IEEE Access
Multidisciplinary | Rapid Review | Open Access Journal

Received June 27, 2021, accepted July 3, 2021, date of publication July 7, 2021, date of current version July 13, 2021.

Digital Object Identifier 10.1109/ACCESS.2021.3095296

Online Food Delivery Platforms and Restaurants' Interactions in the Context of the Ban on Using Single-Use Plastics

KEQUAN LI[1], YAN CHEN[1], JIACHEN LIU[2], LIN ZHANG[1], AND XIANGWEI MU[1]
[1]School of Maritime Economics and Management, Dalian Maritime University, Dalian 116026, China
[2]School of Computer and Information Engineering, Hebei Finance University, Baoding 071051, China

Corresponding author: Xiangwei Mu (muxiangwei@dlmu.edu.cn)

This work was supported in part by the Ministry of Education of Humanities and Social Science Project under Grant 18YJC630124, in part by the Scientific Research Fund of Liaoning Provincial Education Department under Grant L2014203, in part by the Liaoning Social Science Planning Foundation under Grant L14BGL012, in part by the Social Science Planning Fund of Liaoning Province under Grant L18CTQ004, and in part by the Fundamental Research Funds for the Central Universities under Grant 3132020241.

ABSTRACT The boom in online food delivery(OFD) platforms brings convenience to both consumers and restaurants but leads to pollution from nonbiodegradable plastic food containers. To reduce pollution, the Chinese government enacted a ban on using multiple single-use plastics, including nondegradable OFD food containers. There may be various interests involved in enforcing the ban, so careful analysis is required before implementing the ban. This study applied evolutionary game theory to examine the interaction mechanism of the problematic behaviors between OFD platforms and restaurants. By theoretical research and simulation, we analyzed the conditions under which the game can converge to the expected outcome. In addition, we discussed the measures that are most important to promote restaurants using degradable food packaging in their service.

INDEX TERMS Online food delivery, evolutionary game theory, behavior modeling, food packaging, ban on using single-use plastics.

I. INTRODUCTION

The online food delivery (OFD) platform is a third-party platform that integrates information from consumers, restaurants, and riders [1]. The platform obtains food information from numerous independent restaurants (food providers) and shows food information to OFD consumers via websites or mobile apps. Consumers browse and order prepared foods on the platform [2]. The platform accepts consumers' orders and relays these orders to the restaurants to inform them to prepare food (including plastic bags, food containers, and tableware) according to consumers' needs. After the food is ready, the platform assigns delivery people (also called riders) to pick up the food from the restaurants and deliver it to consumers. As a third-party platform, the OFD platform takes responsibility for food quality and delivery [3]. In addition, it is the OFD platforms' responsibility to supervise restaurants according to government regulations [4]–[6].

The associate editor coordinating the review of this manuscript and approving it for publication was Cheng Qian.

As OFD platforms provide direct and efficient services for large numbers of customers and restaurants [3], OFD has experienced robust growth in recent years, particularly in China [7], [8]. The OFD market scale increased from CNY ¥124.8 billion in 2015 to CNY ¥291.2 billion in 2019, and the number of OFD consumers increased from 113.56 million in 2015 to 457.70 million in 2019. The expansion of OFD positively impacts the economy and society [9]. From an economic perspective, OFD provides job opportunities (e.g., chefs, riders [10], and computer programmers) and creates a bonanza for support industries (e.g., disposable food container production, disposable tableware production, and electric bicycle production) [11]. OFD also changes restaurants' operating modes [12]. From a sociological perspective, OFD provides people with access to a wide range of meal options and saves them time that would be spent going out for a meal. Notably, OFD provided a critical lifeline during the COVID-19 pandemic in 2020 when millions of people were quarantined at home [13]. Currently, ordering food online is popular and normative for consumers, but it comes with extensive quantities of plastic waste-plastic bags, food containers, and cutlery [14]. This study uses the term "food packaging" to refer to the bags, containers, and cutlery that are provided with delivered food. As summarized by Zhou *et al.* [15], the Chinese OFD market results in the use of 7.3 billion plastic food packaging sets per year. The consumption of plastic food packaging leads to pollution.

To reduce pollution, many initiatives have been proposed. One of the most important initiatives is the ban on using single-use plastics. In January 2020, the state council of China announced a strict ban on using single-use plastics [16]. The ban forbids restaurants from providing single-use food packaging (SFP) to consumers. As a substitute, restaurants have to provide degradable food packaging (DFP) to fulfill consumers' needs.[1] Unfortunately, the ban was not strictly enforced [13] due to the COVID-19 outbreak. With the epidemic gradually becoming under control in China, the government has revived the ban. On July 13, 2020, the state development planning commission of China and eight other departments published a notice to solidly promote reductions in the use of plastic pollution and requested that the ban be implemented in 2021 [17]. At the beginning of 2021, the ban was implemented in many cities. For example, restaurants in Shanghai were banned from providing nondegradable plastic bags in their OFD service. Restaurants in urban built-up areas of Beijing are also implementing similar behaviors. In addition, well-known milk tea chain brands such as "Honey Snow City" and "CoCo" were banned from providing plastic straws in their OFD services. These phenomena signify that the Chinese government will re-enforce the ban on using single-use plastics countrywide as the epidemic is brought under control.

As the OFD market is large, the ban can reduce massive amounts of plastic pollution while harming the OFD industry if the ban is performed improperly. The conflicts of interest among the government, OFD platforms, restaurants, and consumers make it difficult to successfully implement the ban. The government desires to implement the ban because the ban is accompanied by significant environmental benefits. Furthermore, consumers only consider their convenience rather than considering the environmental consequences [18]. To satisfy consumers, a high proportion of restaurants choose to provide SFP, even though SFP is not environmentally friendly. A solution to the change in restaurants' behavior is to punish restaurants if they insist on using SFP. Nevertheless, a series of studies have shown that it is not sensible for the government to directly supervise and punish restaurants [19]–[21]. Thus, cogovernance is introduced in implementing the ban. In cogovernance, OFD platforms are responsible for supervising restaurants' behavior, and they can punish restaurants if the restaurants still choose to use SFP. Then, the government can punish OFD platforms if they do not fully satisfy their responsibility. In other words, the core of cogovernance is to coordinate the government, OFD platforms, restaurants, and consumers' conflicts of interest. To construct this cogovernance, some conditions must be met. The fundamental solution for stopping the use of SFP in OFD service is that the government, OFD platforms, and restaurants make efforts to implement the ban. However, restaurants tend to cater to customers' needs, and OFD platforms' supervisory behavior is usually opportunistic. Therefore, the government needs to take measures to change restaurants' and OFD platforms' behavior.

[1]This study uses the term "SFP" to refer to the nondegradable plastic items provided in OFD service. Correspondingly, the term "DFP" refers to other types of food packaging (e.g., aluminum food containers, paper spoons, and degradable plastic bags).

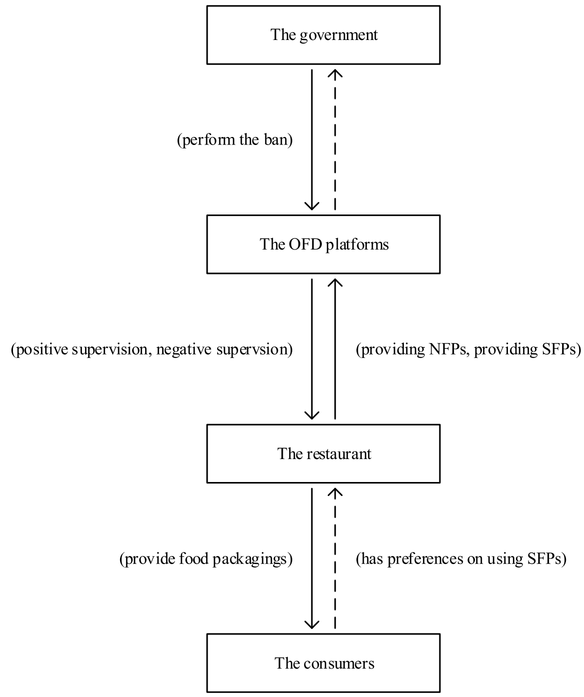

FIGURE 1. Interactions between the government, OFD platforms, restaurants, and consumers.

Accordingly, we develop a theoretical model of the behavioral strategy interaction of restaurants and OFD platforms in the ban on using single-use plastics and discuss how to restrain restaurants' and OFD platforms' willingness to resist the ban. As restaurants' and OFD platforms' behavioral strategy interaction is a dynamic process, we employ evolutionary game theory [22], [23] to develop the model. The process has four participants: the government, OFD platforms, restaurants, and consumers. We depict the interactions between the four participants in Fig.1. Among the four participants, the government and consumers' behaviors are constant: the government will stick to the ban, and consumers tend to use inexpensive and convenient SFP. Therefore, our model considers only how OFD platforms and restaurants choose their behavioral strategies according to the government's and consumers' preferences.

II. LITERATURE REVIEW

Plastic waste management in the OFD industry is a hot topic, and recent studies in this field focus on various aspects of the problem. A series of studies focus on analyzing the environmental impact of OFD plastic waste.

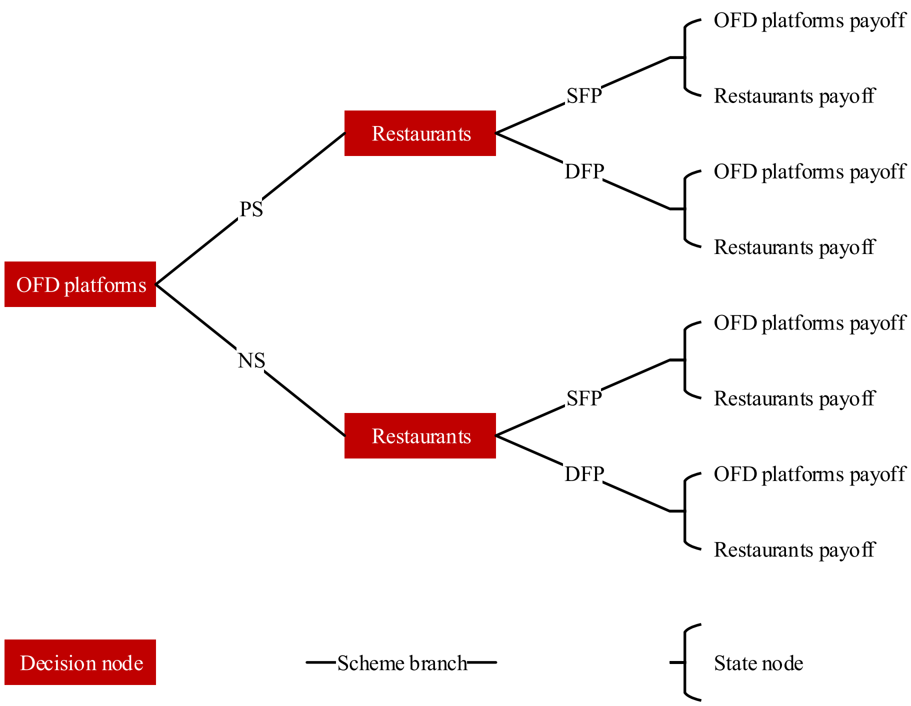

FIGURE 2. A decision tree demonstrating the stakeholders' payoff (utility).

For example, [11], [15], [24], [25] estimated the volume and composition of food delivery packaging waste in China based on OFD platforms' quarterly sales data, web crawling, and sample survey methods. Reference [7] counted the harmful chemicals from online food packaging and their harm to human health. Reference [26] compared the environmental impacts of three widely used types of food packaging and concluded that single-use plastics are the worst option for producing food packaging. All these studies point to the need to reduce the use of SFP in the OFD industry. Some studies focus on finding the factors can encourage people to choose environmentally friendly food packaging. Questionnaire surveys [27] and various comprehensive models [28]–[30] were employed in these studies. All these studies concluded that consumers' attitudes toward the environment are important in reducing the use of SFP. Unfortunately, the most important issue, how to change consumers' attitudes, is still a problem. Many studies have analyzed policy instruments [31]–[33] for single-use plastic reduction as many countries have reduced the use of single-use plastics in various industries. These studies provide references and a basis for this study.

However, all the studies above focused on the visible aspects of plastic waste management in the OFD industry, and no study has considered stakeholders' behavioral strategy interaction in plastic waste management. The present study provides a promising method for analyzing the behavioral strategy interaction between restaurants and OFD platforms to fill this gap. References [21] and [34] are similar to our study; all these studies employ evolutionary game theory to analyze OFD-related problems, while the two studies focus on food quality and food waste recycling, respectively. In addition, evolutionary game theory is employed in modeling various problems, e.g., retailer competition [35], resource management [36], and bid evaluations [37], [38]. All these studies contribute to our study.

III. MODEL DESCRIPTION AND ESTABLISHMENT

A. MODEL DESCRIPTION

We develop an evolutionary game model to analyze an OFD platform's and a restaurant's behavioral strategies in the context of the ban on using single-use plastics. The game players in the process are an OFD platform and a restaurant. Both players are stakeholders in the process, and they are finitely rational. Fig.2 depicts the game strategy combinations of the two players. The strategy spaces of OFD platforms and restaurants are $\mathbf{S}_P = \{PS, NS\}$ and $\mathbf{S}_R = \{DFP, SFP\}$, where PS and NS denote positive supervision and negative supervision, respectively, and DFP and SFP denote providing DFP and SFP, respectively. Based on the two players' strategies, we propose the following four hypotheses.

Hypothesis 1: We suppose that the probability of the restaurant choosing the DFP strategy is x, so the probability of the restaurant choosing the SFP strategy is $1 - x$. Moreover, the OFD platform has two choices. We use y to represent the probability of the OFD platform choosing the PS strategy, so the probability of the OFD platform choosing the NS strategy is $1 - y$. It is obvious that $x, y, 1 - x, 1 - y \in [0, 1]$.

Hypothesis 2: We assume that the Chinese government resolutely enforces the ban on using single-use plastics in OFD service. Thus, the restaurant will suffer a penalty from the OFD platform if the restaurant and OFD platform choose the SFP and PS strategies, respectively. We assume the value

TABLE 1. Description for the abbreviations and notations.

Notation	Description
OFD	Online food delivery.
SFP	Single-use food packaging.
DFP	Degradable food packaging.
S_P	The OFD platform's strategy space.
S_R	The restaurant's strategy space.
PS	The OFD platform's positive strategy if it chooses to stop the restaurant providing SFP.
NS	The OFD platform's negative strategy if it chooses to stop the restaurant providing SFP.
DFP	The restaurant's strategy if it chooses to provide DFP to consumers.
SFP	The restaurant's strategy if it chooses to provide SFP to consumers.
C_{11}	The penalty from the OFD platform if the restaurant chooses the SFP strategy and the OFD platform chooses the PS strategy.
C_{12}	The extra cost if the restaurant chooses the DFP strategy.
C_{21}	The cost for the OFD platform's supervisory behavior if it chooses the PS strategy.
C_{22}	The penalty from the government if the OFD platform chooses the NS strategy.
C_{23}	The impacts from the restaurant's negative cooperation.
C_{24}	The OFD platform's loss if the restaurant chooses the SFP strategy and the OFD platforms chooses the NS strategy.
R_{11}	The restaurant's sales if it chooses the DFP strategy.
R_{12}	The restaurant's sales if it chooses the SFP strategy.
R_{21}	The reward from the government if the OFD platform chooses the PS strategy.
R_{22}	The benefits from the OFD platform's regular operations.
x	The restaurant's probability of choosing the DFP strategy.
y	The OFD platform's probability of choosing the PS strategy.

of the penalty is C_{11}, and it is reasonable to let $C_{11} > 0$. If the restaurant chooses the *DFP* strategy, it will never experience the penalty regardless of what strategy the OFD platform chooses. However, the restaurant will have an extra cost of C_{12} for purchasing the DFP. It is reasonable to let $C_{11} > C_{12} > 0$. Moreover, the current DFP has fewer functional advantages than NFP, making them inconvenient for consumers. Consumers who cannot endure the inconvenience of DFP will order food through other channels. Thus, we assume that restaurants' behavioral strategies lead to different sales. The sales when a restaurant adopts the *DFP* strategy and *SFP* strategy are R_{11} and R_{12}, respectively. Previous studies have shown that consumers are more concerned about their dining experience than environmental protection, so we assume $0 < R_{11} < R_{12}$.

Hypothesis 3: The OFD platform will pay extra costs for their supervisory behavior (e.g., pay the salaries of regulators and develop features related to the supervision in their apps) if it chooses the *PS* strategy. The cost $C_{21} > 0$. Correspondingly, the OFD platform will receive a reward or subsidy R_{21} from the government if it chooses the *PS* strategy. It is reasonable to let $R_{21} > 0$. In contrast, when the OFD platform chooses the *NS* strategy and the restaurant chooses the *SFP* strategy, the ban will have no effect. Then, the OFD platform will experience a penalty of C_{22} from the government due to its dereliction of duty. To ensure the effectiveness of the penalty, assume $C_{22} > C_{21} > 0$. In addition, the restaurant is independent of the OFD platform, and when the platform forces it to choose the *DFP* strategy, they will adopt negative cooperation to address it. Negative cooperation will have a negative impact C_{23} on the platform when the restaurant chooses the *SFP* strategy. Assuming that the impact is negatively correlated with the restaurant's probability of choosing the *DFP* strategy, $C_{23}(x) = (1 - x)C_{23}$, and $C_{23} > 0$.

Hypothesis 4: The OFD platform's normal operations generate benefits R_{22} to itself when the restaurant chooses the DFP strategy. The OFD platform's operations are abnormal when the OFD platform chooses the *NS* strategy and the restaurant chooses the *SFP* strategy. The OFD platform will suffer a loss (e.g., negative reports about the platform appearing in the news, resulting in a drop in the share price of the platform) if it operates abnormally. We assume that the loss is C_{24}, and $R_{22}, C_{24} > 0$.

B. MODEL ESTABLISHMENT

Based on the above assumptions, all parameters are depicted in Table 1. Additionally, the payoff matrix between OFD platforms and restaurants is depicted in Table 2.

We define the restaurant's and the OFD platform's payoff matrices as **H** and **B**, respectively, as depicted in (1) and (2), respectively:

$$\mathbf{H} = \begin{pmatrix} R_{11} - C_{12} & R_{11} - C_{12} \\ R_{12} - C_{11} & R_{12} \end{pmatrix}, \quad (1)$$

$$\mathbf{B} = \begin{pmatrix} R_{21} + R_{22} - C_{21} & R_{22} - C_{22} \\ R_{21} - C_{21} - (1-x)C_{23} & -C_{22} - C_{24} \end{pmatrix}. \quad (2)$$

When the restaurant chooses the *DFP* strategy, we represent its expected payoffs as U_{R1}. Correspondingly, we represent the restaurant's average expected payoffs as $\overline{U}_R$. U_{R1} and $\overline{U}_R$ are calculated as (3) and (4), respectively:

$$U_{R1} = \begin{pmatrix} 1 & 0 \end{pmatrix} H \begin{pmatrix} y \\ 1-y \end{pmatrix} = R_{11} - C_{12}, \quad (3)$$

$$\overline{U}_R = \begin{pmatrix} x & 1-x \end{pmatrix} H \begin{pmatrix} y \\ 1-y \end{pmatrix} = xR_{11} + (1-x)R_{12} - (1-x)yC_{11} - xC_{12}. \quad (4)$$

According to equations 3 and 4, the growth of the restaurant's probability of choosing the *DFP* strategy should be equal to the expected utility U_{R1} minus the average expected utility $\overline{U}_R$. Thus, the restaurant's replicator dynamic equation is calculated as (5):

$$F(x) = \frac{dx}{dt} = x(U_{R1} - \overline{U}_R) = x(1-x)(R_{11} - R_{12} + yC_{11} - C_{12}). \quad (5)$$

TABLE 2. Payoff matrix for both stakeholders.

		OFD platform	
		PS	NS
Restaurant	DFP	$R_{11}-C_{12}; R_{21}+R_{22}-C_{21}$	$R_{11}-C_{12}; R_{22}-C_{22}$
	SFP	$R_{12}-C_{11}; R_{21}-C_{21}-(1-x)C_{23}$	$R_{12}; -C_{22}-C_{24}$

TABLE 3. The values of the six potential equilibrium points.

Point	Value
$E_1(x_1, y_1)$	$x_1=0$ $y_1=0$
$E_2(x_2, y_2)$	$x_2=0$ $y_2=1$
$E_3(x_3, y_3)$	$x_3=1$ $y_3=0$
$E_4(x_4, y_4)$	$x_4=1$ $y_4=1$
$E_{51}(x_5, y_5)$	$x_5=\frac{-C_{24}-\sqrt{C_{24}^2+4C_{23}(R_{21}-C_{21}+C_{22})}}{2C_{23}}+1$ $y_5=\frac{R_{12}-R_{11}+C_{12}}{C_{11}}$
$E_6(x_6, y_6)$	$x_6=\frac{-C_{24}+\sqrt{C_{24}^2+4C_{23}(R_{21}-C_{21}+C_{22})}}{2C_{23}}+1$ $y_6=\frac{R_{12}-R_{11}+C_{12}}{C_{11}}$

According to Table 2, when the OFD platform chooses the PS strategy, its expected payoffs are represented as U_{P1}, and the OFD platform's average expected payoffs are represented as $\overline{U}_P$. U_{P1} and $\overline{U}_P$ are calculated as (6) and (7), respectively:

$$U_{P1} = \begin{pmatrix}1 & 0\end{pmatrix} B^{\mathrm{T}} \begin{pmatrix}x \\ 1-x\end{pmatrix} = R_{21} + xR_{22} - C_{21} - (1-x)^2 C_{23}. \tag{6}$$

$$\overline{U}_P = \begin{pmatrix}y & 1-y\end{pmatrix} B^{\mathrm{T}} \begin{pmatrix}x \\ 1-x\end{pmatrix} = yR_{21} + xR_{22} - yC_{21} - (1-y)C_{22} - (1-x)^2 yC_{23} - (1-x)(1-y)C_{24}. \tag{7}$$

According to (6) and (7), the OFD platform's replicator dynamic equation is calculated as (8), shown at the bottom of the page. We use (5) and (8) to build the dynamic system S, as depicted in (9), shown at the bottom of the page.

IV. EVOLUTION GAME ANALYSIS OF THE INTERACTION OF THE RESTAURANT's AND THE OFD PLATFORM's BEHAVIORAL STRATEGIES

A. EVOLUTIONARY EQUILIBRIUM POINT

According to the stability theory of first-order differential equations, let $F(x) = 0$ and $F(y) = 0$. We obtain six potentially equilibrium points of the dynamic system S and depict the five points in Table 3.

Among the six points depicted in the table, E_1, E_2, E_3, and E_4 are the system's equilibrium points. Whether the other two points are interior equilibrium points needs further analysis.

A point (x, y) is an interior equilibrium point if it satisfies the following conditions: (1) $F(x) = 0$, (2) $F(y) = 0$, (3) $x \in (0, 1)$, and (4) $y \in (0, 1)$. Both E_5 and E_6 satisfy conditions (1) and (2). Thus, we just need to analyze the conditions under which the two points can satisfy both conditions (3) and (4).

For the point E_5, When $x_5 \in (0, 1)$, we can infer:

$$(1-x_5) = \frac{C_{24}+\sqrt{C_{24}^2+4C_{23}(R_{21}-C_{21}+C_{22})}}{2C_{23}} \in (0, 1), \tag{10}$$

Under the condition $R_{21}-C_{21}+C_{22} > 0$, as $C_{22} > C_{21}$ and $R_{21} > 0$, this condition is constantly established. As $C_{23} > 0$ and $C_{24} > 0$, $1-x_5 > 0$ is constantly established. Thus, condition $x_1^* \in (0, 1)$ is equal to $\frac{C_{24}+\sqrt{C_{24}^2+4C_{23}(R_{21}-C_{21}+C_{22})}}{2C_{23}} < 1$. Solving the inequality, we can obtain $R_{21} - C_{21} + C_{22} - C_{23} + C_{24} < 0$. Thus, assuming $\alpha = R_{21} - C_{21} + C_{22} - C_{23} + C_{24}$, we have that $x_5 \in (0, 1)$ is established only when $\alpha < 0$. As $R_{12} > R_{11} > 0$, $C_{12} > 0$, and $C_{11} > 0$, $y_5 > 0$ is constantly true. Thus, $y_5 \in (1, 0)$ is equal to $R_{11} - R_{12} + C_{11} - C_{12} > 0$. In other words, assuming $\beta = R_{11}-R_{12}+C_{11}-C_{12}$, $y_5, y_6 \in (0, 1)$ is established only when $\beta > 0$. Note that R_{21}, C_{21}, C_{22}, C_{23} and C_{24} are applied to the OFD platform, so we say that the OFD platform suffers a large punishment for not supervising the restaurant strictly when $\alpha > 0$. Correspondingly, we say that the ban does not have a discernible impact on the OFD platform's costs when $\alpha < 0$. Similarly, R_{11}, R_{12}, C_{11}, and C_{12} are applied to the restaurant, so we say that the restaurant suffers a large loss for providing SFP when $\beta > 0$. Correspondingly, we say that the ban does not have a discernible impact on the restaurant's cost when $\beta < 0$.

As $R_{21} - C_{21} + C_{22} > 0$ and $C_{23} > 0$, $C_{24}^2 + 4C_{23}(R_{21} - C_{21}+C_{22}) > C_{24}^2$ is established. Thus, $x_6 > 1$, and $x_6 \in (0, 1)$ is constantly not established. According to the analysis above, we can conclude that point E_5 is an interior equilibrium point only when $\alpha < 0$ and $\beta > 0$ while point E_6 is not an equilibrium point in system S.

B. ANALYSIS OF THE MODEL's EVOLUTIONARY STABILITY

Then, we employ a Jacobi matrix to obtain the evolutionary stability of the replicated dynamic system. The dynamic

$$F(y) = \frac{dy}{dt} = y(U_{P1} - \overline{U}_P) = y(1-y)\big(R_{21} - C_{21} + C_{22} - (1-x)^2 C_{23} + (1-x)C_{24}\big) \tag{8}$$

$$\begin{cases} F(x) = x(1-x)(R_{11} - R_{12} + yC_{11} - C_{12}) \\ F(y) = y(1-y)\big(R_{21} - C_{21} + C_{22} - (1-x)^2 C_{23} + (1-x)C_{24}\big) \end{cases} \tag{9}$$

TABLE 4. The expressions of the determinant and trace for the five equilibrium points.

Equilibrium Point		Expression
$E_1(0,0)$	$det(\mathbf{J})$	$(R_{11}-R_{12}-C_{12})(R_{21}-C_{21}+C_{22}-C_{23}+C_{24})$
	$tr(\mathbf{J})$	$(R_{11}-R_{12}-C_{12})+(R_{21}-C_{21}+C_{22}-C_{23}+C_{24})$
$E_2(0,1)$	$det(\mathbf{J})$	$-(R_{11}-R_{12}+C_{11}-C_{12})(R_{21}-C_{21}+C_{22}-C_{23}+C_{24})$
	$tr(\mathbf{J})$	$(R_{11}-R_{12}+C_{11}-C_{12})-(R_{21}-C_{21}+C_{22}-C_{23}+C_{24})$
$E_3(1,0)$	$det(\mathbf{J})$	$-(R_{11}-R_{12}-C_{12})(R_{21}-C_{21}+C_{22})$
	$tr(\mathbf{J})$	$-(R_{11}-R_{12}-C_{12})+(R_{21}-C_{21}+C_{22})$
$E_4(1,1)$	$det(\mathbf{J})$	$(R_{11}-R_{12}+C_{11}-C_{12})(R_{21}-C_{21}+C_{22})$
	$tr(\mathbf{J})$	$-(R_{11}-R_{12}+C_{11}-C_{12})-(R_{21}-C_{21}+C_{22})$
$E_5(x_5,y_5)$	$det(\mathbf{J})$	$(1-2x_5)(1-2y_5)(R_{11}-R_{12}+y_5C_{11}-C_{12})\big(R_{21}-C_{21}+C_{22}-(1-x_5)^2C_{23}+(1-x_5)C_{24}\big)$ $+x_5y_5(1-x_5)(1-y_5)C_{11}\big(2(1-x_5)C_{23}-C_{24}\big).$
	$tr(\mathbf{J})$	$(1-2x_5)(R_{11}-R_{12}+y_5C_{11}-C_{12})+(1-2y_5)\big(R_{21}-C_{21}+C_{22}-(1-x_5)^2C_{23}+(1-x_5)C_{24}\big)$

system's Jacobi matrix $\mathbf{J}$ is:

$$\mathbf{J}=\begin{pmatrix}\frac{dF(x)}{dx} & \frac{dF(x)}{dy}\\ \frac{dF(y)}{dx} & \frac{dF(y)}{dy}\end{pmatrix}, \tag{11}$$

and the expressions of $\frac{dF(x)}{dx}$, $\frac{dF(x)}{dy}$, $\frac{dF(y)}{dx}$, and $\frac{dF(y)}{dy}$ are depicted as (12), shown at the bottom of the page.

Then, we can compute the determinant and trace of $\mathbf{J}$ from the five equilibrium points as depicted (13) and (14), and we depict the expressions of the determinant and trace from the five equilibrium points in Table 4.

$$det(\mathbf{J})=\frac{dF(x)}{dx}\frac{dF(y)}{dy}-\frac{dF(x)}{dy}\frac{dF(y)}{dx} \tag{13}$$

$$tr(\mathbf{J})=\frac{dF(x)}{dx}+\frac{dF(y)}{dy} \tag{14}$$

Using the Jacobi matrix method, we can analyze the partial stability of the system $\mathbf{S}$ using the values of the determinant and trace of the equilibrium points. Four cases are discussed in this study.

When $\beta<0$, $R_{11}-C_{12}<R_{12}-C_{11}$ and $R_{11}-C_{12}<R_{12}$ are established, the restaurant can achieve higher payoffs by choosing the *SFP* strategy regardless of the strategy chosen by the OFD platform. In comparison, the OFD platform will choose its strategy according to different conditions.

Case 1. If $\alpha>0$ and $\beta<0$, then the evolutionary stability of the local equilibrium points is depicted in Table 5. In this case, $E_3(1,0)$ is the unstable point, $E_0(0,0)$ and $E_4(1,1)$ are saddle points, and $E_4(1,1)$ is the only ESS. The evolutionary phase diagrams of case 2 are depicted in Fig.3.

In this case, the restaurant chooses the *SFP* strategy to obtain higher payoffs. In this context, $R_{21}-C_{21}-(1-x)C_{23}>-C_{22}-C_{24}$, so the OFD platform chooses the *PS* strategy anyway. Thus, the evolutionary game will converge to pure strategy $\{SFP, PS\}$, and this is an unexpected outcome.

TABLE 5. The evolutionary stability of the local equilibrium points in case 1.

Equilibrium Point	$det(\mathbf{J})$	$tr(\mathbf{J})$	Stability
$E_1(0,0)$	-	Uncertain	Saddle point
$E_2(0,1)$	+	-	ESS
$E_3(1,0)$	+	+	Unstable point
$E_4(1,1)$	-	Uncertain	Saddle point

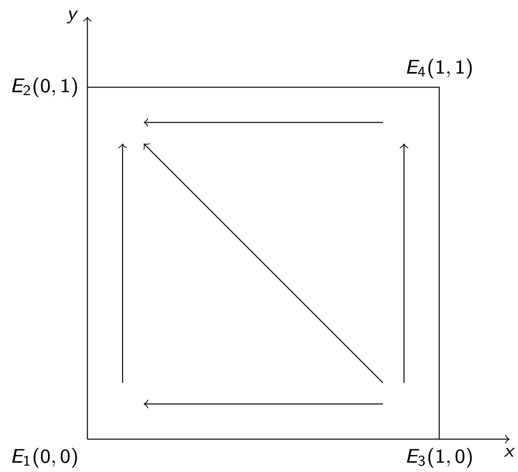

FIGURE 3. The evolutionary phase diagram of case 1.

Case 2. If $\alpha<0$ and $\beta<0$, then the evolutionary stability of local equilibrium points is depicted in Table 6. In this case, $E_3(1,0)$ is an unstable point, $E_2(0,1)$ and $E_4(1,1)$ are saddle points, and $E_1(0,0)$ is the only ESS. According to the values of the equilibrium points', we depict the evolutionary phase diagrams of case 2 in Fig.4.

In this case, the restaurant chooses the *SFP* strategy to obtain higher payoffs. When $x>x_5$, $R_{21}-C_{21}-(1-x)C_{23}>-C_{22}-C_{24}$, so the OFD platform chooses the *PS* strategy.

$$\begin{aligned}\frac{dF(x)}{dx}&=(1-2x)(R_{11}-R_{12}+yC_{11}-C_{12})\\ \frac{dF(x)}{dy}&=x(1-x)C_{11}\\ \frac{dF(y)}{dx}&=y(1-y)(2(1-x)C_{23}-C_{24}),\\ \frac{dF(y)}{dy}&=(1-2y)(R_{21}-C_{21}+C_{22}-(1-x)^2C_{23}+(1-x)C_{24})\end{aligned} \tag{12}$$

TABLE 6. The evolutionary stability of the local equilibrium points in case 2.

Equilibrium Point	$det(\mathbf{J})$	$tr(\mathbf{J})$	Stability
$E_1(0, 0)$	+	-	ESS
$E_2(0, 1)$	-	Uncertain	Saddle point
$E_3(1, 0)$	+	+	Unstable point
$E_4(1, 1)$	-	Uncertain	Saddle point

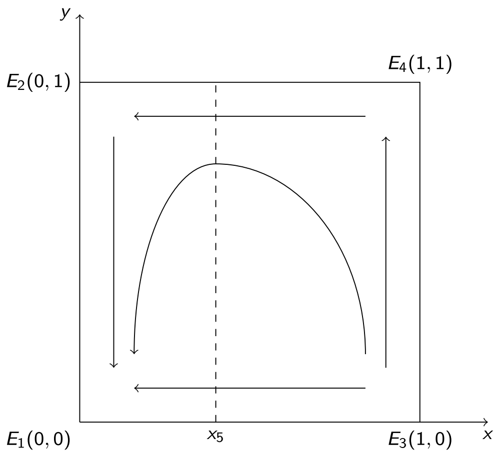

FIGURE 4. The evolutionary phase diagram of case 2.

TABLE 7. The evolutionary stability of the local equilibrium points in case 3.

Equilibrium Point	$det(\mathbf{J})$	$tr(\mathbf{J})$	Stability
$E_1(0, 0)$	-	Uncertain	Saddle point
$E_2(0, 1)$	-	Uncertain	Saddle point
$E_3(1, 0)$	+	+	Unstable point
$E_4(1, 1)$	+	-	ESS

Thus, y increases as x decreases when $x > x_5$. In condition $x < x_5$, we have $R_{21} - C_{21} - (1-x)C_{23} < -C_{22} - C_{24}$, so the OFD chooses the *NS* strategy to increase its payoffs. Thus, y decreases as x decreases when $x < x_5$. The evolutionary outcome is the pure strategy $\{SFP, NS\}$, and this is an unexpected outcome.

When $\beta > 0$, the evolutionary game can converge to the expected pure strategy $\{DPF, PS\}$; however, regarding the difference value of α, we have the following two cases:

Case 3. If $\alpha > 0$, $\beta > 0$, the evolutionary stability of local equilibrium points is depicted as Table 7. We can see that $E_3(1, 0)$ is the unstable point, $E_0(0, 0)$ and $E_2(0, 1)$ are saddle points, and $E_4(1, 1)$ is the only ESS. According to the result, we depict the evolutionary phase diagrams of case 3 in Fig.5.

In this case, $R_{21} + R_{22} - C_{21} > R_{22} - C_{22}$ and $R_{21} - C_{21} - (1-x)C_{23} > -C_{22} - C_{24}$ are established, so the OFD platform chooses the *PS* strategy to obtain higher payoffs. When $y < y_5$, the OFD platform's probability of choosing the *PS* strategy is relatively low, so the restaurant's probability of choosing the *SFP* strategy is increasing because choosing the *SFP* strategy can allow it to obtain higher payoffs. However, when $y > y_5$, with the OFD platform's probability of choosing the *PS* strategy increasing, the restaurant will receive higher payoffs by choosing the *DFP* strategy. Thus, the system converges to the pure strategy $\{DFP, PS\}$, and this is the expected outcome.

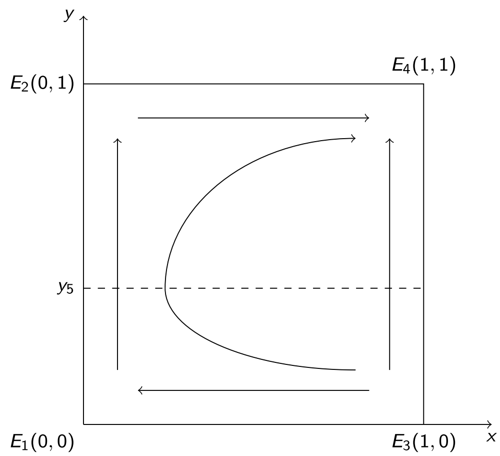

FIGURE 5. The evolutionary phase diagram of case 3.

TABLE 8. The evolutionary stability of the local equilibrium points in case 4.

Equilibrium Point	$det(\mathbf{J})$	$tr(\mathbf{J})$	Stability
$E_1(0, 0)$	+	-	ESS
$E_2(0, 1)$	+	+	Unstable point
$E_3(1, 0)$	+	+	Unstable point
$E_4(1, 1)$	+	-	ESS
$E_5(x_5^*, y_5^*)$	+	0	Central point

Case 4. If $\alpha < 0$, $\beta > 0$, the case has an interior equilibrium point $E_5(x_5, y_5)$. We will estimate the determinants and traces of the points first. When $x = x_5$ and $y = y_5$, both $R_{11} - R_{12} + yC_{11} - C_{12}$ and $R_{21} - C_{21} + C_{22} - (1-x_5)^2C_{23} + (1-x)C_{24}$ are equal to zero, and $2(1-x)C_{23} - C_{24} = \sqrt{C_{24}^2 + 4C_{23}(R_{21} - C_{21} + C_{22})} > 0$ is established. Thus, the determinant value on point $E_5(x_5, y_5)$ is positive, and its trace value is zero. Table 8 depicts the evolutionary stability of the five local equilibrium points in this case. One important issue is that one of the five points is an internal equilibrium point. The outcomes of most symmetric two-by-two games are equilibrium points because the payoffs for playing a particular strategy depend only on the other strategies employed, not on who is playing them [39], [40]. In this case, what we consider is an asymmetric game. That is, the two players, the OFD platform and restaurant, have different identities, and one player's strategy selection has an impact on the other's decision. Thus, the game's outcome seldom converges to an equilibrium point. For more details about the equilibrium points of the symmetric game and asymmetric game, see [41]–[45]. In this case, $E_5(x_5, y_5)$ is a central point, so it is not a stable point as most results in the asymmetric game. In addition, $E_2(0, 1)$ and $E_3(1, 0)$ are unstable points, and $E_1(0, 0)$ and $E_4(1, 1)$ are the system's local ESSs. We depict the evolutionary phase diagrams of case 4 in Fig.6.

The figure shows that the game has two potential outcomes. The system converges to which point depending on the relative position between the game's initial state and central point $E_5(x_5, y_5)$. When the initial state is located at ① or ②, the game converges to pure strategy $\{SFP, NS\}$, and this is the unexpected outcome. In contrast, the game converges

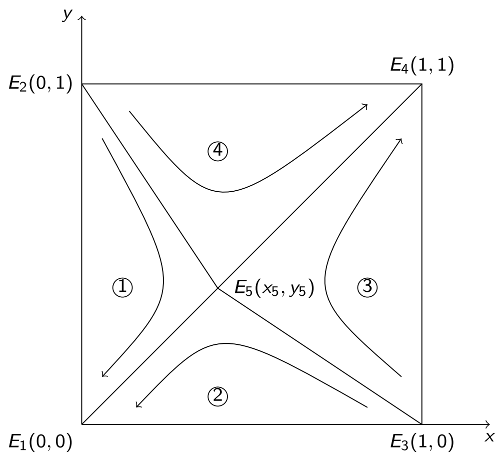

FIGURE 6. The evolutionary phase diagram of case 4. We use ①, ②, ③, and ④ to represent four different relative positions between the game's initial state and central point $E_5(x_5, y_5)$.

to pure strategy {*DFP*, *PS*} when the initial state appears in regions ③ or ④. Thus, moving the position of the central point $E_5(x_5, y_5)$ to the lower left side contributes to reducing the area of ① and ②, corresponding to expanding the area of ① and ②, making more initial states converge to the expected outcome.

In the four cases discussed above, the game converges to the expected outcome only when $\beta > 0$. Thus, the value of expression $R_{11} - R_{12} + C_{11} - C_{12}$ determines whether the ban can take effect. We have three main methods to increase $R_{11} - R_{12} + C_{11} - C_{12}$. First, lower the difference between R_{11} and R_{12}. For example, the OFD platform can recommend more items for restaurants who choose the *DFP* strategy to allow them to achieve higher sales. Second, collect a higher penalty C_{11} from restaurants that choose the *SFP* strategy to change their strategy selection. Third, lower the restaurant's extra costs C_{12} for choosing the *DFP* strategy. For example, the OFD platform can subsidize the restaurants that choose the *DFP* strategy to lower their costs.

The game has two possible outcomes when $\alpha < 0$ and $\beta > 0$ while it converges to the expected strategy when $\alpha > 0$ and $\beta > 0$. Thus, a higher value of the expression $R_{21} - C_{21} + C_{22} - C_{23} + C_{24}$ also contributes to performing the ban. We have some suggestions to increase the value of α as follows. First, the government can give OFD platforms that choose the *PS* strategy a higher reward R_{21}. Correspondingly, the government can also collect a higher penalty C_{22} from OFD platforms that choose the *NS* strategy. Second, the government can use subsidies to reduce the impact of the implementation of the ban on OFD platforms, such as C_{21} and C_{23}. Third, the government can influence public opinion through news and other media to higher the value of C_{24}.

When $\alpha < 0$ and $\beta > 0$, lower values of x_5 and y_5 contribute to making more initial states converge to the expected outcome. Thus, we can perform some actions to lower the values of expressions $\frac{-C_{24}-\sqrt{C_{24}^2+4C_{23}(R_{21}-C_{21}+C_{22})}}{2C_{23}} + 1$ and $\frac{R_{12}-R_{11}+C_{12}}{C_{11}}$. To do so, actions should be performed to increase the values of R_{11}, R_{21}, C_{11}, C_{22}, and C_{24} and lower the values of R_{12}, C_{12}, C_{21}, and C_{23}. Actions that can achieve this goal have been introduced above.

TABLE 9. The assumed values of the parameters under the four cases.

Parameter	Case 1	Case 2	Case 3	Case 4
C_{11}	0.9	0.9	2.4	2.4
C_{12}	0.8	0.8	0.8	0.8
C_{21}	2.0	2.0	2.0	2.0
C_{22}	2.2	2.2	2.2	2.2
C_{23}	2.5	8.0	2.5	8.0
C_{24}	2.0	2.0	2.0	2.0
R_{11}	2.5	2.5	2.5	2.5
R_{12}	3.0	3.0	3.0	3.0
R_{21}	0.8	0.8	0.8	0.8
R_{22}	3.2	3.2	3.2	3.2

V. SIMULATION EXPERIMENT

To intuitively observe the dynamic evolutionary process of the strategy selected between the restaurant and the OFD platform, we applied the MATLAB system simulation tool to the four cases. Table 9 depicts the assumed values of the parameters under the four cases. In each case, we select nine initial states: (0.2, 0.2), (0.2, 0.5), (0.2, 0.8), (0.5, 0.2), (0.5, 0.5), (0.5, 0.8), (0.8, 0.2), (0.8, 0.5), and (0.8, 0.8). For an initial state (x, y), the table shows that the restaurant has a probability of x of choosing the *DFP* strategy, and the OFD platform has a probability of y of choosing the *PS* strategy in the initial stage. Fig.7 depicts the dynamic evolutionary process between the two players under the four cases.

In case 1, R_{21}, C_{22}, and C_{24} have more significant impacts on the OFD platform than those from C_{21} and C_{23}. Thus, the OFD platform chooses the *PS* strategy ever since the ban started. However, the supervision of the OFD platform has not effectively affected the behavior of the restaurant. Even though the OFD platform's probability of choosing the *PS* strategy is increasing, the restaurant insists on choosing the *SFP* strategy. In the figure, all nine initial states converge to pure strategy {*SFP*, *PS*}, and this is the worst result. In this case, the OFD platform experiences considerable supervision costs. Nevertheless, the ban does not affect reducing the use of SFP.

In case 2, all nine initial states converge to pure strategy {*SFP*, *NS*}. The restaurant insists on choosing the *SFP* strategy ever since the ban started. In the beginning stage, the OFD platform increases its probability of choosing the *PS* strategy to stop the restaurant's behavior. Although the restaurant suffers punishment from the OFD platform if it chooses the *SFP* strategy, the restaurant still has a higher payoff than when choosing the *DFP* strategy, so the OFD platform's attempt has no effect. Then, the OFD platform's probability of choosing the *PS* strategy decreases as the restaurant's probability of choosing the *DFP* strategy decreases.

In case 3, all nine initial states converge to pure strategy {*DFP*, *PS*}. The OFD platform insists on choosing the *DFP* strategies ever since the beginning. In the beginning stage, the restaurant's probability of choosing *DFP* is low. The OFD platform's probability of receiving reward R_{22} is low, but it has a high probability of experiencing loss C_{23}. Thus, the OFD platform's probability of choosing the *NS* strategy is

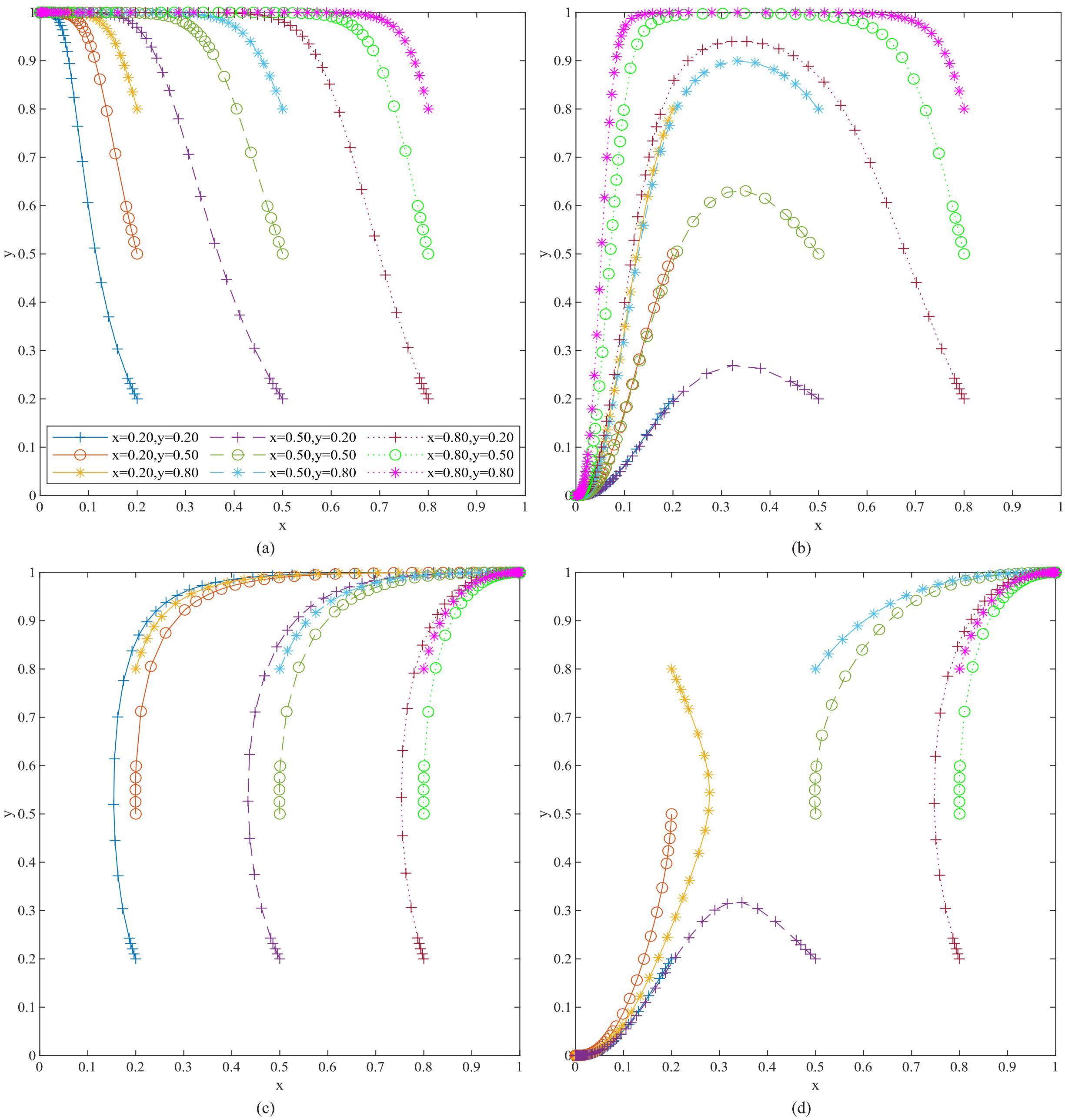

FIGURE 7. Strategy evolution path chart of the evolutionary game between the restaurant and OFD platform under the four cases. (a) case 1, (b) case 2, (c) case 3, and (d) case 4. To prevent the content of the figure from being obscured by legends, we only drew the legend in (a). In other words, the legend in (a) is shared by all four subfigures.

increasing. However, the restaurant's probability of choosing *DFP* is also increasing to escape the OFD platform's penalty. Then, the OFD platform's probability of receiving reward R_{22} is higher, the probability of experiencing loss C_{23} is lower, and the OFD platform's probability of choosing the *PS* strategy is increasing. Finally, the game converges to the expected outcome. This case indicates that the restaurant's willingness to choose the *DFP* strategy is the key to achieving the expected outcome. The OFD platform's action plays a crucial role in promoting the restaurant's willingness.

In case 4, four initial states converge to the pure strategy $\{SFP, NS\}$, and the other five initial states converge to the pure strategy $\{DFP, PS\}$. The figure shows that the result the initial state converges to depends on the position of the state. This conclusion is consistent with our previous analysis.

VI. CONCLUSION

The widely used SFP in the OFD industry results in plastic pollution. One feasible solution for reducing pollution is to stop using single-use plastics in the OFD industry. Unfortunately, consumers, restaurants, and OFD platforms are unwilling to stop using SFP, and it is infeasible for the government to directly supervise restaurants' behavior. Thus, cogovernance is introduced to coordinate the conflicts of interest of the government, OFD platforms, restaurants, and consumers. The restaurant and the OFD platform are the two players in the cogovernance game. They choose their behavioral strategies according to different conditions (e.g., the government's punishment or reward). The two players' strategy selection is a complex dynamic process, and some conditions must be met to achieve the goal of reducing the use of single-use plastics. To analyze the complex behavioral strategy interaction between the restaurant and OFD platform, we use evolutionary analysis to model the process.

According to different conditions, the game has four cases, and each case has its evolutionary outcome. Among the four cases, the game converges to the expected outcome only when the restaurant experiences a large loss from insisting on providing SFP ($R_{11} - R_{12} + C_{11} - C_{12} > 0$). Many actions can be taken to meet this condition. For example, the OFD platform can recommend more items for restaurants who choose the *DFP* strategy to increase their sales, collecting a higher penalty C_{11} from the restaurant, and subsidizing the restaurant for their choice of the *DFP* strategy. As these actions aim to change the restaurant's willingness to choose the *DFP* strategy, we say that the restaurant's willingness is the key in implementing the ban. When the restaurant experiences a large loss from insisting on providing SFP ($R_{11} - R_{12} + C_{11} - C_{12} > 0$) but the ban does not have a discernible impact on the OFD platform's costs ($R_{21} - C_{21} + C_{22} - C_{23} + C_{24} < 0$), the game still potentially converges to the unexpected outcome. Thus, actions should be taken to increase the value of expression $R_{21} - C_{21} + C_{22} - C_{23} + C_{24}$. For example, the government can increase the value of R_{21} or decrease the value of C_{22}. The government can also use subsidies to reduce the impacts of implementing the ban on OFD platforms. In addition, the government can influence public opinion to change the OFD platforms' strategy selection. When the restaurant experiences a large loss from insisting providing SFP ($R_{11} - R_{12} + C_{11} - C_{12} > 0$) but the ban does not have a discernible impact on the OFD platform's costs ($R_{21} - C_{21} + C_{22} - C_{23} + C_{24} < 0$), the strategy that the game converges to depends on the relative position between the game's initial state and the central points. The actions introduced above can also effectively increase the game's probability of convergence to the expected outcome.

REFERENCES

[1] M. Maimaiti, X. Zhao, M. Jia, Y. Ru, and S. Zhu, "How we eat determines what we become: Opportunities and challenges brought by food delivery industry in a changing world in China," *Eur. J. Clin. Nutrition*, vol. 72, no. 9, pp. 1282–1286, Sep. 2018.

[2] H.-S. Chen, C.-H. Liang, S.-Y. Liao, and H.-Y. Kuo, "Consumer attitudes and purchase intentions toward food delivery platform services," *Sustainability*, vol. 12, no. 23, p. 10177, Dec. 2020. [Online]. Available: https://www.mdpi.com/2071-1050/12/23/10177

[3] Z. He, G. Han, T. C. E. Cheng, B. Fan, and J. Dong, "Evolutionary food quality and location strategies for restaurants in competitive online-to-offline food ordering and delivery markets: An agent-based approach," *Int. J. Prod. Econ.*, vol. 215, pp. 61–72, Sep. 2019. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0925527318302020

[4] H. Lan, L. Ya'nan, and W. Shuhua, "Improvement of online food delivery service based on consumers' negative comments," *Can. Social Sci.*, vol. 12, no. 5, pp. 84–88, 2016.

[5] Y. He, H. Huang, D. Li, C. Shi, and S. J. Wu, "Quality and operations management in food supply chains: A literature review," *J. Food Qual.*, vol. 2018, Mar. 2018, Art. no. 7279491, doi: 10.1155/2018/7279491.

[6] Y. Yu and Y. He, "Information disclosure decisions in an organic food supply chain under competition," *J. Cleaner Prod.*, vol. 292, Apr. 2021, Art. no. 125976. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0959652621001967

[7] Y. Han, J. Cheng, Z. Tang, Y. He, and Y. Lyu, "Widespread occurrence of phthalates in popular take-out food containers from China and the implications for human exposure," *J. Cleaner Prod.*, vol. 290, Mar. 2021, Art. no. 125851. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0959652621000718

[8] X. Zhao, W. Lin, S. Cen, H. Zhu, M. Duan, W. Li, and S. Zhu, "The online-to-offline (O2O) food delivery industry and its recent development in China," *Eur. J. Clin. Nutrition*, vol. 75, pp. 232–237, Feb. 2021.

[9] C. Li, M. Mirosa, and P. Bremer, "Review of online food delivery platforms and their impacts on sustainability," *Sustainability*, vol. 12, no. 14, p. 5528, Jul. 2020, doi: 10.3390/su12145528.

[10] P. Sun, "Your order, their labor: An exploration of algorithms and laboring on food delivery platforms in China," *Chin. J. Commun.*, vol. 12, no. 3, pp. 308–323, 2019, doi: 10.1080/17544750.2019.1583676.

[11] G. Song, H. Zhang, H. Duan, and M. Xu, "Packaging waste from food delivery in China's mega cities," *Resour., Conservation Recycling*, vol. 130, pp. 226–227, Mar. 2018. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S092134491730438X

[12] M. Chen, M. Hu, and J. Wang. (2019). *Food Delivery Service and Restaurant: Friend or Foe*. [Online]. Available: https://ssrn.com/abstract=3469971

[13] J. Liu, A. D. Vethaak, L. An, Q. Liu, Y. Yang, and J. Ding, "An environmental dilemma for China during the COVID-19 pandemic: The explosion of disposable plastic wastes," *Bull. Environ. Contamination Toxicol.*, vol. 106, pp. 237–240, Feb. 2021.

[14] K. Molina-Besch, "Food delivery packaging and tableware waste," *Nature Food*, vol. 1, no. 9, pp. 531–532, Sep. 2020. [Online]. Available: https://www.nature.com/articles/s43016-020-00146-z

[15] Y. Zhou, Y. Shan, D. Guan, X. Liang, Y. Cai, J. Liu, W. Xie, J. Xue, Z. Ma, and Z. Yang, "Sharing tableware reduces waste generation, emissions and water consumption in China's takeaway packaging waste dilemma," *Nature Food*, vol. 1, no. 9, pp. 552–561, Sep. 2020. [Online]. Available: https://www.nature.com/articles/s43016-020-00145-0

[16] *Ministry of Ecology and Environment, National Development and Reform Commission Opinions on Further Strengthening the Control of Plastic Pollution*. Accessed: Jan. 16, 2020. [Online]. Available: https://www.ndrc.gov.cn/xxgk/zcfb/tz/202001/t20200119_1219275.html

[17] *Circular on Solidly Promoting the Control of Plastic Pollution*. Accessed: Jul. 13, 2020. [Online]. Available: https://www.ndrc.gov.cn/xxgk/zcfb/tz/202007/t20200717_1233956.html

[18] C. Liu and J. Chen, "Consuming takeaway food: Convenience, waste and Chinese young people's urban lifestyle," *J. Consum. Culture*, vol. 14, Oct. 2019, Art. no. 1469540519882487. [Online]. Available: https://journals.sagepub.com/doi/abs/10.1177/1469540519882487

[19] M. Cantley, "How should public policy respond to the challenges of modern biotechnology?" *Current Opinion Biotechnol.*, vol. 15, no. 3, pp. 258–263, Jun. 2004. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S095816690400059X

[20] B. Halkier and L. Holm, "Shifting responsibilities for food safety in europe: An introduction," *Appetite*, vol. 47, no. 2, pp. 127–133, Sep. 2006. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0195666306003928

[21] S. Yang, J. Zhuang, A. Wang, and Y. Zhang, "Evolutionary game analysis of chinese food quality considering effort levels," *Complexity*, vol. 2019, Nov. 2019, Art. no. 6242745. [Online]. Available: https://www.hindawi.com/journals/complexity/2019/6242745/

[22] Y. He, P. He, F. Xu, and C. Shi, "Sustainable tourism modeling: Pricing decisions and evolutionarily stable strategies for competitive tour operators," *Tourism Econ.*, vol. 25, no. 5, pp. 779–799, Aug. 2019, doi: 10.1177/1354816618806729.

[23] P. He, Y. He, and F. Xu, "Evolutionary analysis of sustainable tourism," *Ann. Tourism Res.*, vol. 69, pp. 76–89, Mar. 2018. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0160738318300082

[24] G. Liu, F. Agostinho, H. Duan, G. Song, X. Wang, B. F. Giannetti, R. Santagata, M. Casazza, and M. Lega, "Environmental impacts characterization of packaging waste generated by urban food delivery services. A big-data analysis in Jing-Jin-Ji region (China)," *Waste Manage.*, vol. 117, pp. 157–169, Nov. 2020. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0956053X20304062
[25] J. Liu, T. Zhang, S. Piché-Choquette, G. Wang, and J. Li, "Microplastic pollution in China, an invisible threat exacerbated by food delivery services," *Bull. Environ. Contamination Toxicol.*, pp. 1–8, Oct. 2020. [Online]. Available: https://link.springer.com/article/10.1007/s00128-020-03018-1
[26] A. Gallego-Schmid, J. M. F. Mendoza, and A. Azapagic, "Environmental impacts of takeaway food containers," *J. Cleaner Prod.*, vol. 211, pp. 417–427, Feb. 2019. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0959652618336230
[27] H.-H. Zhao, Q. Gao, Y.-P. Wu, Y. Wang, and X.-D. Zhu, "What affects green consumer behavior in China? A case study from Qingdao," *J. Cleaner Prod.*, vol. 63, pp. 143–151, Jan. 2014. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0959652613003302
[28] V. C. S. Yeo, S.-K. Goh, and S. Rezaei, "Consumer experiences, attitude and behavioral intention toward online food delivery (OFD) services," *J. Retailing Consum. Services*, vol. 35, pp. 150–162, Mar. 2017. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0969698916302855
[29] Y. Zhao and F. Bacao, "What factors determining customer continuingly using food delivery apps during 2019 novel coronavirus pandemic period?" *Int. J. Hospitality Manage.*, vol. 91, Oct. 2020, Art. no. 102683. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0278431920302358
[30] K. Annaraud and K. Berezina, "Predicting satisfaction and intentions to use online food delivery: What really makes a difference?" *J. Foodservice Bus. Res.*, vol. 23, no. 4, pp. 305–323, Jul. 2020, doi: 10.1080/15378020.2020.1768039.
[31] R. J. Kish, "Using legislation to reduce one-time plastic bag usage," *Econ. Affairs*, vol. 38, no. 2, pp. 224–239, Jun. 2018. [Online]. Available: https://onlinelibrary.wiley.com/doi/abs/10.1111/ecaf.12287
[32] B. Bharadwaj, J. M. Baland, and M. Nepal, "What makes a ban on plastic bags effective? The case of Nepal," *Environ. Develop. Econ.*, vol. 25, no. 2, pp. 95–114, Apr. 2020.
[33] C. Chan-Halbrendt, D. Fang, and F. Yang, "Trade-offs between shopping bags made of non-degradable plastics and other materials, using latent class analysis: The case of Tianjin, China," *Int. Food Agribusiness Manage. Rev.*, vol. 12, p. 20, Nov. 2009. [Online]. Available: http://ageconsearch.umn.edu/record/92561
[34] 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," *J. Cleaner Prod.*, vol. 275, Dec. 2020, Art. no. 123937. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0959652620339822
[35] C. Li and Z. Huang, "Evolutionary game analysis of online and offline drug retailer competition based on network externalities," *IEEE Access*, vol. 7, pp. 96620–96627, 2019.
[36] S. Lin, W. Ni, H. Tian, and R. P. Liu, "An evolutionary game theoretic framework for femtocell radio resource management," *IEEE Trans. Wireless Commun.*, vol. 14, no. 11, pp. 6365–6376, Nov. 2015.
[37] X. Liu, Z. Zhang, W. Qi, and D. Wang, "An evolutionary game study of the behavioral management of bid evaluations in reserve auctions," *IEEE Access*, vol. 8, pp. 95390–95402, 2020.
[38] X. Liu, Z. Zhang, W. Qi, and D. Wang, "Behavior analysis with an evolutionary game theory approach for procurement bid evaluation involving technical and business experts," *IEEE Syst. J.*, vol. 13, no. 4, pp. 4374–4385, Dec. 2019.
[39] J. Tanimoto and H. Sagara, "Relationship between dilemma occurrence and the existence of a weakly dominant strategy in a two-player symmetric game," *Biosystems*, vol. 90, no. 1, pp. 105–114, Jul. 2007.
[40] Z. Wang, S. Kokubo, J. Tanimoto, E. Fukuda, and K. Shigaki, "Insight into the so-called spatial reciprocity," *Phys. Rev. E, Stat. Phys. Plasmas Fluids Relat. Interdiscip. Top.*, vol. 88, no. 4, Oct. 2013, Art. no. 042145.
[41] H. Ito and J. Tanimoto, "Scaling the phase-planes of social dilemma strengths shows game-class changes in the five rules governing the evolution of cooperation," *Roy. Soc. Open Sci.*, vol. 5, no. 10, Oct. 2018, Art. no. 181085.
[42] M. R. Arefin, K. M. A. Kabir, M. Jusup, H. Ito, and J. Tanimoto, "Social efficiency deficit deciphers social dilemmas," *Sci. Rep.*, vol. 10, no. 1, p. 16092, Dec. 2020.
[43] J. Tanimoto, *Sociophysics Approach to Epidemics*. Singapore: Springer, 2021.
[44] J. Tanimoto, *Evolutionary Games with Sociophysics: Analysis of Traffic Flow and Epidemics*. Singapore: Springer, 2018.
[45] *Fundamentals of Evolutionary Game Theory and its Applications*. Tokyo, Japan: Springer, 2015.

KEQUAN LI received the M.S. degree from Dalian Maritime University, China, where he is currently pursuing the Ph.D. degree. His research interests include machine learning, big data, and data mining.

YAN CHEN received the Ph.D. degree from the Dalian University of Technology, China. She is currently a Professor with Dalian Maritime University. Her research interests include decision support systems, knowledge management, data warehouse, and data mining.

JIACHEN LIU received the M.S. degree from Dalian Maritime University, China. She is currently an Assistant Professor with Hebei Finance University. Her research interests include artificial intelligence, knowledge management, data warehouse, and data mining.

LIN ZHANG received the B.S. and Ph.D. degrees from Dalian Maritime University, China. She is currently an Associate Professor with Dalian Maritime University. Her research interests include data mining and knowledge discovery.

XIANGWEI MU received the B.S. and Ph.D. degrees from Dalian Maritime University, China. He is currently an Associate Professor with Dalian Maritime University. His research interests include data mining and knowledge discovery.