Evolutionary game analysis and regulatory strategies for online group-buying based on system dynamics

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Abstract

The emergence of online group-buying provides a new consumption pattern for consumers in e-commerce era. However, many consumers realize that their own interests sometimes can't be guaranteed in the group-buying market due to the lack of being regulated. This paper aims to develop effective regulation strategies for online group-buying market. To the best of our knowledge, most existing studies assume that three parties in online group-buying market, i.e. the retailer, the group-buying platform and the consumer, are perfectly rational. To better understand the decision process, in this paper, we incorporate the concept of bounded rationality into consideration. Firstly, a three-parties evolutionary game model is established to study each player's game strategy based on bounded rationality. Secondly, the game model is simulated as a whole by adopting system dynamics to analyze its stability. Finally, theoretical analysis and extensive computational experiments are conducted to obtain the managerial insights and regulation strategies for online group-buying market. Our results clearly demonstrate that a suitable bonus-penalty measure can promote the healthy development of online group-buying market.

Keywords: online group-buying; bounded rationality; three-parties evolutionary game; system dynamics; regulatory strategies

1. Introduction

In recent years, people tend to use online shops to meet some of their daily needs, and the prosperous e-commerce and network economy have driven rapid development in emerging business applications and created noteworthy market opportunities that are characterized by the elimination of time and spatial limits (Azadeh et al. 2017; Bharadwaj et al. 2013; Shiau and Luo 2012). The pervasive spread of the high-speed internet has led to a significant spurt in online trading such as group-buying platforms, where consumers leverage social networks to make more efficient and effective purchases (Jiang et al. 2013; Heo 2016). Originated by Mercata.com and Accompany. com in 1999, online group-buying has experienced rapid growth and evolved into a huge ecommerce market (Che et al. 2015). Examples of companies operating with group-buying format are increasing in the USA and well-known examples include Groupon, Eversave, Living Social and Amazon Local. Different from traditional e-commerce, online group-buying is a business model that aggregates the buyers' power, allowing the buyers to obtain lower prices (Kauffman and Wang 2002). With the emergence of online group-buying, it is observed in a variety of product categories, ranging from consumer electronics and furniture to dental services and museum visits (Edelman, Saffe, and Kominers 2016).

Although the popular trend in online group-buying has experienced significant growth for the past few years, many online group-buying practitioners have encountered a decline in customer traffic, and many firms have exited this market (Chen et al. 2015). In the first half of 2011-2015, the turnover continues increasing, while the growth rate is rapidly decreasing in the online group-buying market, which is reduced from 657.1% to 90.8%[1]. Especially, the closure rate of online group-buying platforms is more than 86% in 2014[2]. The reason for this phenomenon is the faultiness of online group-buying market such as the risk of product quality, the lack of regulation and the deception or dishonesty of retailers (Liu and Wang 2013). For example, some retailers try to sell inferior-quality products with lower cost in online group-buying market. Recently the events that violation of consumer rights and interests are repeated emergence in online trade. In 2016, the Alibaba have confirmed and dealt with 4495 false selling cases

[1] http://zixun.tuan800.com/a/tuangoushujubaogao/20150727/50585.html.

[2] http://www.ebrun.com/20140327/94877.shtml.

whose average value is more than 50, 0000 CNY. It not only caused huge property loss, but also has a negative influence on the society. In fact, the group-buying platforms should have responsibility for inspecting the behavior of the retailers ensure that goods bought and sold online are not counterfeit. But many of them may deregulate due to the inspection cost. And the government should develop special laws to inspection online trade (Bahaddad et al. 2015). This leads to a challenging decision problem for online group-buying market about how to deal with retailers' low honesty, group-buying platforms' lax inspection and so on (Wang, Wang, and Liu 2016).

Generally, online group-buying operated by three parties, that is, the retailer, the group-buying platform and the consumer. Traditional game theory can solve the above three-parties game problems to a certain extent. However, it has an important hypothesis on the players are intelligent rational (Liu, Li, and Hassall. 2015). This assumption was inconsistent with the real world because individual rationality was restricted by the available information, cognitive limitations, and time available to make decisions (Szabó and Fáth 2007). Besides, the traditional game theory neglects the dynamic process of game. In reality, game is a long term interaction process which each party can learn to acquire knowledge from the opposite parties to change their strategies. Evolutionary game theory breaks out the limitation through relaxing assumption that each player is boundedly rational, in which each player has some adaptive learning capacity. At present, it has been widely used into different areas such as ecological economy, contemporary economy, environment, urbanization construction, supply chain management, marketing management, regulation policies (Wu, Liu, and Xu 2017; Matveenko, Korolev and Zhdanova 2017; Wang, Cai, and Zeng 2011; Zhang, Bao, and Skitmore 2015; Ji, Ma, and Li 2015; Zhao et al 2016; Chen and Lai, 2016).

The above mentioned development leads to the following questions:

How to establish a three-parties evolutionary game model for online group-buying market?

How does the behavior of three-parties interact with each other in online group-buying market?

How to make effective regulation strategies to promote the healthy development of online group-buying market?

This paper first builds a three-parties evolutionary game based on the replicated dynamic equation, and we analyze each player's game strategy in the evolutionary game model. Next, a system model including retailers, online group-buying platforms and consumers is established to study the interaction. Then a dynamic penalty strategy is introduced in the model. Theoretical analysis and extensive computational experiments are conducted in hope to answer the three questions raised before.

The rest of the paper is organized as follows. Section 2 contains a literature review on the online group-buying and three-parties evolutionary game. The detailed problem description, assumptions and notation are given in Section 3. Then, game model and solution based on system dynamics and stability analysis are carefully studied in Section 4. Section 5 provides Nash equilibrium analysis and effective regulation strategies for online group-buying market. The conclusion is given in Section 6.

2. Literature review

In online group-buying market, there are three stakeholders: the retailer, the group-buying platform and the consumer. (Hu, Shi, and Wu 2013). Different interests and influences of the three stakeholders lead to conflicts of interest. Evolutionary game theory has been widely used as a methodology to explain human interactions based on bounded rationality (Kolokoltsov 2017). Especially, system dynamics is an effective way to better understand how the evolutionary game systems change over time (Duan et al., 2016).

2.1 Online group-buying

Online group-buying unites consumers apart through internet and enhance their bargaining power against sellers in order to make a deal in a lower price. Unlike direct online shopping, online group-buying enables a group of consumers to obtain a special discount (Cheng and Huang 2013; Kauffman and Wang 2002; Van Horn, Gustafsson, and Woodford 2003).

Online group-buying have been extensively studied in the economics literature (Jing and Xie 2011; Hu, Shi, and Wu 2013). In most studies, researchers focus on analyzing “how the group-buying mechanism is attracted for consumers” and “how to maximize profit”. Hence, previous studies of online group-buying are around group-buying models, price discounts and pricing mechanisms (Rezabakhsh et al. 2006). For instance, Anand and Aron (2003) derived the monopolist's optimal group-buying schedule under varying conditions of heterogeneity in the demand regimes. Chen, Chen, and Song (2006) considered the seller's pricing strategy with the group-buying auction. They point out that the best discount rate is zero, which implied the optimal price is equivalent to the optimal fixed pricing mechanism. A two-stage pricing game model was also proposed to evaluate the profitability and efficiency of community-based group buying (Li et al., 2012). Li and Chen (2013) studied retailer's pricing and service decisions by the method of non-cooperative game theory. It demonstrated that retailers' pricing and service decision present the inverse change under asymmetric case for the online group-buying market. Focusing extant literature, these studies fall short of capturing the complexity and unique characteristics such as consumer's perception in the online group-buying market.

Latterly, online group-buying gets considerable attentions from the consumer's perspective. There are a few interesting papers studying this issue. Vaghefi, and Beheshti (2014) explored a pricing model which took into account both consumers' and sellers' satisfaction based on waiting-time in a group-buying auction market. Kauffman, Lai, and Lin (2010) used an experiment indicating that textual comments affected a consumer's trust in the group- buying. Tsai, Cheng, and Chen (2011) found that trust is determinants of online group-buying intention in the virtual community. Erdoğmus and Çiçek. (2011) analyzed the online group-buying system in Turkey and the results indicated that consumers hate the discriminatory and dishonest behavior of the service provider. This is difficult for the group-buying trade. Consumer's trust in online group-buying platforms has positive influences on perceived quality of platforms and satisfaction in addition to the proper pricing (Hsu et al. 2014). These papers show us that consumer's trust is very important to improve consumer stickiness for online group-buying market. Therefore, the issues that how to make consumers trust and choose the group-buying platforms is essential in online group-buying market.

It should be noted that some existing literature studies consumer's trust on online group-buying often focus on the benefits received by consumers and do not consider the retailer's response to online group-buying (Zhou and Xie 2014; Dana Jr 2009). Although some literature stands on retailers' perspective to analyze the online-group buying market, they only consider how to set suitable price mechanism to attract consumers. In reality, consumers' stickiness has a positive relationship with the behavior of retailers' honesty. However, all these studies do not consider how to improve retailer's honesty and strengthen the inspection of retailers. Moreover, these studies only focus on the interaction between retailers and consumers, ignoring the interaction among all parties, in which the online group-buying platform's inspection imposed on retailers is an important aspect.

2.2 Three-parties evolutionary game

Traditional game theory is based on many assumptions. One key assumption is that players are perfectly rational, and we have a common knowledge of this rationality inconsistent with the facts (Samuelson 2002; Shubik, 2002). Evolutionary game theory is proposed to overcome the hypothesis of perfect rationality in a game model (Zhao et al., 2016). As a kind of evolutionary games, three-parties evolutionary game is more complex. At present, three-parties evolutionary game has been used in the extensive areas, especially for supply chain research. Based on the direction, Tian, Govindan, Zhu (2014) studied green supply chain management, and they showed that the subsidies for manufacturers are better than that for consumers to promote green supply chain management diffusion in China. Wang (2015) analyzed the dynamic game relationship among the government, enterprise and society under the incomplete information condition. The authors concluded the optimal strategy of three-parties and provided suggestions on the issue of corporate social responsibility. Liu, Li, and Hassall (2015) explored the penalties of Chinese coal mining safety inspection system, and the results indicated that the dynamic penalties can effectively restrain the fluctuations and make stakeholder interactions more stable. Generally speaking, these papers generally build evolutionary game model and conclude the dynamic equilibrium solution. And via analyzing the interaction among parameters, they can finally provide some suggestions.

Also, some scholars employed game theory to study the group-buying. Yao, Li, and Wang (2010) focused on the trust issue of group-buying and built a group-buying game model. Ni et al (2014) established three group-buying game structures by considering different market power between the platforms and the sellers. In fact, each player is boundedly rational. Additionally, each player learns each other and changes strategy depending on the process of long-term interaction in the online group-buying market.

Yet, there has been little work incorporating bounded rationality into group-buying market. And rare attention is paid to study group-buying issues with evolutionary game. Recently, Zhan and Xie (2014) established the evolutionary game model of information service between group-buying platforms and users based on evolutionary game theory, and provided beneficial scientific guidance for the improvement of information service quality of group buying websites. Nevertheless, this paper only considered two parties including group-buying websites and consumers neglecting the retailers. Thus, our work differs from these contributions in that we take three-parties into account in the online group-buying market.

The literature shows that there exists a good potential to bridge the two streams of research discussed in this section. It would be more realistic and challenging to closely examine regulatory strategies in the online group-buying market with boundedly rational players based on a three-parties evolutionary game. According to evolutionary game theory and system dynamic theory, this paper figures out optimal equilibrium solutions in the group-buying market. And it also provides constructive suggestions for the healthy development of online group-buying market.

3. Evolutionary game description and design

We study the problem faced by retailers who intend to sell products/services through the online group-buying platform. Taking into account the behavior of bounded rationality, evolutionary game theory is employed to study the long-term dynamic game with boundedly rational players in online group-buying market.

3.1 Game description

There are three principal parties played by actors in online group buying market, that are, retailers, group buying platforms, and consumers. For retailers, there are two kinds of strategies. One is the honest marketing strategy which means product price matching its quality (call "honesty" strategy in brief). Another one is the fraudulent marketing strategy representing a great difference between in actual quality and its description on website (call "dishonesty" strategy in brief) (Sebastian Heese and Kemahlıoğlu-Ziya 2016; Ketron 2016; Bo 2015). Let x, where $0\leq x \leq 1$, represents the proportion of the retailers that choose the strategy "honesty" among all retailers.

The group-buying platform acts as an online intermediary between the retailers and the consumers, and enables retailers selling products/services to consumers at a lower group-buying price. However, due to the particularity of the Internet, there are many fake products and information in the online transactions. The defective products sold by retailers may result the increasing of dissatisfaction, and it also decreases the amount of consumers visiting on the group-buying platform. Therefore, it is necessary to inspect the retailers for online-group buying platforms. The decisions about the inspection strategy have cost implications. The real-time inspection cost is high, so limited inspection time is practical. Hence, there are two kinds of strategies for online group-buying platforms. One is strict execution of real-time inspection (call "inspection" strategy in brief). Another one is not inspection on retailers (call "no-inspection" strategy in brief). Let y where $0\leq y \leq 1$, represents the proportion of the online group-buying platforms that choose the strategy "inspection" among all group-buying platforms.

Consumers have two strategies. There are "buying" or "not-buying" through the online group-buying platforms respectively (call "buying" strategy and "not-buying" strategy in brief). Let z, where $0\leq z \leq 1$, represent the proportion of the consumers that choose the strategy "buying" among all consumers.

For the sake of convenience, some assumptions for the game are given below.

(1) Each player is boundedly rational to decide whether to change their strategies, and they are all self-interest when entering the system.

(2) In online-group buying market, each player always adjusts game behavior in the long-term equilibrium. That is to say, they have a limited ability to know the complete information, and learning is a necessary process to enrich their knowledge.

(3) Consumers report complaints to the government when group-buying platforms can't make sure consumer's interest, then the government punishes group-buying platforms and urges them to be rectified.

(4) For government, the social stability benefits of retailer honest operation are far greater than the government's income from penalties.

3.2 Game design

According to game description on retailers, group-buying platforms and consumers, the game strategies and parameters are as shown in Table 1.

Table 1. Game parameters setting and meanings.

Variables	Meaning of the variables	Constraints
C_1	Fixed cost of retailers choosing "honesty" strategy	$C_1 > 0$
C_2	Variable cost of retailers choosing "honesty" strategy	$C_2 > 0$
C_3	Fixed cost of retailers choosing "dishonesty" strategy	$C_1 > C_3 > 0$
C_4	Variable cost of retailers choosing "dishonesty" strategy	$C_2 > C_4 > 0$
R	Selling price	$R > 0$
C_0	Inspection cost of group-buying platforms	$C_0 > 0$
F_0	Royalty fee extracted by the platforms from the retailers	$F_0 > 0$
P_1	Penalties of dishonest retailers imposed by group-buying platforms	$P_1 > 0$
P_2	Adjustment cost of group-buying platforms with "no- inspection"	$P_2 > 0$
F_1	Rewards of honest retailers provided by group-buying platforms	$F_1 > 0$
π_1	Net value of consumers choosing honest retailers	$\pi_1 > 0$
$-\pi_2$	Net value of consumers choosing dishonest retailers	$\pi_2 > 0$
π_3	Penalties of group-buying platforms charged by government due to be reported by consumers	$\pi_3 > 0$
x	Proportion of retailers choosing "honesty" strategy	$1 \geq x \geq 0$
y	Proportion of group-buying platforms choosing "inspection" strategy	$1 \geq y \geq 0$
z	Proportion of consumers choosing "buying" strategy	$1 \geq z \geq 0$

Noting: the reason that retailers choose strategy "dishonesty" is that the cost of "dishonesty" is lower than cost of "honesty". So, we set this condition $C_1 > C_3$, $C_2 > C_4$.

For retailers:

(1) When consumers choose the strategy "buying", the cost of retailers is fixed and variable cost ($C_1 + C_2$) or ($C_3 + C_4$). Otherwise, there is only the fixed cost.

(2) If retailers choose the strategy "honesty" and group-buying platforms choose the strategy "inspection", retailers will receive the rewards provided by group-buying platforms F_1.

(3) When retailers choose the strategy "dishonesty" and group-buying platforms choose the strategy "inspection", the retailer will be fined penalties imposed by group-buying platforms P_1, however retailers have no penalty cost when the group-buying platforms choose the strategy "no-inspection".

For group-buying platforms:

(1) A royalty fee is charged from the retailers F_0.

(2) There is inspection cost C_0 if group-buying platforms choose the strategy "inspection".

(3) When retailers choose the strategy "dishonesty" and group-buying platforms choose the strategy "no-inspection", group-buying platforms will have penalty cost π_3 and adjustment cost P_2.

(4) If retailers choose the strategy "honesty" and group-buying platforms choose the strategy "no-inspection", consumers will not report it, then the group-buying platforms have no penalty cost.

For Consumers:

There are only two perceived value: choosing honest retailers π_1 or choosing dishonest retailers $-\pi_2$.

The three-parties game payoff matrix in online group-buying market is as shown in Table 2. The payoffs of retailers, group-buying platforms and consumers are arranged in turn in the Table 2.

Table 2. Payoff matrix.

Payoff		Consumer		Payoff	
		Buying	Not-buying		
Retailer	Honesty	$R-C_1-C_2+F_1$, $F_0-F_1-C_0$, π_1	F_1-C_1, $F_0-F_1-C_0$, 0	Inspection	Group-buying platform
	Dishonesty	$R-C_3-C_4-P_1$, $F_0-C_0+P_1$, $-\pi_2$	$-P_1-C_3$, $F_0-C_0+P_1$, 0		
	Honesty	$R-C_1-C_2$, F_0, π_1	$-C_1$, F_0, 0	No-inspection	
	Dishonesty	$R-C_3-C_4$, $F_0-P_2-\pi_3$, $-\pi_2$	$-C_3$ F_0-P_2, 0		

4. Evolutionary game model and solution

According to the evolutionary game theory, replicator dynamic equation is used to represent the learning and evolution mechanism of individuals in the process of online group-buying market (Liu et al. 2015).

4.1 The retailer's game

The expected payoff when the retailers choose "honesty" is set as E_x, the average expected payoff of the retailers is set as $\overline{E}$, and the expected payoff of the retailers choosing "dishonesty" is E_{1-x}. So the expressions are as follows

$$\begin{aligned} E_x &= y[(R-C_1-C_2+F_1)z+(F_1-C_1)(1-z)]+(1-y)[(R-C_1-C_2)z+(-C_1)(1-z)] \\ &= F_1 y+(R-C_2)z-C_1 \end{aligned} \tag{1}$$

$$\begin{aligned} E_{1-x} &= y[(R-C_3-C_4-P_1)z+(-P_1-C_3)(1-z)]+(1-y)[(R-C_3-C_4)z+(-C_3)(1-z)] \\ &= -P_1 y+\left(R-C_4\right)z-C_3 \end{aligned} \tag{2}$$

$$\overline{E} = xE_x+\left(1-x\right)E_{1-x} \tag{3}$$

According to the replicator dynamics equations, the change rate of x is

$$dx/dt = x\left(E_x-\overline{E}\right) = x\left(1-x\right)\left(E_x-E_{1-x}\right) \tag{4}$$

Make $f\left(x\right)=dx/dt$, the replicator dynamics equation (Smith 1982) of choosing "honesty" strategy for retailers can be expressed as

$$\begin{aligned} f\left(x\right) &= dx/dt = x\left(E_x-\overline{E}\right) \\ &= x\left(1-x\right)\left(E_x-E_{1-x}\right) = x\left(1-x\right)\left(F_1 y-C_2 z-C_1+P_1 y+C_4 z+C_3\right) \end{aligned} \tag{5}$$

(1) When $F_1 y-C_2 z-C_1+P_1 y+C_4 z+C_3=0$, namely $f\left(x\right)=0$,we have z = $z_0=[\Delta C_{31}+y(P_1+F_1)]/\Delta C_{24}$, where $\Delta C_{31}=C_3-C_1$, $\Delta C_{24}=C_2-C_4$, so the above replicator dynamic equation is equal to zero, which means that all levels x is in steady state.

(2) When $z\neq z_0$, we set that the function $f\left(x\right)$ is to zero. Then we can get x=0 and x=1. The derivative of the function $f\left(x\right)$ is

$$f'\left(x\right) = (1-2x)\left(F_1 y-C_2 z-C_1+P_1 y+C_4 z+C_3\right) \tag{6}$$

There are two situations to further analyze. The first situation is that if $z > z_0$, then $f'(x = 1) > 0$ and $f'(x = 0) < 0$. According to the principle of evolutionary game theory, x^*=0 is the evolutionarily stable strategy (Nash 1950). In this situation, retailers will choose "dishonesty" strategy. Also, there is another situation that if $z < z_0$, the $f'(x=1) < 0$ and $f'(x=0) > 0$. So x^*=1 is the strategy, and retailers will choose "honesty" strategy.

4.2 The group-buying platform's game

Similarly, the expected payoff when the online group-buying platforms choose "inspection" is set as E_y, and the expected payoff of "no-inspection" is $E_{1\text{-}y}$.

$$\begin{aligned} E_y &= x[(F_0-F_1-C_0)z+(F_0-F_1-C_0)(1-z)]+(1-x)[(F_0-C_0+P_1)z+(F_0-C_0+P_1)(1-z)] \\ &= F_0-C_0+P_1-(F_1+P_1)x \end{aligned} \tag{7}$$

$$\begin{aligned} E_{1\text{-}y} &= x[F_0z+F_0(1-z)]+(1-x)[(F_0-P_2-\pi_3)z+(F_0-P_2)(1-z)] \\ &= F_0-P_2-\pi_3z+(P_2+\pi_3z)x \end{aligned} \tag{8}$$

The replicator dynamics equations of choosing "inspection" strategy for online group-buying platforms is

$$\begin{aligned} f(y) &= dy/dt = y(1-y)\left(E_y-E_{1-y}\right) \\ &= y(1-y)[-C_0+P_1-(F_1+P_1)x+P_2+\pi_3z-(P_2+\pi_3z)x] \end{aligned} \tag{9}$$

(1) When $x=x_0=(P_1+P_2+\pi_3z-C_0)/(P_1+P_2+\pi_3z+F_1)$, we have $f(y) = 0$, all levels y is in steady state.

(2) When $x \neq x_0$, we make $f(y) = 0$. Then y=0 and y=1. The derivative of the function $f(y)$ is

$$f'\left(y\right)=(1-2y)[-C_0+P_1-(F_1+P_1)x+P_2+\pi_3z-(P_2+\pi_3z)x] \tag{10}$$

If $x > x_0$, we have $f'(y=1) > 0$ and $f'(y=0) < 0$, So y^*=0 is the evolutionarily stable strategy. Group-buying platforms will choose "no-inspection" strategy. If $x < x_0$, the $f'(y=1) < 0$ and $f'(y=0) > 0$. Hence, $y^* = 1$ is the strategy, and group-buying platforms will choose "inspection" strategy.

4.3 The consumer's game

The expected payoff when the consumers choose "buying" is E_Z and "not-buying" is $E_{1\text{-}z}$. So the two expressions are

$$E_z = x[(\pi_1y+\pi_1(1-y)]+(1-x)[(-\pi_2)y+(-\pi_2)(1-y)]=(\pi_1+\pi_2)x-\pi_2 \tag{11}$$

$$E_{1-z}=x[0\cdot y+0\cdot(1-y)]+(1-x)[(0\cdot y+0\cdot(1-y)]=0 \tag{12}$$

The replicator dynamics equations of choosing "buying" strategy for consumers is

$$f(z)=dz/dt=z(1-z)[(\pi_1+\pi_2)x-\pi_2] \tag{13}$$

(1) When $x=\pi_2/(\pi_1+\pi_2)$, we have $f(z)=0$. All levels z is in steady state.

(2) When $x\neq\pi_2/(\pi_1+\pi_2)$, make $f(z)=0$, then $z=0$ and $z=1$. The derivative of the function $f(z)$ is

$$f'(z)=(1-2z)[(\pi_1+\pi_2)x-\pi_2] \tag{14}$$

If $x<\pi_2/(\pi_1+\pi_2)$, we have $f'(z=1)>0$ and $f'(z=0)<0$, then $z^*=0$ is the evolutionarily stable strategy and the consumers will choose "not-buying" strategy. If $x>\pi_2/(\pi_1+\pi_2)$, then $f'(z=1)<0$ and $f'(z=0)>0$. It can be seen that $z^*=1$ is the strategy, consumers will choose "buying" strategy.

4.4 Game analysis based on system dynamics

When the replicator dynamics equations of three parties are all equal to zero, it shows that the speed of strategy adjustment is zero and the evolutionary game system reaches a relatively stable equilibrium state. The stability of equilibrium solution can be obtained by analyzing the Jacobian matrix's determinant and trace of the game, which reflects the existence of the evolutionary stable strategy. However, it is difficult to analyze the Jacobian matrix's determinant and trace in the three-parties system. Therefore, we adopt the system dynamics to study the stability of the equilibrium solution (Liu et al. 2015; Wu, Guo, and Yu 2013; Gan and Gao 2012).

As a result, the population dynamic of the evolutionary game in online group-buying market can be represented by replicated dynamic equation set as follows.

$$\begin{cases} f(x)=\dfrac{dx}{dt}=x(1-x)\left(F_1y-C_2z-C_1+P_1y+C_4z+C_3\right) \\ f(y)=\dfrac{dy}{dt}=y(1-y)[-C_0+P_1-(F_1+P_1)x+P_2+\pi_3z-(P_2+\pi_3z)x] \\ f(z)=\dfrac{dz}{dt}=z(1-z)[(\pi_1+\pi_2)x-\pi_2] \end{cases} \tag{15}$$

Now, we set the conditions that these equations are equal to zero, then get 10 equilibrium solutions in system is as follows $X_1 \sim X_{10}$

$$X_1=(0,0,0),\, X_2=(1,0,0),\, X_3=(1,1,1),\, X_4=(1,0,1),\, X_5=(1,1,0),$$

$$X_6=(0,1,1),\, X_7=(0,1,0),\, X_8=(0,0,1),\, X_9=\left(\frac{\pi_2}{\pi_1+\pi_2},1,\frac{C_1-C_3-F_1-P_1}{C_4\text{-}C_2}\right)$$

$$X_{10}=\left(\begin{array}{l}\dfrac{\pi_2}{\pi_1+\pi_2},\left[\dfrac{\pi_1\pi_3(C_1-C_3)+(C_2-C_4)\left[\pi_1(C_0-P_1-P_2)+\pi_2(C_0+F_1)\right]}{\pi_1\pi_3(F_1+P_1)}\right],\\ \dfrac{\pi_1(C_0-P_1-P_2)+\pi_2(C_0+F_1)}{\pi_1\pi_3}\end{array}\right)$$

However, whether equilibrium solutions are steady or not, it is essential to introduce into system dynamic for simulation. System dynamics take a variety of system factors as well as the causality among the factors as the basis for its modeling, and reflects the dynamic behaviors of the system through these causal relationships (Tesfamariam and Lindberg 2005).

Therefore, by using Vensim PLE, the evolutionary game SD model is established, as shown in Figure 1. The functional relationship among state variables, rate variables and intermediate variables relying on the above replicated dynamic equations in the online group-buying market game system, namely (15).

The model conditions are as follows:

(1) The game players' strategy choice is learning process, and not a sudden change.

(2) The value of "Proportion of retailers choosing 'honesty' strategy", "Proportion of group-buying platforms choosing 'inspection' strategy" and "Proportion of consumers choosing 'buying' strategy" are influenced by the factors in the models, and not by other external factors.

(3) The models do not consider the influence of technological progress.

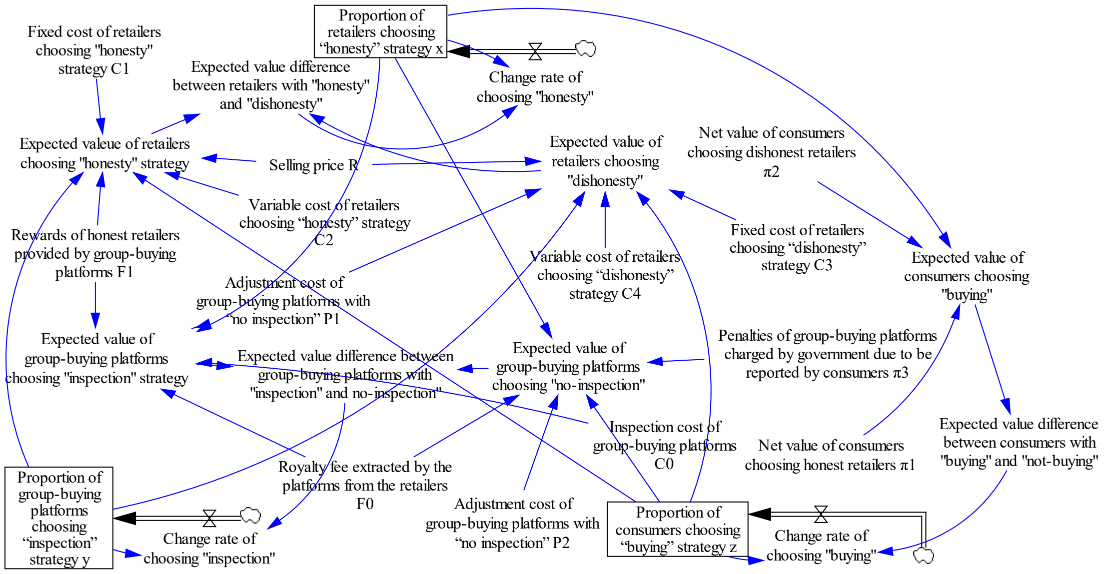

Figure 1. Evolutionary game SD model.

The system dynamic model consists of 3 state variables, 3 rate variables, 6 intermediate variables and 13 external variables. Arrows mean the correlation between variables. Three state variables represent "Proportion of retailers choosing 'honesty' strategy *x*", "Proportion of group-buying platforms choosing 'inspection' strategy y" and "Proportion of consumers choosing 'buying' strategy *z*" respectively. And the three rate variables represent "Change rate of choosing 'honesty' strategy", "Change rate of choosing 'inspection' strategy" and "Change rate choosing 'buying' strategy". Six intermediate variables are "Expected value of retailers choosing 'honesty' strategy", "Expected value of group-buying platforms choosing 'inspection' strategy", "Expected value of consumers choosing 'buying' strategy", "Expected value difference between retailers with 'honesty' and 'dishonesty'", "Expected value difference between group-buying platforms with 'inspection' and 'no-inspection'" and "Expected value difference between consumers with 'buying' and 'not-buying'". The initial values of external variables are shown in Table 3.

Table 3. The initial values of external variables in SD model.

Variables	Meaning of the variables	Initial values
C_1	Fixed cost of retailers choosing "honesty" strategy	6
C_2	Variable cost of retailers choosing "honesty" strategy	1
C_3	Fixed cost of retailers choosing "dishonesty" strategy	4
C_4	Variable cost of retailers choosing "dishonesty" strategy	0.4
R	Selling price	15

C_0	Inspection cost of group-buying platforms	2
F_0	Royalty fee extracted by the platforms from the retailers	3
P_1	Penalties of dishonest retailers imposed by group-buying platforms	2
P_2	Adjustment cost of group-buying platforms with "no- inspection"	1
F_1	Rewards of honest retailers provided by group-buying platforms	0.5
π_1	Net value of consumers choosing honest retailers	1
$-\pi_2$	Net value of consumers choosing dishonest retailers	−0.5
π_3	Penalties of group-buying platforms charged by government due to be reported by consumers	0.5

Noting: We set these values to sensitivity analysis. And each simulation value doesn't represent the actual value for simplify analyzing.

So the equilibrium solutions are changed as follows.

$$X_1=(0,0,0), X_2=(1,0,0), X_3=(1,1,1), X_4=(1,0,1), X_5=(1,1,0),$$
$$X_6=(0,1,1), X_7=(0,1,0), X_8=(0,0,1), X_9=(1/3,1,5/6),\ X_{10}=(1/3,23/25,1/2)$$

Evolutionary game steady strategy must have the function of the resistance to fluctuations (Friedman, D. 1991). In order to verify the stability of the equilibrium solution, we set the model parameters as: the simulation period is 100, INITIALTIME=0, FINAL TIME=100, TIME STEP=0.25, the main measurement index is the evolution proportion of three-parties games.

Take equilibrium solution X_9, for example, the above evolutionary game SD model was simulated by putting X_9 into the model and then the game result was shown in Figure 2. The simulation results show that the three players do not actively change their initial strategies and no one adopts new strategy, which reflects a relatively balanced state.

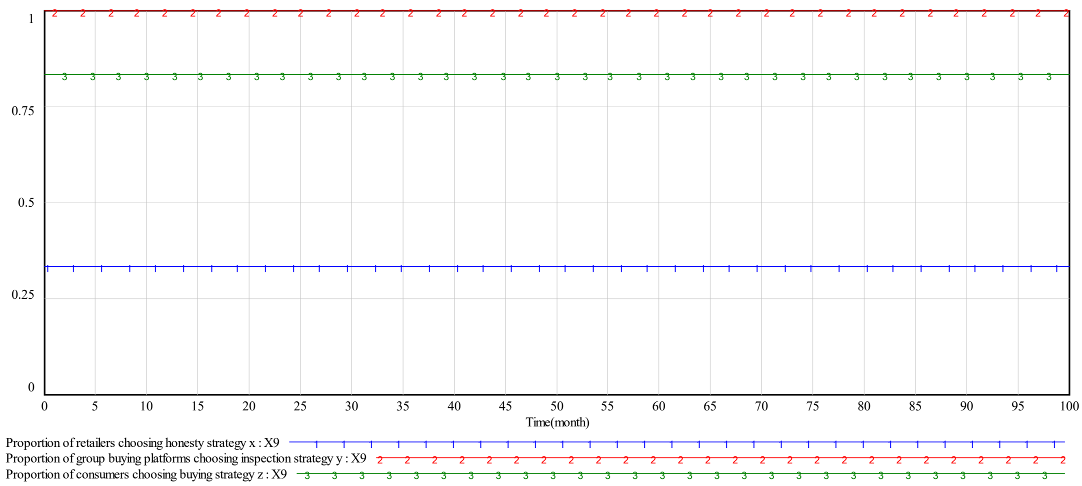

Figure 2. Game results (initial strategy X_9).

However, those relatively balanced states maybe unsteady. Taking X_9 for example, if a very small part of the group-buying platforms mutate their initial strategies, that is, the ratio change from 1 to 0.6, namely (1/3,0.6,5/6), then the game can be simulated again as shown in Figure 3. The simulation results indicate that the balanced states of X_9 are unsteady. Similarly, the balanced states of the other 9 equilibrium solutions are also all unsteady according to the simulation results.

The existing fluctuations make the government's strategies difficult to develop effectively. Therefore, it's necessary to study the effective stability control scenarios on the fluctuations.

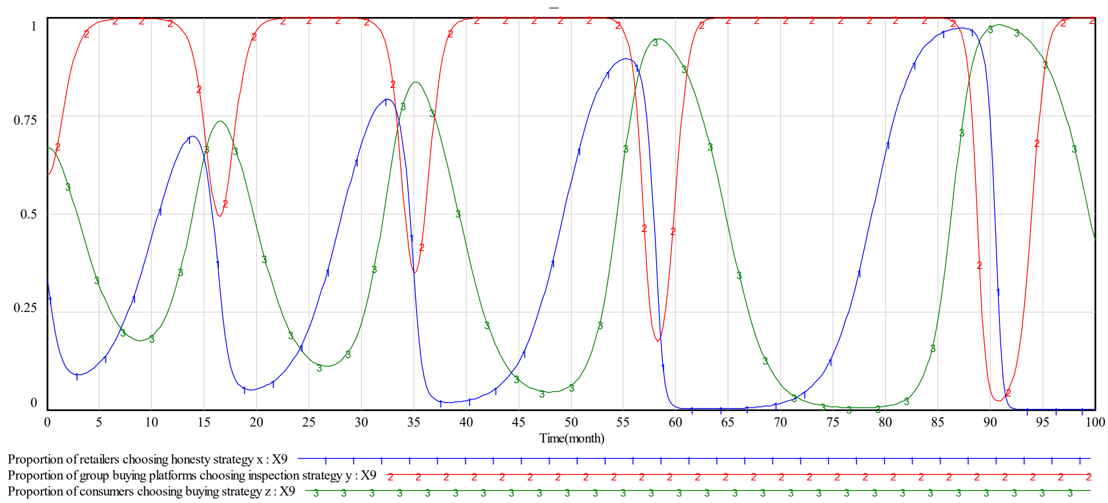

Figure 3. Game results with fluctuations (initial strategy X_9).

4.5 Stability analysis and check under the dynamic penalty control scenario

According to the previous study, the penalties change with proportion of unlawful behavior that can effectively restrain the fluctuations (Wang, Cai, and Zeng 2011). It is necessary to verify whether the dynamic penalty strategy taken by group-buying platforms and the government influences the stability of the game, so we take next steps. The group-buying platforms make penalties dynamically according to the proportion of retailers' "dishonesty" strategy and the government makes penalties dynamically according to the proportion of group-buying platforms' "no-inspection" strategy, which were shown in the following formula

$$P_1' = P_1 \times n_1 \times (1-x), \pi_3' = \pi_3 \times n_2 \times (1-y) \tag{16}$$

Here, n_1 and n_2 represent penalty coefficients of the retailers and group-buying platforms, respectively. If we set $n_1 = n_2 = 1$, then we have

$$P_1^{'} = 2(1-x), \pi_3^{'} = 0.5(1-y) \tag{17}$$

Thus the evolutionary game SD model in Figure 1 is changed into as showed in Figure 4 under the dynamic penalties control scenario. Compared to Figure 1, dynamic penalties $\pi_3{}^{'}$ are correlated to "the proportion of group-buying platforms choosing "inspection" strategy y" and "penalties coefficients n_2" in this SD model.

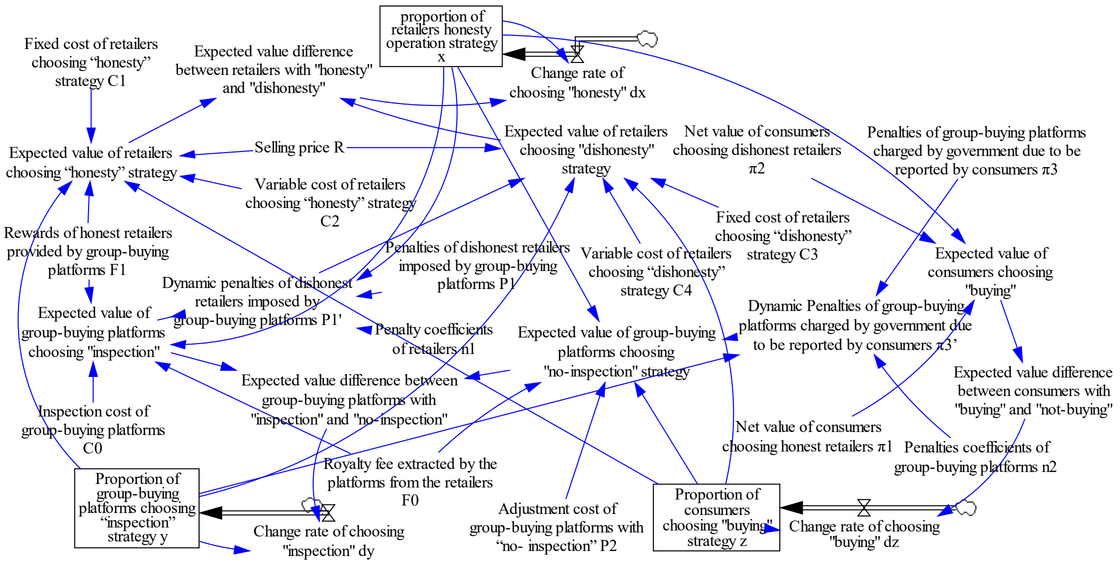

Figure 4. Evolutionary game SD model under the dynamic penalties control scenario.

The initial values of system is Y_1=(x, y, z) = (0.5, 0.5, 0.5), Y_2=(x, y, z) = (0.5, 0.1, 0.2), game results are given in Figure 5 and Figure 6.

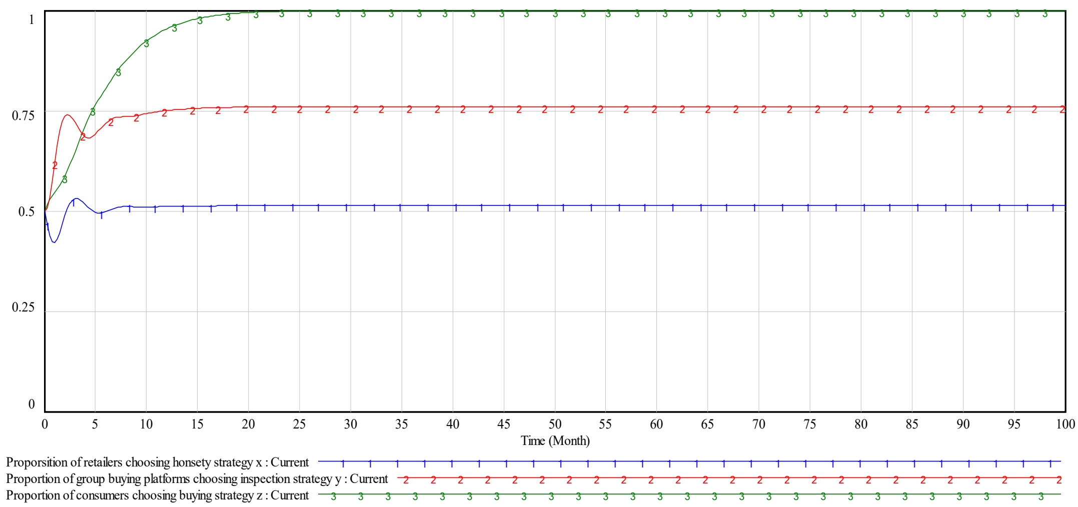

Figure 5. Game results under dynamic penalties control scenario (initial strategy Y_1).

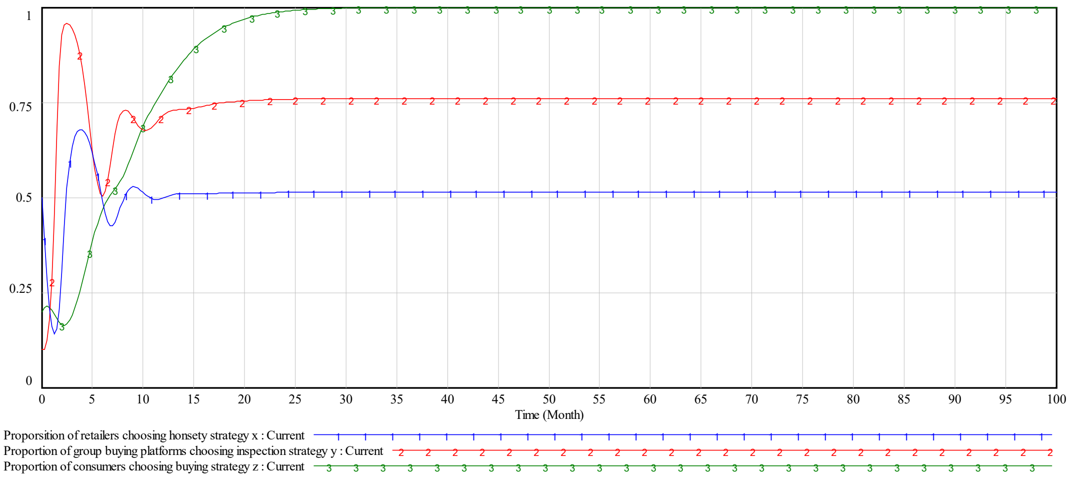

Figure 6. Game results under dynamic penalties control scenario (initial strategy Y_2).

Figure 5 and Figure 6 show that different initial values are stabilized eventually, dynamic penalties can effectively restrain the fluctuations and make the game steady around $y^* = (0.52, 0.77, 1)$, which indicates the evolutionary steady strategy existing under the dynamic penalties control scenario.

If a very small part of the group-buying platforms mutates their initial strategies, that is, the ratio group-buying platforms choosing "inspection" strategy changes from 0.77 to 0.65, namely (0.52,0.65,1), then the game can be simulated again as shown in Figure 7. The simulation results indicate that the balanced states (0.52,0.77,1) are steady and can resist to fluctuations.

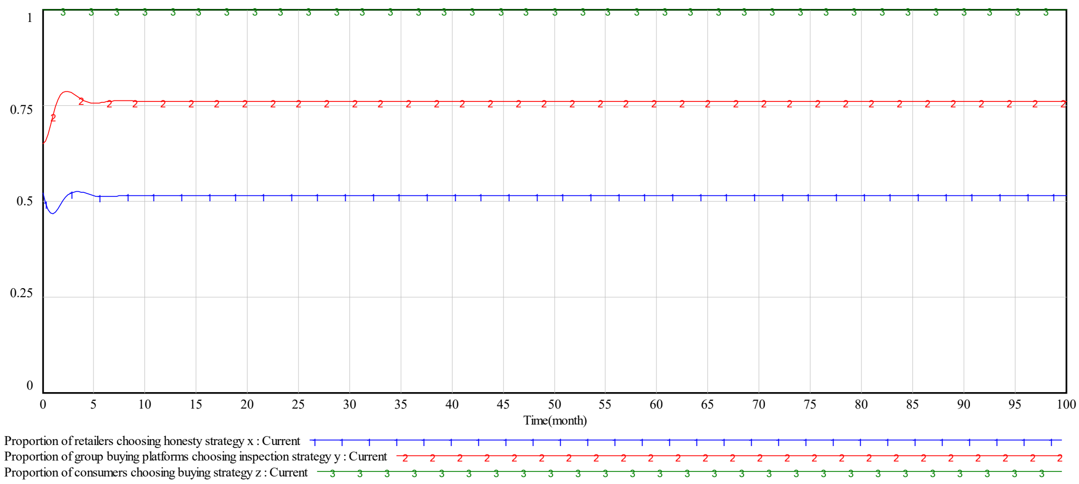

Figure 7. Game results resisting fluctuations (initial strategy (0.52,0.65.1)).

In order to explain clearly the advantages of dynamic penalty strategy, we conducted a comparison of two penalty strategies. Taking the example of consumers' decision, the initial value is set as $(x, y, z) = (0.5, 0.5, 0.5)$. The results of simulation are given in

Figure 8. The proportion of consumers choosing a strategy shows unstable state under the static penalty strategy. While under the dynamic penalty strategy, the proportion of consumers choosing "buying" strategy is a stable state and approximately equal to 1. In the same way, we can conclude that the proportions of retailers choosing "honesty" strategy and online group-buying platforms choosing "buying" strategy are stable at the equilibrium points.

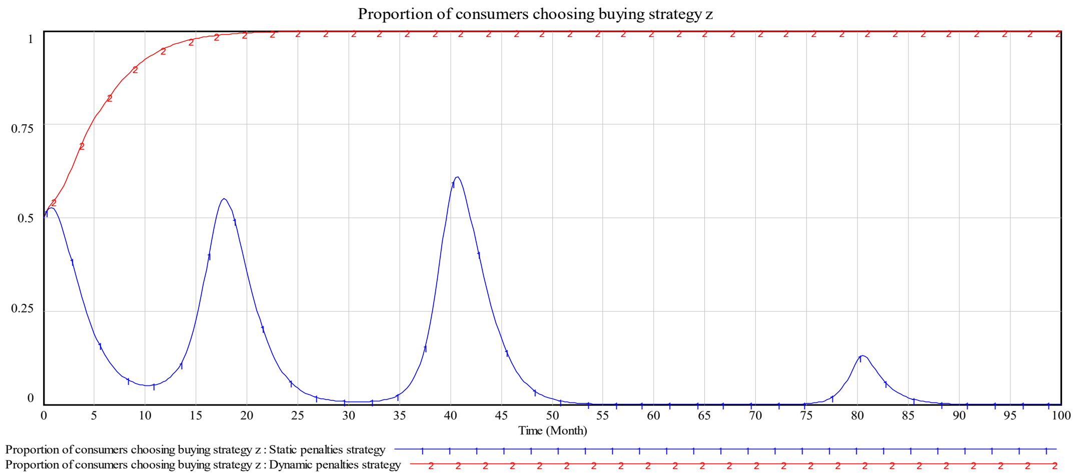

Figure 8. The process comparison under the different penalty strategies.

5. Nash equilibrium analysis and discussion

In this section, we will analyze the equilibrium of the proposed three-parties evolution game model that may influence the online group-buying market.

5.1 Nash equilibrium analysis

5.1.1 Retailers' Nash equilibrium solution

We focus on analyzing the dynamic trend and the stability. From the above results, we can know that when the proportion of consumers choosing "buying" strategy is less than z_0, the best strategy of retailers is "honesty". Vice versa.

It can be seen that z_0 increase with the increase in ΔC_{31}, P_1, F_1. Specifically, ΔC_{31} denotes the difference of the fixed cost between retailers with "dishonesty" and "honesty" strategy. The higher ΔC_{31}, the more likely retailers will choose the "honesty" strategy, and the "buying" strategy of consumers will increase. It will form a healthy online group-buying environment. The same is true for the difference of variable cost ΔC_{24}. As the enhancement of penalties for dishonest retailers (P_1), retailers will gradually draw to "honesty" strategy to avoid more penalties. In the same way, more and more retailers choose the “honesty” strategy with the improving rewards for honest retailer ($F1$).

5.1.2 Group-buying platforms' Nash equilibrium solution

When the proportion of retailers choosing “honesty” strategy is less than x_0, the best strategy of group-buying platforms is to strengthen inspection to reduce the number of dishonest retailers in the market. Vice versa.

For the function:

$x_0 = (P_1 + P_2 + \pi_3 z - C_0)/(P_1 + P_2 + \pi_3 z + F_1) = 1/(1 + (C_0 + F_1)/(P_1 + P_2 + \pi_3 z - C_0))$

Obviously, we can get that the enhancement of P_2, π_3, causes an increase in x_0. However, x_0 decreases with the increase in C_0, F_1. Specifically, the group-buying platforms will pay a lager cost for their “no-inspection” behavior with the enhancement of P_2. Similarly, as the penalties of “no-inspection” π_3 enhances, group-buying platforms will have a tendency to improve strength of inspection to reduce the cost. Also when C_0 decreases, it shows that the group-buying platform’s inspection cost decreases, group-buying platforms will have a tendency to inspect the retailers.

5.1.3 Consumers' Nash equilibrium solution

When the proportion of retailers choosing “honesty” strategy is less than $\pi_2 / (\pi_1 + \pi_2)$, the best strategy of consumers is “not-buying”. Vice versa.

In the function $\pi_2 / (\pi_1 + \pi_2) = (1 / (1 + \pi_1 / \pi_2))$, $\pi_2 / (\pi_1 + \pi_2)$ increases with π_1 (or π_2) decreasing (or increasing). The increase in π_1 represents raise in net value of consumers choosing honest retailers. It also means there will be more consumers to buy the honest retailers' products. And the increase in π_2 shows that reduction in net value of consumers choosing dishonest retailers (the negative net value increases). So consumers will tend to choose “no-buying” strategy.

5.1.4 Dynamic penalty strategy

Dynamic penalty strategy is an important inspection measure for the government and group-buying platforms. Comparing with the static penalty strategy, the dynamic penalty strategy can effectively restrain the fluctuations and make the three-parties game steady. As previously mentioned, the dynamic penalties imposed by group-buying platforms is positively relevant to the proportion of retailers with “dishonesty” strategy. In other words, the penalties P'_1 is increasing in the proportion of dishonest retailers (1－

x). According to the figure 6 and figure 7, the proportion of retailers choosing "honesty" strategy is 52% under the dynamic penalty strategy, which increase by 20% in comparison with the static penalty strategy. Similarly, the dynamic penalties π'_3 increases with the increase in the proportion of derelict group-buying platforms ($1-y$). Furthermore, this method allows to perform market analysis in the proportion of unlawful behavior, which leads to more practically efficient strategy for online group-buying market inspection.

5.2 Results Discussion and Managerial Insights

According to the above results of the simulation and analysis, we discuss the regulatory strategies for online group-buying as follows.

From the perspective of the online group-buying platforms, three suggestions or managerial insights are provided.

(1) Strengthen the penalties for the dishonest retailers. Dishonest retailers not only damage consumers' benefit, and they also bring some negative effects on the group-buying platforms. Through strengthening penalties $P_1\uparrow$, retailers will choose the "honesty" strategy to avoid expensive penalties i.e. $x\rightarrow1$. The net value of consumers will increase $\pi_1\uparrow$. With the improvement of consumer's trust for group-buying, consumers will purchase products i.e. $z\rightarrow1$, it is beneficial to the development of group-buying market.

(2) Improve the rewards for the honest retailers. When the rewards of honest retailers increase $F_1\uparrow$, retailers will choose the "honesty" strategy to gain more revenues, so consumers can enjoy a good quality $\pi_1\uparrow$. More and more consumers will choose and trust group-buying platforms i.e. $z\rightarrow1$.

(3) Adopt a dynamic penalty strategy. In the current group-buying market, the common practice is to use static penalties P_1 for inspecting retailers. The single and static penalties lack some flexibility in competitive and complex markets. Also, the dynamic penalty strategy can effectively restrain the fluctuations and make the three-parties game steady in comparison with static penalty strategy. Therefore, group-buying platforms should take a flexible penalties strategy P'_1 to effectively inspect retailers, i.e. $x\rightarrow1$.

From the perspective of government, two suggestions or managerial insights are provided.

(1) Strengthen the penalties on the group-buying platforms. The corresponding measures should be taken to regulate the market of online group-buying. Government should strength penalties of group-buying platforms π_3↑. This will make group-buying platforms realize that their non-inspection cost is larger than inspection cost $\pi_3 + P_2 > C_0 + F_1$. In order to avoid the penalties π_3↑ and adjusting cost P_2↑, group-buying platform will choose inspection on retailers, i.e. $y \rightarrow 1$.

(2) Adopt a dynamic penalties strategy. Similarly, the dynamic penalty strategy can effectively restrain the fluctuations of online group-buying platforms choosing "inspection" strategy and make the proportion around 75%. It is beneficial for the government to execute pointed strategy. The government should take a flexible penalties strategy π'_3 to effectively inspect group-buying platforms, i.e. $y \rightarrow 1$.

6. Conclusions

Online group-buying market is a new developing field of study, and it is a crucial consideration for the government plagued by the risk of product quality issues and dishonest operation of retailers. In order to solve these issues, effective regulation becomes very important for online group-buying market.

This study employs evolutionary game theory and system dynamics to build the three-parties evolutionary game models in online group-buying market. For the baseline study, we first analyze each player's game strategy in each of the evolutionary game model, and conclude the influencing factors and equilibrium solutions. Then we present a system model including retailers, online group-buying platforms and consumers to study the interaction, the game model is simulated by adopting system dynamics to analyze its equilibrium solution and stability. Nash equilibrium and results are also discussed in this study. Finally, we introduce a dynamic penalties strategy which can effectively inspect the group-buying platforms' and retailers' behavior. Moreover, we summarize a suitable bonus-penalty measure for online group-buying market.

We believe there are three important contributions of our work. First, it is a relatively new of introducing the bounded rationality assumption into the inspection study of online group-buying market. Second, we propose a system analysis of retailers, online group-buying platforms and consumers by using system dynamics. And we studied the stability of the equilibrium solution. Third, the managerial insight obtained supports that dynamic penalty strategy to effectively inspect online group-buying platforms and retailers.

Although a comprehensive study is conducted in this paper, there are still two limitations. The first one is that our study puts more consideration to the influence of three players, and the horizontal competition among enterprises such as the competition in online group-buying platforms or competition in retailers are not involved in the model. Another limitation is that the system does not incorporate the government into the consideration. We mainly focus on the government implements policy according to the behavior characteristics of the three players. When considering government as a player, a dynamic model of four-parties evolutionary game among retailers, group-buying platforms, consumers and the government may be established.

Future extensions of this research could occur along several directions. First, an interesting direction to consider the government into the game model, namely four-parties evolutionary game. Focus on bounded rationality of the players, studies should be conducted on examining government's effect in the online group-buying market. Furthermore, it is necessary to take some behavior factors into the model, for instance, fairness concern, to analyze the decision process of online group-buying market. Third, this research can be extended to other management work for inspection control.

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