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How Smartphones Transformed Market and Competition of Mobile Broadband in OECD Member Countries

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How Smartphones Transformed Market and Competition of Mobile Broadband in OECD Member Countries.

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Abstract

Smartphones such as iPhones and Android was introduced to the market around 2007-9 in various OECD member countries. Since then, the transformation of the market was observed, which include (i) rapid growth of mobile broadband (3G+4G); (ii) severer market competition; and (iii) upheaval of market share of mobile carriers. More concretely, 34 OECD countries show the following: (i) the average diffusion rate of mobile broadband in 2008 was about 40%, whereas in 2012 it increased up to 80%; (ii) HHI also reduced in all countries; and (iii) it is common to countries that the carriers which introduced iPhones raised their market shares, whereas those which did not introduce lowered shares. This paper examines the above three transformations in 34 OECD countries by panel data analysis from 2000 to 2012 to identify factors of rapid growth of mobile broadband and market competition. In so doing, the paper estimates the mobile broadband adoption ratio by the following variables: monthly charge of voice services; monthly Data rate; download speed; HHI; GDP per capita; FTTH adoption ratio; the launches of Androids and iPhones; and other policy variables such as Frequency auction and MNP. By using the instrumental variables method, the results obtained are summarized as follows: (1) Price (Voice) is negatively significant; (2) Price (Data)/Speed is not significant; (3) Income is positively significant; (4) HHI is negatively significant; and the followings are positively significant; (5) FTTH adoption ratio; and (6) Launches of smartphones. The results of the analysis also use for discussing the above transformations such as (ii) and (iii).

Keywords: Mobile broadband, Panel data analysis, Smartphone, iPhone, Android, Backhaul

1. Introduction

Broadband systems can be divided into (1) fixed broadband such as FTTH (fiber to the home, i.e., fiber optic subscriber line), DSL (digital subscriber line, i.e., metal wire subscriber line), cable modem (coaxial subscriber line based on CATV networks) and (2) mobile broadband based on wireless technology. Fixed broadband is capable of achieving ultra-high speeds above 100 Mbps (especially in the case of FTTH) in the Gbps range. Meanwhile, although mobile broadband, represented by third generation (3G) and the next generation 4G (LTE) cellular network technology, had been slower than fixed broadband, recent advances in technology have increased data transfer speeds to between 100 and 150 Mbps. From the standpoint of technological neutrality, there is no distinction between fixed and mobile broadband and, instead, seek widespread access to high-speed broadband, in whatever form, for their citizens. However, given the greater mobility and ubiquitous nature of mobile broadband compared to fixed broadband, there is potential for mobile broadband to replace fixed broadband in the future.

The objective of this paper is to examine how the introduction of mobile broadband such as Android smartphones and iPhones contribute to the diffusion of mobile broadband and transformation of the market, that is, smartphones promote (i) rapid growth of mobile broadband (3G+4G), (ii) market competition severer, and (iii) changes in the market share of mobile carriers. In so doing, it is useful to first examine the background of factors contributing to the adoption of mobile broadband from the standpoint of both demand and supply. The use of smartphones spread rapidly starting in 2007 as a result of the deployment of 3G networks that enabled speeds in the several hundred kbps to the Mbps range (Takada and Fujita, 2013). Underlying the adoption of smartphones were the following factors: Smartphones are extremely small, yet are able to perform some of the same functions as a PC, such as viewing general-purpose websites, and can be used for tethering. Furthermore, unlike Japanese NTT Docomo's *i-mode*, the devices are not tied to a certain cellphone carriers and can also be accessed by any cellphone carrier. It is also necessary to pay attention to the key difference between Android phones and iPhones, which are the most common smartphones. Whereas the former devices are based on an

open source operating system (OS), the latter devices are based on Apple Inc.'s proprietary operating system. This fundamental difference in the nature of smartphone devices has brought about fierce competition for customers that is believed to have had an impact on the overall adoption of mobile broadband.

Next, with regard to the supply side, the adoption of fixed telephone service was realized through massive investment in infrastructure across a country over the course of nearly a century. DSL makes use of these metal wire subscriber lines. Cable modems utilize coaxial subscriber lines laid by cable television companies for the purpose of broadcasting cable television. The currently mainstream FTTH, which enables ultra-high access speeds in the Gbps range, requires the installation of new fiber optic subscriber lines. The authors identified the following as factors contributing to the adoption of these fixed broadband technologies in the 34 OECD member countries: (1) the extent of CATV adoption in 2000 when cable modem broadband was first introduced (i.e. initial condition); (2) the opening of metal wire subscriber lines for DSL and policies such as unbundling to encourage competition, which resulted in increased competition among DSL providers; and (3) in the case of FTTH, the business decisions of telecommunications companies that have undertaken capital investment in installing fiber optic cable (Shinohara, Akematsu, and Tsuji, 2012).

Meanwhile, the mobile broadband devices utilize wireless signals with coverage areas ranging between several hundred meters to 10 km, one of the challenges is securing frequencies for wireless. For example, frequency auctions directly impact a provider's ability to compete (Baquero and Kuroda, 2011). In addition, although mobile broadband does not require the installation of subscriber lines as in the case of fixed broadband, it does require the establishment of base stations and related facilities. In the case of Japan, for example, each cell phone carrier will need to construct up to 200,000 base stations throughout the country not only in urban areas but in sparsely populated areas as well. Furthermore, it is necessary to install fiber optic cable to connect these networks of base stations (i.e. wireless backhaul). In other words, in terms of infrastructure, excluding the wireless connection between mobile devices and base stations, it is exactly the same as for

fixed broadband. With regard to such wireless backhaul networks, it is possible to pay for and use fiber optic cable networks installed by other telecommunications companies. In a country such as Japan, where the adoption of FTTH is advanced, this has not surfaced as a major issue because of the availability of fiber optical cable laid by NTT East/West and other regional telecommunications companies established by power companies. However, for cell phone carriers overall, in countries where the adoption of FTTH is lagging, the enormous cost and time associated with creating a national wireless backhaul network is an obstacle for the adoption of mobile broadband (Clarke, 2013; Crandall, Crandall and Allan, 2013). The above are the key points to consider in analyzing the supply side of mobile broadband.

Based on the above discussion, this paper seeks how smartphones promote the adoption of mobile broadband and transformation of the mobile market by examining the cases mainly in three top and three bottom countries among the 34 OECD members. This paper shows useful policies related to the adoption of mobile broadband not only in other OECD countries but also in developing countries in which the adoption of mobile broadband is still in the early stages.

2. Literature review

Early studies on mobile phones focused on verification of the substitutability of fixed phones and mobile phones rather than identifying factors contributing to adoption. For example, Ahn and Lee (1999) demonstrated the complementary nature of fixed and mobile phones based on cross-sectional data from 64 ITU member countries. In contrast, Madden and Coble-Neal (2004) utilized dynamic panel data for ITU countries from 1994 to 2000 to demonstrate the substitutability of fixed and mobile phones. Examples of studies focusing on factors related to the adoption of mobile phones include Gruber (2001), which analyzed non-linear dynamic panel data for 15 European countries from 1984 to 1997, Balamoune-Lutz (2003), which identified geographical factors and income levels as contributing factors, Rouvinen (2006), which found income level to be the only contributing factor, Kamssu (2005), which also took into consideration socio-cultural attributes and internet and

telecommunications use, Kshertri and Cheung (2002) and Minges (1999), which focused on countries' industrial structures and availability of mobile phones. With regard to mobile phones in Asia, Kim (2005) identified video phone capability, international roaming, and mobile internet connection as factors contributing to the adoption of the IMT-2000 mobile phone in Korea.

The first empirical study on Japan's mobile phone market was Iimi (2005), which identified (1) fee, (2) differentiated services, and (3) network externalities as factors contributing to the adoption of 2G services using a nested logit model. An example of a study after the introduction of 3G networks is Ida and Kuroda (2009), which measured the substitutability of 2G and 3G services using a mixed logit model and found that (1) although NTT Docomo's 3G was substitutable for 2G, this was not the case for other cell phone carriers and concluded that (2) there was no difference in the price elasticity for 2G and 3G services. In addition, Nakamura (2010) investigated mobile number portability (MNP) and mobile address portability (MAP). Based on two-sided market theory, Kuroda (2010) found that the introduction of MNP led to an increase in content number and that increased user utility.

Few studies have attempted to identify factors contributing to the adoption of smartphones, which are the focus of this paper, using statistical methods. Gerpott, Thomas and Weichert (2013) analyzed the characteristics and frequency of mobile internet use by German consumers owning advanced mobile devices including iPhones and Android phones in 2011. Gerpott (2010) used cross-sectional analysis methods to analyze how frequency of mobile internet use impacts demand for SMS and voice services from cell phone carriers using 2008 data from Germany. Yamakawa et al. (2013) investigated the adoption of cell phones in Peru using time series analysis. Examples of studies analyzing panel data include a study by Ward and Zheng (2012) on the substitutability of fixed and mobile phone services in China and studies by Akematsu, Shinohara, and Tsuji (2012) employing standard panel data and dynamic analysis based on the Arellano-Bond estimator, respectively, which identified the launch of the iPhone 3G, music downloads, and introduction of a flat fee structure for data transfer as factors contributing to the adoption of

3G services in Japan from 2001 to 2012. In terms of empirical analysis using micro data on the demand for smartphones, Saito and Yoshida (2013) examined use aimed at protecting youth with regard to television viewing and social media use in 2011 and 2012, while Takada and Fujita (2013) investigated factors related to the demand for mobile data services by smartphone owners in 2012.

Taking the findings of these previous studies into consideration, this paper employs panel data to identify factors contributing to the adoption of mobile broadband in top three and bottom three OECD countries.

3. Transformations initiated by smartphone usage in OECD countries

This section shows the transformations in the mobile market and its relationships with smartphone in the top and bottom three countries are discussed. The transformations discussed here are the growth of penetrations rates, HHI and market shares of mobile carriers.

3.1 Growth of penetrations rates caused by smartphones

Figure 1 shows the change over time in mobile broadband penetration rate of the three countries each with the highest and lowest penetrations rates among OECD countries along with the average penetration rate for all OECD countries. As of the end of 2012, the three countries with the highest penetration rates are Finland (no. 1), Austria (no. 2), and Sweden (no. 3), while the three countries with the lowest penetration rates are Belgium (no. 32), Chile (no. 33), and Mexico (no. 34). As can be seen in Figure 1, mean penetration rate in OECD countries was on the order of 20 to 30% in 2007 and 2008, when iPhones and Androids were first introduced, and increased with time, exceeding 80% by the end of 2012. Especially in the three countries with the highest penetration rates, penetration began to accelerate after reaching 20 to 30% in the period around 2006 to 2007, exceeding 100% in each country by 2011. With respect to the three countries with the lowest penetration rates, penetration rate in Mexico remains approximately 20% as of the end of 2012. In Belgium and Chile, ranked no. 32 and no. 33, respectively, penetration rate reached 20% around

2010 and has subsequently accelerated, reaching approximately 40 and 60%, respectively, by the end of 2012.

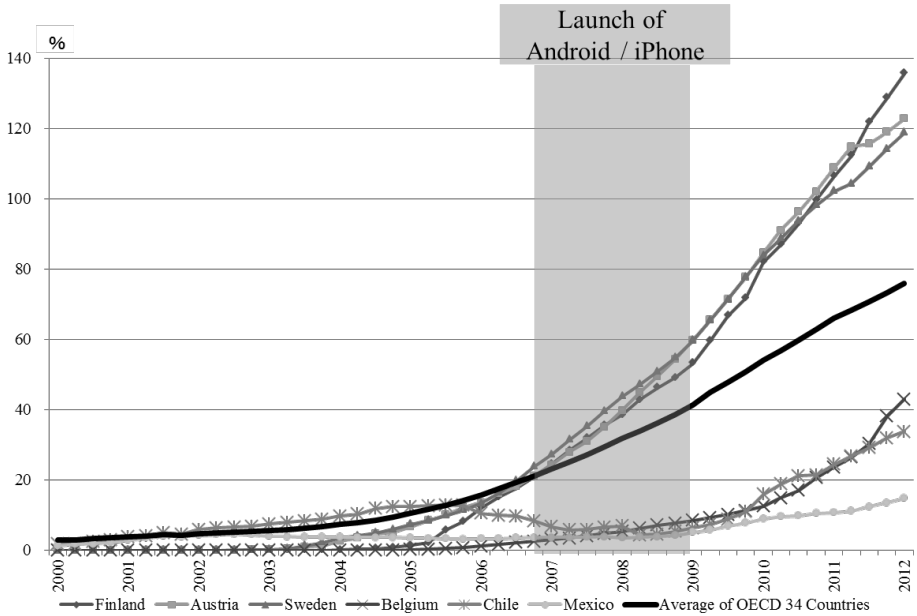


Figure 1 Changes in mobile broadband penetration rate in the top three and bottom three OECD countries in terms of penetration rate (as of the end of 2012).

Note: Top three countries: Finland (no. 1), Austria (no. 2), and Sweden (no. 3).
 Bottom three countries: Belgium (no. 32), Chile (no. 33), and Mexico (no. 34)

Source: Compiled from mobile phone, national regulatory agencies, and international organizations by the author.

3.2 Changes in mobile broadband competition caused by smartphones

The HHI scores for the top and bottom three countries and the mean for all 34 OECD countries are presented in Figure 2. Among smartphones such as iPhones and Android phones that are the focus of this study, the first to be introduced was the iPhone in Q2 of 2007 in the US. In six countries above, iPhones and Android phones were introduced between 2008 and 2009. Around this time, mean HHI in OECD countries ranged between 3900 and 4600. HHI in the three countries with the highest penetration rates ranged between 2600 and 3800, and have subsequently remained static. In contrast, HHI in the three countries with the lowest penetration rates ranged between 4500 and 9300 and,

generally, have since fallen to around 4000

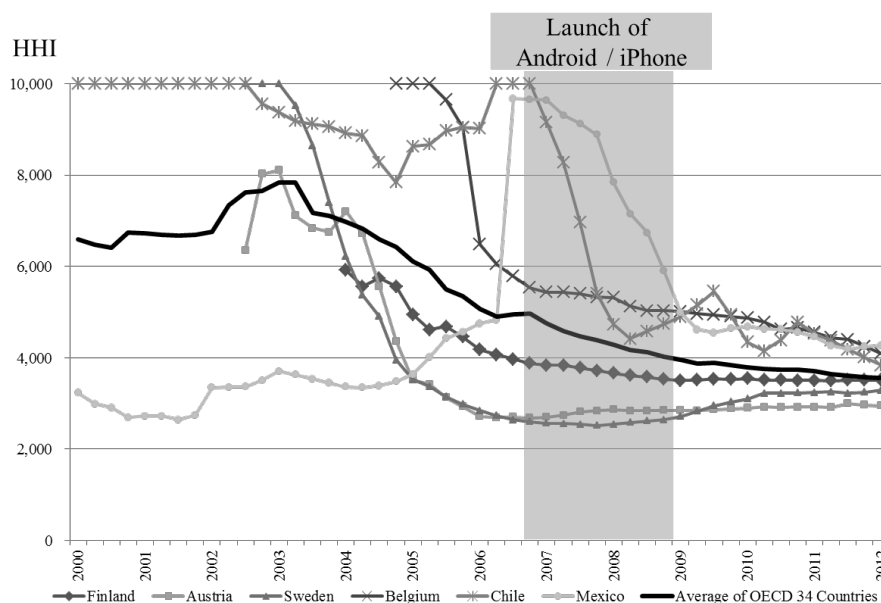


Figure 2 Changes in mobile broadband market HHI for mobile phone carriers in the top three and bottom three OECD countries in terms of penetration rate (as of the end of 2012).

Note: Top three countries: Finland (no. 1), Austria (no. 2), and Sweden (no. 3).

Bottom three countries: Belgium (no. 32), Chile (no. 33), and Mexico (no. 34)

Source: Compiled from mobile phone carriers, national regulatory agencies, and international organizations by the author.

3.3 Transformation of market structure caused by smartphones

In this section, how the introduction of smartphones shifted the market structure of individual mobile carriers, that is, how the timing of smartphones adoption influenced their market shares by examining individual carriers closely.

3.3.1. Top three OECD countries

In this subsection, the individual circumstances and the effect of smartphones introduction on mobile broadband markets will be examined for the three countries with the highest mobile broadband penetration rates as of the end of 2012, i.e. Finland, Austria, and Sweden. It should be noted that the years of Androids' introduction cannot be obtained and we

confine only iPhones in this section. Among these countries, iPhones were initially introduced by a single carrier in Finland and Sweden and by two carriers in Austria. iPhones were introduced into Finland, Austria, and Sweden in Q3 of 2008, Q1 of 2008, and Q3 of 2008, respectively. Android phones were introduced in each country in Q1 of 2009. Below, the market shares of individual mobile phone carriers in each country will be examined at the two points that iPhones were introduced and at the end of 2012.

Finland

As can be seen in Figure 3, in Finland, the country with the highest mobile broadband penetration rate, market shares of the three largest mobile phone carriers—TeliaSonera Finland, Elisa-Finland, and DNA-Finland—at the time iPhones were introduced in Q3 of 2008, were 46, 36, and 19%, respectively. The same figures at the end of 2012 were 38, 40, and 23%. It can be seen that while the market share of DNA-Finland, a late entrant in the mobile broadband market in around 2004 and 2005, has steadily increased, that of TeliaSonera Finland, which was first to introduce iPhones in Q3 of 2008, has reached a plateau after declining substantially.

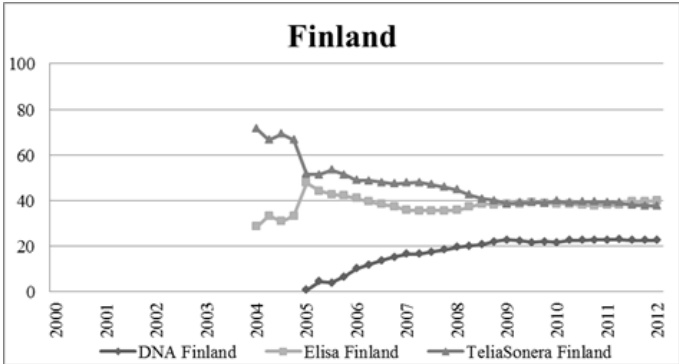


Figure 3 Changes in the market share of individual mobile phone carriers (Finland)

Source: Compiled from mobile phone carriers, national regulatory agencies, and international organizations by the authors.

Austria

As can be seen in Figure 5.2, in Austria, the country with the second highest mobile broadband penetration rate, market shares of the four largest mobile phone carriers,

i.e., mobilkom Austria, Orange Austria, T-Mobile Austria, and Hutchison 3G Austria—at the time iPhones were introduced in Q1 of 2008, were 38, 22, 22, and 18%, respectively. The same figures at the end of 2012 were 39, 17, 31, and 13%. It can be seen that the market shares of mobilkom Austria and T-Mobile Austria, which were first to introduce iPhones in Q1 of 2008, have increased, while those of the remaining two carriers have fallen.

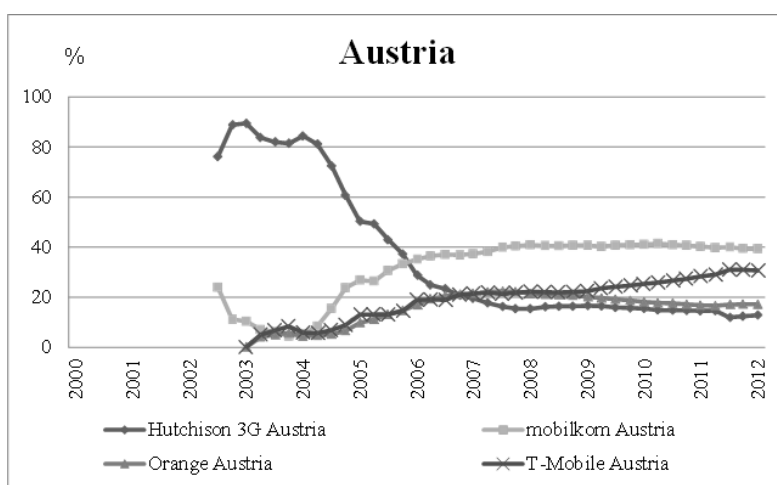


Figure 4 Changes in the market share of individual mobile phone carriers (Austria)

Source: Compiled from mobile phone carriers, national regulatory agencies, and international organizations by the authors.

Sweden

As can be seen in Figure 5, in Sweden, the country with the third highest mobile broadband penetration rate, market shares of the four largest mobile phone carriers—Telenor Sweden, TeliaSonera Sweden, Tele2 Sweden, and HI3G—at the time iPhones were introduced in Q3 of 2008, were 29, 27, 23, and 21%, respectively. The same figures at the end of 2012 were 18, 49, 19, and 13%. It can be seen that market share of TeliaSonera Sweden, which was first to introduce iPhones in Q3 of 2008, has increased dramatically, while those of the remaining carriers have fallen substantially.

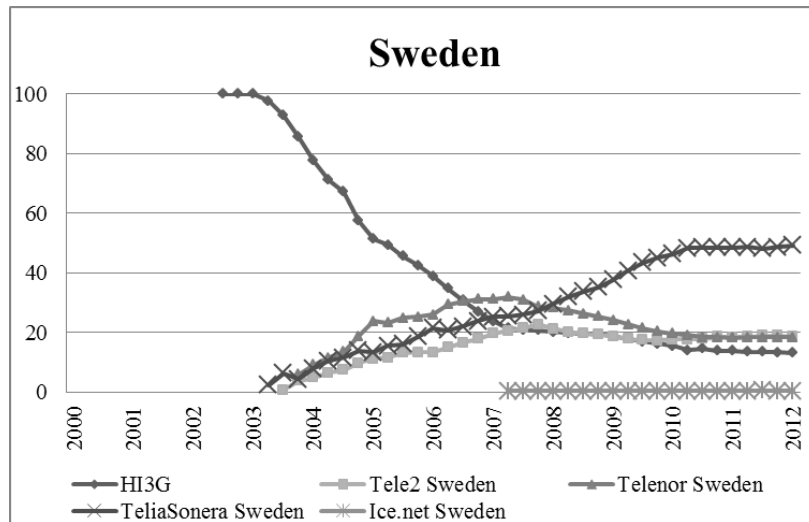


Figure 5 Changes in market share of individual mobile phone carriers (Sweden)

Source: Compiled from mobile phone carriers, national regulatory agencies, and international organizations by the authors.

3.3.2. Countries with the three lowest penetration rates

In this subsection, the effect of iPhone introduction on mobile broadband markets will be examined for the three countries with the lowest mobile broadband penetration rates as of the end of 2012, i.e., Belgium (no. 32), Chile (no. 33), and Mexico (no. 34). Among these countries, iPhones were initially introduced by two carriers in Chile and Belgium and by a single carrier in Mexico.

iPhones were introduced in Chile, Belgium, and Mexico in Q3 of 2008, while Android phones were introduced in Q4 of 2009, Q2 of 2009, and Q4 of 2009, respectively. Below, the market shares of individual mobile phone carriers in each country will be examined at the point that iPhones were introduced and at the end of 2012.

Belgium

As can be seen in Figure 6, in Belgium, the country with the third lowest mobile broadband penetration rate, market shares of the three largest mobile phone carriers--Belgacom Mobile, Mobistar, Clearwire Belgium--at the time iPhones were introduced in Q3 of 2008 were 67, 29, and 4%, respectively. The same figures at the end of 2012 were 46,

42, and 0.3%. Market share of KPN Group Belgium, which entered the market in Q1 of 2009, was 11%. It can be seen that market share of Mobistar, which was first to introduce iPhones in Q3 of 2008, has increased, while those of the two carriers that were in the market in Q3 of 2008 have fallen substantially.

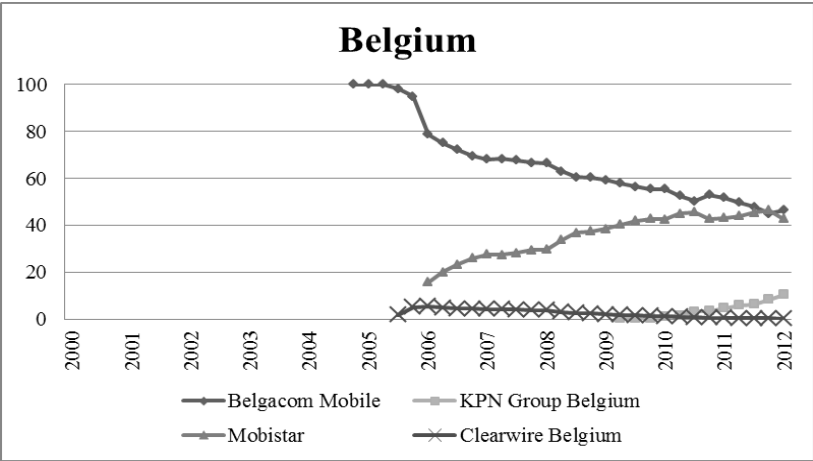


Figure 6 Changes in market share of individual mobile phone carriers (Belgium)

Source: Compiled from mobile phone carriers, national regulatory agencies, and international organizations by the authors.

Chile

As can be seen in Figure 7, in Chile, the country with the second lowest mobile broadband penetration rate, market shares of the three largest mobile phone carriers—Claro Chile, Entel Chile, and Movistar Chile—at the time iPhones were introduced in Q3 of 2008 were 69, 24, and 7%, respectively. The same figures at the end of 2012 were 19, 53, and 25%. It can be seen that market shares of Entel Chile and Movistar Chile, which were first to introduce iPhones in Q3 of 2008, have increased, while that of remaining carrier has fallen dramatically.

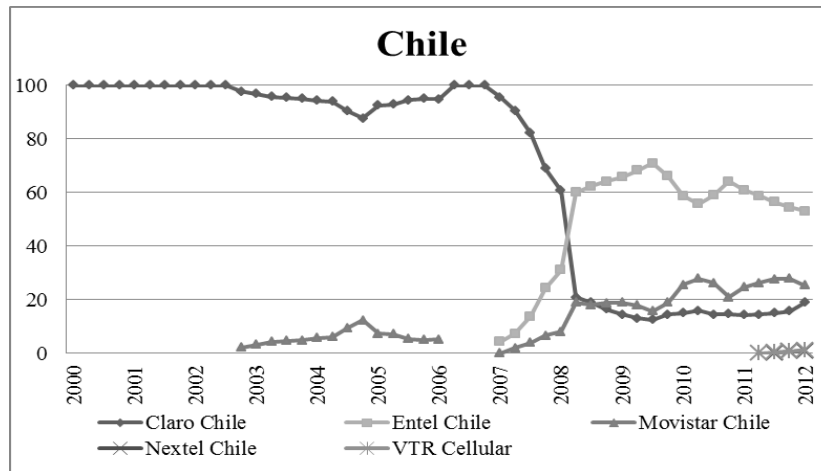


Figure 7 Changes in market share of individual mobile phone carriers (Chile)

Source: Compiled from mobile phone carriers, national regulatory agencies, and international organizations by the authors.

Mexico

As can be seen in Figure 8, in Mexico, the country with the lowest mobile broadband penetration rate, market shares of the four largest mobile phone carriers—Iusacell Celular, Telcel Mexico, Axtel, and Movistar Mexico—at the time iPhones were introduced in Q3 of 2008 were 94, 48, 2, and 0.2%, respectively. The same figures at the end of 2012 were 30, 57, 2, and 11%. It can be seen that market shares of Telcel Mexico and Movistar Mexico, which were first to introduce iPhones in Q3 of 2008, have increased, while those of the two remaining carriers have either fallen or remained static.

3.3.3 US and Japan

In addition to the above top and bottom three countries, it is better to add the situation of other presentative countries in OECD member countries such as the US and Japan.

US

As can be seen in Figure 9, in the US, which is ranked 8th in terms of mobile broadband penetration rate, market shares of the four largest mobile phone carriers--Verizon Wireless, Sprint (including carriers affiliated with Sprint, here and below), AT&T

Mobility USA, and US Cellular--at the point when iPhones were introduced in Q2 of 2007 were 46, 24, 9, and 4%, respectively. The same figures at the end of 2012 were 37, 17, 32, and 2%. Market share of T-Mobile US, which entered the market in Q2 of 2008, was 6%. It can be seen that market share of AT&T Mobility USA, which was first to introduce iPhones in Q2 of 2007, increased dramatically while the shares of the two carriers that initially had higher shares than AT&T Mobility USA declined.

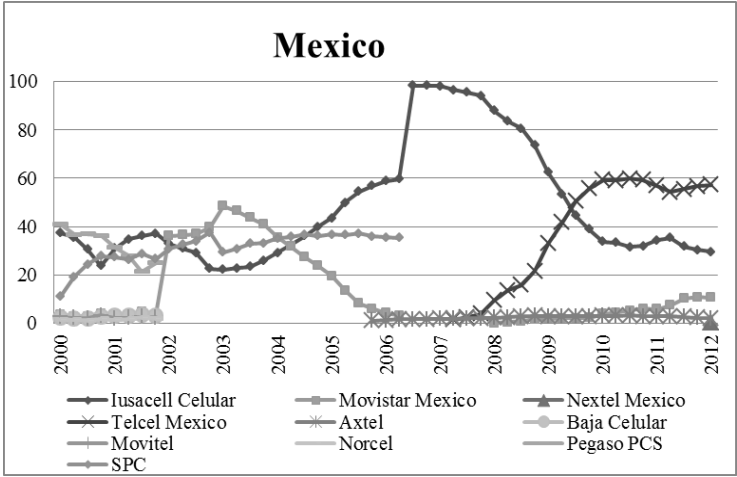


Figure 8 Changes in market share of individual mobile phone carriers (Mexico)

Source: Compiled from mobile phone carriers, national regulatory agencies, and international organizations by the authors.

Japan

As can be seen in Figure 10, in Japan, which is ranked 7th in terms of mobile broadband penetration rate, market shares of the four largest mobile phone carriers—NTT DoCoMo, KDDI, Softbank, and e-Access—at the point when iPhones were introduced in Q3 of 2008 were 49, 32, 17, and 0.9%, respectively. The same figures at the end of 2012 were 46, 28, 24, and 3%. It can be seen that market share of Softbank, which was first to introduce iPhones, increased while the shares of the two carriers that initially had higher shares than Softbank declined.

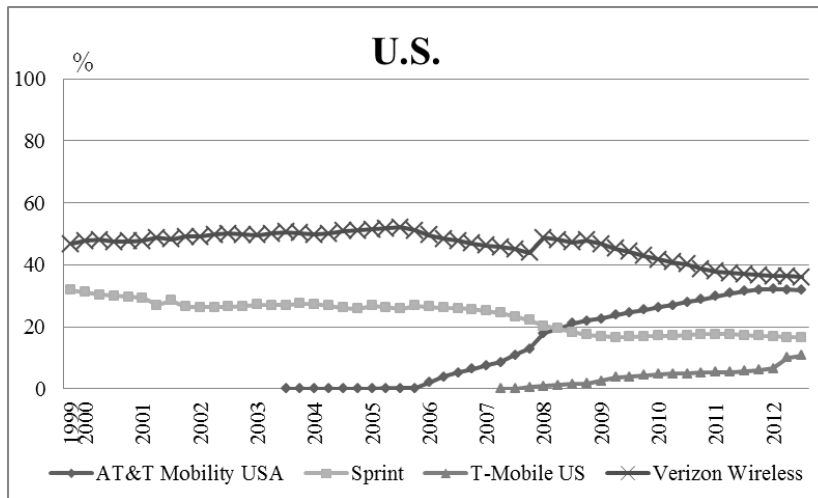


Figure 9. Changes in the market share of individual mobile phone carriers (the US)

Note: Includes only the top four companies in terms of market share as of the end of 2012.

Source: Compiled from mobile phone carriers, national regulatory agencies, and international organizations by the authors.

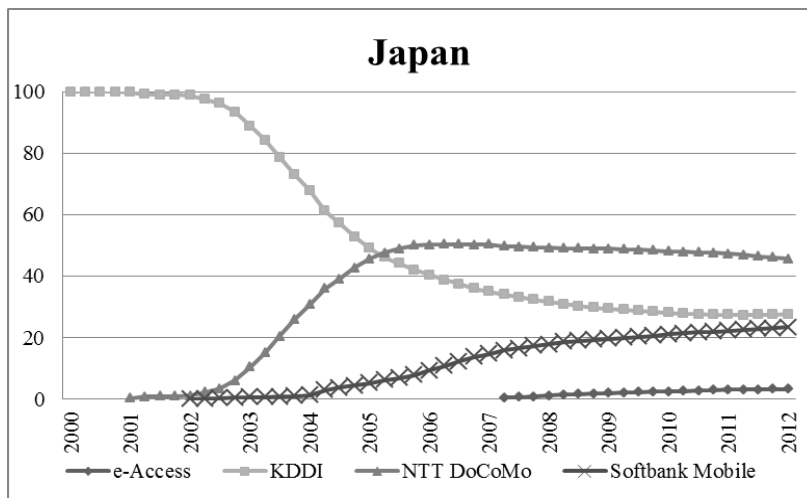


Figure 10. Changes in the market share of individual mobile phone carriers (Japan)

Source: Compiled from mobile phone carriers, national regulatory agencies, and international organizations by the authors.

4. Analysis of factors contributing to adoption

An overview of the empirical analysis using panel data is presented in this section. Based on the authors' previous studies such as Shinohara, Akematsu, and Tsuji (2012), a model which explains the diffusion of the mobile broadband is proposed.

4.1. Methods

The following equation is used to estimate the number of cell phone subscribers.

$$\begin{aligned} Subscriber_{it} = & \alpha_1 Subscriber_{it-1} + \alpha_2 Price(Voice)_{it} \\ & + \alpha_3 Price(Data) / Speed_{it} + \alpha_4 Income_{it} \\ & + \alpha_5 HHI_{it} + \alpha_6 FTTH_{it} + \sum_j \alpha_7^j Factor_{it}^j + \alpha_8 Z \end{aligned}$$

where $Subscriber_{it}$ is the penetration rate of mobile broadband in country i at time t , $Subscriber_{it-1}$ is the penetration rate with one term lag which is aimed at verifying network externalities, $Price(Voice)_{it}$ is the monthly fee for voice services calculated from (Voice ARPU)/MOU, and $Price(Data)_{it}/Speed$ is the monthly fee for data services calculated from (Data ARPU)/Speed in country i . Although it would be ideal for the price variables for a given country to be calculated based on a weighted average of the voice and data fees from all carriers in that country, due to limitations related to data collection, the second best option was chosen to use the voice and data fees for the carrier with the largest market share in each country. Assuming the monthly data fee (Data ARPU) to be fixed, it was divided by connection speed. Prices in the different countries were made comparable by purchasing price parity. $Speed$ is mobile broadband download speed (defined as the highest speed offered by the carrier in a given country with the greatest market share), $Income$ is per capita GDP, HHI is a proxy for the degree of mobile broadband market competition, and $FTTH$ is the penetration rate of fiber optic cable-based fixed broadband. $Factors$ are dummy variables that represent (1) Android availability (0 = no, 1 = yes; the same designations apply to dummy variables (2) to (5)), (2) iPhone availability, (3) Fixed-mobile convergence (FMC), (4) existence of a radio frequency auction, and (5) Mobile number

portability (MNP). It should be noted that (3) *FMC* applies only to carriers that existed during the telecommunications monopoly period. If such a carrier is allowed to provide both fixed and mobile phone services, then the dummy takes a value of 1; otherwise it takes a value of 0. For estimating the number of cell phone subscribers, $Price(Voice)_{it-1}$, $Price(Data)/Speed_{it-1}$, HHI_{it-1} , and $Subscribers_{it-2}$ were used as instrumental variables, which are represented collectively in the equation by Z . Population and GDP data were drawn from data provided by international organizations such as the OECD and the ITU. Other data were drawn from national regulatory agencies, telecommunications companies' websites, and IR documents maintained in the Informa database.

4.2. Estimation results

Descriptive statistics of the quarterly data examined for the estimation period (2000 to 2012) are provided in Table 11. The mean variance inflation factor (VIF) of the explanatory variables was 3.51, and the VIF of individual variables was 6 or less, indicating the absence of multicollinearity.

Table 11. Descriptive Statistics

Variables	No. of Obser.	Mean	Std. Dev.	Max	Min
Mobile Broadband Adoption Ratio (one lag, Log)	249	3.216682	1.540417	4.696976	-4.78088
Price (Voice, Log)	312	-1.823610	0.614531	-0.577300	-3.04236
Price/Speed (Data, Log)	256	0.654528	1.61142	6.083785	-2.50080
Income (GDP/Capita, Log)	312	10.35820	0.230029	10.85863	9.69237
HHI (Log)	249	8.278625	0.361672	9.210340	7.64102
FTTH (Adoption Ratio, Log)	197	0.394302	2.68979	4.192044	-8.28205
Android	312	0.298077	0.458148	1	0
iPhone	312	0.375000	0.484901	1	0
FMC	312	0.048077	0.048077	1	0
Frequency Auction	312	0.519231	0.500433	1	0
Mobile Number Portability	312	0.737180	0.44087	1	0

Source: Authors

Estimates based on the instrumental variable method (Table 12) are summarized as follows. Android availability was found to be significantly positively related to the dependent variable, mobile broadband adoption, while no such correlation was observed for

the iPhone availability. This result is believed to be due to the fact that iPhones were initially only offered by a single carrier in each country and, therefore, did not have a substantial impact on acquiring new users. Competition among cell phone carriers as represented by HHI was found to be significantly negatively related to mobile broadband adoption.

Table 12. Estimation results

Dependent variable: mobile broadband subscribers (Log)		
Mobile Broadband Adoption Ratio (one lag, Log)	0.769 (0.00789)	***
Price (Voice, Log)	-0.0736 (0.0244)	***
Price/Speed (Data, Log)	-0.0000145 (0.00474)	
Income (GDP/Capita, Log)	0.0505 (0.0927)	
HHI (Log)	-0.305 (0.0265)	***
FTTx (Adoption Ratio, Log)	0.0273 (0.00682)	***
Android (Dummy)	0.032 (0.0113)	***
iPhone (Dummy)	0.00485 (0.0115)	
FMC (Dummy)	-0.0518 (0.0195)	***
Frequency Auction (Dummy)	-0.0193 (0.0160)	
Mobile Number Portability (Dummy)	-0.00881 (0.0133)	
Constant	2.739 (0.911)	***
Observations	190	
R-squared (within)	0.9973	
R-squared (between)	0.9890	
R-squared (overall)	0.9923	
Wald test (model)	1.90E+06	
Prob. > χ^2	0.00000	
Test of overidentifying restrictions (Sargan-Hansen statistic)	0.027	
Prob. > χ^2	0.8686	

Note: Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: Authors

FTTH was found to be significantly positively related to mobile broadband adoption. Furthermore, (1) the price of voice service was found to be significantly negatively related to mobile broadband adoption, while the price of speed-adjusted data service was not found to be significant. (2) FMC was also found to be significantly negatively related to mobile broadband adoption. In other words, incumbent carriers that did not offer both fixed and mobile phone services tended to have greater numbers of mobile broadband subscribers. This is likely because carriers that do not operate both fixed and mobile phone services have focused greater attention on obtaining mobile broadband customers as a means of survival.

4.3 Implication to other objectives of the paper

Equation (1) is adequate to examine whether and how smartphones promote the growth of mobile broadband, but it is not so to demonstrate other objectives such as how smartphones promote HHI and how they shifted the market shares of carriers. The estimation results, however, show that the number of mobile broadband subscribers is highly correlated with HHI and Android smartphones, and accordingly HHI and Android smartphones. Regarding the market shares of carriers, there is no monthly data and it is impossible to examine by panel data. This is our problem to overcome in the future.

5. Discussions and conclusions

5.1. Factor identification in this paper

Although factors contributing to the adoption of mobile broadband were identified in this paper, research on this issue is still in the early stages. The conclusions drawn in this study are limited to the data that has been collected up to this point. In terms of the number of countries surveyed, while it can be said that the trend among OECD member countries has been captured to a certain degree, given that the six countries examined in this study account for majority of the population (56.0%), mobile broadband devices (63.7%), and GDP (68.1%) of the 34 OECD countries, country biases have not been completely

eliminated. As such, efforts must be made to collect further data to generate more detailed results.

In addition, although it would be ideal to use the actual number of Android devices and iPhones in use, due to difficulties in acquiring this data, the influence of Android devices and iPhones was tested in our model using a dummy variable for their availability at the time smartphones were introduced. Even if these variables are handled as dummies, it is expected that the model can be improved by using dummies for each of the iPhones at the time of their introduction. Further improvement can be expected by using the number of carriers offering each of the iPhones. For example, in Japan, the iPhone 3 was offered by only one carrier, whereas the iPhone 4S was offered by two carriers and the iPhone 5S/5C were offered by three carriers. By doing so, it will be possible to evaluate the impact of each type of phone on each carrier's market share.

In this paper, mobile broadband is defined as 3G and 4G. Furthermore, while MNOs were taken into consideration, MNVOs were not. Although other mobile systems such as WiFi and WiMAX exist, these were excluded due to difficulties in acquiring data. As can be seen in Figs. 3.1 to 3.4, the adoption of mobile broadband (3G + 4G) has been greatly impacted by migration from older network technologies (1G + 2G). Analyses should take this into consideration. However, due to limitations related to data collection, it was not possible to obtain pricing and speed data for the older technologies, and, thus, these factors were not included in analyses. This is an issue that will hopefully be improved in the future. Similarly the impact of OTT (over-the-top) content such as Google and Line was not addressed, again due to limitation in data collection. Continuous data collection is needed for more detailed analysis.

As mentioned earlier, FTTH influences mobile broadband adoption from the standpoint of both market demand and supply. However, in this study, difficulties were encountered in obtaining data on backhaul networks, that is, what percentage of fiber optic networks are used for backhaul or for fixed broadband, and it was not possible to separate out the impacts of the two. It will be necessary to continue seeking methods for discriminating the two influences in future research.

Finally, although the instrumental variable method was employed in this study, other methods such as the Arellano-Bond Estimator and Gaussian Mixture Model should be attempted in future investigations. The focus of this paper was limited to mobile broadband. Future research is necessary to address the substitutability and complementarity of fixed and mobile broadband.

This paper examined the main factors contributing to the adoption of mobile broadband in six major OECD countries. The main findings regarding factors identified through analysis of panel data are as follows: (i) Contrary to the initial hypothesis that the introduction of smartphones promoted adoption of mobile broadband, it was found that only the introduction of smartphones based on the open-source Android platform was associated with the mobile broadband adoption. The initial sales strategy to offer iPhone services through only a single carrier did not promote the overall adoption of mobile broadband. (ii) The penetration rate of FTTH does not influence mobile broadband adoption. (iii) Decline in HHI influences mobile broadband adoption. The result regarding HHI indicates that carrier consolidation, which is being discussed in various countries, has an inhibitory effect on mobile broadband adoption. The results of this study have policy implications that are universally relevant.

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