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Consumer Network Evolution Game Based on Product Crowdfunding

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Abstract:

Recently, with the continuous innovation of Internet finance, the model of crowdsourcing emerged, in order to make the product crowdsourcing program obtain more consumer support, promote the success of crowdsourcing and achieve the efficient development of the crowdsourcing industry, this paper took the consumer group as the research object, and then analyzed the evolution of Crowdfunding consumers cooperation in the context of product crowdsourcing. According to the public goods game model, a two strategy multi person evolution game system for crowdsourced consumers based on replication dynamics was established, the integrated influencing factors considering node distance and node importance were introduced, the strategy selection mechanism of the traditional replication dynamics model was optimized, and mutations are introduced, and the effects of mutation factors on the evolutionary stability equilibrium were analyzed. Research found: (1) both support and no support for crowdsourcing are evolutionarily stable strategies in the context of traditional replication dynamics. (2) In the context of improved dynamics, no supporting and partially favoring crowdsourcing are evolutionarily stable strategies, and the presence of a mutation somewhat inhibits the success of crowdsourcing. At the same time, in order to promote the success of crowdsourcing programs, managers should enhance product impact and effectively motivate consumers to engage in product crowdsourcing by means of directed marketing; On the other hand, consumers mutations should be reduced or even avoided as much as possible, improving product quality and increasing consumer loyalty.

***Keywords**: Consumer Network, Evolutional Game theory, Replicator Dynamics, Product crowdfunding.*

I. INTRODUCTION

In the context of the informatics era, with the rapid development of communication technology and the Internet, crowdsourcing comes of age as the breadth, depth, and frequency of interaction between different subjects increases significantly. Crowdsourcing refers to start-up individuals or groups who post a project through an Internet platform calling on a relatively large group of people to act as investors in their project, each offering a relatively small investment as financial support for the project [1], and where the investor can receive some incentive or equity interest as a small return on investment [2]. Based on the different returns obtained, crowdsourcing is classified into four types: product type crowdsourcing, equity ownership type crowdsourcing, claims type crowdsourcing, and charity type crowdsourcing, of which the

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development of product type crowdsourcing is the most rapid and massive, becomes the focus of this research.

Product crowdsourcing refers to a form of crowdsourcing in which an investor investigates funds for funders to develop a product (or service) and to the extent that that the product (or service) is starting to be sold externally or is already available, the funder makes a form of crowdsourcing in a manner agreed to make the developed product (or service) unpaid or less costly to the investor. As can be seen, product crowdsourcing is growing as a nascent force in our financial market. But a fact that cannot be ignored is that our state's development status of crowdsourcing industry is not optimistic after experiencing well blown outbreaks, highlighted by the lower line or transformation of the eutopic crowdsourcing platform, and the dramatic decrease in the number of new platforms added. As of January 2020, only 66 remain for the still normally operating crowdsourcing platforms in the country, and the sustainability of the crowdsourcing business model becomes a much-needed concern. From practices of crowdsourcing models, there are generally modest success rates for crowdsourced projects [3], and even successful projects have problems, such as 37% successful projects on the Kickstarter having production costs that exceed the original budget, causing project promoters to delay or even cancel delivery of the product, or delivering the product with suboptimal quality [4].

With the rapid development of Internet technology, crowdsourcing, as an innovative model of Internet finance, has received much attention and research from scholars. The emergence of this novel financial model of product crowdsourcing has also significantly impacted traditional consumer networks. In traditional consumer networks, each consumer has a low degree of relatedness and strong independence, and each consumer's decision is not susceptible to the influence of other consumers, whose willingness to purchase a product arises from their own judgment of the value and efficacy of the product; Whereas in the novel business context of product crowdsourcing, each consumer's product investment decision is susceptible to the influence of other crowdsourcers, their judgments about whether a product is worth investing partly depend on their own value judgments about the product itself and the crowdsourced sponsor or the originator, partly depend on the judgments and decisions of other crowdsourcers. However, due to the late emergence of product crowdsourcing, the fast evolution from traditional to novel consumer networks, and the relatively complex evolution, there is little literature examining novel consumer networks in the context of product crowdsourcing. Therefore, in the large context of product crowdsourcing, researching on novel consumer networks have strong theoretical value and practical significance.

II. RESEARCH REVIEW

2.1 Review of relevant literature on product crowdsourcing

2.1.1 Materials and methodology

In terms of the motivations for product crowdsourcing initiations, different domestic and foreign

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scholars put forward different perspectives: among them Belleflamme et al 2013b[5] argues that crowdsourcing promoters choose crowdsourcing as their funding instrument with the following motives: Firstly, funding seeking can be made more rapid and convenient through Internet platforms, second, crowdsourcing can gain public attention, and thirdly, product consumer feedback can be obtained during the crowdsourcing process. Belleflamme et al Building on this, Hienerch and Riar, 2013[6], Macht and Weatherston, 2014[7] identify crowdsourcing motives that also include: the speed and flexibility of financing, less obligation constraints, testing products on the market, positive signaling effects, and the use of population intelligence in various corporate tasks. In addition, product crowdsourcing enables firms to use their market potential more effectively. Besides, Ordaninietal, 2011[8] argue for product crowdsourcing as an emerging channel that allows consumers to simultaneously pursue the role of investors. Those who are willing to invest in a crowdsourced product are generally those who believe that the product succeed, and hence Martin, 2012[9] argues that firms are able to gain consumer trust through product crowdsourcing while helping to build customer groups.

2.1.2 Literature review based on the Internet product crowdsourcing proponents' perspective

The involvement of product crowdsourcing is critical to the success of product crowdsourcing. Much research has focused on investigating the behavioral motives of crowdsourced supporters. In response to Internet product crowdsourcing, Ryu and Kim, 2016[10] proposed four types of crowdsourcing supporters: Angel supporters, bonus hunters, fans, and cryptic supporters. The primary motivation of angel supporters is charity with little incentive for rewards, whereas that of bonus hunters is mainly for rewards. Fans are the most enthusiastic and open sponsors, with strong interpersonal motivation. Cryptic supporters are similar to fans in the level of support but have an inward disposition and do not seek relationships or recognition. Moreover, in terms of the involvement of crowdsourced supporters in the primary or secondary motivation for crowdsourcing, according to an experiment by Cholakova and Clarysse, 2015 [11], nonfinancial motives play a smaller role, because the primary motivation is driven financially.

In addition to research on product crowdsourced supporters' motives, there is a strong place for timing of investment in product crowdsourcing because others' behavior signals subsequent crowdsourced supporters. Kuppuswamy and Bayus, 2013, 2015[12-13], after examining the dynamic decision-making effect of social information on Internet product crowdsourcing, argue that potential supporters are negatively correlated with preexisting supports in the early stage of the crowdsourcing period, but positively correlated in the later stage. In addition, Ward and Ramachandran, 2010[14] also found that, in product crowdsourcing, the higher the current popularity ranking or recommendation from blogs, the more supported people or the amount of support a crowdsourcing project receives posteriorly.

2.1.3 Literature review based on the perspective of Internet product crowdsourcing platforms

Product crowdsourcing platforms as mediators involved in crowdsourcing offer advantages to both crowdsourced promoters and crowdsourced supporters. From the perspective of influential factors established by the product crowdsourcing platform, Dushnitsky et al, 2016[15] argue: various countries' populations, gross domestic output, object products, and regulations make a great impact on the

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establishment of product crowdsourcing platforms.

From the perspective of the role of product crowdsourcing platforms, in addition to providing standardized processes, crowdsourcing platforms also play an important role on information flow, exchange, and execution. Haas et al., 2014[16] argue: platforms can reduce the emergence of information asymmetries and thus reduce proponents' investment risk. In addition, Burtch et al, 2013a[17] argue: the platform can enable supporters to build confidence. Finally, according to Yang et al, 2016[18] perspective: product crowdsourcing platforms' preheat behavior prior to the start of crowdsourcing is one of the key factors for success.

In the area of product crowdsourcing platform financing design, Wash and Solomon, 2014[19] identified the following two types of financing designs: the return to rules or the direct donation model. In the case of return of rules, a payment is made to a crowdsourced sponsor only if a pre-defined threshold is reached. Otherwise, funding be returned to crowdsourced supporters; The direct donation model implies that all collected funds be paid to a crowdsourced sponsor.

2.2 Relevant literature review on the game of crowdsourcing evolution

Internet crowdsourcing is currently a hot topic receiving widespread attention from scholars and industry at home and abroad, but research on crowdsourcing in academia is still at a primary stage. Evolution game theory as a new method of game analysis has gradually become widely concerned among the economics, management, and physics communities. Many relevant literatures exist at home and abroad that use an evolutionary game approach to study the mechanisms of strategic interactions between Internet crowdsourcing parties, which are generally crowdsourcing platforms, promoters, consumers and regulatory authorities.

2.2.1 Evolutionary games between promoters and consumers of crowdsourcing projects

Domestic scholars are interested in studying the evolutionary game between consumers and promoters in a crowdsourcing context: Zhiying Liu[20] aimed at the characteristics of both the investing and funding parties in the crowdsourcing process, and analyzed the profit game process between the two parties under different information conditions in the crowdsourcing context, based on yield, product return, discount coefficient and innovativeness four explanatory variables, which are explored for their impact on both interests and decisions, ultimately prompting both investing and financing parties to make corresponding strategy choices. His research shows that under both complete and incomplete information conditions, both the investing and financing parties can eventually reach the equilibrium state and obtain their respective maximum gains, and at the same time, propose that innovation and cooperation is a win-win strategy. Jiang Hong Zeng and Xiao Sha[21] constructed a cooperative game model consisting of project parties and investing parties, and gave the distribution scheme of benefits to all parties involved in the project; In addition, Zeng Jiang Hong [22] aimed at the problem of generally absent interaction and low quality of value co creation in domestic crowdsourcing environments, and then constructed a value co creation model

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by analyzing real cases and carrying out a game analysis of proponents' and initiators' strategic evolution to explore the pathways and influencing factors for improving the willingness to engage in value co creation between both parties. Liu Yu et al[23] analyze the risk of the presence of crowdsourcing investment according to the information asymmetry theory of the crowdsourcing industry and construct an information asymmetric game model of the crowdsourcing industry by carrying out an empirical analysis on "Jingdong crowdsourcing" to obtain factors that affect investors' decisions. Xiumei Lue[24] constructed a three-stage model of crowdsourcing finance, offering products to supporters and rewarding crowdsourcing products to general consumers, taking into account the pricing decisions of promoters that increase the returns of promoters and improve the success of crowdsourcing in projects, and a comparative static method is applied to explore the influence of the value-added service provided by the sponsor to the proponents and the factors of patience of consumption of investors on the sponsor's pricing decisions. The findings point to promoters versus consumers as a dynamic game process regarding price and utility, and ultimately obtain Nash equilibrium.

2.2.2 Evolutionary games between crowdsourcing platforms and project promoters

In recent years, Chinese scholars have also focused their eyes on the games between platforms and promoters: Bing Lu[25] selects the more prevalent reward type of crowdsourcing in the crowdsourcing model, aims at the information asymmetry problem existing between project promoters and crowdsourcing platforms, and develops a signaling game model with an in-depth analysis of three Bayesian equilibria, Policy suggestions are provided for crowdsourcing platforms to refine their own functions and develop continuously and steadily. Using evolving game theory, Xianjia Wang[26] analyze the interactive mechanisms of strategic choices between Internet crowdsourcing platforms and project promoters with bounded rationality, concluding that effective implementation of regulation and application of different degrees of punishment strategies can effectively regulate the crowdsourcing platform behaviors of promoters to hide product information from deceive consumers, and lead promoters to reveal the project types truthfully, reducing adverse selection from information asymmetries and increasing consumers' positivity to engage in crowdsourcing. In the area of decisional mechanisms to study the choice behavior in the operational model of reward based crowdsourcing platforms, Biteng Deng[27] applies analytical methods from evolutionary game theory to construct an evolutionary game model of crowdsourcing platforms under reward based crowdsourcing models with the project promoters' strategic behaviors, and makes evolutionary dynamic stability analysis of the choice of strategies across subjects of interest, and explore the key factors affecting the choice of the operation mode of reward based on crowdsourcing platforms through numerical simulation. Using evolutionary game theory, Fei Wang[28] studied the interactive mechanism of strategy selection between crowdsourcing platforms and promoters with bounded rationality, explored the effects of the magnitude and punishment of handling fee offers and the size of financing targets on the evolution of stable equilibrium of the promoter's strategy, and critically examined the effects of cost on the stable equilibrium of crowdsourcing platform strategies, and gave related policy suggestions, Provides a basis for addressing the breach risk problem in crowdsourced markets. Guoshun Ma[29] Based on the theory of evolution game, and obtained evolutionarily stable strategies for both parties of the game by establishing replicating dynamic equations and analyzing the dynamic evolution

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process of crowdsourcing platform and promoter strategy selection.

2.2.3 Other intersubjective evolution games

In other intersubjective evolution game studies: Guang Qi Ma[30] makes targeted recommendations for the normative regulation and health development of equity crowdsourcing by constructing a game model that includes equity crowdsourcing platforms, financing parties, investors, regulators, and the eastern Beijing family as a case example, including minor issuance exemptions, rational investment, efficient exit regulatory improvement et al. Qilong He[31] analyzed the game strategy evolution process between regulators and crowdsourcing platforms from the perspective of an evolutionary game by establishing a replicating dynamic equation to draw an evolutionarily stable equilibrium of the two parties' strategies. Under the assumption that crowdsourcing platforms, as well as social platforms, do not charge platform service fees, Shaojian Qu[32] aims to maximize the net financing amount for project funders and the expected benefit from investors, and presents three different mechanisms for crowdsourcing. He analyzes a fully informative dynamic game model of social crowdsourcing versus unsocialized crowdsourcing, while comparatively analyzing different financing mechanisms as well as existing cases of crowdsourcing socialization, concluding that social network push marketing phenomena for crowdsourced markets are fully existential.

2.2.4 Crowdsourcing consumer network evolution game

Xianjia Wang[33] adopted a large group recurrent game replicating dynamic evolution game, and under both scenarios of fair contribution and altruism, established an evolutionary system in which consumer groups with bounded rationality continuously adjust their support for crowdsourcing and unsupport for crowdsourcing two strategies by mimetic learning in a multiperson game. By analyzing the effects of varying parameters on the stable equilibrium and domain of attraction in the phylogeny, we investigate the mechanisms by which various factors contribute to the success of crowdsourcing evolution in the presence of consumer regret. Additionally, based on the grounded probability of Moran's process, he also calculates the probability of engaging in crowdsourcing strategies and not engaging in successful invasion by crowdsourcing strategies in limited consumer groups. Comparing the probability of individual rooting and the magnitude of probability of neutral invasion yields conditions for which the two strategies are dominant under strong and weak selective strengths, respectively[34]. Qilong He[35] introduced the crowdsourcing model into environmental governance and used the evolution game theory to analyze the evolutionary dynamics of the decision-making behavior of limited reason farmers under the two scenarios of equitable contribution and altruistic preference, and then studied the risk occurrence probability, pro environmental preference, group utility, initial wealth, financing objectives, and crowdsourcing share, which contribute to the success of crowdsourcing finance in environmental governance.

In summary, Internet crowdsourcing is currently a popular concern at home and abroad, but research on crowdsourcing in academia is still at the primary stage. From the grooming process of the above literature, we can find that more mature studies of evolutionary games involving crowdsourcing project promoters versus consumers, crowdsourcing platforms versus project promoters, and other subjects have

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resulted in well-established research frameworks and research ideas, as well as more fruitful studies. However, in the field of games of crowdsourced consumer network evolution, related studies remain scarce. The funder collaboration evolution is a multidisciplinary interdisciplinary research field, and studying the formation of funder collaboration from an evolutionary perspective is a new research hotspot in academia.

III. ANALYSIS OF CLASSICAL RELICATION DYNAMICS MODEL

Given a group game $U(x) = (U_1(x), U_2(x), \cdots, U_m(x))$. Set $S = (1,2, \dots, m)$ as collection of each individual strategy. $x = (x_1, x_2, \cdots, x_m)$ is the group state, where x_i represents the proportion of strategy i in the group, therefore $\sum_{i \in S} x_i = 1$.

In the traditional replication dynamics model, individuals adjust their own strategies by imitating the strategies of other individuals. Each individual randomly selects an imitation object from the group. If the income of the imitation object is greater than the individual's own income, the individual adopts the imitation object strategy with a probability proportional to the income difference between them, otherwise the original strategy remains unchanged. Under this update rule, the adjustment protocol of group state can be obtained. To be specific, the ratio of i strategy individuals to j strategy individuals is:

$$\tau_{ij}(U(x), x) = x_j[U_j(x) - U_i(x)]_+ \quad (3.1)$$

Where when $y \geq 0$, $[y]_+ = y$; otherwise, $[y]_+ = 0$

According to the average kinetic equation:

$$\dot{x}_i = \sum_{j \in S} x_j \tau_{ji}(U(x), x) - x_i \sum_{j \in S} \tau_{ij}(U(x), x), \forall i \in S \quad (3.2)$$

Substituting equation (1.1) into the average dynamic equation (1.2) to obtain:

$$\begin{aligned} \dot{x}_i &= \sum_{j \in S} x_j x_i [U_i(x) - U_j(x)]_+ - x_i \sum_{j \in S} x_j [U_j(x) - U_i(x)]_+ \\ &= x_i \sum_{j \in S} x_j \left(U_i(x) - U_j(x)\right) \end{aligned} \quad (3.3)$$

Let $\overline{U}(X) = \sum_{j \in S} x_j U_j(x)$ represents the average income of the group, the above equation can be rewritten as:

$$\dot{x}_i = x_i(U_i(x) - \overline{U}(x)), \forall i \in S \quad (3.4)$$

Replication dynamics model, which is the most basic model of evolutionary game strategy renewal, but it still has some shortcomings. This paper applies it to the product consumer network. Based on the

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characteristics of crowdfunding consumer selection strategy, it is found that the traditional replication dynamics model has the following two shortcomings:

1.The imitation object selection mechanism is unreasonable.

According to the assumption of traditional replication dynamics, decision makers need to randomly select imitation objects in the full scope. In the consumer network based on product crowdfunding, consumers' choice of imitation objects is not random, instead, it has a certain tendency, that is, people tend to imitate individuals close to themselves or individuals who are more important to themselves. In general, The closer the imitation object is to the decision-maker, the imitation object is more likely to be selected for imitation; The higher the importance of the imitation object to the decision maker, the easier it is to influence the decision maker, and thus the easier it is to be imitated.

2. The strategy decision-making mechanism does not consider the mutation factor.

The traditional replication dynamics assumes that the number of individuals in the population is infinite and mixed evenly, and does not consider the uncertain factors in the decision-making environment. Therefore, this is a non mutation natural selection learning model, which does not describe the random exploration process of individuals, that is, the mutation behavior is not considered. In the real consumer crowdfunding strategy game, participants not only choose strategies, but also explore strategies themselves. That is, participants' strategic decision-making is not only by copying others' strategies, they also change the selected strategy according to the exploration of themselves, the environment and other factors. For example, in the process of product crowdfunding, some participants choose cooperation according to the decision of copying others, but the initial decision is changed due to factors such as changes in the environment or the belief that the product is not a necessity, and change the cooperation strategy to betrayal strategy, which is a mutation.

IV. OPTIMIZATION OF IMITATION OBJECT SELECTION MECHANISM BASED ON NODE INFLUENCE

4.1 Improved analysis of selection mechanism

In traditional replication dynamics, the selection of imitation objects by nodes is random, which is inconsistent with the actual situation. Therefore, this paper considers the comprehensive influencing factors of replication nodes to optimize the selection mechanism. Here, we think that the node influence includes: node distance and node importance, which jointly determine the influence of nodes, thus affecting the probability of node selection. In general, the closer the node is and the more important it is to the decision-maker, the greater the influence of the node, and the greater the probability of being selected for replication. Based on this, this paper first introduces the node distance and node importance, and the specific assumptions are as follows:

1. Average distance of nodes

In crowdfunding consumer network, there is a certain connection between nodes. Here, we use social distance instead of node distance. Firstly, this paper defines the node social distance: according to the six degree separation theory, there be no more than five people between us and any stranger. Therefore,

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for users in any two crowdfunding consumer networks, the social distance between nodes is 1, 2, 3, 4, 5 and 6.

Here, we define $V = (1,2,\dots,n)$ as the set of network nodes, the distance from node a to node b is d_{ab}, the average distance of node a in group V is:

$$d_a = \frac{\sum_{b \in V} d_{ab}}{n} \tag{4.1}$$

We normalize the average distance so that its value is between [0,1], and express the standardized social distance as ds_a. Then:

$$ds_a = \frac{d_a - \min\{d_a\}}{\max\{d_a\} - \min\{d_a\}} \tag{4.2}$$

2. Node importance

In the product crowdfunding consumer network, node importance depends on two parts: one is the interaction between complex network users, and the other is the network traffic heat that nodes can bring.

① Interaction between users.

Specific interaction behaviors include attention, praise and forwarding. For any user in the network, the more frequently he interacts with other nodes, the higher the influence of other nodes on the user. When a user interacts with other nodes, the importance of the node to the user is increased by 1. Here, e is used to represent the node importance. Assuming that the number of interactions between node b and node a is e_{ba}, we take the average of the importance of node a in group V as:

$$e_a = \frac{\sum_{b \in V} e_{ba}}{n} \tag{4.3}$$

In order to define the impact of node importance on users, we standardize it here. Finally, we express the standardized node importance as:

$$es_a = \frac{e_a - \min\{e_a\}}{\max\{e_a\} - \min\{e_a\}} \tag{4.4}$$

It can be seen from the above formula, $es_a \in [0,1], e_a \in [0,+\infty), e_a \in N^+$.

② Node network traffic heat

Here, we use the number of fans of a platform user to quantify the user's network traffic heat, expressed by I. In order to better define the impact of node network traffic heat on users, we standardize it. Finally, we define the network traffic heat of node a as follows:

$$is_a = \frac{i_a - \min\{i_a\}}{\max\{i_a\} - \min\{i_a\}} \tag{4.5}$$

It can be seen from the above formula, $is_a \in [0,1], i_a \in [0,+\infty), i_a \in N^+$.

3. Node influence

In the product crowdfunding consumer network, the influence of nodes is jointly determined by the distance and importance of nodes. According to the above definition, it is easy to know that the node distance is inversely proportional to the influence of the node. The smaller the distance, the greater the influence; On the contrary, the importance is directly proportional to the influence of the node. The more important the node is, the greater the influence of the node is. Here, we define the node influence as a probability. The greater the influence, the greater the probability that the node be selected. Here,

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suppose the number of nodes is C, $z_a = \frac{es_a \cdot is_a}{ds_a + 1e-7}$, here, we introduce the minimum quantity (1e-7) ,make the denominator is not equal to 0. Therefore, according to the above two influencing factors, we define the influence of node a as P_a:

$$P_a = \text{Softmax}(z_a) = \frac{e^{z_a}}{\sum_{c=1}^{C} e^{z_a}} = \frac{e^{\frac{es_a \cdot is_a}{ds_a+1e-7}}}{\sum_{c=1}^{C} e^{\frac{es_a \cdot is_a}{ds_a+1e-7}}} \quad (4.6)$$

Apparently, $P_a \in [0,1]$.

4.2 Node degree distribution of consumer interaction network under different selection mechanisms.

The node selection probability shown in formula (4. 6) is affected by the distance and importance of individual nodes. The selection mechanism of imitation object in traditional replication dynamics is random, but based on the above improvement, the selection mechanism changes from random selection to probability selection. Here, according to the simulation data of 100 different users, we conduct sampling analysis in two ways: the traditional replication dynamics selection mechanism and the improved replication dynamics selection mechanism, select 30 different users, and compare the differences of extraction nodes under the two different mechanisms. Here, we consider using the distribution function of the node degree of the interactive network to describe the difference of the extracted nodes:

The frequency distribution diagram of the initial interactive network degree is as follows:

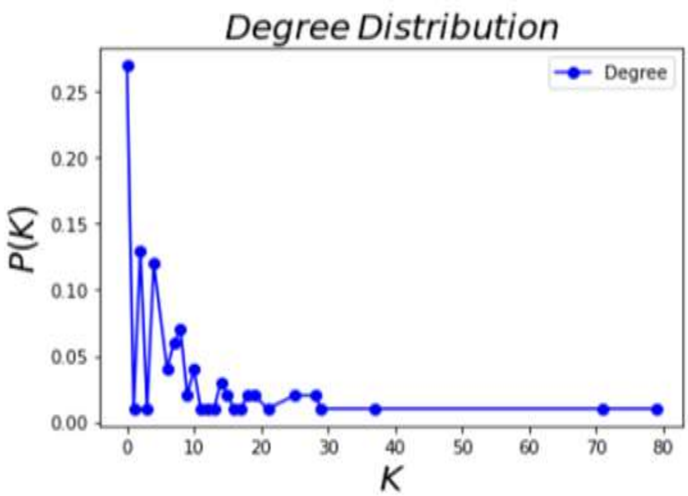

Fig 1 frequency distribution diagram of initial interactive network node degree

In Fig 1, the abscissa P represents the node degree value, and the ordinate P (k) represents the ratio of the number of nodes with K in the network to the total number of nodes. It can be seen from the Fig that the distribution follows the power-law distribution and meets the characteristics of scale-free

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network, that is, most nodes have small degree values, and only a few nodes have large degree values.

Firstly, we extract 30 users from this group according to the random selection mechanism under the traditional dynamics to obtain the interactive network degree distribution in this case, as shown in Fig 2:

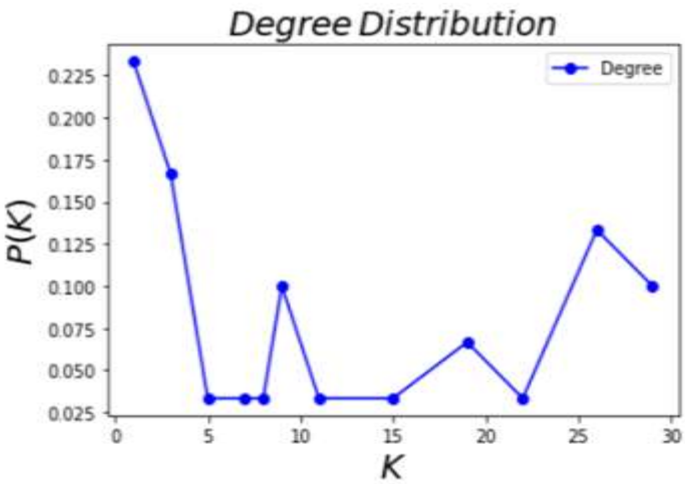

Fig 2 frequency distribution of node degree of interactive network under random selection mechanism

In Fig 2, the abscissa K represents the node degree value, and the ordinate P (k) represents the ratio of the number of nodes with K in the network to the total number of nodes. Generally speaking, the 30 users selected under the traditional replication dynamics selection mechanism are densely distributed, and they are nodes with small degrees, of which the maximum degree value is no more than 30. Secondly, according to the improved probability selection mechanism, the same number of samples are taken to analyze the interactive network degree distribution diagram:

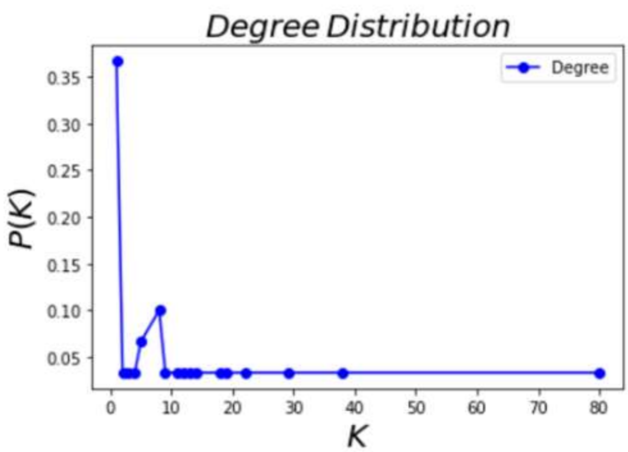

Fig 3 frequency distribution of node degree of interactive network under probability selection mechanism

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In Fig 3, the abscissa K represents the node degree value, and the ordinate P (k) represents the ratio of the number of nodes with K in the network to the total number of nodes. It can be seen from the Fig that under the rule of probability extraction, the degree distribution of the extracted nodes is relatively scattered, and the nodes with large and small degree values exist.

From the above analysis, it can be seen that since most nodes in the original network have less interaction times, the general degree value of the selected node is small when randomly selected; In the case of probability selection, the number of interactions determines the influence of the node, and affects the probability that the node is selected, so that the node with greater influence is also selected.

The experimental results show that by improving the selection mechanism of copying dynamics, a new definition of the application background of traditional copying dynamics has been made, making the improved selection mechanism more in line with the real crowdfunding consumer network. In the process of individual strategy replication, the selection of imitation object is not completely random, but there is a certain degree of subjective judgment, which depends on the node influence factor, and the node influence is determined by the node distance and node importance, which jointly affect the probability that the imitation object is selected by the decision-making individual. The selection mechanism based on the comprehensive influencing factors of nodes can better describe the selection of imitation objects by real crowdfunding individuals.

V. OPTIMIZATION OF STRATEGY DECISION-MAKING MECHANISM BASED ON MUTATION FACTORS

As a dynamic evolution process, consumer crowdfunding has more rationality than static stability. The existing research has obvious deficiencies in theory. In the modeling process, it excessively depends on a single theory for interpretation, most of which are only based on replication dynamics. As a complex system, consumer game needs to be studied from multiple angles, not limited to and copying dynamics, but also to explore its random exploration process. The existing traditional replication dynamics can not effectively explain why many consumers who initially choose to participate in crowdfunding eventually change their strategies unplanned after a period of evolution. To solve this problem, we can consider it from the perspective of mutation. The discrete change of consumer strategy from one equilibrium state (i.e. stable cooperation) to another equilibrium state (i.e. unstable cooperation) can be effectively analyzed by mutation.

In the process of crowdfunding, especially in the early stage of crowdfunding, consumers' support for crowdfunding is often affected by the people around them. Most customers are an imitation of others' strategies. To a large extent, people's consumption behavior and purchase decision also be affected by cultural, social, personal and psychological factors, which lead to the sudden change of consumer strategy. Firstly, it is affected by its own factors, mainly including: consumers' own economic

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conditions, such as consumers' income, assets, deposits and borrowing ability. Consumers with different economic conditions have different choices; Consumers' age and gender, consumers' demand for products change with age. Individuals of the same age group and consumers of different gender have different purchase tendencies; Consumers' occupations and social strata, and consumers of different occupations often have certain differences in their needs and hobbies for goods; Consumers with different personalities have different strategic choice behaviors. Secondly, whether consumers choose to support crowdfunding also be affected by major psychological factors such as motivation, perception, attitude and belief.

In the process of social economics, in the face of different strategy choices, individuals either choose those strategies with advantages or randomly choose a strategy. Here, we assume that in the process of crowdfunding, consumers first imitate those successful strategies, and make random strategic mutations in the process of imitation. This hypothesis can better describe the game behavior of crowdfunding consumers.

In the decision-making process of consumer crowdfunding strategy, individuals not only have replication behavior, but also have a random exploration process. Here, we describe this strategy exploration process as a mutation process, that is, individual strategies have a certain probability of mutation. Here, we regard $q_{ij} \in [0,1]$ as the probability of individual mutation from strategy i to strategy j. Apparently $\sum_{j \in S} q_{ij} = 1$, therefore, we consider mutation factors here:

$$\dot{x}_i = \left(\sum_{j \in S} x_j q_{ji} - x_i\right) \cdot U_i(x), \forall i \in S \tag{5.1}$$

Where, the first part on the right of the equation $\sum_{j \in S} x_j q_{ji}$ represents the proportion of individuals who mutated from other strategies to strategy i, and the second part $-x_i$ represents the proportion of individuals who mutated from strategy i to other behaviors.

Mutation is a common phenomenon in the process of biological evolution and social development. Many scholars have studied the influence of mutation effect on replication dynamics. However, for the game between consumers, only replication behavior is often considered, and the research on mutation behavior is scarce. This paper optimizes the strategy decision-making mechanism based on mutation factors. Firstly, the introduction of mutation factors into the strategy decision-making mechanism is more in line with the characteristics of decision-making in the game process of product crowdfunding consumers, making the consumer decision-making process more dynamic, not only limited to the choice of strategy, but also the exploration of strategy. Secondly, the Mutation behavior is introduced into the overall dynamics, which makes the algorithm model more universal and suitable for more general network game scenarios.

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VI. OPTIMIZED REPLICATION DYNAMICS MODEL

In this section, we introduce the improved imitation object selection mechanism and the mutation-based policy decision-making mechanism into the traditional replication dynamics, and give the improved replication dynamics model:

1. Individual strategy imitation

In the traditional replication dynamics process, individuals randomly select imitate objects globally to imitate strategies. According to the characteristics of individual behavior in the actual network and combined with Section 4.1, this paper optimizes the global random selection rules to form a selection mechanism that considers the influence of nodes.

In the process of product crowdfunding, consumers choose the replication node according to the probability determined by the synthesized impact factors of node after determining the required replication strategy.

In the product crowdfunding game, given the group game state $U(x) = (U_C(x), U_D(y))$, and the individual strategy set is $S = (C, D)$. x indicates the proportion of strategy C in the group, and y indicates the proportion of strategy D in the group, therefore x + y = 1.

Based on the imitation object selection mechanism, the selected object is simulated strategically, the strategy update rules are the same as the traditional replication dynamics: the probability of an individual adopting the imitation object strategy depends on the size of the imitation object income and the self-revenue. If the benefit of the imitated object is greater than the individual's own benefit, the individual use the strategy of the object of imitating, which is directly proportional to the probability of the difference between the two object, otherwise the original strategy remains unchanged. Therefore, an adjustment protocol for the group state can be obtained.

At that moment, the proportion of specific D-strategic individuals transformed into C-strategic individuals is:

$$\tau_{DC}(U(x), x) = x[U_C - U_D]_+ \tag{6.1}$$

Conversely, the proportion of C-strategic individuals to D-strategic individuals is:

$$\tau_{CD}(U(x), x) = y[U_D - U_C]_+ \tag{6.2}$$

Where, when $z \geqslant 0$, $[z]_+ = z$, otherwise, $[z]_+ = 0$.

2. Group strategy update

According to the average dynamics model, we use 3.1 section, formula (3.4) to represent the change of strategy i over a certain period of time:

$$\dot{x}_i = x_i(U_i(x) - \overline{U}(x)), \forall i \in S$$

In the context of product crowdfunding, the above expression is:

$$\dot{x} = x(U_C - \overline{U}) \tag{6.3}$$

$$\dot{y} = y(U_D - \overline{U}) \tag{6.4}$$

3. Strategy mutational updates

According to the optimization of the strategy decision-making mechanism based on mutation factors in Chapter 5, substituting the replication dynamics equations considering mutation factors into the

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population strategy update under average dynamics and obtain (5.1):

$$\dot{x}_i = (\sum_{j\in S} x_j q_{ji} - x_i) \cdot U_i(x), \forall i \in S$$

Applying the above formula to crowdfunding, we can obtain:

$$\dot{x} = (x \cdot q_{CC} + y \cdot q_{DC} - x) \cdot U_C \quad (6.5)$$

$$\dot{y} = (x \cdot q_{CD} + y \cdot q_{DD} - y) \cdot U_D \quad (6.6)$$

4. Solution

Combine (3.4) and (5.1) into one system, and its differential equation is:

$$\dot{x}_i = \sum_{j\in S} x_j U_j(x) q_{ji} - x_i \overline{U}(x) \quad (6.7)$$

The above equation is the replication dynamics model considering the comprehensive influencing factors and mutation of nodes.

Introduce it into the crowdfunding consumer game:

$$\dot{x} = x q_{CC} U_C + y q_{DC} U_D - x\overline{U} \quad (6.8)$$

When $q_{CC} = 1, q_{DC} = 0$, formula (6.8) degenerates to formula (6.3). At that moment, the individual behavior only considers replication and does not consider mutation.

On the other hand, if all behaviors are equally important, that is, there is $U_C = U_D$ for any strategy, the behavior selection mechanism will not exist, and formula (6.8) will degenerate into formula (6.5), which is only consider mutation. Similarly:

$$\dot{y} = y q_{DD} U_D + x q_{CD} U_C - y\overline{U} \quad (6.9)$$

VII. CROWDFUNDING BALANCE ANALYSIS

7.1 Evolutionary game model based on public goods game

In the actual product crowdfunding, the consumer crowdfunding game requires many participants to interact at the same time, which is similar to the public goods game. When a crowdfunding project is launched, the initiator will determine the target crowdfunding amount according to the budget of project start-up costs and expenses. If the final crowdfunding amount reaches the target amount, crowdfunding will succeed, otherwise crowdfunding will fail. Here, we assume that the number of consumers N is randomly selected from an infinite group to study the strategy evolution. Each consumer can invest c and the target amount is N*c. Based on the following parameter descriptions:

The regret degree of supporters caused by the failure of project crowdfunding is P;

c represents the cost paid by the crowdfunding partners.

The return coefficient r represents the benefit that supporters can enjoy after the success of crowdfunding, which can intuitively represent the value that crowdfunding products bring to supporters, including product quality level, marginal utility, community welfare, etc. It is related to the cost paid by the partners. In order to make the utility of consumers supporting crowdfunding greater than the cost paid, it is assumed that r > 1;

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i indicates the number of people who support crowdfunding when the participant is N. when i = N, crowdfunding succeeds, otherwise, crowdfunding fails.

Through the above parameter setting and explanation, the return matrix of random n-person game is:

TABLE I. Return matrix of N person game

	N-1	⋯	k	⋯	1	0
C(cooperate)	r·c-c	⋯	-p	⋯	-p	-p
D(betray)	0	⋯	0	⋯	0	0

Therefore, the benefits of crowdfunding supporters and betrayers are:

$$\omega_C(i) = \begin{cases} (r-1)c, i = N \\ -p, 0 \le i < N \end{cases}$$

In the group composed of N random individuals, the probability composed of a C strategy individual, j supporters and N-1-j traitors obeys the hypergeometric distribution. And the decision-making income of any individual is affected by his own strategy and the strategies of other individuals. Here we assume that x is the proportion of supporters in the group and y is the proportion of betrayers in the group. Apparently, x+y=1. The evolution of the system over time is represented by the improved replicated dynamic equation:

$$\begin{cases} \dot{x} = xq_{CC}U_C + yq_{DC}U_D - x\overline{U} \\ \dot{y} = yq_{DD}U_D + xq_{CD}U_C - y\overline{U} \end{cases} \tag{7.1}$$

Where U_C indicates the expected return of consumers who support crowdfunding in this group, U_D indicates the expected return of consumers in this group who do not support crowdfunding. Then:

$$U_C = \sum_{j=0}^{N-2} x^j y^{N-1-j}(-p) + x^{N-1}(r-1)c$$

$$U_D = 0$$

According to the binomial formula: $\sum_{j=0}^{N-1} x^j y^{N-1-j} = 1$, get:

$$U_C = -p + x^{N-1}(p + (r-1)c)$$

$$U_D = 0$$

From the above formula, the expected expenditure of supporters and non supporters is $p - x^{N-1}(p + (r-1)c)$ and 0 respectively. When x = 0, the expected return that supporters can obtain is -p < 0, and only when $x^{N-1}(p + (r-1)c) > p, U_C > U_D = 0$, it is rational for consumers to choose to support crowdfunding.

Here, substituting $x + y = 1, \overline{U} = xU_C + yU_D, U_C, U_D$ into (7.1), get:

$$\begin{aligned} \dot{x} &= x(q_{CC} - x)\, U_C + (1 - \mathrm{x}) \cdot (q_{DC} - x)U_D \\ &= x(q_{CC} - x) \cdot [-p + x^{N-1}(p + (r-1)c)] \end{aligned} \tag{7.2}$$

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7.2 Evolutionary stable equilibrium

Let $\dot{x} = 0$, the three stable states of the game model are obtained:

$$x^* = 0, x^* = \sqrt[N-1]{\frac{p}{p + (r-1)c}}, x^* = q_{CC}$$

According to the definition of evolutionary stability strategy and differential equation, whether $x^*$is an evolutionary stable equilibrium point depends on whether the derivative at the stable state is less than 0. Here, we verify the derivatives of the three stable states:

$$\dot{x}' = [Nq_{cc}x^{N-1} - (N+1)x^N] \cdot [p + (r-1)c] + (2x - q_{cc}) \cdot p$$

(1) When $x^* = 0$, $\dot{x}' = -q_{cc} \cdot p$。

Therefore, if $p \neq 0, q_{CC} \neq 0$, then $\dot{x}' < 0$, at that moment, $x^* = 0$ is the evolutionary stable equilibrium point; otherwise if $p = 0$ or $q_{CC} = 0$, then $x^* = 0$ is not an evolutionary stable equilibrium point.

(2) When $x^* = \sqrt[N-1]{\frac{p}{p+(r-1)c}}$:

Let $f(x) = U_C - U_D = -p + x^{N-1}(p + (r-1)c)$, apparently $f(0) = -p < 0, f(1) = (r-1)c > 0, f'(x) = (N-1)x^{N-2}(p + (r-1) \cdot c) > 0$, therefore $x^* = \sqrt[N-1]{\frac{p}{p+(r-1)c}}$ is the only root of $f(x)$ on $[0,1]$.

Otherwise $\dot{x} = x(q_{CC} - x) \cdot [-p + x^{N-1}(p + (r-1)c)] = x(q_{CC} - x) \cdot f(x)$,

$$\dot{x}' = (q_{cc} - 2x)f(x) + (q_{cc} - x)(N-1)x^{N-1}(p + (r-1)c) = (q_{cc} - x^*) \cdot (N-1) \cdot p$$

When $p \neq 0$, if $0 < \sqrt[N-1]{\frac{p}{p+(r-1)c}} < q_{cc}, \dot{x}' > 0, x^* = \sqrt[N-1]{\frac{p}{p+(r-1)c}}$ is the only internal unstable equilibrium point; if $q_{cc} < \sqrt[N-1]{\frac{p}{p+(r-1)c}} < 1, \dot{x}' < 0, x^* = \sqrt[N-1]{\frac{p}{p+(r-1)c}}$ is a stable equilibrium point for evolution.

(3) When $x^* = q_{cc}, \dot{x}' = -{q_{cc}}^N \cdot [p + (r-1)c] + q_{cc} \cdot p$

Therefore, when $q_{cc} > \sqrt[N-1]{\frac{p}{p+(r-1)c}}, x^* = q_{cc}$ is stable equilibrium point; otherwise, $x^* = q_{cc}$ is the only internal unbalanced and stable point.

The details are shown in Fig 4, 5, 6:

Fig 4 when p= 0

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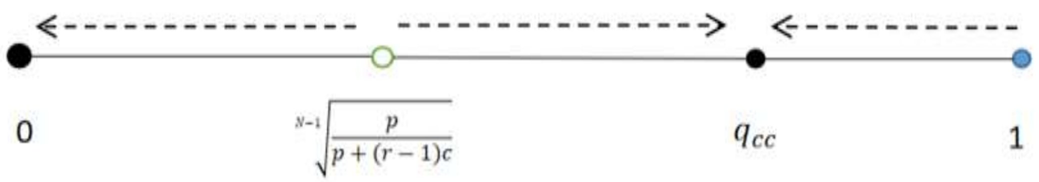

Fig 5 when $p \neq 0, q_{cc} > \sqrt[N-1]{\frac{p}{p+(r-1)c}}$

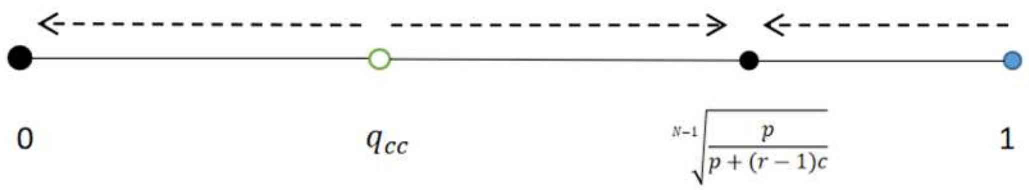

Fig 6 when $p \neq 0, q_{cc} < \sqrt[N-1]{\frac{p}{p+(r-1)c}}$

To sum up, when $p = 0, x^* = q_{CC}$ is the only stable equilibrium point under this mechanism; when $p \neq 0$, if $q_{cc} > \sqrt[N-1]{\frac{p}{p+(r-1)c}}$, then $x^* = 0, x^* = q_{CC}$ is stable equilibrium point; otherwise $x^* = \sqrt[N-1]{\frac{p}{p+(r-1)c}}$ is internal unique unstable equilibrium point; if $q_{cc} < \sqrt[N-1]{\frac{p}{p+(r-1)c}}$, then $x^* = 0, x^* = \sqrt[N-1]{\frac{p}{p+(r-1)c}}$ is stable equilibrium point, otherwise $x^* = q_{CC}$ is internal instability equilibrium.

Since the final evolution result of the population depends on the initial state of the system, the evolution trend is inferred according to the initial state of the system:

(1) When p= 0, as is shown in Fig 4, since $x^* = q_{CC}$ is the only stable equilibrium point, the final evolution of the system tends to support the proportion of consumers supporting crowdfunding close to q_{CC}.

(2) When $p \neq 0, q_{cc} > \sqrt[N-1]{\frac{p}{p+(r-1)c}}$, as is shown in Fig 5, 0, $\sqrt[N-1]{\frac{p}{p+(r-1)c}}, q_{cc}$, 1 divide the interval [0,1] into three regions.

①When the initial state is $[0, \sqrt[N-1]{\frac{p}{p+(r-1)c}}]$, evolution tends to have no support for crowdfunding, and the number of supporters is 0.

② When the initial state is $\left[\sqrt[N-1]{\frac{p}{p+(r-1)c}}, 1\right]$, evolution tends to support crowdfunding for

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consumers with q_{cc} probability.

(3) When $p \neq 0, q_{cc} < \sqrt[N-1]{\frac{p}{p+(r-1)c}}$, as is shown in Fig 6, 0, q_{cc}, $\sqrt[N-1]{\frac{p}{p+(r-1)c}}$, 1 divide the interval [0,1] into three regions.

① When the initial state is $[0, q_{cc}]$, the evolution tends to no one supports crowdfunding, and the number of supporters is 0.

② When the initial state is $[q_{cc}, 1]$, the evolution tends to support crowdfunding by consumers with $\sqrt[N-1]{\frac{p}{p+(r-1)c}}$ probability.

Crowdfunding will succeed only when N participants choose to support crowdfunding. Therefore, the above evolutionary analysis shows that the evolutionary results will not tend to be successful in any case. If you want the system to eventually evolve into crowdfunding success, you need to let $q_{cc} \to 1$ or $\sqrt[N-1]{\frac{p}{p+(r-1)c}} \to 1$, Since $c \neq 0$, that is, $q_{cc} \to 1$ or $r \to 1$ is required, and because r is clearly greater than 1. Therefore, only the case of $q_{cc} \to 1$ is considered.

When $q_{cc} = 1$, the mutation behavior will not exist. At that moment, the dynamics degenerates to the traditional replication dynamics, and only the selection mechanism is considered. At that moment:

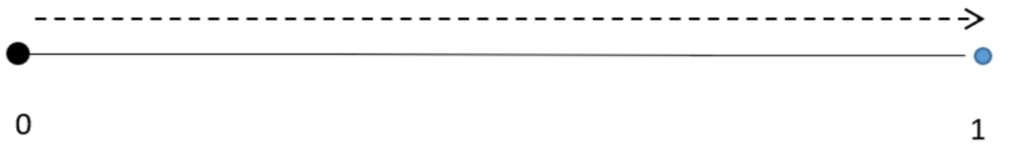

Fig 7 when p= 0

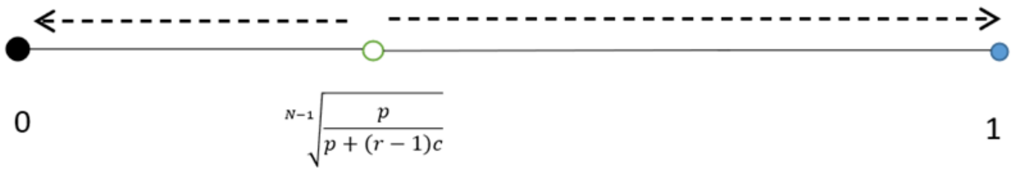

Fig 8 when p≠ 0

This is because the improvement mechanism takes into account the mutation, that is, in any state, consumers have a certain probability to change their strategy, and even if they choose to support, there is a certain probability of mutation to not support.

When $q_{cc} = 1$, if the regret caused by the failure of crowdfunding is not considered, the system will evolve into that everyone chooses to support crowdfunding regardless of the initial state of the group; If the degree of regret P is considered, the dominant strategy will also change with the change of

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$\sqrt[N-1]{\frac{p}{p+(r-1)c}}$, that is, crowdfunding is supported as the dominant strategy when $\sqrt[N-1]{\frac{p}{p+(r-1)c}} \to 0$; When $\sqrt[N-1]{\frac{p}{p+(r-1)c}} \to 1$, the system evolves into a dominant strategy that does not support crowdfunding.

VIII. SIMULATION EXPERIMENT

8.1 Evolution of consumer network game under traditional replication dynamics

Here, considering that the success of crowdfunding does not require the participation of all nodes in the network, but we only need some nodes in the whole participate in crowdfunding to meet the capital limit required by the initiator, therefore, we select some nodes in Facebook social data set from Stanford University to analyze the evolution of the consumer network. Here we set the number of nodes N = 100.

According to the traditional replication dynamics, the evolution equilibrium of consumer network in the process of crowdfunding is simulated. Assuming p= 5, r = 2 and c = 100, the mutation is not considered in the traditional complex dynamics, therefore q_{cc}=1. According to the above assumptions, it can be seen that $\sqrt[N-1]{\frac{p}{p+(r-1)c}} = 0.9003$. Therefore, a consumer network game evolution diagram based on traditional replication dynamics is obtained as shown in 5.1:

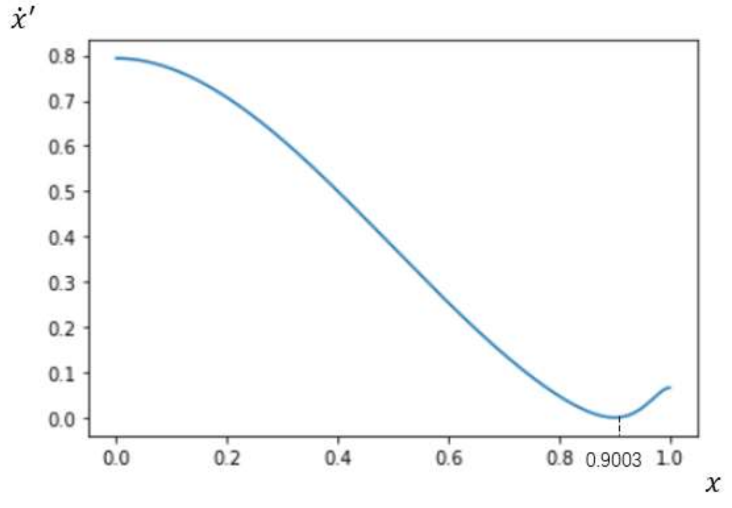

Fig 9 Evolution of consumer network game under traditional replication dynamics

In Fig 9, the abscissa represents the group state x, which is the proportion of individuals who choose strategy C in the group, and the ordinate represent $\dot{x}'$. It can be seen from the Fig that in the traditional replication dynamics, without considering the mutation factor, the system has two evolutionary stable equilibrium points, x = 0 and x = 1 respectively. And because the only internal disequilibrium stability

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point $\sqrt[N-1]{\frac{p}{p+(r-1)c}}$ of the system is 0.9003, therefore, the system evolves into a dominant strategy that does not support crowdfunding. When the proportion of strategy C in the initial state is greater than 0. 9003, the system will evolve to support crowdfunding as the dominant strategy, and crowdfunding will be successful.

1. When the initial state x=0.92>$\sqrt[N-1]{\frac{p}{p+(r-1)c}}$, the evolution trend of crowdfunding is shown in Fig 10:

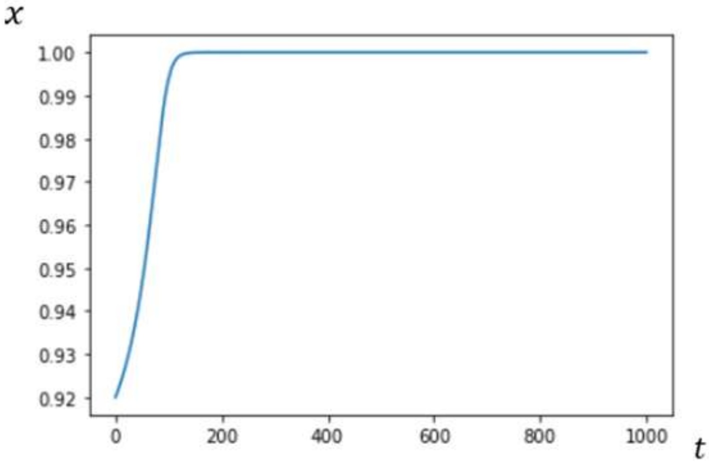

Fig 10 When initial state x = 0.92, crowdfunding evolution trend

From Fig 10, when the initial state x = 0.92, the system will evolve to support crowdfunding as the dominant strategy, and crowdfunding will succeed.

2. When the initial state x=0.3<$\sqrt[N-1]{\frac{p}{p+(r-1)c}}$, the evolution trend of crowdfunding is shown in Fig 11:

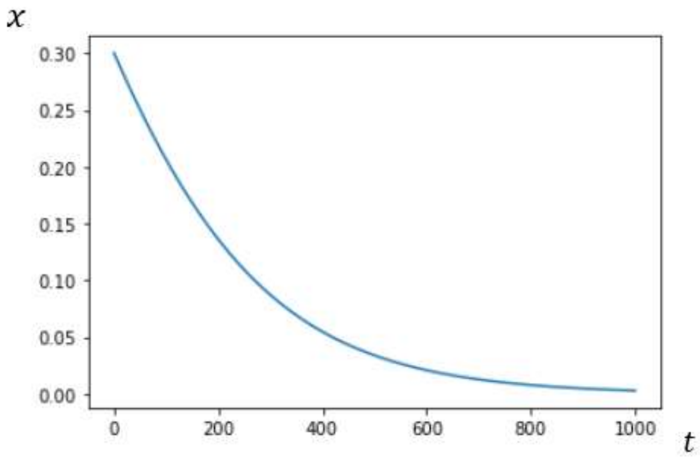

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Fig 11 When initial state x = 0.3, crowdfunding evolution trend

From Fig 11, when the initial state x = 0 3, the system will evolve into a dominant strategy that does not support crowdfunding, and crowdfunding will fail.

Under the traditional replication dynamics, whether crowdfunding evolves into support depends on whether the initial state is greater than $\sqrt[N-1]{\frac{p}{p+(r-1)c}}$. When p = 0, regardless of the regret caused by the failure of crowdfunding and the initial state, consumers support crowdfunding is the optimal strategy; the greater the cost c and return coefficient r, the easier the initial state fall between ($\sqrt[N-1]{\frac{p}{p+(r-1)c}}$, 1), which is also conducive to the success of crowdfunding.

8.2 Evolution of consumer network game based on optimal replication dynamics

In this section, the consumer network evolution equilibrium in the crowdfunding process will be simulated according to the replication dynamics with mutation under the probabilistic selection mechanism. Similarly, through the evolutionary game analysis of the above 100 consumer nodes, assuming p=5, q_{cc}=3/5, r=2, c=100, it can be seen that $\sqrt[N-1]{\frac{p}{p+(r-1)c}} = 0.9003$.

In the case of $p \neq 0, q_{cc} < \sqrt[N-1]{\frac{p}{p+(r-1)c}}$, we can obtain the game evolution analysis of consumer network based on optimal replication dynamics, as is shown in Fig 12:

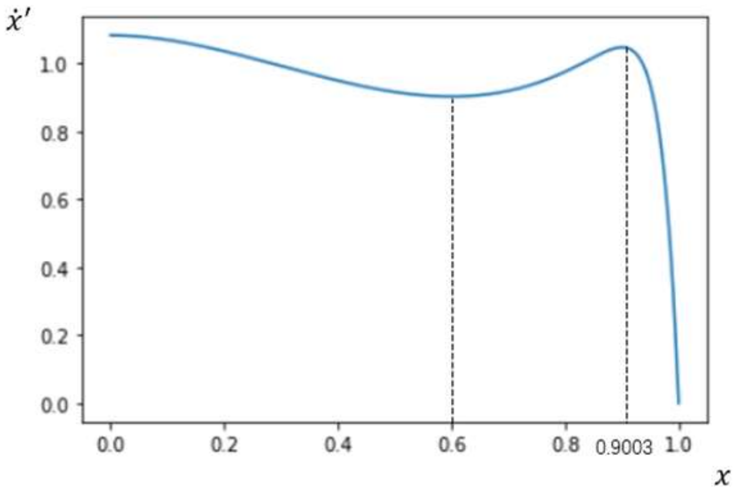

Fig 12 Evolution of consumer network game under optimal replication dynamics

Similarly, in Fig 12, the abscissa represents the group state x, which is the proportion of individuals who choose strategy C in the group, and the ordinate represents $\dot{x}'$.It can be seen from the Fig that in the replication dynamics with mutation, there are two evolutionary stable equilibrium points of the system,

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with x=0 and x=$\sqrt[N-1]{\frac{p}{p+(r-1)c}}$ respectively. And because the internal non-equilibrium stability pointq_{cc} of the system is 0.6. Therefore, when the proportion of strategy C in the initial state is (0,0.6), the system evolves into a dominant strategy that does not support crowdfunding, and eventually tends to not support crowdfunding at all; When the proportion of strategy C in the initial state is greater than 0.6 and less than 0.9003, or in the range of (0.9003,1), the system will evolve to exist at 0.9003 consumers choose to support crowdfunding. Due to the existing of mutation in the process of system evolution, all individuals cannot support crowdfunding.

1. When the initial state x=0.92>$\sqrt[N-1]{\frac{p}{p+(r-1)c}}$, the evolution trend of crowdfunding is shown in Fig 13:

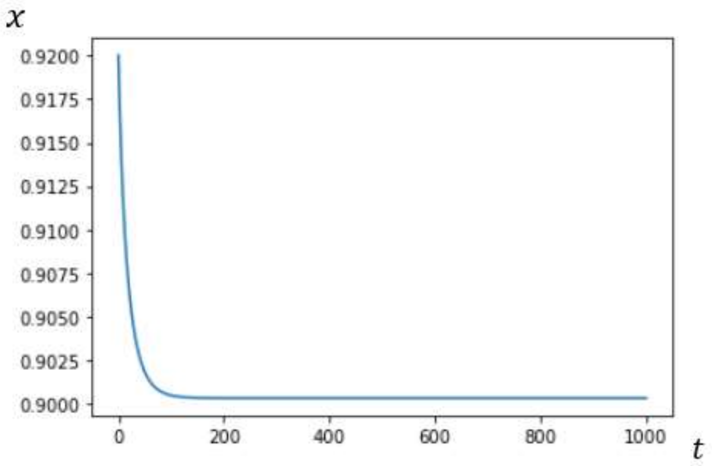

Fig 13 When initial state x = 0.92, crowdfunding evolution trend

From Fig 13, when the initial state x = 0.92, the system will evolve to exist 0.9003 consumers choose to support crowdfunding.

2. When the initial state is 0.6<x=0.8<$\sqrt[N-1]{\frac{p}{p+(r-1)c}}$, the evolution trend of crowdfunding is shown in Fig 14:

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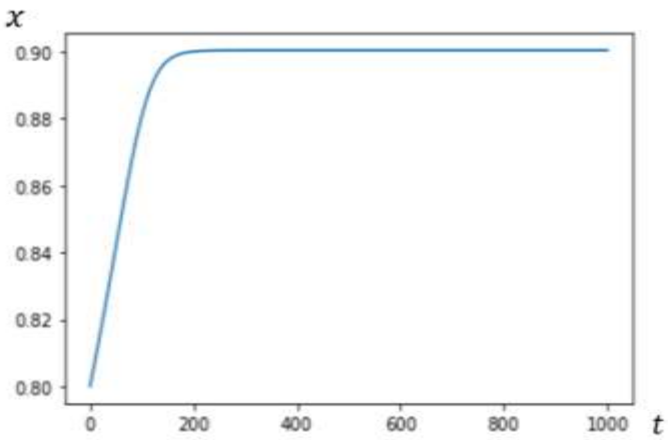

Fig 14 When initial state x = 0.8, crowdfunding evolution trend

From Fig 14, when the initial state x = 0.8, the system will evolve to exist 0.9003 consumers choose to support crowdfunding.

3. When the initial state x = 0.3<0.6, the evolution trend of crowdfunding is shown in Fig 15:

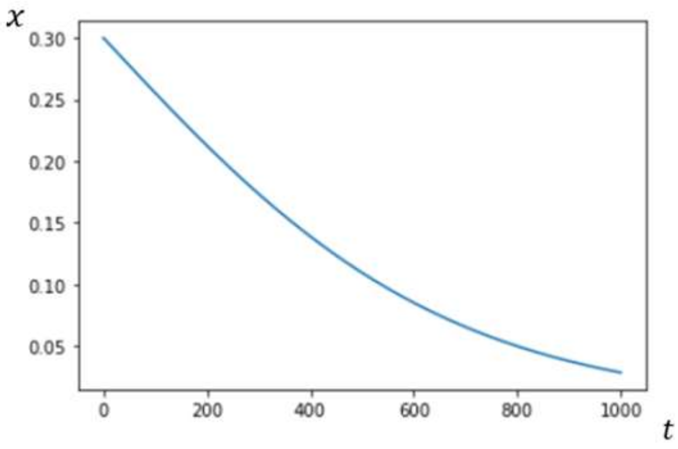

Fig 15 When initial state x = 0.3, crowdfunding evolution trend

From Fig 15, when the initial state x = 0.3, the system will evolve into a dominant strategy that does not support crowdfunding, and crowdfunding will fail.

The above simulation verifies the situation when $p \neq 0, q_{cc} < \sqrt[N-1]{\frac{p}{p+(r-1)c}}$. Similarly, when $p = 0$ and $p \neq 0, q_{cc} > \sqrt[N-1]{\frac{p}{p+(r-1)c}}$ can be obtained. In the optimized replication dynamics, due to the possibility of mutation of individual strategies, even if the initial state falls between q_{cc} and $\sqrt[N-1]{\frac{p}{p+(r-1)c}}$, it does not exist that all individuals choose to support crowdfunding, and the proportion of supporting individuals will tend to a stable state. The stable state depends on the larger

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value between q_{cc} and $\sqrt[N-1]{\frac{p}{p+(r-1)c}}$, crowdfunding evolution will be infinitely close to support with the increase of this value. Therefore, the existence of mutation inhibits the success of crowdfunding to a certain extent.

8.3 Commercial application value

According to the above simulation results, in order to better encourage consumers to participate in crowdfunding, promote the success of product crowdfunding projects and improve the success rate of crowdfunding, this paper puts forward several management suggestions:

(1) Directional marketing

In the product crowdfunding consumer network, the influence of the node determines whether other nodes copy the strategy of the node, Node influence is determined by node distance and node importance. The smaller the distance between nodes, the greater the importance, and the greater the influence of the node. Therefore, the sponsor should adopt the way of targeted marketing to encourage consumer groups to participate in product crowdfunding and promote the success of crowdfunding projects.

In the actual process of consumer crowdfunding, the crowdfunding platform can promote the nodes with greater influence and smaller average distance. First, through vigorously publicize groups with high social influence, such as star online celebrities, promote advertising and other cooperation; At the same time, more influential individuals should participate in crowdfunding and let more consumers know the project through marketing to specific groups, in order to achieve the purpose of full marketing. Secondly, pull and cultivate early supporters to make the initial support rate reach the peak after going online. Use social media to build communities and convey ideas and creativity of crowdfunding products; Conduct user surveys for target groups to let more people know about product projects. In addition, the sponsors of crowdfunding can conduct targeted product design for important groups to influence the surrounding people, so as to make the crowdfunding results tend to be cooperative and improve the probability of success of crowdfunding.

(2) Improve product quality.

Based on the optimized replication dynamics, it can be seen that mutation is the reason why crowdfunding cannot tend to cooperate. Therefore, it is necessary to make the mutation factor q_{cc} approach to 1, that is, consumers are expected to make decisions only by replicating others' strategies. Therefore, product quality is very important. By improving product quality, the actual benefits of products are greater than the expected benefits of consumers, so as to prevent consumers from changing their purchase behavior from the root.

The sponsors of crowdfunding should increase investment in technology and R&D, improve the quality of crowdfunding products, increase publicity, make consumers feel the value of the commodity, increase consumers' value expectation, and provide after-sales maintenance, replacement, return and other services. Provide consumers with a good crowdfunding consumption experience, reduce the mutation probability after choosing a support strategy, and then promote the success of crowdfunding.

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IX. CONCLUSION

China's crowdfunding industry started late with immature development, and the development of product crowdfunding is also in the preliminary stage. At the same time, the imperfections of relevant laws and regulations, risk control system and supervision also hinder the development of China's crowdfunding industry. To increase the activity of the crowdfunding industry and ensure the interests of sponsors and consumers, we should improve the success rate of crowdfunding as much as possible and improve the norms of the crowdfunding market. As an emerging capital market, the Internet financial market implies tens of thousands of consumer or investor group behavior decisions behind its vigorous development. The process of consumer behavior decisions is a complex dynamic game process. This paper discusses the game evolution of crowdfunding from the perspective of consumers, starts with customers, provides management suggestions for sponsors, and promotes the realization of crowdfunding projects.

According to the game model of public goods, this paper improves the traditional replication dynamics, introduces the selection mechanism and mutation mechanism of individual influence, establishes a crowdfunding consumer two strategy multi person evolutionary game system based on the improved replication dynamics, and analyzes the influence of mutation factors on the evolution of stable equilibrium. The results show that: (1) under the background of traditional replication dynamics, supporting crowdfunding and not supporting crowdfunding are evolutionary stability strategies. (2) Under the improved dynamic background, not supporting crowdfunding and partially supporting crowdfunding are evolutionary stability strategies, and the existence of mutation inhibits the success of crowdfunding to a certain extent. At the same time, in order to promote the success of crowdfunding projects, managers should enhance product influence and effectively encourage consumers to participate in product crowdfunding through targeted marketing; On the other hand, On the one hand, businesses should do their best to avoid mutations in consumers, improve product quality and improve consumer loyalty.

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