



The forecasting of the mobile Internet in Taiwan by diffusion model

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Abstract

From the government's perspective, it is very important to estimate the growing path of the mobile Internet market and then to forecast the trend. The purpose of this paper is to propose a diffusion model that reveals the growth pattern of the mobile Internet subscriber in Taiwan utilizing the concepts of the "technical substitution" and the "multi-product competition", which suits the characteristics in the mobile Internet market in Taiwan. From the regression results, the estimated ultimate market potential of GPRS is 6.4 million, which is going to saturate in about 2008Q1. On the other hand, the estimated range of the market potential of PHS/3G is about 7.2 to 8.0 million. That is, the total mobile Internet market in Taiwan is forecasted to be around 13.6 to 14.4 million subscribers.

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1. Introduction

Taiwan is one of the countries with great ICT (information and communications technologies) strengths in *The Global Information Technology Report* released by the World Economic Forum [26].¹ In

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¹ The Global Information Technology Report includes the assessment of more than 100 countries in terms of the applications of information technologies. This Report uses the Networked Readiness Index (NRI) to measure the degree of preparation in one nation or community to participate in and benefit from ICT developments. WEF runs a feature on Taiwan for its special mode and success in the ICT industries.

recent years, the mobile, broadband, and wireless communications industries are growing rapidly in Taiwan, since the government expects to establish this island as a global ICT center, supported by its high-technology manufacturing and solid R&D abilities. Taiwan is one of the highest mobile phone penetration rate – the number of mobile phone subscribers as a percentage of the population – in the world. Furthermore, the mobile industries and the commercial applications are the most expected industries to progress based on past glory experience in the semiconductor and computer industries [1].

In 2002, the “*e-Taiwan Program*” launched by the government, with more than 50 subprojects including six million broadband household-subscribers, *e-Government*, *e-Industry*, *e-Society* and *e-Transportation*, has the intention to build Taiwan as a digital-technology island on the platform of digital economy, and Taiwan has achieved significant improvements in ICT infrastructures as well as the applications.² On the other side, by the end of 2005, the total amount of mobile phone users – including 2G (Second Generation Mobile Communications), PHS (Personal HandypHONE System) and 3G (Third Generation Mobile Communications) – increased up to 22.17 million, which represents nearly 100% mobile phone penetration rate compared to 22.88 million population in Taiwan [2]. Almost every person in Taiwan subscribes to a mobile phone account! According the Worldwide Mobile Internet Survey (WMIS) in 2005, about 36% of the mobile phone subscribers in Taiwan used mobile Internet services.³ Therefore, in 2005 the Taiwan government focused on the implementation and applications of enterprise mobilization and carried out the “*M-Taiwan Deploying Project*”. This project includes both mobile and wireless Internet, in regard to the development of the seamless Internet environment and further a ubiquitous network society (UNS) in Taiwan.⁴

“Mobile Internet subscribers” in this paper refers to mobile users who possess mobile phone handset capable of accessing the Internet, including WAP (Wireless Application Protocol), GPRS (General Packet Radio Service), PHS, and 3G. According to the survey by ACI-III in 2004, mobile phones are the main interface for mobile/wireless Internet connection which represents 63.7% of all connections in Taiwan.⁵ The number of mobile Internet subscribers has increased to 5.35 million, mainly via GPRS, which shows a solid foundation for the development of mobile Internet services and the business markets in Taiwan [1].⁶

The substantial growth of mobile Internet in Taiwan can be expected with increase in innovative technologies, services and competitions. Therefore, from the government’s perspective, a precise mobile Internet market forecasting is desirable and necessary to policy makers and all enterprises. The growth pattern (or the cumulative sales) of a new product generally follows an S-shaped curve to capture the life-cycle dynamic [21]. The analytical and empirical evidence for the existence of this S-shaped curve represents the growth of a new “durable product” in the field of Marketing Science was first introduced by Bass [3]. Bass diffusion model is one of the most well-known and widely-used models to forecast the

² See *e-Taiwan Program* website (<http://www.etaiwan.nat.gov.tw/content/application/etaiwan/english/index.php>) for more detail.

³ In order to achieve a more effective comparison of Mobile Internet development, several countries – including Japan, South Korea, Finland and Greece – agreed to implement a Worldwide Mobile Internet Survey (WMIS), and Taiwan joined in the survey since 2003. WMIS is proposed to analyze the global mobile Internet services, including mobile communications services, mobile commerce, mobile contents, and entertainment services.

⁴ See *M-Taiwan Deploying Project* website (<http://www.pwlan.org.tw/mp.asp?mp=3>) for detail.

⁵ The next most popular devices were wireless Internet cards and notebooks at 41.3% and PDAs at 14.4%.

⁶ The current status about the “mobile environment” in Taiwan is available in the following websites: <http://www.find.org.tw/> and <http://mit.find.org.tw/>.

demand of a new durable good, and many researches have proposed to apply this model to describe the S-shaped curve of the new product diffusion.⁷ Generally speaking, Bass diffusion model exhibits superior performance in predicting the growth patterns of many products [14,27]. From the empirical study, the pattern of mobile telecommunications in Taiwan is actually characterized by an S-shaped curve [11].

It is difficult to find a new product uninfluenced by the sales of others – either the existing or new ones. It conflicts with the “single-product” assumption of Bass diffusion model if the influence of other product is non-ignorable. In the mobile Internet market, as described above, several technologies (products) are available and the interrelationships among these technologies are intuitively non-ignorable. To solve this problem, in this paper a new model that combines both the concepts of “multi-generation” and “multi-product interaction” is proposed to capture the market dynamic of the mobile Internet market in Taiwan.

Generation shifts are points of interest to management in both ICT companies and the government. Therefore, it is necessary to develop an understanding on the demand dynamics about the interrelationships among technological generations of mobile Internet [24,25].⁸ The concept of the “multi-generation” diffusion model introduced by Norton and Bass [17] is selected to show the “technological substitution” among the mobile Internet technologies. On the other side, the concept of the “multi-product” diffusion model presented by Peterson and Mahajan [19] analyzes market interactions, especially the competition among different mobile Internet technologies in Taiwan (See Section 2.3 for detail). By combining these extensions to reveal the interrelationship among these technologies, the main purpose of this study is to verify and forecast the growth pattern of the mobile Internet market in Taiwan.

This paper is organized as following. After this Introduction, Section 2 outlines the original concepts of Bass diffusion model as well as the extensions for multi-product interactions. Section 3 shows the empirical analysis and discussions in Taiwan. Section 4 concludes the research results.

2. Model

In this section, a particular diffusion model for the mobile Internet in Taiwan is presented after introducing the concepts and notations of Bass diffusion model, the multi-generation as well as multi-product diffusion models.

2.1. Bass diffusion model

Bass diffusion model, which targets the “first-purchase” demand, is based on a simple premise from the “hazard function” in epidemiology to show the conditional probability that an adoption (consumption) will occur at time t given what has not yet occurred. This model suggests that the adopting probability, at time t , in the hazard function could be expressed as a linear function of the cumulative probability:

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

where the parameters p and q are defined as the coefficient of innovation and imitation, separately. These two coefficients summarize the complex dynamic process of the adoption decision, in which the

⁷ See [7,15,16] for literature reviews. Moreover Fields [6] provides a comprehensive review of the demand forecasting in the telecommunications industry. In his review, Bass diffusion model and its extensions play an important role; see p.503–513 for detail.

⁸ See [12] for more discussions.

adopters (consumers) of a product consist of “innovators” and “imitators” by definitions [3]. Besides, $f(t)$ and $F(t)$ denote the probability density function (PDF) and the cumulative density function (CDF).⁹ Furthermore the adopting probability, from Eq. (1), can be shown as a differential equation:

$$(2) \quad f(t) = \frac{dF(t)}{dt} = (p + qF(t))(1 - F(t)).$$

However, by the discrete concept, Eq. (2) could be transformed to

$$(3) \quad n(t) = \frac{dN(t)}{dt} = \left(p + \frac{m}{q}F(t)\right)(m - N(t)), \quad t = 1, 2, \dots$$

in terms of the number of the new adopters, where m is the ultimate (ceiling) market potential, $N(t)$ and $n(t)$ denote the number of the cumulative and new adopters at the given time t , respectively.¹⁰ In empirical studies, most of the literatures follow the non-linear square (NLS) estimation suggested by Srinivasan and Mason [22]. By solving the differential equation, Eq. (2), the CDF can be presented as

$$(4) \quad F(t) = \frac{1 - e^{-(p+q)t}}{1 + \frac{p}{q}e^{-(p+q)t}}.$$

The number of the new adopters $n(t)$, i.e. the difference of the cumulative adopters between two periods, is

$$(5) \quad n(t) = N(t) - N(t-1) = m[F(t) - F(t-1)], \quad t = 1, 2, \dots$$

By substituting Eq. (4) into Eq. (5), the new adopters at each time is

$$(5') \quad n(t) = m \left(\frac{1 - e^{-(p+q)t}}{1 + \frac{p}{q}e^{-(p+q)t}} - \frac{1 + \frac{p}{q}e^{-(p+q)(t-1)}}{1 - e^{-(p+q)(t-1)}} \right), \quad t = 1, 2, \dots$$

By collecting the empirical data, Srinivasan and Mason [22] suggest regressing this discrete-form diffusion process to estimate the parameters p and q as well as the market potential m .¹¹

2.2. The multi-generation diffusion model

Many high-technology companies develop their products in sequence, that is, there are many product generations and the new generation is assumed to be always superior, with better performance or quality,

⁹ In the other words, $f(t)$ represents as the fraction of the ultimate market potential who adopt the product (or technology) at time t and $F(t)$ denotes the cumulative fraction of the ultimate market potential who has adopted by time t .
¹⁰ By the continuous concept, $n(t)$ is the differential change in cumulative adopters $N(t)$ in the time period dt .
¹¹ The NLS estimation has generally become the standard procedure in the diffusion researches [14,20].

to its predecessor. Intuitively, the introduction of a new generation attracts adopters (consumers) from different constituencies: fresh adopters and adopters of earlier generations of that technology who want to replace their obsolescent equipment.¹² Such interdependence among generations will affect the adoptions or sales of any given technology, i.e. the diffusion process [4].

To involve in the interdependence of product generations, Norton and Bass [17] proposed a “multi-generation” diffusion model (abbreviated to NB model). This model has been tested mostly on high-technology and/or durable product categories by presuming the interdependent relationships. It is also called the “technological substitution” that newer technologies are continually replacing older ones [4,18].^{13,14} In NB model, each generation enters the market before its predecessor has fully diffused to its market potential. Moreover, the adopters of each successive generation are formed by potential “additional” consumers, who have not adopted the earlier generations, and the “existing” users of the earlier generations, i.e. each generation cannibalizes the diffusion of its predecessors.

In NB model, if it takes a two-generation market, the cumulative adopters of the first generation is

$$N_1(t) = F_1(t)m_1 - F_2(t - \tau_2)F_1(t)m_1 = F_1(t)m_1[1 - F_2(t - \tau_2)], \text{ for } t > 0; \quad (6-1)$$

and the second generation is

$$N_2(t) = F_2(t - \tau_2)[m_2 + F_1(t)m_1] \text{ for } t > \tau_2, \quad (6-2)$$

where τ_2 is the time when the second generation is introduced into the market, m_1 and m_2 refer to each market potential for the corresponding generation, and $F(t)$ is the same as Eq. (4). From the concepts of NB model, the ultimate market potential of the second generation will be the sum of both generations because the users who have adopted the earlier generation will finally adopt (switch to) the later one.¹⁶

In NB model, constancy assumption of the parameters p and q is set from the plausibility that for a given technology class, the behavioral processes for the adoption of advancing generations could be expected to be similar.¹⁷ Islam and Meade [9] release this assumption of constancy and present the

¹² For example, GPRS technology was introduced to replace the narrower-bandwidth WAP technology. The subscribers of GPRS consist of the new mobile Internet users and the ones who switch from the “old mobile Internet,” WAP.
¹³ [17] designed the model for interdependence between some technological products, such as DRAM and SRAM chips, the MPU and MCU, and extended their model to discuss various product types [18]. Based on NB model, [13] discuss the introduction and diffusion of several generations of IBM mainframe computers. Their model tests the optimal timing of the introductions of new generations.

¹⁴ Bass diffusion model can be thought as a reduced “one-generation” model, which is a special case of NB model.
¹⁵ $N_2(t - \tau_2)$ will increase monotonically after τ_2 , and $F_2(t - \tau_2) = 0$ for $t < \tau_2$.

¹⁶ NB model assumes that: (1). The existence of a series of advancing generations, each of which can do everything the previous generation could do, and possibly more; (2). A density function of time to adoption for each generation applying against a time-varying market potential; and (3). The substitution of actual and potential sales from earlier to later generation

([17], p1075).

¹⁷ Norton and Bass [17] argue that if the p_i and q_i are really different for each generation i , it should be difficult to obtain reasonable fits to the empirical data and reasonable forecast using the simpler model. They do find one example where the assumption of constant coefficients is not supported, but maintain their performance and no detected deterioration in forecasting under the assumption of constancy [9]. Speece and MacLachlan [23] as well as Mahajan and Muller [13] also adopt this assumption in their studies.

empirical evidence of non-constancy in several technology areas with discussions of forecasting and planning implications under the existence of non-constancy.¹⁸ By using the full information maximum likelihood (FIML) procedure for simultaneous estimations, Islam and Meade [9] state that the hypothesis of constancy can be rejected in most cases and modify the CDF of each generation as

$$F_i(t) = \frac{1 + (q_i/d_i)e^{-(p_i+q_i)t}}{1 - e^{-(p_i+q_i)t}}, \quad i = 1, 2, \quad (7)$$

where $p_2 = p_1 + \Delta p_2$ and $q_2 = q_1 + \Delta q_2$. Furthermore, the consistency hypothesis is:

$$H_0: \Delta p_2 = \Delta q_2 = 0, \quad (8-1)$$

$$H_1: \text{At least one of } \Delta p_2 \text{ and } \Delta q_2 \neq 0. \quad (8-2)$$

From the hypothesis testing by likelihood ratio test, the model suggested by Islam and Meade [9] (abbreviated to LM model) can verify whether the properties of the adopters for different technologies are the same or not.

2.3. The multi-product diffusion model

Although Bass diffusion model has been applied in various marketing strategy research with excellent performance, the assumption for "single-product" is unsuitable in most non-monopoly market, where "multi-product" interactions should be discussed. Peterson and Mahajan [19] introduce a class of deterministic, multi-product, first-purchase growth models (abbreviated to PM model) by proposing a system of diffusion equations of four types of inter-product relationships: independent, complementary, contingent and substitutes.^{19,20}

¹⁸ In some technologies, changes in the nature as well as the number of potential adopters have occurred between successive generations. Take PC industry for example, initially the personal computer was mainly a business purchase, but technological development in both hardware and software in successive generations of personal computers have lowered the skill threshold to its use and it is now a common consumer durable [9]. In this paper, intuitively, the properties of the subscribers of each mobile Internet technologies should be different, just like improving performances and applications in PC market.
¹⁹ Peterson and Mahajan [19] use this model to estimate the substitution relationship between black/white and color televisions and the independent situation among insurance policies. Bucklin and Sengupta [5] use the complementary products formulation to study the co-diffusion of supermarket scanners and the use of UPC symbols.
²⁰ Successive product generations can be regarded as a particular case of multi-product interactions in which it is implicitly assumed that each successive product generation dominates the previous generation — that is, there is a one-way product interaction in that the newest generation only has a negative impact on the previous generation's market size [4]. On the other hand, Bass diffusion model is a special case of a "single-product" diffusion. See more discussions in [4].