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An Analysis of Demand-based Factors for Broadband Migration

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This paper explores the factors that influence the users' decision to migrate from narrow-band to broadband services. Data used were obtained from web questionnaire surveys in Japan and the annual Internet User Profile Survey of the National Electronics and Computer Technology Center (NECTEC) in Thailand. The economic, technological and demographic factors were analyzed by using a mixed logit model. The results suggest that price, as a proxy for economic factor, is an important factor in a developing country. In Thai case, lowering the price of broadband services to 50% would increase the probability of the users migrating to broadband by more than 5%. Demographic factors including income, location, and internet experience also contribute to the decision, but their impacts are smaller than that of price. Contrary to previous studies, speed is not a statistically significant factor.

Keywords: broadband, choice probability, mixed logit model, discrete choice model
JEL Classification: C25, D12, L63

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Introduction

Information and Communication Technology (ICT) has become a powerful tool to transform the lives of people and improve the economies of nations by, among others, enhancing workers' productivity, leveraging low-cost manufacturing as well as generating more revenues for firms. The effectiveness of ICT was greatly enhanced by the Internet, especially with the introduction of the broadband internet.

The pace of broadband availability and adoption has drawn the increasing attention of policy makers, as a growing body of evidence shows a strong link between broadband and economic development (Ford and Koutsky, 2005). Building broadband infrastructure and motivating people and businesses to utilize it are the two primary goals of ICT policies of several countries. The Japanese experience has shown that under the "e-Japan Strategy" in the 2000s, infrastructure development was easier to achieve. In less than three years, Japan had achieved its five-year policy goal of expanding broadband coverage to 30 million households by different types of Digital Subscriber Line (DSL) and 10 million households by Fiber to the Home (FTTH). Motivating people to utilize such infrastructure and introducing new lifestyles or business models have been among the top priorities in the e-Japan Strategy.

Although the technical details of ICT infrastructure development are widely available and the costs of equipment and software have been dramatically decreasing, developing nations often find it difficult to achieve a level of broadband migration on a par with developed nations. This may perpetuate the existing digital divide in the narrowband (NB) era and further widen it in the broadband (BB) era, with a serious negative impact on the development of the knowledge-based global society. In recent years, the Thai government has been trying to promote the use of BB internet; however, the penetration rate was still less than 2.5% as of 2008 (National Broadcasting and Telecommunications Commission, 2008a). The number of BB internet subscribers surpassed the 1 million mark only in 2007, three years behind the target date of the Ministry of Information and Communication Technology. The diffusion of BB internet has been the subject of many studies around the world but few have examined Japan and Thailand as case studies (Ida and Kuroda, 2006; Jirachaipravit and Probert, 2007; Tajiri *et al.*, 2006). In addition, the studies have paid more attention to the supply side and related policy recommendation than the demand.

These supply side and policy approaches were made on the premise that technology deployment (supply) translates directly into technology adoption (demand). However, the premise does not seem to hold against the fact that adoption of BB internet is still low despite the widespread availability of broadband. In this regard, we propose a consumer-perspective method to understand how an individual makes decision to adopt the BB internet.

This paper is organized as follows. The background of Japanese and Thai BB markets is discussed in next section, followed by discussion of the conceptual framework and a mixed logit model used to analyze factors affecting the decision to adopt different BB internet services. The subsequent sections include data, results, and conclusion.

Background

The International Telecommunications Union (ITU) has conducted comprehensive surveys and published reports on how users in various countries use ICT. In 2007 the average BB penetration rate among OECD members was 22%, while that of ASEAN members was as low as 3% (International Telecommunications Union, 2008). Compared to Japan's BB penetration rate of 22.10%, Thailand's was only 1.43% as of 2007. These numbers represent a big difference in BB penetration rates between developed and developing countries. A look at the penetration rates by year in both countries (Table 1) reveals that the disparity was also widening.

Table 1 Broadband subscribers' penetration rates in Japan and Thailand, 2000-2007

Year	Japan	Thailand
2000	0.67	0
2001	3.01	0
2002	7.37	0.02
2003	11.68	0.07
2004	15.29	0.12
2005	18.18	0.16
2006	20.62	0.16
2007	22.1	1.43

Source: International Telecommunications Union (2008)

According to the Ministry of Internal Affairs and Communication of Japan, the number of BB subscribers overtook that of NB subscribers in December 2004. In Thailand, it was not until the end of 2007 that the number of BB subscribers surpassed that of NB internet subscribers (National Broadcasting and Telecommunications Commission, 2008b).

In Japan's internet services market, Nippon Telegraph and Telephone Corporation (NTT)[1] had long enjoyed a monopolistic position as a provider of access line to home users. It provided Integrated Services Digital Network (ISDN) services and was reluctant to develop a DSL offering. Instead it invested in FTTH services which were believed to be the future of BB services. The turning point of DSL service started in December 2000 when the company was required to unbundle its copper-to-the-home lines. Softbank Group took advantage of the unbundling rule to launch a new low-price DSL offering in September 2001, and was a huge success. During that time, NTT continued to invest in its FTTH infrastructure and services. FTTH market started to gain momentum in 2004, while Asymmetric Digital Subscriber Line (ADSL) and Cable Television (CATV) internet market shares have decreased. By June 2008, the number of FTTH subscribers had surpassed that of ADSL subscribers. As of 2007, Yahoo BB (Softbank Group's DSL services) was the market leader in the DSL market and Open Computer Network (OCN), a subsidiary of NTT, in the FTTH service.

In Thailand, there are two types of internet service providers, the two incumbents, TOT Public Company Limited (TOT)[2] and CAT Telecom Public Company Limited (CAT)[3] and the concessionaires. The concessionaires are required to build the facilities and transfer these to the incumbents in exchange for a certain period of time to provide services to customers. The concessionaires have to share some revenues with the incumbents. This situation is different from the case of NTT in Japan where NTT builds and owns all infrastructures. Examples of concessionaires in Thailand are True Corporation, which operates in Bangkok and vicinity area, and TT&T, which provides the internet services in provincial

[1] NTT was previously a state-owned most dominant telecommunications company that provides telecommunications services, both fixed lines and mobile, all over Japan including remote rural areas.

[2] TOT is a Thai state-owned telecommunications company, which main line of business is fixed line telephony, but it also has several other businesses, including mobile telephony and internet services.

[3] CAT is the other state-owned company that provides Thailand's international telecommunications infrastructure, including its international gateways, satellite, and submarine cable network connections.

areas. Both are granted a concession from TOT. As of December 2007, True Corporation was the market leader in ADSL services with a 43.30% market share. It also provides cable modem services to users subscribing to their cable TV systems, but the number of subscribers was still small. In recent years, the market share of TOT's ADSL services has been increasing most likely because of its price-cutting strategy and faster speed.

Concept

Economic, technological and demographic factors are the three main constructs presented as potential factors influencing an individual's decision to adopt BB, as illustrated in Figure 1.

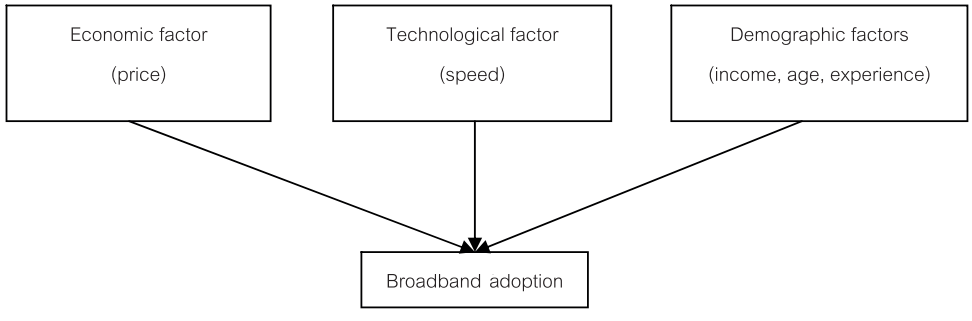

Figure 1 Conceptual framework

Price is arguably one of the most significant factors that affects BB diffusion. García-Murillo (2005) found that fixed BB price has been an influential factor in fixed BB adoption. Using data from a sample of US households, Rappoport *et al.* (2001) conclude that price elasticity of demand for BB service is much higher than NB service. Ida and Kuroda (2006) performed a discrete choice model analysis on Japan's BB market and concluded that ADSL is price inelastic while FTTH and CATV are price elastic.

Savage and Waldman (2004) examined factors influencing a household's willingness to pay for BB service and conclude that the most important attribute leading to adoption of BB in the U.S. is the reliability of the service. They also found that speed and the ability to conduct file sharing increase the rate of adoption. Lee and Brown (2008) show

that platform competition, BB speed, information and communication technology use, and content contribute to global BB adoption. Lee and Chan-Olmsted (2004) suggest that the differences between South Korea and the U.S. in the development of their BB internet could be explained by a combination of policy, consumer demand, and the supporting or related technological factors.

Using a discrete choice model, Madden and Simpson (1997) found that education, region of origin, and age are significant factors in BB subscription decision of Australian households. Clements and Abramowitz (2006) found that income, age, education, and the presence of children have an impact on BB adoption services in the U.S. A more recent survey of U.S. households by Horrigan (2008) indicates that younger age, higher education and income, and urban living share of population may lead to a higher level of BB adoption. Using path analysis to examine factors that cause BB internet service adoption, LaRose *et al.* (2007) show that prior experience with the internet, the expected outcomes of BB usage, direct personal experience with BB, and self-efficacy have direct effects on BB intentions in rural U.S. communities.

Model

To understand the relationships between BB adoption and its influential factors, the mixed logit model is adopted. It overcomes the limitations of a more restricted model, such as the conditional logit model, which assumes Independent and Identical Distribution (IID) of random terms. The Independence from Irrelevant Alternatives (IIA) property, which is derived from the IID assumption, states that the ratio of the choice probabilities of any pair of alternatives is independent of the presence or absence of any other alternative in a choice set. To test the appropriateness of the IIA assumption, Hausman and McFadden (1984) propose the Hausman test to verify whether the conditional logit model is an appropriate model. Since the conditional logit model assumes the IIA property that is too strict when dealing with a more general pattern of discrete choices, the mixed logit model is introduced to alleviate this problem by allowing for random taste variation, unrestricted substitution patterns, and correlation in unobserved factors over time (McFadden and Train, 2000).

A mixed logit model is based on random utility theory (McFadden, 1974). The random utility function *(U)* is composed of the deterministic part *(V)* and the random components (ε). In this study, mixed logit model is adopted since it is natural to assume that an evaluation of choosing internet access method is not the same among individuals. The mixed logit model captures variations of preferences by introducing stochastic terms into the coefficients created by deviations from the mean preferences. The mixed logit model allows these coefficients to be correlated with each other across attributes.

Consider the utility function expressed as $U_{ij} = \beta'_i V_{ij} + \varepsilon_{ij}$ where U_{ij} represents the utility that individual *i* obtains from choosing an alternative *j*, and V_{ij} is a vector of variables as a set of attributes when individual *i* chooses alternative *j*. As the distribution of β_i is unknown, it is common to estimate the parameters of the distribution by assuming parametric probability distribution function. The coefficients vector β_i is allowed to be distributed normally across the population with mean vector *b* and variance covariance matrix .

Individual *i* will choose alternative *j* if and only if $U_{ij} > U_{ik}$ for any $j \neq k$. With the mixed logit model, we assume distributed as independent and identical extreme value distribution, and the probability of individual *i* choosing alternative *j* that is facing β_i can be described as:

$$L_{ij}(\beta_i) = \frac{e^{\beta'_i V_{ij}}}{\sum_k e^{\beta'_i V_{ik}}} \tag{1}$$

As β_i is unknown, let the distribution function of β_i be $f(\beta)$; thus, the probability of individual *i* choosing alternative *j* out of *J* alternatives is:

$$P_{ij} = \int \frac{exp(U,(\beta_{ij},V_j))}{\sum_{j=1}^{j} exp(U,(\beta_{ij},V_j))} f(\beta) d(\beta) \tag{2}$$

In this study, it is assumed that an individual will adopt a particular internet service if the utility of the chosen one is more than the rest of the choices. The utility function of internet access user is specified as follows:

$$\begin{aligned} U_{ij} &= \alpha_j + (\beta_1 + \beta_2 * D) * price_i + (\beta_3 + \beta_4 * D) * speed_i + (\beta_5 + \beta_6 * D) * income_i \\ &+ \beta_{7_j} * location_i + \beta_{8_j} * internet\_experience_i + \beta_{9_j} * age_i + \varepsilon_{ij} \end{aligned} \tag{3}$$

where U_{ij} is the utility of individual i choosing internet access service j . $\alpha_{j|}$ is a constant term of internet access service j where j = 1 if dial-up (DU), j = 2 if ISDN, j = 3 if BB, j = 4 if others. β's are estimated parameters. D is a country dummy variable where D = 1 if Japan, and D = 0 if Thailand to allow different effects of variables on internet access service adoption between Japan and Thailand.

If β_2 , β_4 , or β_6 is statistically different from 0, the effect of those respective variables on each country is different.

In this study, the explained variables will be choices of different internet access service that an individual can choose. The internet services in Japan and Thailand are different so that we had to make the analyses comparable by classifying the various internet access services into four categories: DU, ISDN, BB, and others. In Japan, BB includes ADSL, FTTH, and CATV services, while "others" include mobile and other services. On the other hand, in Thailand, BB includes ADSL and CATV services, while "others" are the rest of the services such as wireless and mobile services.

As discussed above, price is one of the most important factors influencing BB internet adoption. In this model, price is set as a proxy of economic factor. Price variable is the actual charge that an individual pays every month for a particular internet service. The purchasing power parity (PPP) method is used to make the data from Japan and Thailand comparable. Speed is assumed as proxy of technological factor, and described by the actual speed of DU and ISDN choices. Since BB and others are created as two new alternatives from the actual services, the average speed is used as a surrogate speed for those services in each category. Speed was measured by the internet download speed in kilobit per second.

Income, location, internet experience, and age are the demographic factors hypothesized to influence the migration from NB to BB service. Annual individual income is used in the model, and the PPP method is applied to data in both countries. Location is a dummy variable in which 1 means an individual lives in a rural area and 0 otherwise. Internet experience is measured by the number of months an individual had been using internet. In this analysis, "other" alternative is the base case to measure the influences of the explanatory variables on probability of internet service adoption, compared

to other alternatives. It is assumed that price and speed are random variables with normal distribution, while the rest of explanatory variables are non-random. Based on this specification, the expected signs of explanatory variables are summarized in Table 2.

Table 2 Expected signs of explanatory variables

Variables	Estimated parameters	Signs
Price	β_1 and $\beta_1 + \beta_2$	-
Speed	β_3 and $\beta_3 + \beta_4$	+
Income	β_5 and $\beta_5 + \beta_6$	+
Location	β_{7j}	-
Internet experience	β_{8j}	+
Age	β_{9j}	-

Data

The data were obtained from the web surveys on individual use of internet access services through collaboration between Waseda Institute for Digital Society in Japan and NECTEC in Thailand. The survey was based from the NECTEC's annual Internet User Survey including users' characteristics and internet usage behaviors. The questionnaire survey in Thailand was posted on several popular websites, and internet users were requested to fill in the survey. The total sample size was 28,545. In Japan, the data were collected and randomly selected from the pre-registered consumer panels in July 2007 through an online questionnaire. The number of valid responses was 912.

Result and Discussion

Table 3 describes demographic results of the samples from Japanese and Thailand surveys. There are more female than male respondents from both surveys while the female/male ratios are similar. However, the age distributions are different; from the Thailand data, teenagers represent about 23% of the total sample while only 2.20% of the same age group participated in this survey in Japan. More than half of the respondents from both countries are working full-time, and most of them have a college degree or higher.

Table 3 Demographics of samples

Demographic factor	Japan (912 samples) (%)	Thailand (28,545 samples) (%)
Gender		
Male	48.79	42.83
Female	51.21	57.17
Age		
15-19	2.20	23.15
20-29	21.20	38.56
30-39	38.30	22.27
40-49	25.40	11.20
50-59	9.40	4.19
60 and more	0.75	0.63
Occupation		
Full-time job	50.80	52.14
Part-time job	9.80	12.66
Student	15.70	24.67
Housewife/Unemployed	23.80	10.53
Education		
Below high school	6.00	8.90
High school	27.40	11.71
College	23.40	12.55
Undergraduate	42.30	52.76
Above undergraduate	1.00	14.03

Table 4 and Table 5 present the distribution of users accessing different internet categories. All but 4% of the respondents use BB internet in Japan. The percentages of ADSL and FTTH are similar at about 40%. In Thailand, about 28% of the respondents used NB internet such as DU and ISDN. This figure shows a big difference between the distributions of internet users in Japan and Thailand. It also reflects the difference in the internet speeds provided in both countries. For example, the speed of ADSL services in Thailand is up to 10 Mbps, while Japan's is up to 40 Mbps. In addition, Japan has FTTH service, which has a speed up to 100 Mbps. [4]

[4] At the time of the study, Thailand did not have FTTH service. It was introduced in 2010.

Table 4 Internet Access Method in Japan, 2007

Types of Internet	Ratio (%)
FTTH	40.17
ADSL	41.25
CATV	12.79
WiFi	1.09
Mobile	1.09
ISDN	1.93
Dial-up	1.70
Total	100.00

Table 5 Internet Access Method in Thailand, 2007

Types of Internet	Ratio (%)
ADSL	62.15
Cable Modem	3.08
Satellite	3.38
Mobile	4.65
ISDN	2.56
Dial-up	24.18
Total	100.00

From Table 6, although the expenditure for internet access in Thailand is nearly the same as that of Japan, a closer look at the disposable incomes between the two countries shows that Japan's is more than triple Thailand's average income. Based on the ratio of expenditure on internet access and their disposable income (A/B), respondents in Thailand pay over three times more than those in Japan for internet access. The survey also indicates that Japanese respondents are more familiar with both internet and BB internet than Thai users. Japanese respondents had been using internet and BB internet for 92 months and 54 months on average, respectively, while in Thailand, the numbers were 53 months and 18 months. This means that the Thai users started to experience internet during the same time the Japanese users started using BB internet. In addition, the average internet speed in Japan was much faster than in Thailand.

Table 6 Average expenditure on internet access, income, internet experience, and speed in Thailand and Japan, 2007

Variables	Japan	Thailand
Expenditure on Internet Access* (A)	US$48.83 (JPY4,766)	US$50.15 (THB1,807)
Income* (B)	US$4240 (JPY413,870)	US$1,318.54 (THB47,504)
A/B	1.15%	3.80%
Internet Experience	92 months	53 months
BB Experience	54 months	18 months
Speed (Mpbs)	32.67	0.82

Note: * Using exchange rate as of October 24, 2009

The questionnaire surveys also show the reasons why internet users continue using NB internet. The ranking of reasons are BB is too expensive, BB is unnecessary, no information available for BB services, no services available, and BB is difficult to use. This suggests that NB internet users from both countries are price-conscious and think that BB internet connections are not necessary for them. These users primarily use applications that need low-bandwidth, like web access or email. Also in Thailand, users of the TOT NB services pay as low as 3 baht for two-hour use.

In the mixed logit model estimation for each individual, all the attributes except price of the internet were defined to be normally distributed. The model was estimated with simulated maximum likelihood with Halton draws using 500 replications (Train, 2003). Table 7 shows the estimation results from a software package NLOGIT 4.0.[5] Considering the sign, most estimates are as expected. Price is statistically significant at 1% level, which implies that price is an influential factor for BB migration. Similar results are found in previous studies that if the price of internet services was lower, consumers would more likely adopt that particular service. Income variable is statistically significant at 5% except for the DU case, while speed is statistically insignificant. Location representing rural users is inversely statistically significant at 1% level. Internet experience for DU and BB is positively significant at 5% and 1% level, respectively while negatively significant at 10% level for ISDN. Age is statistically insignificant in all services. In addition, only the country dummy coefficient on price β_2 is statistically significant at 1% level. This suggests that the effects of price on BB adoption in both countries are different. In this case, Japanese users might view price as a proxy for a better internet performance and are willing to pay more for it. This result is similar to previous studies in Japan (Jitsuzumi, 2011) and in the U.S. (Rappoport *et al.*, 2003). Speed, our technological factor proxy, statistically is not a major factor in consumers' decision to migrate from NB to BB service. One possible explanation is a potential correlation between unobserved quality and price; this potential endogeneity problem might overestimate the significance of price in the model thus reducing the significance of speed.

[5] Before employing the mixed logit model estimation, we ran the conditional logit model, which assumes independent and identical distributions (IID) of random terms. However, after running the analysis on the IIA property, the Hausman test suggests that the conditional logit model is not appropriate for this study. Therefore, we employ the more flexible mixed logit model.

Table 7 Results of the mixed logit model estimations

Variables	Coefficients	Standard error	t-value	p-value
Non-random parameters				
constant (DU)	11.126	26.830	0.415	0.678
constant (ISDN)	9.663	23.918	0.404	0.686
constant (BB)	–14.081	34.175	–0.412	0.680
income (β_5) (DU)	–0.066	0.0758	–0.877	0.381
income (β_6) (DU)	–0.331	0.403	–0.822	0.411
location (DU)	–0.615	0.138	–4.441	0.000***
internet_experience (DU)	0.164	0.080	2.050	0.040**
age (DU)	–0.040	0.031	–1.304	0.192
income (β_5) (ISDN)	0.207	0.103	2.017	0.044**
income (β_6) (ISDN)	–0.080	0.529	–0.150	0.881
location (ISDN)	–0.690	0.218	–3.169	0.002***
internet_experience (ISDN)	–0.176	0.106	–1.664	0.096*
age (ISDN)	–0.106	0.037	–2.889	0.004***
income (β_5) (BB)	0.586	0.073	8.045	0.000***
income (β_6) (BB)	–0.261	0.352	–0.742	0.458
location (BB)	–0.627	0.130	–4.814	0.000***
internet_experience (BB)	0.544	0.077	7.044	0.000***
age (BB)	–0.015	0.030	–0.513	0.608
Random parameters				
price (β_1)				
Mean	–1.190	0.023	–5.671	0.000***
S.D.	0.008	0.031	0.270	0.787
price (β_2)				
Mean	1.427	0.490	2.914	0.004***
S.D.	0.128	0.651	0.197	0.844
speed (β_3)				
Mean	8.085	21.946	0.368	0.713
S.D.	0.525	0.030	17.600	0.000***
speed (β_4)				
Mean	–4.040	12.753	–0.317	0.751
S.D.	0.506	0.292	1.733	0.083*

Table 7 (Continued)

Number of samples	16258
Maximum log likelihood	–6179
McFadden R^2	0.726

Note: * ** *** are statistically significant at 10%, 5%, and 1%, respectively.

Income, location, and internet experience influence the decision to shift to BB services. A person with higher income tends to adopt internet services more as well as choose BB over DU or ISDN. However, the estimate of β_6 is not statistically significant, which suggests that the income factor makes no difference on BB adoption in both countries. The estimates of location variables imply that an individual in a rural area tends to choose DU services over ISDN or BB services. The results also suggest that an individual who has more internet experience tends to choose BB over DU or ISDN.

The effects of factors included in BB model on choice probability are analyzed by focusing on the variables that are statistically significant, i.e. price, income, and internet experience. A simulation by establishing different levels of the factors mentioned above provides the probability of choosing different internet services. Since more than 96% of Japanese users already use BB internet, a simulation for the effects of the different factors would yield marginal information; thus, the Japanese result was omitted. The simulation results from Thailand data are shown in Table 8 to Table 10. By lowering the price of BB services to 50%, the choice probability of BB increases by more than 5%. The simulation results for demographic factors such as income and internet experience increase the choice probability of BB by 2% and 3%, respectively. These simulation results might be relevant for formulating a policy aimed to increase the penetration of BB internet. Based on our study, lowering the BB price would affect the BB adoption more than other policies.

Table 8 Simulation of choice probability on internet services based on price, Thailand

BB Price (% decrease)	DU	ISDN	BB	Others
10	–0.63%	–0.13%	0.98%	–0.21%
20	–1.29%	–0.28%	2.00%	–0.43%
30	–1.98%	–0.42%	3.06%	–0.66%
40	–2.70%	–0.58%	4.17%	–0.89%
50	–3.44%	–0.74%	5.33%	–1.14%

Table 9 Simulation of choice probability on internet services based on income, Thailand

Income (% increase)	DU	ISDN	BB	Others
10	–0.33%	–0.03%	0.45%	–0.09%
20	–0.62%	–0.06%	0.85%	–0.18%
30	–0.88%	–0.08%	1.21%	–0.25%
40	–1.11%	–0.11%	1.54%	–0.32%
50	–1.32%	–0.13%	1.83%	–0.38%

Table 10 Simulation of choice probability on internet services based on internet experience, Thailand

Internet Experience (year increase)	DU	ISDN	BB	Others
1	–0.49%	–0.30%	1.08%	–0.30%
2	–0.82%	–0.45%	1.75%	–0.47%
3	–1.09%	–0.56%	2.26%	–0.61%
4	–1.31%	–0.64%	2.67%	–0.71%
5	–1.50%	–0.71%	3.01%	–0.80%

Conclusion

This paper investigates the influence of economic, technological and demographic on the decision to adopt a BB service. The data used were from web questionnaire surveys collected in Japan and Thailand. The results suggest that price, a proxy for economic factor, has an important influence on the decision to migrate to BB, especially in a developing country like Thailand. Demographic factors such as income, location, and internet experience also contribute to the BB migration decision, but their influence is smaller than that of the price factor. These findings suggest that governments could increase BB penetration by lowering the price of BB services. One way to do so is to promote more commercial internet service providers. As the number of providers increases, the resulting market competition should decrease the price.

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