Asian Journal of Chemistry; Vol. 26, No. 11 (2014), 3311-3314

ASIAN JOURNAL OF CHEMISTRY

http://dx.doi.org/10.14233/ajchem.2014.17516

Information Propagation Model in Consumer Decision-Making

TAO YIN[1,*], NING WANG[1] and JING WANG[2]

[1]School of Economics and Management, Beijing University of Posts and Telecommunications, Beijing 100876, P.R. China
[2]Personnel and Education Section of Beijing Yanqing Administration for Industry and Commerce, Beijing 102100, P.R. China

*Corresponding author: E-mail: yintao@bupt.edu.cn

Received: 10 February 2014; *Accepted*: 14 April 2014; *Published online*: 25 May 2014; AJC-15238

Since different kinds of consumers have different characteristics in the information propagation, the entire consumer populations can be divided into four classes. And based on those characteristics, with analyzing interactions among those various classes of consumers, we build a decision-making information propagation model (CPUN). Though exploring its system dynamics characteristics, we get the existence conditions of the equilibrium points of the model and the spread threshold. We analyze and find that it plays an important role in increasing user density under the equilibrium state of consumer information propagation system that we increase the proportion of consumers' second buying and the proportion of consumers who turn from potential consumers.

Keywords: Information propagation, Consumer decision-making, Epidemic model.

INTRODUCTION

Information exchange and communication among consumers play an important role in new product adoption and product reputation building. Although consumers are surrounded by the mass media advertising, the effect is limited[1]. Studies have shown that people prefer to turn to their acquaintance in their social network rather than to text and media information when they encounter problems[2]. The social network has become effective information searching path and platform for consumers.

Consumer information can affect the people in consumers' social network and its influence changes with the change of purchase behavour stage. For example, long-term consumers recommend products or service less often than new consumers. New consumers always pay more attention to others' recommendation and are more willing to introduce their buying to others. While, as time goes by, people are getting familiar with the products and service, thus they no longer want to share information with others. Importantly, the change of consumers' desire to propagate information will affect both market acceptance of products and brand reputation building in a direct way, which has a significant impact on enterprise marketing. However, most of the studiesrelated to consumer information propagation concentrate on the roles and impacts of consumer opinion leaders[3,4], whereas there are fewer researches on the propagation behavours of consumers.

In recent years, epidemiology studies have provided an idea for researching such information propagation and it has been widely applied to public opinion and rumor propagation. Sudbury[5] is the earliest person who referenced the SIR epidemic model to study the rumor propagation. SIR stands for three kinds of individuals inthe rumor propagation process. S stands for individuals who have not heard rumors, I for those who have heard and spread rumors and R for those who have heard but have no interest in spreading rumors. Afterwards, Zanette[6] and Moreno[7] introduced the network topology characteristics to the model and studied rumor propagation models in a small world and in the scale-free network separately. Domestic scholars Zhou Tao[8-10], also studied the public opinion and rumor propagation and they made a good conclusion and further testes and verified the applicability and rationality of epidemiology in public opinion and rumor propagation.

The research idea of epidemiology has also been applied in the field of consumer behavour. For example, on word of mouth issues, Lin and Sun[11] proposed a service quality word of mouth evolutionary model in the complex social network, which is based on the mechanism of infectious diseases transmission and then they did the simulation study in a social network, which is established on the basis of real phone records. Finally, they got a meaningful conclusion. In addition, Bai and Liu[12] established a dynamic word of mouth communication model using epidemiology thoughts and explored different effects of word of mouth communication through changing model parameters. Yu[13] and others' were on online-games communication. They introduced the SIR model classification methodology to classify the game group and online-game consumers were divided into three groups, potential users, users and non-users. They then explored how advertising effect and positive/negative word of mouth effect affect the number of consumers and they obtained some useful conclusions.

It has been shown that almost all the present studies of consumer information propagation using epidemiology thoughts are concentrated on building related simulation models and drew conclusions through observing and analyzing the simulation results.However, there are less exploration on the dynamic characteristics of propagation system and the system mechanisms; plus, consumer information propagation model is far more complex than the SIR model, so it calls for further research on consumer behavour characteristics and rational models. Therefore, this paper establishes an information propagation model in consumer decision-making, combing the characteristics of consumer information propagation process, to study its system dynamics characteristics. And through exploring the theoretical and practical significance of the equilibrium point and stability of the system, we provide some reference and advices for enterprises to adopt accurate and effective marketing strategies.

Information propagation model in decision-making

Consumer states: In the traditional infectious disease models, the most widely used models are the SIR model and the SIS model[14]. In the SIR model, population is divided into three classes: the first is the susceptible (S), they will not infect others, but are possible to be infected; the second is the infected (I), they have been sick and are contagious; the third is the recovered (R), they have been cured and get immunity and they are neither contagious nor re-infected. Besides, according to the different characteristics of infectious diseases, there are other corresponding propagation models, such as, the SIRS model with limited immunity period, SEIR model with incubation period *etc*.

In the consumer information propagation process, consumers will not buy until they have been "observing" for a while, that is, there is an "incubation period" between consumers acquiring the information and having a willingness to buy and purchasing for the product or service. Based on the above considerations, we divide the consumer population into four classes: consumers (C), potential consumers (P), users (U) and non-user (N). Consumers refers to those who have not got consumer information yet, but have consumer demand and capacity; potential consumers are those who have received some information and have strong willingness to buy, but has not purchased; users are those who have purchased products and most would like to introduce them to others; non-user refers to those who lose propagation willingness after a period and may continue to purchase products or service or give up to buy them.

Consumer state transformation rules: Consumers' roles in the information propagation will be affected by such external factors as people in their social networks and promotion activities. Interacting with them, consumers will take specific behavours, like imitating and giving up. It is different with SEIQ, of which the infectious disease incubation period cannot be skipped, that consumers will still be affected by activities such as advertisement and external promotion even if they ever have not contacted with users. It means that the consumption incubation period in the information propagation model could be skipped, which is more in line with the real information propagation. In addition, for convenience, we assume that what consumers receive is all positive information. In other words, consumers are willing to buy and become potential consumers, or directly buy products or service and become users, when they receive the information. The detailed behavior transformation rules among various groups are listed as follows:

- After consumers contact with users, they will probably obtain some information and then become potential consumers.
- When potential consumers communicate with users, they could be affected and become users.
- After a period of time, because of their personality, users may neither be interested to communicate with others nor have desire to propagate consumer information, then they become non-users.
- Non-users will not accept any consumer information from users, yet they are possible to buy the products or service and become consumers again.
- Users would like to communicate with consumers; while, potential consumers and non-users do not communicate with others.
- Even without contacting with users, consumersstillmight be affected by advertising, promotions and other activities and then buy products or service directly, through which consumers become users.
- Consumer state transformation model is shown in Fig. 1.

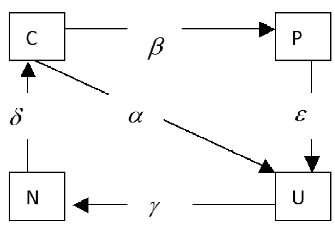

Fig. 1. Consumer state transformation

Model: Based on the above analysis of state transformation rules and the SEIQ model, webuild a dynamic model of information propagation in consumer decision-making, where C (t), P (t), U (t) and N (t) represent node density of various states.

$$\begin{cases} \dfrac{dC(t)}{dt} = -\beta\langle k\rangle C(t)p(T) - \alpha C(t) = \delta N(t) \\ \dfrac{dP(t)}{dt} = \beta\langle k\rangle C(t)P(t) - \varepsilon P(t) \\ \dfrac{dU(t)}{dt} = \varepsilon P(t) = \alpha C(t) - \gamma U(T) \\ \dfrac{dN(t)}{dt} = \gamma U(t) - \delta N(t) \\ C(t) = P(t) = U(t) + n(t) = 1 \\ C(t), P(t), U(t), N(t) \geq 0 \end{cases} \quad (1)$$

The transfer rules among individuals are: consumers contacting with users, they change to potential consumers with probability (β); potential consumers change to users with probability (ε); users lose their communication will and change to non-userswith probability (γ); non-users change back to consumers to repeat purchase with probability (δ). Consumers may be influenced by external factors such as promotions and advertisements and then purchase without hesitation. Based on this situation, it is assumed, that consumers will change to users directly with probability α. Sinceconsumersare easily affected by others in their social network, the network can be approximated for a small-world network. The degree of the small-world networkis highly peaked and its disturbance is very small, so we can approximate it as average degree <k>, that is, $k_i \approx \langle k \rangle$.

Because the analytical solution of eqn. 1 is not easy to get, we turn to consider the solution under equilibrium conditions. In such way, wehave the followings:

$$\begin{cases} -\beta\langle k\rangle C(t)P(t) - \alpha C(t) + \delta N(t) = 0 \\ \beta\langle k\rangle C(t)P(t) - \varepsilon P(t) = 0 \\ \varepsilon P(t) = \alpha C(t) - \gamma U(t) = 0 \\ \gamma U(t) - \delta N(t) = 0 \\ C(t) + P(t) + U(t) + N(t) = 1 \\ C(t), P(t), U(t), N(t) \geq 0 \end{cases} \tag{2}$$

In the second formula of the eqn. 2, there are two situations: P(t) = 0 and P(t) ≠ 0. Next, we are going to discuss each of them:

When P(t) = 0, eqn. 2 can be turned into:

$$\begin{cases} \alpha C(t) - \gamma U(t) = 0 \\ \gamma U(t) - \delta N(t) = 0 \\ C(t) + U(t) + N(t) = 1 \\ C(t), U(t), N(t) \geq 0 \end{cases} \tag{3}$$

The domain is D = {(C(t), U(t), N(t))|C(t), U(t), N(t) ≥ 0 and C(t) + U(t) + N(t) ≤ 1}.

After analyzing, we find that, when, P(t) = 0, there is only one positive equilibrium point in the system (1),

$$\left(\frac{\delta}{\alpha}G^{*}, \frac{\delta}{\gamma}G^{*}, G^{*}\right)$$

where $G^{*} = \dfrac{1}{1 + \frac{\delta}{\alpha} + \frac{\delta}{\gamma}}$.

When, eqn. 2 can be turned into:

$$\begin{cases} -\beta\langle k\rangle C(t)P(t) - \alpha C(t) + \delta N(t) = 0 \\ C(t) = \dfrac{\varepsilon}{\beta\langle k\rangle} \\ \varepsilon P(t) + \alpha C(t) - \gamma U(t) = 0 \\ \gamma U(t) - \delta N(t) = 0 \\ C(t) + P(t) + U(t) + N(t) = 1 \\ C(t), P(t), U(t), N(t) \geq 0 \end{cases} \tag{4}$$

Using N(t) to represent other parameters:

$$P(t) = \frac{\delta}{\varepsilon}N(t) - \frac{\alpha}{\beta\langle k\rangle},\ P(t) = \frac{\delta}{\varepsilon}N(t) - \frac{\alpha}{\beta\langle k\rangle},\ U(t) = \frac{\delta}{\gamma}N(t) \tag{5}$$

Then, by the normalization condition, we can get:

$$\frac{\varepsilon}{\beta\langle k\rangle} + \frac{\delta}{\varepsilon}N(t) - \frac{\alpha}{\beta\langle k\rangle} + \frac{\delta}{\gamma}N(t) + N(t) = 1$$

$$N(t) = \frac{1 - \dfrac{\varepsilon - \alpha}{\beta\langle k\rangle}}{\dfrac{\delta}{\varepsilon} + \dfrac{\delta}{\gamma} + 1} = \frac{1 - H}{\dfrac{\delta}{\varepsilon} + \dfrac{\delta}{\gamma} + 1} \tag{6}$$

where $H = \dfrac{\varepsilon - \alpha}{\beta\langle k\rangle}$.

RESULTS AND DISCUSSION

For H < 1, the equilibrium point of system (1) is (C*, P*, U*, N*), the Jacobian matrix is:

$$J = \begin{pmatrix} \beta\langle k\rangle C(t) - \beta\langle k\rangle P(t) - \varepsilon & -\beta\langle k\rangle P(t) & -\beta\langle k\rangle P(t) \\ \varepsilon - \alpha & -\alpha - \gamma & -\alpha \\ 0 & \gamma & -\delta \end{pmatrix}$$

The eigenvalue of the Jacobian matrix is calculated by the following equations.

$$f(\lambda) = \lambda^3 + a_2\lambda^2 + a_1\lambda + a_0 = 0$$

where

$$\begin{aligned} a_2 &= \delta + \alpha + \gamma + \varepsilon + \beta\langle k\rangle P(t) - \beta\langle k\rangle C(t) \\ a_1 &= \alpha\delta + \gamma\delta + \varepsilon\delta + \varepsilon\alpha + \varepsilon\gamma + \alpha\gamma - \delta\beta\langle k\rangle C(t) \\ &- \alpha\beta\langle k\rangle C(t) - \gamma\beta\langle k\rangle C(t) + \delta\beta\langle k\rangle P(t) \\ &+ \alpha\beta\langle k\rangle P(t) + \gamma\beta\langle k\rangle P(t) + \varepsilon\beta\langle k\rangle P(t) - \alpha\beta\langle k\rangle P(t) \\ a_0 &= \varepsilon\alpha\delta + \varepsilon\gamma\delta + \alpha\gamma\varepsilon - \gamma\delta\beta\langle k\rangle C(t) - \alpha\delta\beta\langle k\rangle C(t) \\ &- \alpha\gamma\beta\langle k\rangle C(t) + 2\alpha\gamma\beta\langle k\rangle P(t) + \gamma\delta\beta\langle k\rangle P(t) \\ &+ \varepsilon\alpha\beta\langle k\rangle P(t) - \varepsilon\gamma\beta\langle k\rangle P(t) \end{aligned}$$

Through analyzing, we get that a_0, a_1, a_2 are positive. And since

$$\Delta_1 = a_1 > 0$$

$$\Delta_2 = \begin{vmatrix} a_1 & a_0 \\ 1 & a_1 \end{vmatrix} > 0$$

$$\Delta_3 = \Delta_2 > 0$$

and judging by the Routh-Hurwits, all the roots of the eqn. 4 have negative real parts, which proves that its equilibrium point is locally asymptotically stable. So the system (1) converges to when H < 1.

We assume that the critical value of the consumer information propagation model is H. From the above analysis, we can get that there is no equilibrium point when H >= 1, whereas the system is stable and there exists a unique equilibrium point when H < 1. Then we can say that the system has a unique positive equilibrium point when $\varepsilon < \beta\langle k\rangle + \alpha$ and it hasn't when $\varepsilon > \beta\langle k\rangle + \alpha$.

Combining eqns. 5 and 6, we explore the derivatives to study the increases or decreases of N(t) and C(t).

Since $\frac{\delta}{\varepsilon} = x$, then

$$\frac{\delta}{\gamma} = \frac{\varepsilon}{\gamma}x, \quad N(t) = \frac{1 - \frac{\varepsilon}{\beta\langle k\rangle} + \frac{\alpha}{\beta\langle k\rangle}}{x + \frac{\varepsilon}{\gamma}x + 1}$$

$$N_x(t) = \frac{-\left(1 - \frac{\varepsilon - \alpha}{\beta\langle k\rangle}\right)\left(1 + \frac{\varepsilon}{\gamma}\right)}{\left(x + \frac{\varepsilon}{\gamma}x + 1\right)^2} < 0$$

Then we can get the following Table-1.

TABLE-1
CHANGING CIRCUMSTANCES OF U(t)

δ	ε	x	N(t)	U(t)
↑	—	↑	↓	↑
—	↓	↑	↓	↓
↓	—	↓	↑	↓
—	↑	↓	↑	↑

From the above table, the probability of which non-users change to consumers and the probability of which potential consumers change to users have great impacts on the equilibrium point of the system. When increasingor , the user density of consumer information propagation system under equilibrium state will increase. From the perspective of enterprise marketing, it is very important that enterprises should keep their productsor service interesting and attractive for making consumers would like to talk about them and love them.

Conclusion

Information propagation in consumer decision-making process is a special form of mass media spread.Previous studies paid more attention to the role of opinion leaders, but paid less attention to consumers, especially to the impact of consumers' state transition in the information propagation. With infectious diseases thoughts being more and more widely used in the study of public opinion and rumor propagation, it provides a new idea for information propagation research. In this paper, an information propagation model in consumer decision-making (CPUN) is proposed, whichis based on the mechanism of spread of infectious diseases and in accordance with characteristics of consumers' role transformation in the information propagation. Through analyzingthe equilibrium point and stability of the system, we get important conclusions and provide a reference for the further study of information propagation using thoughts of infectious disease spreading.

REFERENCES

1. I.N. Athanasiadis and P.A. Mitkas, *Comput. Sci. Eng*., **7**, 65 (2005).
2. D.C. Plez and F.M. Andrews, Scientists in Organizations: Productive Climates for Research and Development, John Wiley & Sons, New York (1996).
3. K. Xue and X. Chen, *J. Quarterly*, **106**, 87 (2010).
4. J. Zhu, *Journalism & Commun*., **6**, 34 (2010).
5. A. Sudbury, *Appl. Prob*., **22**, 443 (1985).
6. D.H. Zanette, *Phys. Rev. E Stat. Nonlin. Soft. Matter Phys*., **64**, 050901 (2001).
7. Y. Moreno, M. Nekovee and A.F. Pacheco, *Phys. Rev. E*, **69**, 066130 (2004).
8. T. Zhou, B.H. Wang, X.P. Han and M.S. Shang, *Eng*., **25**, 742 (2010).
9. X.G. Gong and R.R. Wang, *J. System Simulation*, **20**, 6511 (2008).
10. C.Y. Liu, X.F. Hu, G.Y. Si and P. Luo, *J. System Simulation*, **18**, 3608 (2006).
11. L. Li, J.H. Sun and Z.J. Zhou, *Syst. Eng*., **27**, 1 (2009).
12. Y. Bai and J.L. Liu, *Stat. Decis*., **16**, 31 (2009).
13. T.Y. Yu, R.B. Xiao and X.G. Gong, *Eng.-Theory Pract*., **30**, 919 (2010).
14. T. Zhou, Z.Q. Fu, Y.W. Niu, D. Wang, Y. Zeng, B.H. Wang and P.L. Zhou, *Prog. Nat. Sci*., **15**, 513 (2005).