Summer 6-26-2019

The Social Influence Enhanced by the Mass Media Broadcasting in Innovation Diffusion

Fang Yang
School of Business Administration, Jimei University, Xiamen, 361021, China

Qiping Zhou
School of Business Administration, Jimei University, Xiamen, 361021, China, zhouqp@126.com

Junmin Hu
School of Business Administration, Jimei University, Xiamen, 361021, China

Lifeng Wu
School of Business Administration, Jimei University, Xiamen, 361021, China

The Social Influence Enhanced by the Mass Media Broadcasting in Innovation Diffusion

Fang Yang, Qiping Zhou[*]*, Junmin Hu, Lifeng Wu*
School of Business Administration, Jimei University, Xiamen, 361021, China

Abstract: Based on the Bass model and the micro-model of mass media network, we propose an agent-based threshold approach including the mutual interaction between social relationship network and mass media network. Taking the heterogeneity of individuals into account, it is found that the direct advertisement from mass media broadcasting will attract the potential adopters greatly at the beginning of innovation diffusion. In the middle of diffusion process, the previous adopters formalize a positive feedback to the potential adopters via mass media broadcasting. The social collective effect can be strongly enhanced if the potential adopter prefer to mass media broadcasting. Furthermore, it is found that the complexity of the social relationship network may postpone the social collective effect.

Keywords: Social Influence, Stochastic Threshold Model, Innovation Diffusion, Complex Network

1. INTRODUCTION

When an organization brings out an innovation product, it concerns whether the innovation can spread abroad and be adopted by a successful numbers of consumers in a short time. In fact, the process of spreading determines the marketing to be successful or not. Hence, the study of innovation diffusion process has become more and more important for marketing. The theoretical study on innovation diffusion is always a hotspot in management science. There are several investigations on innovation diffusion and they were summarized recently to illustrate the broad scope in this field [1]-[6].

When an innovation is released into a society, the social members have the chance to become aware of the innovation and decide whether to adopt it or not. The mass media and interpersonal channels are two important types of communication channels and have significant effects on the innovation diffusion process. Many programs have been evaluated by using mass media and/or interpersonal communication for behavior change [7]. Past research in the diffusion of innovations has clearly demonstrated that different kinds of communication channels have differential effects on the adoptive behavior exhibited in a societal system [8]. Early work in this area examined the effect of communication channels on diffusion, and found mass media channels were usually the most rapid and efficient means of informing the potential adopters about the existence of an innovation, while interpersonal channels were more effective in persuading an individual to accept the innovation [9].

Although many scholars agree on the importance of interpersonal communication in the diffusion process, few studies have successfully traced an innovation through a network of social contacts [10]. Recently, lots of different diffusion models have been proposed to investigate the innovation diffusion. Many characteristics of innovation diffusion, such as the speed of diffusion and the extent of diffusion, have been widely investigated and fruitful results were achieved [11]-[14]. In macroscopic viewpoint, the Bass model [15] and its generalizations [16] successfully describe the innovation diffusion and forecast the diffusion to some extent. The classical S-curve can be considered as a general characteristic of innovation diffusion. In microscopic viewpoint, the heterogeneity of consumers' behavior should be considered as a nontrivial factor for the innovation diffusion. For example, consumers' preference between mass media and social relationship will greatly affect the speed and extent of diffusion. Many micro models, such as the percolation models [17]-[18], cellular automata models

[*] Corresponding author. Email: zhouqp@126.com

[19]-[20] and agent-based models [21]-[23], have paid attention to the heterogeneity mentioned above and overcome the homogeneous assumption of the Bass model. In these micro models, the internal and external factors for innovation diffusion can be realized by social relationship network and the mass media network, respectively. Hence, the micro market mechanism of innovation diffusion has been revealed to some extent and the utilization of Bass model is greatly improved.

On the other hand, threshold model is very typical in social science research including innovation, rumours and disease spreading [9], especially in modeling collective behaviors [24]-[25] and considering the heterogeneity of each individual [26]. The main idea of this frequently used model is that each individual has a personal threshold of utility value to decide whether to adopt the behavior of the society or not. Threshold model can formalize a positive feedback into the dynamics of the adoption rate. Generally speaking, the more individuals are involved into the social behavior, the more others will feel the social pressure and join in the social behavior.

With the development of complex networks [27]-[28] and their wide research [29], it is possible to investigate innovation diffusion in a society by computer simulation. In this case the real structure of social relationship can be considered as a complex network. For examples, the small-world network was adopted to predict the new product success [30], the takeoff of new product was investigated with an agent-based model [31], Pastor-Satorras and Vespignani analyzed the influence of complex network structure on epidemic spreading by mean field method [32]-[33], Rahmandad and Sterman compared agent-based and differential equation models in the impact of individual heterogeneity and different network topologies on the dynamics of diffusion [34], Garcia researched diffusion by using agents to represent autonomous decision-making entities that interact with each other and/or with their environment [22]. The heterogeneity of the nodes of the social network is well considered in the works mentioned above. Consequently, the results obtained are quite important for the strategy of new product marketing.

The direct advertisement from the mass media will impact on the potential adopters whether to adopt the innovation or not. Meanwhile, the potential adopters' behaviors are also influenced by the bandwagon pressure. The bandwagon pressure was brought out not only by local adopters who have direct relationships with these potential adopters but also by the whole adopters in the society. Thus, it is quite reasonable to propose some kernel questions such as how the whole adopters affect the potential adopters, and what is the mechanism of the bandwagon pressure that affecting the speed of diffusion and the diffusion rate. However, to our knowledge, the questions mentioned above are seldom investigated from microscopic viewpoint. In present paper, we propose a diffusion model that explicitly includes consumers' decision-making behavior affected by social influences and mass media. The interaction between social network and mass media network are also included. The advantages of Bass model and micro model of mass media effect are combined together. By means of simulation, the social collective effect on the innovation diffusion is investigated and some novel results are obtained. The paper is structured as follows: Section 2 reviews the classical Bass model and introduces our threshold based micro model; Section 3 presents the simulation assumptions; Section 4 reports the results of simulations and Section 5 reports the comments and conclusions.

2. THE MODELS

2.1The Bass model

The Bass model [15] assumes that the behaviors of the potential adopters of an innovation are affected by two processes of communication: (1) external influence via mass media, such as TV, Broadcasting, Newspaper, and so on, and (2) internal influence via word-of-mouth. The differential equation of the Bass model describes the innovation diffusion mechanism, which can be written as

$$\begin{aligned} n(t) &= \frac{dN(t)}{dt} \\ &= (a+\frac{b}{m}N(t))(m-N(t)) \\ &= a(m-N(t))+\frac{b}{m}N(t)(m-N(t)) \end{aligned} , \quad (1)$$

where $N(t)$ is the number of consumers who have adopted the innovation at time t, $n(t)$ means the adoption rate at time t, m is the capacity of market, $a(m-N(t))$ is the number of adopters who was brought by the mass media effect and $\frac{b}{m}N(t)(m-N(t))$ is the number of adopters who was brought by the world-of-mouth effect. The consumers are divided into innovators and imitators in the Bass model. The innovators are the consumers who adopt the innovation due to the external effect via mass media and its coefficient is a. While, the imitators are the consumers who adopt the innovation due to the internal effect via world-of-mouth and its coefficient is b. The internal effect comes from the total adopters. The Bass model describes the social behaviors well and can forecast the diffusion of innovation in the macroscopic viewpoint. However, it assumes all consumers to be homogeneous. It does not specify in microscopic viewpoint that how the consumers' decision-making changes by time and how consumers communicate and influence each other. Moreover, it can not show the micro mechanism of innovation diffusing from the local to the whole society.

2.2 The threshold model based on the interaction between social relationship and mass media

In order to take the heterogeneity of consumers' behavior into account from microscopic viewpoint, we can study the behavior of micro single agent by using the theory of complex system and then the whole macro behavior of the innovation diffusion can be obtained. We use the concepts of the network to describe the diffusion innovation based on the structure of complex social relationship. The nodes of the network are the consumers in the social market and each edge between two nodes represents a direct relationship between two consumers. Without lose generality, we can suppose that there are N consumers in social network. The social network doesn't have direction since the communications among all members in the society are mutual. The degree of the node $k_i = \sum_{j\neq i}^{N}\alpha_{ij}$ is the number of direct connected agents of node i in the network, where $\alpha_{ij}=1$ means the direct connection between i and j and $\alpha_{ij}=0$ is on the contrary. The average degree of the social network is $\bar{k}$ and it can be written as $\bar{k}=\sum_{i=1}^{N}k_i/N=2L/N$, where L is the total number of the edges in the social network.

Based on the kernel idea of threshold modeling, our model in which including the mutual interaction between the social relationship network and the mass media network is given as follows:

$$U_{i,t} = \begin{cases} I_i + a_i S_{i,t-1} + b_i (M_{i,t-1} + cP_{t-1}) & \delta_{i,t-1}=0 \\ U_{i,t-1} & \delta_{i,t-1}=1 \end{cases} , \quad (2)$$

where

$$P_{t-1} = \frac{\sum_{i=1}^{N}\delta_{i,t-1}}{N} , \quad (3)$$

and

$$S_{i,t-1} = \frac{\sum_{j \neq i}^{N} \delta_{j,t-1}\alpha_{ij}}{k_i} \quad . \tag{4}$$

In Eq. (2), $U_{i,t}$ is the utility value of the innovation that the potential adopter i has at time t, I_i is the i-th potential adopter's initial interest on the innovation product, "$\delta_{i,t-1}=0$" means the i-th potential adopter doesn't adopt the innovation at time $t-1$ and "$\delta_{i,t-1}=1$" is on the contrary. $S_{i,t-1}$ is the utility comes from the social relationship network, $0 \le a_i \le 1$ is the preference level of the social relationship network for the potential adopter i. So $a_i S_{i,t-1}$ is the utility value brought out by the adopters who have direct social relationships with the ith potential adopter at time $t-1$. The behavior of the potential adopter i is totally influenced by the social relation network when $a_i = 1$ and it is totally influenced by the mass media network when $a_i = 0$. $b_i(M_{i,t-1} + cP_{t-1})$ is the utility value brought out by the mass media network, where $M_{i,t-1}$ is the utility comes from advertisement or sales promotion via the mass media network. P_{t-1} is the adoption rate at time $t-1$. The adoption rate can be broadcasted to the whole society by mass media network so that more and more potential adopters may be attracted. Therefore, P_{t-1} can be considered as a kind of social collective utility. The value of b_i depicts the i-th potential adopter's preference on the mass media network and the normalization condition requires $a_i + b_i = 1$. The value of c is 1 or 0 to control the adoption rate to be broadcasted or not. 1 is 'ON' and 0 is 'OFF'.

During the process of the innovation diffusion, the criterion for the ith social member to adopt the innovation depends closely on the total utility value, as indicated in Eq. (2). Every social member has his/her own estimation on the innovation, says, the personal threshold E_i. If $U_{i,t} \ge E_i$, the potential adopter adopt the innovation and thus $\delta_{i,t}=1$, else he/she doesn't do any action and $\delta_{i,t}=0$ is still hold. In this model $N(t) = \sum_i \delta_{i,t} / N$ is defined as the adoption rate of the innovation at time t, specifying the percent of the adopters over the whole social market. Consequently, $n(t) = \Delta N(t)/\Delta t$ is the speed of the innovation diffusion, which is the increase number of the adopters per unit time.

3. SIMULATION ASSUMPTIONS

According to the central limit theorem, the ith potential adopter's original utility value I_i for the innovation obeys normal distribution. It can be written as $I_i \sim N(\mu, \sigma^2)$, where μ is the average of the whole potential adopters' estimate for the innovation and σ^2 is the variance of the estimate.

There are N=2000 nodes in the social relationship network. The effect of social relationship network on the ith potential adopter only depends on the adopters who have direct links to him/her. The effect of the direct advertisements ($M_{i,t-1}$) on the potential adopters is independent of the social network. We suppose that the advertisements will directly affect the potential adopters T ($T=3$) times and each time the marginal utility decreasing [35,36]. On the basis of the central limit theorem, each time the mass media network's impact on different potential adopter obeys the normal distribution. The magnitude of the impact depends on the effort of the direct advertisements.

After the potential adopters choose the innovation product, they will form a word-of-mouth effect on the innovation product when they use it. The word-of-mouth effect influences the decision-making of the potential adopters who have direct connections with the adopters. These kinds of influences make effort via the social relationship network. Moreover, the adopters have more chances to contact the mass media [9]. Their comments on the innovation will also affect the potential adopters' decision-making. This kind of collective pressure will give a positive feedback to the potential adopters via the mass media network.

For the i th potential adopter, the coefficients of the social relation network and the mass media network are a_i and b_i, respectively. The coefficients depend not only on the individual characteristics, such as preference and education degree and so on, but also on the innovation's properties, such as the performance, price and the effort of marketing. For the sake of convenience, all the potential adopters' coefficients of the social relation network and the mass media network are $a_i = a$ and $b_i = b = 1 - a$ in the simulations. Such disposal will not bring out essence impact on the results from the statistical point of view. In the assumption, $0 \le a \le 1$. If $a > 1 - b$, it means that the effect on the potential adopters' decision-making from the social relation network is greater than that from the mass media network, or vice versa.

4. THE SIMULATION RESULTS

In present paper we calculate and compare the differences between two different cases. $c = 1$ is the case of mutual interaction between the social relation network and the mass media network, and $c = 0$ is the case of single action of the mass media network. Both of them deal with the innovation diffusion from microscopic viewpoint. $c = 1$ is based on Eq. (2) and it will reduce to $c = 0$ in the $P_{t-1} \to 0$ limit. Thus, the factor P_{t-1} is important to realize the mutual interaction between the social network and broadcasting network. The comparison between the two cases is helpful for us to analyze the questions concerning about innovation diffusion. We present our simulation results for a social network containing 2000 members. Each data is based on the average of 500 times of calculations.

4.1 The innovation adoption rate

Figure 1 shows that the curves of $c = 0$ and $c = 1$ almost overlap together in the first four diffusion period ($t < 4$). It means that the utility value of the innovation for the potential adopters is mainly from the effort of the mass media's direct advertisements. The mechanisms of diffusion for the two cases are almost the same at the beginning and no distinct difference can be observed. However, after the fourth diffusion period ($t \ge 4$), in $c = 1$ the speed of diffusion takes off faster than that of $c = 0$. At the time $t = 18$, the innovation adoption rate of $c = 1$ almost reaches its maximum, while $c = 0$ needs more than 30 diffusion periods to reach the maximum. It shows that the positive collective pressure from the whole adopters influences the potential adopters via the mass media network. This influence is direct, quick and powerful. The result is very important for marketing the innovation diffusion. Furthermore, the final adoption rate in $c = 1$ is lager than that in $c = 0$. Therefore, we can see that the advertisement is useful to promote the former adopters to adopt the innovation at the beginning of diffusion. The effort of the direct advertisement is sharply weakened in the middle and later of diffusion. In these stages, the social relationship network can make positive effort to the innovation diffusion. Our results suggest that the innovation organization should pay more attention to broadcast the positive feedback of the whole adopters to the potential adopters. This indirect advertising will promote the adoption rate to a higher level in a shorter period.

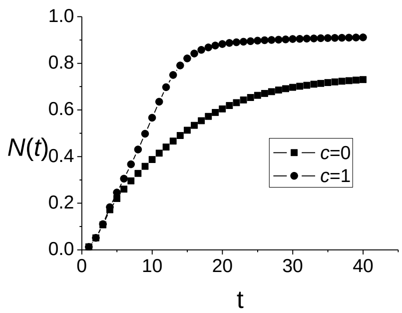

Figure 1. The innovation adoption rate varying with the time evolution at $\bar{k} = 20$

4.2 The speed of the innovation diffusion

We suppose that the direct advertising impact on the potential adopters by 3 times and the marginal utility is decreased by time. From Figure 2, we find that at $t=3$, namely at the third diffusion period, the speeds of the diffusion in $c=0$ and $c=1$ both reach a peak value. It means that the effect of direct advertisement from the mass media network is more important than other factors at the beginning of the innovation diffusion. It can be also seen from Fig. 2 that both of the speed curves decrease monotonically to zero for large t. It means that the adoption rate of the society is going to saturation and consequently the speed decreases. More interestingly, in $c=1$ the diffusion speed reaches a second peak value at $t=10$ and obviously it is a trough between this peak value and the former one. In comparison, such phenomena doesn't appear in $c=0$. This result shows that the mass media network is more important than the social relation network for the later adopters (imitators). The early adopters (innovator) have stronger lead power of public opinion since they have more chance to contact the innovation organization [9]. The early adopters will not only affect the behavior of the potential adopters who have direct relationships with them but also broadcast the innovation over the whole market via the mass media network. They will form a social pressure to make a collective effect on the potential adopters. Thus, the diffusion will reach another high tide in the middle of the diffusion. By all appearances, the speed curve is in accordance with the process of a succeed innovation diffusion [37]. Therefore, the hypothesis that the early adopters make a positive feedback to the whole society through the mass media network is reasonable. In fact, the speed curve in Fig.2 explains the reason that the adoption rate in $c=1$ reaches its saturation more quickly than that in $c=0$, which can be seen from Fig.1. On the other hand, if we consider the time as a uniform and continuous variable, the definition of diffusion speed $n(t)=\Delta N(t)/\Delta t$ may transform to $\lim_{\Delta t\to 0} n(t)=dN(t)/dt$. It shows clearly that the diffusion speed will decrease after two peaks of diffusion. The results are meaningful for the enterprise in advertisement planning and cost controlling.

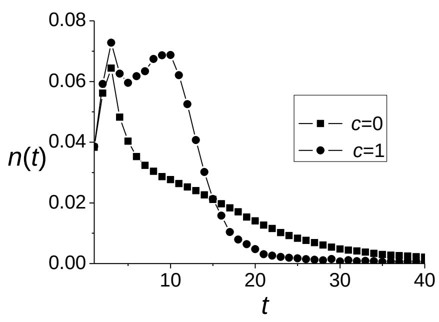

Figure 2. The speed of innovation diffusion varying with the time at $\bar{k}=20$

4.3 The speed of the innovation diffusion at different network's degree and preference level

Let's go further to discuss the speed of innovation diffusion affected by the average degree of the social network. Figure 3 shows the diffusion speeds vary with the time in $c=0$, which only considers the single action of the mass media network. It can be seen from Figure 3 that all the curves decrease monotonically at $t\geq 3$. However, the area under the speed curves is increasing with the average degree. The meaning of the area under the speed curves can be expressed by $N(t)=\int_0^\infty n(t)dt$, which is nothing but the adoption rate of the innovation. Thus, we can draw a conclusion that the final adoption rate increases with the increase of average degree of the social relationship network. This result is in accordance with the one presented in the researches of Pastor-Satorras and Vespignani [32] and Delre et al. [31]. It is worthwhile to point out that the speed curve in $c=0$ will also have double peaks when the social network's average degree is huge (such as $\bar{k}=500$), as shown in Fig. 4. However, average degree equal to 500 is an unacceptable hypothesis since it is unreasonable in the real society. If we switch the calculation to $c=1$ under the same conditions except the average degree, $\bar{k}=20$ for instance, Figure 4 shows clearly that the speed curve also has double peaks. The average degree $\bar{k}=20$ fits the real situation in our society. Therefore, it is quiet reasonable to assume that the social relation network brings a positive feedback on the mass media network.

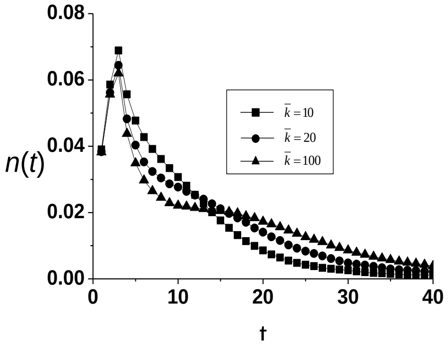

Figure 3. The diffusion speed in $c=0$ varying with the time at different average degrees

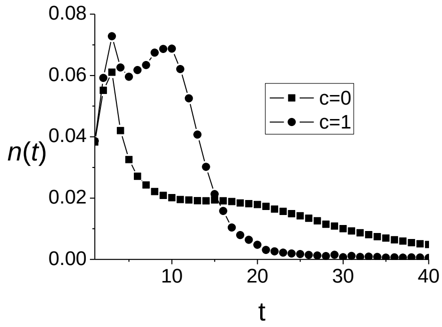

Figure 4. The diffusion speed varying with the time in $c=0$ at $\bar{k}=500$ and $c=1$ at $\bar{k}=20$

Furthermore, it can be seen from Figure 5 that time interval between the two peak values increases with the increase of complexity of the social relationship (namely $\bar{k}$ increases). It means that the more complexity of the social relationship, the longer time it will take to form the collective effect which comes from the potential adopters' response on the former adopters' behaviors. Of course, large time interval is a disadvantage for new product to occupy the prophase market especially when it has other competitive substitutes. However, it is also shown in Figure 6 that the time interval between two peak values depend closely on the value of b. The interval decreases with the increase of b. It means that the potential adopters pay more interest in the mass media network, the second peak appears earlier. Or in another words, the organization make more effort on the broadcasting by mass media network, the collective effect forms sooner. Especially, for $b=0.8$, the second peak appears so quickly that it overlaps directly on the first peak. It is favorable to occupy the market quickly. However, it means that the organization should pay more for the advertisement. Therefore, the organization should optimize the cost of advertisement, based on the real situation of the social network. The key point is to make full use of the collective effect and maximize the benefit with a reasonable advertisement cost.

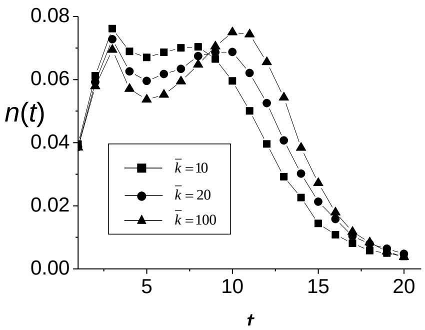

Figure 5. The diffusion speed varying with the time in $c=1$ at different average degrees

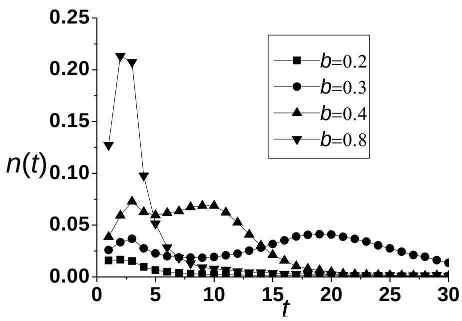

Figure 6. The diffusion speed varying with the time in $c=1$ at different values of b, with the average degree $\bar{k}=20$

5. THE CONCLUDING REMARKS

In present paper, we investigate the social behavior's collective effect on the innovation diffusion by using a micro threshold model. In this model the decision-making behavior of the potential adopters are affected by the following factors: initial estimate of the individual potential adopter, the adopters who have direct relationship with the potential adopters, the advertisement or sales promotion coming from the mass media network, the positive feedback coming from the whole adopters in the society via the mass media network (including the adopters who have no relationship with the potential adopters). With a detailed diffusion tracing, we get the conclusion as follows:

(1) In order to diffuse an innovation, the early advertisement is very important to attract the previous adopters to adopt the innovation product. The effect of direct advertisement is clearly weakened in the middle of diffusion process. At this stage, the social relationship network can promote the innovation diffusion to some extent. Therefore, the organization should pay more attention to make full use of the mass media network to broadcast the adopters' feedback to the potential adopters. Such kind of indirect advertisement will push the adoption rate to a higher level.

(2) At the beginning of the innovation diffusion, the direct advertisement of the mass media network will promote the speed of diffusion to a peak value. Furthermore, the previous adopters have stronger guide ability to public because of contacting more with the organization. The previous adopters bring out the collective effect on the potential adopters via the mass media network and then the speed of diffusion will reach another peak value. The mutual interaction between the social relationship network and the mass media network will cause double peak on the speed of diffusion.

(3) The time for the previous adopters bring out the collective effect on the potential adopters will increase with the enhancive complexity of social relationship. Meanwhile, the time interval between the two peaks of the diffusion speed increases. Nevertheless, the potential adopters pay more interest in the mass media network; the second peak appears earlier which means the sooner to realize the collective effect.

The results obtained here are useful to the innovation diffusion. At the beginning of the innovation diffusion, more advertisements are necessary since it will attract the previous adopters to adopt the innovation in a short time. In the middle of the diffusion process, the previous adopters affect the potential adopters' decisions by the social relationship network. Moreover, the organization should pay more attention to broadcast the adopters' positive feedback to the potential adopters via the mass media network. This indirect advertisement may stimulate the adoption rate to saturation in a shorter period. The innovation diffusion can also reach a higher level.

REFERENCES

[1] Chandrasekaran D, Tellis G J. (2007).A critical review of marketing research on diffusion of new products, in: N.K. Malhotra (Ed.), Review of Marketing Research, Emerald Group Publishing, 2007:39-80.

[2] Hauser J, Tellis G J, Griffin A. (2006).Research on innovation: a review and agenda for "marketing science". Marketing Sci, 25:687-717.

[3] Krishnan T V, Suman A T. (2009).International Diffusion of New Products. London: SAGE Publication.

[4] Mahajan V, Muller E, Wind Y. (2000). New-Product Diffusion Models. New York: Kluwer Academic.

[5] Meade N, Islam T. (2006).Modelling and forecasting the diffusion of innovation – a 25-year review. Int. J. Forecasting, 22:519-545.

[6] Peres R, Muller E, Mahajan V. (2010).Innovation diffusion and new product growth models: a critical review and research directions. Int. J. Res. Mark, 27: 91-106.

[7] Valente T W, Saba W P. (1998).Mass media and interpersonal influence in a reproductive health communication campaign in Bolivia. Commun. Res, 25: 96-124.

[8] Lin N, Burt R S. (1975).Differential effects of information channels in the process of innovation diffusion. Social Forces, 54: 256-274.

[9] E.M. Rogers. (1995). Diffusion of Innovations, 4th ed. New York: Free Press.

[10] Valente T W, Davis R L. (1999).Accelerating the diffusion of innovations using opinion leaders. Ann. Am. Acad. Polit. S. S, 566: 55-67.

[11] Delre S A, Jager W, Bijmolt T H A, Janssen M A. (2010).Will it spread or not? The effects of social influences and network topology on innovation diffusion. J. Prod. Innovat. Manag, 27: 267-282.

[12] Libai B, Muller E, Peres R. (2009).The role of within-brand and cross-brand communications in competitive growth.J. Marketing, 73: 19-34.

[13] Van den Bulte C, Joshi Y V. (2007).New product diffusion with influentials and imitators. Marketing Sci, 26: 400-421.

[14] Kitts JA. (2006). Social influence and the emergence of norms amid ties of amity and enmity. Simul. Model Pract. Th, 12: 407-422.

[15] Bass F M. (1969).A new product growth for model consumer durables. Manage. Sci, 15: 215-227.

[16] Mahajan V, Muller E, Bass F M. (1990).New product diffusion models in marketing: a review and directions for research. J. Marketing, 54: 1-26.

[17] Goldenberg J, Libai B, Solomon S, Jan N, Stauffer D. (2000).Marketing percolation. Physica A, 284: 335-347.

[18] Hohnisch M, Pittnauer S, Stauffer D. (2008).A percolation-based model explaining delayed take-off in new-product diffusion. Ind. Corp. Change, 17: 1001-1017.

[19] Goldenberg J, Libai B, Muller E. (2001).Talk of the network: a complex systems look at the underlying process of word-of-mouth. Market. Lett, 12: 211-223.

[20] Goldenberg J, Libai B, Muller E. (2001).Using complex systems analysis to advance marketing theory development: modeling heterogeneity effects on new product growth through stochastic cellular automata, Acad. Market. Sci. Rev. 9 : 1-19.

[21] Deffuant G, Huet S, Amblard F. (2005).An individual‐based model of innovation diffusion mixing social value and individual benefit. Am. J. Sociol, 110: 1041-1069.

[22] Garcia R. (2005).Uses of agent-based modeling in innovation/new product development research. J. Prod. Innovat. Manag, 22: 380-398.

[23] Zhao J, Mazhari E, Celik N, Son Y J. (2011).Hybid agent-based simulation for policy evaluation of solar power generation systems. Simul. Model Pract. Th, 19: 2189-2205.

[24] Granovetter M. (1978).Threshold models of collective behavior. Am. J. Sociol, 83: 1420-1443.

[25] Macy M W. (1991).Chains of cooperation: threshold effects in collective action. Am. Sociol. Rev, 56: 730-747.

[26] Valente, T W. (1996).Social network thresholds in the diffusion of innovations. Soc. Networks, 18: 69-89.

[27] Barabasi, A L. Albert R. (1999).Emergence of scaling in random networks. Science, 286: 509-512.

[28] Watts D J, Strogatz S H. (1998).Collective dynamics of 'small-world' networks. Nature, 393: 440-442.

[29] Pierreval H, Bruniaux R, Caux C. (2007).A continuous simulation approach for supply chains in the automotive industry. Simul. Model Pract. Th, 15: 185-198.

[30] Garber T, Goldenberg J, Libai B, Muller E. (2004).From density to destiny: using spatial dimension of sales data for early prediction of new product success. Marketing Sci, 23: 419-428.

[31] Delre S A, Jager W, Bijmolt T H A, Janssen M A. (2007).Targeting and timing promotional activities: an agent-based model for the takeoff of new products. J. Bus. Res, 60: 826-835.

[32] Pastor-Satorras R, Vespignani A. (2001).Epidemic dynamics and endemic states in complex networks. Phys. Rev. E, 63: 66-117.

[33] Pastor-Satorras R, Vespignani A. (2001).Epidemic spreading in scale-free networks. Phys. Rev. Lett, 86: 3200-3203.

[34] Rahmandad H, Sterman J. (2008).Heterogeneity and network structure in the dynamics of diffusion: comparing agent-based and differential equation models. Manage. Sci, 54: 998-1014.

[35] Horsky D, Simon L S. (1983).Advertising and the diffusion of new products. Marketing Sci, 2: 1-17.

[36] Simon H, Sebastian K H. (1987).Diffusion and advertising: the German telephone campaign. Manage. Sci, 33: 451-466.

[37] Goldenberg J, Libai B, Muller E. (2002).Riding the saddle: how cross-market communications can create a major slump in sales. J. Marketing, 66: 1-16.