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Competition or smartphones? Factors promote mobile broadband adoption in OECD countries

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Competition or Smartphones?

Factors Promote Mobile Broadband Adoption in OECD Countries.

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Abstract

The adoption of broadband technology is a major policy issue for all countries. The objective of this paper is to identify factors contributing to mobile broadband (3G+4G mobile phones) adoption by focusing on smartphones. Broadband can broadly be divided into fixed (DSL, cable modem, FTTH) and mobile systems. This paper focuses on mobile broadband in six of the 34 OECD member countries—the US, the UK, France, Germany, Korea, and Japan—which represent more than 50% of the total population and mobile devices in use of OECD countries. Panel data analysis using data from 2000 to 2012 identified the introduction of smartphones, market competitiveness in terms of HHI, and FTTH adoption as factors contributing to mobile broadband adoption. The findings regarding HHI are particularly relevant to the much-contested issue of “carrier consolidation” and indicate that consolidation may have a detrimental effect on mobile broadband adoption, and, therefore should not be approved by regulators.

1. Introduction

With the development of both fixed and mobile broadband technologies, nationwide adoption of broadband services has become an important national issue in many countries including Japan, Korea, the US, and the EU. For example, Japan has set a goal of providing broadband connection to every household by 2015 under the name of New Broadband Super Highway (*Hikari-no-michi*) Plan, and the US is moving forward with a National Broadband Plan to provide 100 Mbps broadband connection to 100 million households by 2020. Similarly, the EU is seeking to provide 100% of EU citizens with access to broadband speeds of 30 Mbps and

50% of EU citizens with access to broadband speeds of 100 Mbps or greater by 2020.

Broadband systems can be broadly 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, the above-mentioned countries do not make a 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 identify the factors contributing to the adoption of mobile broadband specifically while taking into consideration the influence of Android smartphones and iPhones. The authors identified factors contributing to the adoption of fixed broadband in a previous paper (Shinohara, Akematsu, Tsuji, 2012) and focus on mobile broadband in this paper. 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. Use of smartphones such as Android phones and iPhones 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 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, in the case of Japan, was realized through massive investment in infrastructure amounting to 72,000 JPY per user for 50 million households across the 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. As such, adoption on a national scale will necessitate investment and time similar to that of the fixed telephone service described above. 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, given that the mobile broadband devices, which are the focus of this paper, 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.

This paper also investigated the problem of mobile carrier consolidation, which has become a target of policy in recent years. As in the case of the fixed telephone market, the mobile

phone market began as a monopoly and was opened up as a result of deregulation aimed at promoting competition through the introduction of other mobile phone companies (Whalley and Peter, 2012). Although there are currently three or four major cell phone carriers in each of the six countries examined in this paper, mergers and acquisitions among cell phone carriers has become an important policy issue. As such, this is also examined

Based on the above discussion, this paper seeks to identify factors that promote the adoption of mobile broadband by examining the case in six major developed countries among the 34 OECD member countries (the US, the UK, France, Germany, Korea, and Japan), while considering the influence of smartphones, which have become the device of choice since the introduction of 3G networks, and the impact of wireless backhaul networks. It is anticipated that doing so will provide insight that will be useful for 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.

Previous studies on mobile broadband are introduced in Section 2 below, while the current status of mobile broadband in six major countries is examined in Section 3. In Section 4, factors contributing to adoption of mobile broadband are identified based on analysis of panel data. Factors identified in the previous section are analyzed and the issue of mobile carrier consolidation is examined in Section 5, and conclusions are presented in Section 6.

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 six major OECD countries.

3. Current state of mobile phone and smartphone usage in six OECD countries

The current state of mobile and smartphone usage in the US, European countries (the UK, Germany, and France), and Asian countries (Korea and Japan) is introduced in this section.

3.1. The US

The mobile phone penetration rate in the US was 108% (as of the first quarter of 2013). The market shares of the four largest mobile phone carriers in the US—Verizon Wireless, AT&T, Sprint, T-Mobile US—were 34, 31, 16, and 10%, respectively, accounting for over 90% of total market share. In terms of market share broken down by generation of mobile network technology, as of the second quarter of 2007 when the iPhone was launched, 1G accounted for 0.1%, while 2G and 3G accounted for 47.4% and 52.5%, respectively. Figure 3.1 shows the introduction of major smartphone services in the US (the analysis in Section 4 takes into account the launch dates of major smartphone services, which differ by as much as 2 years in the different countries). It can be seen that the share of 2G declined and the share of 3G increased rapidly following the introduction of smartphones. The shares of 2G, 3G, and 4G cell phones were 6.7, 79.6, and 13.6%, respectively, as of the first quarter of 2013. The specific circumstances of each carrier are examined below.

Verizon was the first company in the US to offer LTE services in the form of its “4G mobile broadband network” in December 2012. Verizon’s 4G services currently provide coverage for 99% of the US population. Meanwhile, AT&T, Sprint, and T-Mobile launched 4G services in September of 2011, July of 2012, and March of 2013, respectively.

The market shares of the major mobile device manufacturers were Apple (39.9%), Samsung (23.7%), HTC (8.5%), Motorola (7.2%), and LG (6.6%) (three-month average for the second quarter of 2013; source: ComScore). These shares represent changes of 0.9, 2.0, -0.5, -1.3, and -0.2 points relative to the previous month and indicate an increase in share for the top two manufactures and a decrease in share for the remaining three manufacturers.

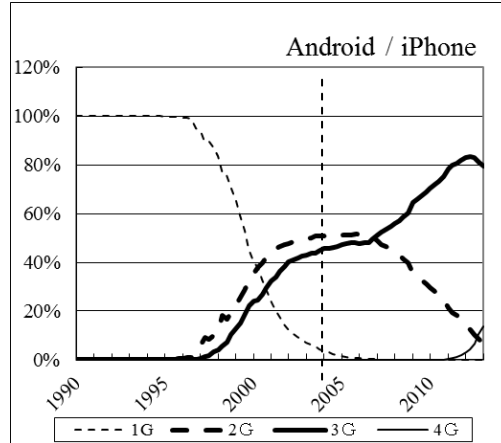


Figure 3.1 The Ratio of Cellular Services by Generation (U.S.).
Source: National Regulatory Authority, International Organizations.

Market shares for the different smartphone operating systems were Android (52.0%), Apple iOS (39.9%), and less than 5% for Blackberry, Microsoft, and Symbian combined. As can be seen from this result, the two major operating systems, Android and Apple iOS, have captured over 90% of the total market share.

Given that Android is an open source platform, each cell phone carrier has offered Android smartphones since the operating system was first introduced in 2007. In contrast, only specific carriers have offered Apple iPhones. In the US, AT&T began offering iPhone services in the second quarter of 2007, and started offering the iPhone 4 in the second quarter of 2010. Until Verizon began carrying the iPhone in the first quarter of 2011, AT&T was the only carrier that offered the iPhone. Following the launch of the iPhone 4S in the fourth quarter of 2011, Sprint and Verizon, along with AT&T, began offering the iPhone 5.

3.2. Europe

3.2.1. The UK

The mobile phone penetration rate in the UK was 126% (as of the first quarter of 2013). The market shares of the three largest mobile phone carriers in the UK—EE (formerly Everything Everywhere, renamed in September of 2013), Telefónica O2UK, and Vodafone UK—were 36.8, 31.1, and 22.5%, respectively, accounting for over 90% of total market share. In terms of UK market share broken down by generation of mobile network technology, as of the second quarter of 2007, 1G accounted for 0% (service was ended in the first quarter of 2001), while 2G and 3G accounted for 86.7% and 13.3%, respectively. The introduction of major smartphone services is shown in Figure 3.2. It can be seen that the share of 2G declined and the share of 3G increased rapidly following the introduction of smartphones. The shares of 2G, 3G, and 4G cell phones were 43.5, 56.1, and 0.4%, respectively, as of the first quarter of 2013.

Telefónica O2UK was the first company to experimentally offer LTE service in the UK as a 4G network in December 2011. Everything Everywhere introduced 4G service in October 2012.

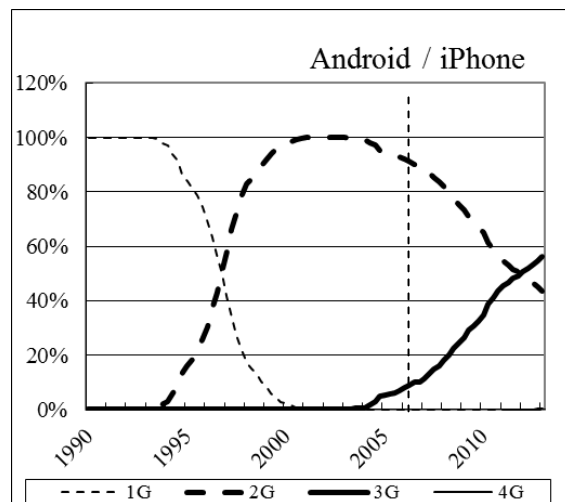


Figure 3.2 The Ratio of Cellular Services by Generation (UK)
Source: National Regulatory Authority, International Organizations.

3.2.2. Germany

The mobile phone penetration rate in Germany was 132% (as of the first quarter of 2013). The market shares of the four largest mobile phone carriers in Germany—T-Mobil, Vodafone D2, E-Plus, and Telefónica Germany (O2)—were 34.2, 28.0, 19.7, and 18.1%, accounting for 100% of total market share.

In terms of the German market share broken down by generation of mobile network technology, 1G accounted for 0% (service was ended in the fourth quarter of 2000), while 2G and 3G accounted for 90.8% and 10.2%, respectively (as of the second quarter of 2007 when the major smartphones were first introduced to the market). The share of 2G declined and the share of 3G increased rapidly following the introduction of smartphones. The shares of 2G, 3G, and 4G cell phones were 58.2, 41.3, and 0.5%, respectively, as of the first quarter of 2013.

T-Mobil, Telefónica Germany (O2), and Vodafone D2 launched LTE services as a 4G network in June, July, and October of 2011, respectively. T-Mobil and Telefónica Germany (O2) have agreed to joint ownership of mobile network facilities.

3.2.3. France

The mobile phone penetration rate in France was 106% (as of the first quarter of 2013). The market shares of the four largest mobile phone carriers in France—Orange (FT Group), SFR, Bouygues Télécom, and Free Mobile—were 40.2, 33.8, 17.1, and 8.9%, accounting for over 90% of total market share.

In terms of the French market share broken down by generation of mobile network technology, 1G accounted for 0% (service was ended in the second quarter of 1999), while 2G

and 3G accounted for 89.8% and 10.2%, respectively (as of the second quarter of 2007 when the major smartphones were first introduced to the market). The share of 2G declined and the share of 3G increased rapidly following the introduction of smartphones. The shares of 2G-, 3G-, and 4G-enabled phones were 40.0, 60.0, and 0.0% (8,600 subscribers), respectively, as of the first quarter of 2013.

Orange was the first company to experimentally introduce LTE services as a 4G network in June 2012. SFR began offering 4G services in November 2012.

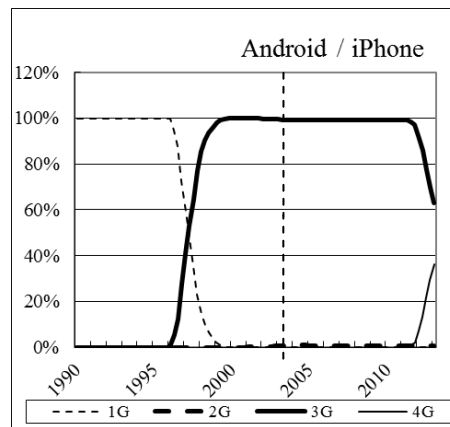


Figure 3.3 The Ratio of Cellular Services by Generation (Korea)
Source: National Regulatory Authority, International Organizations.

3.3. Asia

3.3.1. Korea

The mobile phone penetration rate in Korea was 111% (as of the first quarter of 2013). The market shares of the three largest mobile phone carriers in Korea—SK Telecom, KT, and LG U+—were 49.9, 30.3, and 19.1%, accounting for 100% of total market share. In Korea, the transition to next generation mobile telecommunications technology has progressed rapidly. 2G service was essentially ended in the second quarter of 1999 and replaced on all fronts by 3G. 4G

service was launched in the third quarter of 2011. As can be seen in Fig. 3.3, the market shares of 3G and 4G networks were 63.1 and 36.1%, respectively (as of the first quarter in 2013). SK Telecom and LG U+ were the first companies to offer LTE services for 4G-enabled phones in July 2011. KT launched its 4G network in January 2012.

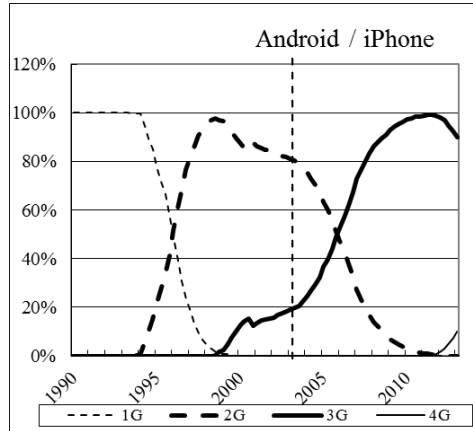


Figure 3.4 The Ratio of Cellular Services by Generation (Japan)
Source: National Regulatory Authority, International Organizations.

3.3.2. Japan

The mobile phone penetration rate in Japan was 108% (as of the first quarter of 2013). The market shares of the four largest mobile phone carriers in Japan—NTT Docomo, KDDI, SoftBank Mobile, and eAccess (bought out by SoftBank in 2012 and currently a part of the SoftBank Group)—were 45.2, 27.7, 23.9, and 3.2%, accounting for 100% of total market share. Market share of the different generations of mobile telecommunications technology were 23.3% for 2G and 76.7% for 3G (as of the second quarter of 2007 when the major smartphones were first introduced to the market, see Fig. 3.4). The market share of 3G began to peak out following the introduction of smartphones. The market shares of 3G- and 4G-enabled devices as of the first quarter of 2013 were 89.8 and 10.2% and together accounted for 100% of market share. NTT

Docomo, KDDI, and SoftBank Mobile began offering LTE as a 4G network in the third quarter of 2010, the third quarter of 2012, and the first quarter of 2012, respectively.

3.4. Hypothesis development based on the current status of the six major countries

In this section, building on the discussion up to this point, the current state of smartphones in the six countries is examined and hypotheses for analysis are postulated.

3.4.1. Current state as of the first quarter of 2013

(1) Penetration rate

Penetration rates in all six countries exceed 100% and are on an upward trend.

(2) Shift in mobile network technology (generations)

While 2G technology continues to account for 40 to 60% of market share in European countries, it accounts for only 7% of the US market and has already been phased out in Korea and Japan. As can be seen in Figs. 3.1 to 3.4, mobile devices in the US, Japan, and Korea have shifted almost entirely to 3G and 4G.

3.4.2. Smartphones

(1) Shift in mobile devices (generations)

As can be seen in Figs. 3.1 to 3.4, 2G peaked out and 3G has increased sharply following the introduction of the major smartphones in the second quarter of 2007 in the US, the UK, South Korea, and Japan. The mobile broadband markets in Germany and France exhibit a similar trend to that in the UK. In the US, Korea, and Japan in particular, market share of 4G services/phones has increased after the launch of 4G networks, while 3G services appear to have peaked out.

(2) Operating Systems

The market share of the different operating systems in the US and Japanese markets are presented here. Market share of Android devices was 64% in Japan (as of June 2012) and 52% in the US (as of June 2013). Market share of iOS devices including iPhones at the same time points was 32% in Japan and 39.9% in the US. In both Japan and the US, market share of Android devices is over 50% and that of iOS devices is between 30 and 40%. Combined, iOS and Android devices account for 90% of total market share.

The following hypothesis arises from the above discussion:

Hypothesis I: Introduction of Android phones and iPhones promotes the adoption of mobile broadband.

3.4.3. The market and competition policies

(1) Competing with incumbent telecommunications companies

Although telecommunications markets prior to the introduction of broadband constituted monopolies or oligopolies by incumbent telecommunications companies, steps to increase market competitiveness have been undertaken as a matter of policy. Verizon, AT&T, and Century Link in the US, BT in the UK, Deutsche Telekom in Germany, FT in France, KT in Korea, and NTT East, NTT West in Japan correspond to “incumbent carriers.” These incumbent carriers do, in fact, have an almost complete monopoly on subscriber lines (78% for KT in Korea). However, in the mobile phone market, no individual carrier can claim to have a majority of subscribers, even when companies within the same group are combined. The carrier with the greatest share of subscribers is Japan’s NTT Docomo, whose subscribers represent 45.2% of all cell phone

subscribers.

(2) Incumbent telecommunications companies and mobile network operators (MNO)

In the five countries excluding the UK, cell phone services are provided by incumbent telecommunications companies or telecommunications companies within groups that act as mobile network operators (MNO). In the UK, BT separated and sold off its cell phone (MNO) division, which currently offers services as O2's mobile virtual network operator (MVNO) division. In the US, France, and Japan, incumbent telecommunications companies claim the largest market shares. Among these carriers, Japan's NTT Docomo claims the largest market share at 45.2%, followed by France's Orange, whose share is 42.7%. That said, the shares of all companies have been on the decline since the introduction of smartphones in the second quarter of 2007. In Germany, T Mobil's market share (34.2%) dropped to second place following the merger of the two companies with the lowest market shares. In Korea, the greatest market share (49.9%) is held by SK, which is not an incumbent telecommunications carrier, while the market share of the incumbent telecommunications carrier, KT, is 30.3%.

(3) Competition policy and the Herfindahl-Hirschman Index (HHI)

Although the merger and acquisition of operators has occurred frequently throughout the development of the mobile phone market, this has recently been recognized as problem. Problems related to carrier consolidation have occurred in various EU countries. For example, in Austria, Ireland, and Germany, the number of carriers has fallen from four to three as a result of consolidation. In the EU, as a common market, it is possible for consolidation to occur across national boundaries. Although Switzerland is not a member of the EU, the Competition Commission (antitrust regulatory agency) has prohibited carrier consolidation, which would reduce the number of carriers from three to two. In the US, the Bureau of Competition did not

approve Sprint’s acquisition of T-Mobile, and, as a result, the number of major carriers remains at four. In Japan, SoftBank acquired eAccess (brought it under the group umbrella), and, as a result, the number of cell phone carriers has fallen from four to three.

In this paper, the Herfindahl-Hirschman Index (HHI) is employed as an index of the degree of competition in markets. The inter-platform HHI is calculated based on a telecommunications operator’s total market share for all generations of network technology (total of 1G to 4G). As can be seen in Fig. 3.5, which shows the HHI scores for the six major countries, HHI has been on an general downward trend from a maximum of 4,080 in the second quarter of 2007 (Japan) to a minimum of 2,669 in the first quarter of 2013 (Germany). This trend indicates increasing competition in the mobile broadband market. The exception is the US, whose HHI was the lowest among the six countries and whose HHI increased from 1,980 in the second quarter of 2007 to 2,478 in the first quarter of 2013.

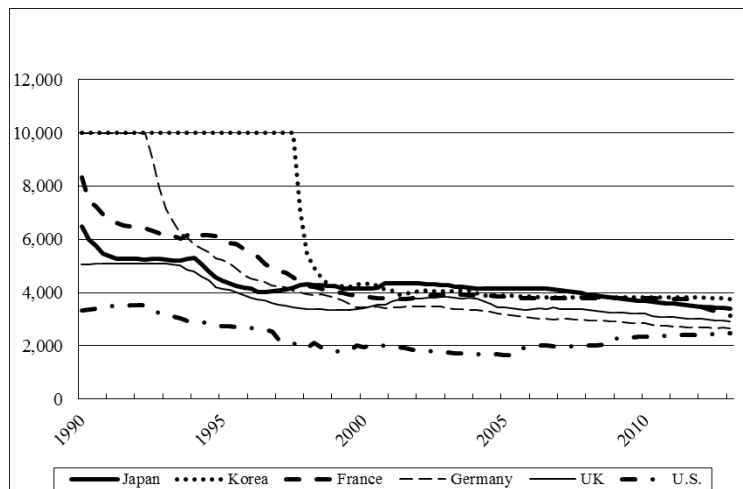


Figure 3.5 HHI of mobile broadband in the six major countries.
Source: National Regulatory Authorities, International Organizations.

Based on the above results, it is believed that adoption will advance if market competition

increases. While there are various indices for estimating market competition, the above-mentioned inter-platform HHI is employed in this paper as a proxy for the level of market competition. Accordingly, the following second hypothesis (Hypothesis II) is formulated:

Hypothesis II: Increasing market competition (i.e., decreasing inter-platform HHI) promotes adoption of mobile broadband.

3.4.4. FTTH penetration rate

Mobile broadband networks in each country comprise a vast number of base stations distributed throughout each country. In Japan, for example, each carrier has as many as 200,000 base stations. As these mobile broadband networks offer high-speed internet, fiber optic networks used in the backhaul connecting base stations as the core network. From the telecommunications companies' perspective, this fiber optic network is used for fixed broadband services such as FTTH. Given the enormous number of households in each country, which could be as high as 50 million for example, it is essential for telecommunications companies to utilize these nation-wide fiber optic networks as efficiently as possible. Meanwhile, heavy users of mobile broadband are able to lower their costs by using fixed broadband via WiFi when at home. In such cases, mobile and fixed broadband are complementary services. In contrast, a growing number of young people are choosing not to own a PC because they have a smartphone. In this case, mobile and fixed broadband are alternative services.

As can be seen from the above, both providers and users of mobile broadband are affected by fixed broadband. Accordingly, the following third hypothesis (Hypothesis III) is formulated:

Hypothesis III: FTTH penetration rate affects adoption of mobile broadband.

3.5. Summary up to this point

Summarizing the discussion up to this point in the form of hypotheses regarding the role played by smartphones in the changing structure of mobile phone markets yields the following: Hypothesis I: acceleration by generational upgrade(in network technology). In most of the countries, the arrival of smartphones has promoted a shift to newer 3G and 4G technologies. Hypothesis II: promotion by competition. The introduction of smartphones has encouraged market competition and lowered HHI, which, in turn, has contributed to the adoption of mobile broadband. Hypothesis III: interrelated nature of fixed and mobile broadband. The adoption of fixed broadband leads to the adoption of mobile broadband.

The above hypotheses are validated based on the following analyses of panel data.

4. Analysis of factors contributing to adoption

An overview of the analysis using panel data is presented in this section.

4.1. Methods

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

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

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. Results and issues

Descriptive statistics of the quarterly data examined for the estimation period (2000 to 2012) are provided in Table 4.1. 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 4.1 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 4.2) 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, partially validating Hypothesis I. 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, validating Hypothesis II that market competition drives mobile broadband adoption.

Table 4.2 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,

validating Hypothesis III. 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.

5. Discussion

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.

5.2. Mobile carrier consolidation

The issue of mobile carrier consolidation should be briefly examined based on the results of the above investigation.

As in the case of fixed telecommunications services, the mobile phone markets mentioned in this paper essentially began as monopolies by single companies and were opened up to competition through deregulation that enabled the entry of new mobile phone carriers. At present, in the mobile broadband markets of the six major countries, which each comprise three or four large mobile phone carriers, the issue of carrier consolidation is starting to be discussed as a matter of policy. Examples in which consolidation has been approved and carrier numbers have declined from four to three have occurred in Austria, Ireland, and Germany. In Japan, carrier numbers have declined from four to three groups (with eAccess being brought under the umbrella of the SoftBank group). An example in which consolidation has not been approved is Sprint's attempt to acquire T-Mobile in the US. If the merger had gone through, the number of carriers would have declined from four to three. However, the merger was not approved by the FCC (based on its so-called "unofficial decision"). In Switzerland, although not a member of the EU, the Swiss Competition Commission (WEKO) has forbidden carrier consolidation, which would result in a reduction in carrier number from three to two.

The results generated by analysis in this study can be applied to the issue of carrier consolidation. Specifically, based on the finding that HHI, which is defined as the sum of squares

of each carrier's market share, is negatively correlated with mobile broadband adoption, carrier consolidation should be prevented from the standpoint of promoting the mobile broadband adoption. That is to say, it is desirable for market share to be shared evenly by each carrier and not to accrue to a single carrier.

Based on the conditions for approval for Telefónica-Deutschland's purchase of E-Plus announced by the European Commission in July 2014, it can be seen that reduction in number of carriers is not the only concern. As conditions for approval, Telefónica-Deutschland agreed (1) to help the entry and expansion of MVNOs—more specifically, to sell off 30% of the company's network capacity after merger to allow the entry and expansion MVNOs; (2) to develop a proposal for selling off a portion of its frequency spectrum and related assets to other new MNOs or MVNOs purchasing network capacity (to lower barriers to entry for new MNOs in conjunction with the German Federal Network Agency's frequency auction); and (3) to extend Telefónica's and E-Plus's current agreements with MVNOs and ISPs. If the merger goes ahead as planned, Telefónica-Deutschland's share will increase to just under 40%, stimulating competition by positioning a new entrant in Germany's mobile phone market in the top position, while knocking T-Mobil (34%) and Vodafone (28%) down to second and third place, respectively, which, in turn, will strengthen the negotiating position of MVNOs with respect to T-Mobil and Vodafone.

In addition to economic analysis as in the case of this paper, the issue of carrier consolidation has also been analyzed from the standpoint of law. An example of this is SoftBank bringing eAccess under its umbrella based on capital ties without dissolving the latter carrier's corporate status. Examination of the Corporate Law, Financial Instruments and Exchange Law, Antitrust Act, and guidelines for establishing 4G indicates that the share of frequency spectrum

allotted to each carrier should be taken into consideration (Hayashi, 2014).

As in the case of fixed telecommunications services, the mobile phone market in each country essentially began as a monopoly by a single company and was opened up to competition through deregulation that enabled the entry of new mobile phone carriers. At the same time, unlike fixed telecommunications markets, which developed in heavily-regulated environments, mobile phone markets have developed in an unregulated manner based on market principles. Given this background, the degree to which regulatory agencies should regulate the number of mobile phone carriers and market share as a matter of policy to ensure competition is an issue that needs to be discussed.

6. Conclusions

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.

*) The views expressed in this paper represent the personal opinions of the authors. They do not necessarily represent the views of the KDDI Group.

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