaction income matrix between local governments and large supermarkets and analyzes the strategic interaction between local governments and large supermarkets by copying dynamic equations, revealing the strategic choice between the two parties evolution process. A simulation-based approach is used to validate the theoretical results and analyze the influence of key parameters on the evolutionary trajectory. The study found the following: (1) to promote the system to an optimal evolutionarily stable strategy (ESS), it is necessary to strengthen policy publicity, increase the willingness of large supermarkets to implement the PAFW, and increase the enthusiasm of the public or third-party organizations to monitor system; (2) stakeholders' initial willingness will influence the evolutionary trajectory; and (3) it is important to strengthen the institutional development of local government regulators, improve the local government's achievements, reduce the local government's regulatory costs, improve policies to support large supermarkets' implementation of the PAFW, and reduce the cost of implementing the PAFW for large supermarkets.

1. Introduction

One of the most challenging issues currently facing societies around the world is the issue of food waste [1, 2]. Item 12 of the sustainable development goals set by the United Nations in 2015, "Ensure sustainable consumption and production patterns," sets out to achieve a reduction in food waste [3]. Currently, the efficiency of the food system is extremely low. One-third of the food produced in the world every year is wasted, amounting to a total of 1.3 billion tons [4, 5]. In the United States, approximately 63 million tons of food is discarded into landfills each year without being eaten. Supermarkets and restaurants contribute 40% of the total food waste. Moreover, the waste produced by supermarkets is much higher than that produced by restaurants. It can be seen that supermarkets account for a large proportion of the food waste [6]. Promoting the PAFW is an important way to reduce food waste from supermarkets [7].

China, a country with a population base of 1.4 billion, also has a serious food waste problem. The value of the food thrown away in the country each year is $28 billion [8], helping make the issue of food waste a very important political and social issue in China [9]. In August 2020, Chinese President Xi Jinping highlighted the problem: "The phenomenon of food waste is shocking and heartbreaking, and despite our successive bumper harvests, we must always be aware of the crisis in food security, and the impact of this year's global novel coronavirus pneumonia is a wake-up call [10]." In this political context, various departments of the Chinese government are formulating and planning policies and raising awareness about food waste [11]. At the same time, the introduction of foreign advanced management techniques has played an important role in alleviating the current situation of food waste in China. France has developed the most advanced management approaches. Since 2013, the French government has introduced several bills to restrict food waste, the most effective of which is the NRDC's 2015 "France Moves Toward a National Policy Against Food Waste," which directly requires that major supermarkets be prohibited from directly discarding unsold but edible foods and that they be forced to sign agreements with charitable organizations to donate these foods to charitable organizations. Then, in the same period, it was proposed that large supermarkets over 400 square meters must sign agreements with charitable organizations before July of the following year [12]. The bill has had a positive impact since its implementation, curbing food waste to a certain extent and producing a significant increase in the number of meals distributed to charities for the poor. Countries such as Italy, Peru, and Finland have followed France's lead in adopting similar measures [13].

Under the current political system with strong enforcement, China will achieve good results if it adopts the French model of management and develops timely policies to address food waste. The prerequisite for such effectiveness is that the policies are widely implemented. When a specific policy is promoted, it may also encounter some resistance and large supermarkets may not implement the policy because of the high cost, immature incentives, and a lack of political impetus. Therefore, in the absence of regulation, a large supermarket will not voluntarily sacrifice its own interests to implement the policy. Given the interplay between local government and large supermarkets, there will be a conflict of interest between the local government pushing for the PAFW and large supermarkets in policy implementation. Game theory can be used to study the mutual strategic decisions in the interest of both parties [14].

This paper first analyzes the conflicts of interest between large supermarkets and the local government in implementing the PAFW in China and constructs an evolutionary game model for the local government and large supermarkets to weigh their respective strategies to be optimized for the corresponding dynamic evolutionary trends. Second, a simulation analysis is conducted to examine how the initial proportion of each stakeholder's strategy affects the evolutionary trend and the influence of key parameters on the final trend in the evolutionary game system toward the ideal stable direction. Currently, from the perspective of evolutionary game, there are relatively few studies on the PAFW, and the new research clearly reveals the complex dynamic evolution game model in the case of the limited rationality, and for the analysis of dynamic game between local government and large supermarket, the process provides a qualitative and quantitative simulation platform, which provides effective theoretical support for the decision-makers.

The paper is structured as follows: Section 2 reviews the related literature and highlights the contributions of the paper. Section 3 describes the conflicts between the participants and the assumptions required in the game. In Section 4, the results of the model are analyzed, and the relevant parameters are simulated and sensitivity analyzed. Finally, Section 5 draws a conclusion and provides policy suggestion.

2. Literature Review

Recently, scholars conducted extensive research on "against food waste management." Thyberg and Tonjes explored the social, demographic, cultural, political, and economic drivers of food waste and highlighted how perceptions of food waste differ globally, suggesting the importance of policies to prevent food waste for sustainable development [15]. Heikkilae et al. studied the causes of food waste in restaurants and catering establishments and determined the diversity of food waste management in the food service sector and how a comprehensive approach can be taken to prevent and reduce it. This analysis revealed that food waste is controllable and should be controlled through management tools [16]. These two studies demonstrated the importance of policy and management approaches to prevent food waste. Lunkes et al. used structural equation modeling to analyze the relationship between management control systems, food waste information, and restaurant financial and nonfinancial performance to examine how a broad information system can support restaurant managers in making decisions about food waste [17]. Muriana discussed the importance of supply chain strategies in the fight against food waste and examined techniques to reduce food waste and management systems to identify factors that lead to food waste and promote food waste minimization [18]. They began by considering the information system and supply chain to provide a decision-making basis for the policy against food waste management. Schneider summarized the evolution of food donation activities; examined the political, legal, social, and logistical barriers to incentivizing food donation; proposed the concept of food donation networks; and discussed their ecological, economic, and social impact [19]. Dolnicar et al. proposed a game to promote the reduction of food waste in hotels in tourist areas by exchanging a "clear your plate" campaign for stamp collection and demonstrated its effectiveness [20]. These studies suggested practical ways to reduce food waste from different perspectives.

The current research confirms that management interventions and policy facilitation are indispensable if food waste is to be reduced and suggests a number of ways to reduce food waste from management and practice perspectives, respectively. However, less literature focused on the issue of PAFW facilitation from a microeconomic point of view. The adoption mechanism of PAFW must be analyzed at the microlevel of interaction between local governments and the large supermarkets. Game theory has been used in the study of conflict coordination and interaction models among different target stakeholders [21]. Game theory can fulfill the expectation of maximizing stakeholder interests by predicting the behavior of others to determine the most advantageous strategy [22]. The classical static game argues that the stakeholders not only are completely rational but also have overall information; however, it is the opposite of the actual situation [23]. Evolutionary game theory improves on the traditional game by treating the participants' strategy selection as a dynamic adjustment process based on the premise of limited rationality [24].

Scholars' applications of evolutionary game theory between government and enterprises bring inspirations to this study. Sheng et al. developed a tripartite evolutionary game model for the implementation of environmental regulatory policies in China between the national government, local governments, and enterprises; studied the stability of various evolutionary strategies and the influence of parameter changes on these strategies through numerical simulations; and concluded that increasing penalties for noncompliance and compliance incentives can encourage local governments to enforce environmental regulations more effectively, thereby alleviating the burden on various stakeholders and the conflicts of interest between them [25]. Zhang and Xi studied the dynamic evolution of local government regulatory strategies and enterprises' nitrogen emission reduction strategies under static and dynamic subsidy policies using the evolutionary game method and found that the choice of enterprises' emission reduction strategies depends mainly on the comparison of nitrogen emission costs and benefits, and whether the government implements regulations depends on the comparison of public opinion costs and monitoring costs, subsidy costs, and other factors [26]. Song et al. analyzed the strategic interaction benefit matrix between management and chemical companies by establishing a strategic interaction between the two parties and replicating the dynamic equation, revealing the evolutionary process of behavioral strategy choice between management and companies, and providing a basis and recommendations for the safety management of chemical engineering [27]. By reviewing these studies, we learn that fines for violations and compliance incentives are the main factors that influence firms' strategic choices.

Evolutionary game theory has also been applied in other fields, which also offers some inspiration. Liu et al., through the in-depth study of a proprietary evolutionary game model between doctors and patients and a numerical simulation, found that the doctor-patient relationship will eventually form a zero-sum game or win-win situation; as to which case is stable, this is closely related to the initial probability and parameter settings of the evolutionary game model [28]. Feng and Ma constructed an asymmetric model of service-based manufacturing firms and service providers based on an evolutionary game, and through stability analysis and numerical simulation, they found that the cooperation between manufacturing firms and service providers is related to the initial choice of initial probability and different parameter settings of the two strategies [29]. The above study leads us to find that the choice of initial probability and different parameter changes of the participants affect their initial state and thus the evolutionary trend if there are two different stability points in the evolutionary process.

3. Model

3.1. Problem Description and Conflicts among the Participants. China accounts for 7% of the world's arable land and 20% of the world's population, which have made food issues a key social concern of the Chinese government [30]. In the current context of increasing food waste, Chinese President Xi Jinping's directive on this issue indicates that the Chinese government attaches great importance to the issue of food waste and has attempted to implement policies to alleviate the situation. In this context, in addition to restricting food waste in the restaurant industry, restricting discarded food in large supermarkets should also be included in sustainable development strategies. However, large supermarkets are reluctant to bear the costs of implementing policies, including contacting charities and logistics. Large supermarkets have to make a choice between maximizing their own profit and implementing policies, and while making this choice, it is more important for the local government to actively guide their support and commitment to environmental protection and provide some regulatory function.

Laws and regulations are an important influencing factor in promoting the PAFW. In 2020, due to COVID-19, international food production will decrease by more than 20%, and the international community is facing a food shortage crisis, which also affects China, making it urgent to promote the implementation of the PAFW [31, 32]. However, because the implementation of regulations will consume many human, material, and financial resources, the local government is also faced with many dilemmas regarding the implementation of regulations.

In summary, policymakers are faced with the challenge of how to help large supermarkets to implement the PAFW; large supermarket policymakers need to consider whether to implement these policies. They are some of the most important stakeholders in the promotion of the PAFW.

3.2. Assumptions of the Evolutionary Game. Before conducting the evolutionary game between local government and large supermarkets, we need to point out several important assumptions. In general, we establish the following 5 assumptions by referencing the relevant studies in the literature [33, 34].

Assumption 1. The subjects of the game in the model are the local government and the large supermarkets, both of whom are finite rational.

Assumption 2. Participants can learn from each other and correct their mistakes to continuously improve their strategies because it is difficult for them to choose the ideal strategy to maximize the benefits at the beginning.

Assumption 3. The local government has two strategies—" positive regulation" and "negative regulation"—with probabilities $x(0 < x < 1)$ and 1-x, respectively.

Assumption 4. Large supermarkets have two strategies—"implementation policy" and " nonimplementation policy"—with probabilities y$(0 < y < 1)$ and 1-y, respectively.

Assumption 5. The probability of a large supermarket not enforcing its policy under negative regulation and exposure to the public or a third-party agency is ω $(0 < \omega < 1)$. When large supermarkets do not enforce the policy, a local government that chooses the "positive regulation" strategy will earn political success and a fine, while a local government that chooses "negative regulation" will be negatively affected and will not receive a fine, which will be enforced by a higher authority.

4. Evolutionary Game between the Local Government and Large Supermarkets

4.1. Evolutionary Game Models and Parameters. Based on the above description of the problem and the conflict between the local government of China and the large supermarkets, the parameters of the game model are defined. When the local government chooses the "positive regulation" strategy and the large supermarkets choose the strategy of "implementation policy," the local government will alleviate the problem of food waste and gain great political success, set to N. At the same time, the local government will incur regulatory costs, denoted as Cr. When large supermarkets are found not to implement the policy, a certain penalty is imposed on them, which is denoted by P.

When large supermarkets choose the "nonimplementation policy," no matter what policy the local government chooses, the benefit is denoted by Rt. When large supermarkets choose "implementation policy," no matter what policy the local government chooses, the large supermarkets will incur additional costs to enforce the policy, denoted by Ca, including the transportation costs of donating food to charities. At the same time, the large supermarket will gain a good corporate image and a hidden benefit, set to Ra. When the local government chooses "negative regulation" and the large supermarket chooses "nonimplementation policy," there is a risk of public or third-party exposure. The probability is recorded as ω; at this point, the local government receives a negative impact, recorded as F. The large supermarket will be penalized by the higher government, which is also P, but the local government will not receive this fine.

Thus, the meaning of the parameters and the matrix of benefits for the local government and the large supermarkets are shown in Tables 1 and 2.

4.2. Systematic Stability Analysis. Initially, U_{g1} and U_{g2} signify the expected earnings when the local government selects the "positive regulation" and "negative regulation" strategies, respectively, and $\overline{U_g}$ signifies the average earnings for local government, described as follows:

$$\begin{aligned} U_{g1} &= y(N - Cr) + (1 - y)(P - Cr), \\ U_{g2} &= -(1 - y)\omega F, \\ \overline{U_g} &= xU_{g1} + (1 - x)U_{g2}. \end{aligned} \tag{1}$$

Similarly, let U_{s1} and U_{s2} denote the expected returns of the large supermarkets when they choose the "implementation policy" and "nonimplementation policy" strategies, respectively, and $\overline{U_s}$ denotes the average returns for large supermarkets, described as follows:

$$\begin{aligned} U_{s1} &= x(Rt + Ra - Ca) + (1 - x)(Rt + Ra - Ca), \\ U_{s2} &= x(Rt - P) + (1 - x)(Rt - \omega P), \\ \overline{U_s} &= yU_{s1} + (1 - y)U_{s2}. \end{aligned} \tag{2}$$

Accordingly, the replication dynamic equation [35] of the local government's "positive regulation" strategy and the large supermarket's "implementation policy" strategy is

$$\begin{aligned} F(x) &= \frac{\mathrm{d}x}{\mathrm{d}t} = x\left(U_{g1} - \overline{U_g}\right) \\ &= x(1 - x)[y(N - P - \omega F) + P - Cr + \omega F], \end{aligned} \tag{3}$$

$$\begin{aligned} F(y) &= \frac{\mathrm{d}y}{\mathrm{d}t} = y\left(U_{s1} - \overline{U_s}\right) \\ &= y(1 - y)[x(P - \omega P) + Ra - Ca + \omega P]. \end{aligned} \tag{4}$$

The result is that the replicated dynamic state can be obtained, by making equations (3) and (4), and local equilibrium points (LEPs) also can be obtained by making equations (3) and (4) equal to 0. Therefore, the five LEPs in the system are (0, 0), (0, 1), (1, 0), (1, 1), and (x^*, y^*), in which $x^* \in [0, 1]$ and $y^* \in [0, 1]$, where $x^* = (Ca - Ra - \omega P)/(P - \omega P)$ and $y^* = (Cr - P - \omega F)/(N - P - \omega F)$. Friedman [36] proposed describing the group dynamics by means of differential equations, and the stability of its equilibrium point can be obtained from the local stability analysis of the Jacobian matrix of the system, which is as follows:

$$J = \begin{bmatrix} \dfrac{\mathrm{d}f(x)}{\mathrm{d}x} & \dfrac{\mathrm{d}f(x)}{\mathrm{d}y} \\ \dfrac{\mathrm{d}f(y)}{\mathrm{d}x} & \dfrac{\mathrm{d}f(y)}{\mathrm{d}y} \end{bmatrix} = \begin{bmatrix} (1 - 2x)[y(N - P - \omega F) + P - Cr + \omega F] & x(1 - x)(N - P - \omega F) \\ y(1 - y)(P - \omega P) & (1 - 2y)[x(P - \omega P) + Ra - Ca + \omega P] \end{bmatrix}. \tag{5}$$

Table 1: Parameters symbol descriptions.

Parameters	Stakeholders	Descriptions
Cr	Local governments	The costs of positive regulation
P		The large supermarket is punished if it does not implement the policy
N		The political achievements from positive regulation
F		Under negative supervision, the problems are exposed by third-party supervision or the public, and the local government is negatively affected
ω		The probability of problems being exposed by third-party supervision or the public under passive supervision
Rt	Large supermarkets	Large supermarkets will be fined if they do not implement the policy
Ca		Extra cost of implementing the PAFW
Ra		Additional earnings

Table 2: Payoff matrix.

		Large supermarket	
		Implementation policy	Nonimplementation policy
Local governments	Positive regulation	N−Cr, Rt + Ra−Ca	P−Cr, Rt-P
	Negative regulation	0, Rt + Ra−Ca	−ωF, Rt-ωP

The LEP of the replicated dynamic system is judged as an ESS if it satisfies the following conditions: det $J > 0$, tr $J < 0$. Det J and tr J for each LEPs are shown in Table 3.

To simplify the analysis, it is first necessary to construct a hypothesis. $N - \omega F > P$, that is, under active local government regulation, large supermarkets will increase the political performance of the local government when they choose the "implementation policy" strategy, and under negative regulation, large supermarkets will increase their political performance when they choose the "nonimplementation policy" strategy if a third party is involved. The difference between institutional or public exposure, which can have a negative effect on the local government, should be greater than the fine the local government receives for negative regulation. Otherwise, the local government has no incentive to regulate aggressively.

As seen from Table 3, to determine the symbols of det J and tr J for different LEPs, the symbols of $P - Cr + \omega F$, $N - Cr$, $Ra + P - Ca$, and $Ra + \omega P - Ca$ should be discussed, where ω is the probability that the problem will be exposed to third-party regulation or public exposure under negative regulation ($0 < \omega < 1$), $\omega P < P$.

As shown in Table 4, there are six evolution states to be analyzed, and we express the regional ABCD as the mixed strategy space of this evolutionary game:

(1) In Scenario 1, Scenario 2, and Scenario 4: as shown in Table 4, point A (0, 0) is the ESS of the system, namely, {negative regulation, nonimplementation policy}, and the evolutionary path is shown in Figures 1(a), 1(b), and 1(d). This scenario is not conducive to policy diffusion. For large supermarkets, the high cost of implementing the policy discourages them from implementing the policy. For the local government, being exposed causes little negative impact, and the penalties for large supermarkets that fail to implement the policy are too light to compensate for the huge cost of local government regulation, and local government incentives to regulate will be greatly discouraged.

(2) In Scenario 3: as shown in Table 4, point B (0, 1) is the ESS of the system, namely, {positive regulation, nonimplementation policy}, and the evolutionary path is shown in Figure 1(c). For the large supermarkets, the high fines make them enforce the policy. The small negative impact of being exposed and the low fines will make the local government choose the "negative regulation" strategy.

(3) In Scenario 5: as shown in Table 4, point A (0, 0) and point D (1, 1) are both the system ESS {negative regulation, nonimplementation policy} and the optimal policy {positive regulation, implementation policy}, respectively, with evolutionary paths shown in Figure 1(e). In this context, when the local government is actively regulating, the cost to the large supermarket of enforcing the policy is less than the amount of the fine imposed for nonimplementation but greater than the expected value of the fine due to public or third-party exposure when the local government is negatively regulating. The cost of local government regulation is still higher than the sum of the fines imposed on large supermarkets that do not enforce the policy and the negative impact of being exposed. As shown in Figure 1(e), the final ESS depends not only on the saddle point (x, y) but also on the participants' initial choice of proportions. Specifically, if a participant's initial state is in the ABEC region and when the participant's initial state converges to A (0, 0), the final choice is the {negative supervision, nonimplementation policy} strategy. If the participant's initial state is in the BECD region and when the participant's initial state converges to D (1, 1), the final choice is the {positive regulation, implementation policy} strategy.

Table 3: The det J and tr J at each LEP.

LEP	det J	tr J
A(0,0)	$(P - Cr + \omega F)(Ra - Ca + \omega P)$	$P - Cr + \omega F + Ra - Ca + \omega P$
B(0,1)	$(N - Cr)(Ca - Ra - \omega P)$	$N - Cr + Ca - Ra - \omega P$
C(1,0)	$(Cr - P - \omega F)(P + Ra - Ca)$	$Cr - P - \omega F + P + Ra - Ca$
D(1,1)	$(N - Cr)(P + Ra - Ca)$	$Cr - N - P - Ra + Ca$
E(x^*, y^*)	$[(P - Cr + \omega F)(Ca - Ra - \omega P)(N - Cr)(P + Ra - Ca)]/[(N - P - \omega F)(P - \omega P)]$	0

Table 4: The evolutionary stability of each LEP.

Scenarios	LEP	det J	tr J	State
Scenario 1: $Cr > N > P + \omega F$	A(0,0)	+	−	ESS
	B(0,1)	−	Uncertain	Saddle point
$Ca > Ra + P$	C(1,0)	−	Uncertain	Saddle point
	D(1,1)	+	+	Unstable
Scenario 2: $Cr > N > P + \omega F$	A(0,0)	+	−	ESS
	B(0,1)	−	Uncertain	Saddle point
$Ra + \omega P < Ca < Ra + P$	C(1,0)	+	+	Unstable
	D(1,1)	−	Uncertain	Saddle point
Scenario 3: $Cr > N > P + \omega F$	A(0,0)	−	Uncertain	Saddle point
	B(0,1)	+	−	ESS
$Ca < Ra + \omega P$	C(1,0)	+	+	Unstable
	D(1,1)	−	Uncertain	Saddle point
Scenario 4: $N > Cr > P + \omega F$	A(0,0)	+	−	ESS
	B(0,1)	+	+	Unstable
$Ca > Ra + P$	C(1,0)	−	Uncertain	Saddle point
	D(1,1)	−	Uncertain	Saddle point
Scenario 5: $N > Cr > P + \omega F$	A(0,0)	+	−	ESS
	B(0,1)	+	+	Unstable
$Ra + \omega P < Ca < Ra + P$	C(1,0)	+	+	Unstable
	D(1,1)	+	−	ESS
Scenario 6: $N > Cr > P + \omega F$	A(0,0)	−	Uncertain	Saddle point
	B(0,1)	−	Uncertain	Saddle point
$Ca < Ra + \omega P$	C(1,0)	+	+	Unstable
	D(1,1)	+	−	ESS
Scenario 7: $N > P + \omega F > Cr$	A(0,0)	−	Uncertain	Saddle point
	B(0,1)	+	+	Unstable
$Ca > Ra + P$	C(1,0)	+	−	ESS
	D(1,1)	−	Uncertain	Saddle point
Scenario 8: $N > P + \omega F > Cr$	A(0,0)	−	Uncertain	Saddle point
	B(0,1)	+	+	Unstable
$Ra + \omega P < Ca < Ra + P$	C(1,0)	−	Uncertain	Saddle point
	D(1,1)	+	−	ESS
Scenario 9: $N > P + \omega F > Cr$	A(0,0)	+	+	Unstable
	B(0,1)	−	Uncertain	Saddle point
$Ca < Ra + \omega P$	C(1,0)	−	Uncertain	Saddle point
	D(1,1)	+	−	ESS

(4) In Scenario 7: as shown in Table 4, point C (1, 0) is the ESS of the system, namely, {positive regulation, nonimplementation policy}, and the evolutionary path is shown in Figure 1(g). In this scenario, the local government will choose the "negative regulation" strategy because of the high fine, while the large supermarkets will not choose the "implementation policy" strategy because the cost is higher than the fine.

(5) In Scenario 6, Scenario 8, and Scenario 9: as shown in Table 4, point D (1, 1) is the ESS of the system, namely, {positive regulation, implementation policy}, and the evolutionary path is shown in Figures 1(f), 1(h), and 1(i). In this scenario, the local government will choose the "positive regulation" strategy due to the high fine. However, large supermarkets will be fined so much when choosing the "nonimplementation policy" strategy in the positive regulation scenario that they can only choose the "implementation policy" in the positive regulation. However, because of the existence of discretion, local governments can choose their own fines within the

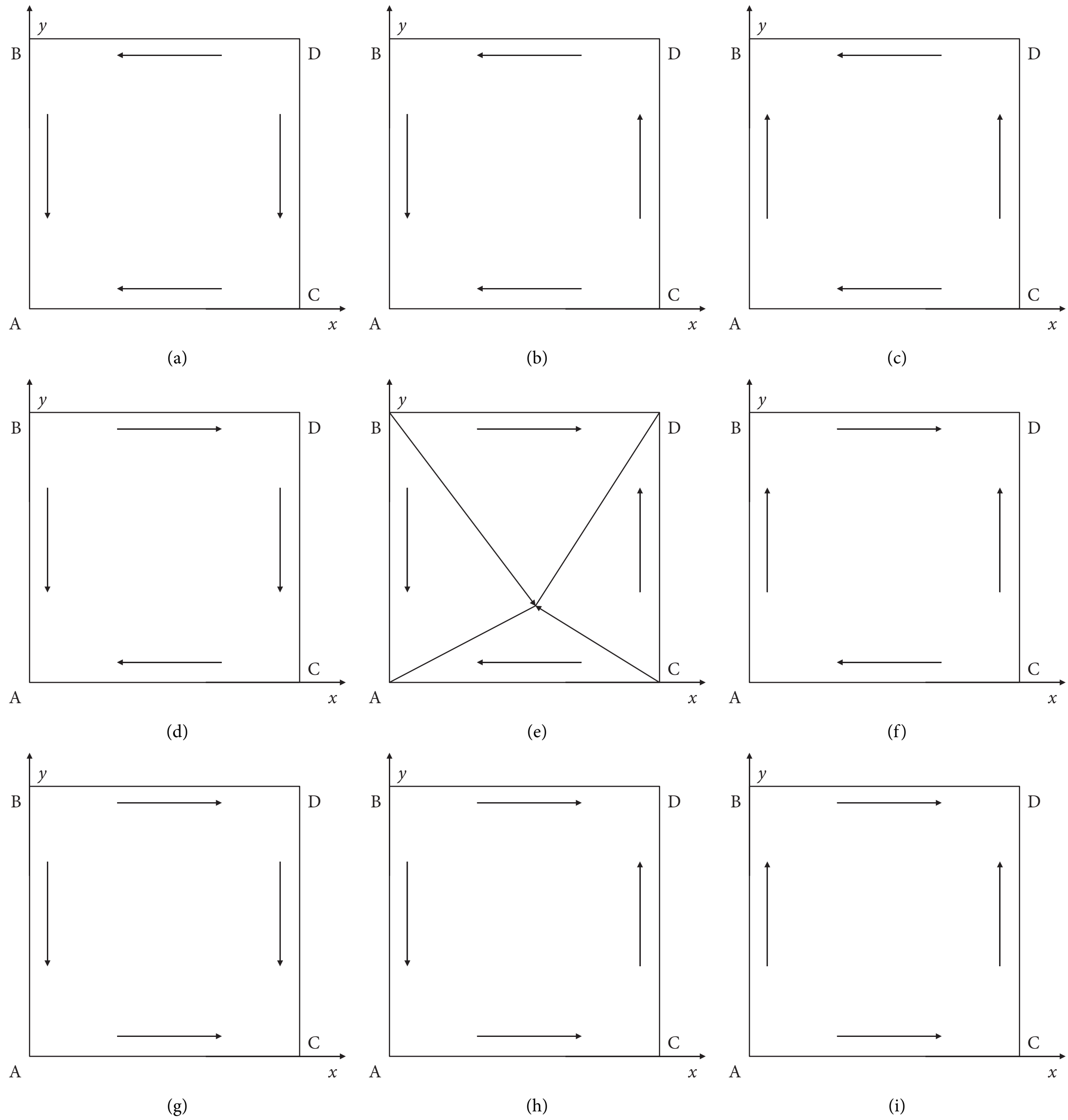


Figure 1: Evolution phase diagram of the system.

standard range. Therefore, to facilitate the development of local enterprises, local governments generally do not implement fines that are too severe.

4.3. System Simulation Analysis. In order to verify the accuracy of the model results and make the dynamic evolution trend clearer and more vivid, we use MATLAB 2020a software to simulate the dynamic evolution trajectory of the evolutionary system. The parameter settings for the different situations are as follows:

(1) In Scenario 1, $N = 16$ $Cr = 22$ $Ca = 17$ $Ra = 8$ $P = 6$, $F = 6$ $\omega = 0.5$, as shown in Figure 2(a), the track of evolution will be eventually inclined to ESS A (0, 0) that is consistent with the analysis of the model.

(2) In Scenario 2, $N = 16$ $Cr = 22$ $Ca = 17$ $Ra = 8$ $P = 12$, $F = 6$ $\omega = 0.5$, as shown in Figure 2(b), the track of evolution will be eventually inclined to ESS A (0, 0) that is consistent with the analysis of the model.

(3) In Scenario 3, $N = 16$ $Cr = 22$ $Ca = 17$ $Ra = 8$ $P = 20$, $F = 6$ $\omega = 0.5$, as shown in Figure 2(c), the track of evolution will be eventually inclined to ESS B (0, 1) that is consistent with the analysis of the model.

(4) In Scenario 4, $N = 28$ $Cr = 22$ $Ca = 17$ $Ra = 8$ $P = 6$, $F = 6$ $\omega = 0.5$, as shown in Figure 2(d), the track of evolution will be eventually inclined to ESS A

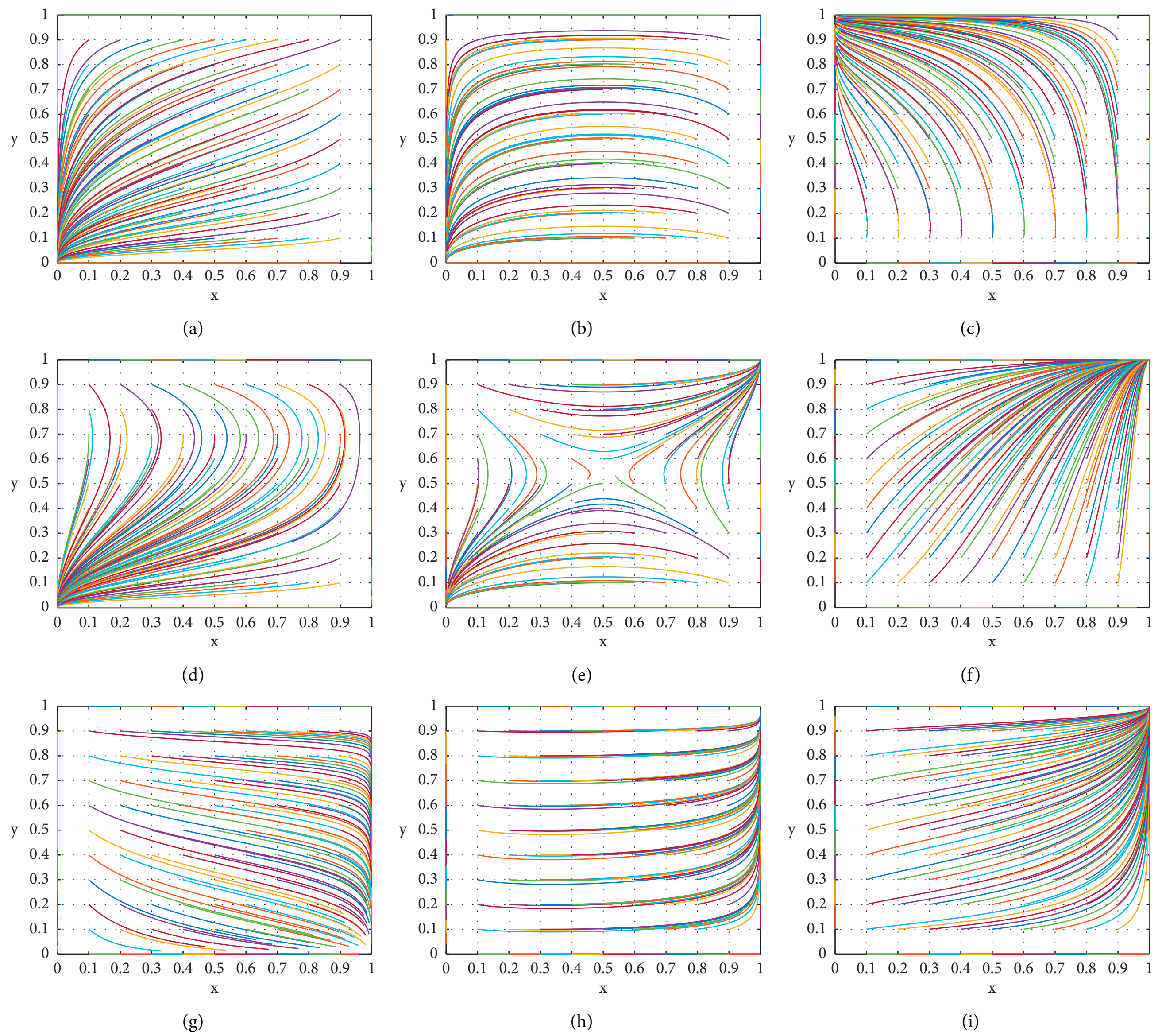


Figure 2: System evolution phase diagram.

(0, 0) that is consistent with the analysis of the model.

(5) In Scenario 5, $N = 28$ $Cr = 22$ $Ca = 17$ $Ra = 8$ $P = 12$, $F = 6$ $\omega = 0.5$, as shown in Figure 2(e), the track of evolution will be eventually inclined to ESS A (0, 0) and D (1, 1) that is consistent with the analysis of the model.

(6) In Scenario 6, $N = 28$ $Cr = 22$ $Ca = 17$ $Ra = 8$ $P = 20$, $F = 6$ $\omega = 0.5$, as shown in Figure 2(f), the track of evolution will be eventually inclined to ESS D (1, 1) that is consistent with the analysis of the model.

(7) In Scenario 7, $N = 16$ $Cr = 3$ $Ca = 12$ $Ra = 8$ $P = 3$, $F = 2$ $\omega = 0.5$, as shown in Figure 2(g), the track of evolution will be eventually inclined to ESS C (1, 0) that is consistent with the analysis of the model.

(8) In Scenario 8, $N = 16$ $Cr = 3$ $Ca = 12$ $Ra = 8$ $P = 6$, $F = 2$ $\omega = 0.5$, as shown in Figure 2(h), the track of evolution will be eventually inclined to ESS D (1, 1) that is consistent with the analysis of the model.

(9) In Scenario 9, $N = 16$ $Cr = 3$ $Ca = 12$ $Ra = 8$ $P = 10$, $F = 2$ $\omega = 0.5$, as shown in Figure 2(i), the track of evolution will be eventually inclined to ESS D (1, 1) that is consistent with the analysis of the model.

4.4. System Sensitivity Analysis. According to the above analysis, the evolutionary game systems of Scenario 1, Scenario 2, Scenario 3, Scenario 4, Scenario 6, Scenario 7, Scenario 8, and Scenario 9 all have only one ESS. Scenario 5 ESS will be {negative regulation, nonimplementation policy} and the perfect one, {positive regulation, implementation policy}. Due to the position of the saddle point (x^*, y^*) and the initial selection probability of each participant, the evolutionary game system tends to have different stable points [37]. Hence, it has great significance to study which factors will influence the system.

It can be seen from Figure 1(e), when the initial state is in the ABEC region, point A (0, 0) is the ESS. Similarly, when the initial state is at BECD, then point D (1, 1) will be the ESS. In order to reach the probability that the evolutionary game system will tend toward the optimal strategy {positive regulation, implementation policy}, the location of point E should be inclined to the direction of point A to reduce the area of ABEC, which can be calculated as follows:

$$S_{ABEC} = \frac{1}{2}\left(x^* + y^*\right) = \frac{1}{2}\left(\frac{Ca - Ra - \omega P}{P - \omega P} + \frac{Cr - P - \omega F}{N - P - \omega F}\right). \tag{6}$$

Equation (6) shows that the area of SABEC changes with the change in x^* and y^*, and the change in x^* and y^* changes with the change in seven parameters: Ca, Cr, Ra, N, P, F, and ω. Intuitively, Ca and Cr are positively correlated with SABEC, and Ra, F, and ω being negatively correlated. However, the effect of the remaining parameters on the SABEC is uncertain. Therefore, in order to facilitate the analysis, the method of numerical simulation is used in Scenario 5, the initial selection of participants and the change in various parameters affect the evolutionary trajectory.

4.4.1. Sensitivity Analysis of the Initial Probability of Strategies. First, it discusses the influence of the initial strategy choice probability of local governments and large supermarkets on the ESS is discussed. The probabilities of choosing X and Y are (0.5, 0.5) and (0.8, 0.8), respectively. The simulation results are shown in Figure 3. It can be known that the different selection probabilities will make the evolutionary game system have different evolutionary directions. The simulation results show that the method can effectively improve the performance of the system. The initial probability that the local government chooses the "positive regulation" strategy and the large supermarket chooses the "implementation policy" strategy is 0.5, and the ESS is {negative regulation, nonimplementation policy}, as shown in Figure 3(a). However, when the initial probability rises to 0.8 and 0.8, the ESS is {positive regulation, implementation policy}, and it is shown in Figure 3(b). This finding proves that the initial state of both participants will immediately impact the final ESS. Hence, it is a must to establish clear guidance measures to improve the probability of local government choosing positive regulation and the probability of the large supermarket initially choosing to implement the policy, which has important guiding significance for the promotion of the PAFW.

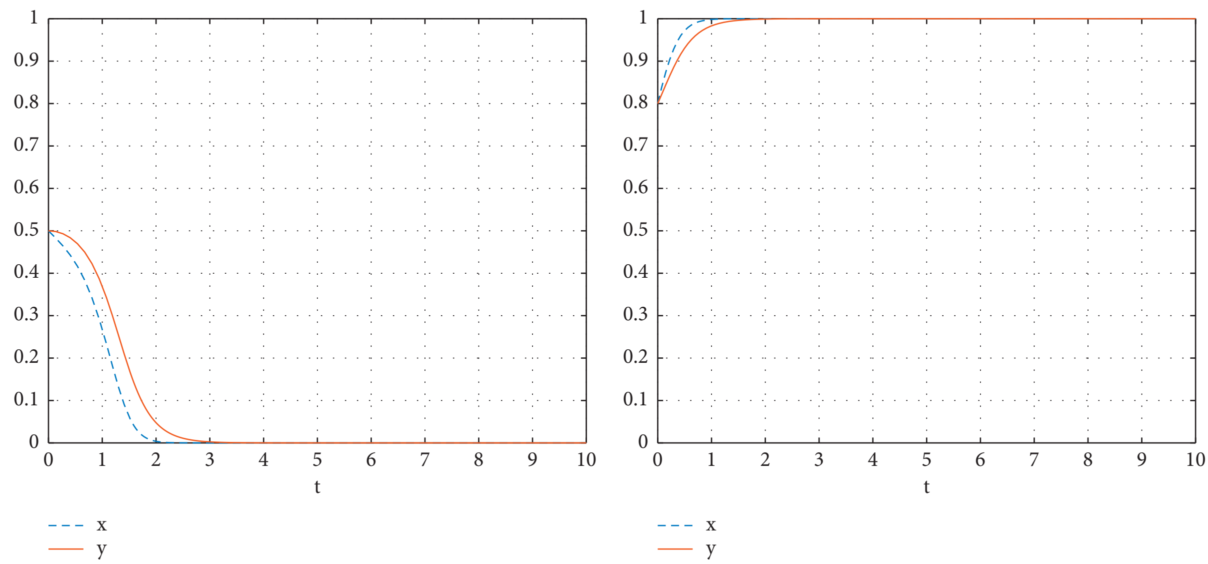
4.4.2. Sensitivity Analysis of the Parameters. In this section, the parameter sensitivities of the participants in Scenario 5 are examined, that is, the additional cost to the large supermarket from implementing the policy (Ca), the additional profit (Ra), the penalty to the large supermarket for not implementing the policy (P), the monitoring expenditure (Cr), and the political achievement from active monitoring (N). Under negative supervision, the problems are exposed by third-party supervision or the public, the government is negatively affected (F), and problems can be exposed by third-party supervision or the public under passive supervision (ω). We assume that when simulating the sensitivity of one parameter, the values of the other parameters are held constant in Scenario 5, where the initial choice probabilities of the stakeholders are 0.5 [38]:

(1) Figure 4 shows the sensitivity of stakeholders to the expenditure cost (Ca) of large supermarkets when implementing policies by setting Ca to 15, 17, and 19. When the expenditure cost of large supermarkets implementing policies is low (Ca = 15), the ESS will tend toward {positive regulation, implementation policy}. When Ca increases to 17 and 19, the ESS will tend toward {negative regulation, non-implementation policy}, and when Ca increases from 17 to 19, the rate of evolution increases, indicating that supermarkets will choose the "non-implementation policy" strategy when the cost of enforcing the policy is higher than a certain level.

(2) Figure 5 shows the sensitivity of stakeholders to political achievement (N) when the local government is actively enforcing regulations, setting N to 28, 30, and 32. When the political achievement that the local government receives as a result of active regulation is too low ($N = 28$), the ESS will tend toward {negative regulation, nonimplementation policy}. As N increases to 30 and 32, the ESS will tend toward {positive regulation, implementation policy}, and when Ca increases from 30 to 32, the rate of evolution increases, indicating that when the local government's political achievement from positive regulation is below a certain level, the local government will choose the "negative regulation" strategy.

(3) Figure 6 shows the sensitivity of stakeholders to the additional gains (Ra) that large supermarkets make from choosing to implement the policy, setting Ra to 6, 8, and 10. When the local government's political success from active regulation is too low (Ra = 6, 8), the ESS will tend toward {negative regulation, nonimplementation policy}. When $r = 6$, the evolution is faster. When Ra increases to 10, the ESS will tend toward {positive regulation, non-implementation policy}. When Ra rises to 10, the ESS will tend toward {positive regulation, implementation policy}, indicating that large supermarkets will choose the "implementation policy" strategy when the additional gains from enforcing the policy are above a certain level.

(4) Figure 7 shows the sensitivity of stakeholders to the cost of local government regulation (Cr), setting Cr to 22, 24, and 26. The ESS will evolve toward



(a) (b)

Figure 3: Dynamic evolution path of various initial probabilities.

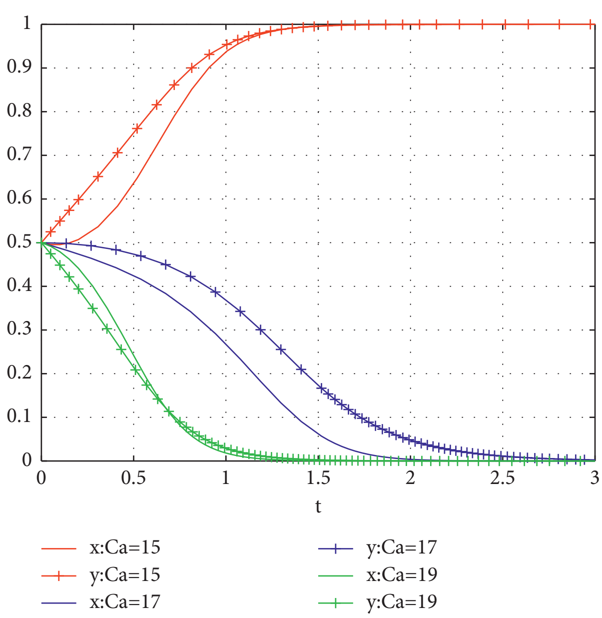


Figure 4: The sensitivity of Ca.

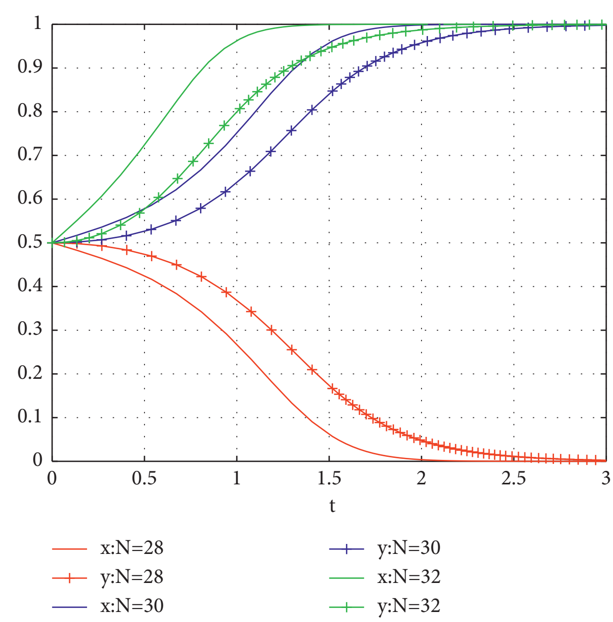


Figure 5: The sensitivity of N.

{negative regulation, nonimplementation policy}, and it evolves more quickly as Cr increases, which further suggests that measures should be taken to reduce the cost of local government regulation.

(5) Figure 8 shows the sensitivity of stakeholders to a penalty on large supermarket (P), setting P to 12, 14, and 16. When the local government imposes a lower penalty on large supermarkets ($P = 12$), the ESS will be {negative regulation, nonimplementation policy}. When P increases to 14 and 16, the ESS will be {positive regulation, implementation policy}, and as P increases from 14 to 16, the speed of evolution increases, indicating that large supermarkets tend to choose the "implementation policy" strategy when the large supermarket penalty (P) is higher.

(6) Figure 9 shows the sensitivity of stakeholders to the negative impact (F) on the local government when issues are exposed to third-party agencies or the public under negative regulation, setting F to 5, 6, and 7. The ESS evolves toward {negative regulation, nonimplementation policy}, and this evolution slows as F increases, suggesting that the smaller the negative impact is, the more the government tends to regulate negatively.

(7) Figure 10 shows the sensitivity of stakeholders to the probability (ω) that a local government issue will be

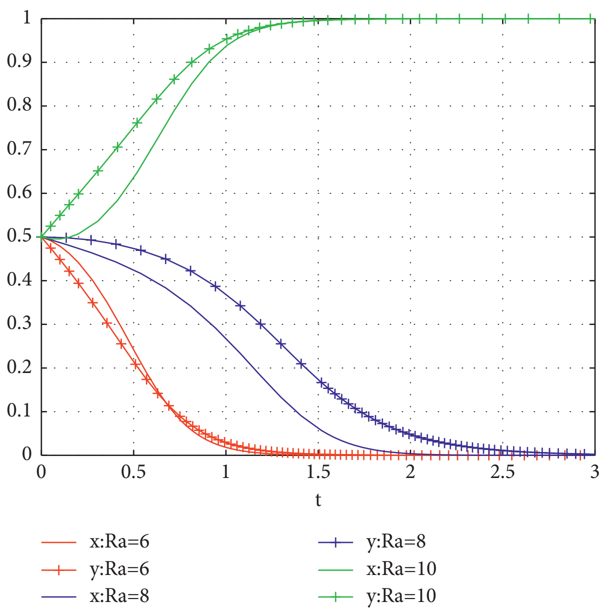


Figure 6: The sensitivity of Ra.

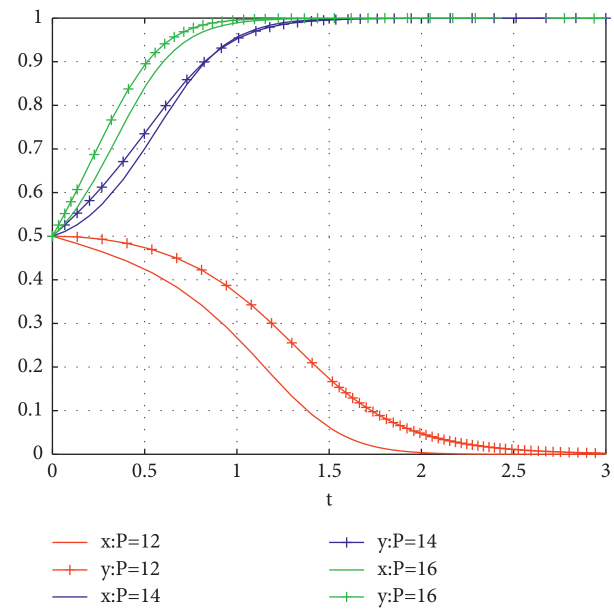


Figure 8: The sensitivity of P.

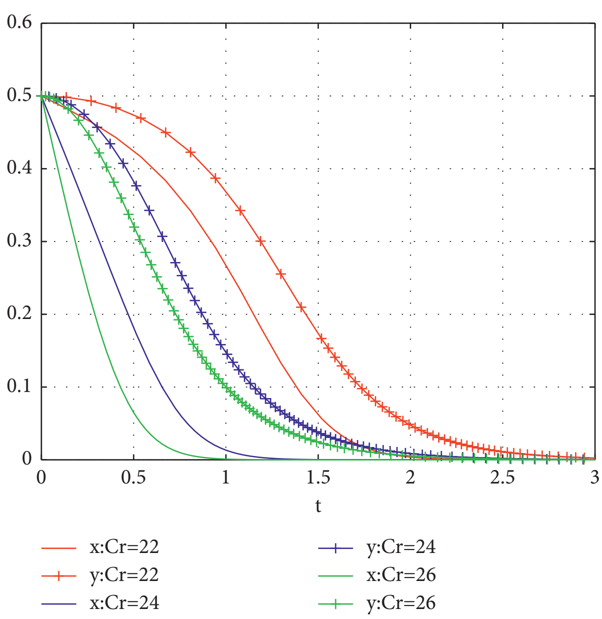


Figure 7: The sensitivity of Cr.

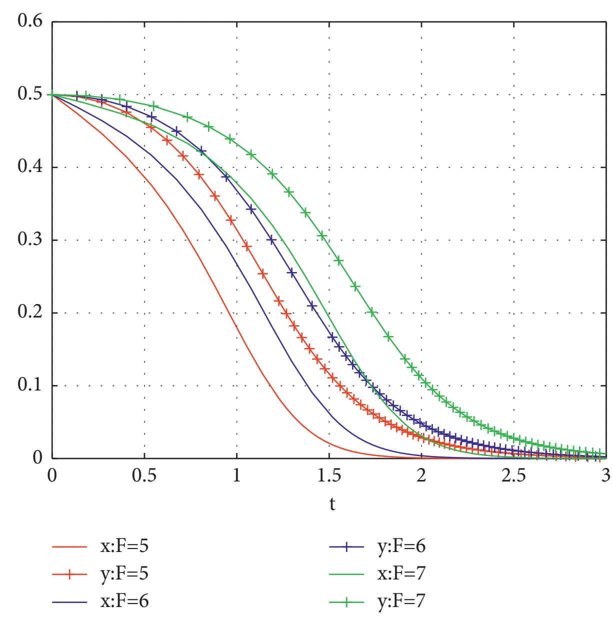


Figure 9: The sensitivity of F.

exposed to a third-party agency or the public under negative regulation, setting ω to 0.3, 0.5, and 0.7. When the probability of exposure is too low ($\omega = 0.3$, 0.5), the ESS will evolve toward {negative regulation, nonimplementation policy}, and when the probability of exposure rises to 0.7, the ESS will evolve toward {positive regulation, nonimplementation policy}. This further demonstrates the need for measures to increase the publicity and public awareness of environmental protection so that they have a higher probability of exposing large supermarkets that do not enforce their policies.

4.5. Simulation Results' Discussion. From the above simulation results, it can be concluded that the local government plays a key role in promoting the effective implementation of the PAFW in large supermarkets, and the effective and positive regulation of the PAFW is the key issue. The ESS is {negative regulation, nonimplementation policy} if the local government spends huge regulatory costs and very light penalties for large supermarkets that do not enforce the policy. Thus, local governments can use regulation by the public, NGOs, the press, and the Internet to reduce regulatory costs while gaining a good reputation and political success. In the scenario of large supermarkets, the strategy

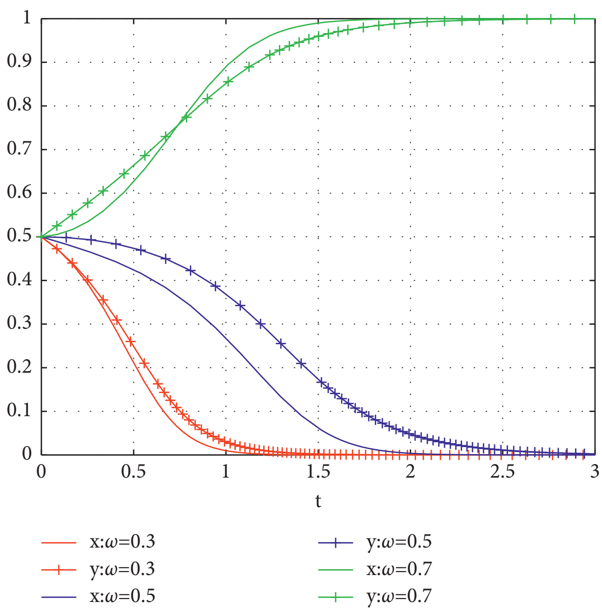


FIGURE 10: The sensitivity of ω.

depends on the degree of local government regulation, the cost of implementing the PAFW, and the additional benefits gained. It is therefore necessary for local governments to increase the penalties for large supermarkets that choose the "nonimplementation policy" strategy beyond what is already in place. In addition, greater awareness of the dangers of food waste and the importance of the PAFW will increase the public regulation of large supermarkets and the additional benefits that large supermarkets gain from implementing them.

5. Conclusions and Policy Implications

5.1. Conclusions. Food waste not only causes economic losses but also seriously endangers the natural resources on which human beings depend for survival. Therefore, the implementation of the PAFW is necessary. In this paper, the local government-large supermarket game model is established to explore how to promote the PAFW among large supermarkets in China from a micro perspective. The results show that to achieve the most effective strategy of active local government regulation and large supermarket policy implementation, China should adopt the following three measures: (1) strengthen local government regulation, including improving the local government's political performance and reducing regulatory costs; (2) enhance the willingness of large supermarkets to implement the PAFW, including reducing the cost of implementing the policy and increasing the benefits of implementation policy, such as the local government giving large supermarkets a certain amount of tax exemption due to the implementation of the policy and establishing a good image, and the public welcoming and promoting change; (3) facilitate the public's and third parties' exposure of large supermarkets' failure to implement the policy. Through numerical simulation, we find that increasing the initial probability of the local government and the large supermarket choosing the active regulation and implementation strategy will have guiding significance for the research. In addition, to obtain a greater probability of achieving the optimal strategy {positive regulation, implementation policy}, the key is to reduce the local government's regulatory costs, improve the implementation of the large supermarket policy to obtain additional benefits, reduce the cost of implementing the policy, and improve the public's and third parties' exposure of large supermarkets' failure to implement the policy and the negative impact on the local government after exposure.

5.2. Policy Implications.

(1) The local government should increase public awareness about saving food so that large supermarkets and the public grasp the need to save food; it should also highlight the importance of the PAFW and the related policies in France, Italy, Finland, and other countries in terms of economic benefits, social benefits, and environmental benefits. Relevant departments should strengthen the legislative work in this regard, developing laws against food waste as well as the corresponding specific standards, and it is necessary to strengthen the efficiency of local government supervision of large supermarkets. At the same time, through supervision by NGOs, the Internet, the news media, the public, and large supermarkets' implementation policy, the policy will lead to a good corporate image. In contrast, when a large supermarket does not implement the policy and is exposed by these parties, the large supermarket is fined, and the reputation of the local government is affected and severely punished by the higher-level government; this will promote the local government to strengthen its supervision of supermarkets.

(2) Because the implementation of the policy may involve high costs and lower income, large supermarkets may not be willing to choose the "implement the policy" strategy, and the local government must give some preferential policies, such as a certain amount of tax exemptions, to encourage the large supermarkets to implement the policy; it should also encourage nonprofit organizations to actively cooperate with large supermarkets, reducing the costs of implementing the policy for large supermarkets. To strengthen the implementation of the policy and improve large supermarkets' publicity, other large supermarkets should choose the "implementation policy" strategy to inject new momentum.

(3) The local government should strengthen the construction of the regulatory system, optimize the structure, and reduce the cost of supervision. First, management should be strengthened by establishing and improving the regulatory authorities at the level of laws and regulations and establishing financial

standards. The basic principles and system of the regulatory authorities should be established; work requirements should be clarified, the regulatory authorities should carry out regulatory activities according to the established principles, the implementation of the system should be implemented, and the standards should be enforced to further improve the level of standardization and institutionalization. Additionally, to obtain the maximum management and service benefits, logistics service resources should be used; administrative expenses, energy consumption, and the operating costs of regulatory authorities should be reduced; human, financial, and material resources should be allocated and used reasonably; and as few as possible resources should be consumed.

In general, promoting the regulations on the PAFW relies on the collaborations among government, companies, and the public society. In particular, it can indirectly increase the food supply in China and smooth the trend of rapid growth in the import rate, which benefits the issues on food safety in China. Furthermore, it will release the pressure from the increase in food prices in China, which makes certain contributions in controlling inflation.

5.3. Limitations. This study contends with several limitations. First, the promotion of the PAFW involves many stakeholders, including the local government, large supermarkets, higher authorities, NGOs, and the news media. The game between the local government and large supermarkets is established under the premise of ignoring other game models. Second, this paper only uses the scenario for simulation because of the lack of real data. In future research, it is hoped that the real data can be used to test the interest coordination of stakeholders in the policy promotion process. Third, the parametric assumptions used in our game model are static. In addition to static scenarios, dynamic parameters can enrich the content of this article. Fourth, in addition to the evolutionary game, data-driven approaches could provide useful solutions in addressing the problem of the donation intention of supermarkets and the implementation cost for different policies [39, 40].

Data Availability

No data were used to support the findings of this study.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

This research was funded by the Faculty Research Grants of Macau University of Science and Technology (Grant no. FRG-19-040-MSB).

References

[1] R. Ishangulyyev, S. Kim, and S. H. Lee, "Understanding food loss and waste – why are we losing and wasting food?" *Foods*, vol. 8, no. 8, 2019.

[2] L. V. Geffen, E. V. Herpen, and S. J. Sijtsema, "A broader perspective on household food waste: a call for encompassing consumers' food related goals, the food system, and the impact of reduction activities," *Resources, Conservation and Recycling*, vol. 163, 2020.

[3] United Nations, *Resolution Adopted by the General Assembly on 25 September 2015-70/1. Transforming Our World: The 2030 Agenda for Sustainable Development*, United Nations, New York, USA, 2015.

[4] D. Pleissner, "Recycling and reuse of food waste," *Current Opinion in Green and Sustainable Chemistry*, vol. 13, pp. 39–43, 2018.

[5] A. Heidari, F. Mirzaii, M. Rahnama, and F. Alidoost, "A theoretical framework for explaining the determinants of food waste reduction in residential households: a case study of Mashhad, Iran," *Environmental Science and Pollution Research*, vol. 27, no. 7, pp. 6774–6784, 2020.

[6] W.360 staff. ReFED Releases 2018 U.S. Food Waste Investment Report. Retrieved from https://www.waste360.com/food-waste/refed-releases-2018-us-food-waste-investment-report. 2018.

[7] J. Rosenlund, Å. Nyblom, H. Matschke Ekholm, and L. Sörme, "The emergence of food waste as an issue in Swedish retail," *British Food Journal*, vol. 122, no. 11, pp. 3283–3296, 2020.

[8] CYS, *China Statistical Yearbook*, China Statistical Publishing House, Beijing, China, (in chinese), 2016.

[9] P. Loizia, N. Neofytou, and A. A. Zorpas, "The concept of circular economy strategy in food waste for the optimization of energy production through anaerobic digestion," *Environmental Science and Pollution Research*, vol. 26, 2018.

[10] L. Zhu, "Deeply understand food security from the height of national strategy — interpretation of general secretary Xi jinping's important instructions on Stopping," *Food Waste. Theoretical Investigation*, vol. 52020, in Chinese.

[11] S. K. Cheng, "Multiple measures to curb food waste in urban restaurants," *Chinese Cadres Tribune*, vol. 09, pp. 69–71, 2020, in Chinese.

[12] M. Mourad, "France Moves toward a national policy against food waste. [Research report]," *Natural Resources Defense Council*, vol. 9, 2015.

[13] B. Garske, K. Heyl, and F. Ekardt, "Challenges of food waste governance: an assessment of European legislation on food waste and recommendations for improvement by economic instruments," *Land*, vol. 9, 2020.

[14] J. Jin, J. Zhuang, and Q. Zhao, "Supervision after certification: an evolutionary game analysis for Chinese environmental labeled enterprises," *Sustainability*, vol. 10, no. 5, p. 1494, 2018.

[15] K. L. Thyberg and D. J. Tonjes, "Drivers of food waste and their implications for sustainable policy development," *Resources, Conservation and Recycling*, vol. 106, pp. 110–123, 2016.

[16] L. Heikkilä, A. Reinikainen, J.-M. Katajajuuri, K. Silvennoinen, and H. Hartikainen, "Elements affecting food waste in the food service sector," *Waste Management*, vol. 56, pp. 446–453, 2016.

[17] R. J. Lunkes, F. S. Rosa, and P. Lattanzi, "The effect of the perceived utility of a management control system with a broad scope on the use of food waste information and on financial

and non-financial performances in restaurants," *Sustainability*, vol. 12, no. 15, 2020.
[18] C. Muriana, "A focus on the state of the art of food waste/losses issue and suggestions for future researches," *Waste Management*, vol. 68, pp. 557–570, 2017.
[19] F. Schneider, "The evolution of food donation with respect to waste prevention," *Waste Management*, vol. 33, no. 3, pp. 755–763, 2013.
[20] S. Dolnicar, E. Juvan, and B. Grün, "Reducing the plate waste of families at hotel buffets - a quasi-experimental field study," *Tourism Management*, vol. 80, Article ID 104103, 2020.
[21] J. Xu, J. Cao, Y. Wang, X. Shi, and J. Zeng, "Evolutionary game on government regulation and green supply chain decision-making," *Energies*, vol. 13, no. 3, p. 620, 2020.
[22] H. Xie, W. Wang, and X. Zhang, "Evolutionary game and simulation of management strategies of fallow cultivated land: a case study in Hunan province, China," *Land Use Policy*, vol. 71, pp. 86–97, 2018.
[23] S. Abapour, B. Mohammadi-Ivatloo, and M. T. Hagh, "Robust bidding strategy for demand response aggregators in electricity market based on game theory," *Journal of Cleaner Production*, vol. 243, 2020.
[24] H. Long, H. Liu, X. Li, and L. Chen, "An evolutionary game theory study for construction and demolition waste recycling considering green development performance under the Chinese government's reward-penalty mechanism," *International Journal of Environmental Research and Public Health*, vol. 17, no. 17, p. 6303, 2020.
[25] J. C. Sheng, W. H. Zhou, and B. Z. Zhu, "The coordination of stakeholder interests in environmental regulation: lessons from China's environmental regulation policies from the perspective of the evolutionary game theory," *Journal of Cleaner Production*, vol. 249, 2020.
[26] J. Zhang and X. Xi, "Complexity analysis of a 3-player game with bounded rationality participating in nitrogen emission reduction," *Complexity*, vol. 2020, Article ID 2069614, 16 pages, 2020.
[27] Q. Song, P. Jiang, and S. Zheng, "Application of evolutionary game theory in safety management of chemical production," *Processes*, vol. 8, no. 4, p. 472, 2020.
[28] J. S. Liu, C. R. Yu, C. R. Li, and H. Jingti, "Cooperation or conflict in doctor-patient relationship? An analysis from the perspective of evolutionary game," *IEEE Access*, vol. 99, p. 1, 2020.
[29] C. Feng and R. Ma, "Analysis of evolutionary game between manufacturing enterprises and service providers based on servitization," *Chinese Journal of Management Science*, vol. 9, pp. 1–12, 2020, In Chinese.
[30] D. F. Wu, J. S. Jiang, Q. Q. Sun et al., "Effect of reduced nitrogen fertilization on spring maize production and environmental impacts in rain-fed areas," *Journal of Agro-Environment Science*, vol. 35, no. 6, pp. 1202–1209, 2016, In Chinese.
[31] C. M. Galanakis, "The food systems in the era of the coronavirus (COVID-19) pandemic crisis," *Foods*, vol. 9, no. 523, 2020.
[32] P. Farrell, A. M. Thow, J. T. Wate et al., "COVID-19 and Pacific food system resilience: opportunities to build a robust response," *Food Security*, vol. 12, no. 4, pp. 783–791, 2020.
[33] C. Zhu, R. Fan, M. Luo, J. Lin, and Y. Zhang, "Urban food waste management with multi-agent participation: a combination of evolutionary game and system dynamics approach," *Journal of Cleaner Production*, vol. 275, Article ID 123937, 2020.
[34] Y. Yang, W. Yang, and H. Chen, "China's energy whistleblowing and energy supervision policy: an evolutionary game perspective," *Energy*, vol. 213, 2020.
[35] P. D. Taylor and L. B. Jonker, "Evolutionarily stable strategies and game dynamics," *Mathematical Biosciences*, vol. 40, no. 1-2, pp. 145–156, 1978.
[36] D. Friedman, "Evolutionary games in economics," *Econometrica*, vol. 59, no. 3, pp. 637–666, 1991.
[37] B. Yan, Z. Jin, L. Liu, and S. Liu, "Factors influencing the adoption of the internet of things in supply chains," *Journal of Evolutionary Economics*, vol. 28, no. 3, pp. 523–545, 2018.
[38] T. Zhao and Z. Liu, "A novel analysis of carbon capture and storage (CCS) technology adoption: an evolutionary game model between stakeholders," *Energy*, vol. 189, 2019.
[39] H. T. Li, F. Jin, S. L. Sun et al., "A new secondary decomposition ensemble learning approach for carbon price forecasting," *Knowledge-Based Systems*, vol. 214, Article ID 106686, 2020.
[40] S. L. Sun, F. Jin, H. T. Li, and L. Yong, "A new hybrid optimization ensemble learning approach for carbon price forecasting," *Applied Mathematical Modelling*, vol. 97, 2021.