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Modeling Competitive Diffusion Process in Japanese ADSL Service Market

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ABSTRACT

This study models innovation diffusion process with brand-level competition, focusing on the competition among ADSL service providers in Japan. For a particular brand (service provider), the diffusion process is assumed to be influenced by three forces: (1) the external influence through mass media, (2) the internal influence of the communication with the brand adopters, and (3) the influence due to the market growth of the product category. Through the assumption that the internal influence of each brand in a product category has the identical structure, the proposed brand-level model can be summed up to the Bass model of the product category, and solved with a closed-form expression. Applying the model to the diffusion of ADSL market in Japan, the empirical results reveal that the proposed model describes the brand-level diffusion patterns very well.

Keywords: ADSL service, diffusion process, competition, Bass model

1. INTRODUCTION

Following the success of the Bass model (1969), marketing researchers have developed different types of diffusion models to address various issues concerning the sales growth of new products (Krishnan, Bass, and Kumar 2000). These issues include analyzing the role of marketing-mix variables in the diffusion process, developing multi-product interaction diffusion models, investigating the innovation diffusion process in multi-markets, and so forth. However, most of the models focus only on category-level diffusion problems. For companies such as Intel and Microsoft that hold near-monopoly positions in their respective markets, the category-level sales growth is of primary concern. But in industries such as minivans and cellular-phones with severe competition, brand managers are likely to pay attention to understanding the sales growth at the brand-level.

The diffusion literature recognizes that all categories evolve from a centralized diffusion process, initially dominated by a monopolist, into a decentralized process having many competitors (Rogers, 1995). Cross-brand or competitive interpersonal influence was first investigated in the marketing literature by Peterson and Mahajan (1978). They proposed a system of equations for different types of multiple product interactions including complement, substitute, and contingent. Since the 1990s, researchers have proposed several models to describe brand-level innovation diffusion process. Currently, researches on brand-level innovation diffusion are not sufficient and always concern a special problem. As pointed out by Chatterjee, Eliashberg, and Rao (2000), there are opportunities for empirical researchers to work on competitive diffusion model specifications across product and service categories and across competitive positions within categories.

The paper first reviews the past researches about the brand-level innovation diffusion. Then a competitive diffusion model is proposed and applied to the diffusion of ADSL subscribers in Japan, followed by some managerial implications and limitations.

2. BRAND-LEVEL DIFFUSION MODELS

Mahajan, Sharma, and Buzzell (1993) extended the Bass model to assess the impact of new-brand entry on market expansion of the incumbent brands as well as the whole market. Specifically, they introduced a new interaction term to capture the internal influence of one brand's growth through drawing adopters from other brands' potential adopters. The model was illustrated by applying it to the Polaroid and Kodak case in instant photography industry from 1976 to 1985. The model was estimated under the assumption that the intensity of internal influence is identical for all brands. Estimation results suggest that the model is appropriate for the Polaroid and Kodak case.

Parker and Gatignon (1994) developed a framework to provide a systematic analysis of alternative specifications for brand-level first purchase diffusion. They started with a general specification in which the brand-level adoption is a function of diffusion effects, price and advertising, and suggested four types of brand-level diffusion processes depending on the nature of interpersonal communication and brand-level competition. They have evaluated these specifications by estimating these four models on brand trial data in a new packaged goods category, using the NLS procedure. The results showed that no one specification appeared to dominate others across brands, and the effectiveness of the models appeared to be significantly different across brands.

Givon, Mahajan, and Muller (1997) provided an example of a competitive brand level diffusion model with a more specific focus than Parker and Gatignons' (1994) work. In a competitive extension to their earlier model (Givon, Mahajan, and Muller 1995), the authors investigated the implications of piracy in a duopolistic software market. The market dynamics are captured in a framework that extends the Bass model to incorporate brand switching as well as legal and illegal uses of the competing software brands. This modeling approach was used to analyze the diffusion of Lotus 1-2-3 versus Other Spreadsheets and WordPerfect versus Other Word Processors in the United Kingdom. The results showed that for Lotus 1-2-3 the users were likely to switch to Other Spreadsheets than vice versa, and for WordPerfect the users were likely to influence the users of Other Work Processors to switch than vice versa.

Krishnan, Bass, and Kumar (2000) proposed a model to analyze the impact of later entrant on the sales growth and diffusion speed for the whole category as well as for the incumbent brands. The authors supposed that two brands were presented in the market from the time of introduction. When the third brand was introduced, the market potential of the whole category would expand and the category market would start diffusing faster. Furthermore, the diffusion speed of the incumbent brands might be affected either positively or negatively depending on the model parameters. The model was applied to the cellular phone industry of six markets in the United States from 1983 to 1996. The results revealed that the effects of the third entry on incumbent brands and total category were different across markets.

Past researches on brand-level innovation diffusion have provided limited knowledge to understand both of the brand-level growth pattern and the relationships among brands. Researchers have made efforts to specify model parameters appropriate for special cases. All these models seem appropriate for the special cases in their works. However, the models cannot be solved in closed-form expressions, which made researchers employ discrete formulations to estimate continuous diffusion processes. This would result in the estimation bias and decrease the attractiveness of the models. Krishnan, Bass, and Kumar (2000) proposed a brand-level diffusion model for investigating the effects of a new entrant on diffusion speed and market potential for both the incumbent brands and the whole product category. Although their model has a closed-form solution, it did not incorporate the competitive effect among brands directly.

3. THE PROPOSED DIFFUSION MODEL

The concept underlying the Bass model is the assumption that the diffusion of an innovation is stimulated by two forces: (1) the external influence such as the mass media, and (2) the internal influence such as the communication between adopters and potential

adopters. For a particular brand in a product category, the brand-level diffusion may be affected by three forces: (1) the external influence through mass media, (2) the internal influence through adopter-nonadopter communication of the brand, and (3) the influence from the growth of product category (Nakajima, 1990). Hence, given that there are n brands in a product category, the diffusion process of the brand j ($j=1, \dots, n$) can be expressed as follows:

$$f_j(t) = (1 - F(t))(p_j + q_j F_j(t) + r_j F(t)) \quad (1)$$

where $F(t)$ and $F_j(t)$ are the cumulative adoption distribution for the product category and brand j , respectively. $f_j(t)$ is the p.d.f. of adoption for brand j . The term $p_j(1-F(t))$ captures the adoption due to external influence for brand j , and $q_j F_j(t)(1-F(t))$ captures the adoption due to internal influence of brand j . The parameters p_j and q_j represent external and internal coefficients, respectively, which are the same as those in the basic Bass model. The term $r_j F(t)(1-F(t))$ in the above equation represents the adoption due to the influence of the growth of the whole product category on brand j . For each brand, the influence from the maturity of total market may be different. This difference is captured by the parameter r_j .

It is common that the success of product category would influence the adoption of a particular brand in several ways, such as communicating the positive information about the product category, decreasing the uncertainty of the product, and so forth. Although brand-level communication would be the main force impacting the subsequent adoption of that brand, the effect of the cumulative adoption level of product category must be considered. Note that in equation (1), the adoption for brand j comes from the rest of the whole market potential, that is, $1-F(t)=1-\sum_i F_i(t)$. As Krishnan, Bass, and Kumar (2000) has pointed out, when consumers make decision to buy a new product, the question of "what brand to buy" would be only the secondary to the "whether or not to buy the product" question. In this case the category effect is likely dominant and the specification of market potential for each brand may not be suitable. If the category effect is not dominant, in contrast, the adoption for brand j can be expected to come only from $1-F_j(t)$ as in Mahajan, Sharma, and Buzzells' model (1993). In effect, for analyzing category-level diffusion, the Bass model (1969) which focuses on $f(t)/(1-F(t))$ should be used. On the contrary, for analyzing the brand-level diffusion, in which the category effect dominates the brand-level effect in consumer's buying behavior, $f_i(t)/(1-F(t))$ should be considered.

Summing up the both sides of equation (6) including all brands yields:

$$\sum_j f_j(t) = (1 - F(t))(P + \sum_j q_j F_j(t) + R F(t)) \quad (2)$$

where $P=\sum_i p_i$, $R=\sum_i r_i$. Furthermore, assuming that the intensity of internal communication effect for each brand in the product category is identical, that is, $q_j=Q$,

the above equation results in the category Bass model (Bass 1969):

$$f(t) = (1 - F(t))(P + (Q + R) \cdot F(t)), \quad f(t) = \sum f_j(t). \quad (3)$$

And for brand j ,

$$f_j(t) = (1 - F(t))(p_j + Qx_j + r_j F(t)). \quad (4)$$

Thus, the cumulative diffusion rate $F(t)$ can be easily solved as a function of time t :

$$F(t) = \frac{1 - C \cdot e^{-(P+Q+R)t}}{1 + (Q + R) / P \cdot C \cdot e^{-(P+Q+R)t}} \quad (5)$$

$$C = \frac{1 - F_0}{1 + (Q + R)F_0 / P}, \quad F_0 = F(0). \quad (6)$$

Substituting $F(t)$ into the brand level equation (4) and then it can be solved to yield $F_j(t)$ as a function of time:

$$F_j(t) = \frac{Pr_j - p_j R}{QR} + \frac{r_j}{R} F(t) - K_j \left(F(t) + \frac{P}{Q + R} \right)^{Q/(Q+R)} \quad (7)$$

$$K_j = \frac{r_j}{R} \left(F_0 + \frac{P}{Q + R} \right)^{Q/(Q+R)} - \left(F_{j0} + \frac{p_j}{Q} - \frac{r_j P}{Q(Q+R)} \right) \times \left(F_0 + \frac{P}{Q + R} \right)^{Q/(Q+R)}, \quad F_{j0} = F_j(0) \quad (8)$$

Unlike the model proposed by Krishnan, Bass, and Kumar (2000), the model proposed here incorporates the effects of category growth on adoption for a particular brand directly. The parameter r_j represents the intensity of influence of the growth of product category on brand j , and r_j may differ across brands. This turns to be important when considering the brand-level innovation diffusion issues. Furthermore, the brand-level model proposed here can be summed up to the Bass model (1969). This gives validity to the proposed model because the Bass model has a strong behavioral basis and has found excellent empirical support over a wide range of products (Mahajan, Muller, and Bass 1993). The assumption that $q_i = Q$ seems reasonable because the communication pattern may be the same for all brands in a product category. In addition, the closed-form expression of the proposed model has some other advantages, especially it enables researchers to employ the NLS estimation procedure.

4. APPLICATION: DIFFUSION OF ADSL SERVICE IN JAPAN

4.1 The ADSL Market in Japan

According to the Japan Ministry's statistics, by the end of September 2002, the number of ADSL subscribers in Japan totaled about 4.22 million, adding about 1.8 million or an increase of 77.5 percent as of a-half-year before, at the end of March 2002¹. This number breaks

down to 1.72 million subscribers of NTT East and NTT West, and 2.50 million subscribers of other service providers.

The ADSL market of Japan expanded rapidly with the entrance of large competitors. At the end of 1999, Tokyo Metallic Communications and eAccess began to launch internet connection service – ADSL for home users by offering data transfer speeds up to 640kbps. Its cost subscribers more than 6,000 yen per month at that time. The ADSL market experienced slow-growth in the first year. But with the entry of NTT, the market began to take off. The ADSL had not been a viable choice for NTT, because NTT had decided to employ optical-fiber cables for access lines instead of copper-cable based technologies (ADSL). However, it would be projected to take more than ten years to complete the overall implementation. Therefore NTT decided to adopt ADSL during the construction of the optical-fiber networks. By the end of June 2001 when NTT had entered into the ADSL service market about half a year ahead of Yahoo!BB's new entry, the total number of cumulative subscribers increased up to 300 thousands. This number was about thirty times larger than that of a half-year before when NTT entered into the market. The market share of NTT was as high as 63 percent. In addition, not only the NTT, other companies such as Tokyo Metallic and eAccess also expanded their markets more rapidly than before.

With the entry of Yahoo!BB, the competition among companies became intense, especially in terms of price reduction. Before Yahoo!BB entered into the market, average monthly fees of the top-three companies (NTT, Tokyo Metallic Communications, and eAccess) were around 5,400 yen, which is approximately 20 percent reduction compared with that of the previous year. When Yahoo!BB offered monthly fee of 2,280 yen in August 2001, the large price reduction contributed to the rapid expansion of the market. The number of monthly subscribers increased from 110 thousands in July 2001 to 270 thousands in October 2001. Thereafter, the number of monthly subscribers remained around 330 thousands. From the beginning of 2002, the market share of NTT East and NTT West remained virtually unchanged about 40 percent. This means the market shares of NTT and the non-NTT camp were stabilized. However, the market shares among the non-NTT camp had been changed. According to the ministry's statistics, with the integration of Metallic Communications Corp. into the Softbank group, Yahoo!BB held about 21.6 percent of Japan's ADSL market. It appeared that Yahoo!BB and NTT began fierce competition for the top market share. With the development of ADSL technology, the maximum speed for data transmission has been changed from 640kbps to 26Mbps. Now, the difference of ADSL monthly fees among the companies is not large – from 3,500 to 4,000 yen. At present, the competition among companies is mainly based on service and quality but not price.

¹ To investigate the competition between the NTT group and the Others in the ADSL market, period from Jan. 2000 to Sep. 2002 is under consideration.

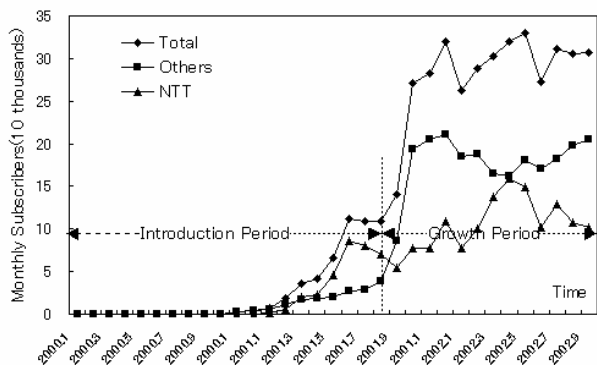


Figure 1 Monthly subscribers of ADSL in Japan

Figure 1 outlines the growth of monthly subscribers for the total market, the NTT group, and the Others. Since the data on the number of subscribers of each company could not be obtained easily, we used the data provided by the ministry's statistics to analyze the competitive relationship between the NTT group (the total of NTT East Corp. and NTT West Corp.) and the Others (the total of other companies) in this study.

4.2 Methodology

At the time when the analysis was conducted, the ADSL market in Japan was at the growth stage finishing up the introduction stage. With the entrance of large players like NTT and Yahoo!BB, the market grew up rapidly. In the concept of the proposed model, three forces – the external communication, the internal communication of a particular brand, and the growth of the total market would influence the diffusion of the particular ADSL service in a social system. Though both the NTT group and the Others benefited from the growth of the total market, the magnitude of the influence might be different. The influence of the total market on NTT would be large, since it was a popular brand among the people. On the other hand, the growth of the total market and the cumulative knowledge about the ADSL service made people consider the ADSL providers in a reasonable way. That is, the service offered by each provider did not differ significantly. Hence, the Others also benefited on some extent from the growth of the total market.

From August 2001, when Yahoo!BB entered into the market and announced to provide a low monthly fees of only 2,280 yen, the market demonstrated the aspects of the growth stage. The intense competition brought rapid price reduction and market expansion. Since Yahoo!BB was thought to have the advanced technology as well as low priced and high quality service, it would make some change in the competitive structure of the market. In this period, the influence from the growth of the market on the adoption of NTT service was expected to be getting similar with that of the Others. The proposed model is used to analyze the competitive relationship of ADSL service in Japan. The closed-form solution of the proposed model was used for estimation. Since the

characteristics of the ADSL market varied largely before and after Yahoo!BB's entry into the market, a two-period estimation was executed.

4.3 Empirical Results

Monthly cumulative data of ADSL subscribers for the NTT group and the Others were used for empirical analysis. The data were simultaneously fitted to the equation (7) ($j=1, 2$), employing the NLS procedure. The market potentials, however, must be separately estimated before conducting the NLS procedure. Since the ADSL market in Japan changed greatly after Yahoo!BB had entered into the market, the market potentials were also assumed to be changed. Therefore two different market potentials corresponding to before/after the Yahoo!BB's entry should be estimated. Although recent applications of diffusion models reported better forecasting results by using exogenous sources of information such as market surveys, secondary sources, management judgments, or other analytical models (Gatignon et al.,1989, Mahajan and Sharma 1986), the estimation of the market potential could be derived directly from the diffusion time-series data. In detail, applying the original Bass model to the category data for each periods, the market potentials of the introduction stage and the growth stage were estimated as 0.75 million and 5.55 million, respectively. We also assumed that p_2 , the innovative influence for the NTT group equal to zero in the estimation step. This is somewhat similar to the method used by Krishnan, Bass, and Kumar (2000).

Table 1 Estimation results of diffusion parameters

diffusion parameters	introduction stage (2000.1-2001.7)	growth stage (2001.8-2002.9)
Q	.3510 (.0741)	.1092 (.0408)
P_1	.0000034 (.00000093)	.0140 (.0014)
r_1	.0997 (.0242)	.0448* (.0212)
r_2	.2115 (.0323)	.0502 (.0184)

*: significant at 0.05; others: significant at 0.01
() : standard error

The estimation results are represented in Table 1. All the estimates are significant at 0.01 level except the one with asterisk mark. The results showed that the diffusion patterns for the NTT group and the Others are different. As for the Others, the three forces – the external influence, the internal influence, and the influence from the market growth all have positive and significant effects on diffusion, though the external influence is very small. The diffusion of the ADSL subscribers of the NTT group is mainly determined by the internal influence and the growth of the total market. The results also suggest that the diffusion patterns differ between the introduction stage and the growth stage. In the introduction stage, the influence of the total market's

growth on NTT was twice as large as that of the Others. Since the internal influence for each provider group was assumed to be identical and the external influence is very small, the larger value of the parameter r_2 means the rapid growth of the NTT group. In the growth stage, the difference of the influence of the total market's growth on the NTT group and the Others became small. This is probably contributed to the entry of Yahoo!BB as the principal member of the Others.

Using the estimated diffusion parameters, the estimated diffusion patterns are computed separately for the NTT group and the Others. Figures 2 and 3 represent the estimated and the actual diffusion patterns for the NTT group and the Others, respectively. Comparing the diffusion patterns of the estimated with the observed, it is obvious that the proposed brand-level diffusion model fits to the ADSL data in Japan very well.

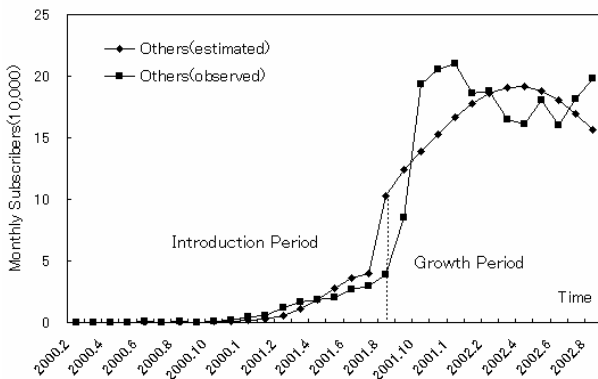


Figure 2 Observed and estimated subscribers (Others)

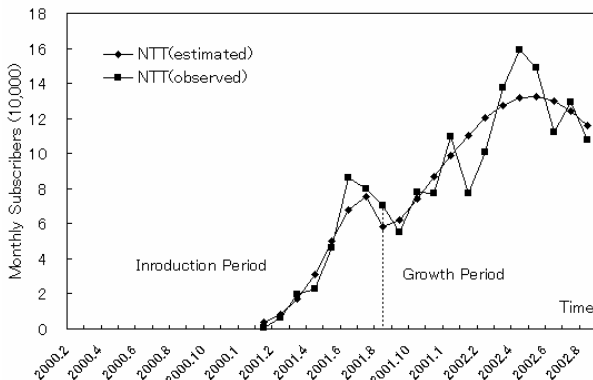


Figure 3 Observed and estimated subscribers (NTT)

5. CONCLUSIONS AND MANAGERIAL IMPLICATIONS

This work would be the first attempt to capture the diffusion dynamics by the three forces – the external influence, the internal influence, and the influence from the growth of the total market. Since the Bass model (Bass, 1969) was introduced into the marketing literature, a number of researches about innovation diffusion used the external coefficient p and the internal coefficient q to describe and explain the difference of innovation diffusion patterns. Empirical results across

different products and markets revealed that the Bass model fitted to the innovation diffusion data very well. Undoubtedly, using parameters p and q , the Bass model can successfully capture the diffusion dynamics when a particular product category is under consideration. However, managers are much more interested in the adoption or growth process of a particular brand and the competitive relationship among brands in a product category. One of the advantages of the Bass model is that it depends on the communication pattern underlying the diffusion process – the external communication through mass media, and the internal communication with the early adopters of the product. When we consider the communication pattern for a particular brand in a product category, not only the mass media and the early adopters of a particular brand, but also the growth of the total market would influence the diffusion of that brand. For some products or services such as the cellular phone and the ADSL service, the primary advantages of adopting these products or services are not so much different depending on the competing providers. Therefore, the influence of the growth of the category on the growth of each brand may be large. In the case of other products such as cars, the market of which is characterized as a completely differentiated market, the success of the total market may only have little impact on the adoption of a particular brand.

The principal implication of this study is the consideration of the category growth effect on the adoption of a particular brand to describe the brand level diffusion process. In the concept of the proposed model, the influence of the category growth on each brand can be different, and captured by the value of the parameter r_j . The empirical analysis revealed that the category growth effect on each brand was different, and varied with the growth of the market. The later entry may have the advantages of facing a established market with familiarity with the innovation, confidence about the innovation, and preparation for its adoption. In this study, the entry of NTT made up the ADSL market category and several brands grew up in the market. This also happened when Yahoo!BB entered into the market by using low pricing strategy. The success of the NTT and Yahoo!BB in the ADSL service market implied that the timing of entry is very important. NTT entered into the market about one year after the leaders such as Tokyo Metallic Communication and eAccess entered into market, when the ADSL had obtained high recognition. Yahoo!BB entered into the market six months after the NTT, and expanded its market share through large price reduction.

Through assuming that the internal influence parameter of each brand in a product category is identical, the proposed model can be aggregated to the category Bass model. This assumption brings the advantage of the proposed model that it can be solved in a closed-form expression as a function of time t only. Researches about the brand level innovation diffusion have

employed discrete models to describe continuous phenomenon (Mahajan, Sharma, Buzzell 1993; Parker and Gatignon 1994; Givon, Mahajan, Muller 1997, Modis 1997). Although the discrete method make it possible to easily handle the problems and test various assumptions about the effect of competition among brands, it has fatal shortcoming of estimation biases and sometimes it cannot provide the information on the estimation errors. Using the closed-form solution of the proposed model, the estimates and their standard errors can be obtained directly.

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