Platform Incentives and Willingness of Participant for Investment on Livestreaming E-commerce Model

Computer-aided simulated analysis based on evolutionary game

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***Abstract*—Computer simulation is a common research method in the field of evolutionary game. This paper introduce a selection on the strategy of both buyers and sellers for participating in livestreaming e-commerce model by aiming at the current development of livestreaming e-commerce. We study the platform's third-party incentive mechanism to construct the buyers-sellers evolutionary game model by aiming at the hypothesis of bounded rationality. To slove the evolutionarily stable strategy by the stability principle, we figure out the systematic stable development conditions by the quantitative language, and conduct the numerical simulation for the evolutionarily stable strategy under different parameters by the Matlab. As what it was shown by the results: buyers and consumer's concern and investment on online livestreaming shopping form are closely related to its yield rate, cost, and interest acquired from "free riding"; Platform incentive has significant positive impact on the investment willingness of both game parties.As the gaining rate of investment income increases gradually, both game parties' probability of selecting concern and investment is increasing accordingly and many evolutionary stable strategies may emerge.**

Keywords-Computer Simulation;Livestreaming E-Commerce; Evolutionary Game; Computer-aided Simulated Analysis

I. INTRODUCTION

In the context of co-action arising from the constant improvement of e-commerce construction, gradual diversification of network marketing means and popularization of plenty of social media platforms, the e-commerce livestreaming industry emerges as the times require[1]. The vast consumption market is the premise of flourishing e-commerce. By 2020, there were 988.99 million netizens and 617.00 million live streaming users in China[2]. From the first mobile live streaming shopping app Developed by Livby in USA to the live streaming business started by the e-commerce tycoon Amazon[3,4], the e-commerce in the world is realizing an active industrial leap and tending to a good prospect. Such leap is mainly originated from more interactivity, visuality and authenticity than that of traditional e-commerce[5]. This characteristic makes the correlation between consumers and platforms enhanced hugely. M. Hu, S. S. Chaudhry(2020) reckons that the improvement in the participation degree of consumers in e-commerce livestreaming can affect the purposive buying behavior of consumers and thereby establish their consumers loyalty[6]. For example, consumers may understand the details of merchandise by watching livestreaming without going outside, and may enjoy the price discount of livestreaming[7]; again, vendors, by virtue of the livestreaming platform and the anchor, can divert sales, expand marketing modes, promote revenue to grow, optimize buyers' experience and promote product premium and make all parties interested benefit.

This work, from the perspective of evolutionarily stable strategy, analyzes the evolution path and stable strategy of participant's investment behavior, makes the simulated analysis, and finally studies the behavior selection of livestreaming participant, it aims to promote the healthy circulation development of the industry.

II. RESEARCH BACKGROUND

Currently, main researches on e-commerce livestreaming focus only on its basic features, marketing styles, motivation models and existing problems. F. Jiang(2018) reckons that livestreaming embodies the interactivity, visuality and authenticity of online shopping, such feature is helpful to meet the personalized demands of consumers and thereby brings higher sales volume[8]. M. Hu(2017) proposes for the marketing style that the typical livestreaming activity of selling products includes the one that broadcast company uploads the real-time video to show the different angles of product and thereby encourage audiences to buy[9]. Such a marketing style will become the positive incentive of stimulating consumers to join. Existing studies, from the concepts, verify that consumers' participation are jointly triggered by external factors such as consciousness and internal factors such as mood [10].

Simultaneously, existing studies discuss mostly the nash equilibrium point of double subjects in the traditional e-commerce decision, but e-commerce livestreaming needs the collaboration of more subjects, such as vendors, consumers, and livestreaming platforms[11,12]. In the process that all parties interested make a long-term decision for the continuous investment in labor resources, material resources and technology, the nash equilibrium is not assuredly unique. In this work, we explore to acquire the equilibrium point of acquiring the optimal solution in the long-term game and consider simultaneously the impact of third party's incentive

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mechanism, aiming at providing a new research perspective for game decision.

III. Materials and Methods

A. The Building of Theory Model

The evolutionary game theory converts the "participant" into the "game parties" of bounded rationality and achieves balance by continuously adjusting the game strategy, such strategy will be the evolutionarily stable strategy when the function in the balancing process becomes and stays in the steady state[13]. In the trading process of livestreaming e-commerce, buyers and sellers adjust the investment strategy by the cost and benefit brought by the transaction. In this work, the participant in the game process is defined as the sellers adopting the livestreaming sales pattern and the consumers watching the livestreaming and buying the commodity, both of them make their decision based on the hypothesis of bounded rationality.

The strategy defining both game parties is the high-efficiency investment and the low-efficiency investment. The high-efficiency investment refers to the one that both game parties are willing to invest higher cost and transact via livestreaming. The low-efficiency investment refers to the one that both game parties transact via the online livestreaming style without investing economic cost or energy. When one party selects the high-efficiency investment and the other party selects the low-efficiency investment, the party making low-efficiency investment will acquire extra benefit brought by the "free-riding". The solution to be adopted for such phenomenon is: e-commerce's livestreaming platform introduces the incentive mechanism and provides compensation to the participant making high-efficiency investment, but punishes the participant making low-efficiency investment, aiming at pushing both parties to select high-efficiency investment strategy. Livestreaming e-commerce platform usually profits by receiving a given percentage of commission charges and promotion expenses, and attracts more users by incentive mechanisms to exert their transaction, which can bring more potential economic benefits. Based on the analysis hypothesis aforesaid, we show the parameters related to the definition model in Table I.

TABLE I. Parameters Related to The Definition Model

Parameter	Parameter Description
P	Sellers
C	Buyers
C_P	High-Efficiency investment cost of sellers
C_C	High-Efficiency investment cost of buyers
E_P	Low-Efficiency investment benefit of sellers
E_c	Low-Efficiency investment benefit of buyers
AE_P	Sellers free-rider benefit
AE_c	Buyers free-rider benefit
C_{x0}	Buyers input gain coefficient (sellers low-efficient investment)
C_{x1}	Buyers input gain coefficient (sellers high-efficient investment)
P_{y0}	Sellers input gain coefficient (buyers low-efficient investment)
P_{y1}	Sellers input gain coefficient (buyers high-efficient investment)

B. Benefit Analysis and Payoff Matrix

In the beginning time when the livestreaming e-commerce model emerges, both buyers and sellers are cautious, and are inclined to select the low-efficiency investment. In this process, both parties can acquire certain benefits and thereby improve their investment willingness. When buyers select high-efficiency investment and sellers do not increase his/her investment, but user's size enlarges and their time to stay online increases, the benefits of buyers at the time may be defined as $(1+C_{x0})E_c$-C_C. The sellers form the "free-riding effect", the benefit therefrom is A_{EP}. When sellers select high-efficiency investment and buyers do not increase their investment, but sellers enlarge their marketing and promotion scale, the benefit therefrom can be defined as $(1+P_{y0})E_p$-C_p. The buyers form the "free-riding effect", the benefit therefrom is AE_c. When both parties select high-efficiency investment, buyers and sellers may acquire higher benefits. At the time, buyers's benefit is $(1+C_{x1})E_c$-C_C, and sellers's benefit is $(1+P_{y1})E_p$-C_p. See Table II for the payoff matrix of both game parties.

TABLE II. Payoff Matrix

C	P	
	High-Efficiency	***Low-Efficiency***
High-Efficiency	$(1+C_{x1})E_c$-C_C, $(1+P_{y1})E_p$-C_p	$(1+C_{x0})E_c$-C_C, AE_P
Low-Efficiency	AE_c, $(1+P_{y0})E_p$-C_p	E_c, E_p

C. Equilibrium Points of Evolution Model

According to the hypothesis of evolutionary game model, some of buyers and sellers may select high-efficiency investment or low-efficiency investment. Hypothesizing the proportion of buyers selecting low-efficiency investment as X, the proportion of buyers selecting high-efficiency investment as 1-X. Hypothesizing the proportion of sellers selecting low-efficiency investment as Y, the proportion of sellers selecting high-efficiency investment as 1-Y. Define the expected revenue R_{1H}, R_{1L} and average expected revenue R_1 of buyers selecting respectively high-efficiency investment and low-efficiency investment is:

$$\begin{aligned} R_{1H} &= y\left[(1+C_{x1})E_c - C_c\right] + (1-y)\left[(1+C_{x0})E_c\text{-}C_c\right] \\ R_{1L} &= yAE_c + (1-y)E_c \\ \overline{R}_1 &= xR_{1H} + (1-x)R_{1L} \end{aligned} \tag{1}$$

According to the Malthusian Model[14], the replicator dynamics equation is shown by Formula (2):

$$\begin{aligned} \frac{dx}{dt} &= x(1-x)\left\{C_{x0}\times E_c - C_c - \left[AE_c - (C_{x1} - C_{x0} + 1)E_c\right]y\right\} \\ \frac{dy}{dt} &= y(1-y)\left\{P_{y0}\times E_P - C_P - \left[AE_P - (P_{y1} - P_{y0} + 1)E_p\right]x\right\} \end{aligned} \tag{2}$$

Given $\left(\frac{dx}{dt}, \frac{dy}{dt}\right) = (0,0)$, so we can obtain 5 equilibrium points of evolution model, *i.e.*: (0, 0), (0, 1), (1, 0), (1, 1)and (A, B), (A, B)is defined as:

$$\left(\frac{P_{y0}\times \mathrm{E}_P - C_P}{AE_P-\left(P_{y1}-P_{y0}+1\right)E_P}, \frac{C_{x0}\times \mathrm{E}_c - C_c}{AE_c-\left(C_{x1}-C_{x0}+1\right)E_c}\right) \tag{3}$$

The stability of evolutionary equilibrium point can be obtained by the local stability analysis of Jacobian matrix; by solving the partial derivative of G(x) and G(y) in proper order, we can obtain the Jacobian matrix[15]. If matrix elements meet the given conditions, the equilibrium point of replicator dynamics equation will be the evolutionary stable strategy. So the concrete value of 5 partial equilibrium points, *i.e.*: (0, 0), (0, 1), (1, 0), (1, 1), (A, B), can be obtained.

D. The Evolutionary Stable Strategy

Evolutionary Stable Strategy 1: When buyers' investment gain rate meets $0<C_{x0}<\frac{C_c}{E_c}, C_{x0}<C_{x1}<\frac{AE_c+C_c-E_c}{E_c}$ and sellers' investment gain rate meets $0<P_{y0}<\frac{C_p}{E_p}, P_{y0}<P_{y1}<\frac{AE_p+C_p-E_p}{E_p}$, the evolutionarily stable strategy of both game parties will be (low-efficiency investment, low-efficiency investment).

Testifying:

$$\begin{aligned}
&\left(C_{x0}+1\right)E_c - C_c < \left(1+\frac{C_c}{E_c}\right)E_c - C_c = E_c \\
&\left(C_{x1}+1\right)E_c - C_c < \left(1+\frac{AE_c+C_c-E_c}{E_c}\right)E_c - C_c = AE_c \\
&\left(P_{y0}+1\right)E_p - C_p < \left(1+\frac{C_p}{E_p}\right)E_p - C_p = E_p \\
&\left(P_{y1}+1\right)E_p - C_p < \left(1+\frac{AE_p+C_p-E_p}{E_p}\right)E_p - C_p = AE_p
\end{aligned} \tag{4}$$

Similarly, evolutionary stable strategy 2-5 are in Table III.

TABLE III. EVOLUTIONARILY STABLE STRATEGY

Buyers	Sellers	Strategy
$0<C_{x0}<\frac{C_c}{E_c}, C_{x0}<C_{x1}<\frac{AE_c+C_c-E_c}{E_c}$	$\frac{C_p}{E_p}<P_{y0}<P_{y1}<\frac{AE_p+C_p-E_p}{E_p}$	Low, High
$\frac{C_c}{E_c}<C_{x0}<C_{x1}<\frac{AE_c+C_c-E_c}{E_c}$	$0<P_{y0}<\frac{C_p}{E_p}, P_{y0}<P_{y1}<\frac{AE_p+C_p-E_p}{E_p}$	High, Low
$\frac{C_c}{E_c}<C_{x0}<C_{x1}<\frac{AE_c+C_c-E_c}{E_c}$	$\frac{C_p}{E_p}<P_{y0}<P_{y1}<\frac{AE_p+C_p-E_p}{E_p}$	Uncertain
$\frac{AE_c+C_c-E_c}{E_c}<C_{x0}<C_{x1}$	$\frac{AE_p+C_p-E_p}{E_p}<P_{y0}<P_{y1}$	High, High

E. Analysis under platform incentives

In the condition of strategy uncertainty, the benefits acquired by both parties from high-efficiency investment are higher than cost and the benefits brought by the "free-riding" effect may result in the one that both parties' game equilibrium tends to the low-efficiency investment. At the time, the platform party has enough motives to adopt certain incentive mechanisms, for example, mitigate sellers' expense, provide technical support, make free-of-charge promotions. There are such shows in the model: one of game parties selects high-efficiency investment, the other one of game parties selects low-efficiency investment, and the party selecting high-efficiency investment may be awarded the platform incentives. Define the economic benefit under the incentive function as K. By the method same to the one in the preceding part of the text, calculate the replicator dynamics equation in the condition of platform incentive, see the Formula as follows:

$$\begin{aligned}
\frac{dx}{dt} &= x(1-x)\left\{C_{x0}\times \mathrm{E}_c - C_c - \left[AE_c - \left(C_{x1}-C_{x0}+1\right)E_c\right]y + K\right\} \\
\frac{dy}{dt} &= y(1-y)\left\{P_{y0}\times \mathrm{E}_P - C_P - \left[AE_P - \left(P_{y1}-P_{y0}+1\right)E_p\right]x + K\right\}
\end{aligned} \tag{5}$$

The purpose of platform incentive is the one that both game parties select the high-efficiency investment strategy. In order to let the one that both parties select high-efficiency investment become the only strategy of our model, the following stable conditions of Jacobian matrix should be satisfied:

$$\begin{aligned}
&-\left(C_{x1}\times E_c - C_c - AE_c + E_c + K\right) < 0 \\
&-\left(P_{y1}\times E_p - C_p - AE_p + E_p + K\right) < 0
\end{aligned} \tag{6}$$

At the time, the parameter K needs to be larger than the difference between the "free-riding" benefit and the "high-efficiency" benefit selected by game parties, and meet the formula:

$$K > Max\left\{AE_c - \left[\left(C_{x1}+1\right)E_c - C_c\right], AE_p - \left[\left(P_{y1}+1\right)E_p - C_p\right]\right\} \tag{7}$$

IV. RESULTS & DISCUSSION

In this work, we make the numerical simulation for the different model parameters by Matlab to more intuitively show the evolution process of both game parties in the livestreaming e-commerce transaction process.

According to the public data, the largest e-commerce platform of China in 2019, namely Taobao-livestreaming, achieved the gross merchandise volume of CNY250.0 billion[16]. By measuring comprehensively the average profit rate of China's commodity circulation industry, we set the benefits that buyers and sellers respectively select low-efficiency investment as CNY10.0 billion and CNY8.0 billion. For the intuitive purpose, we adopt the values Ec=10, Ep=8, the cost that both game parties select "high-efficiency investment" Cc=6, Cp=4; the benefit acquired by both game parties by selecting "free-riding" is AEc=18, AEp=14. The investment income gain rate assignment in the different evolutionary stable strategy conditions, see Table IV.

TABLE IV. MATLAB SIMULATION

Condition	C_{X0}	C_{X1}	P_{Y0}	P_{Y1}	Strategy	Simulation Result
I	0.3	0.6	0.25	0.5	Low, Low	Fig. 1(a)
II	0.3	0.6	0.65	0.85	Low, High	Fig. 1(b)
III	0.75	0.9	0.25	0.5	High, Low	Fig. 1(c)
IV	0.75	0.9	0.65	0.85	Free-Riding	Fig. 1(d)
V	1.5	1.7	1.4	1.6	High, High	Fig. 1(e)

The evolutionarily stable strategy: When the investment benefit gain of both game parties'information safety meets condition I, both parties are inclined to select "low-efficiency investment". At the time, the benefit brought by the high-efficiency investment selected by both game parties is lesser, where the evolutionary stable point is (0, 0), and the simulation result is shown in Fig1(a).

Under the action of platform incentive mechanism, both parties can't acquire benefits from their "free-riding" behaviors, both parties select high-efficiency investment strategy to promote the development of livestreaming e-commerce pattern. At the time, the economic benefit of incentive parameter needs to meet Formula (7). Hypothesizing the model parameter value to meet the conditions of forming "free riding", K>(5, 3.2) at the time; see the simulation result in Fig 1(f); under the conditions of platform incentive, both game parties select "high-efficiency" investment strategy.

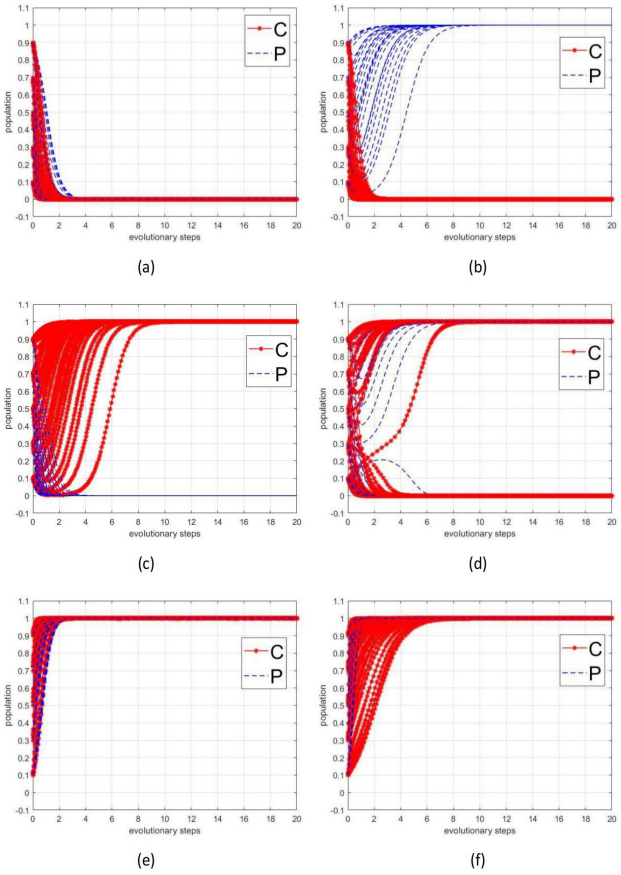

Figure 1. Simulation Results

V. CONCLUSIONS AND PROPOSALS

This paper introduces the platform's third-party incentive mechanism to construct the buyers-sellers evolutionary game model by aiming at the hypothesis of bounded rationality. We solve the evolutionarily stable strategy by the stability principle, figure out the systematic stable development conditions by the quantitative language, and conduct the numerical simulation for the evolutionarily stable strategy under different parameters by the Matlab. As was shown by the results: buyers and consumer's concern and investment on online livestreaming shopping form are closely related to its yield rate, cost, and interest acquired from "free-riding"; platform incentive has a significant positive impact on the investment willingness of both game parties. As the gaining rate of investment income increases gradually, both game parties' probability of selecting concern and investment is increasing accordingly and many evolutionary stable strategies may emerge. Based on the conclusions aforesaid, the suggestions as follows can be made for the livestreaming e-commerce pattern:

- Enhancing livestreaming e-commerce platform construction, optimize push algorithm, improve buyers and sellers' transaction efficiency. Guide high-quality merchants to join, attract potential consumers and improve their investment gain.
- Optimizing platform incentive policy, support and select exactly the buyers and the sellers selecting high-efficiency investment, avoid from "free riding" phenomenon, and form good transaction environment.
- Improving the transaction transparency of buyers and sellers, reduce the sense of distrust brought by information asymmetry.

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