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Modeling and Analysis of Community Group Buying Product Information Dissemination Based on SEIR Model

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Abstract: This paper constructs a SEIR epidemic model that conforms to the community group buying product information dissemination in the WeChat social network based on the improved SEIR epidemic model, studies the dynamic information dissemination process of products in the WeChat social network, and compares the user's total number, infection probability and group effect on information dissemination. The results show that the user's total number is positively correlated with the information dissemination breadth, the larger the infection probability , the more users receive the information, the faster the information dissemination speed, the interest threshold in the group effect is positively correlated with the information dissemination speed, and the quality of the product will have a certain impact on the interest threshold. This paper has some reference value for the product information push mechanism and environment optimization of the community group buying platform.

Keywords: community group buying; information dissemination; SEIR model; social network

1.Introduction

Community group buying is a new retail method in which users rely on an online platform to place orders online for goods initiated by the group leader, and receive the goods offline at the group leader or pickup point. The head of the group is responsible for the display and purchase of the group purchase goods, but also responsible for maintaining the old users and broadening the new users. In the early stage of the development of the community group buying market, the platform recruits moms, small store owners or residents with a certain degree of influence in the community to become "group leaders" to accomplish the tasks of attracting customers and promoting the platform, and to complete the "last kilometer" in the supply chain through the provision of instant delivery services. The last kilometer" in the supply chain is accomplished by providing instant delivery services.

According to social science theory, the general pattern of human behavior is the S-O-R pattern, i.e., "stimulus-individual physiological, psychological-response". The model suggests that consumer buying behavior is caused by stimuli, which come from both physiological and psychological factors within the consumer's body and the external environment. Consumers are stimulated by various factors to generate motivation, driven by motivation, to make decisions to buy goods, the implementation of the purchase behavior, after the purchase of goods and their related channels and manufacturers to make evaluation, so as to complete a complete purchasing decision-making process. plays a dual role as a friend and a commercial entity, which positively affects consumers' trust and engagement actions.

The group leader in community-based group buying plays a dual role as a friend and a commercial entity, which positively affects consumers' trust and engagement actions[1]. As a member of a community group, the group leader accumulates more community resources - a wide social network - and is able to drive the consumption of the residents in the community, help the platform and the consumers to quickly establish trust, and provide consumers with responsive pre-sale and after-sale services as an intermediary[2]. As an intermediary, it provides consumers with responsive pre-sale and after-sale services. On the other hand, as one of the consumers using the platform, the "leader" has established a long-term stable customer base through the establishment of WeChat groups and circles of friends, and when he releases his experience or product information on the social platform, he can spread it among the community groups through the "third-person effect", forming a good product promotion effect[and]. When posting experience or product information on social platforms, the "third-person effect" spreads among community groups, forming a good product publicity effect. In the community group buying, the product information from the group leader can improve the exposure of the product and attract more users to buy. Based on the improved seir infectious disease transmission model, we can better simulate the process of information dissemination, and help the community group buying platform to manage

the information of commodities and make corresponding sales measures according to the scope and breadth of information dissemination.

Therefore, this article uses an optimized SEIR model to simulate and analyze the dissemination of product information, and considers the influence of user interest thresholds on the probability of dissemination. It has important reference value for the perception and information management optimization of commodity information dissemination on community group buying platforms.

2. Literature Review

2.1 Research on Community Group Buying

Social community buying refers to the practice of individuals coming together as a community to collectively determine what products and services they want to purchase, as well as when and how they want them to be marketed. This approach allows the community to have more control over their purchasing decisions and potentially obtain better prices. It also helps to reaffirm the community's identity[and]. In the context of online platforms, community commerce plays a crucial role in enabling transactions between strangers. Exclusive membership to closed groups, regulation and sanctioning of behavior, and a shared group identity are key trust mechanisms that foster trust between members who buy, sell, or share among themselves[and]. Gaining community buy-in is essential for the success of socially oriented programs such as urban farming. It involves aligning farm services with local residents' desires and addressing concerns about negative impacts on the neighborhood. Strategies for gaining community support include gaining entry into a neighborhood, introducing the idea for an urban farm, and engaging the neighborhood in the urban farm[and]. In the context of group offers, a social incentive structure can be established to encourage the sharing of offers within social circles. This structure provides a reward to the initial recipient if they share the offer with a second-level recipient who meets certain qualifications[and].Social media platforms have become integral to the purchasing decisions of consumers. Building online relationships, executing sales strategies for different platforms, and leveraging social media trends are key to growing sales and expanding customer bases. Online tools and analytics can be used to track social influencers and identify relevant conversations[and].

2.2 Research on SEIR Model

The SEIR model has been applied in various ways in social networks. One study explored the spread of public opinion in multi-layer networks, such as WeChat, Weibo, and Tiktok, and found that the multi-layer network had higher transmission efficiency and longer duration compared to single-layer networks[and]. Another study focused on the coupling between social networks and epidemic transmission, using a nonlinear dynamic model on a hyper network. The results showed that an individual's recovery rate is influenced by their social network and the degree of information forgetting[and]. Additionally, the SEIR model has been used to investigate the spread of infectious diseases in populations. Stochastic simulations were performed to analyze the effects of disease parameters and network characteristics on disease dynamics. It was found that infection and recovery rates, as well as the average degree of the network, significantly impact the spread of disease[and]. Furthermore, the SETQR model, an extension of the SEIR model, was proposed to study information dissemination in social networks. The model's equilibrium point and basic reproduction number were derived, and the effects of time lag, containment, and forgetting mechanisms on information dissemination were analyzed[and]. Lastly, the SEIR model was utilized for rumor source detection in online social networks. An optimal infection process was proposed, and an estimator for identifying the rumor source was derived. Experimental results showed the effectiveness of the proposed scheme[and].

3. Research Models and Parameter Interpretation

3.1 Construction of Social Network Dissemination Model for Community Group Buying

The main way of product information dissemination in community group buying platform is that the group leader sends the group buying product information to his direct group members through WeChat group and friends circle, and these direct group members will also share the product to other friends in the same way, and those who become group members through re-sharing are called secondary group

members in this paper, as shown in Fig. 1.

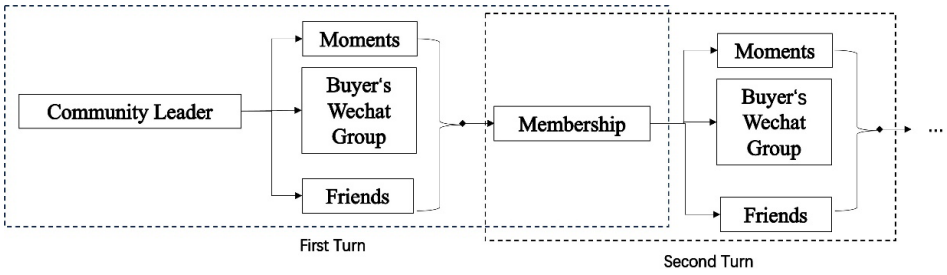

Fig. 1 Social Network Information Dissemination Model

According to the improved SEIR epidemic model[and], the users in the community group buying network are divided into four categories: users who have access to the "group leader" product push, that is, susceptible individuals (S state); users who buy products but do not forward and share, that is, latent individuals (E state); users who buy and forward the product information to friends circle or friends, that is, infected individuals (I state); users who lose interest in the product after seeing the product push, that is, immune individuals (R state).

3.1.1 Model assumptions

Susceptible individuals contact with infected individuals and become latent individuals, latent individuals become infected individuals after an average incubation period, infected individuals can be cured and become immune individuals, immune individuals are immune for life and no longer susceptible. One round is the minimum time unit.

3.1.2 Simulation experiment independent variable definition

The total number of users N, where the total number of users is fixed without considering user cancellation or registration. The number of rounds of product information dissemination is denoted as t, and the group leader's push of product information to group members is denoted as the first round of dissemination.

The ratio of each population to the total number of people in round T is denoted as s(t), e(t), i(t), r(t), respectively, and the number of each population is S(t), E(t), I(t), R(t).

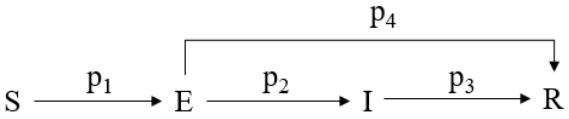

Fig. 2 The Improved SEIR Epidemic Model

(1) S→E represents that susceptible individuals browse the information and buy it without dissemination behavior and become latent individuals;

(2) E→I represents that latent individuals disseminate the product information to neighboring nodes and become infected individuals;

(3) E→R represents that latent individuals lose interest in the product and do not forward and share the product, and become immune individuals;

(4) I→R represents that infected individuals eventually lose interest in the information and become immune individuals;

The differential equations of the model's dissemination dynamics are as follows:

$$\frac{dS(t)}{dt} = -P_1 S(t) I(t) \quad (1)$$

$$\frac{dE(t)}{dt} = P_1 S(t) I(t) - (P_2 + P_4) E(t) \quad (2)$$

$$\frac{dE(t)}{dt} = P_2 E(t) - P_3 I(t) \quad (3)$$

$$\frac{dE(t)}{dt} = P_4 E(t) + P_3 I(t) \quad (4)$$

$$\mathrm{N} = \mathrm{S(t)} + \mathrm{E(t)} + \mathrm{I(t)} + \mathrm{R(t)} \quad (5)$$

In this paper, matlab software is used to simulate the dissemination model of group buying product information on WeChat social net-

work. In the information dissemination simulation modeling, the group leader and group members are abstracted as nodes in the network, and the fan relationship between the group members and the direct group members and the friend relationship between the group members are abstracted as edges in the network. The information is initially disseminated from the group leader node to the fan user node, and then forms secondary/third/... dissemination among the direct group member nodes and their friend nodes, until the system only has nodes in S state (susceptible) and R state (immune), the information dissemination stops, and the whole system is in a stable state.

3.2 Parameter Setting

For the convenience of model operation, this paper sets the initial value of the total number of users to 1000. The average number of contacts per person per day during the infection stage is 1.3 (ContactRateInfectious=1.3), and if the infected person (I) contacts the susceptible person (S), the infection probability of S is 0.6 (Infectivity=0.6). The incubation period lasts for 10 days after infection (AverageIncubationTime=10); exposed is used to describe people in the latent stage (E). The E stage ends and enters the infectious stage (I), which lasts for 15 days (AverageIllnessDuration=15). People who recover from the disease are immune to the second infection. That is, N0=1000, S=990, E=0, I=10, = 0.65, =0.5, =0.2, =0.15.

4.Simulation Results and Analysis

4.1 Initial Model

The results of the initial model run are shown in Fig. 3. The immune population increases to a certain extent and then stabilizes, and the susceptible population decreases to a certain extent and then stabilizes. The latent and infected populations show an initial increase and then a decrease and return to zero. The reason for this phenomenon is mainly because the latent and infected populations belong to transitional groups, and the increase and decrease of these groups require a certain amount of time, so they show a fluctuating rise and fall. Some susceptible individuals do not become latent because they are not interested in the product push information or are in an inactive state.

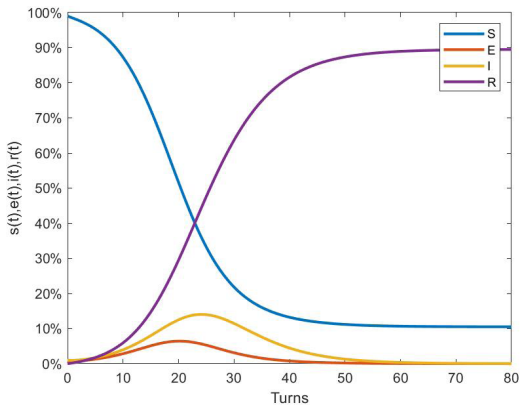

Fig. 3 Results of Initial Model Run

3.2 The impact of the total number of users on the spread

At present, the community group buying platform is still expanding rapidly, and the more members the group leader has, the more conducive it is to the development of the community group buying platform. Therefore, this paper will study the impact of the number of members that a group leader has on the purchase of products. In order to more objectively show the impact of the number of members on the peak value of the infected population, this paper uses the method of controlling variables, and only changes the number of members N, and sets N=2000, 4000, 6000. The results are shown in the following figures. By comparison, it can be seen that the curves shift to the right as a whole, and the number of rounds for the immune population ratio to start increasing increases with the increase of the total number of people, but the number of rounds required to stabilize is negatively correlated with the change of the total number of people. At the same time, the

number of rounds required for the latent and infected populations to reach the peak value also increases with the increase of the variable, and the time required to recover to zero also increases.

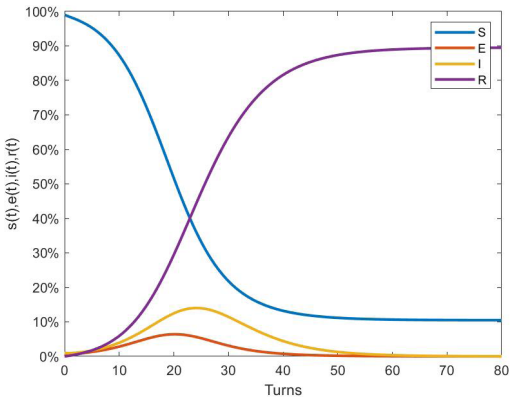

Fig. 4 N=1000

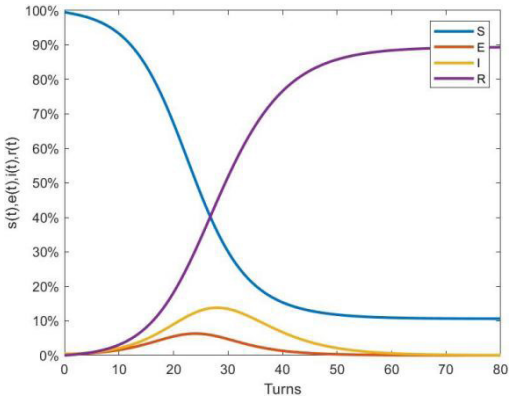

Fig. 5 N=2000

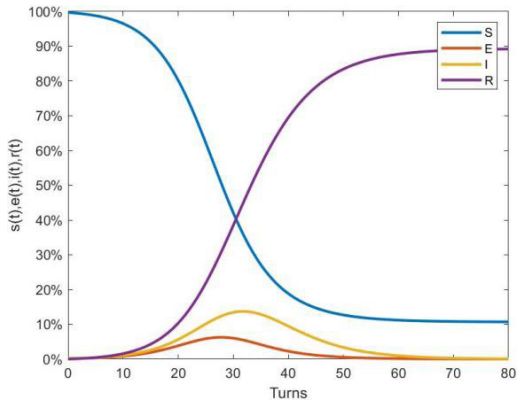

Fig. 6 N=4000

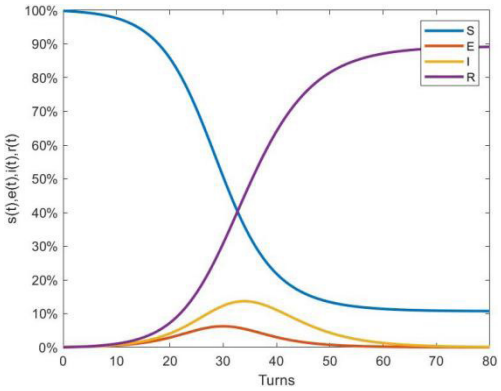

Fig. 7 N=6000

3.3 The impact of infection probability on the spread:

Users may not buy the product after seeing the product push sent by the group leader, because they are not interested in the product description or the product details description does not meet their expectations. The infection probability can convert the product information browsing volume into actual sales volume, which is an important link to convert the click-through rate into the purchase rate. In this experiment, the method of controlling variables is used, and only the value of is changed, and =0.4 and 0.8 are taken. The simulation results are compared as shown in the following figures. It can be seen from the comparison that the change of infection probability will affect the final number of susceptible and immune populations after stabilization, that is, the higher the value of , the lower the final proportion of susceptible population, and the higher the final proportion of immune population. In addition, the growth rate and peak value of the latent and infected populations are also affected by the change of infection probability . The higher the value of , the higher the peak value of the two groups, and the greater the increase and decrease. When the value of is low, the number of rounds required for information dissemination is also longer. This indicates that the higher the attractiveness of the product, the faster the information dissemination speed, the more people who receive the information, and the more people who buy the product.

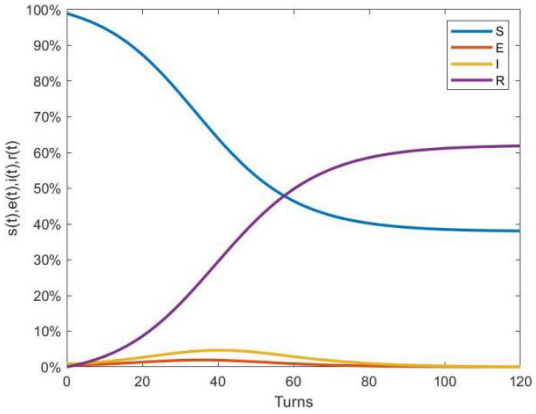

Fig. 8 P_1=0.4

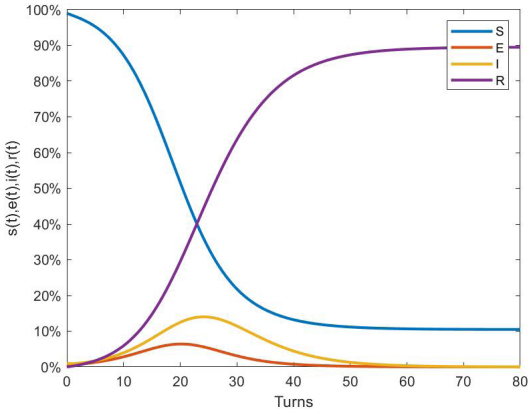

Fig. 9 P_1=0.65

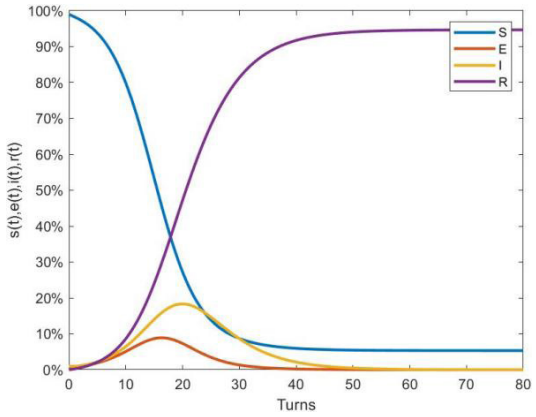

Fig. 10 P_1=0.8

3.4 The impact of transmission probability on the spread

The transmission probability is the probability that users choose to share the product, which can be understood as the willingness of users to strongly recommend others to buy the product. It is an important indicator to increase product sales and also affects the secondary sharing and dissemination of the product. The value of is affected by many factors, such as the quality, price, and purchase intention of others of the product. This paper mainly studies the impact of the interest threshold and disgust threshold of users affected by the circle effect on the transmission probability , and ultimately the impact on the product information dissemination.

The circle effect refers to the phenomenon that people gather together in social networks because of their interests, hobbies, occupations and other factors, forming different circles or groups, which have relatively little contact with each other. The WeChat circle is a interpersonal network based on the real social relationship, and the real interpersonal relationship is established, consolidated and strengthened by WeChat due to the acceleration of the pace of life. For example, the WeChat groups such as “work group”, “industry group”, and “family group” that are established through the group chat mode are all the maintenance and enhancement of real interpersonal relationships. The circle effect can improve the user stickiness and conversion rate of community group buying, because users can see the purchase behavior and evaluation of others in the WeChat group, thereby increasing trust and participation. The circle effect can also increase the richness and differentiation of community group buying products, because users can propose their own needs and suggestions in the WeChat group, thereby prompting the platform and suppliers to provide more diversified and personalized products. Therefore, the user’s sharing of community group buying products is affected by the interest level of other group members. The probability of an individual transforming from a latent to an infected person is related to the purchase situation of adjacent nodes as follows:

$$P_2 = \begin{cases} a \times (k + c) & , k \le k_0 \quad (6) \\ b \times (k_1 - k) + a \times c & , k_0 < k \le k_1 \quad (7) \\ 0 & , k_1 < k \quad (8) \end{cases}$$

Where, k represents the proportion of adjacent node users who buy the same product, P0 represents the user's interest threshold, and P1 represents the user's disgust threshold. a is the attractiveness of the product, $b=\frac{a \times k_0}{k_1 - k_0}$ represents the boredom of the product, that is, the degree of disgust for the product when knowing that the proportion of users who buy this product is too high. c represents the probability of users choosing to share because of the product quality.

This formula indicates that even if the user's interest in the product is low, the probability of choosing to buy and share the product will be higher if they are affected by the number of adjacent node users who buy the product. However, when the number of adjacent node users who buy the product is large, the user thinks that the value of forwarding the product is low, and the probability of choosing to forward it will decrease. When the proportion of adjacent node users who buy the product reaches a certain level, the user will stop sharing.

In this experiment, the method of controlling variables is used, and without changing the model structure and other parameters, let a=5,c=0.05, the interest threshold and disgust threshold are set to P_0=0.1, P_1=0.4 and P_0=0.6,P_1=0.9 respectively. After the comparative experiment, the following figure shows the running results. When the psychological threshold is low, it means that users are more sensitive to the opinions of the circle, and are more likely to lose interest in the product information. It can be seen from the comparison of the results that when the psychological threshold is low, the overall curve shifts to the right, the hesitation time becomes longer, the peak values of the latent and infected populations are relatively low, and the number of users who participate in the product purchase and forwarding is also relatively small. This shows that the interest threshold brought by the circle effect is positively correlated with the speed of information dissemination, and the quality of the product will have a certain impact on the height of the interest threshold.

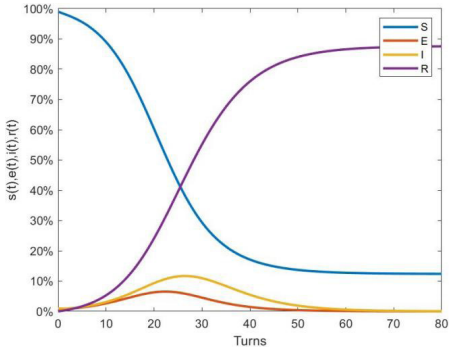

Fig. 11 k_0=0.1， k_1=0.4

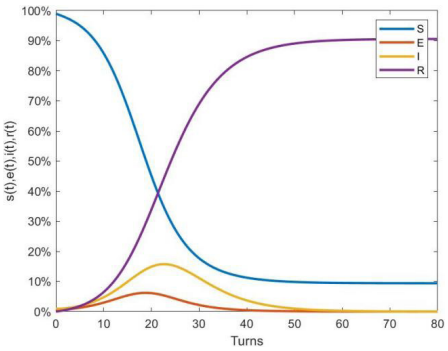

Fig. 12 k_0=0.6, k_1=0.9

4. Conclusion and Suggestions

Based on the information dissemination process of community group buying products in the WeChat social group centered on the group leader, this paper constructs a SEIR infectious disease model that conforms to the information dissemination in the WeChat social network based on the improved SEIR infectious disease model, studies the dynamic information dissemination process of products in the WeChat social network, and compares the effects of user total number, infection probability , and group effect on information dissemination. Based on the experimental results, the following conclusions and suggestions are made:

(1) The impact of user total number on information dissemination: The user total number is positively correlated with the information dissemination breadth, and the time required for users who receive the information to reach a stable state is also longer. That is, the more members the group leader has, the longer the information dissemination takes. The suggestion for this is that although community group buying is still expanding the number of users as the main goal, but because the more members the group leader has, the slower the information dissemination speed. Community group buying platforms can recruit more group leaders, disperse the resources in the hands of one group

leader, and speed up the information dissemination. At the same time, the products purchased by each group leader are homogenized, that is, each group leader recommends the same product, which does not affect the information dissemination range in this way. However, it should be noted that one member may be in the range of multiple group leaders, resulting in inaccurate user actual numbers.

(2) The impact of infection probability on information dissemination: The larger the value of infection probability , the more users who receive the information, the faster the information dissemination speed, and the longer the time required for the system to reach a stable state. The suggestion for this is to optimize the product information push interface, make the product push more attractive to users, and increase the product purchase rate. You can also reward and punish the group leader, use the reward and punishment mechanism, and increase the enthusiasm of the group leader to sell the product.

(3) The impact of transmission probability on information dissemination: This paper considers the impact of group effect, and determines the user interest threshold and disgust threshold range, and obtains that the higher the interest threshold and disgust threshold, the faster the product information dissemination speed, and the faster the transmission peak is reached. The speed is faster, and the time required for the system to reach a stable state is shorter. Based on the above results, community group buying platforms can provide diversified and personalized products, increase user interest threshold for products. In addition, the platform can also stimulate the user's interest threshold through various preferential promotions and increase the product sharing rate. Or based on the group effect, promote the product, users will be more likely to buy and spread the product because of the large number of surrounding buyers.

In summary, if community group buying platforms want to increase product information dissemination and product purchases, they need to consider not only the cost-effectiveness of the product itself, but also the product information push mechanism and environment, and consider various variable influencing factors.

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