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Empirical Study of Effect of Deregulation, Competition, and Contents on Mobile Phone Diffusion: Case of the Japanese 3G Market

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**Empirical Study of Effect of Deregulation, Competition, and Contents on
Mobile Phone Diffusion: Case of the Japanese 3G Market**

Abstract

The Japanese mobile market has recently shown a remarkable growth in the last decade, with more than 106.2 million 3G (3rd Generation, or W-CDMA) subscribers and 4.4 million 2G (2nd Generation, or PDC) as of December 2009. This paper attempts to analyze factors promoting Japanese mobile phone, focusing on 3G technologies. Factors promoting it can be summarized as follows: (1) deregulations by government, such as MNP (Mobile Number Portability) and collocation; (2) competition among carriers, such as introduction of new charge plans; (3) technological development, such as connection speed; and (4) contents and applications. This paper utilizes the panel data of three main carriers of the mobile phone market, namely, NTTdocomo, au (KDDI), and Softbank. As for a model for estimation, we apply that of Madden and Coble-Neal [2004] which studied the relationship between fixed and mobile phone with the panel data by the dynamic random effects estimation. Dynamic models are based not only on the assumption such that carriers do not instantaneously adjust to satisfy their long-term demand but also on network externalities. Besides, the paper applies a dynamic panel data model in order to take care of the endogeneity problem. This paper deals with this problem rigorously by applying Arellano-Bond estimator (Arellano and Bond [1991] and Arellano and Bover [1995]) which estimates exogenous or predetermined variables, in addition to instrumental variables, using the two-step generalized method of moments (GMM). Based on this framework, this paper identifies service innovations such as entertainment, flat rate charges are found significant for the 3G mobile phone diffusion.

JEL codes

L52, L86, L96

Key words

dynamic panel data analysis; competition policy; network externalities; endogeneity; m-commerce; e-entertainment; MNP

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1. INTRODUCTION

The Japanese mobile market has shown a remarkable growth in the last decade, with more than 106.2 million 3G subscribers and 4.4 million 2G as of December 2009. The 3G diffusion rate accounts for 90%, followed by that of Korea and this implies the market is almost saturated. Another remarkable transformation is found in its usage: data communication exceeded voice services. Consumers use more often mobile phone as wireless devices not only for transmitting and receiving information via e-mail, SNS, blog, or search engines but also for executing transactions to purchase good at stores or reserve trains and airplanes than for traditional communications. In this sense, Japanese 3G mobile phone has entered a new era first in the world.

1.1. Objectives of analysis

The reason why that the data communication via mobile phone has been developing was traced back to the beginning of 3G or 2G. Japanese 3G (2G) mobile phone originally had much variety of functionality other than voice services, being based on supply and demand side of the services: the former is 3G technology which enabled new services such as m-commerce and e-entertainment, while the latter is due to existence of consumers who are willing to utilize various services. This paper aims at analyzing factors promoting 3G mobile phone from these two viewpoints. Our series of papers such as Tsuji and Tomizuka [2006], Akematsu [2008], and Tsuji and Akematsu [2009], [2010] attempted to identify factors promoting Japanese broadband of ADSL (Asynchronous Digital Subscriber Line) and FTTH (Fiber to the Home), being summarized as technology, competition, and policy (deregulation). This paper also uses the same viewpoints to analyze the diffusion of Japanese 3G mobile phone. In so doing, this paper attempts to apply a dynamic panel data model initiated in Madden and Coble-Neal [2004] and Datta and Agarwal [2004] in telecommunications. In particular, the former introduced a lagged dependent variable, which is the number of 3G subscribers in the previous period, as presenting unsatisfied demand which usually occurred in providing new services in telecommunications. In other words, the underlying reason for using dynamic models is the assumption such that carriers do not instantaneously adjust to satisfy their long-term demand. Besides this, this paper motivates to introduce a lagged dependent variable from another reason. That is the “network effect.” That is, the number of 3G subscribers in the previous period represents the size of the market. The telecommunication market is a typical example which shows the network effect or “network externalities.” The dynamic panel data

model can capture this essential character of the market.

In this paper, there is another reason to utilize a dynamic panel data model, which is related to the endogeneity of data in the telecommunications. In econometrics, endogenous problems related to variables often occur, and care should be taken to guard against them. When there are correlations between explanatory variables and error terms, estimated coefficients of variables are not true values, and endogenous bias occurs. There are few papers successfully analyzed the endogeneity problem by checking rigorously whether the instrumental variable method worked or not. Most of papers simply mentioned that they applied the instrumental variable method without testing it. This paper, on the other hand, deals with this problem rigorously and provides a solution to it by applying Arellano-Bond estimator initiated by Arellano and Bond [1991] and Arellano and Bover [1995] which estimates exogenous or predetermined variable, in addition to instrumental variable, using the two-step generalized method of moments (GMM).

In sum, this paper incorporates the two important characteristics particular to empirical analysis in the telecommunications such as the endogeneity and network externalities in the analytical framework of a dynamic panel data model.

1.2. Overview of Japanese mobile phone market

Three major carriers, NTTdocomo, au, and Softbank, have been dominating the market since the advent of the Internet in mobile phone in 1999. As of March 2010, the total number of subscribers amounted to 112.18 million, of which docomo alone holds 50.00 percent market share. In contrast, au and Softbank holds 28.41 and 19.50 percent market share, respectively.

Figure 1 demonstrates briefly to show the whole telecommunications market in Japan according to their subscriber achievement and growth. While the number of fixed phone has remained steady since 1996, mobile phone subscribers have been increasing rapidly. Therefore, the mobile phone market has reached to the saturation stage, and the growth rate of subscribers has been slowing down. Moreover, the recent development is found in the fact that data communications exceeds traditional voice communication, and being the first phenomenon in the world. Japanese consumers tend to use more mobile phone as a device to connect to the Internet in order to download various contents such as games (currently social games attract interests of younger generations), digital TV, movies, and music as well as use value added services such as shopping at convenience stores and reservation of trains and airplanes. Now small handsets can even view HPs built for PC access and tend to be devices for mobile computing.

In June 2007, EMOBILE, the fourth mobile phone operators, entered the market using the W-CDMA technology. The carrier offers only 3G services, having obtained NTTdocomo's authorization to use its network on an access cost basis. It has currently 2.35 million subscribers. At the same time, mobile broadband services named WiMAX started and two carriers entered this market.

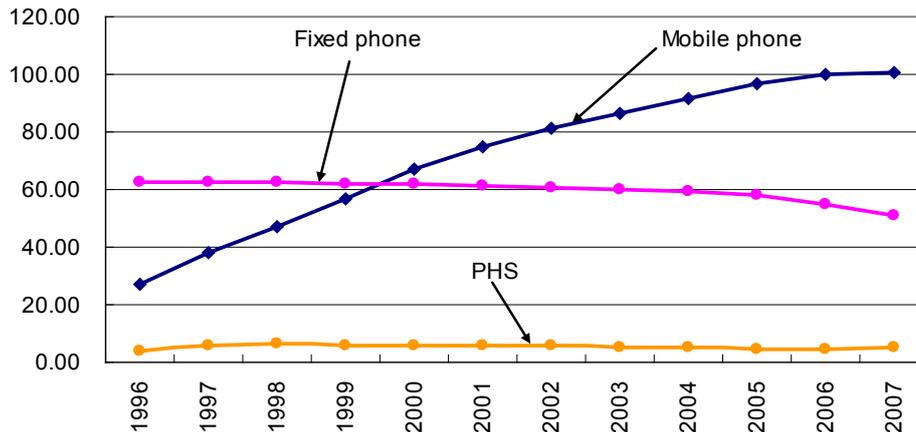


Figure 1 Transition in total number of subscribers (in millions).

Figure 2 indicates the fluctuation of market share of each carrier in 3G services. Note that, while in 2003, NTTdocomo had only 13.7% market share of 3G comparing to au (85.5%) and Softbank (0.8%), in 2008 it has been raised to 50%. The au's largest market share at the beginning were due to the fact that it offered almost same technology as 2G and bandwidth like 800 MHz for its 3G subscribers which can be said it is not actually 3G rather than 2.5G. This enabled au to use not only the same 800 MHz network and base stations to support 3G deployment, but also the same 2G handsets (Ishii, 2004). In contrast, NTTdocomo started with constructing new W-CDMA network and required to install new base stations to renovate and upgrade existing 2G to 3G network. Besides, focusing on market areas is also different, that is, au has been targeting market areas of populated areas, while NTTdocomo intended to provide services all areas in the country. These made NTTdocomo lagged behind au at the beginning. Despite the trend, NTTdocomo and Softbank offered a number of innovative services to subscribers embodied in handsets; in particular, since the latter entered the 3G market lastly, it offered remarkable pricing strategies including no charges for call between its subscribers.

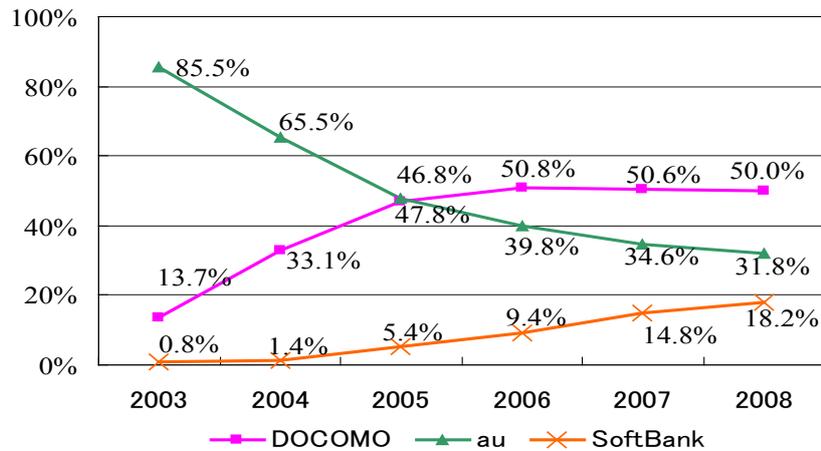


Figure 2 3G market share shift by carrier based on the number of subscribers.

1.3. Literature review

In respect to mobile phone diffusion in the world, Ahn and Lee [1999] were first to undertake a cross-country modeling of mobile services in 64 countries using ITU (International Telecommunication Union) data for 1984. They found a complementary relationship between mobile and fixed telephone. Gruber and Verboven [2001] analyzed factors promoting mobile phone among EU 15 countries using data for 1984-1997 by non-linear dynamic panel data model. Substitution effect between mobile and fixed-telephone was estimated by Madden and Coble-Neal [2004] using ITU data 1994-2000 in a lagged dependent variable model which is termed by a dynamic panel data approach. They found that mobile phone can be a substitute for fixed-telephone in many countries. Banerjee and Ros [2004] found that technological substitution in some countries and economic substitution in others can explain the differential patterns of development in global fixed and mobile telephony. Many of the diffusion studies are based on econometrics, relying on aggregate measures of mobile phone penetration, compared across countries. Some researches explained penetration rates using geography and the income level, such as Balamoune-Lutz [2003], income alone by Rouvinen [2004], socio-cultural attributes and the Internet, telecommunication use by Kamssu [2005] or national industry structure, pricing schemes and feature availability by Kshetri and Cheung [2002], and Mingos [1999]. Kim [2005] estimated the preferences of mobile phone in Korea for IMT-2000 (International Mobile Telecommunication-2000) services by using the conjoint analysis. He identified three major players in the Korean mobile market attracted subscribers by providing services like video calling, global roaming and upgrade services via the mobile multimedia

Internet.

Though there is a great deal of research on mobile phone around the world, there are only a few empirical studies focusing on the diffusion of 3G mobile phone in Japan. Iimi [2005] focused on the demand for mobile phone services during 1996-1999. A nested logit model was used to examine the influence of basic 2G services, including voice mail and specific discount packages offered by individual carrier. He identified the effects of (a) price elasticity, (b) product differentiation of various carriers, and (c) network externalities increase the demand for mobile phone. Ida and Kuroda (2006) used a mixed logit model to estimate demand for mobile phone services in Japan. They compared both 2G and 3G mobile phone for major carriers to find whether 3G can be a substitute for 2G by using survey data carried by MIC (The Ministry of Internal Affairs and Communications) and concluded that NTTdocomo's 2G services can be a substitute for its 3G. In case of au, 3G services were not substitute for NTTdocomo's 3G. Nelson [2004] analyzed the development of camera phone in Japan. She identified technology, and social factors for the success of camera phone development. Abu [2010] presented panel data models to identify factors promoting Japanese 3G mobile phone in the framework similar to this paper. He identified that technological innovations such as electronic payment, high-speed access and consumers' attitude toward entertainment and m-commerce are important factors for the success of 3G.

Unlike the case with mobile phone, the diffusion of ADSL has been closely investigated. Eisner and Waldon [2001], Kridel, Rappoport and Taylor [2001], Sidak, Crandall and Singer [2002] utilized discrete choice methods to analyze competition of broadband market in the US. Tsuji and Tomizuka [2006] analyzed factors promoting Japanese ADSL by AHP (Analytical Hierarchical Process) analysis. They divided these factors into three types: deregulation, competition, and technology, then calculated degrees of importance. Finally, they monetarily evaluated factors, in which competition mostly contributed the development of ADSL. Akematsu [2008] analyzed factors promoting ADSL based on the data of ADSL carriers using panel data analysis.

From the discussion above, this paper attempts to examine the diffusion of 3G mobile phone in Japan using panel data analysis. The research is based on monthly data collected from different sources. In addition, the paper analyzes not only the whole market but also the three major carriers focusing policy as well as technology development related to services which have been developing rigorously involving music, e-payment (m-commerce), digital TV, high speed Internet services, pricing strategy. By taking all these factors into consideration, this paper has conducted an empirical analysis to reduce authentic results for the diffusion of 3G mobile phone which may

serve as a model to upgrade services to 4G (fourth generation) mobile phone in near future.

2. DEVELOPMENT OF MOBILE TELECOMMUNICATION MARKET

Here we briefly present technological development of 3G mobile phone, which characterize the Japanese mobile phone market in Japan, and in accordance with new technologies, new services which met consumers' preference were provided by carriers. These two are drivers of Japanese 3G mobile phone diffusion. In addition, these also induced carriers to coordinate their businesses according to needs of subscribers. New business models including a flat rate charging plan can play an increasingly important role. Operators under these circumstances are confronted with fierce competition due to the short product life cycle and the pressure to differentiate their services.

2.1. 3G technologies

Although 2G networks are adequate for voice, there was a growing interest in shifting from 2G to 3G, based on a number of important drivers. First, the higher speed of 3G technologies translates into added convenience, capacity and functionality for the user. Second, there is much excitement over adding Internet protocol (IP) capability, and hence Internet access to the mobile phone. 3G networks also use the spectrum more efficiently, and support a family of global standards to facilitate roaming. In developing 3G standards, International Telecommunication Union (ITU) worked with regional organizations and industry associates to reduce a large number of initial proposals to a smaller number of global standards such as IMT-2000 family to ensure interoperability.

The purpose of the IMT-2000 project was to harmonize different radio interfaces and produce a single family of 3G standards that would be able to cover future value-added services and applications. Three different access technologies such as Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA) and Frequency Division Multiple Access (FDMA) for five radio interfaces were included in the IMT-2000 family (ITU, 2006). Most deployments to date have used one of two interfaces, CDMA 2000 and Wide-band Code Division Multiple Access (W-CDMA) same as Universal Mobile Telecommunication System (UMTS) in Europe. China has chosen a third interface, Time Division Synchronous Code Division Multiple Accesses (TD-SCDMA), for its national deployment of 3G.

Table 1 illustrates the diversification of 3G technologies that have been frequently used by Japanese mobile phone operators to provide the most sophisticated and

user-oriented services amongst the World (Abu, 2010). au chose a U.S.-developed 3G technology, CDMA2000, which is different from the European technology, W-CDMA, which NTTdocomo and Softbank chose. au found CDMA technology based on cdma2000 standards are capable of distinct carrier configurations, employing carriers with lower bandwidth, could make a smooth upgrading from 2G to 3G, as already mentioned in the previous section.

Table 1 Types of 3G technologies in Japan

| Carrier | Technology | Service Name | Start of Service | Max. Speed |
|-----------|-------------|--------------|------------------|------------|
| NTTdocomo | W-CDMA | FOMA | October, 2001 | 384 Kbps |
| au | cdma2000 1x | cdma2000 1x | April, 2002 | 144 Kbps |
| Softbank | W-CDMA | VGS | December, 2002 | 384 Kbps |
| au | EV-DO | WIN | November, 2003 | 2.4 Mbps |
| NTTdocomo | HSDPA | Hsdpa | November, 2005 | 14.4 Mbps |

Source: White paper of MIC

The technological development from 2G to 3G such as W-CDMA and CDMA2000 was thus aimed at providing high speed data communications. The maximal down load speed of CDMA2000 and W-CDMA are 2.4Mbps and 14.4Mbps, respectively. Without these technologies, various mobile services would not have been provided by many carriers.

2.1. Bandwidth

High bandwidth wireless enabled services which require large volume of data. Mobile communications were allocated only low bandwidth at the beginning. In 2000, the MIC initially appropriated the 800 MHz and 1.5 GHz bands for second-generation mobile phone in 2000. As the number of mobile phone subscribers skyrocketed, however, the assigned frequencies became in such a heavy demand that it became impossible for additional companies to enter the market without the allocation of new bandwidth. To correct this situation, and thereby promote the continuing development of ubiquitous connectivity in Japan, the MIC decided to allocate the 1.7 GHz and 2 GHz bands for new mobile carriers which are depicted in Table 2. For voice services, bandwidth matters less difference between 2G and 3G, except avoiding traffic congestion, while but for data communications, they show entirely different quality. 3G mobile enables much high speed communication with larger volume so that higher bandwidth was necessary.

Table 2 Frequencies used by mobile phone

| Carriers | 800MHz | 1.5GHz | 1.7GHz | 2GHz |
|-----------|--------|--------|--------|------|
| NTTdocomo | ○ | ○ | | ○ |
| au | ○ | | | ○ |
| Softbank | | ○ | ○ | ○ |
| EMOBILE. | | | ○ | ○ |

Source: White paper of MIC

2.4 Innovations in services

In accordance with the rapid development of mobile technology as mentioned previously, services already provided in 2G mobile phone such as i-mode were upgraded and consumers needed not feel jittered while using these services including mail services (e-mail, photo-mail, and video mail), web access, and download (music, movie and game). Moreover, carriers provide their customers more innovative functions such as video mail, video clips, video phone, broadcasting type video program, walk navigation, ringing tone songs, high speed Internet connection, wallet phone, double phone numbers and email addresses in single handset, digital terrestrial TV broadcasting, etc. via 3G mobile phone. In short, 3G services add multimedia facilities to 2G phone by allowing video, audio, and graphic applications. The followings are examples of new services available in 3G mobile phone

(a) Viewing web service

Since 2G mobile had technological limitations of networks and handsets, data transmitted via 2G was mainly text, while due to development of networks and handsets, pictures and Flash moving pictures are available and some handsets enabled to view HPs for PC. Google and Yahoo started mobile search engines. Thus 3G mobile becomes platform to use mobile contents such as games, access to SNS and blog, mapping services, etc.

(b) Full music downloads

When NTTdocomo started music services in 1996, it could be downloaded via low speed data communication. Because of this, only short music was available. On the other hand, 3G mobile high quality formatted music became available such as MP3. Since then, the largest category of mobile entertainment in terms of market size was music. au is pioneering thorough its music services from the beginning by launching “*Chaku-Uta*” in November 2002 that allowed users to download songs in their original

format as released by music distributors, and to set these songs as the ringer tone on mobile phone. Following the concepts of “*Chaku-Uta*” and “*Chaku-uta Full*” service was introduced into the market and subscribers enjoyed full download of their favorite music whenever and wherever they like. Thus 3G mobile became a “player” of music.

(c) Wallet phone

A large number of “wallet phone (mobile phone with electronic money functions)” subscribers have emerged in Japan since NTTdocomo first released wallet mobile phones in 2004 using Sony’s FeliCa technology. Two types of mobile payment services are available in the market, namely credit (future payment) and electronic money (advanced payment). iD, QUICPay, Smart plus are classified as credit payment, while Edy, *Suica*, PASMO, *nanaco*, and WAON are e-money (electronic money) services as of 2009. IC card was embodied in the handsets, which enabled e-payment. Consumers were able to pay via mobile phone in shops and stores, and this increased their convenience.

(d) Flat rate for data communication

As mentioned earlier, data communication such as viewing web showed remarkable increase in 3G mobile phone, but monthly charges also increase and this became serious problem. In case of the Internet access in fixed communication, the flat rate charges are already introduced, and au started this service for obtaining more subscribers.

Table 3 summarizes the factors considered to promote or affect 3G mobile diffusion, which will be used for empirical study.

Table 3 Category of factors promoting diffusion

| | Carrier | Service | Time and carrier |
|--------------|------------------|---------------------------|-------------------|
| MNP | All | Mobile Number Portability | Oct., 06 |
| iPhone | Softbank | Release of iPhone | Jan., 07 (SB) |
| FeliCa | All | Launch of FeliCa | July, 04 (docomo) |
| One-Seg | All | Launch of Mobile TV | May, 06 (au) |
| Data Roaming | All | Packet Roaming Service | Dec., 04 (docomo) |
| Full Music | All | Full Music Downloading | Oct., 04 (au) |
| 2 in 1 | docomo, Softbank | Double Number | May, 07 (docomo) |
| Flat rate | All | Flat Rate Packet Plan | Nov., 03 (au) |

Note: The time of service started is chosen as the earliest among carriers.

Source: Based on the service operators’ homepages, TCA’s annual report

3. EMPIRICAL ANALYSIS

3.1. Model for estimation and data

In order to specify the factors promoting 3G mobile, monthly subscriber of 3G is taken as a dependent variable. A period subject to the analysis is during the time when each carrier starts 3G to the end of March 2010. We define W-CDMA of NTTdocomo and Softbank, and CDMA 1X of au as 3G technology. Data of subscriber is published in TCA (Telecommunications Carriers Association) website. Independent variables are, subscriber of 2G which is an existing alternative technology of 3G, ARPU (Average Revenue Per User) representing price index, which consists of the sum of voice ARPU normalized by traffic (MOU: monthly Minutes Of Usage) and packet ARPU. ARPU and MOU are published at Investors Relations information in website of each carrier. Real GDP obtained from the Cabinet Office is utilized as an income index, which is monthly smoothed. All variables mentioned above are transformed into logarithms. Factors promoting 3G mobile is selected according to the annual report of TCA. Such services or events started after 3G launched are utilized as dummy variables which indicate 0 before the services/events start and 1 after they start. Some other factors are also taken from news releases for each carrier, and used for independent variables.

Some variables such as GDP or factors promoting 3G mobile are exogenous, but ARPU and subscriber of 2G are obviously endogenous. Here, we arbitrarily employ some instrumental variables of mobile technology which do not directly affect subscribers' choice behavior. In particular, HSDPA, IP network, IP phone, and Highbands represent instrumental variables. In addition, some previous researches note that mobile carriers do not instantaneously adjust to satisfy their long-term demands, and then dynamic model approaches are available. Especially, network externality or network effect has to be considered in telecommunication. In this respect, effect of network size, or lag-effect of subscriber had better be taken into account. Linear dynamic panel-data model by Arellano and Bond [1991) can estimate with considering both endogeneity and lag-effect of variables. However, Arellano-Bond estimator generally assumes "large N, short T." Our dataset consists of only three carriers of docomo, au, and Softbank, which is extremely small sample, so this estimator is not always reliable. In this paper, we present the following models: (i) Ordinary panel data estimation (fixed- and random-effect estimation); (ii) Maximum likelihood estimation; (iii) Instrumental variable estimation; (4) Arellano-Bond dynamic panel estimation; and (v) Instrumental variable estimation of each carrier.

Summary statistics of data is summarized in Table 4.

Table 4 Summary Statistics

| | Observation | Mean | S.D. | Min | Max |
|---------------|-------------|---------|--------|---------|---------|
| Subscriber 3G | 286 | 15.6325 | 2.1541 | 7.0901 | 17.7896 |
| Subscriber 2G | 332 | 15.6802 | 1.4833 | 12.4184 | 17.6089 |
| Price | 287 | 3.7261 | 0.1367 | 3.3210 | 3.9155 |
| GDP | 333 | 13.1816 | 0.0378 | 13.1211 | 13.2453 |
| iPhone | 333 | 0.0631 | 0.2434 | 0 | 1 |
| FeliCa | 333 | 0.5315 | 0.4998 | 0 | 1 |
| One-Seg | 333 | 0.4414 | 0.4973 | 0 | 1 |
| Data Roaming | 333 | 0.7237 | 0.4478 | 0 | 1 |
| Full Music | 333 | 0.5285 | 0.4999 | 0 | 1 |
| 2 in 1 | 333 | 0.1682 | 0.3746 | 0 | 1 |
| Flat rate | 333 | 0.6396 | 0.4808 | 0 | 1 |

3.2. Result of estimation: Panel data analysis

Table 5 shows the results of the fixed-effect model, the random-effect model, maximum likelihood estimation, the instrumental variable model (random-effect EC2SLS estimation), and Arellano-Bond estimation. Let us discuss from the ordinary panel data analysis. F test selects the fixed-effect model, the Lagrange Multiplier test selects the random-effect model, and the Hausman test selects the fixed-effect model. Finally, the fixed effect model is selected, in which Price and GDP significantly satisfy the sign condition. The price elasticity indicates -5.66 which is elastic. A sign of subscriber of 2G is negative, and it naturally represents the substitutive relationship with 3G mobile. All factors except “One-Seg” and “2 in 1” services are positively significant. “Data Roaming,” which has the highest estimator, is a service so that we can use packet service internationally. As mentioned, the Japanese mobile phone market has specific characteristics during its growth process, and it is sometimes referred to as “Galapagos Syndrome.” It is ironical that services that Japanese mobile phone can be supplied in other countries actually promote 3G mobile phone in Japan. A result of maximum likelihood estimation is quite similar to that of the fixed-effect model, which ensures the reliability of results.

Next, regarding instrumental variable estimation, although it clears the Sargan’s overidentification test and instrumental variables work well, Price does not satisfy the sign condition. This might be due to that this model is based on random-effect estimation, and care should be taken to solve this problem by utilizing fixed-effect estimation. We can obtain the similar results with regard to the factors promoting 3G mobile phone.

Finally, Arellano-Bond dynamic panel estimation shows a desirable result. After

controlling the endogeneity and lag-effect, Price and GDP satisfy the sign condition significantly. Some variables turn to be insignificant, but we can identify that variables such as “release of iPhone,” “FeliCa,” “Data Roaming,” “Full Music,” and “Flat rate” promote Japanese 3G mobile in great extent.

3.3. Result of estimation: Individual carrier

The results of estimation on three individual carriers are summarized in Table 6. They also clear the overidentification test, however these estimations are rather problematic because of multicollinearity. Accordingly some variables are omitted in estimation. The estimations results of all carriers satisfy the sign condition of Price and GDP significantly. It should noted that the price elasticity amounts -5.58 for NTTdocomo, -1.14 for au, and -2.14 for Softbank. All carriers have an elastic coefficient, but NTT’s differs greatly from the others. This result is different from that of Akematsu, Shoji, Abu and Tsuji [2010], namely, NTTdocomo’s price elasticity is about -8.795. au -1.597, and Softbank -8.803. This seems to be due to difference in data used. They utilized data announced by carriers, while this paper uses those calculated from ARPU and MOU.

This result is also the opposite of that of ADSL diffusion case; NTT’s elasticity is the smallest and Yahoo!BB’s the highest (Akematsu 2009). It suggests that demand structure of fixed and wireless access might be different.

3.3.1 NTTdocomo

According to the estimation result of NTTdocomo Table 6, Charges and GDP satisfy the sign conditions. FeliCa (1%), Data Roaming (1%) and Flat rate (1%) are identified as significant. NTTdocomo’s price elasticity is about -5.58.

NTTdocomo is characterized by reliable network infrastructures and supplies diversified value-added services. It was NTTdocomo that offered PDC (Personal Digital Cellular) branded as 2G mova in March 1993 providing 2.4 kbps data speed and increased to 9.6 kbps in April 1995 using both 800MHz and 1.5GHz bandwidth. 3G FOMA services was commercially launched in October 2001 for the first time all over the world embedded with 384 kbps data speed, 2GHz bandwidth, and varieties of services meeting needs of subscribers. Note that, as a part of the giant NTT family, NTTdocomo’s 3G FOMA maintains high quality of services ranging from communication to behavior assistance.

3.3.2 au

According to the estimation result, Charges and GDP satisfy the sign condition, and au's price elasticity is around -1.14. MNP (5%), Data Roaming (1%) and Flat rate (1%) are positively significant. The sign of MNP is positive, which indicated that by MNP au tends to obtain its subscribers from the other carriers.

au holds the second market position according to total number of subscribers. Following docomo, au introduced 144 kbps high-speed CDMA2000.1x 3G services simultaneously in major cities across Japan in April 2002. CDMA2000 was recognized by the ITU to be an IMT-2000 3G communications system. Initially, 2 GHz bands were required for accreditation, but the ITU later determined that frequency bands other than 2 GHz, such as 800 MHz bands, were acceptable in IMT-2000 systems. au thus took the first initiative toward the development of 3G services using 800 MHz which caused its high market share compare to NTTdocomo and Softbank at the beginning, being demonstrated in Figure 1.

In response to increasing demand for data transmission, au started CDMA1xEV-DO technology, an IMT-2000 high-speed 3G wireless data services that operated at a frequency of 2 GHz and offered transmit data economically at speed of up to 2.4 Mbps for the first time in Japan in November 2003. Thus, it is obvious that au's introduction of CDMA1xWIN, a new 3G services that enabled the full functionality of actual 3G.

3.3.3. Softbank

According to the result, Charges and GDP satisfy the sign condition and its price elasticity is about -2.14. Significant factors are iPhone (5%), FeliCa (1%), and Full Music (1%). MNP is not significant. Price elasticity obtained here is rather small in comparison with

Softbank uses the same W-CDMA technology as docomo for its 3G network. This operator is renounce for its picture mail ("*Sha-Mail*" in Japanese) innovation for 2G services across the world for the time in November 2000. For 3G services, a number of technological innovations find significant to compete with other operators.

4. DISCUSSIONS

In accordance with the recognition of the importance of factors promoting 3G mobile phone as discussed earlier in Table 3, explanation is based on the findings from

empirical analysis and its implications to whole market and individual carriers followed by technological innovations, policy and different marketing strategies to capture subscribers. Here we discuss particular problems related to the diffusion of Japanese 3G mobile phone.

4.1. Competition policy

The Japanese mobile phone market including 3G mobile was originally designed to develop under a competitive framework, accordingly the market was quite competitive and there was less room for competition policy. MIC has less intervention in the market in contrast with the fixed phone and ADSL markets analyzed by Tsuji and Tomizuka [2006] and Akematsu [2008]. In order to benefit subscribers and to increase competition among operators, and thereby lower the prices, the MNP was first introduced in Japan in October 2006. The main regulatory objective of this policy is to benefit subscribers and to increase competition among operators.

In this paper, MNP is included as a independent variable in the estimation of only individual carriers, while in the whole market MNP did not show any good result. The estimation results of individual carriers is shown in Table 6 and summarized in Table 7. According to this, MNP increased significantly au's subscribers, while it did not affect significantly those of NTTdocomo and Softbank. In our previous estimation in Akematsu, Shoji, Abu, and Tsuji [2010], however, MNP finds significance at the 1% level in the whole market, which contributed to diffusion. As for the effect to individual carriers, it reduced subscribers of docomo and au. This result is different from the findings of Shin [2006] who discussed instead of small mobile operators of the US, only the top five national operators added subscribers with MNP. These are natural outcomes due to switching cost, subscribers lock-in, and customer loyalty. Switching cost is incurred when switching, including time, money and psychological costs, and is defined as perceived risk of performance of losing contents related to existing operator.

NTTdocomo's customers are often thought to be loyalty, since it is a group company of giant NTT and established the brand name since monopoly. Since these also consist of switching cost. Other carriers always require to take into consideration in the competition policy.

The largest switching cost for Japanese 3G mobile phone is changing the e-mail address. Since most of subscribers use mobile e-mail (59.5%) more often than via PC (55.0%) as of MIC survey 2007, MNP itself is not enough to shift subscribers to another carrier in this aspect. A policy such as "Mobile Address Portability (MAP)" in which subscribers can maintain the same address under a different carrier requires in future.

4.2 Pricing plan

Based on our estimation, “flat rate” plays an important role for 3G subscribers. Various discount schemes offered by individual carriers increased subscribe with 3G mobile phone. For au, this variable finds significance at the 1% level and it has the largest coefficient, while NTTdocomo has the second largest. Softbank, however, is not significant. The reasons for this is found in the fact that au initiated flat rate for packet, as mentioned earlier and, since Softbank’s aggressive pricing strategies were implemented in the later period, and these are less reflected in this estimation. If all discount plans are include in estimation, Akematsu, Shoji, Abu, and Tsuji [2010] concluded that Softbank has the largest price elasticity among three mobile carriers at the 1% significance level, and followed by Softbnak, au has the second largest price elasticity.

5. CONCLUSIONS

Using rigorous panel data analysis, we heuristically identified the effect of technological innovations and policy on the diffusion of 3G mobile phone. This study identifies specific technologies which have been developing in the Japanese mobile phone market to betterment of services and advancing to LTE and 4G. In accordance with the estimated results, technologies innovations in entertainment and flat rate charges are crucial and are found significant in all aspect for the 3G diffusion. A brief summary of result is elaborated in Table 7. NTTdocomo leads the market for every functionality development until now. Following NTTdocomo, other two carriers emphasize to develop the same technology or upgrade according to their skilled R&D.

Table 7 Summary of result

| | Whole market | Carrier | | |
|--------------|--------------|---------|------|----------|
| | | docomo | au | Softbank |
| MNP | N.A. | | ** | |
| iPhone | *** | N.A. | N.A. | ** |
| FeliCa | *** | *** | | |
| One-Seg | | | | |
| Data Roaming | *** | *** | *** | N.A. |
| Full Music | *** | | | *** |
| 2 in 1 | *** | | N.A. | N.A. |
| Flat rate | *** | *** | *** | *** |

***, **and * indicate significance at the 1%, 5%, and 10% levels, respectively

N/A: Excluded from analysis

Mobile telephone is the most widely used form of communications in the world today. Mobile communications boost the earnings of many users, change the local economy and even significantly raise the GDP of many countries. The diffusion of mobile telephony has a number of benefits, but there is a huge gap in diffusion of 3G mobile phone. Dippon [2010] raises the following question: “yet, why is the case that only two countries, Japan and Korea, have more 3G than 2G subscribers? Similarly, why do leading nations, like the U.S., U.K., and Germany, have 3G penetration rates of less than 30%?” This paper attempts to answer the question. The conclusion we obtained technological innovation were achieved first, then based on this various service innovation were followed. It should stress that the former includes innovations embodied in handsets as well as those related to network and IP technologies. The diffusion of new services depends on how they meet consumers preference and needs, but behind services innovations there always technological innovations.

On the other hand, some other social backgrounds such as consumers’ attitudes, economic and business systems are required. One example is found by Funk (2007) mentioning “the Japanese and later other service providers solved the first startup problem for mobile Internet (mobile Internet uses proxy for 3G) with entertainment content that was supported by a micro-payment system (service providers collect and pass on content fees to content providers) and customized handset that enabled to display this content in a consistent manner, while Western service providers were slow to introduce micro-payment systems and entertainment content due to their initial focus on business users.”

In the context of factors diffusion in Japanese mobile phone, one example related to the above point is found in iPhone. To date, iPhone has been attracting subscribers, particularly younger generation. Its share is far less than that of U.S. The reason is simple, it lacks in functionalities such as payment, although it has many other functions. iPhone subscribers have to carry another handset, 3G mobile phone for e-payment or train or airplane reservations.

The analysis and discussion in this paper surely contribute to further diffusion of 3G mobile in other economies, developed and developing.

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Table 5 Result of Estimation (Panel Analysis)

| | Model 1: Fixed Effect Model | | | Model 2: Random Effect Model | | | Model 3: MLE Estimation | | | Model 4: EC2SLS IV Estimation | | | Model 5: Arellano-Bond Dynamic Estimation | | |
|---|-----------------------------|---------|-----|------------------------------|---------|-----|-------------------------|---------|-----|-------------------------------|---------|-----|---|--------|-------|
| | Coef. | S.E. | | Coef. | S.E. | | Coef. | S.E. | | Coef. | S.E. | | Coef. | S.E. | |
| Subscriber 2G | -0.3738 | 0.1161 | *** | -0.8071 | 0.0686 | *** | -0.3963 | 0.1122 | *** | -1.0906 | 0.0846 | *** | -0.0247 | 0.0146 | * |
| Price | -5.6608 | 1.1024 | *** | 8.7298 | 0.9110 | *** | -5.4648 | 1.0796 | *** | 14.8728 | 1.1970 | *** | -0.2408 | 0.1450 | * |
| GDP | 20.3956 | 2.3483 | *** | 12.8319 | 3.3099 | *** | 20.4359 | 2.2834 | *** | 11.6855 | 3.6934 | *** | 0.7438 | 0.3427 | ** |
| iPhone | 0.8619 | 0.2398 | *** | 1.4180 | 0.3609 | *** | 0.8709 | 0.2337 | *** | 3.2451 | 0.4443 | *** | 0.1350 | 0.0301 | *** |
| FeliCa | 0.6408 | 0.2327 | *** | 1.3889 | 0.3473 | *** | 0.6494 | 0.2267 | *** | 1.7667 | 0.3894 | *** | 0.1059 | 0.0289 | *** |
| One-Seg | -0.4459 | 0.1786 | ** | -0.4117 | 0.2566 | | -0.4557 | 0.1737 | *** | -0.4036 | 0.2863 | | -0.0140 | 0.0222 | |
| Data Roaming | 1.9661 | 0.1795 | *** | 0.9267 | 0.2494 | *** | 1.9483 | 0.1751 | *** | 1.7133 | 0.2908 | *** | 0.3075 | 0.0268 | *** |
| Full Music | 1.0622 | 0.1635 | *** | 0.8357 | 0.2470 | *** | 1.0569 | 0.1593 | *** | 1.5422 | 0.2851 | *** | 0.1775 | 0.0218 | *** |
| 2 in 1 | -0.7304 | 0.1895 | *** | 0.5309 | 0.2178 | ** | -0.7319 | 0.1837 | *** | -0.0959 | 0.2514 | | -0.0751 | 0.0240 | *** |
| Flat rate | 0.6641 | 0.2314 | *** | 1.3904 | 0.3406 | *** | 0.6659 | 0.2253 | *** | 0.6563 | 0.3874 | * | 0.1006 | 0.0288 | *** |
| Constant | -229.5070 | 29.9758 | *** | -176.5150 | 43.3778 | *** | -229.8722 | 29.2208 | *** | -180.4471 | 48.3777 | *** | -6.6322 | 4.2302 | |
| Number of observation | 277 | | | 277 | | | 277 | | | 277 | | | 273 | | |
| R-squared: within | 0.9499 | | | 0.8882 | | | - | | | 0.8584 | | | - | | |
| R-squared: between | 0.3371 | | | 0.8602 | | | - | | | 0.9932 | | | - | | |
| R-squared: overall | 0.4381 | | | 0.8892 | | | - | | | 0.8664 | | | - | | |
| Log likelihood | - | | | - | | | -162.54 | | | - | | | - | | |
| F test (Pooled OLS vs. FEM) | F(2, 185) = 124.83 | | | 0.0000 | | | - | | | - | | | - | | |
| LM test (Pooled OLS vs. REM) | Chi2(1) = 10.91 | | | 0.0010 | | | - | | | - | | | - | | |
| Hausman test (FEM vs. REM) | Chi2(10) = 285.31 | | | 0.0000 | | | - | | | - | | | - | | |
| Arellano-Bond test for AR(1) in first differences | | | | - | | | - | | | - | | | z = 4.19 | | 0.000 |
| Arellano-Bond test for AR(2) in first differences | | | | - | | | - | | | - | | | z = 0.99 | | 0.323 |
| Sargan test of overidentification restrictions | | | | - | | | - | | | - | | | chi2(2) = 2.18 | | 0.336 |

Note: ***, ** and * indicate the 1%, 5% and 10% significance level, respectively.

Table 6 Result of Estimation (Individual Carriers, IV estimation)

| | NTTdocomo | | | AU | | | Softbank | | |
|----------------|-----------|--------|-----|---------|--------|-----|----------|--------|-----|
| | Coef. | S.E. | | Coef. | S.E. | | Coef. | S.E. | |
| Price | -5.578 | 1.907 | *** | -1.135 | 0.522 | ** | -2.138 | 0.454 | *** |
| GDP | 13.113 | 3.981 | *** | 2.588 | 1.451 | * | 9.327 | 2.501 | *** |
| MNP | -0.039 | 0.317 | | 0.195 | 0.076 | ** | 0.195 | 0.181 | |
| iPhone | | - | | | - | | 0.472 | 0.216 | ** |
| FeliCa | 0.874 | 0.273 | *** | 0.082 | 0.128 | | 0.640 | 0.155 | *** |
| One-Seg | 0.467 | 0.374 | | 0.111 | 0.128 | | 0.142 | 0.181 | |
| Data Roaming | 2.212 | 0.223 | *** | 0.357 | 0.104 | *** | | - | |
| Full Music | 0.002 | 0.430 | | 0.163 | 0.105 | | 1.817 | 0.125 | *** |
| 2 in 1 | 0.097 | 0.237 | | | - | | | - | |
| Flat rate | 0.784 | 0.293 | *** | 1.194 | 0.085 | *** | | - | |
| Constant | -139.063 | 46.942 | *** | -14.856 | 17.708 | | -102.780 | 33.326 | *** |
| Number of obs. | 102 | | | 92 | | | 84 | | |
| Adjusted R2 | 0.9112 | | | 0.8592 | | | 0.8992 | | |

***1%, **5%, *10% of significance level, respectively.