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Service Diffusion in a Market Considering Consumers' Subjective Valuations

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Abstract

With increasing networking and market globalization, it is becoming increasingly difficult to understand how social valuations of products or services emerge based on the interaction of consumers' value judgments. This paper presents a description of a service market model and constructs an agent model of consumers considering a consumer's subjective value using data obtained from a lifestyle survey. Results of the survey elucidate the relation between the usage of information technologies and other consumer attributes. Results of a multi-agent simulation show that the service diffusion pattern can change according to the influence of the intensity of network externalities.

Keywords: service diffusion, lifestyle, network externality, agent-based modeling, multi-agent simulation

1. Introduction

Recently, prediction of the diffusion of products and services is becoming more complicated. Along with development of information technologies, we can select products and services fitting our preferences and be affected by others. As consumers' preferences become increasingly diversified through the growth of information networking, "long-tail" phenomena emerge in the market. This phenomenon shows that our culture and economy specifically examine numerous niches in the tail of the demand curve. On the other hand, some products or services become a big hit. This is called the "winner-take-all" phenomenon [7]. This is true because such products provide innovative functions and the platform for it is given on the internet. Because of the value of networking, we cannot ignore the social factor. To understand such phenomena, we must devote due attention to consumers' behaviors and their decision-making. Many researchers of services are becoming increasingly interested in consumer behavior and lifestyles. However, elucidation of consumer decision-making necessitates consideration not only of their lifestyles but also of their mutual interaction because consumers make decisions depending not only on subjective valuations but also on social factors [20].

Network externalities are social factors determining interaction among people in the market. It is an externality by which a consumer's utility depends on the number of users who consume the same product [11-13,15]. Studies on the network externality address the diffusion of technologies. Katz classified network externalities into two groups: direct network externality and indirect network externality [11]. The former is an externality by which utility depends on the number of units or users connected through a physical network through which information exchange can be done. The latter is an externality by which utility depends on the interdependent relation to the consumption of complementary goods [2][3]. Another aspect of a network externality arises in markets such as that of cellular phone services [14][18]. In such markets, the charge between two different networks is set high, and the charge within a network is set low. Consequently, consumers can obtain higher benefit from companies which have a large network: it is attractive to select such a large company.

The adoptions of information technologies are studied by using questionnaire data. Davis farmed hypotheses related to the decision making of the adoption of the information technology and developed TAM model [4]. In this model, the results of a questionnaire survey verified the validity of these hypotheses. Moreover, Hong et al. [8] and Lopez-Nicolas [16] et al. proposed the models developed on the TAM model, in which the importance of the social influence exerted on a person to use information service is emphasized. However, these models cannot account for the dynamic process of diffusions considering social factors.

It is an effective technique to clarify the spreading process of a service because the agent-based model facilitates incorporation of diversity and interaction of individuals' preferences [17]. For instance, Janssen demonstrated the dynamics of various markets considering product characteristics and the structure of interactions among agents [9][10]. Beck et al. demonstrated the impact of direct and indirect network effects on the adoption of technology [1].

We construct consumers' agent models based on actual data obtained from a lifestyle survey. We also conduct multi-agent system simulations to verify service diffusion mechanisms. Using real data, we try to produce consumer agents resembling real consumers, considering their subjective values. Moreover, the model incorporates network externalities as social factors.

Section 2 presents some lifestyle survey results. This section includes an outline of the survey and results of the analysis. Section 3 presents a model of service markets comprising producer(s) and consumers. In this section, we describe consumer agents based on real data. Section 4 presents results of multi-agent simulations.

2. Lifestyle Survey

This section presents results of the lifestyle survey. We conducted a lifestyle survey comprising multiple questionnaires that assessed daily behavior, leisure, personality, and attitudes toward information technologies. This survey was designed to identify effective segmentations of lifestyles and to specify effective parameters to build human agent models. Takenaka and Ueda explained the effective segmentation of lifestyles through factor analysis [19]. This paper presents other results of the survey to identify relations among consumers' characteristics of various topics.

The survey was conducted for eight days during July 2007 using a membership questionnaire system on a cell phone network. In this system, participants' information about age, sex, jobs, and living area were available.

In all, 8177 people (4443 female and 3744 male) participated in the survey. Including the missing value, two questionnaires were excluded.

We asked 41 questions. Table 1 presents some questions.

Table 1. List of questions.

No.	Question
	:
Q6	How much time do you spend watching television or videos?
Q7	How much time do you spend using the internet on a PC?
Q8	How much time do you spend on telecommunications or text messages on cell phones?
Q9	How much time do you spend using functions other than communication services on cell phones?
Q10	How often do you do online shopping?
Q11	Do you put information on the internet (e.g. homepages, blogs, bulletin boards, and SNS)?
Q12	Do you easily change your mood?
	:
Q16	Do you plan ahead for holidays?
	:
Q19	Do you rely on other opinions on the internet?
Q20	Do you often watch rental DVDs or videos?
	:
Q24	Are you sensitive to fashion and items?
	:
Q26	Do you prefer lively places?

As described in this paper, we particularly examine the relation between the usage of information technologies (the internet on PC and cell phone services) and other attributes (daily behaviors and personalities). This relation was elucidated using Spearman's rank method. Table 2 presents the coefficients of correlation.

These results suggest that the usage of information technologies might be related to daily behaviors and personalities. People who often use cell phone services show different tendencies from those who often use the internet on PCs. We identify cell phone service users' characteristics and those of internet users on PCs as discussed briefly below.

First, in terms of personalities (Q12, Q16, Q24, and Q26), cell phone service users and internet users show quite different tendencies. The amount of the internet use on PCs (Q7) correlates with Q16 and negatively correlates with Q12 and Q26. People who often use the internet on PCs might tend to be emotionally stable and scheduled; they are less open. In contrast, the amount of cell phone service use (Q8 and Q9) correlates with Q12, Q24, and Q26. People who often use cell phone services tend to be emotionally unstable and more open. Additionally, they are prone to sensitivity to fashion and consumption of items, which suggests that cell phone service usage is related to a person's sensitivity to trends.

Furthermore, these attitudes are related to daily behaviors. All three questions (Q7, Q8, and Q9) correlate with Q11 and Q19. Both PC users and cell phone users might tend to put information on the internet and rely on opinions received from other internet users. However, only Q7 correlates with Q10 (Q8 and Q9 negatively correlates with it). Only the internet on PCs might be related to the online shopping services. It is also noteworthy that Q8 and Q9 correlate with Q6 and Q20 but Q7 does not, which suggests that people who often use cell phone services tend to use media such as TV.

Table 2. Spearman's rank-correlation coefficient.

	Q7	Q8	Q9
Q6	0.018	0.121**	0.165**
Q10	0.263**	-0.029**	-0.063**
Q11	0.145**	0.168**	0.183**
Q12	-0.050**	0.131**	0.163**
Q16	0.051**	0.005	-0.070**
Q19	0.060**	0.066**	0.106**
Q20	-0.008	0.063**	0.036**
Q24	0.000	0.118**	0.077**
Q26	-0.035**	0.095**	0.042**

Significance levels: *$p < 0.05$, **$p<0.01$

From these results, we identified the relations between the use of information technologies and other attributes. These results of analyses enable us to understand consumers' characteristics and design new services. In the next section, we describe construction of a market model. The market is assumed to resemble that for cell phone services. We consider the relation between this service and sensitivity to fashions.

3. Modeling of Service Markets

3.1. Outline of the model

Artificial society models are used for explication of social phenomena through application of agent-based computer modeling techniques to social studies [6]. Agent-based modeling enables consideration of individual heterogeneity [17]. We describe the market model as an artificial society model comprising one or two producer(s) and N consumers. Moreover, by setting a parameter based on actual data, we attempt to construct a realistic model.

In this model, the producer offers a service and each consumer decides, based on a personal reservation value and demand, whether to use the service. In this model, the value of services is not dependent solely on its functionality: it is dependent on each consumer's value assessment. We do not seek to distinguish products from services in the following model because both include some functions related to consumer demand. In this study, we particularly assume a service such as a cell phone service as an integration of products and services. Detailed models of a service, consumers, and a producer are described below.

Let each service, S, comprise some functions. We define s_j as the service provided by provider j. In this study, we set three functions:

$$s_j \in S = \begin{pmatrix} f_1 & f_2 & f_3 \end{pmatrix}, \text{ where } f_1, f_2, f_3 \in \{0,1,2,3\}.$$

Here, f_i (i = 1,2,3) is the level of each function; P_j is the price of a service s_j, which is given as

$$P_j = s_j \Gamma^{\mathrm{T}} = \begin{pmatrix} f_1 & f_2 & f_3 \end{pmatrix} \begin{pmatrix} \gamma_1 \\ \gamma_2 \\ \gamma_3 \end{pmatrix}, \quad (1)$$

where $\Gamma = \begin{pmatrix} \gamma_1 & \gamma_2 & \gamma_3 \end{pmatrix}$ denotes the unit prices of f_1, f_2, and f_3. The price is determined by the unit prices multiplied by the functions of the service. The unit prices are given as a cost-plus price in the market in advance.

The one or two producer agent(s) is (are) indexed by $j \in \{A, B\}$. The producer produces services with unit cost $T = \begin{pmatrix} \tau_1 & \tau_2 & \tau_3 \end{pmatrix}$. The profit the producer gains when providing s_j is defined as Π_j.

$$\Pi_j = (P_j - s_j T^{\mathrm{T}}) \times N_j \quad (2)$$

In that equation, τ_1, τ_2, and τ_3 denote the unit cost of f_1, f_2, and f_3. The difference between the price and the cost is the producer's profit. Here, N_j represents the number of consumers using s_j.

The producer is modeled as a learning agent with a Q-learning mechanism, which is a reinforcement approach [21]. The producer acquires a policy through repeated interaction with the environment. The producer decides which service to produce at each step, with the intention of creating a service to maximize his total profit.

Each consumer C_n (n = 1, 2,…, N) has a demand level:

$$d_n = \begin{pmatrix} d_{n1} & d_{n2} & d_{n3} \end{pmatrix}, \text{where } d_{n1}, d_{n2}, d_{n3} = \{0,1,2\}.$$

A consumer's own reservation value $V_n = (v_{n1}\ v_{n2}\ v_{n3})$ expresses the willingness to pay for one level of each function. Furthermore, RP_n is the reservation price; price C_n represents a willingness to pay for a service, given as the following.

$$RP_n = d_n V_n^T = \begin{pmatrix} d_{n1} & d_{n2} & d_{n3} \end{pmatrix} \begin{pmatrix} v_{n1} \\ v_{n2} \\ v_{n3} \end{pmatrix} \quad (3)$$

Therein, C_n makes the decision of whether to use s_j or not based on the uncompensated rule [5]: C_n uses s_j when the following two equations are satisfied.

$$RP_n - P_j \geq 0 \quad (4)$$

$$f_1 \geq d_{n1} \cap f_2 \geq d_{n2} \cap f_3 \geq d_{n3} \quad (5)$$

When C_n uses s_j , it gains utility U_n.

$$U_n = RP_n - P_j \quad (6)$$

Furthermore, the network externality is introduced only into the second function.

$$v_{n2} = a + bN_j \quad (7)$$

In that equation, parameter a is its own value of f_2. Parameter b is the value of the network scale. With the increasing number of users of service s_j, the value of the producer j's service s_j increases.

3.2. Consumer demand modeling based on a lifestyle survey

To consider a consumer's subjective value, this section determines the demand levels (d_n) of consumers based on actual data analyzed in the preceding section. As described above, we assume services such as cell phone services. The values associated with this service might be categorized into the following three types: (i) value linked to the functionality of the product, (ii) value connected with the communications themselves, and (iii) added value such as brand loyalty. Taking the example of cellular telephones, the types described above can be related as follows: (i) the amount of time spent on the use of functions other than talking and text messaging; (ii) the amount of time spent on the use of talking and text messaging functions; and (iii) sensitivity to styles and fashions. Based upon the answers to these, d_{n1}, d_{n2}, and d_{n3} are determined, respectively, using three levels (0, 1, 2). A market model of 767 consumers was constructed based on these survey data.

Details of consumers' demand are presented in Figure 1. For example, consumers for whom demand is d_n = (2 2 2) are most consumers. Furthermore, d_n = (2 2 2) are consumers with high demand levels for all functions. Their answers of those questions are (i) over 2 hours a day spent on the use of functions, (ii) over 2 hours a day spent on the use of talking and text messaging, and (iii) sensitive to styles and fashions. They can be considered as very active consumers. This reflects the result of the analysis as described in the preceding section. In addition, d_n = (1 1 2) denotes consumers with normal demand levels for f_1 and f_2 and high demand levels for f_3.They give great attention to the added value. Finally, d_n = (1 1 0) represents consumers who have normal demand levels for f_1 and f_2 and low demand level for f_3. Their answers of those questions are (i) under 30 min a day spent on the use of functions, (ii) under 30 min a day spent on the use of talking and text messaging, (iii) not sensitive to styles and fashions. They have some demand for services but they are passive consumers.

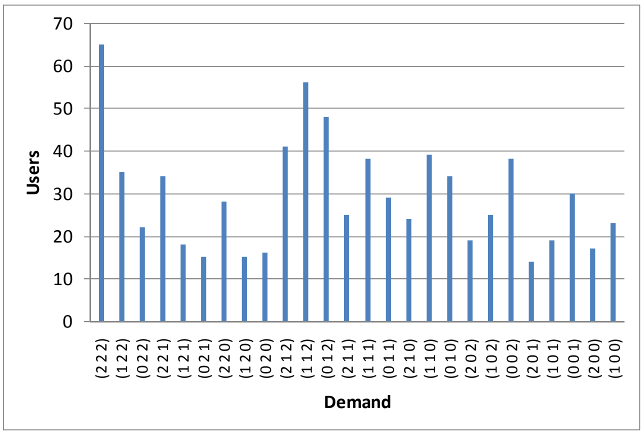

Figure 1. Consumers' demand.

4. Mult-Agent Simulation

4.1. Simulation setup

To examine service diffusion, this section presents three simulations designated as Case 1, Case 2, and Case 3. Case 1 has one producer. Case 2 has two producers (Producer A and Producer B). Competition holds in the market. Moreover, consumers' preferences are considered in Case 3. Effects of network externalities on market selection are examined by changing coefficient b of the second function (b=0, 0.005, 0.01) in all cases. We set the range of b so that consumers' reservation prices were set within appropriate ranges. For example, setting b = 0.005, when the number of users (N) is 100, v_2 increases by 0.5 points.

In Case 1 and Case 2, the reservation values (V_i) of all consumers are determined uniformly, which signifies a lack of differences between the value of Producer A's service and that of Producer B's service. Therefore, considering consumers' preferences in Case 3, we discern differences in the value of services. In Case 3, consumers are assumed to have their preferences: $j \succ j' \quad (j \neq j')$. Based on their preferences, their reservation values for service $s_k \in S$ are determined. We update the third function (v_{n3}) in V_n according to the consumer's preferences:

$$v_{n3} \leftarrow \begin{cases} \overline{v_{n3}} + 1 & k = j \\ \overline{v_{n3}} - 1 & k = j' \end{cases} , \tag{8}$$

in which $\overline{v_{n3}}$ signifies the constant value of v_{n3} in Case 1 and Case 2. When the service is provided by the producer a consumer (C_n) prefers, his reservation value is set higher than those in Case 1 and Case 2. Otherwise, it is set lower. $j, j' \in \{A, B\}$ are stochastically set before simulations. Consequently, about half of consumers have their preferences $A \succ B$; the remaining consumers have $B \succ A$.

The other parameters are fixed as follows. We set those parameters so that the number of users can be maintained within appropriate ranges while ensuring the producer's profit to some degree.

As a summary, Table 3 presents all parameters.

A trial of simulations contains 5000 × 10 steps. During steps, producers acquire their policy. Every 5000 steps, the parameters except for learning tables are initialized. Learning tables continue to be updated. We define the market situation in the last (50 000th) step. We conducted some trials of each simulation. The following results are representative examples.

Table 3. Model parameters.

Parameter	**Value**
Total number of consumers (N)	767
Consumer demand level (d_n)	set using actual data (Figure 1)
Consumer reservation value (V_n)	・Case 1 or Case 2 (3 2.5+bN 2) ・Case 3 (3 2.5+bN 3) or (3 2.5+bN 1) *According to consumer preferences.
Coefficient of network externality (b)	{0, 0.005, 0.01} (Simulation settings)
Level of service function (f_1, f_2, f_3)	{0, 1, 2, 3} (Producer sets this based on policy))
Unit prices of the service (Γ)	(2 1.5 1.5)
Unit costs of the service (T)	(1.5 0.5 1)

4.2. Simulation results (Case 1)

Table 4 and Figure 2 present results of Case 1; one producer exists in the market. They are the coefficient of the network externality, the selected service, the producer's profit, and the consumers' utility. Actually, s_j = (2 2 2) is selected in the market through learning processes when the network externality is not considered (b=0); it is a service with sufficient inclusion of each function. Figure 1 shows that this service best meets the demands of most consumers. When the network externality is considered as mild (b=0.005), although the same service is selected, the consumers' utility, producer's profit, and number of users all increase. Actually, s_j = (2 2 2) becomes accepted by users whose original demand levels were not high; positive network externality enhances their motivation. When the network externality is considered strong (b=0.01), s_j = (2 3 3) is selected in the market through learning processes, which has higher functions than the most generally accepted service: s_j = (2 2 2). Moreover, the producer obtains higher profit, but consumers garner less utility than in Case 1 (b= 0.005).

Table 4. Diffusion of a service in Case 1

Network externality (*b*)	**Selected service (s_j)**	**Number of users (N_j)**
0	(2 2 2)	265
0.005	(2 2 2)	397
0.01	(2 3 3)	354

By increasing the value of the coefficient b, the consumers' reservation value becomes high and the number of users increases. However, when the value of b is too high (b = 0.01), the service with high functions is selected and the number of users decreases. In a monopoly market, the producer is known to become a price maker and set prices high. However, we can not determine why a producer sets high functionality in this model, which remains as one issue to be clarified in future studies.

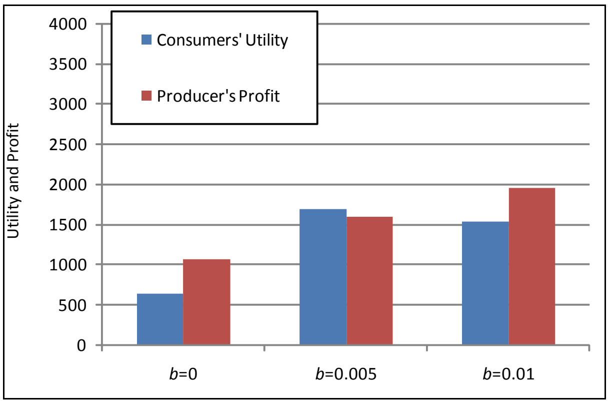

Figure 2. Producer's profit and consumers' total utility in Case 1.

4.3. Simulation results (Case 2)

Table 5 and Figure 3 present results obtained for Case 2; this case has two producers and the competition is considered. Whether the network externality is considered or not, service s_B = (2 2 2) is selected in the market as one of two services. On the other hand, other selected services have lower level functions such as s_A = (2 1 2), s_A = (1 2 2), and s_A = (1 1 2). When the network externality is considered strong, consumers' utility is much higher than that obtained in Case 1. This is true because, in Case 1, s_j = (2 3 3) is selected: it has higher-level functions than those which consumers demand. However, in Case 2, s_B = (2 2 2) is selected, which meets the demands of many consumers. As a result of competition among producers, appropriate services for consumers are provided in the market. In this case, by increasing the value of coefficient *b*, the total number of users increases and consumers can obtain much profit.

Additionally, when the network externality is considered strong, the gap separating Producer A's profit and Producer B's profit widens, which is considered to be one aspect of the effect of network externalities.

Table 5. Diffusion of services in Case 2

Network externality (*b*)	Producer A's service (s_A) / Number of users (N_A)	Producer B's service (s_B) / Number of users (N_B)
0	(2 1 2) / 165	(2 2 2) / 180
0.005	(1 2 2) / 199	(2 2 2) / 236
0.01	(1 1 2) / 235	(2 2 2) / 357

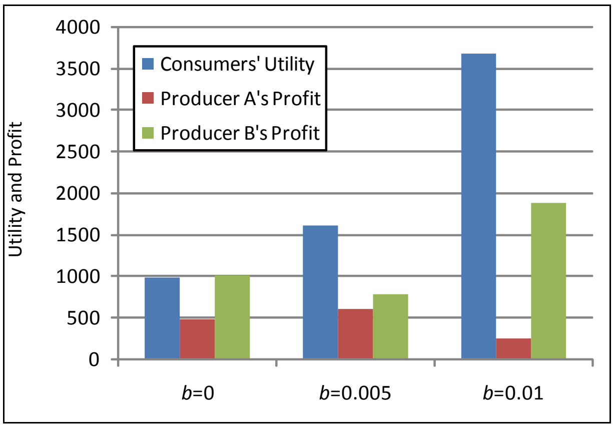

Figure 3. Each producer's profit and consumers' total utility in Case 2.

For Case 2, Figure 4, Figure 5, and Figure 6 show the distribution of users. These figures enable us to classify users. In Figure 4 and Figure 5, consumers are divisible into two groups according to their demand level for f_2 (d_2). The value connected with the communications themselves (f_2) is not required much when the network externality is not considered. Consequently, users choose the service based on their demand level for f_2 (d_2). Users who have a high demand level for f_2 (ex. d_n = (2 2 2) or d_n = (2 2 1) …) choose s_B = (2 2 2). On the other hand, users who have a normal demand level for f_2 (ex. d_n = (2 1 2) or d_n = (1 1 2) …) choose s_A = (2 1 2). In Figure 5, when the network externality is considered mildly, the value connected with the communications themselves is required. Therefore, users who have a high demand level for f_2, i.e., active users, choose the service based on the demand level for f_1 (d_1). Here, active users are classifiable into s_B = (2 2 2) users and s_A = (1 2 2) users. Moreover, users who have a normal demand level for f_2 are considered as users following after active users; they choose the service based on the demand level for f_1.

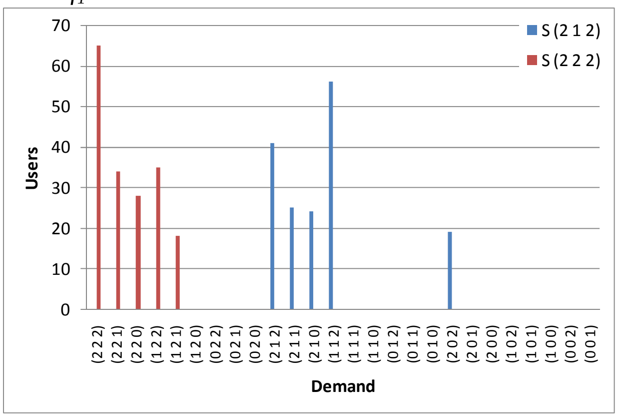

Figure 4. Distribution of users (b = 0) in Case 2.

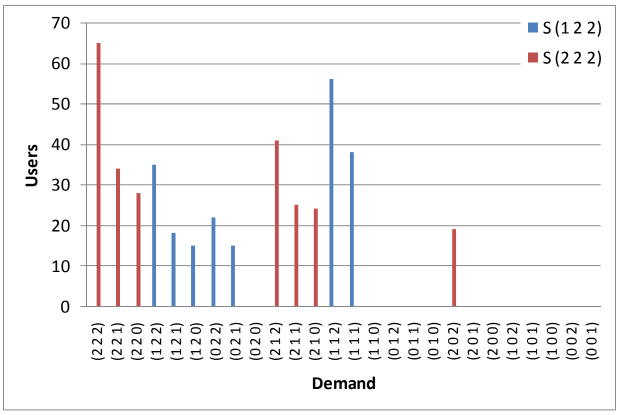

Figure 5. Distribution of users (b = 0.005) in Case 2.

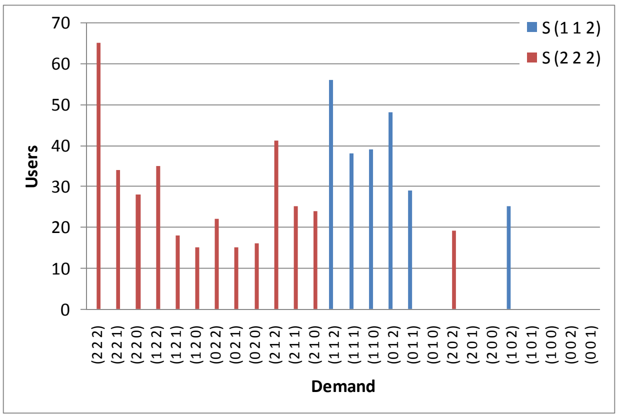

Figure 6. Distribution of users (b = 0.01) in Case 2.

As shown in Figure 6, when the network externality is considered strong, all active users choose the same service, s_B = (2 2 2), because the effect of the network externality is so strong that consumers can not choose the service based on their own preference. This phenomenon might be considered as a winner-take-all phenomenon.

Additionally, f_3 of all services selected in the markets in every case is always 2: more users have a demand level for f_3 that is high ($d_3 = 2$) than have a demand level for f_3 that is low or normal ($d_3 = 0$ or 1). These phenomena suggest that users whose demand level for f_3 is high—users who are sensitive to fashions and styles—play an important role in service diffusion.

4.4. Simulation results (Case 3)

Table 6 and Figure 7 present results obtained for Case 3; consumers' preferences are considered. When the network externality is considered, the same services ($s_A = s_B$ = (2 2 2)) are selected. When consumers have the high reservation price for one serivice (A's or B's), the market is not segmented by producers.

The consumers' total utility increases in all coefficients of b compared within Case 2. This is true because it is easy for consumers to select a service they prefer. When the network externality is not considered (b = 0), the same services as those in Case 2 are selected and total service users ($N_A + N_B$) increase compared within Case 2. This also results from the consideration of consumers' preferences.

From the producers' perspective, because some consumers potentially prefer each producer's service, both producers acquired the same strategy. They did not segment the market. When the network externality is considered (b= 0.005), the producers compete for consumers and obtain less profit than in Case 2. When the network externality is considered strong (b = 0.01), Producer B got many more users than Producer A, which also results from a lack of market segmentation. When consumers' preferences are considered, one producer obtains much profit. The other producer gets less profit.

Table 6. Diffusion of services in Case 3

Network externality (b)	Producer A's service (s_A)/ Number of users (N_A)	Producer B Selected service / Number of users
0	(2 1 2) / 158	(2 2 2) / 253
0.005	(2 2 2) / 149	(2 2 2) / 194
0.01	(2 2 2) / 61	(2 2 2) / 471

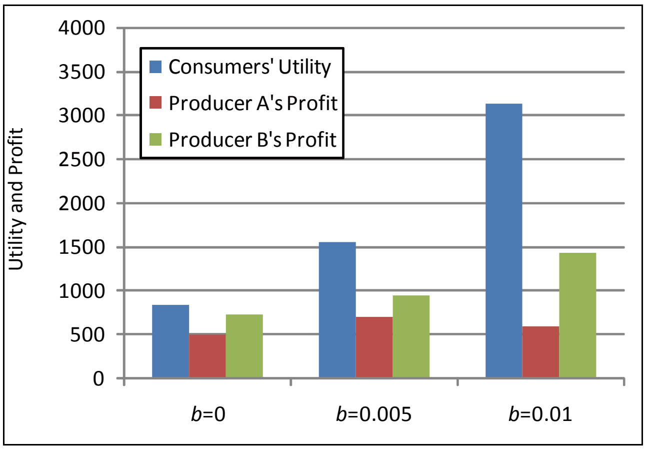

Figure 7. Each producer's profit and consumers' total utility in Case 3

For Case 3, Figure 8, Figure 9, and Figure 10 portray the distribution of users. In Figure 8 and Figure 9, some consumers with the same demand level select Producer A's services. Others select Producer B's services. Especially, this phenomenon is apparent in Figure 9 because both producers produce the same services. Moreover, according to the network effects, Producer B obtained more users than Producer A. Consumers with d_n = (2 2 0) selected the Producer B's service because of the network scale. On the other hand, when the network externality is considered strong (b = 0.01), irrespective of consumers' preferences, most consumers selected Producer B's service. This is true because the network effects are so strong that consumers' preferences have little effect on their decision-making. After exceeding a critical threshold of the number of users, one service might spread among all people, reflecting a winner-take-all phenomenon.

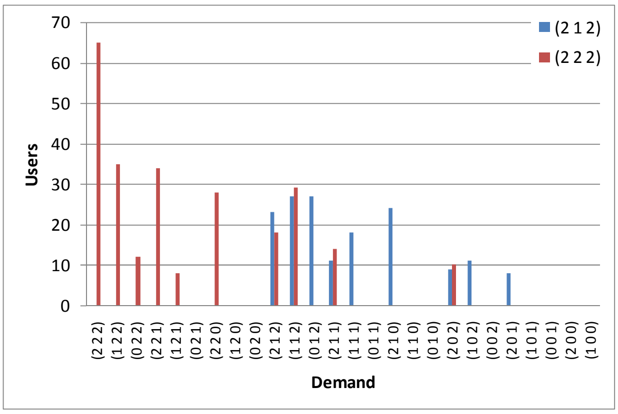

Figure 8. Distribution of users (b = 0) in Case 3

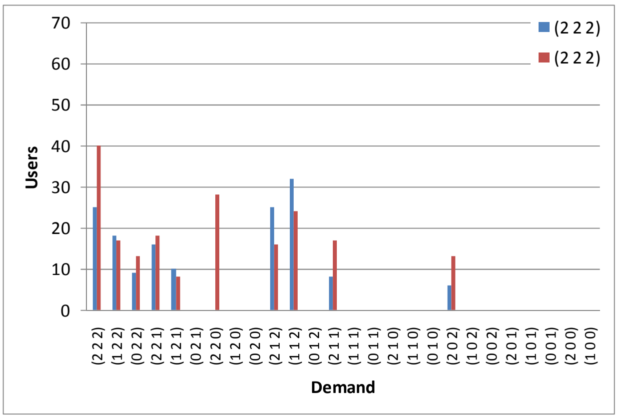

Figure 9. Distribution of users (b = 0.005) in Case 3

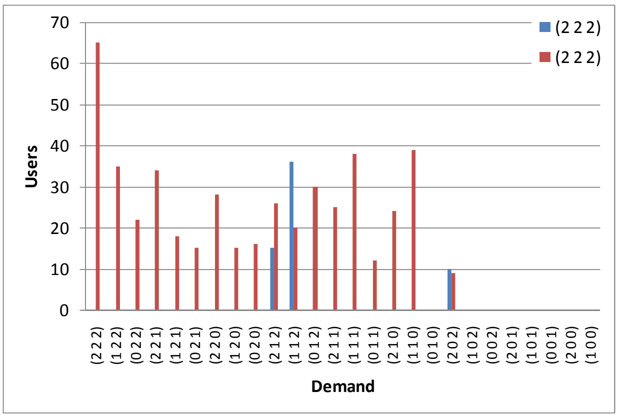

Figure 10. Distribution of users (b= 0.010) in Case 3

In the Japanese market of cell phone services, similarly to the simulation results, some service providers produce services with similar functions. In Japan, users are distributed among three large provider companies. In this case, consumers' preferences for service providers such as brand images have a strong influence on the selection of services. In this model, similar phenomena might emerge through simulations.

5. Conclusion

This paper presented discussion of the mechanism of service diffusion using multi-agent system simulations.

First, it denotes results of the lifestyle survey, showing relations between the usage of information technologies and other attributes. Especially, we identified different relations with personalities and daily behaviors between consumers who often use cell phones and those who often use the internet on a PC. Then it identified relations between cell phone services and sensitivity to fashions. We considered this relation in the construction of a market model.

We constructed a market model using survey data. To clarify the diffusion mechanism, we specifically investigated the following three points: competition among producers, the effect of the network externality, and consideration of consumers' preferences. Results of simulations show that, through competition, the services which meet demands for consumers are selected (Case 2). When consumers' preferences are considered (Case 3), simulation results show that consumers can select the service they prefer, but producers cannot segment the market. Overall, network externalities have positive effects on consumers, but widen the gap between producers' profit levels. These factors might have great effects on service diffusion. Producers must consider these factors when they design a service.

As described in this paper, agents' decision-making is implicitly assumed to be rational. However, in the real world, people do not always make decisions rationally. Future studies will address bounded rationality in decision making. Moreover, we will examine temporal changes in social valuations of services through dynamic interaction among consumers.

6. References

[1] R. Beck, D. Beimborn, T. Weitzel, and W. Konig. "Network effects as drivers of individual technology adoption: Analyzing adoption and diffusion of mobile communication services", *Information Systems Frontiers*, vol. 10, pp. 415–429, Sep. 2008.

[2] C.-F. Chou and O. Shy. "Network effects without network externalities", *International Journal of Industrial Organization*, vol. 8, pp. 259–270, 1990.

[3] J. Church and N. Gandal. "Network Effects, Software Provision, and Standardization", *Journal of Industrial Economics*, vol. 40, pp. 85–103, 1992.

[4] F. D. Davis. "Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology", *MIS Quarterly*, vol. 13, pp. 319–340, 1989.
[5] FF Engel, RD Blackwell, and P. Miniard. *Consumer Behavior*, The Dryden Press, 1993.
[6] J. M. Epstein and R. Axtell. *Growing artificial societies: social science from the bottom up*, Washington, DC, USA The Brookings Institution, 1996.
[7] R. H. Frank and P. J. Cook. *The Winner-Take-All Society: Why the Few at the Top Get So Much More Than the Rest of Us*, Penguin, 1996.
[8] S. J. Hong, J. Y. L. Thong, J. Y. Moon, and K. Y. Tam. "Understanding the behavior of mobile data services consumers", *Information Systems Frontiers*, vol. 10, pp. 431–445, Sep 2008.
[9] M. A. Janssen and W. Jager. "Fashions, habits and changing preferences: Simulation of psychological factors affecting market dynamics", *Journal of Economic Psychology*, vol. 22, pp. 745–772, Dec 2001.
[10] M. A. Janssen and W. Jager. "Simulating market dynamics: Interactions between consumer psychology and social networks", *Artificial Life*, vol. 9, pp. 343–356, Fall 2003.
[11] M. L. Katz and C. Shapiro. "Network Externalities, Competition, and Compatibility", *American Economic Review*, vol. 75, pp. 424–440, 1985.
[12] M. L. Katz and C. Shapiro. "Technology Adoption in the Presence of Network Externalities", *Journal of Political Economy*, vol. 94, pp. 822–841, Aug 1986.
[13] M. L. Katz and C. Shapiro. "Network effects, Software provision, and Standardization", *The Journal of Industrial Economics*, vol. 40, pp. 85–103, 1992.
[14] J.-J. Laffont, P. Rey, and J. Tirole. "Network competition: II. Price discrimination", *RAND Journal of Economics*, vol. 29, pp. 38–56, Spring, 1998.
[15] Deishin Lee and H. Mendelson. "Adoption of Information Technology Under Network Effects", *Information Systems Research*, vol. 18, Dec. 2007.
[16] C. Lopez-Nicolas, F. J. Molina-Castillo, and H. Bouwman. "An assessment of advanced mobile services acceptance: Contributions from TAM and diffusion theory models", *Information & Management*, vol. 45, pp. 359–364, Sep. 2008.
[17] H. Rahmandad and J. Sterman. "Heterogeneity and network structure in the dynamics of diffusion: Comparing agent-based and differential equation models", *Management Science*, vol. 54, pp. 998–1014, May 2008.
[18] M. Z. Shi, J. W. Chiang, and B. D. Rhee. "Price competition with reduced consumer switching costs: the case of "wireless number portability" in the cellular phone industry", *Management Science*, vol. 52, pp. 27–38, Jan. 2006.
[19] T. Takenaka and K. Ueda. "An analysis of service studies toward sustainable value creation", *Int. J. Sustainable Manufacturing*, vol. 1, pp. 168–179, 2008.
[20] K. Ueda, T. Takenaka, and K. Fujita. "Toward value co-creation in manufacturing and servicing", *CIRP Journal of Manufacturing Science and Technology*, vol. 1, pp. 53–58, 2008.
[21] C. Watkins and P. Dayan. "Technical Note: Q-Learning", *Machine Learning*, vol. 8, pp. 279–292, 1992.

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