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A hybrid Bass–Markov model for the diffusion of a dual-type device-based telecommunication service: The case of WiBro service in Korea

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ABSTRACT

Because the increasing complexity of technology embedded in telecommunication services enables services to be provided via various mediums, the vital requisite for forecasting the diffusion of such services is to simultaneously capture different diffusion phenomena for different devices. This paper proposes a new diffusion model for a dual-type device-based service called the hybrid Bass–Markov model. The proposed model is targeted at the service environment where one type of device is new to the market, and the other type has existing competing services. The Bass model is selected to model service diffusion through the former type of device, while the Markov transition model is employed to capture the diffusion through the latter type of device. The hybrid Bass–Markov model is then developed to produce the aggregate demand. The case of the wireless broadband (WiBro) service in Korea is presented to illustrate the proposed model with a policy sensitivity analysis. This research is expected to be the basis of multi-type device-based service forecasting and, ultimately, will help researchers conduct demand forecasting of services offered by several different devices.

1. Introduction

Great attention from academia and practice has been given to the modeling and forecasting of innovations. Since its introduction to marketing in the 1960s, the theory of innovation diffusion has sparked a considerable amount of research in a variety of disciplines, including economics, medicine, agriculture, sociology, anthropology, and technology management (Chandrasekaran & Tellis, 2007). In the field of technology management, what diffuses is a technology or a technological innovation, while the marketing discipline has focused on the diffusion of products, particularly consumer durables (Meade & Islam, 2006). A technological innovation may usually spread in the form of a product, but it can also take the form of a service. In this context, the diffusion of services has also attracted increasing attention (Libai, Muller, & Peres, 2009).

Recently, the increasing complexity of technology in services has made it difficult to forecast future demands of services because a single service can be provided via several devices, especially in the telecommunications industry. Even for the same service, if they are provided by different types of devices, diffusion patterns for each device can be substantially different due to the differences in industry characteristics and competing technologies. With the increase of new types of mobile devices, more and more telecommunication services can be delivered by more than one device. Although there have been significant advances in the diffusion models by adding greater flexibility in various ways (Meade & Islam, 2006), no models are available to capture this phenomenon, service delivery through multi-type devices, in the diffusion of technology-embedded services. This silence in the literature prompted our research. Accordingly, this paper aims to develop a new diffusion model applicable to dual-type device-based services, which is the most basic form of multi-type device-based services.

This research focuses specifically on the service environment where one type of device is new to the market (Type 1), and the other has existing competing services (Type 2). The environment makes it difficult to forecast demand using a single forecasting model. Therefore, two types of forecasting models are required to be combined in a hybrid model. For this purpose, the Bass model is selected to model the diffusion of service through the adoption of Type 1 devices, while the Markov transition model is employed

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to capture the diffusion through Type 2 devices. The Bass model is one of the most well-known and widely used forecasting models for the first-purchase demand (Bass, 1969). It has a relatively high power of forecasting despite its simple structure (Mahajan, Muller, & Bass, 1990). However, the Bass model assumes that the diffusion of one service is independent of that of other ones, which is not suitable for Type 2 devices. Moreover, telecommunication services, which are of particular interest in the context of multi-type, device-based services, are distinct from consumer durable goods because they have a characteristic of easy churn between competitive services (Kim & Jeong, 2004). To explain the competitive service diffusion process for Type 2 devices, this research adopts the Markov transition model that can capture the choice behavior of the consumer in the process of transitioning between competing services. It is capable of forecasting demands through the transition probability and the past and future states of the previous and new service groups (Cho, Huh, Rho, & Choi, 2004). Consequently, a new model, called the hybrid Bass–Markov model, has been developed to forecast aggregate demand.

The proposed model is applied to wireless broadband (WiBro) service in Korea. The WiBro service is delivered by two different mediums: modems and mobile phones. The two types of devices are totally different in terms of market condition; thus, different approaches should be employed and combined to forecast aggregate demand of the service, which is exactly what this paper aims to do. In addition, a policy sensitivity analysis is conducted to draw policy implications. Recent years have seen a growing number of studies on induced diffusion, which explores whether policy tools or interventions can incentivize the diffusion of innovations (Davies & Diaz-Rainey, 2011). A sensitivity analysis on policy alternatives with respect to the WiBro service can also show how much the policy options induce the diffusion of the WiBro service.

The remainder of this paper is organized as follows. The paper proceeds with a theoretical background of the two main models used in this research. The model development process is then described in Section 3, which is followed by the model application to the WiBro service in Korea in Section 4. Finally, the conclusion and limitations with future research directions are presented in Section 5.

2. Theoretical background

This section briefly introduces the two underlying models of the proposed approach, the Bass model and the Markov transition model, and discusses their advantages and research gaps.

2.1. Bass model

The forecasting of the diffusion of innovation has been a major research topic in the fields of technology management as well as marketing. Growth curve analysis has mainly been used for modeling and forecasting the diffusion phenomena (Meade & Islam, 2006; Young, 1993). Among various types of growth curves, probably the most widely used one in technological and marketing studies is the Bass model, which is a combination of the two popular growth models, the logistic and modified exponential (Carrillo & González, 2002).

The Bass model (Bass, 1969) is based on the assumption that technology innovation is spread by two types of influences: external ones by the mass media and internal ones via word-of-mouth. The basic concept of the Bass model can be written as a hazard function representing the probability that an adoption occurs at time t given that it has not yet occurred:

$$h(t) = \frac{f(t)}{1 - F(t)} = p + qF(t) \tag{1}$$

where $f(t)$ is the density function of time to adoption, $F(t)$ is the cumulative fraction of adopters at time t, and p and q are the coefficient of innovation and imitation, respectively. Because the number of adopters at time t, $n(t)$, can be obtained by multiplying $f(t)$ with the potential market size, m, rearranging Eq. (1) yields the following differential equation of the Bass model:

$$n(t) = \frac{dN(t)}{dt} = \left[p + \frac{q}{m}N(t)\right][m - N(t)]. \tag{2}$$

where $N(t)$ represents the cumulative number of adopters at time t. Eq. (2) can also be rewritten in a discrete form to obtain the three parameters from discrete time series data using the ordinary least square (OLS) procedure:

$$n(t) = a + bN(t-1) + cN^2(t-1), \quad t = 2, 3, \cdots \tag{3}$$

where $a = pm$, $b = q - p$, and $c = -q/m$. Regression analysis is then used to estimate a, b, and c. Once these are obtained, p, q, and m can be estimated. In this study, we also employ the discrete form of the Bass model to obtain the parameters and produce the aggregate demand by combining the results of the Markov chain model.

Over the past 35 years, a vast body of literature has sought to extend the original Bass model to incorporate various aspects of diffusion (Phu, Yu, & Chou, 2013). Many studies have attempted to consider the marketing variables, such as price (Kamakura & Balasubramanian, 1988), advertising (Dodson & Muller, 1978; Horsky & Simon, 1983), and both (Bass, Krishnan, & Jain, 1994; Kalish, 1985). Some researchers have considered the effect of other parties in a market on diffusion, such as the competitive effect (Mahajan, Sharma, & Buzzell, 1993; Parker & Gatignon, 1994; Peterson & Mahajan, 1975; Seol, Park, Lee, & Yoon, 2012) and the complementary effect (Bayus, 1993; Bucklin & Sengupta, 1993). Technological generations are also captured by several studies (Kim, Lee, & Kim, 2005; Norton & Bass, 1987). Various types of purchasing behavior, such as replacement purchase (Kamakura & Balasubramanian, 1987), multiple purchase (Steffens, 2002), and trial-repeat purchase (Hahn, Park, Krishnamurthi, & Zoltners, 1994), have been dealt with. Several researchers have paid attention to the heterogeneity or duality among consumers in terms of adoption behavior, which results in the dual-market model where a market is bisected into influentials (early market) and imitators (main market) (Muller & Yogev, 2006; van den Bulte & Joshi, 2007). However, the heterogeneity in terms of medium for providing services has not been considered.

2.2. Markov transition model

The Markov transition model is a probability model for decision making, which enables continuous forecasting of future events based on the dynamic characteristics of past events. Therefore, it helps to analyze the phase changes in the past and to predict the future phase using a non-parametric equation. The model is best known in political science (Przeworkski, Alvarez, Cheibub, & Limongi, 2000), but it is also suitable for modeling the diffusion process of service innovation. Unlike a product that is delivered only once, service is delivered continuously until a user cancels a contract or moves to another service provider.

If there exist I services in a market and the cumulative adopters of service i at time t are defined as $N_i(t)$ ($i = 1, 2, \ldots, I$), the Markov transition matrix can be presented by the relationship between the cumulative adopters of services at time $t-1$ and at time t as follows:

$$\begin{bmatrix} N_1(t) \\ \vdots \\ N_I(t) \end{bmatrix} = \begin{bmatrix} p_{1,1} & \cdots & p_{1,I} \\ \vdots & \ddots & \vdots \\ p_{I,1} & \cdots & p_{I,I} \end{bmatrix} \begin{bmatrix} N_1(t-1) \\ \vdots \\ N_I(t-1) \end{bmatrix} \tag{4}$$