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Research on the Influence Mechanism of Consumer Network Structure on the Diffusion of New Products of Technology Proximity Based on Rate-Variable Fundamental In-Tree Method

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Abstract:

In view of this, based on the analysis of consumer decision-making process, this paper makes use of the advantages of system dynamics in characterizing the complexity of the system to make up for the lack of "explanation" of the traditional Bass model. By constructing the rate-variable fundamental in-tree modeling, it explores the influence of three main variables, namely average path length of consumer network, average degree and reconnection probability of network on the new product diffusion in the technology proximity, in order to provide some ideas and methods for the related research and some theoretical references for the decision makers of new product diffusion in the technology proximity. The process of consumers' adoption of new products in the technology proximity is a risk decision-making process under the condition of asymmetric information between consumers and manufacturers. Generally, it goes through three stages of information acquisition, utility evaluation and adoption and feedback. Questions addressed the analysis of consumers' decision-making process, this paper constructs a system dynamics model of new product diffusion in the technology proximity by using rate-variable fundamental in-tree modeling to investigate the influence of consumer network structure variables on new product diffusion in the technology proximity. Results show that the influence direction of average path length of consumer network on new product diffusion in the technology proximity has nothing to do with the characteristics of consumer preference. Increasing average path length of consumer network will always reduce the overall potency of new product diffusion in the technology proximity. The average of consumer network and the probability of network reconnection are positively correlated with the changing trend of new product diffusion in the technology proximity under the characteristics of consumer convergence preference, but negatively correlated with the characteristics of consumer differentiation preference. The results of this study suggest that when making new product promotion strategies, decision makers should first judge the preference types of consumers of new products in the technology proximity to be promoted. For example, consumers of daily consumer goods generally have the characteristics of convergence preference, while consumers of luxury goods generally have the characteristics of differentiation preference. Then, based on the types of consumers' preferences, the promotion areas of new products are targeted. Under the condition of consumers' convergent preferences, decision makers should choose areas with low average path length, high network average and high network retraining probability to promote new products in the technology proximity, which will achieve better diffusion effect. On the contrary, under the condition of consumers' differentiated preference, it is necessary to choose areas with low average path length, low average network degree and low network retraining probability for the promotion of new products in the technology proximity. Among them, the average degree, retraining probability and average path length of consumer network can be obtained by social network analysis methods such as questionnaire survey and statistical analysis. After analyzing and explaining its internal mechanism, the research conclusions have certain reference significance for enriching the theory of new product diffusion and formulating new product promotion strategies.

Keywords: *Rate-variable fundamental in-tree method, Network structure, New product diffusion, Influence mechanism, Technology proximity*

I. BACKGROUND

The diffusion of new products is an important driving force for social and economic development. Once the new products are integrated into the general and large-scale production process and effectively promoted and popularized, their potential economic benefits can be brought into full play, thus leading to the improvement of the overall technical level and welfare of society. Therefore, the diffusion of new products has always been a hot issue in the field of social and economic management. Scholars at home and abroad have also developed a series of models to predict and explore the diffusion law of new products. Among them, Bass model [1] and its extended models, such as time-varying parameter model [2], repeat purchase diffusion model [3], time delay model [4] and multiple influence model [5], are the most famous models, which are also called Bass model cluster. Bass model cluster focuses on how to use mathematical statistics to predict the degree and speed of new product diffusion more accurately under as few assumptions as possible, greatly simplifying the process of new product diffusion, and providing a concise analysis idea and feasible operation method for people to study new product diffusion.

The development and perfection of Bass model cluster provides rich theoretical reference for the research of new product diffusion, but there are still some limitations. First of all, the Bass model cluster models the diffusion process of new products under strict assumptions. Due to the limitation of historical data and the difficulty of data acquisition, the factors considered are very limited, which are insufficient to analyze and grasp the overall complexity of the system and the internal feedback mechanism, and lack of explanation for the internal mechanism of new product diffusion [6]. Secondly, although there are many kinds of Bass model clusters, they are basically built with "internal influence coefficient" [7] and "external influence coefficient" [8] as the core, and the main driving force of new product diffusion is positioned on two factors, namely, mass media and oral communication, but the structural factors of consumer network, which are crucial to new product diffusion, are not considered. The diffusion of new products refers to the process of new products spreading in the social system over time through a certain channel, and its essence is a kind of cognition and adoption behavior of potential adopters in the diffusion network [9]. The elements of consumer network structure are very important to the diffusion of new products, which is what Bass model cluster ignores at present.

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In view of this, based on the analysis of consumer decision-making process, this paper makes use of the advantages of system dynamics in characterizing the complexity of the system to make up for the lack of "explanation" of the traditional Bass model. By constructing the rate-variable fundamental in-tree modeling, it explores the influence of three main variables, namely average path length of consumer network, average degree and reconnection probability of network on the new product diffusion, in order to provide some ideas and methods for the related research and some theoretical references for the decision makers of new product diffusion.

II. SUBJECTS AND METHODS

The process of consumers' adoption of new products is a risk decision-making process under the condition of asymmetric information between consumers and manufacturers [10]. Generally, it goes through three stages [1,11,12] of information acquisition, utility evaluation and adoption and feedback. The specific contents are as follows:

2.1 Information Acquisition

Before adopting a new product, consumers will first search for information about the price, appearance, function and other aspects of the new product. There are two main channels of information acquisition: mass media and interpersonal communication networks. Among them, the mass media (including radio, television, newspapers and magazines, etc.) regularly disseminate information about new products in the form of "pulse" [11], which covers a wide range of information but is not detailed enough. Interpersonal communication network mainly disseminates by oral communication through the daily contact of consumers, which is more detailed and true than the mass media.

2.2 Utility Evaluation

After knowing the basic information of a new product, consumers will not buy it immediately, but will evaluate the utility it can bring to themselves. Only when the evaluated utility is greater than their psychological expectation can they adopt the new product. In this process, consumers' evaluation of new product utility mainly includes two aspects: ① new product attribute utility. It mainly refers to the utility brought by the performance to consumers, including two parts: consumer perceived usefulness and perceived ease of use; ② Social utility of new products. It mainly refers to local network effects such as "group" recognition and realization of personal values obtained by consumers after adopting this new product.

2.3 Adoption and Feedback

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When the utility evaluation is less than their own adoption threshold, consumers will give up adopting the new product, but when it is greater than the threshold, they will adopt with a certain probability. The reason why it is a certain probability, rather than necessity, is consumers' forward-looking behavior [13], such as expecting the price of the new product to decrease or some properties of the new product to be improved in the future, etc., so they will choose to adopt the new product after a certain time delay. Consumers who give up adopting new products will convey negative word-of-mouth of new products to potential consumers, while those who adopt will give back positive word-of-mouth, as shown in Figure 1.

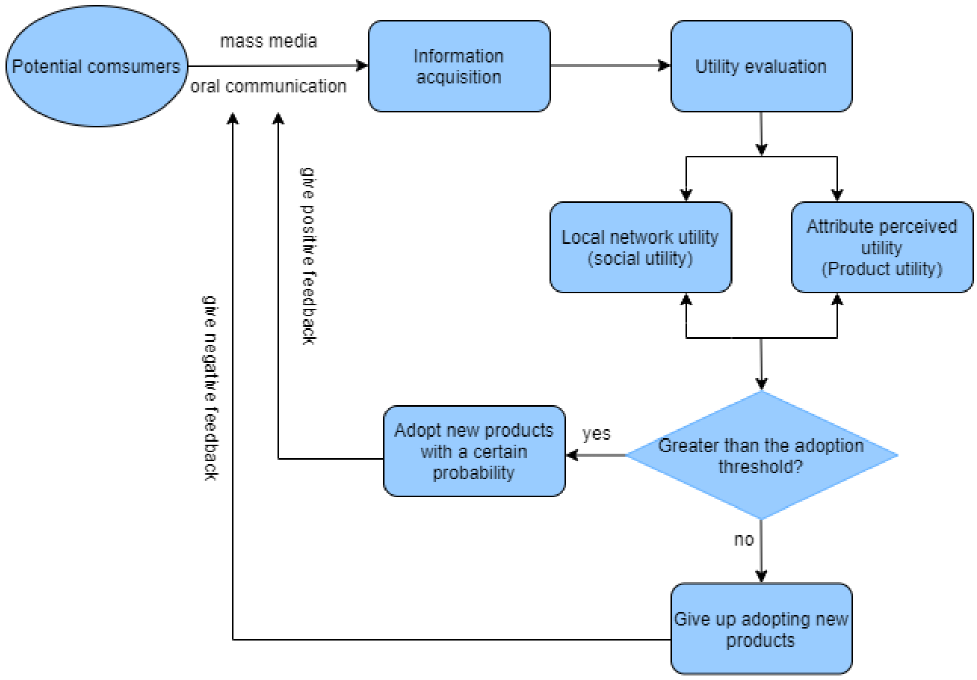

Figure 1. Schematic diagram of consumer decision-making process

III. SYSTEM DYNAMICS MODEL OF NEW PRODUCT DIFFUSION

3.1 Model Boundary

Based on the above analysis of consumer decision-making process, this part will refine the key variables to form the system boundary of new product diffusion. Among them, the main flow variables of the model include the number of potential consumers, the number of consumers who have learned new product information and adopted new product information. The main flow rate variables include new product information dissemination rate and adoption rate. The main auxiliary variables include consumer interpersonal communication network influence coefficient, mass media influence coefficient, social utility, attribute utility, adoption willingness and adoption probability of new products, etc. Constants mainly include average path length of consumer network, network average, network reconnection probability, etc. The variables involved in this model cover the whole process of new product diffusion, and the basic problems of new product diffusion studied can be reflected through these variables and the relationships

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among them. Therefore, the boundary of the model constructed in this paper is approximately consistent with the actual system.

3.2 Model Construction Method

In this paper, the system dynamics model of new product diffusion will be built by using the rate-variable fundamental in-tree modeling, which is created by Professor Jia Ren 'an of Nanchang University and his research team. Based on the idea of reductionism, this method applies the spanning tree protocol in graph theory to the analysis of complex feedback structure of dynamic system, describes the causal relationship among variables in the system by using a set of tree models with flow rate variables as the root, and then constructs the system chart by embedding operation, so as to explore the changing rules and dynamic functions of the whole system during the change of flow rate variables [14]. The flow rate basic tree-entry method can more intuitively understand the modeling process of complex systems and the characteristics of each basic model, which is helpful to further understand the operation rules of the system. The concept is as follows:

Definition 2.1

With flow rate as the root of the tree, through auxiliary variables, each flow rate Ri(t) can be replaced by variables in the tree model, and Ri(t) can only depend on flow rate variables through auxiliary variables. In-tree T(t) is called rate-variable fundamental in-tree modeling.

Rate-variable fundamental in-tree basic mode

According to the interaction relationship among various flow level variables, flow rate variables, auxiliary variables and constant selection in the process of new product diffusion, the following six S D flow rate basic in-tree basic mode are established, as shown in Figure 2(a)- Figure 2(f):

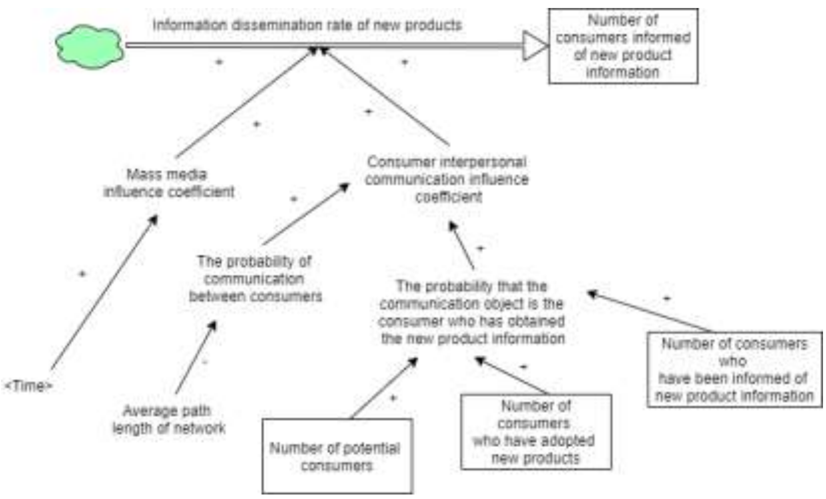

Fig. 2(a) Basic mode of New Product Information Dissemination

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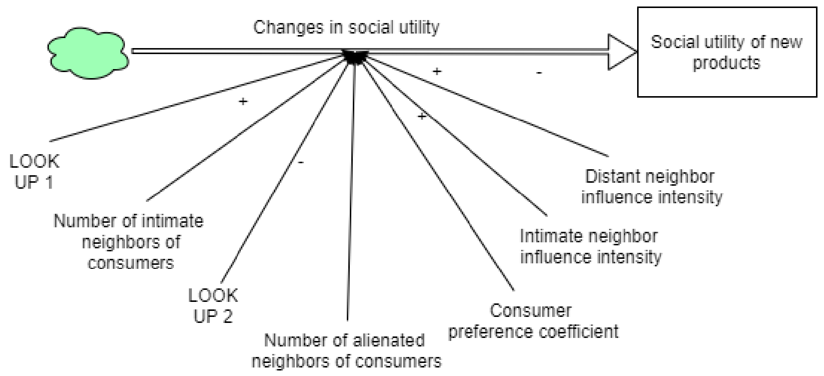

Figure 2(b) Basic mode of social utility evaluation of new products

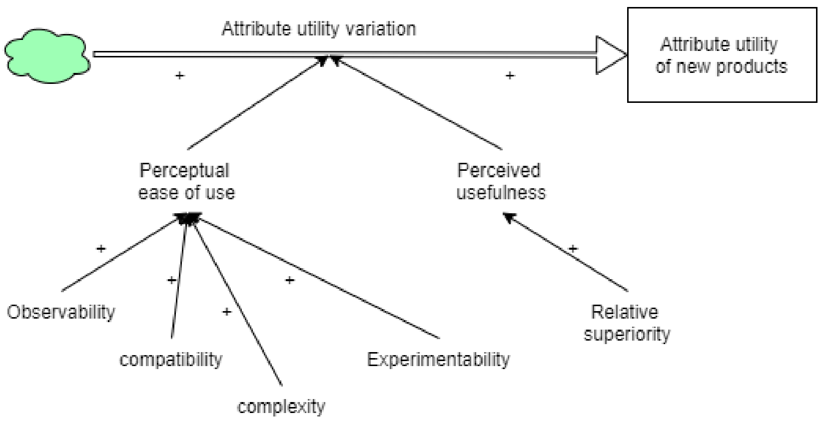

Fig. 2(c) Basic mode of new product attribute utility evaluation

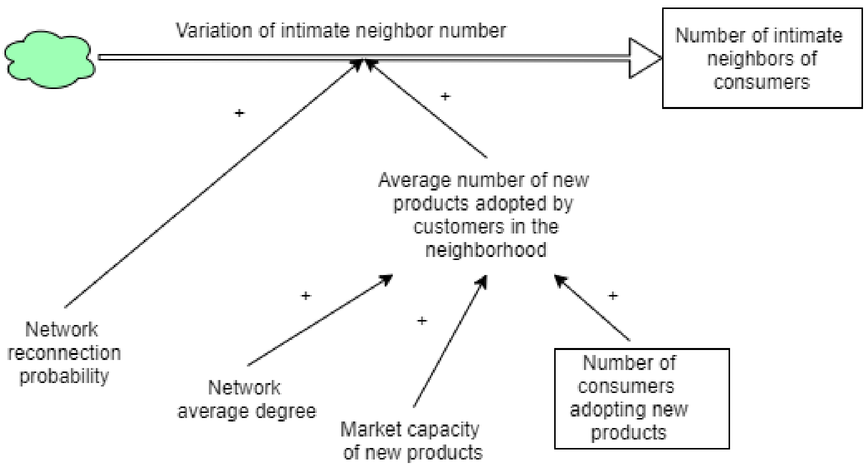

Fig. 2(d) Basic mode of the number of consumers' intimate neighbors

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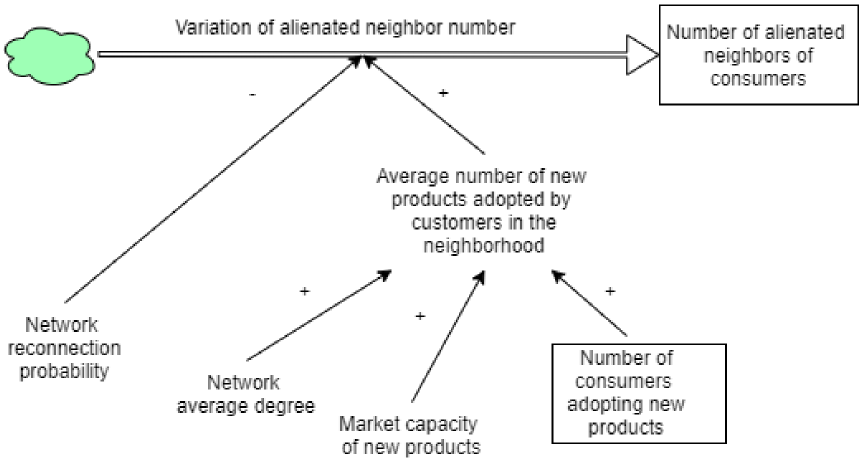

Figure 2(e) Basic mode of the number of distant neighbors of consumers

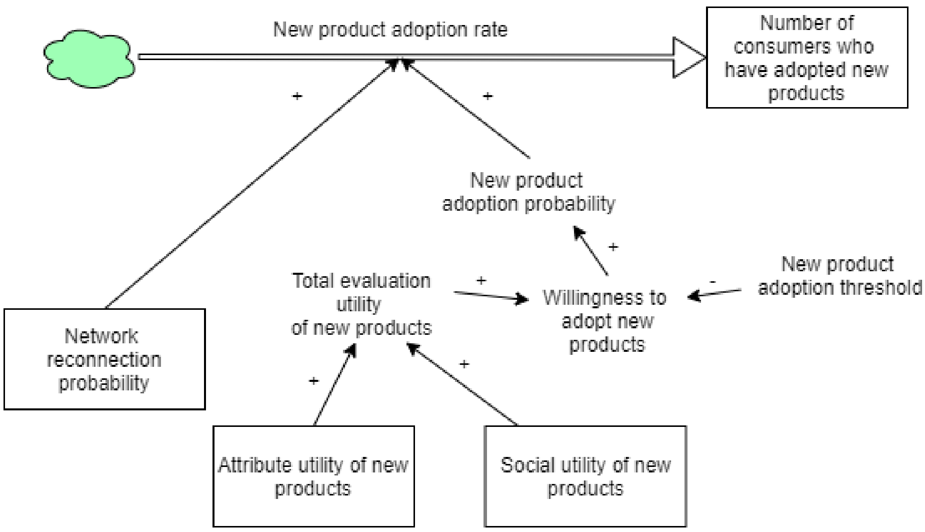

Figure 2(f) The new product adoption template integrates these figures together.

3.3 Basic Mode Equation Setting

3.3.1 The basic model equation setting of new product information dissemination

Bass model holds that the transmission rate of new product information is mainly influenced by the influence coefficient of mass media, the influence coefficient of consumer interpersonal communication and the number of potential consumers [14]. Based on this, the specific equations in this part are set as follows:

① New product information dissemination rate = number of potential consumers who have not been informed of new product information * (consumer interpersonal communication influence coefficient + mass media influence coefficient)

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② According to the advice of Jeuland scholars, set the influence coefficient of mass media below 1%, and set it as the table function of the time variable < time >, and each iteration decays at a rate of 0.2%.

③ Consumer interpersonal communication influence coefficient = the probability that the communication object is the consumer who knows the new product information * the probability that any two consumers in the network communicate.

④ The probability that the object of communication is consumers who know new product information = (number of consumers who have adopted new products + number of potential consumers who have learned new product information)/(number of consumers who have adopted new products + number of potential consumers who have learned new product information + number of potential consumers who have not learned new product information)

⑤ The probability of communication between any two adopters in the network =1/ average path length of the network

3.3.2 Setting the social utility basic model equation of new products

The social utility of new products mainly affects consumers' adoption behavior through the structure of consumers' neighbors. Under the condition of consumers' convergence preference, the more people adopt new products among consumers' neighbors, the greater the social utility that new products bring to consumers. On the contrary, under the condition of consumers' differentiation preference, the more people adopt new products among consumers' neighbors, the smaller the social utility that new products bring to consumers. The specific equations in this part are set as follows:

⑥ Social utility of new products =IF THEN ELSE (consumer preference coefficient > =0, LOOK UP 1 ((number of intimate neighbors * influence intensity of intimate neighbors + number of alienated neighbors * influence intensity of alienated neighbors) *ABS (consumer preference coefficient)), LOOK UP 2 ((number of intimate neighbors * influence intensity of intimate neighbors + number of alienated neighbors * influence intensity of alienated neighbors) *ABS (consumer preference coefficient).

3.3.3 Setting of new product attribute utility basic model equation

Drawing lessons from the viewpoint of TAM 2 (Venkatesh V, Davis F D, 1996) [15] model, this section takes the perceived usability and perceived usefulness of consumers as two indicators of new product attribute utility evaluation, in which the relative superiority of new products is positively correlated with perceived usefulness of consumers, the observability, operability and experimentability of new products are positively correlated with perceived usability of consumers, and the complexity is negatively correlated with perceived usability of consumers. The specific equations in this section are set as follows:

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⑦ new product attribute utility = perceived ease of use + perceived usefulness

⑧ perceived ease of use =WITH LOOKUP (compatibility + observability + experimental - complexity), ([(0,0)-(10,10)], (0,0), (0.25,0.2), (0.5,0.4), (0.75,0.0)

⑨ Perceived usefulness =WITH LOOKUP (relative superiority, [(0,0)-(10,10)], (0,0), (0.15,0.2), (0.45,0.4), (0.75,0.6), (1,1)

3.3.4 Setting the basic mode equation of the number of intimate neighbors and alienated neighbors of consumers.

In the complex network theory, the network reconnection probability ϕ represents the proportion of intimate neighbors among the "neighbors" of each consumer on average [9], and the proportion of distant neighbors of consumers is 1-ϕ. Among them, the average number of neighbors around consumers who have adopted new products is mainly related to the average degree of consumer network, the number of consumers who have adopted new products and the market capacity of new products. The equations in this part are set as follows:

⑩ Attending the number of alienated neighbors = the average number of consumers' neighbors who have adopted new products *(1- network reconnection probability)

⑪ Number of intimate neighbors = average number of consumers' neighbors who have adopted new products * network reconnection probability

⑫ Average number of customers who have adopted new products among neighbors = (number of customers who have adopted new products/market capacity of new products) * network average

3.3.5 New products adopt the basic model equation setting

When the potential consumers who have been informed of the new product information evaluate the total utility of the new product more than its threshold value, they will adopt the new product with a certain probability, otherwise they will give up the adoption of the new product. The adoption probability is positively related to the degree that the total utility evaluation of the new product is more than its adoption threshold value. The equation in this part is set as follows:

⑬ Number of consumers who have adopted new products =INTEG (new product adoption rate, 0)

⑭ Adoption rate of new products = probability of adoption * number of potential consumers who have been informed of new product information

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⑮ Number of potential consumers who have been informed of new product information =INTEG (new product information dissemination rate-new product adoption rate, 0)

⑯ Adoption probability =WITH LOOKUP (willingness to adopt, [(0,0)-(10,10)], (0,0), (0.2,0.025), (0.4,0.05), (0.6,0.075), (0.7,0.15)

⑰ Willingness to adopt = total evaluation utility of new products-adoption threshold = total evaluation utility of new products + social utility of new products.

IV. MODEL SIMULATION AND RESULT ANALYSIS

In this part, we will use Vensim PLE software to simulate and analyze the flow rate of new product diffusion into the tree model under the two situations of consumers' convergence and differentiation preference characteristics. The basic initial parameters of the model are set as follows: INITIAL TIME=0, FINAL TIME=100, TIME STEP=0.25, Units for Time: Week, new product market capacity =2000, distant neighbor influence intensity =0.3, intimate neighbor influence intensity =0.7, adoption threshold =0.05, and relative superiority =0.758. Complexity =0.235, compatibility =0.425, experimentability =0.611, observability =0.521 (Note: the assignment of each model parameter in this part is a set of random simulation data given under the condition of not affecting the trend change and comparability of the model).

4.1 Model Simulation Analysis of Consumer Convergence Preference Situation

4.1.1 Average path length of network and innovation diffusion

Set the parameter values of the network average variable to 1-4-7-9 respectively, and simulate and analyze the model in two scenarios of consumer convergence preference (Scheme 1) and differentiation preference (Scheme 2), and get two simulation schemes, as shown in Figure 3 (a)-3 (d):

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Scheme 1 simulation results:

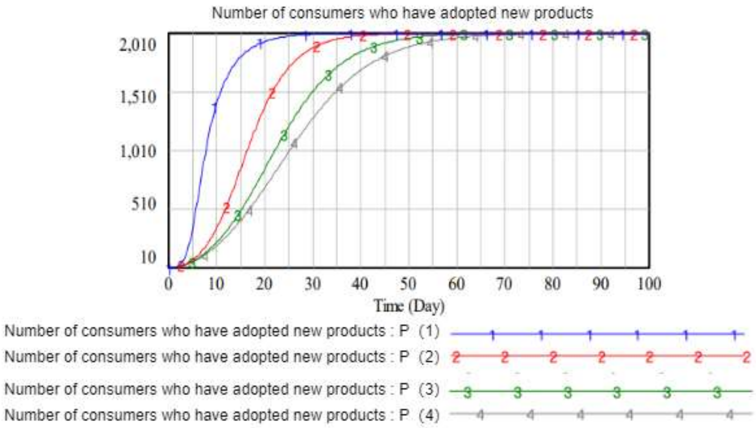

Figure 3(a) Trends in the number of consumers who have adopted new products

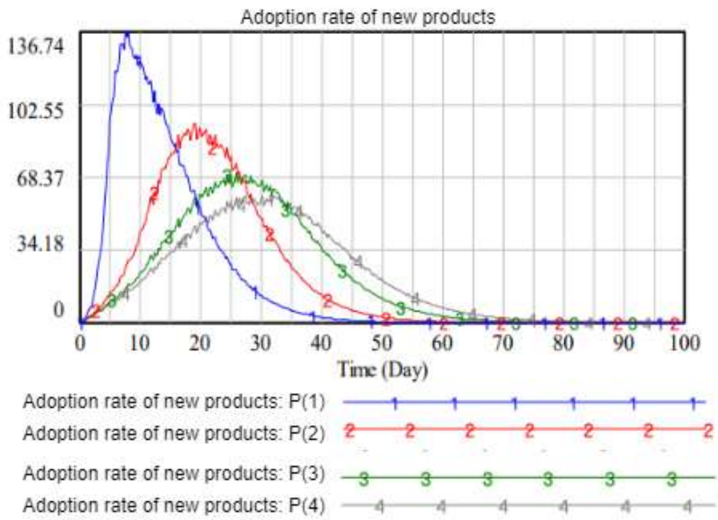

Figure 3(b) Change trend of new product adoption rate

Scheme 2 simulation results:

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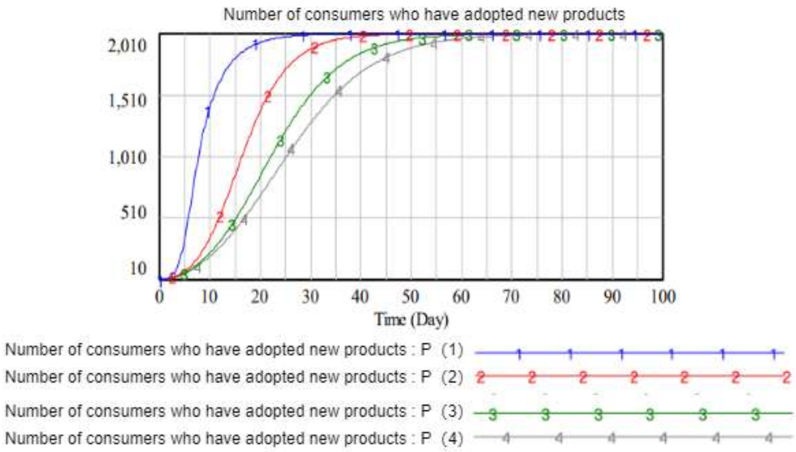

Figure 3(c) Changing trend of the number of consumers who have adopted new products

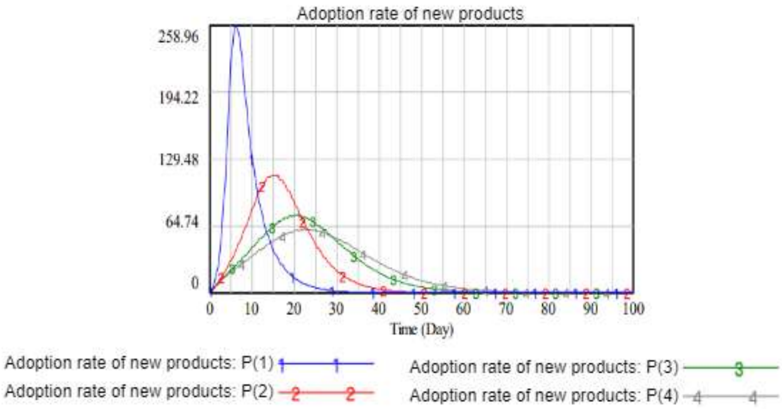

Figure 3(d) Change trend of new product adoption rate

From 3 (a) to 3 (d), it can be seen that increasing the average path length of consumer network will always reduce the overall efficiency of new product diffusion, whether in the context of consumer convergence preference or consumer differentiation preference. This is because the increase of the average path length of the consumer network will increase the average difficulty of communication between any nodes in the consumer network, thus reducing the influence coefficient of consumer interpersonal communication, and then delaying the whole process of new product diffusion. However, because there is no direct causal relationship between the average path length of the consumer network and the consumer preference coefficient, the influence direction of the average path length of the consumer network on the new product diffusion will not be influenced by the consumer preference characteristics. At the same time, although the increase of average path length of consumer network will reduce the overall efficiency of new product diffusion, it will not make the new product diffusion rate show absolute speed. As can be seen from Figure 3(b) and Figure 3(d), the new product diffusion rate shows a very complicated dynamic change process under different network average path length parameter settings, so in the actual decision-making process, scientific analysis should be carried out according to the system dynamics model of new product diffusion to effectively grasp the overall law of new product diffusion.

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4.1.2 Network average and new product diffusion

Set the parameter values of the network average variable to 15-35-55-75 respectively, and simulate and analyze the model in two scenarios of consumer convergence preference (scheme 1) and differentiation preference (scheme 2), and get two simulation schemes, as shown in Figure 4 (a)-4 (d).

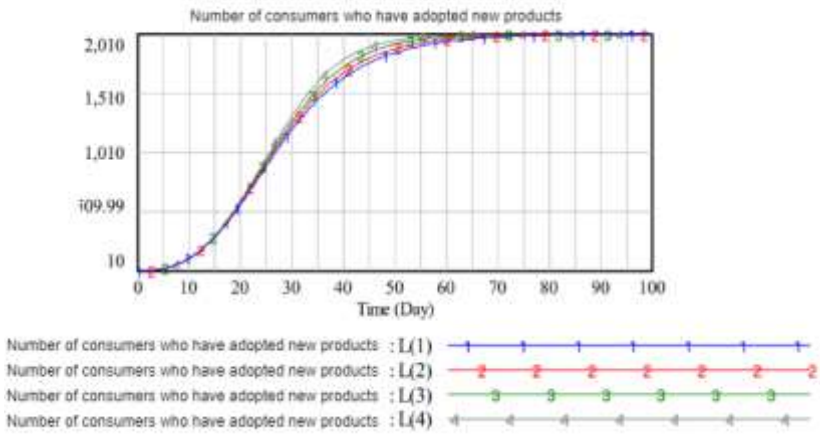

Figure 4(a) Trends in the number of consumers who have adopted new products

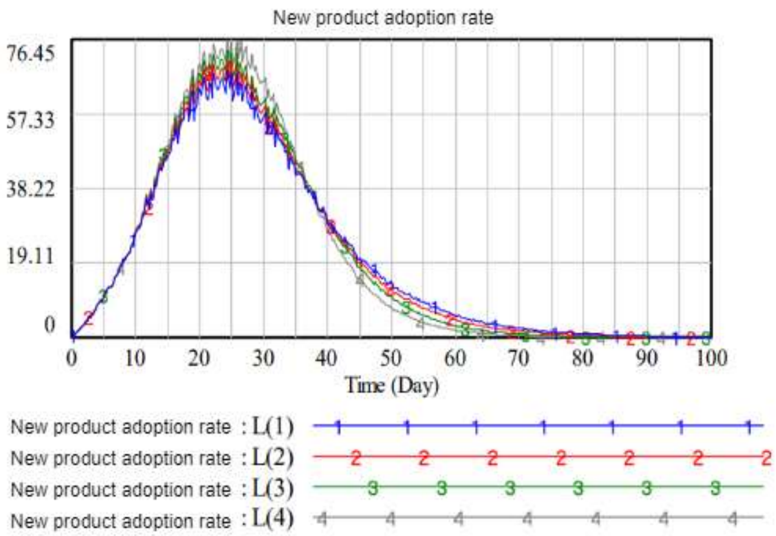

Figure 4(b) Change trend of new product adoption rate

Scheme 2 simulation results:

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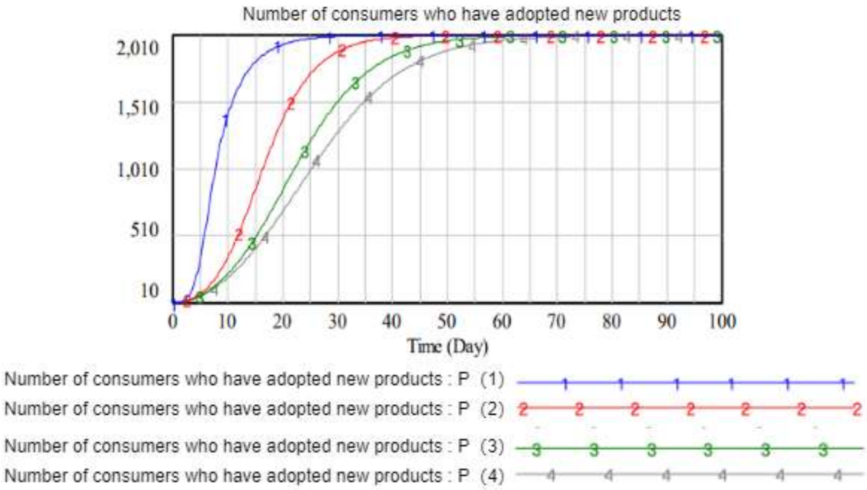

Figure 4(c) Changing trend of the number of consumers who have adopted new products

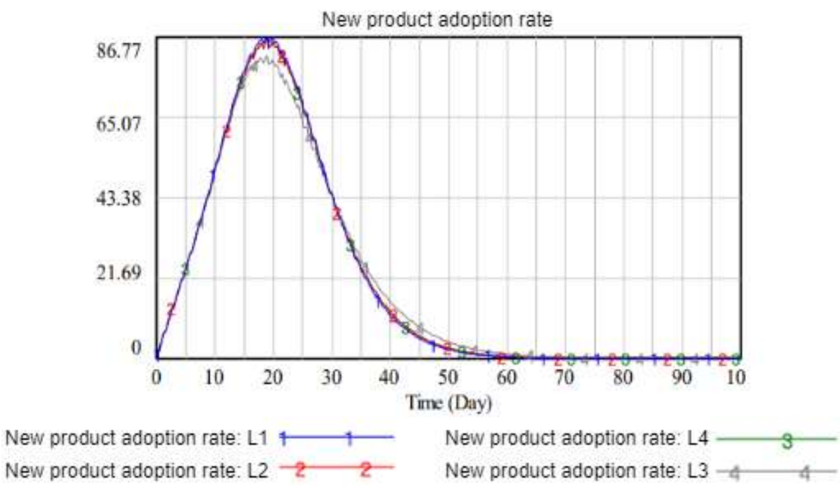

Figure 4(d) Change trend of new product adoption rate

From the above figure, it can be seen that increasing the average degree of consumer network will make the curve of new product diffusion steeper, indicating that increasing the average degree of consumer network can improve the overall efficiency of new product diffusion, and the greater the parameter value of network average degree, the higher the efficiency of new product diffusion. On the contrary, under the condition of consumers' differentiated preferences, increasing the average degree of consumers' networks will reduce the overall efficiency of innovation diffusion. This is because the improvement of the average degree of consumer network will increase the average number of neighbors of consumers. Under the condition of consumers' convergence preference, the increase of the number of neighbors of consumers will improve the social utility of new products to consumers, thus enhancing consumers' willingness to adopt and promoting the diffusion of new products. On the other hand, under the condition of consumers' differentiated preference, the more people among consumers' neighbors adopt new products, the lower social utility consumers get, such as the proliferation of luxury goods, which will reduce consumers' willingness to adopt and restrain the proliferation of new products.

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4.1.3 Network reconnection probability and new product diffusion

Set the parameter values of network reconnection probability variables to 0.25-0.5-0.75-0.9 respectively, and simulate and analyze the model in two scenarios of consumer convergence preference (Scheme 1) and differentiation preference (Scheme 2), and get two simulation schemes, as shown in Figure 3 (a)-3 (d):

Scheme 1 simulation results:

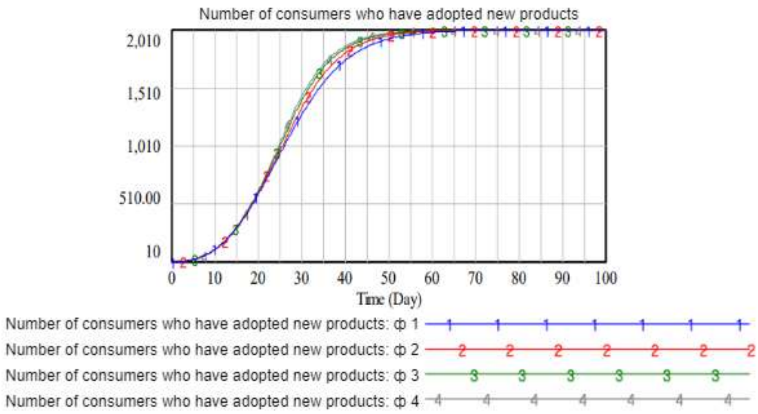

Figure 5(a) Changing trend of the number of consumers who have adopted new products

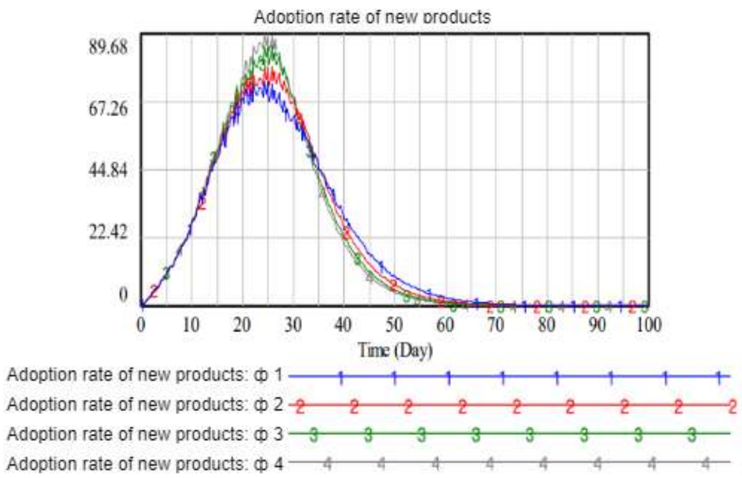

Figure 5(b) Change trend of new product adoption rate

Scheme 2 simulation results:

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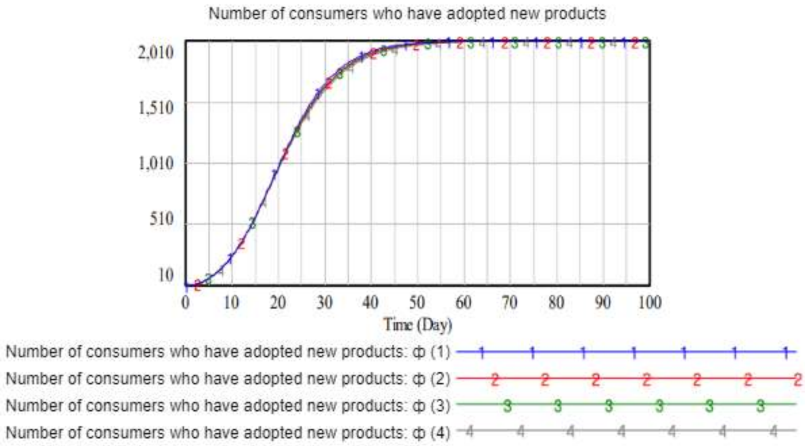

Figure 5(c) Changing trend of the number of consumers who have adopted new products

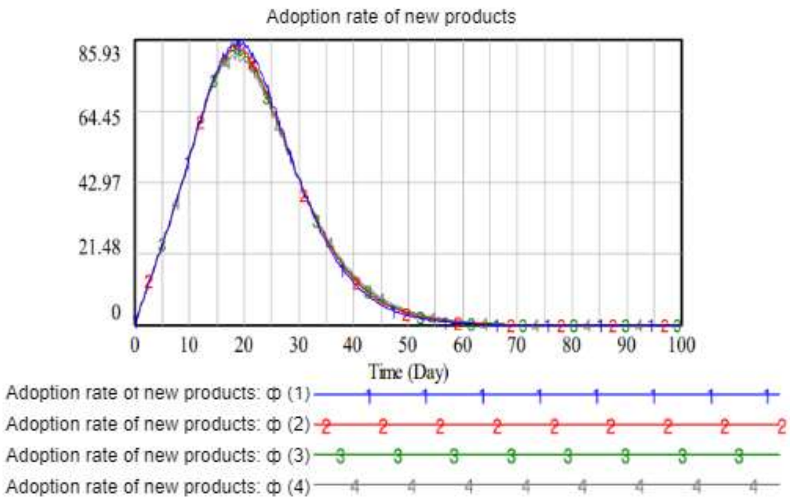

Figure 5(d) Change trend of new product adoption rate

From Figures 5 (a) to 5 (d), it can be seen that the new product diffusion curve will become steeper when the network reconnection probability is increased, that is, the overall efficiency of diffusion will be improved. This is mainly related to the fact that increasing the network reconnection probability will increase the proportion of intimate neighbors of consumers in the total number of neighbors. Under the condition that the total number of consumers' neighbors is unchanged, the increase of intimate neighbors among consumers' neighbors will improve the social utility of potential consumers, and then increase the average adoption rate of new products. The diffusion rate also shows a complex changing trend, with no obvious change in the initial stage of diffusion, a rapid increase in the middle stage of diffusion and a decline after reaching the extreme value.

Under the condition of consumers' differentiated preference, increasing the network reconnection probability will reduce the overall efficiency of innovation diffusion. This is because the increase of the reconnection probability of consumer network will enhance the influence intensity of potential consumer

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neighbors on potential consumers. However, because consumers have differentiated preferences, the greater the influence intensity of consumer neighbors on consumers, the lower the social utility of consumers' adoption of new products, which will reduce the average willingness of consumers to adopt new products, thus reducing the overall efficiency of new product diffusion and inhibiting the proliferation of new products.

V. CONCLUSION

The adoption of a new product by consumers generally goes through three stages: information acquisition of new products, utility evaluation of new products, adoption and feedback of new products. Based on the decision-making process of consumers, the system dynamics model of new product diffusion is built by using the flow rate basic tree modeling method. On the one hand, it can better reflect the micro-adoption behavior of new product diffusion, on the other hand, it can dig deeper into the valuable information inside the system on the basis of considering multiple feedback characteristics among factors. Through the simulation analysis of the model constructed in this paper, it is found that the influence direction of consumer network reconnection probability and network average on new product diffusion is related to the type of consumer preference. Under the condition of consumer convergence preference, increasing the network average and network reconnection probability can improve the overall efficiency of new product diffusion; under the condition of consumer differentiation preference, increasing consumer network average and network reconnection probability will reduce the efficiency of new product diffusion. The influence of average path length of consumer network on new product diffusion has nothing to do with the type of consumer preference. Increasing the average path length of consumer will always reduce the new product.

The results of this study suggest that when making new product promotion strategies, decision makers should first judge the preference types of consumers of new products to be promoted. For example, consumers of daily consumer goods generally have the characteristics of convergence preference, while consumers of luxury goods generally have the characteristics of differentiation preference. Then, based on the types of consumers' preferences, the promotion areas of new products are targeted. Under the condition of consumers' convergent preferences, decision makers should choose areas with low average path length, high network average and high network retraining probability to promote new products, which will achieve better diffusion effect. On the contrary, under the condition of consumers' differentiated preference, it is necessary to choose areas with low average path length, low average network degree and low network retraining probability for the promotion of new products. Among them, the average degree, retraining probability and average path length of consumer network can be obtained by social network analysis methods such as questionnaire survey and statistical analysis.

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