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# Diffusion, substitution and competition dynamism inside the ICT market: The case of Japan

Chaojung Chen, Chihiro Watanabe *

*Department of Industrial Engineering and Management, Tokyo Institute of Technology, 2-12-10 W9-49 Ookayama, Meguro-ku, Tokyo 152-8522, Japan*

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**Abstract**

Under the new information society paradigm that emerged in the 1990s, contrary to its conspicuous achievement as an industrial society, Japan is experiencing a vicious cycle between non-elastic institutions and insufficient utilization of the potential benefits of information and communication technology (ICT).

However, a dramatic deployment of mobile telephones with Internet access service such as NTT DoCoMo's i-mode service in the late 1990s provides encouragement that, once the potential is exploited, Japan's institutional systems can effectively stimulate the self-propagating nature of ICT. The rapid deployment of Internet Protocol (IP) mobile service in Japan can be attributed to worldwide advances in the utilization of personal computers (PCs) and the Internet. Thus, a complex technology web triggered by the dramatic advancement of PCs and the Internet and co-evolving diffusion, substitution and competition dynamism has emerged in the global ICT market, particularly in Japan's mobile communication business.

The above observations prompt the hypothetical view that, despite a lack of institutional elasticity, recent advances in Japan's IP mobile service deployment can be attributed to a co-evolutionary dynamism between diffusion, substitution and competition inside the ICT market. Thus, policy questions could be how to create such a co-evolutionary dynamism by means of ICT innovation, enriched functions, reduced price and competitive environment.

* Corresponding author. Tel.: +81 3 5734 2248; fax: +81 3 5734 2252.
*E-mail address:* chihiro@me.titech.ac.jp (C. Watanabe).


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In order to demonstrate the foregoing hypothesis, an empirical analysis of the mechanism co-evolving diffusion, substitution and competition dynamism inside Japan's ICT market is attempted by utilizing four types of diffusion models identical to respective diffusion dynamics.


*Keywords:* ICT; Institution; Institutional elasticity; Diffusion model; Mobile telephony; Internet

## 1. Introduction

Under the new paradigm of an information society which emerged in the 1990s, contrary to its conspicuous achievement in an industrial society, Japan is experiencing a vicious cycle between non-elastic institutions and insufficient utilization of the potential benefits of information and communication technology (ICT or IT, hereinafter refers as ICT) [1].

Comparison of the growth rate of ICT investment in G7 countries over the period 1985–1996 demonstrates that Japan's ICT investment level ranks third after the US and UK, and is comparable to other G7 countries [2].

Notwithstanding such investment in ICT, Japan's utilization of its benefits is hardly satisfactory as pointed out by OECD in 2001 [3]. OECD demonstrates the relationship between the access costs and a diffusion of the Internet in OECD countries which reveals that countries with lower access costs have more Internet hosts. However, in spite of its moderate Internet access cost enabled by the foregoing ICT investment, Japan does not achieve the expected Internet penetration rate. By contrast, the US performs fairly well. This gap should be attributed to the contrastive institutional elasticity of the two countries in an information society [1].

However, a dramatic deployment of mobile telephone with Internet access service (Internet Protocol (IP) mobile) such as i-mode service (NTT DoCoMO's mobile Internet access service) in the late 1990s provides encouragement that, once the potential is exploited, Japan's institution systems can effectively stimulate the self-propagating nature of ICT through dynamic interaction with them as is typically observed in high level utilization of IP mobile. ITU demonstrates that Japan's dependency on IP mobile out of total mobile telephony is conspicuously high as 72.3% in 2001 while the same ratio in the US and Germany is 7.9% [4].

Such a rapid deployment in IP mobile in Japan can be attributed to a worldwide dramatic advancement of personal computers (PCs) and the Internet [5].

In addition, rapidly developing *trans*-generationary substitution of mobile communicating system accelerates such dramatic IP mobile deployment [6].

Thus, a complex technology web triggered by the dramatic advancement of PCs and the Internet and co-evolving diffusion, substitution and competition dynamism as illustrated in Fig. 1 emerges in the world wide ICT market, particularly in Japan's mobile communication business.

These observations prompt us a hypothetical view that a dramatic deployment of Japan's IP mobile despite its institutional less elasticity can be attributed to a co-evolutionary dynamism between diffusion, substitution and competition inside its ICT market. Thus, policy questions could be how to create such a co-evolutionary dynamism by means of ICT innovation, enriched functions, reduced price and competitive environment.

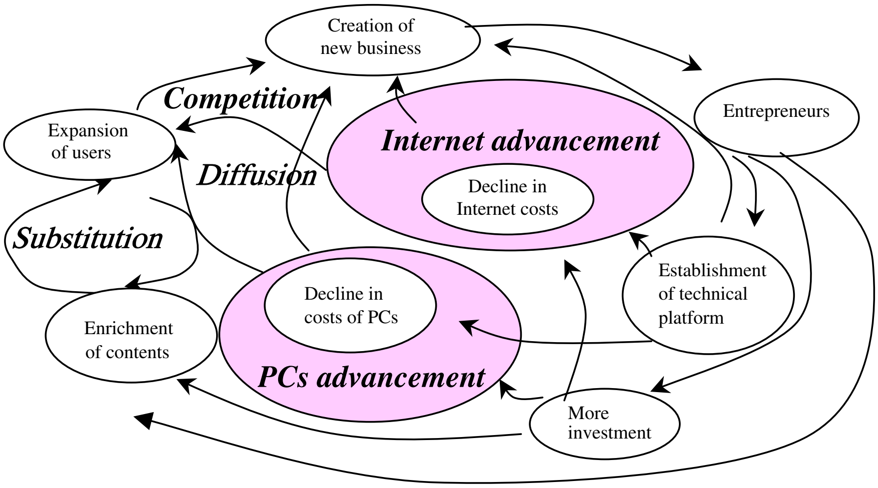


Fig. 1. Complex technology web emerging Japan's mobile communication business. Source: Authors' elaboration based on [7].

Early applications of diffusion models addressed primarily durable goods market such as TV set, refrigerator, etc. The well-known first-purchase diffusion new products in marketing are those of Woodlock and Fourt [8], Mansfield [9], Bass [10], Easingwood, Mahajan and Muller [11], etc. While Bass took diffusion speed coefficient as a constant, the Nonsymmetric Responding Logistic (NSRL) model, proposed by Easingwood et al., treated the diffusion speed coefficient as a function of multiplication of diffusion rate so that it decreases or increases depending on the situations. These models were single-product models concerned only with the sales growth for a single product. The often-criticized insufficiency of them is that new products or technologies are not adopted into a completely new market without any other existing similar or related technology. The existence of other products and technologies may affect, no matter positively or negatively, the sales of a new product.

Although those first-purchase models succeeded in illuminating the curve of diffusion at first, due to the increasing diffusion potential of technologies resulted from the increasing population, existence of other products or upgraded function of technology, constant potential has become the conceptual limit. In order to overcome the restriction and single-product models, Norton and Bass [12], Mahajan and Muller [13] and Jun and Park [14] proposed multi-generation diffusion models that simultaneously trace the diffusion and substitution trends for the successive generations of a durable technological innovation. Mahajan and Muller [13] used their model to explore the diffusion of four generations of IBM mainframe computers and signified that the introduction time of a new technology is a key element in the new product strategy. While Norton and Bass [12] and Mahajan and Muller [13] just extended the form of the Bass model, Jun and Park [14], by taking the utility function of consumers into account, proposed a diffusion model for multiple generations of products representing customer choice behavior.

Competitive influence was first discussed in the marketing literature by Peterson and Mahajan [15]. As Parker and Gatignon [16] noted, the optimal strategy for various marketing mix variables has been an integral part of most models of brand-level or competitive market behavior. These models incorporated price (Rao and Bass [17]; Dockner and Jorgensen, [18]), advertising (Teng and Thompson, [19]; Horsky and Mate, [20]), and both price and advertising (Thompson and Teng, [21]). In recent years, much interest has focused on developing aggregate diffusion models in a competitive environment. Mahajan, Sharma and Buzzell [22] proposed a diffusion modeling approach for assessing the impact of entry by a new competitor into a market previously served by a single firm. Parker and Gatignon [16] investigated diffusion at the brand level, i.e. in the context of products or firms that compete in a new market. Effects of each user's history on the diffusion were first analyzed by Allison [23], Oren and Rothkopf [24] and Hedstrom [25] etc. using multinomial logit model in a diffusion context. Aiming at representing the processes generating events in discrete-time units, Allison [23] specified a discrete-time hazard rate as a function such as logit model, which depended on time and the explanatory variables. The method was to break up each individual's event history into a set of discrete time units in which an event either did or did not occur. Hedstrom [25] also estimated the hazard rate using the logit model based on the discrete-time event history approach. Moreover, Jun and Park [14] advocated studying the utility-maximizing choice behavior of customers to understand the sales patterns of new products and to develop sales forecasting models for multiple generations of products in a competitive market.

Concerning the substitution of technologies in the ICT market, such as fixed phone and mobile phone, the spread of mobile services comes at a time when telecommunications authorities and the public are concerned over the lack of development of competition in local services. Cadima and Barros [26] estimated the diffusion of Portuguese fixed-line and mobile networks, and concluded that mobile telephone adoption slowed fixed-line growth, while fixed-line subscription growth had no impact on mobile subscription growth. Gruber and Verboven [27] found, for the European Union, a negative impact of fixed-line network size on mobile telephone subscription, i.e. fixed-line and mobile service are substitute. Rodini et al. [28] analyzed fixed and mobile services for telecommunications access using a large US household survey conducted over the period 2000–2001 and concluded that substitutability between fixed and mobile telephone service impacts public policy toward competition in both of these market. In the US, the principal concern over competition in these markets derives from the market power initiated by providers of fixed-line local telephone service. However, connection quality and number portability discrepancies between the two services are fading, and substitutability may increase over time due to continued price declines and greatly improved connection quality. Furthermore, upgraded functions and improvements of mobile services will outpace those of fixed service.

While all these analyses relevant to the PCs and the Internet driven substitutions of technologies in the ICT market provide supportive evidence to the aforementioned hypothetical view that a dramatic deployment of Japan's IP mobile can be attributed to a dynamism between diffusion, substitution and competition inside Japan's ICT market, they are hardly satisfactory to elucidate the mechanism of the dynamism.

In light of the foregoing, an empirical analysis of the mechanism governing diffusion, substitution and competition dynamism inside Japan's ICT market is attempted by utilizing the diffusion models identical to respective diffusion dynamics. First the Simple Logistic Diffusion Model is used for realizing a primary idea about the market size with the diffusion potential and parameters. Next, the structural change in the market is analyzed by using the Bi-logistic Model and Logistic Growth within a Dynamic Carrying Capacity (LGDCC) Model, which is an extended form of Simple Logistic Function, taking the phenomenon of potential growth into consideration. Last, in order to understand the internal factors affecting consumers and the market mechanism, the substitution modeling approach is introduced based on "Choice-based Substitution Diffusion Model" proposed by Jun and Park [16,29].

Section 2 presents the methodology of this research, including model synthesis and data construction. Section 3 provides the results of empirical analysis and clear description about the ICT market in Japan characterized by mobile telephony, telephony and the Internet. Section 4 briefly summarizes the conclusion and direction for further research.

## 2. Methodology

### 2.1. Model synthesis

#### 2.1.1. Simple logistic model

The Simple Logistic Model depicted in Eqs. (1) and (2) is used to estimate the size and primary structure of the ICT market taking whole telephony, mobile telephony and the Internet Ignoring the difference of service quality or content such as fixed or mobile in telephony, IP and NonIP in mobile phone and access methods in the Internet, the user of ICT can be simply defined as the service subscriber of respective ICT examined.

$$\frac{\mathrm{d}Y(t)}{\mathrm{d}t} = \left(a\frac{Y(t)}{N}\right)(N - Y(t)) \tag{1}$$

$$Y(t) = \frac{N}{1 + e^{-at+b}} \tag{2}$$

where $Y(t)$: number of users at the time $t$; $N$: constant potential of the technology (carrying capacity); $a$: imitation coefficient; and $b$: coefficient denoting the initial status of the market.

#### 2.1.2. Bi-logistic model

The Bi-logistic Model is useful in modeling many systems that contain complex growth processes not well or completely described by the single logistic function such as the co-existence of IP and NonIP subscribers in the mobile phone and dial-up and broadband in the Internet access. By adding two single logistic models together, the Bi-logistic model can be depicted as Eq. (3).

$$Y(t) = Y_1(t) + Y_2(t) = \frac{N_1}{1 + \exp(-a_1(t - \tau_1) + b_1)} + \frac{N_2}{1 + \exp(-a_2(t - \tau_2) + b_2)} \tag{3}$$

where

$Y(t)$ number of total users, including generation 1 and generation 2, at the time $t$
$Y_1(t)$ number of users of generation 1 at the time $t$
$Y_2(t)$ number of users of generation 2 at the time $t$
$N_1$ constant potential of generation 1
$N_2$ constant potential of generation 2
$a_1$ imitation coefficient of generation 1
$a_2$ imitation coefficient of generation 2
$b_1$ coefficient denoting the initial status of generation 1

$b_2$ coefficient denoting the initial status of generation 2
$\tau_1$ time of introduction of generation 1
$\tau_2$ time of introduction of generation 2

*2.1.3. Logistic growth within a dynamic carrying capacity model*

Not all technologies can be divided into clearly separate generations as the Bi-logistic model assumes. Most of the time new functions are created gradually, added to the technology little by little. It is considered that the number of potential technological adopters increases whenever new functions are introduced. The model Sharif and Ramanathan [30] proposed has the upper bound increasing according to the logistic curve. In this paper it is called the Logistic Growth within a Dynamic Carrying Capacity (*LGDCC*) Model, which can be enumerated as Eq. (4):

$$\frac{\mathrm{d}Y(t)}{\mathrm{d}t} = \left(a\frac{Y(t)}{N(t)}\right)(N(t) - Y(t)). \tag{4}$$

In the LGDCC model, potential of the technology (carrying capacity) $N$ is a function of time as depicted in Eq. (5).

$$\frac{\mathrm{d}N(t)}{\mathrm{d}t} = a_k\frac{N(\mathrm{t})}{N_k}(N_k - N(t)). \tag{5}$$

By synchronizing Eqs. (4) and (5), LGDCC model can be developed as follows:

$$Y(t) = \frac{N_k}{1 + \exp(-at + b) + \frac{a}{a - a_k}\exp(-a_k t + b_k)} \tag{6}$$

where $a_k$ and $b_k$: coefficients; and $N_k$: ultimate carrying capacity.

*2.1.4. Choice-based substitution diffusion model*

The utility that the $i$-th potential customer (i.e. non-subscriber) would obtain by choosing not to subscribe or by subscribing to service at time $t$ can be depicted as:

$$U_{ti}^{(0,k)} = V_t^{(0,k)} + \varepsilon_t^{(0,k)}, \qquad k = 0, 1, 2 \tag{7}$$

where $k$=0, 1, 2 indicate non-subscription, generation 1 and 2 service subscription, respectively.

In the superscript, the first term represents the subscription status of the individual just before the choice, and the second term represents the choice made at time $t$. Thus, the superscript (0,0) means that the $i$-th non-subscriber remains a non-subscriber. The superscripts (0,1) and (0,2) mean that the $i$-th non-subscriber chooses generation 1 and 2 service at time $t$, respectively. Similarly, the superscript (1,1) means that the $i$-th generation 1 subscriber remains the same service and (1,2) that the consumer upgrades to generation 2 service.

In the equation, $V$ and $\varepsilon$ denote the deterministic term and the error term of the utility. Assume $V$ is independent from the individual consumer and is dependent only on the attributes of each service (e.g. price, advertising, design, etc.), the error term, $\varepsilon$, is stochastic and captures both random taste variation across the population and model specification error. These assumptions make it possible to aggregate across individuals. In the second choice situation, the $i$-th generation 1 subscriber at time $t$ must decide whether to upgrade its service dependency. The utility that the

$i$-th generation 1 subscriber would obtain by choosing a specific alternative at time $t$ can be depicted as follows:

$$U_{ti}^{(1,k)} = V_t^{(1,k)} + \varepsilon_t^{(1,k)}, \qquad k = 1,2,3 \tag{8}$$

(where 3 implies the coexistence of generation 1 and 2).

Based on Jun and Park [16], the model for the ICT market in Japan is synthesized. In order to trace the diffusion and substitution dynamics for successive generations of products as well as for a single generation, the deterministic terms of the utility is specified as follows:

When

$$t<\tau_2, V_t^{(0,0)} = C_{\tau l}^{(0,0)} C_{\tau l}, V_t^{(0,1)} = Q_{r01} \times r_1 \tag{9}$$

where $\tau_2$: time of introduction of generation 1; $r_1$: penetration rate in the preceding period; $C_{\tau_i}^{(0,0)}$: coefficient of $V_t^{(0,0)}$ condition at time $\tau_i$ ($i$= 1,2); and $Q_{xjk}$ ($x$=$r$, $t$, $f$, $p$; $j$=0, 1; and $k$=0, 1, 2, 3): coefficient of $V_t^{(j,k)}$ condition due to penetration ($r$), time trend ($t$), function ($f$) and price ($p$), respectively.

When

$$t \geq \tau_2, V_t^{(0,0)} = C_{\tau 2}^{(0,0)} = C_{\tau 2}, V_t^{(0,1)} = Q_{t01} \times (t - \tau_1 + 1), V_t^{(1,1)} = Q_{t11} \times (t - \tau_1 + 1),$$
$$V_t^{(0,2)} = Q_{t02} \times (t - \tau_2 + 1) Q_{f02} \times f, V_t^{(1,2)} = Q_{12} \times (t - \tau_2 + 1) + Q_{f12} \times f + Q_{p12} \times p. \tag{10}$$

When a new product is introduced into the market, information about the product is uncertain and insufficient. However, as more information becomes available to consumers (***r*** increase), they can achieve higher levels of utility as product recognition increases. While some attributes, such as price (***p***) and function (***f***), are available, others are not easy to quantify or to observe even if they have a significant influence on the decision process of consumers. In such situations, the time variables (***t***) may explain the effect of factors such as design, sales promotion and fashion.

When the error terms $\varepsilon$ is assumed to follow independent Gumbel distribution, the probability that a consumer $i$ subscribes enjoy utility by generation 1 or 2 service at time $t$ is:

$$P_t^{(0,k)} = \frac{\exp\left(V_t^{(0,k)}\right)}{\exp\left(V_t^{(0,0)}\right) + \exp\left(V_t^{(0,1)}\right) + \exp\left(V_t^{(0,2)}\right)} \tag{11}$$

where the subscript $i$ is omitted in the probability because the choice probability in Eq. (11) is the same for all individual under the assumption that the deterministic terms are independent from the individual. Similarly, the probability that generation 1 subscriber upgrades to generation 2 service at time $t$ can be depicted by Eq. (12):

$$P_t^{(1,2)} = \frac{\exp\left(V_t^{(1,2)}\right)}{\exp\left(V_t^{(1,1)}\right) + \exp\left(V_t^{(1,2)}\right)} \tag{12}$$

Define the total market potential of the choice based model at time $t$ $N_t$ as Eq. (13) since it is possible that the market potential may be unchanged throughout the time period:

$$N_t = N_k, \tau_k \leq t < \tau_{k+1}. \tag{13}$$

The total number of subscribers both generation 1 and 2 services at time $t-1$ is denoted as $Y_{t-1}$. Then the total number of non-subscribers at time $t$ is $(N_t\text{-}Y_{t-1})$. Before the introduction of generation 2 service ($t<\tau_2$), the expected net number of subscribers for generation 1 service at time $t$ can be depicted:

$$\Delta Y_t^1 = (N_t - Y_{t-1})P_t^{(0,1)} = (N_1 - Y_{t-1})\frac{\exp\left(V_t^{(0,1)}\right)}{\exp\left(V_t^{(0,0)}\right) + \exp\left(V_t^{(0,1)}\right)}. \tag{14}$$

After the introduction of generation 2 service ($t \geq \tau_2$), the expected net number of subscribers at time $t$ for each service can be defined as:

$$\Delta Y_t^1 = (N_2 - Y_{t-1})\frac{\exp\left(V_t^{(0,1)}\right)}{\exp\left(V_t^{0,0}\right) + \exp\left(V_t^{(0,1)}\right) + \exp\left(V_t^{(0,2)}\right)} - Y_{t-1}^1\frac{\exp\left(V_t^{(1,2)}\right)}{\exp\left(V_t^{(1,1)}\right) + \exp\left(V_t^{(1,2)}\right)} \tag{15}$$

$$\Delta Y_1^2 = (N_2 - Y_{t-1})\frac{\exp\left(V_t^{(0,2)}\right)}{\exp\left(V_t^{0,0}\right) + \exp\left(V_t^{(0,1)}\right) + \exp\left(V_t^{(0,2)}\right)} + Y_{t-1}^1\frac{\exp\left(V_t^{(1,2)}\right)}{\exp\left(V_t^{(1,1)}\right) + \exp\left(V_t^{(1,2)}\right)} \tag{16}$$

where $Y_t^k = Y_{t-1}^k + \Delta Y_t^k$, $k=1, 2$ and $Y_t = Y_t^1 + Y_t^2$.

Eq. (15) denotes the increase of subscribers who were previous non-subscribers, while Eq. (16) denotes the upgraders who switch from generation 1 service to generation 2 service.

### 2.2. Data construction

Data for subscriber base of mobile phone service in Japan, including NonIP and IP mobile phone, is published by Telecommunications Carriers Association (TCA) Japan [31]. Data for subscriber base of the Internet connection service, including dial-up, ISDN, DSL and optical fiber, is published by the Ministry of Public Management, Home Affairs, Posts and Telecommunications (MPHPT) Japan [32]. Further data about ICT in Japan is retrieved from IT White Paper published by Japan Information Processing Development Corporation and from annual survey result of ICT usage style [33].

Overall data worldwide, including population and other indicators such as GDP per capita, is retrieved from World Development Indicators published by World Bank [5]. Digital Access Index of each country is published by ITU [4].

The empirical analysis, including multi-factor analysis, nonlinear regression and correlation analysis is conducted with the statistical software, SPSS.

## 3. Diffusion and Substitution Process of ICT in Japan–Empirical analysis with diffusion and substitution models

### *3.1. Telephony market in Japan*

#### *3.1.1. Fixed phone line diffusion trend in Japan*

In order to analyze telephony market in Japan, first, by using Simple Logistic Model and Choice-based Substitution Diffusion Model as synthesized in Section 2, fixed phone line diffusion trend is analyzed.

*3.1.1.1. Simple Logistic Model.* Similar to the situation in other countries, fixed line phone service had been continuing its steady progress in Japan until 1996. However, it turned down since then with its peak in 1996, claiming that it is no longer an isolated ICT industry that could spread out as it had. This is demonstrated by the Simple Logistic Model using the TCA's empirical data. As summarized in Table 1 and illustrated in Fig. 2, the potential (carrying capacity) of fixed phone line subscription is anticipated to 61.8 million, equivalent level of the diffusion in 1996.

*3.1.1.2. Choice-based Substitution Diffusion Model.* The possible reason for such dramatic inflection point followed by decline in fixed line phone service can be attributed to the emergence of the mobile phone service. As mentioned in Section 1, mobile phone and fixed phone may complement and substitute each other. In case of the complement, fixed phone can survive, while the substitution leads it to obsolescent. In order to elucidate this dynamism, the markets of both services are analyzed by using the Choice-based Substitution Diffusion Model.

While the difficulty in taking both services into a single model lies in the double counting of both fixed and mobile phones subscribers, and it is generally difficult to identify such double subscribers, a solution was obtained by depending on the survey conducted by MPHPT [32].

Similar to the model explained in Section 2 and the model to be used in subsections 3.2 and 3.3 for mobile phone and the Internet access analyses, $Y_t^1$ denotes the first generation technology (in this case, fixed phone line) and $Y_t^2$ denotes the second generation technology (similarly, mobile phone). $\tau_1$ and $\tau_2$ indicates the time of introduction of fixed phone and mobile phone, respectively. Impulses for substitution diffusion are penetration of fixed phone line ($r_{01}$),time trend ($t_{01}$) and price ($p_{jk}$ where $j=0$, 1 and $k=2$, 3) are taken. $Q_{p13}$ indicates the coefficient of fixed phone subscriber's adoption of both mobile phone and fixed phone due to price ($p$) reason. It is assumed that non-subscribers first sign up to only one service, and fixed-line-only user may switch to mobile phone service but not vice versa. The concept of this switching is illustrated in Fig. 3.

Table 1
Estimation results of the fixed phone line subscription diffusion in Japan by simple logistic model (1953–2002)

| Parameter | Estimate | $t$-value | adj. $R^2$ |
|---|---|---|---|
| $a$ | $1.52\times10^{-1}$ | 4.26 | 0.991 |
| $b$ | $3.70\times10^{0}$ | 3.56 | |
| $N$ | $6.18\times10^{-3}$ | 6.45 | |

Estimated model $Y(t)=\frac{N}{1+\exp(-at+b)}$.

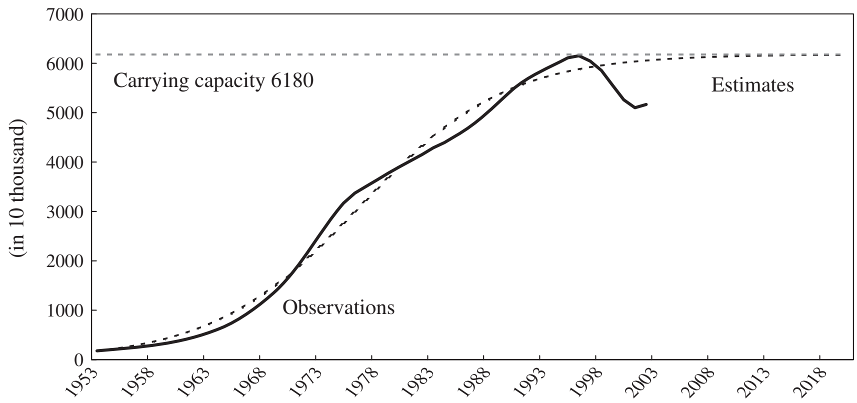


Fig. 2. Observations[a] and estimates[b] of the fixed phone line subscription diffusion in Japan by Simple Logistic Model. [a]1953–2002. [b]1953–2020.[c]Original statistics are based on monthly reports by TCA, Japan [31].

The estimated result is summarized in Table 2 and illustrated in Fig. 4. Looking at Table 2 we note that while fixed line phone penetrates into non-subscriber ($Q_{r01}$=.67), its attractiveness decreases as time passes ($Q_{\mathrm{to1}}$=−1.00). Price decrease induces mobile phone subscriber from non-subscriber ($Q_{\mathrm{p02}}$=−0.47), shifting from fixed phone ($Q_{\mathrm{p12}}$=−1.06 and $Q_{\mathrm{p13}}$=−3.02). Fig. 4 demonstrates clearly that mobile phone emerged in Japan's ICT market in 1991 and exhibited a dramatic deployment exceeding the diffusion level of fixed phone in 1998 and approaching to its carrying capacity 103.5 million ($N_2$), 1.7 times higher than the capacity of fixed phone. While this demonstrates that mobile phone substitutes for fixed phone, Table 2 suggests that the potential of fixed phone ($N_1$) is 57.4 million and 7% lower than the estimate of the Simple Logistic Model. This balance suggests the co-existence of both fixed and mobile phones in the initial stage of the emergence of mobile phone due to the price decrease of telephony service by the emergence of mobile service. A coefficient $Q_{p13}$ (−3.02) demonstrates this dynamism. Thus, we could conclude that mobile phone is substituting for fixed phone with certain complement induced by price decrease.

### 3.1.2. From fixed to mobile telephony, and from voice to data

The substitutability of mobile phone to replace fixed phone can be attributed largely to (i) its functionality of not only voice but also data, (ii) belonging to individual from sharing by

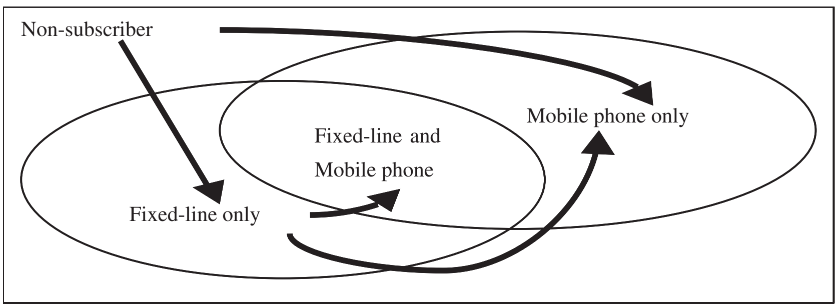


Fig. 3. Switching among different groups in telephony market.

Table 2
Estimation results of the substitution trajectory of mobile subscribers for fixed line in Japan by choice-based substitution diffusion model

| Parameter | Estimate | $t$-value | adj. $R^2$ |
|---|---|---|---|
| $C_{\tau 1}$ | $1.22 \times 10^2$ | 1.86 | 0.994 |
| $C_{\tau 2}$ | $6.50 \times 10^{-1}$ | 1.97 | |
| $N_1$ | $5.74 \times 10^3$ | 5.76 | |
| $N_2$ | $10.35 \times 10^3$ | 3.22 | |
| $Q_{r01}$ | $1.67 \times 10^0$ | 2.67 | |
| $Q_{t01}$ | $-1.00 \times 10^1$ | 3.12 | |
| $Q_{p02}$ | $-4.72 \times 10^{-1}$ | 2.43 | |
| $Q_{p12}$ | $-1.06 \times 11.0^0$ | 1.98 | |
| $Q_{p13}$ | $-3.02 \times 10^0$ | 2.43 | |

[a] $C\tau_1$, $C\tau_2$: coefficients of the initial utility before and after the introduction of mobile phone; $N_1$, $N_2$: potential market of fixed phone and mobile phone; $Q_{r01}$: coefficient of non-subscriber chooses fixed phone due to its market penetration; $Q_{t01}$: fixed phone subscriber chooses mobile phone due to time trend; and $Q_{p02}$, $Q_{p12}$, $Q_{p13}$; coefficient of non-subscriber and fixed phone subscriber choose mobile phone or both fixed and mobile phones, respectively due to price.

family, and (iii) mobility, particularly, no need to change telephone numbers whenever customers move.

With such understanding, trends in number of telephony service in Japan by type are illustrated in Fig. 5 by compiling the MPHPT's data.

The trends in portable and non-portable telephony subscription as well as voice-only and data and voice telephony subscription can be compared as illustrated in Fig. 6. Portable category contains mobile phone and PHS services while non-portable represents fixed phone and ISDN. Voice-only category contains fixed mainline while data-and-voice consists of ISDN, mobile phone and PHS. All demonstrates the significance of a mobile phone market in Japan (Table 3).

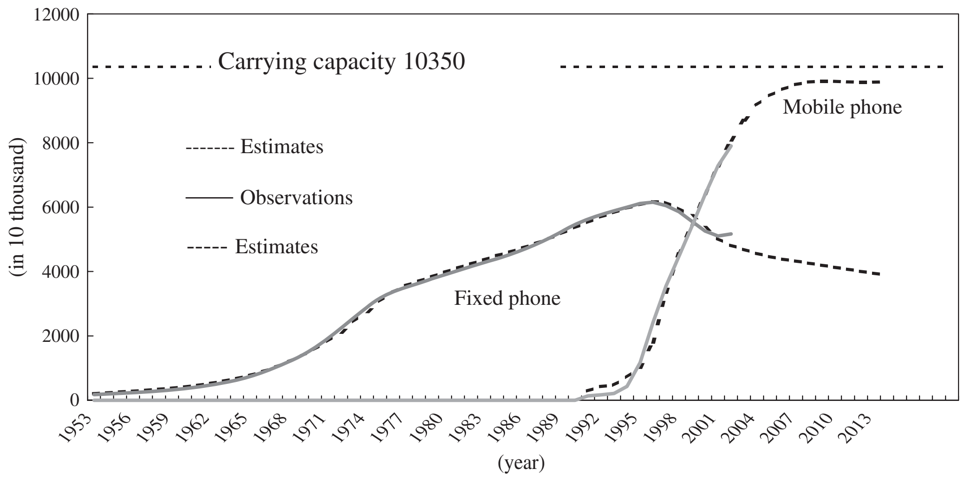


Fig. 4. Observations[a] and estimates[b] of the substitution trajectory of mobile subscribers for fixed line in Japan by Choice-based Substitution Diffusion Model. [a]1953–2002. [b]1953–2015. [c]Original statistics are based on monthly reports by MPHPT, Japan [32].

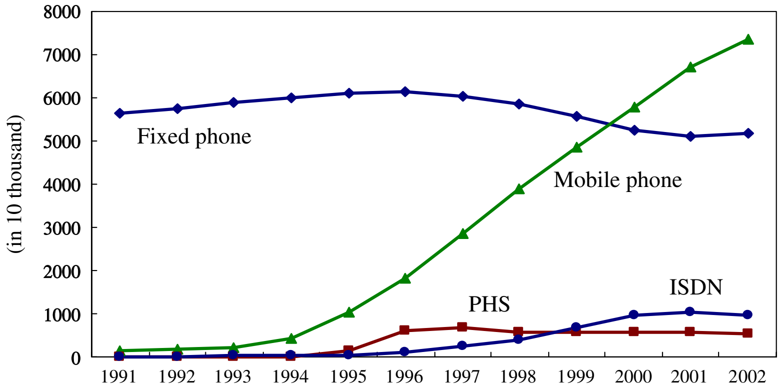


Fig. 5. Trends in number of “Fixed mainline,” “Mobile phone,” “PHS” and “ISDN” subscribers in Japan (1991–2002).

## 3.2. Mobile telephony market in Japan

### 3.2.1. Restructured telecom industry

When NTT DoCoMo first introduced i-mode service in February 1999, only 5000 out of 40.5 million mobile subscribers registered for the service. Following NTT DoCoMo, au and J-PHONE started mobile Internet service “ezweb” and “J-Sky” in April and December 1999, respectively. This resulted in price reduction and new service leading to mobile Internet subscriber base (Internet Protocol (IP) mobile subscribers) surging to 67.8 million, occupying 84.98% of mobile subscriber base as demonstrated in (Figs. 7 and 8).

### 3.2.2. Mobile phone diffusion dynamism in Japan

In order to analyze the mobile phone diffusion dynamism in Japan. Simple Logistic Model, Bi-logistic Model, Choice-based Substitution Diffusion Model, and Logistic Growth within a Dynamic Carrying Capacity Model are used.

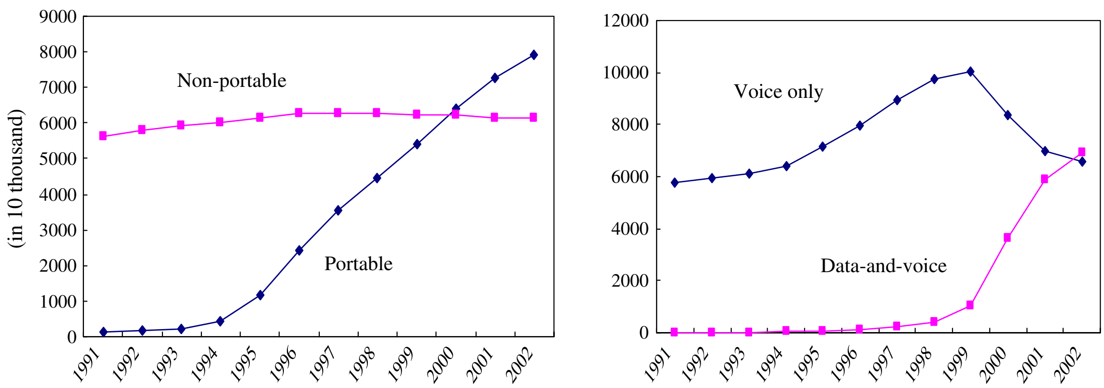


Fig. 6. Trends in number of portable and non-portable telephony subscription and number of voice-only and data-and-voice telephony subscription in Japan (1991–2002). Source: Compiled base on data from MPHPT, Japan [32]. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 3
Trend in new services and functions introduced by mobile phone carriers (1999–2003)

| Time | New service/function | Carrier |
|---|---|---|
| Feb 1999 | i-model (e-mail) | NTT DoCoMo |
| Apr 1999 | Ezweb (e-mail) | au |
| Dec 1999 | J-Sky (e-mail) | J-PHONE* |
| Jan 2000 | CocoNay (navigation) | NTT DoCoMo |
| May 2000 | J-navi (navigation) | J-PHONE* |
| Nov 2000 | J-pic-mail (camera) | J-PHONE* |
| Jan 2001 | i-appli (Java) | NTT DoCoMo |
| Jun 2001 | JgalvaAppli (Java) | J-PHONE* |
| Jul 2001 | ezplus (Java) | au |
| Nov 2001 | i-motion (video clip) | NTT DoCoMo |
| Dec 2001 | ezmovie (video clip) | au |
| Dec 2001 | eznavi (navigation) | au |
| May 2002 | i-shot (camera) | NTT DoCoMo |
| May 2002 | au-shot (camera) | au |
| Dec 2002 | J-movie (video clip) | J-PHONE* |
| Dec 2003 | Movie TV | Vodatone |

Sources: IT White Book [33].

*3.2.2.1. Simple Logistic Model.* The result of taking the whole mobile market to fit the Simple Logistic Model is summarized in Table 4 and also illustrated in Fig. 9, with observations (Jan. 1996–Dec. 2003) and estimates (Jan. 1996–Jan. 2008).

By means of the interpretation of the result, the recent phenomenon of slowing-down growth can be explained as an outcome of saturated market. The time required to reach half of the potential is $b/a$, which equals 126.8 (months), and this indicates that Japan took only about 10 years (since 1988) to reach the half point. While the similar analysis is conducted with the data of high-income countries, the

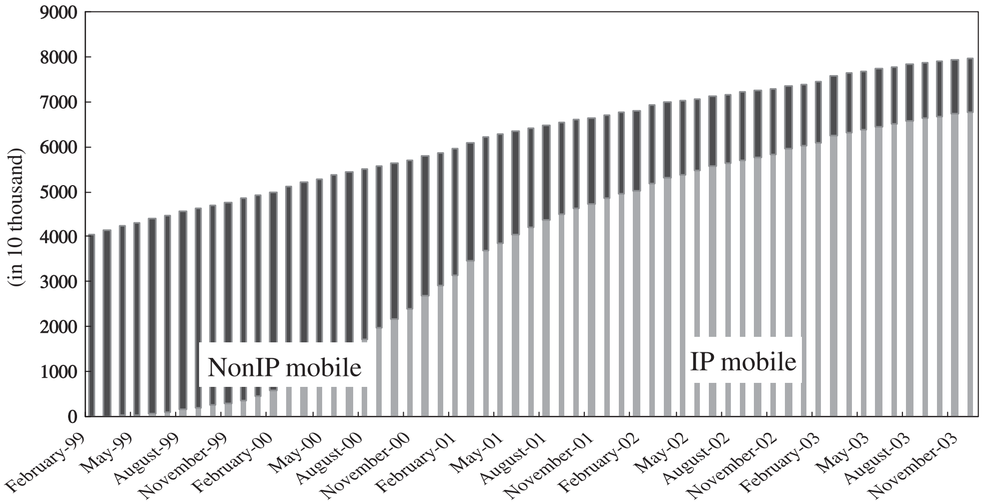


Fig. 7. Trends in number of NonIP and IP mobile subscribers in Japan (Feb. 1999–Dec. 2003). Source: Telecommunications Carriers Association, Japan [31].

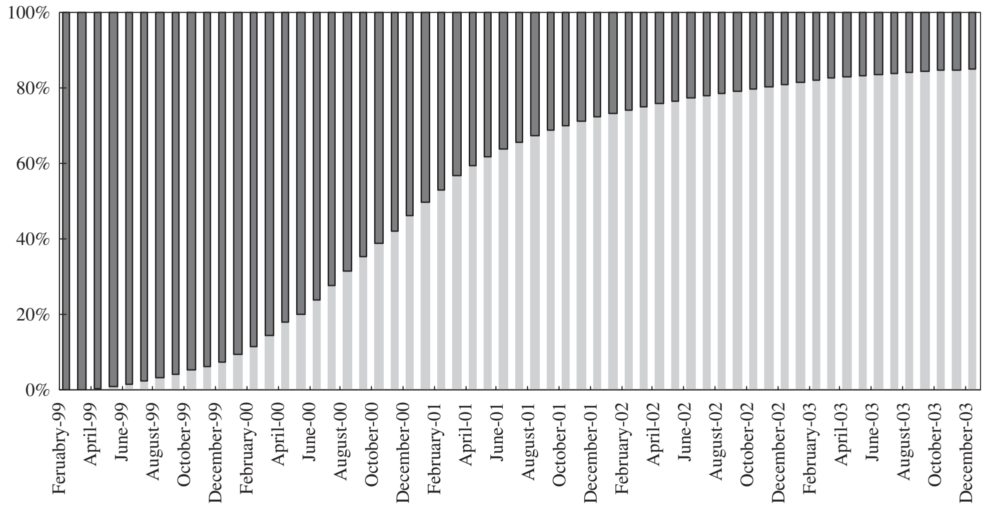


Fig. 8. Share of NonIP and IP mobile subscribers in Japan (Feb. 1999–Dec. 2003). Source: Telecommunications Carriers Association, Japan [31].

time required to reach 50% of potential is about 13 years. Compared with the average of high-income countries, Japan is a relatively active mobile market.

*3.2.2.2. Bi-logistic Model.* Although taking the mobile market as a whole helps to understand the overall vision, it is necessary to separate the mobile market into two stages: before and after the mobile Internet was introduced. With the Bi-logistic Model, it is attempted to capture the two impulses inside the market. Let $N_1$ and $N_2$ be the potential of NonIP mobile and IP mobile diffusion, respectively. The result of Bi-logistic Model analysis is summarized in Table 5 and also illustrated in Fig. 10, with the observations of the overall market size (Jan. 1996–Dec. 2003) along with the estimates (Jan. 1996–Jan. 2008) representing for the whole market, NonIP impulse followed by the IP impulse.

Judging from the parameters obtained from the model, the total diffusion process is divided into two impulses. The first impulse came from the mobile service only capable of voice calls transmission. The potential is approximately 49.1 million, which means without the mobile Internet service, it was possible that only half of the population would have been using mobile phone. However, earning growth due to mobile service capable of non-voice communication, the potential rises up by 32.3 million, pulling high the upper limit of mobile phone diffusion to 81.4 million.

Table 4
Estimation results of the mobile subscriptions in Japan by simple logistic model (Jan. 1996–Dec. 2003)

| Parameter | Estimate | $t$-value | adj. $R^2$ |
|---|---|---|---|
| $a$ | $4.44\times10^{-2}$ | 5.22 | 0.996 |
| $b$ | 5.63 | 7.31 | |
| $N$ | $8.47\times10^{-3}$ | 10.24 | |

Estimated model $Y(t)=\frac{N}{1+\exp(-at+b)}$.

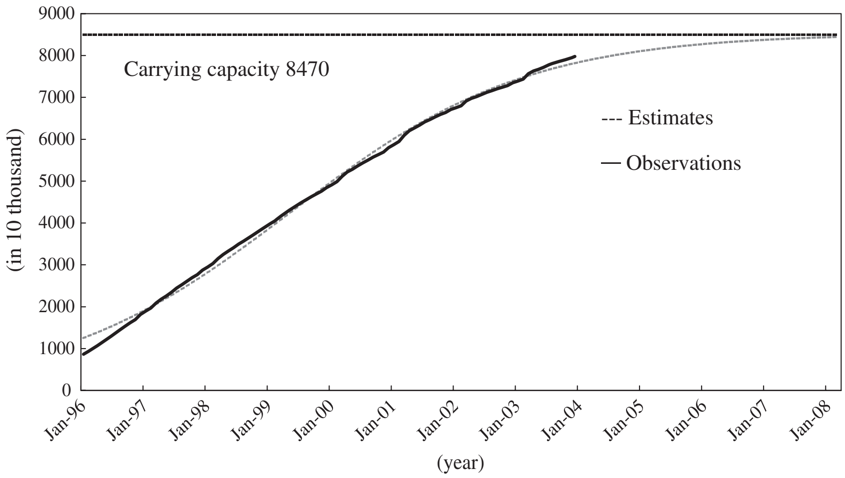


Fig. 9. Observations[a] and estimates[b] of mobile subscribers in Japan by Simple Logistic Model: in 10 thousands. [a]Jan. 1996–Dec. 2003. [b]Jan. 1996–Jan. 2008. [c]Original statistics are based on monthly reports by TCA, Japan [31].

*3.2.2.3. Choice-based Substitution Diffusion Model.* Base on the result of Bi-logistic Model analysis, it is plausible that the dramatic increase in IP mobile subscriber base does not come from the second impulse only. There must have been internal mechanism pushing IP mobile service to spread out so fast. Therefore, it is considered that those previously existing users switched from NonIP to IP mobile service after the introduction of IP mobile. Thus, a diffusion trajectory by means of Choice-based Substitution Diffusion Model is used to analyze this internal change after IP mobile phone was introduced.

As explained in Section 2, based on the existing studies, factors such as penetration ($r$), time trend ($t$), price ($p$) and function ($f$) are taken into the model. The choices made by consumers consist of the following possibilities: (i) before IP mobile is introduced, non-subscribers sign up to mobile service or not; (ii) after IP mobile was introduced, non-subscribers sign up to mobile service or not; (iii) they can choose NonIP or IP service if they sign up to mobile service; and (iv) existing subscribers may switch from NonIP to IP service. Thus, IP mobile gain more population from new subscribers as well as existing subscribers.

The result of Choice-based Diffusion Model analysis is summarized in Table 6 and also illustrated in Fig. 11, with the observations of the overall market size (Jan. 1996–Dec. 2003) along with the estimates (Jan. 1996–Jan. 2007) representing NonIP mobile and IP mobile service subscriber bases.

Table 5
Estimation results of the mobile subscriptions in Japan by Bi-logistic model (Jan. 1996–Dec. 2003)

| Parameter | Estimate | $t$-value | adj. $R^2$ |
|---|---|---|---|
| $a_1$ | $7.66\times10^{-2}$ | 8.27 | 0.998 |
| $b_1$ | 8.00 | 12.31 | |
| $a_2$ | $8.62\times10^{-2}$ | 5.56 | |
| $b_2$ | 2.68 | 10.15 | |
| $N_1$ | $4.91\times10^{-3}$ | 15.21 | |
| $N_2$ | $3.23\times10^{3}$ | 13.38 | |

Estimated model $Y(t)=Y_1(t)+Y_2(t)=\frac{N_1}{1+\exp(-a_1(t-\tau_1)+b_1)}+\frac{N_2}{1+\exp(-a_2(t-\tau_2)+b_2)}$.

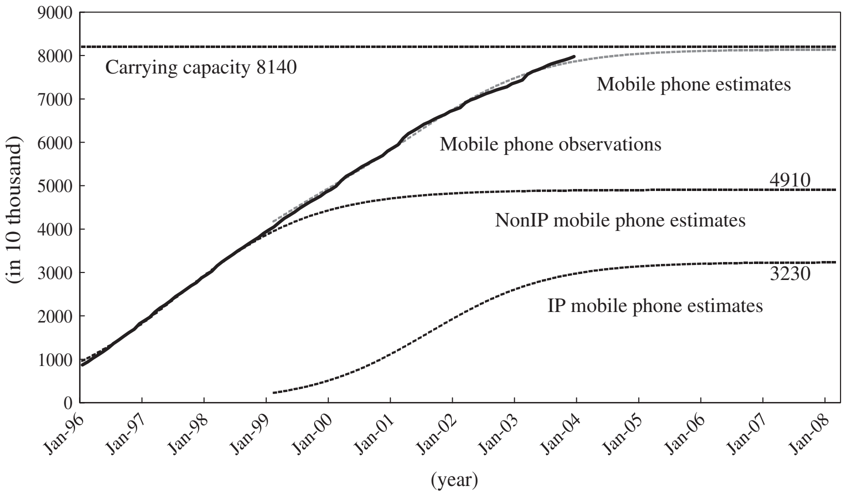


Fig. 10. Observations[a] and estimates[b] of mobile subscribers in Japan by Bi-logistic Model. [a]Jan. 1996–Dec. 2003. [b]Jan. 1996–Jan. 2008. [c]Original statistics are based on monthly reports by TCA, Japan [31].

Looking at Table 6 we note that while NonIP mobile phone penetrates into non-subscriber ($Q_{r01}$=6.17), its attractiveness decreases as time passes ($Q_{t01}$=−1.77). Contrary to NonIP, IP mobile gains popularity and attracts customers from non-subscriber and IP mobile subscriber as time passes ($Q_{t02}$=0.12, $Q_{12}$=0.02). In addition, as function improves, subscriber rushes into IP mobile ($Q_{f02}$=0.005, $Q_{f12}$=0.005). Consequently, price decrease induces a shift from NonIP to IP mobile subscriber ($Q_{p12}$=−8.00). Fig. 16 demonstrates clearly that IP mobile phone emerged in Japan's ICT market in 1999 and substitutes NonIP dramatically leading to carrying capacity of mobile phone 82.3

Table 6
Estimation results of the mobile subscriptions in Japan by choice-based substitution diffusion model (Jan. 1996–Dec. 2003)

| Parameter | Estimate | $t$-value | adj. $R^2$ |
|---|---|---|---|
| $C_{\tau 1}$ | $7.65\times10^{1}$ | 5.20 | 0.997 |
| $C_{\tau 2}$ | $7.43\times10^{1}$ | 3.51 | |
| $N_1$ | $5.57\times10^{3}$ | 1.85 | |
| $N_2$ | $8.23\times10^{3}$ | 6.87 | |
| $Q_{t01}$ | $-1.77\times10^{0}$ | 7.52 | |
| $Q_{t02}$ | $1.16\times10^{-1}$ | 3.45 | |
| $Q_{t11}$ | $1.60\times10^{-2}$ | 2.65 | |
| $Q_{t12}$ | $2.00\times10^{-2}$ | 3.21 | |
| $Q_{f02}$ | $4.61\times10^{-3}$ | 1.86 | |
| $Q_{f12}$ | $5.00\times10^{-3}$ | 3.12 | |
| $Q_{p12}$ | $-8.00\times10^{0}$ | 5.15 | |

[a] $C\tau_1$, $C\tau_2$: coefficients of the initial utility before and after the introduction of mobile phone; $N_1$, $N_2$: potential market of NonIP and IP mobile phone; $Q_{r01}$: coefficient of non-subscriber chooses NonIP mobile phone due to its market penetration; $Q_{t01}$, $Q_{t02}$: non subscriber chooses NonIP and IP mobile phone, respectively due to time trend; $Q_{t11}$, $Q_{t12}$: similarly, NonIP subscriber chooses NonIP and IP mobile phone, respectively due to time trend; $Q_{f02}$, $Q_{f12}$: coefficient of non-subscriber chooses mobile phone, NonIP subscriber chooses IP mobile, respectively due to function; and $Q_{p12}$: NonIP subscriber chooses IP mobile due to price.

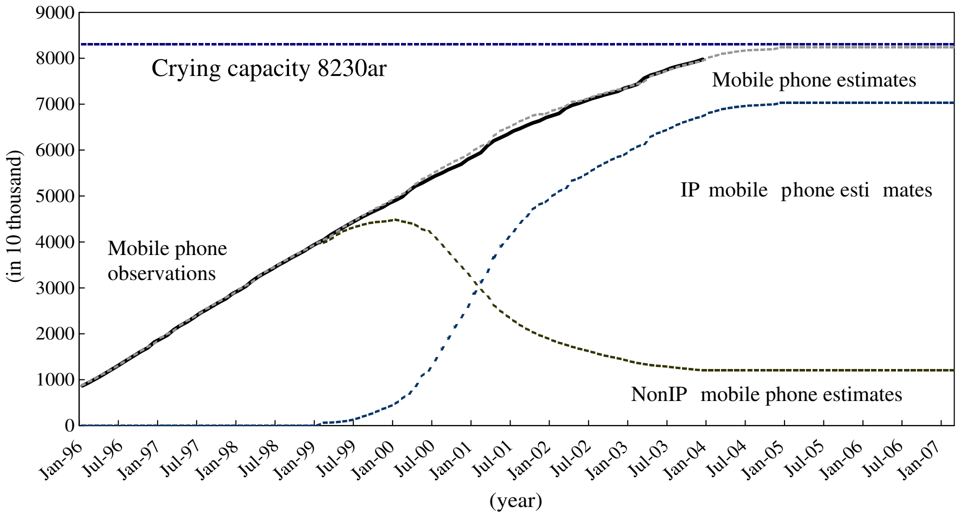


Fig. 11. Observations[a] and estimates[b] of NonIP and IP mobile subscribers in Japan by Choice-based Substitution Diffusion Model. [a]Jan. 1996–Dec. 2003. [b]Jan. 1996–Jan. 2007. [c]Original statistics are based on monthly reports by TCA, Japan [31].

million ($N_2$). This estimate is almost the same as the estimate by Bi-logistic model (81.4 million). However, the estimation by Choice-based Substitution Diffusion Model expects stronger substitution of IP for NonIP mobile phone subscriber.

Next, the positive $M$ shows that in the first stage, as the penetration rate increases, consumers' utility of adopting mobile service rises; this can also be regarded as the so-called "imitation" in Bass model. However, the negative $Q_{01}$ identifies that, once the second stage starts, non-subscribers' utility of adopting NonIP mobile service decreases as time goes by because they have one more choice, IP mobile service. NonIP mobile offers less and less utility to users; NonIP mobile service becomes obsolete after mobile Internet enters the market. On the contrary, the positive $Q_{02}$ points out that, for non-subscribers, IP mobile service seems to be the main mobile service as time passes; therefore, the later they decide to sign up to mobile service, the more possibly they would sign up to IP mobile phone directly.

*3.2.2.4. Logistic growth within a dynamic carrying capacity.* With the result of Choice-based Substitution Diffusion Model, it is appropriate to assume that in the mobile market in Japan the potential of market grows with the evolving technology. Although in the empirical study of Choice-based Substitution Diffusion Model the diffusion process is only divided into two phases, technology innovation and development can also be considered as a continuous process that is difficult to draw a line in between two generations. Whenever the performance is improved or the product is upgraded, the potential is lifted up in some degree. Therefore, the Logistic Growth within a Dynamic Carrying Capacity is introduced to deal with such continuous innovation process. Taking the mobile phone market as a whole to observe its growth since December 1988, the diffusion trajectory is analyzed and the result is summarized in Table 7 and also illustrated in Fig. 12.

The final potential of mobile phone market estimated by the Logistic Growth within a Dynamic Carrying Capacity reaches about 93.8 million, higher than potentials previously estimated by other models. Moreover, while the Simple Logistic Model and the Bi-logistic Model seem underestimate the growth after year 2004, the Logistic Growth within a Dynamic Carrying Capacity seems to reflect the

Table 7
Estimation results of the mobile subscriptions in Japan by logistic growth within a dynamic carrying capacity (Jan. 1996–Dec. 2003)

| Parameter | Estimate | $t$-value | adj. $R^2$ |
|---|---|---|---|
| $a'$ | $1.48\times10^{-1}$ | 8.94 | 0.998 |
| $b'$ | $1.44\times10^{2}$ | 9.85 | |
| $a_K$ | $3.43\times10^{-2}$ | 7.63 | |
| $b_K$ | $4.21\times10^{0}$ | 8.65 | |
| $N_N$ | $9.38\times10^{3}$ | 10.89 | |

Estimated model $Y(t)=\frac{N_N}{1+\exp(-a't+b')+\frac{a'}{a'-a'_N}\exp(-a'_N t+b_N)}$.

growing feature of market potential due to expanded functions, reduced prices, increased population or other non-specific factors.

As long as the market mechanism and mobile technology innovation work smoothly hereafter as expected, the current slowing-down market growth will still climb up to fulfill the final potential.

### 3.3. Internet access in market Japan

#### 3.3.1. Diffusion of the Internet access in Japan

Fig. 13 demonstrates trend in number of the Internet access subscribers in Japan by classifying PC-terminal Internet access, Dial-up access and Broadband access. Fig. 14 demonstrates service of mobile Internet subscribers in Japan used by the customers.

In order to explore how competition and price reduction affected the Internet market in Japan in the past few years, numerical analysis are conducted by applying Single Logistic Model, Bi-logistic Model and Choice-based Substitution Diffusion Model.

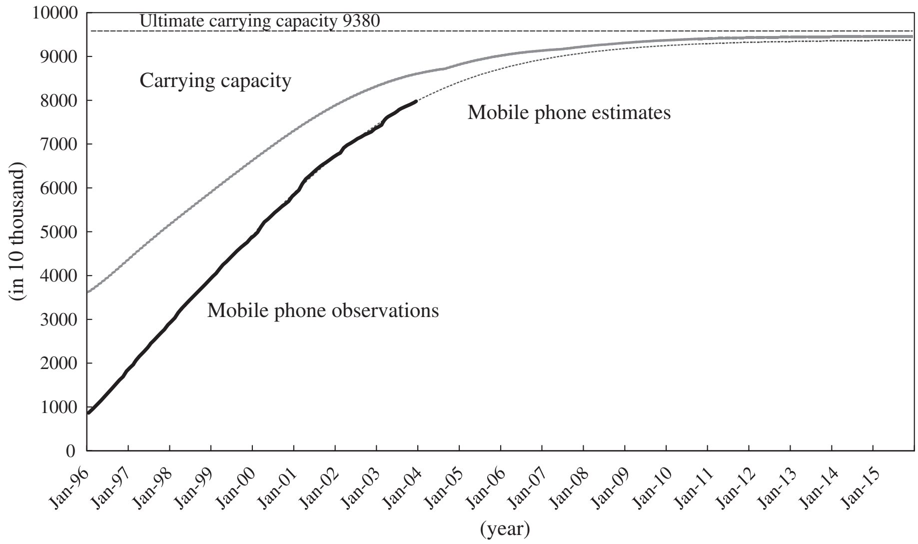


Fig. 12. Observations[a] and estimates[b] of mobile subscribers in Japan by Logistic Growth within a Dynamic Carrying Capacity. [a]Jan. 1996–Dec. 2003. [b]Jan. 1996–Dec. 2015. [c]Original statistics are based on monthly reports by TCA, Japan [31].

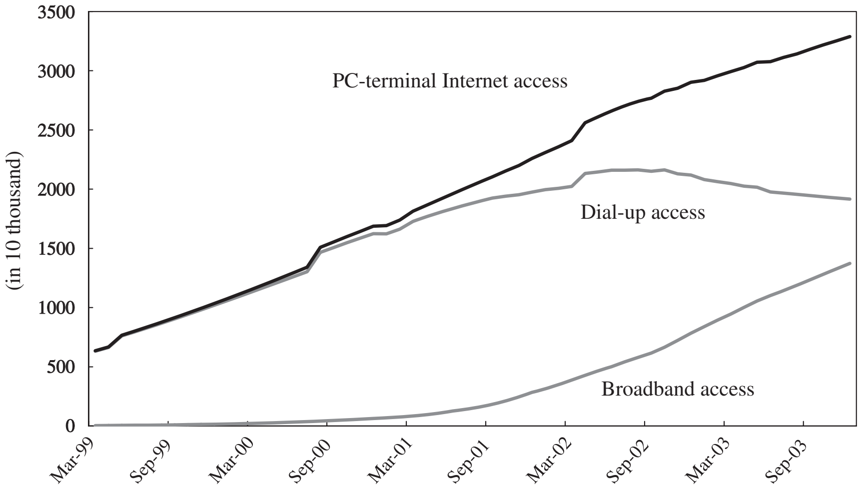


Fig. 13. Trend in number of Internet access subscribers in Japan (Mar. 1999–Dec. 2003). Source: MPHPT, Japan [32].

*3.3.1.1. Simple Logistic Model.* The result of fitting the empirical data of Internet subscription in Japan with Simple Logistic Model shows its diffusion potential is approximately 37 million as summarized in Table 8 and demonstrated in Fig. 15.

Compared with the potential of mobile phone market potential, which is about 85 million, the potential of Internet subscription seems to be much smaller. This can be attributed to the fact that mobile phone service, both the handset and the phone number, is a kind of telecom service for each individual. People rarely share their mobile phone with any one else; however, in the case of Internet, especially all Internet accesses other than Wireless Internet, subscribers usually install the devices (cable, telephone line, personal computer, etc.) at home and share with their family members. It is quite understandable that Internet subscription potential is lower than that of mobile phone. However,

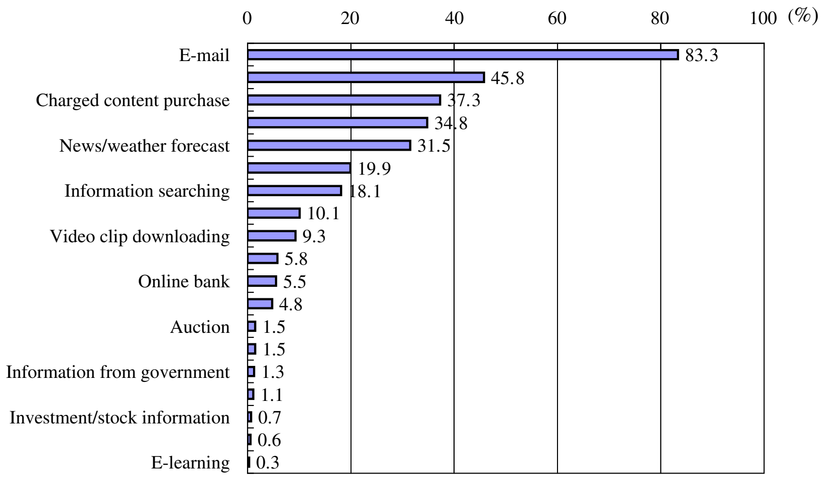


Fig. 14. Service used by mobile Internet subscribers in Japan. Source: Telecommunications Usage Trend Survey 2003 [32].

Table 8
Estimation results of internet access subscribers in Japan by simple logistic model (Oct.1999–Dec.2003)

| Parameter | Estimate | $t$-value | adj. $R^2$ |
|---|---|---|---|
| $a$ | $6.15\times10^{-2}$ | 6.58 | 0.995 |
| $b$ | $7.61\times10^{0}$ | 7.46 | |
| $N$ | $3.71\times10^{3}$ | 9.44 | |

Estimated model $Y(t)=\frac{N}{1+\exp(-at+b)}$.

the diffusion speed $b/a$ of Internet access does not reveal significant difference from that of the mobile phone.

*3.3.1.2. Bi-logistic Model.* While the Simple Logistic Model analysis gives a general outline about this market in Japan, aiming at exploring its internal change, the Bi-logistic Model is applied to analyze the two impulses of Internet accesses, namely "dial-up" and "broadband." The start of dial up, $\tau_1$, is identified as January 1991 while the start of broadband service, $\tau_2$, is identified as March 1999. The result and estimated parameters are summarized in Table 9 and also illustrated in Fig. 16.

*3.3.1.3. Choice-based Substitution Diffusion Model.* While contributing to the whole subscription potential, broadband service also attracts subscribers from the existing dial-up service user base, in order to decompose this mechanism of the dynamic change of both dial-up and broadband service diffusion. Choice-based substitution Diffusion Model is applied. Let the start of dial up, $\tau_1$, as Jan. 1991 and the start of broadband service, $\tau_2$, as Mar. 1999. As the model implemented in the previous sections,

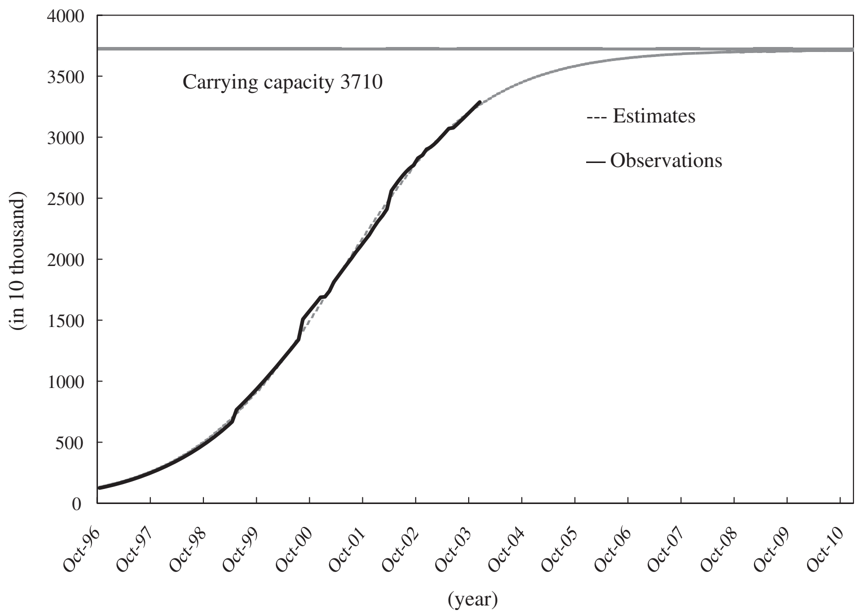


Fig. 15. Observations[a] and estimates[b] of Internet access subscribers in Japan by Simple Logistic Model. [a]Oct. 1999–Dec. 2003. [b]Oct. 1999–Dec. 2010. [c]Original statistics are based on monthly reports by MPHPT, Japan [32].

Table 9
Estimation results of internet access subscribers in Japan by Bi-logistic Model (Oct.1999–Dec.2003)

| Parameter | Estimate | $t$-value | adj. $R^2$ |
|---|---|---|---|
| $a_1$ | $6.28\times10^{-2}$ | 2.98 | 0.997 |
| $b_1$ | 7.72 | 6.45 | |
| $a_2$ | $9.42\times10^{-2}$ | 7.86 | |
| $b_2$ | 3.69 | 7.47 | |
| $N_1$ | $2.35\times10^{3}$ | 7.26 | |
| $N_2$ | $1.21\times10^{3}$ | 4.87 | |

Estimated model $Y = Y_1(t) + Y_2(t) = \frac{N_1}{1+\exp(-a_1(t-\tau_1)+b_1)} + \frac{N_2}{1+\exp(-a_2(t-\tau_2)+b_2)}$ where $Y_1$: Dial-up subscription; $Y_2$: Broadband subscription.

suppose generation 1 represents the dial-up access and generation 2 the broadband. Similar to preceding analyses, impulses of penetration ($r$), time trend ($t$), and price ($p$) are examined.

The estimated result is summarized in Table 10 and illustrated in Fig. 17, depicting the curve of dial-up diffusion and broadband diffusion estimates (Oct. 1999–Dec. 2010) as well as empirical observations (Oct. 1999–Dec. 2003).

Looking at Table 10 we note that dial-up penetrates into non-subscriber ($Q_{r01}=0.10$), its attractiveness shifts to broadband as time passes ($Q_{t01}=0.03$, $Q_{t02}=0.19$, $Q_{t11}=0.05$, $Q_{t12}=0.09$). Price decrease induces non-subscriber to broadband ($Q_{p02}=-3.02$) while dial-up subscriber shifts to broadband despite its price increase ($Q_{p12}=0.72$) as dial-up subscriber has realized the attractiveness of the high quality of broadband.

Before broadband service was offered, the market potential was about 7.8 million ($N_1=7.75\times10^6$), with the improved capacity of broadband, more consumers are likely to adopt Internet access than before enhancing potential market by broadband 39.6 million ($N_2=3.96\times10^7$). In the first stage when only dial-up service existed, positive $Q_{r01}$ shows that consumers' utility increased as the subscribers became more. In the second stage with both services, consumers' utility of using broadband service increases

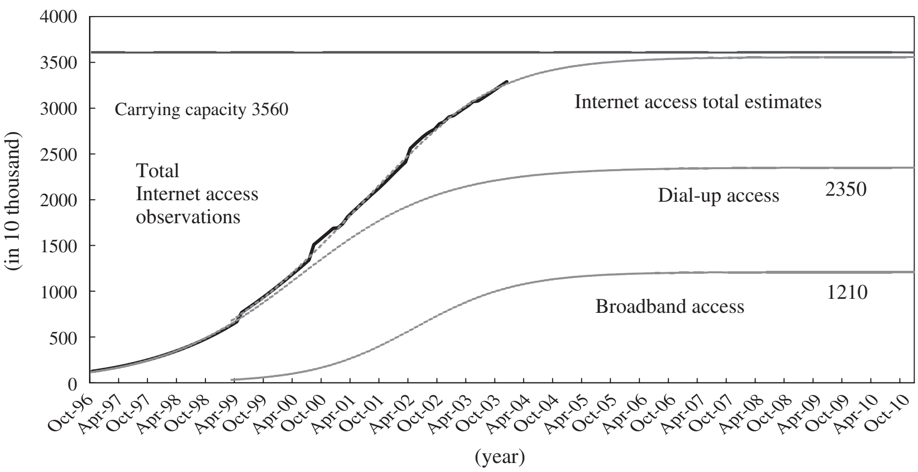


Fig. 16. Observations[a] and estimates[b] of Internet access subscribers in Japan by Bi-logistic Model. [a]Oct. 1999–Dec. 2003. [b]Oct. 1999–Dec. 2010. [c]Original statistics are based on monthly reports by MPHPT, Japan [32].

Table 10
Estimation results of the substitutive trajectory among internet, dial-up, and broadband access subscribers in Japan by choice-based substitution diffusion model (Oct.1999–Dec.2003)

| Parameter | Estimate | $t$-value | adj. $R^2$ |
|---|---|---|---|
| $C_{\tau 1}$ | $2.30\times10^{2}$ | 2.02 | 0.997 |
| $C_{\tau 2}$ | $4.01\times10^{2}$ | 1.87 | |
| $N_1$ | $7.75\times10^{2}$ | 2.14 | |
| $N_2$ | $3.96\times10^{3}$ | 7.15 | |
| $Q_{r01}$ | $9.71\times10^{-2}$ | 1.98 | |
| $Q_{r01}$ | $2.71\times10^{-2}$ | 3.67 | |
| $Q_{t02}$ | $1.90\times10^{-1}$ | 2.12 | |
| $Q_{t11}$ | $5.00\times10^{-2}$ | 2.65 | |
| $Q_{t12}$ | $8.51\times10^{-2}$ | 2.64 | |
| $Q_{p02}$ | $-3.02\times10^{0}$ | 1.85 | |
| $Q_{p12}$ | $7.21\times10^{-1}$ | 2.75 | |

[a] $C\tau_1$, $C\tau_2$ coefficients of the initial utility before and after the introduction of broad band; $N_1$, $N_2$: potential market of dial-up and broadband; $Q_{r01}$: coefficient of non-subscriber chooses dial-up due to its market penetration; $Q_{t01}$, $Q_{t02:}$ coefficient of non-subscriber chooses dial-up and broadband, respectively, due to time trend; $Q_{t11}$, $Q_{t12}$: coefficient of dial-up subscriber chooses dial-up and broadband, respectively due to time trend; and $Q_{p02}$, $Q_{p12}$: coefficient of non-subscriber chooses broadband and dial-up subscriber chooses broad, respectively due to price.

with time faster than that of using dial-up service since $Q_{t11}<Q_{t12}$. Furthermore, consumers' utility of switching from dial-up to broadband service increases with time faster than that of keeping using dial-up service since $Q_{t11}<Q_{t12}$. The price factor affects the non-subscribers more (when they decide to sign up to broadband service) than the existing dial-up users (when they decide to switch to broadband service)

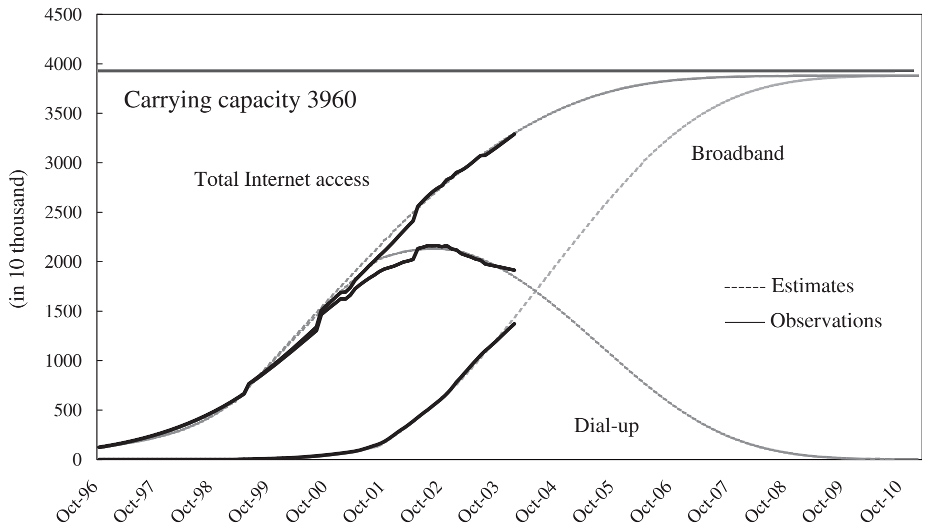


Fig. 17. Observations[a] and estimates[b] of Internet, dial-up, and broadband access subscribers in Japan by Choice-based Substitution Diffusion Model. [a]Oct. 1999–Dec. 2003. [b]Oct. 1999–Dec. 2010. [c]Original statistics are based on monthly reports by MPHPT, Japan [32].

since $|Q_{p11}|<|Q_{p12}|$. All demonstrates the significance of the advancement of broadband in leveraging Internet access.

### *3.3.2. Comparison between broadband diffusion in Japan and other countries*

With the understanding of the significance of the advancement of broadband in leveraging Internet access, Fig. 18 analyzes the correlation between GNI (Gross National Income) per capita and broadband penetration rate in 30 countries the world which demonstrates that broadband penetration rate increases logistically as GNI per capita increases.

With South Korea as the outstanding outlier, this correlation can be described as an exponential function which indicates that Japan actually lies over the average level. Japan, one of the leading well-developed economies, has attained the strength for broadband diffusion, such as high GNI, relatively low price and high access speed. Most important feature is that it has been the most successful country in mobile telephony diffusion, just as South Korea in broadband diffusion. Its success in mobile telephony shows that Japan is a market capable of ICT adoption. After "Yahoo BB!" entered the market in September 2001, the increase of subscriber number surged up over 200,000 per month immediately and the broadband population increased by over 30,000 each month afterwards. Currently Japan still lags behind South Korea due to the late start in constructing competitive circumstances. However, with steady growth in competitive circumstances, it is possible to catch up with South Korea in a few years. In order to accelerate the growth rate, the government should play a more active role in promoting broadband adoption and development. In addition, the threshold of high Internet diffusion rate depends on the personal computers possession rate, which is over 78% in South Korea. For either dial-up, fixed broadband or wireless Internet access subscribers, at least one desktop/laptop computer is necessary. Thus, in order to develop the qualified Internet infrastructure further, constructing an inducing dynamism in leveraging both high rates of personal

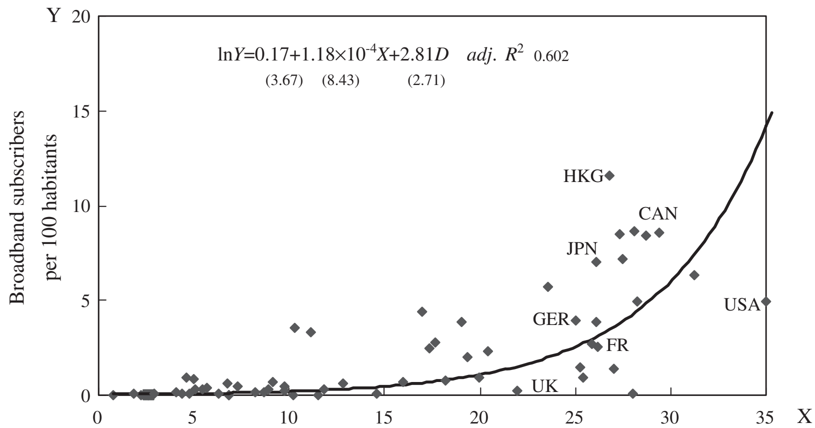


Fig. 18. Correlation between broadband subscribers per 100 inhabitants and GNI per capita worldwide (2002). [a]GNI: Gross National Income using PPP. [b]Broadband subscribers per 100 inhabitants in leading countries in 2002 are: Korea (21.3), Hongkong (14.9), Canada (11.2), Taiwan (9.4), Sweden (7.8), Netherlands (7.2), Japan (7.1), USA (6.9), Finland (5.3), Germany (3.9), France (2.4), UK (2.3), and Italy (1.5). [c]D: Dummy variables (Korea = 1, Other countries = 0). [d]Korea, Luxemburg and Norway are omitted from the graph but included in the trend line computation. [e]Original statistics are based on ITU [34].

computers possession and Internet access subscription should be important strategies for the government to endeavor [35].

## 4. Conclusion

### 4.1. General summary

In light of the significance of the reconstruction of Japan's vicious cycle between non-elastic institutions and insufficient utilization of the potential benefits of ICT, this paper analyzed diffusion, substitution and competition dynamism inside Japan's ICT market.

Prompted by the hypothetical view that recent advances in its IP mobile service deployment such as NTT DoCoMo's i-mode service can be attributed to a co-evolutionary dynamism between diffusion, substitution and competition inside its ICT market, an empirical analysis of the mechanism co-evolving this dynamism in telephony, mobile telephony and Internet access markets was attempted by utilizing four types of diffusion models identical to respective diffusion, substitution and competition dynamics.

### 4.2. New findings

#### 4.2.1. Telephony market

i. The Simple Logistic Model demonstrate that the potential of fixed line phone market in Japan is about 62 million, lower than that of the mobile phone since fixed line phone is usually shared by people who live together such as family members while mobile phone is always possessed by individual.
ii. However, the subscription of fixed line phone has started to decline after reaching the peak in 1996. It is considered that the complementary feature between mobile and fixed line telephone is the reason for such decrease in a matured fixed phone line market.
iii. By taking mobile and fixed line telephony as two generations of telephony with substitutability and analyzing with the Choice-based Substitution Diffusion Model, it is demonstrated that the potential of the overall telephony can be about 100 million, consisting of double-subscribers who sign up to both mobile phone and fixed line phone.
iv. Consumers' utility to adopt fixed line phone increase as time goes by before mobile phone is introduced but decreases with time after mobile phone appeared in the market. The price of monthly subscription fee of mobile phone is a negative factor for users to adopt or switch to mobile phone, moreover, the double-subscribers reveal the highest price elasticity and non-subscribers seem to consider price less than those who have already subscribed to either one service. The result can be attributed to the fact that for people who have not yet adopted any telephony service, they have higher need to subscribe than those who just consider to switch.
v. Moreover, even after mobile phone is introduced into the market, existing subscribers of fixed line phone still tend to continue such subscription as long as the price of mobile phone does not drop too much.
vi. In both mobile and fixed line telephony cases, it is observed that voice-only service is occupying less and less share of communication market while data-and-voice service is still growing. With

only mobile and fixed line telephony taken into consideration, the substitution effect lead the subscription of fixed line phone to decrease, however, including the impact by the Internet access demand, the fixed line phone demand will decrease less than analyzed with this model.

#### *4.2.2. Mobile telephony market*

i. Both Simple Logistic Model and Bi-logistic Model demonstrate that the potential of mobile phone market in Japan is between 83 million and 85 million, with the speed that half of the potential can have been reached within about 13 years.
ii. While the diffusion process is divided into two impulses, the Bi-logistic Model demonstrates that the potential of market increased from 50 million to more than 83 million after the IP mobile phone was introduced into the market.
iii. However, with the Choice-based Substitution Diffusion Model that takes the substitution of NonIP by IP mobile phone into consideration, the potential of NonIP mobile phone was originally about 56 million, but the penetration rate slowed down before reaching this level and users switching from NonIP to IP mobile phone service make the diffusion of IP mobile phone move faster than expected. The overall potential of mobile phone is still estimated as about 83 million with this model.
iv. The analysis with the Choice-based Substitution Diffusion Model demonstrates the factors that affect consumers' adoption intension. Consumers' utility of adopting NonIP mobile phone increases as time goes by before IP mobile phone is introduced. However, after IP mobile phone appeared in the market, consumers' utility of adopting NonIP decreases with time due to obsolescence. Users' utility of keeping using NonIP mobile phone increases with time but more slowly than that of adopting or switching to IP mobile. As expected, consumers are more likely to adopt IP mobile phone with reduced price and enriched functions.
v. Finally, based on the previous analysis, analysis with Logistic Growth within a Dynamic Carrying Capacity demonstrates that, with the consideration about positive impact of enriched functions on ICT development, the potential of mobile phone can actually reach to about 94 million, which is higher than the estimates with previously implemented models.
vi. Observations of the newly gained market share shows that the relatively stable market might be changed in the near future. This is an evidence of more and more competitive environment that is a positive driving force of mobile phone diffusion.

#### *4.2.3. Internet access market*

i. The Simple Logistic Model demonstrates that the potential of the Internet access market in Japan is about 37 million, even lower than that of the fixed line phone. The reason is considered to be that Internet access diffusion is limited by personal computer possession rate. Moreover, fixed line Internet access can also be shared by people who live together such as family members just as in the case of fixed line phone.
ii. While the diffusion process is divided into two impulses, dial-up access and broadband access, the Bi-logistic Model demonstrates that the potential of mobile phone market in Japan increased by about 12 million contributed by broadband Internet access service. The impulse cause by broadband Internet access grows at a speed faster than the first impulse of dial-up access. Such a

difference in diffusion speed is attributed to the always-connected feature and the high access speed of broadband that is more appealing to the Internet users.

iii. Moreover, with the Choice-based Substitution Diffusion Model that takes the substitution of dial-up access by broadband Internet access into consideration, the potential of Internet access was originally only about 8 million, but after broadband access is introduced, both subscription of dial-up access and broadband Internet access increase dramatically.
iv. The analysis with the Choice-based Substitution Diffusion Model demonstrates that both time and price affect consumers' adoption intension. Time also represents the degree of maturity of Internet technology as well as the bandwidth, thus it is rational so have the result that consumers' utility increases with time. Consumers' utility of using broadband access increases faster with time than that of using the dial-up service.
v. However, the case of Internet is different from that of the telephony because users' utility of adopting dial-up access increases with time no matter before or after broadband access is introduced. This reason is considered to be that people still sign up to dial-up service while broadband has already been introduced into the market because they consider themselves as non-frequent-users of the Internet. Therefore, they can still be satisfied with the limited speed offered by dial-up access.
vi. The penetration rate of dial-up access that has started to slow down since 2002 is expected to decline rapidly during the coming years. Users switching from dial-up access to broadband access make the diffusion of broadband access move faster than expected. The overall potential of the Internet access is estimated as about 40 million with the Choice-based Substitution Diffusion Model.
vii. Competition is expected to be the most important driving force to fill up the gap between broadband market development in Japan and Korea.

#### 4.2.4. Diffusion, substitution and competition dynamism inside the transitional market in telephony, mobile and internet

All these findings obtained in the substitution dynamism in the markets of telephony (fixed line to mobile), mobile telephony (NonIP mobile to IP mobile) and Internet access (dial-up to broadband) demonstrate a noting co-evolutionary dynamism between diffusion, substitution and competition emerging inside the Japanese ICT market in transition. Key factors governing this dynamism are identified as ICT innovation, enriched functions, reduced price and competitive environment.

### 4.3. Policy implications

Given the foregoing dynamism can be the south of Japan's noting advances in IP mobile servile deployment, despite a lack of institutional elasticity, systems approach in stimulating a co-evolution between ICT innovation, diffusion, substitution and competition with the special attention to the following policies would be essential:

i. With IP mobile phone as the mainstream of telephony market, it is expected that everyone can have an ubiquitous information receiver. Being able to communicate with others via not only voice but also data will definitely increase the mobility and hence improve the efficiency of necessary communication. Deregulations to promote competition are furthering smoothly in most advanced countries, and the government should continue to make effort to keep such competitive environment rolling. Moreover, the possibility of mobile phone may be extended from only e-mail receiver to more practical Internet terminal. Making mobile Internet a required function for convenient life will increase its penetration rate more efficiently.

ii. With the substitution by mobile phone, fixed line phone seems to be considered as a sunset industry. However, judging from the increasing demand for data-and-voice service, it is possible that the demand for fixed line phone will increase again if the demand for the Internet is sufficient.

iii. Currently the broadband access still depends on the fixed line phone infrastructure, so the government should take such impact into consideration when deciding to continue expanding fixed line phone infrastructure development or not.

### 4.4. Future works

i. In this research, the empirical diffusion and substitution analysis of ICT market is focused on Japan's market. However, given the significance of such analysis done with data of more countries, similar analysis should be conducted for other countries.

ii. In the part of telephony market analysis, it is noted that the ratio of double-subscribers are so difficult to capture that we can only facilitate the result of annual investigation. However, with the subscription rate reported monthly, double-subscriber ratio should also be collected on a monthly base if possible.

iii. The personal computer market is expected to reveal similar characteristics of diffusion and substitution. However, unlike services that users have to subscribe to, personal computers are hardware that consumers buy and go. It is more difficult to keep track in the real possession rate of personal computer rate. Similar analysis should be conducted with sufficient data of personal computers if possible.

iv. Based on the result of personal computers diffusion analysis, the correlation between personal computers penetration rate and the Internet access penetration rate can be analyzed to decompose their interaction, including the restriction that personal computers possession rate might have on the Internet access rate and the contribution that the Internet access might have on personal computers purchasing.

v. Finally, the whole ICT market including the service section and the hardware section can be analyzed from a comprehensive level. It is expected that the ICT policies can be made from a more comprehensive view with such analysis conducted well.

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**Chaojung Chen** is a Ph. D. candidate at the Dept. of Industrial Engineering and Management, Graduate School of Decision Science and Technology at Tokyo Institute of Technology She received her ME from the same Department and a Bachelors degree in Mathematics from National Taiwan Normal University.

**Chihiro Watanabe** is a professor of the Dept. of Industrial Engineering and Management, Graduate School of Decision Science and Technology at Tokyo Institute of Technology. He is also Senior Advisor to the Director on Technology at the International Institute for Applied Systems Analysis (IIASA). He graduated from Tokyo University with BE (Urban Planning) and received a Ph.D. (Arts and Sciences) from the same university.