A CROSS-COUNTRY ANALYSIS OF UBIQUITOUS BROADBAND DEPLOYMENT: EXAMINATION OF ADOPTION FACTORS

By

SANGWON LEE

A DISSERTATION PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

2008

To my parents, parents-in-laws, and wife, Eunjeong.

ACKNOWLEDGMENTS

First, I thank God for his unconditional love for me. Without his love, I could not complete my study and dissertation in the doctoral program. Second, I am sincerely grateful to my dissertation chair, Dr. Justin Brown. He supported my study during three years while I am studying telecommunication policy and media economics field at University of Florida. Without his support, help, and advices, I could not achieve anything during my Ph.D. study. Third, I truly appreciate my dissertation co-chair, Dr. Sylvia Chan-Olmsted. From her I learned a lot of valuable direction and creative ideas of my research in media economics and management field. It was truly honor for me to write seven research papers with her. Forth, I thank Dr. David Ostroff. He gave me theoretical approaches about new media systems, which I haven't familiar with. These theoretical perspectives are truly useful for my dissertation and research.

Also, I truly appreciate Dr. Sanford Berg's comments and ideas, which were very influential for dissertation. Without his comments and ideas, I could not write better dissertation. I also thank Dr. Mark Jamison's comments and supports for my research. From Dr. Jamison, I got a lot of valuable information about broadband issues. Without his support, I could not receive a research grant from the NET Institute.

In addition, I gratefully acknowledge a research grant from the NET Institute, which supported part of my dissertation research. Also, I thank my parents, parents-in-law, and brother-in-law, Kue Cheol, for their loving encouragement. Finally I truly thank my wife, Eunjeong's unconditional sacrifice and support for my study.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Abstract of Dissertation Presented to the Graduate School
of the University of Florida in Partial Fulfillment of the
Requirements for the Degree of Doctor of Philosophy

A CROSS-COUNTRY ANALYSIS OF UBIQUITOUS BROADBAND DEPLOYMENT:
EXAMINATION OF ADOPTION FACTORS

By

Sangwon Lee

August 2008

Chair: Justin S. Brown
Cochair: Sylvia M. Chan-Olmsted
Major: Mass Communication

Broadband infrastructure is a key component of the knowledge economy. Broadband connections on both fixed and mobile networks are becoming an indicator of the knowledge economy. A growing body of scholarship details contributing factors that may lead to broadband adoption. In spite of the growing body of literature about broadband adoption, these previous studies have the following limitations: 1) small number of independent variables; 2) insufficient number of observations; 3) lack of theoretical background; 4) focus on only fixed broadband technology; and 5) inconsistent empirical results. Employing the largest secondary data set, this study examines adoption factors of fixed and mobile as well as ubiquitous broadband (fixed and mobile).

The result of nonlinear and linear regression analysis of fixed broadband deployment suggests local loop unbundling (LLU) policy, platform completion between different broadband technologies and other diverse industry, ICT (Information and Communication Technology) and demographic factors influenced fixed broadband diffusion. Specifically, the regression analysis of fixed broadband penetration found different types of LLU policies and previous fixed broadband penetration are significant factors of fixed broadband deployment. Some of the

significant factors of fixed broadband deployment are different in the developed countries and developing countries.

The result of linear regression analysis of mobile broadband deployment suggests market mediated standardization policy, income, and 1G and 2G mobile penetration are significant factors of mobile broadband deployment.

Also, the result of linear regression analysis of ubiquitous broadband deployment suggests with other industry, ICT, and demographic variables, network competition between fixed and mobile and interactions of platform completion in fixed broadband markets and multiple standardization policy in mobile markets are significant factors of ubiquitous broadband deployment. Some of the significant factors of ubiquitous broadband deployment were different in the developed countries and developing countries.

Considering the result of this study, countries fostering broadband deployment need to adopt LLU policy for broadband, but the costs and benefits of LLU policy should be carefully considered. The results of this study also implies for the initial 4G mobile markets, whereby fixed and mobile broadband networks will be converged, governments need to be open to diverse competitive standards instead of government-mandated standards. However, in the long term, industry-wide coordination and mutual learning processes are more important.

CHAPTER 1
INTRODUCTION

Broadband Deployment and Knowledge Economy

During the last part of the twentieth century, there has been a steady growth in Internet and mobile adoption around the globe. Continuous technological innovations in the telecommunication industry enable society to enter the era of convergence between broadband Internet, wireless networks, and multimodal content and services. Broadband communications and infrastructure lie at the heart of this trend. Broadband connections, on both fixed and mobile networks, are now recognized as indicators of the so-called knowledge economy. Widespread and affordable broadband access encourages innovation and economic growth in an economy, and attracts foreign investment (ITU, 2003a).

Although there exist various definitions of broadband, the International Telecommunication Union (ITU) defines broadband as a network offering a combined speed of equal to, or greater than, 256 kbit/s in one or both directions (ITU, 2005; ITU, 2006).[1] According to the International Telecommunication Union (ITU), as of December 2005, telecommunication providers in more than 166 countries offered fixed-broadband services and roughly 68 nations launched mobile-broadband services (ITU, 2006). Fixed broadband may be defined as transmission capacity with sufficient bandwidth to permit combined provision of voice, data, and video, with no lower limit through a fixed line (ITU, 2003b). 3G mobile systems, which provide higher transmission rates than possible in second generation wireless technologies, supporting data transport rates of at least 256 kbit/s for all radio environments, are

[1] Initially broadband was defined as communication technologies that provide high-speed, always-on connections to the Internet for large numbers of residential and small-business subscribers (Crandall, 2005; Fransman, 2006; ITU, 2003). This definition of broadband focuses on the fixed broadband technologies such as DSL and cable modem. The definition of broadband by the ITU - network offering a combined speed of equal to, or greater than, 256 kbit/s in one or both directions- may include more diverse broadband technologies such as mobile broadband.

commonly referred to as "mobile broadband" (ITU, 2006; ITU, 2003b; Shelanski, 2003). Successful diffusion of fixed and mobile broadband is necessary for the provision of advanced IP-based services such as VoIP (Voice over Internet Protocol) and IP TV (Internet Protocol Television) as well as mobile television (Lee et. al, 2007; Lee & Brown, 2007).

Technologies for Broadband Communications

For broadband connectivity, either fixed mobile, and portable Internet technologies may be employed. Fixed broadband is mainly implemented through technologies such as digital subscriber line (DSL), cable modem, and fiber- to- the- home (FTTH) (ITU, 2003b). Mobile broadband is mainly implemented through technologies such as W-CDMA, CDMA 2000 1x EV-DO, and HSDPA (ITU, 2006). Main portable Internet technologies are wireless local area networks (WLAN), wireless metropolitan area networks (WMAN), and IEEE 802.16 (WiMAX).

Fixed Broadband

Thus far, for fixed-broadband, globally the dominant platforms are DSL (64.34 %) and cable modem (29.89 %), though other platforms, such as fiber-to-the-home and other platforms serve around 6 percent (ITU, 2006).

DSL can bring high-bandwidth information to homes and small businesses over ordinary copper telephone lines (ITU, 2005). DSL is distance-sensitive meaning that speeds and signal qualities are influenced by the distance between the subscriber and local exchange carrier's nearest switching office (ITU, 2003b). Typically, the download speed of DSL services range from 256kbit/s to 6 Mbit/s, depending on DSL technology (Crandall, 2005). The most popular DSL technology is Asymmetric Digital Subscriber Line (ADSL), which is used mainly for Internet access, video on demand, and remote LAN access (ITU, 2006; Crandall, 2005). In terms of market share, DSL is typically the dominant fixed-broadband technology in most countries (OECD, 2007; ITU, 2006).

Cable modems may provide high-speed interactive services, including internet access, to be delivered over the cable television infrastructure, to give subscribers Internet speeds up to 1.2Mbit/s (ITU, 2006). Cable modem is a dominant fixed-broadband technology in the United States and Canada (OECD, 2007; ITU, 2006).

Fiber- to- the- home (FTTH) generally refers to broadband telecommunications systems deployed on fiber-optic cables directly to homes or business (ITU, 2006). Fiber- to- the- home is an enabling technology, which can offer the highest speed fixed-broadband connections (Crandall, 2005). In Japan, new FTTH subscribers outnumbered new DSL subscribers in 2005 (ITU, 2006).

Mobile Broadband

For mobile broadband, the dominant standards in operation are W-CDMA (60.04 %) and CDMA 2000 1x EV-DO (39.95 %) (ITU, 2006). W-CDMA (Wideband Code Division Multiple Access) is a third-generation mobile standard under the IMT-2000 banner, first deployed in Japan, also referred to as UMTS in Europe (ITU, 2006). Theoretically W-CDMA can achieve a data rate of 2 Mbit/s for low-mobility environment and 384 kbit/s for mobile systems (ITU, 2006). These are adequate speeds for broadband application such as downloading music and video to a handset (ITU, 2003b; ITU, 2006). HSDPA (High-Speed Downlink Packet Access) is an enhanced protocol to W-CDMA networks which boosts network capacity up to

14.4 Mbps (GSM Association, 2007; ITU, 2006). HSDPA technologies were first deployed in 2005 by AT&T in the United States (GSM Association, 2007). CDMA 2000 (Code Division Multiple Access 2000) is another third-generation digital cellular standard under the IMT-2000 banner, first deployed in Korea, which includes CDMA2000 1x and 1xEV-DO (Evolution, Data Optimized) (ITU, 2005). CDMA 1xEV-DO is currently the dominant technology in the U.S. and

Korea. Theoretically it can achieve a data rate of up to 2.4 Mbit/s and supports advanced data applications, such as MP3 transfers, video conferencing, and video downloads (ITU, 2006).

Portable Internet

Portable Internet can be defined as a platform for high-speed data access using Internet Protocol (IP) (ITU, 2004). Compared to the fixed and mobile broadband, portable Internet technologies can offer a better level of mobility than fixed-broadband services but a higher level of speed than mobile broadband services (ITU, 2006).

For portable Internet, wireless local area networks (WLAN), wireless metropolitan area networks (WMAN), and IEEE 802.16 (WiMAX) are main technologies (ITU, 2006). WLAN is a wireless network whereby a user can connect to a local area network (LAN) through a wireless connection, as an alternative to a wire-based local area network. The most popular standard for WLAN is Wi-Fi (wireless fidelity) (ITU, 2006; ITU, 2004). WLAN technology enables mobile devices connect to a fixed-broadband network via radio links with an "access point" (ITU, 2006). WMAN is a wireless communications network that covers a geographic area, such as a city or suburb (ITU, 2006; ITU, 2004). By increasing signal power of the base stations, the technology can reach mobile devices at a considerable distance (ITU, 2006).

WiMAX is a fixed-wireless standard IEEE 802.16 that allows for long-range communications at 70 Mbit/s over 50 kilometres (ITU, 2004). It can be used as a backbone Internet connection to rural areas. WiMAX could eventually be combined with 3G mobile broadband to offer more customized high-speed environments (ITU, 2006). WiMax is being considered as a pre-4G standard with WiBro.[2] In Korea, the first commercial mobile application

[2] "System beyond IMT-2000" or 4G mobile technology will be able to provide a comprehensive IP solution where voice, data and streamed multimedia (ITU, 2004). 4G will be achieved after wired and wireless technologies converge and will capable of providing 100 Mbit/sec and 1 Gbit/sec speeds both indoors and outdoors with premium quality and high security (Wikipedia, 2007).

for WiMAX certified products took place with the launch of WiBro services (OECD, 2007d). WiBro employs the licensed 2.3 GHz frequency band with an 8.75 MHz channel bandwidth (OECD, 2007d). Both WiBro and Mobile WiMAX use OFDMA, but the number of sub-channels and the frame structure differs between the two standards (OECD, 2007d).

Current Status of Global Broadband Deployment

Many countries are still in the early stages of broadband, as evidenced by the differences in deployment between countries. According to the latest Organization for Economic Co-operation and Development (OECD) penetration data (December 2006), Denmark, Netherlands, Iceland, Korea, and Switzerland are leading broadband economies among OECD countries (see Table 1-1).

According to the International Telecommunication Union (ITU), there were approximately 216 million fixed-broadband subscribers and just over 60 million mobile broadband subscribers at the end of 2005 (ITU, 2006). According to the Organization for Economic Co-operation and Development the OECD, fixed-broadband adoption over the first 10 years is faster than previous services like cellular and dial-up services across OECD countries (OECD, 2006).

There exists a wide range of mobile broadband diffusion levels across countries. As of December 2005, Korea, Italy, Japan, Portugal and Hong Kong were the top five mobile broadband economies in terms of the 3G mobile penetration rate (ITU, 2006; see Table 1-2).

WCDMA and CDMA 2000 are the two main standards for 3G wireless technologies (Gandal, Salant, & Waverman, 2003). Most of the European Community adopted WCDMA for 3G wireless services. By November 2005, almost 92 percent of the European 3G mobile customers subscribed to WCDMA technology-based services (ITU, 2005). On the other hand, many countries in the Americas, Asia, and Africa adopted CDMA 2000 or both CDMA 2000 and WCDMA in their 3G markets.

Table 1-1. Fixed-Broadband Penetration (Top 20 OECD countries) by Technology, December 2006

	DSL	Cable	Fiber/LAN	Total	Rank	Total Subscribers
Denmark	19.6	9.4	2.8	31.9	1	1,590,539
Netherlands	19.5	12.0	0.4	31.8	2	5,192,200
Iceland	28.8	0	0.2	29.7	3	87,738
Korea	11.4	10.7	7.0	29.1	4	14,042,728
Switzerland	18.8	8.8	0	28.5	5	2,140,309
Norway	21.7	3.8	1.5	27.7	6	1,278,346
Finland	23.5	3.5	0	27.2	7	1,428,000
Sweden	16.0	5.2	0	26.0	8	2,346,300
Canada	11.4	12.3	0	23.8	9	7,675,533
Belgium	14.0	8.4	0	22.5	10	2,353,956
U.K.	16.5	5.1	0	21.6	11	12,993,354
Luxembourg	18.2	2.2	0	20.4	12	93,214
France	19.1	1.1	0	20.3	13	12,699,000
Japan	11.1	2.8	6.2	20.2	14	25,755,080
United States	8.5	10.3	0.3	19.6	15	58,136,577
Australia	15.0	3.3	0	19.2	16	3,939,288
Austria	10.6	6.4	0	17.3	17	1,427,986
Germany	16.4	0.5	0	17.1	18	14,085,232
Spain	12.1	3.1	0	15.3	19	6,654,881
Italy	13.8	0	0.4	14.8	20	8,638,873

Note. Data were derived from Organization for Economic Co-operation and Development (2007a). For the measurement of fixed-broadband penetration rate, the total number of fixed-broadband subscribers per 100 inhabitants was employed. The ranking is based on the fixed-broadband penetration rate.

Source: OECD broadband statistics. Paris: OECD.

Table 1-2. Mobile Broadband Penetration (Top 20 ITU membership countries), December 2005

	Mobile Broadband Penetration Rate	Rank	Total Mobile Broadband Subscribers
Korea	25.95	1	12,530,945
Italy	17.67	2	10,262,000
Japan	13.89	3	17,792,600
Portugal	8.79	4	922,560
Hong Kong, China	8.19	5	576,500
Brunei Darussalam	8.11	6	30,000
U.K.	7.60	7	4,536,800
Sweden	7.31	8	660,790
Austria	6.84	9	559,000
Luxembourg	5.76	10	26,480
Ireland	4.94	11	205,200
Australia	3.97	12	801,100
Singapore	3.11	13	131,920
Germany	2.77	14	2,289,000
Israel	2.71	15	187,000
France	2.62	16	1,583,000
Norway	2.49	17	115,000
Denmark	2.27	18	123,210
New Zealand	2.24	19	90,300
Spain	2.20	20	939,000

Note. Data were derived from the International Telecommunication Union (2006). For the measurement of mobile broadband penetration rate, the total number of mobile broadband subscribers per 100 inhabitants was employed. The ranking is based on the mobile broadband penetration rate.

Source: ITU Internet Reports 2006. Geneva: ITU.

Thus, with the deployment of higher-speed mobile networks such as 3G, users can access networks at any time, though always-on connectivity by fixed and mobile technologies (ITU, 2005). Now ubiquitous broadband connections through both fixed and mobile networks are becoming the norm in the knowledge economy (ITU, 2006).[3] Also, in the near future, it is expected that all wired and wireless communications will converge with Next Generation Networks (NGN) (OECD, 2007c). In this context, it is necessary to examine the extended definition of broadband-"ubiquitous broadband" including both fixed and mobile broadband.

[3] Vision of a ubiquitous broadband network is broadband connection anytime, anywhere, by anyone and anything (ITU, 2005).

Table 1-3. Ubiquitous Broadband Penetration (Top 20 ITU membership countries), December 2005

	Total Broadband Penetration Rate	Rank	Total Broadband Subscribers
Korea	51.20	1	24,721,656
Hong Kong, China	31.80	2	2,235,598
Japan	31.40	3	40,157,748
Italy	29.40	4	17,082,048
Sweden	27.60	5	2,498,790
Netherlands	27.20	6	4,437,000
Iceland	26.50	7	78,017
Switzerland	24.50	8	1,830,446
Norway	23.90	9	1,106,352
Finland	23.80	10	1,251,700
United Kingdom	23.60	11	14,076,700
Austria	21.20	12	1,733,000
Luxembourg	21.00	13	97,713
Canada	20.90	14	6,741,699
Taiwan, China	20.60	15	4,716,103
Israel	20.50	16	1,416,626
Portugal	20.30	17	2,134,594
Belgium	19.30	18	1,992,791
Singapore	18.40	19	794,420
France	18.30	20	11,048,600

Note. Data were derived from the International Telecommunication Union (2006). For the measurement of total broadband penetration rate, the total number of fixed and mobile broadband subscribers per 100 inhabitants was employed. The ranking is based on the total broadband penetration rate. Source: ITU Internet Reports 2006. Geneva: ITU.

There were over 275 million total broadband subscribers including fixed and mobile broadband at the end of 2005 (ITU, 2006). In terms of the total broadband penetration rate including fixed and mobile broadband subscribers, there were 4.3 subscribers per 100 inhabitants at the end of 2005 (ITU, 2006). As of December 2005, Korea, Hong Kong, Japan, Sweden and Netherlands were the top broadband economies in terms of the total broadband penetration rate (see table 1-3) (ITU, 2006).

Significance of the Study

A growing body of scholarship details contributing factors that may lead to broadband adoption. Some empirical studies find that platform competition (inter-modal competition), local loop unbundling (LLU), income, and demographic variables such as population density increase fixed-broadband diffusion (Distaso et al., 2006; Garcia-Murillo, 2005; Grosso, 2006; Lee, 2006b).

Many countries have considered local loop unbundling (LLU)[4] and facilities-based competition as important policy initiatives to promote rapid fixed-broadband diffusion. Platform competition (facilities-based competition among several different broadband platforms) is often thought to be crucial for reducing prices, improving the quality of service, increasing the number of customers and promoting investment and innovation (ITU, 2003b; DotEcon and Criterion Economics, 2003). There is a growing body of empirical research about fixed-broadband diffusion. In their study of 30 OECD countries, Cava-Ferreruela and Alabau-Muňoz (2006) find that technological competition, low cost of deploying infrastructures, and predilection to use new technologies are key factors for broadband supply and demand. Analyzing data from 14 European countries, Distaso et al. (2006) argue that inter-platform competition drives broadband diffusion, but that competition in the DSL market does not play a significant role. Using logit regression, Garcia-Murillo (2005) finds that unbundling an incumbent's infrastructure only results in a substantial increase in broadband deployment for middle-income countries, but not for their high-income counterparts. Kim and others (2003) suggest the preparedness of a nation and the cost conditions of deploying advanced networks are the most consistent factors

[4] Local loop unbundling refers to the process of requiring incumbent operators to open, wholly or in part, the last mile of their telecommunications networks to competitors (ITU, 2003b; OECD, 2003).

explaining broadband uptake in OECD countries. Using generalized least squares, Grosso (2006) finds that competition, income, and unbundling increase broadband diffusion.

Despite the growing body of literature about broadband adoption, these previous studies have the following limitations: 1) small number of independent variables; 2) insufficient number of observations; 3) lack of theoretical background; 4) focus on only fixed-broadband technology; and 5) inconsistent empirical results. The previous empirical studies on fixed-broadband adoption employed only a limited number of independent variables with insufficient data. Also, previous studies have not covered some important independent variables such as institutional environment, international Internet bandwidth, telecommunication infrastructure investment, content, and age. Previous studies did not propose refined and diverse theoretical frameworks like platform/network competition, network effects, path dependence, and leapfrogging. Also, previous studies focused only on fixed-broadband technology and didn’t include the mobile broadband from the analysis. In addition, the results of these empirical studies are not consistent.[5]

Convergence in application and services, technology, industry, policy, consumer demand and multiple-play strategies have lead to the expansion of the definition of broadband. As broadband technology is developed, the definition of broadband is extended as a network offering across various types of platforms including both fixed and mobile broadband access at the same time (ITU, 2006). Also fixed and mobile networks will be converged in the Next Generation Networks (NGN) (OECD, 2007c).

To incorporate this trend, this study also examines influential factors that lead to the deployment of this “extended definition of broadband-ubiquitous broadband,” which includes

---

[5] For instance, the effects of local loop unbundling policy still are not clearly understood and the results of empirical studies are consistent.

both fixed and mobile broadband. Currently no cross-cultural empirical work exists that incorporates and measures factors that affect fixed and mobile broadband adoption. Also, it is interesting to examine whether network competition between fixed and mobile broadband network has influenced broadband deployment.

Employing more independent variables based on refined theoretical framework with the largest data sets, this study examines adoption factors of fixed and mobile as well as ubiquitous broadband (fixed and mobile).

Purpose of the Study

Current study examined why broadband adoption differs among countries. Diverse macro-level factors such as policy, industry, technology, consumer demographics, ICT, and institutional environment might influence new media technology adoption. In particular, regulation and competition policy are important macro-level factors of new media technology adoption.

Regarding fixed-broadband deployment, many countries have considered local loop unbundling (LLU) and facilities-based competition as important policy initiatives to promote rapid fixed-broadband diffusion. It is widely held that platform competition (facilities-based competition among several different broadband platforms) is crucial for reducing prices, improving quality of service, increasing customers and promoting investment and innovation (DotEcon & Criterion Economics, 2003).

Regarding mobile deployment, there have been debates on whether single or multiple standards policy is more effective for faster adoption of mobile. Competition among different mobile standards might be a key driver of mobile broadband deployment (Lee & Marcu, 2007). Regulation and competition policy are also important factors in the deployment of ubiquitous broadband (including fixed and mobile broadband at the same time). LLU and network competition between fixed and mobile networks with other factors — ICT, technology, consumer, industry, and institutional factors — might be key drivers of ubiquitous broadband deployment.

Using a large data set from the ITU (International Telecommunication Union) and the OECD (Organization for Economic Co-operation and Development), this empirical study examines determinants of the global fixed, mobile and ubiquitous broadband deployment. Based upon the results of this empirical research, this dissertation suggests policy and strategy implications. Also this study has implications for the deployment of future 4G or Next Generation Networks (NGN), which fixed and mobile broadband services will be offered over the same network.

CHAPTER 2
LITERATURE REVIEW

This section discusses scholarship that addresses theoretical background and influential factors of broadband adoption. Typically broadband adoption research either examines factors at a micro-individual level or macro-national level (between countries) or case analysis, employing both quantitative and qualitative methodologies. While this review focuses on empirical studies regarding broadband adoption between countries, micro-individual level and case studies are also discussed. Based upon the classification of existing research, policy, industry, demographic, and Information and Communication Technology (ICT) and institutional factors may influence fixed and mobile broadband deployment. This section also presents theory and research related to network effects, compatibility, path dependence, leapfrogging and digital divide issues.

Theoretical Backgrounds of Broadband Adoption

Micro-Individual Level Approaches

In the micro-individual level, socio-psychological factors may influence broadband adoption. Rogers theorized that innovations would spread through society in an S-curve, as the early adopters select the technology first, followed by the majority, until a technology or innovation is common (Rogers, 2003). In explaining the diffusion of innovation, Rogers (2003) identified five perceived characteristics of an innovation such as relative advantage, compatibility, complexity, trialability and observability. The relative advantage of an innovation refers the degree to which an innovation is perceived as being better than the idea it supersedes and this construct is one of the best predictors of the adoption of an innovation (Rogers, 2003). Compatibility can be defined as the degree to which an innovation is perceived as consistent with the existing values, past experiences and needs of potential adopters (Rogers, 2003). Complexity can be defined as the degree to which an innovation is perceived as relatively difficult to understand and use (Rogers, 2003). Trialability is the degree to which an innovation may be experimented with on a limited basis (Rogers, 2003). Observability refers the degree to which the results of an innovation are visible to others (Rogers, 2003).

These five perceived characteristics may influence the broadband adoption in the individual level. Relating to fixed-broadband adoption, Oh et al. (2003) finds that innovation attributes, such as compatibility, visibility and result demonstrability and perceived usefulness, perceived ease of use and perceived resources based on the extended technology acceptance model have influenced fixed-broadband adoption in Korea.

The Technology Acceptance Model (TAM) suggests that perceived usefulness (PU) — the degree to which a person believes that using a particular system would enhance his or her job performance — and perceived ease-of-use (PEOU) — the degree to which a person believes that using a particular system would be free from effort — may influence technology acceptance by users (Davis, 1989). Through employing the Technology Acceptance Model (TAM) model, Pagani (2004) found perceived usefulness, ease of use, price, and speed are the most important determinants of adoption of 3G multimedia mobile services.

Recently, based on the uses and gratifications perspective, Chang et al. (2006) found that perceived needs for passing time was a significant factor in explaining the difference between adopters and non-adopters of online games.

However, this individual level of analysis on the new media technology adoption cannot explain why there is a difference in broadband diffusion between countries.

Platform Competition

In the macro-national level of analysis, diverse dimensions of competition are useful in explaining broadband adoption. Porter (1979)'s five forces model could be a micro-level basis for macro-level analysis.

Porter (1979) suggested five forces may determine the competitive intensity and therefore attractiveness of a market. Porter referred to these forces as the micro-environment, to contrast it with the more general term macro-environment (Porter, 1979). Five forces include three forces from "horizontal competition," namely threat of substitute products, threat of established rivals, and threat of new entrants. The two remaining forces are based upon "vertical competition" the bargaining power of suppliers and bargaining power of customers (Porter, 1979). Among Porter's five forces, the concept of "horizontal competition" is a useful micro-level basis for explaining different dimensions of competition at the macro-level. In the broadband markets, the threat of substitute products can be transformed into platform competition (intermodal competition-competition between different technologies). The threat of established rivals can be transformed into market competition, and the threat of new entrants could be related to the intra-modal competition through open access policy.

Platform competition is an important theoretical basis of this study. Platform competition occurs when different technologies compete to provide telecommunication services to end-users (Church & Gandal, 2005). Platform competition in network industry involves competition between technologies that are not only differentiated, but also are competing networks (Church & Gandal, 2005). Strong platform competition among different technologies may lead to lower prices, increased feature offerings, and more extensive broadband networks (ITU, 2003a).

Regarding mobile broadband, platform competition could be related to the market-mediated standard policy. Though market-mediated standardization policy might lead to limited network externalities and economies of scale, multiple standards and different types of services across technologies enable the existence of diverse competing systems, which may lead to more and better services in the market (Gruber & Verboven, 2001b). Market-mediated standard policy may also bring differentiated services and lower prices to customers (Gruber & Verboven, 2001b; Church & Gandal, 2005).

Relating to ubiquitous broadband, which includes both fixed and mobile broadband, platform competition could be related to the competition between fixed and mobile network. This competition between networks might lead to lower prices, improving the quality of service, increasing the number of customers and promoting investment and innovation (ITU, 2003b; DotEcon and Criterion Economics, 2003). With other dimensions of competition such as intra-modal competition and market competition (market concentration), platform competition might be a key driver of broadband adoption in many countries.

Network Effect

Network effect may also be related to the broadband adoption. Network effect is the circumstance in which the net value of an action is affected by the number of agents taking equivalent actions (Liebowitz and Margolis, 1994). In other words, network effect means the fact that higher usage of certain products or services makes them more valuable.

One consequence of network effect is that the purchase of a good by one individual indirectly benefits others who own the good. This type of side-effect in a transaction is known as an externality in economics, and externalities arising from network effects are known as "network externalities" (Church & Gandal, 2005). The resulting "bandwagon effect" is an example of a positive feedback loop (Rohlfs, 2001).

For products characterized by network effects the decision by consumers regarding which network to join will depend not only on relative product characteristics and prices, but also the expected size of the network (Church & Gandal, 2005).

The role of the size of the existing installed base in determining the size of the network in the future arises because positive network effects give rise to positive feedback effects (Shapiro,

& Varian, 1999). These positive feedback effects create a strong tendency for "the strong grow stronger " in a virtuous cycle. The greater the installed base, the greater network benefits, the more attractive the network to adopters, the greater adoption and the greater the installed base, etc. (Shapiro, & Varian, 1999; Church & Gandal, 2005).

If network effect exists in the use of broadband, new subscribers joining a broadband network might influence the utility of current subscribers (Madden et al., 2004). Network effects might suggest that current subscription is positively correlated to the previous subscription (Economides & Himmelberg, 1995). Madden et al. (2004) found that these network effects have influenced mobile telephony subscription. However there is no empirical work to test the existence of network effects on fixed-broadband subscription.

Rohlfs (2001) suggested a form of network effects that he calls "bandwagon effects." He suggests that as more and more people subscribe new media technology such as VCRs, personal computer, mobile and broadband Internet, others are attracted to it (Rohlfs, 2001; Haring et al., 2002). Recently Jang et al. (2005) found that the pattern of diffusion of mobile telecommunications for OECD countries is generally characterized by an S-shaped curve; nevertheless, significant differences exist in the spread of the S- curve, largely due to differences in the magnitude of the network externality coefficient.

Digital Divide and Leapfrogging Theory

Digital divide is also related to the broadband adoption issue. The development of new media technology that is valuable to consumers might create concerns for consumers who cannot or will not purchase it (Crandall, 2003). In general, digital divide could be defined as the dichotomy between those who have computers and Internet access and those who do not (Warschauer, 2003). Rice and Katz (2003) identifies and analyzes three kinds of digital divides for both the Internet and mobile—users/nonuser, veteran/recent, and continuing/dropout.

Employing a national representative telephone survey of Americans in 2000, they found similarities and differences among those digital divides that are based on demographic variables (Rice &Katz, 2003). Through an analysis of Australian household survey data, Madden et al. (1996) found there is information inequality (digital divide) resulted from broadband network access. Recently using comprehensive U.S. data covering all forms of fixed-broadband technology, Prieger (2003) finds unequal broadband availability in areas with high concentrations of poor, minority, or rural households. More recently using a panel data from 161 countries over 1999-2001 period, Chinn and Fairlie (2006) finds global digital divide is mainly explained by income differentials. However there is no empirical study on the "broadband digital divide" that employs a cross-country data analysis.

Digital divide concerns of infrastructure deployment of communication technologies are also related to the leapfrogging theory, whereby developing countries may skip inferior, less efficient, more expensive or more polluting technologies and industries and move directly to more advanced ones. According to Steinmueller (2001), leapfrogging can be defined as bypassing stages in capacity building or investment through which countries were previously required to pass during the process of economic development.

Developing countries generally cannot afford to create or rebuild basic ICT infrastructure for new communication technologies. However, because of the lack of investment in legacy systems, hardware, and software, they can be in a good position to leapfrog over some of these incremental steps (Lee, 2006). Since Internet technology makes it easier to develop ICT services, current technologies offer great potential to developing countries looking to introduce ICT into their region (Steinmueller, 2001).

Relating to the new media technology, leapfrogging can be applied to the new media technology adoption such as fixed-broadband. Broadband may have an effect on the digital divide between countries: as developed countries adopt broadband, the current trend is for them to pull even further ahead of developing ones, thus increasing the digital divide (ITU, 2003). However, as the unit costs of providing broadband become cheaper, some developing countries may be able to use the technology to leapfrog ahead, providing an integrated voice, video and data network using the same infrastructure (ITU, 2003). The technology of wireless LANs, in particular, can be used successfully to extend broadband access (ITU, 2003).

However, in developing countries, introducing more advanced new media technology such as 3G mobile is a considerable burden (Lee, 2006). One problem hindering the successful introduction of future 3G mobile in developing countries is the relatively higher cost of 3G services than 2G services for consumers in those countries (ITU, 2001)

Recently an empirical study suggested that an established infrastructure for relevant information and communication technologies is an influential factor for 3G mobile diffusion (Lee et al., 2007). This result of the empirical study might be different from the initial diffusion of 1G or 2G mobile systems which exhibited the phenomenon of leapfrogging in many countries where the mobile penetration rates significantly outpaced the demand for other ICT services (Lee et al., 2007). More refined empirical research on the leapfrogging and new media technology adoption such as broadband is necessary.

Path Dependence

Path dependence theory can be related to the policy choice for broadband diffusion. In general, path dependence refers to the "dependence of a system or network on past decisions of producers and consumers" (Margolis & Liebowitz, 1990). Margolis and Liebowitz (2000) distinguish between different types of path dependence. Some types of path dependence do not imply inefficiencies and, while they may be interesting to study for other reasons, do not challenge the policy implications of neoclassical economics.[1]

The case of the QWERTY keyboard (David, 1985) is a well-known example of path-dependence theory. The current dominance of the QWERTY keyboard today is not thought to be due to its superiority for typing but because it was invented earlier than the Dvorak keyboard(David, 1985; Bensen & Farrell, 1994; Katz & Shapiro, 1994; Shapiro, & Varian, 1999). Paul David called this “path dependence,” and argued that inferior standards can persist simply because of the legacy they have built up. The claim of path dependence, at least as it applies to public policy, is that people often either ignore those interconnections or only look at them in a narrow and myopic manner, and so they get locked into bad solutions.

Relating to the mobile communications standardization policy, in spite of EU’s success story of mandated standard (GSM) in initial stage of 2G, if market-mediated standard policy leads to faster adoption of 3G mobile in the markets, it implies that the EU 3G standard policy that may have assumed WCDMA or locked operators into WCDMA might be a very costly public policy decision (Gandal et al., 2003). In this situation, EU countries would be better off if the countries adopt multiple standards simultaneously, but it would be difficult for them to coordinate - involves such a challenge (Margolis & Liebowitz, 2000). Path dependence induces an inefficiency arising from small differences in initial public policy-making, which lead to outcomes that are likely to be costly to change (Liebowitz & Margolis, 1995)

[1] They contrasted this category both to “first-degree” path dependence, which has no implications for efficiency, and to “second-degree” path dependence, where transactions costs and/or the impossibility of foresight lead to outcomes that offer lower payoffs than some hypothetical -- but unattainable -- alternative. Only what they call “third degree” path dependence - a situation where society would be better off if everybody switched standards simultaneously- may lead to inefficiencies.

Drivers of Ubiquitous Broadband Concept

A purpose of this study is to examine adoption factors of ubiquitous broadband. The concept of "ubiquitous computing" was first used in 1991 by Marc Weiser (1991). He pointed to the "invisibility" of technology through the transformation of everyday items into small computers (Weiser, 1991). In the first paradigm of computing, mainframes were shared by many people (one computer for many people) (ITU, 2006). Now we are moving from the personal computer era (one computer per person) to proceed to the phase of the ubiquitous computing era (many computers per person) (ITU, 2006).

With the development of mobile technologies, this notion of ubiquitous computing can be applied to the ubiquitous broadband access, which means multiple broadband accesses per person with multiple devices. Under the ubiquitous broadband environment, broadband access anytime, anywhere, by anyone and anything through both fixed and mobile broadband is possible (see figure 2-1). For the ubiquitous broadband, network competition between fixed and mobile networks might be a driver of broadband deployment. Also, for the ubiquitous broadband, platform competition among different fixed broadband technologies and standard competition between different mobile standards as well as intra-modal competition in a technology are possible. These multiple modes of competition may suggest implications for competition policy and regulation for broadband infrastructure.

Multiple play strategy, which is a marketing concept for delivering multiple services over a single access network, is also a driver of "ubiquitous broadband concept." For instance, many telecommunications companies and cable operators launched "quadruple play service," which offers fixed-broadband access, television, fixed telephone, and mobile broadband service in a bundled package.

Also, in the near future, in the environment of the Next Generation Networks (NGNs) which will be achieved after fixed and mobile networks are converged by fully IP (Internet Protocol)-based integrated system, the notion of "ubiquitous broadband" could be replaced by "Converged Ubiquitous Broadband (Cubiquitous Broadband)" over a network (see figure 2-1). In this NGN environment, single or multiple standardization policy is possible in a country. In this context, examination of adoption factors of "ubiquitous broadband" is necessary.

Underlying forces of this notion of ubiquitous broadband may be attributed to convergence in services, technology, industry, policy, consumer demand, and multiple play strategy. These underlying forces might be drivers of "ubiquitous broadband concept."

Application and Service Convergence

Initially the main application of fixed-broadband was Internet access, but now fixed-broadband offers more diverse applications and services such as voice, data and video services (e.g. IP TV) (ITU, 2003). Also, in the early developmental stage of mobile, main application and services was voice, but current 3G mobile can provide more diverse applications and services such as Internet, data and video services (e.g. Mobile TV) (ITU, 2001).

Currently both fixed and mobile broadband services offer the same or similar application and services, which might be differentiated. In addition, in fixed and mobile converged environment, this trend of application and service convergence will be accelerated (OECD, 2007c).

Technological Innovation and Convergence

With the development of technology, higher bandwidth and technological convergence is possible (ITU, 2004; ITU, 2005; ITU, 2006; Kim, 2005). Technological innovation and higher bandwidth lead to broadband access anytime, anywhere and by anyone and anything through

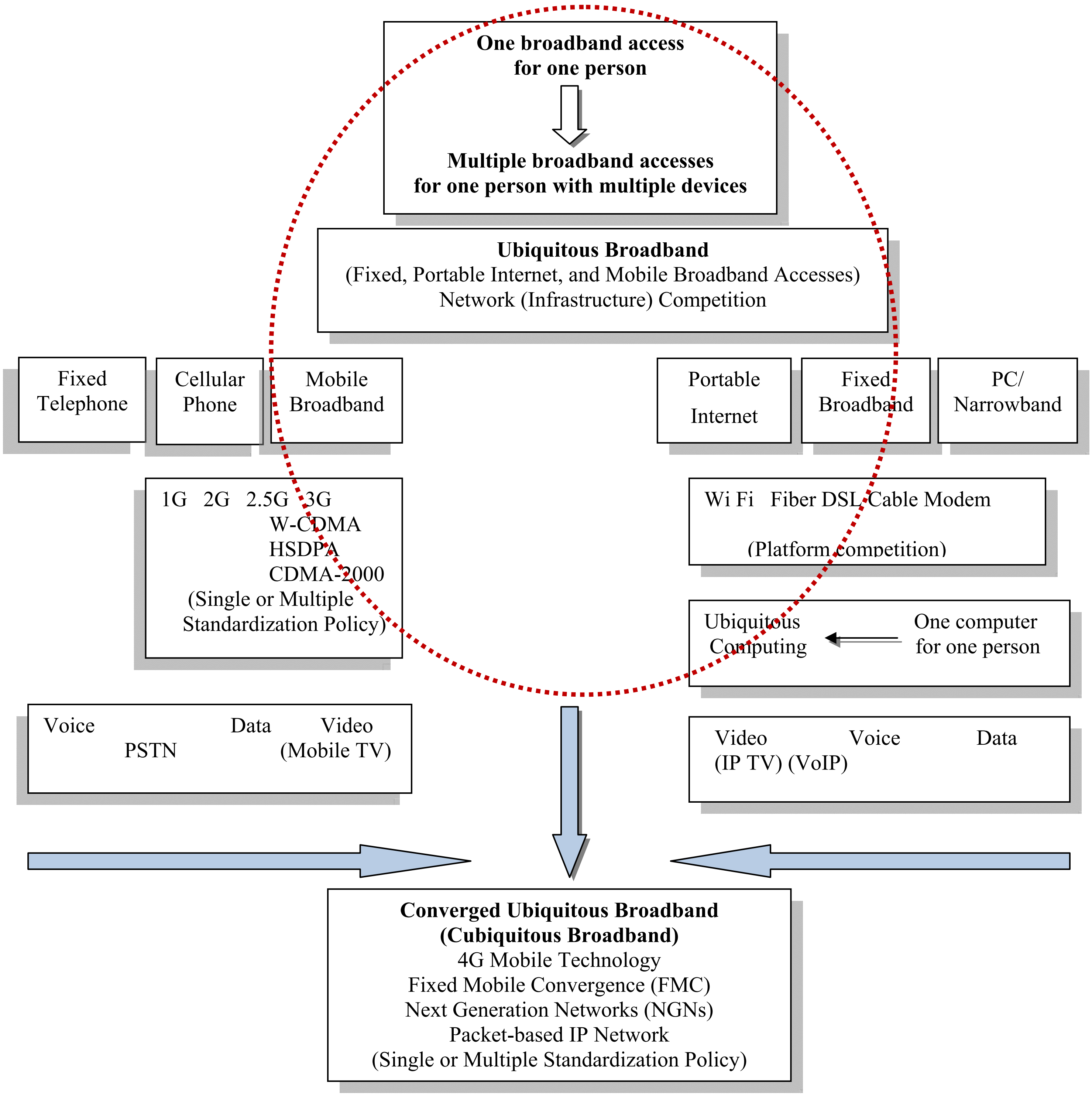


Figure 2-1. Concept of ubiquitous broadband

both fixed and mobile broadband (ITU, 2006). Technological innovation also may lead to the ubiquity of digital technology (many computers for one person) (ITU, 2006; Weiser, 1991).As fixed-mobile convergence develops, voice, data, and video services using the fixed broadband and mobile networks become interrelated (OECD, 2007c).

Industry Convergence and Multiple Play Strategy

Horizontalization of businesses may be a key factor of converged, ubiquitous broadband. Collis et al. (1997) suggested convergence is transforming the multimedia industry from three vertical businesses (telephone, television, and computer) to five horizontal segments such as content, packaging, transmission network, manipulation infrastructure, and terminals. Friedman (2006) suggests that businesses had to begin collaborating horizontally as opposed to vertically, which meant that companies and people had to start collaborating with other departments or companies in order to add value creation or innovation.

Multi-play strategy might also lead to industry convergence and be a driver of broadband diffusion. The strategy of triple or quadruple play has been touted as one of the most significant strategic moves for both cable operators and telephone companies in the last few years (Time Warner, 2007). In this context, bundling strategy might be a factor in broadband deployment. Multi-play services through bundling strategy continue to gain popularity in global telecommunication markets. By September 2005, triple play services were available from 48 providers in 23 OECD countries and quadruple-play offers (including mobile voice) were available in 10 OECD countries (OECD, 2006b). It was said that bundling might increase customer retention and average revenue per user (ARPU) (Krauss, 2006).

Policy Convergence

Wirth (2006) suggests that because technology innovation and standardization, changing consumer characteristics, search for synergy, bandwagon effect, and content repurposing, policy is a driver for convergence. Policy and regulatory responses to media convergence and new media technology may lead to integration of policy and regulatory system, which might lead to converged services (Sawng et al., 2005).

Consumer Demand

Consumer demand for diversity, mobility, higher speeds, interactivity, personal access, and converged multimedia services may be factors leading to ubiquitous broadband. In general, end users are interested in services and applications when underlying technology (platform) is not important to end users (Kim, 2005). Dowling *et al.* (1998) suggests that there are three dimensions of convergence: consumer demand, industry/firm supply, and technology. It was also put forward that a converged product that can fulfill new or existing consumer needs in a novel, more convenient, and/or less expensive way is crucial to the success of its offering (Picard, 2000). Thus, consumer demand may influence converged ubiquitous broadband.

Research on Fixed-broadband Adoption

Policy Factors

On the supply side, many countries have considered local loop unbundling regulation as important policy initiatives to promote rapid broadband diffusion. Local loop unbundling (LLU) — which refers to the process by which incumbent carriers lease, wholly or in part, the local segment of their telecommunications network to competitors — has been considered an important policy to stimulate intra-modal competition (OECD, 2003). Implementation of LLU widely differs among countries. Types of LLU – full unbundling[2], line sharing[3] and bit stream

[2] Full unbundling (physical access to raw copper) exists where an incumbent provides full access to its raw copper (OECD, 2003). With full unbundling new entrants take full control of the copper pairs and can provide both voice and DSL services. However, the incumbent still retains ownership of the unbundled loop and is responsible for maintenance (OECD, 2003).

access[4]— and LLU prices are different across countries (OECD, 2003). There are arguments for and against local loop unbundling. LLU policy might introduce competition in the DSL markets and prices might fall when incumbent carriers are compelled to open up their networks to competitors (ITU, 2003a). Thus, LLU may generate consumer benefits in the near future through open access to competitors (Frieden, 2005a). However, LLU may confiscate incumbents' property and reduce their incentives to invest in advanced telecommunication technologies (Frieden, 2005a).

There have been a lot of debates on the effects of LLU in the United States. Hausman (2001, 2002) claims LLU regulation in the U.S. has impeded the incumbents' deployment of the network facilities required for DSL, conveying competitive advantages and market share to cable operators providing broadband cable modem services.

Through an empirical analysis of CLECs' investment plans and an event study that explores the impact of the Tauzin-Dingell bill on share prices, Glassman and Lehr (2001) found that reduction of network unbundling for broadband deployment places downward pressure on the competitive carriers' equity prices, thereby reducing investment by entrants in network facilities. Employing logit regression analysis from selected ITU countries, Garcia-Murillo (2005) found unbundling an incumbent's infrastructure only results in a substantial improvement in broadband deployment for middle-income countries, but not for their high-income counterparts. Distaso et. al. (2006) also found LLU price is an explanatory variable of fixed-

[3] Line sharing (shared access) allows an incumbent to maintain control over copper pairs while new players can lease part of the copper pair spectrum for data services including Integrated Services Digital Network (ISDN) and DSL (OECD, 2003). However, there are some technical concerns such as line noise (OECD, 2003).

[4] Bit stream access (wholesale access) is a type of wholesale arrangement in which new entrants have no managing control over the physical lines and are not allowed to install their own equipment(OECD, 2003). The new entrants generally do not favor this type because, unlike full unbundling and line sharing, they can only provide the services that the incumbent designates (OECD, 2003).

broadband adoption. Recently through regression analysis of OECD countries' data, Grosso (2006) found LLU have influenced fixed-broadband deployment. Through their empirical study with 179 observations, Wallsten (2006) found unbundling is a key driver of fixed-broadband adoption in OECD countries. In spite of a growing body of literature on the effects of LLU policy on broadband deployment, the effectiveness of different types of LLU policies such as full unbundling, line sharing, and bit stream access and the impact of LLU price regulation have not been clearly understood.

Cross-ownership also might influence broadband deployment. An ITU report suggests some broadband markets have struggled with broadband deployment because of cross-ownership issues (ITU, 2003a). If a provider owns portions of a cable company and telecommunication company, the provider has disincentives to roll out both DSL and cable modem (ITU, 2003a). For successful broadband deployment, government role is also important. Especially in the rural regions, there is often insufficient private investment for network construction. In these high cost regions, full public funding for infrastructure or public-owned network is often the only option (ITU, 2003b).

Institutional environment might also influence broadband deployment. Using ordinary least-squares hierarchical regression analysis, Andonova (2006) finds institutional environment such as political rights and civil liberties are correlated with deployment of the Internet. In spite of these previous studies, there was no empirical study, which tests the influences of cross-media regulation, and institutional environment on fixed-broadband diffusion.

Industry Factors

A few studies argue that inter-modal competition (platform competition among different technologies) with other factors in the supply side of the broadband market increase broadband adoption. Aron and Burnstein (2003) suggest that broadband availability in a state is driven by inter-modal competition and cost factors, but not by the raw availability of broadband services. Using U.S. state data in 2000, they found that the independent effect of direct, inter-modal competition is associated with increased household subscription to broadband services (Aron & Burnstein, 2003).

Recently, through two different econometric analyses (time-series analysis and multiple-regression analysis) using data from 50 states, Lee (2006) suggests platform competition and the availability of different broadband platforms have influenced broadband diffusion in the United States. Through panel data analysis, Denni and Gruber (2005) find that inter-platform competition, intra-platform competition in the DSL market, and telecommunication density have a positive impact on broadband diffusion in the United States.

Beyond research that assesses industry factors that contribute U.S. broadband adoption, several studies compare multiple factors of broadband adoption among countries. From the analysis of EU membership countries' data, a report from DotEcon & Criterion Economics shows that inter-modal competition among platforms rather than access-based market entry increases the adoption of broadband. This report suggests broadband penetration tends to be higher in European countries where DSL and non-DSL platforms have similar market share, but the report was not supported by statistical methods (DotEcon & Criterion Economics, 2003). Based upon analysis of data from 14 European countries, Distaso, Lupi and Maneti (2006) demonstrate that inter-platform competition drives broadband adoption, but that competition in the DSL market does not play a significant role. Through a comparative study of Korea and the United States, Lee and Chan-Olmsted (2004) suggest a combination of policy, consumer demands, and technological factors supported by broadband-related industry could make differences in broadband deployment among countries. Through statistical analysis of approximately 100 countries, Garcia-Murillo (2005) found fixed-broadband price, income (GDP per capita), competition have been influential factors of fixed-broadband adoption.

Cava-Ferreruela and Alabau-Muňoz (2006) suggest technological competition, low cost of deploying infrastructures, and prediction of the use of new technologies might be key factors for broadband supply and demand, respectively. Grosso (2006) found competition and LLU influenced broadband penetration among OECD countries. More recently Fransman (2006) suggested "disruptive competitors" are an important determinant of global broadband performance.[5]

More recently employing multivariate analysis of 110 country data, Lee and Brown (2007) find platform competition, broadband speed, and content contribute global broadband adoption. They also find the impacts of platform competition are strong when market share of dominant technology and non-dominant technology is similar (Lee & Brown, 2007).

Recently Ridder (2007) found low fixed-broadband price is correlated to the high level of broadband diffusion. More recently, Atkinson et al. (2008) also found low level of broadband price is factor of broadband adoption in OECD countries.

Higher bandwidth[6] also might be correlated with the broadband adoption. Growth in demand for higher capacity is a key driver of broadband diffusion (ITU, 2006). Fansman (2006) suggests capacity of broadband is a measure of national performance in broadband. In spite of

---

[5] "Disruptive competition" can be defined as existing when competitors to the incumbent in the markets have been so aggressive with their pricing that they even do not cover their marginal costs in the markets and end up making short-run losses (Fransman, 2006). Fransman (2006) argues that a main reason for superior broadband performance of Korea and Japan is results of "disruptive competition."

[6] Bandwidth is a measure of how fast data flows on a given transmission path, and determines the quantity and the speed of information transmitted (ITU, 2003b).

importance of bandwidth, there was no empirical work, which tests correlation between bandwidth and broadband deployment.

Telecommunication infrastructure investment from private and public sector is a contributing factor of telecommunication network deployment (ITU, 2003b). Some top broadband economies such as Korea and Sweden employed national deployment strategies to promote infrastructure investment from public and private sector (ITU, 2003a).

Demographic Factors

Some empirical studies on fixed-broadband deployment suggest demographic factors such as income and population density have influenced fixed-broadband adoption. In addition to the supply-side research, several empirically-driven studies illustrate the demand side of broadband adoption in the U.S. Through data analysis of a national sample of U.S. households, Rappoport, Kridel, Taylor and Alleman (2001) found that price elasticity of demand for broadband service is much greater than narrowband service. Using an estimation of an economic model based on statistical data from 2000 to 2001, Crandall, Sidak and Singer (2002) showed that the decision to use a broadband connection depends on the opportunity cost of time for the user and intensity of Internet use. Kim, Bauer and Wildman (2003) suggest the preparedness of a nation and population density as a cost condition of deploying advanced networks are the most consistent factors explaining broadband uptake in OECD countries.

More recently, through a nationwide U.S. survey, Savage and Waldman (2005) found that preference for high-speed access is apparent among higher income and college-educated households. Through data analysis of U.S. national surveys from 2002 to 2005, Horrigan (2005) claims the intensity of online use is the critical factor in understanding the home broadband adoption decision and suggests the intensity of Internet use is a function of connection speed and years of online experience. Horrigan's more recent survey demonstrates younger age, higher education and income, and urban living share of population may lead to higher level of broadband adoption (Horrigan, 2007). In addition, the United States Government Accountability Office (2006) found consumers with higher incomes and college degrees are significantly more likely to adopt fixed broadband.

Chaudhuri, Flamm and Horrigan (2005) found the influences of traditional socio-demographic variables like income and education on broadband deployment are strong in the U.S.. They also find substantial variation observed in access price may largely have a spatial explanation of Internet access (Chaudhuri et al., 2005). Recently, through a household-level analysis, Clements and Abramowitz (2006) found income, age, educational attainment, and the presence of children influence adoption of broadband service in the United States. Using data from 50 states in the United States, Lee (2006) also suggests income have influenced broadband deployment in the United States. Recently Grosso (2006) found income measured by GDP per capita is related to the broadband penetration among OECD countries.

Wallsten (2006) also found income and urbanization are factors of broadband adoption in OECD countries. In his empirical study, Turner (2006) found income and poverty rate are influential factors of broadband deployment. Recently Ridder (2007) and Atkinson (2008)'s empirical study found age is negatively correlated to the broadband adoption in OECD countries.

More recently Trkman et al. (2008) found population density and education are influential demographic factors of fixed-broadband deployment in EU countries.

ICT Factors

Recent studies on broadband diffusion provide ICT factors such as infrastructure and teledensity have influenced fixed-broadband adoption. Through a comparative study of broadband deployment in Canada, Japan, Korea, and the United States, Frieden (2005) argues the role of government in Information and Communication Technology (ICT) incubation is important for rapid broadband deployment. Kim, Bauer and Wildman (2003) suggest the preparedness of a nation is a factor of broadband deployment. Using panel data analysis of the U.S. states, Denni and Gruber (2005) also find that telecommunication density has been an influential factor of broadband deployment in the United States. Recently Wallsten (2006) also found teledensity is a factor of broadband adoption in OECD countries. Through a multivariate analysis of ITU membership countries, Lee and Brown (2007) find ICT infrastructure is a significant factor of global broadband adoption. More recently, through a factor analysis, Trkman et al. (2008) found that communication technology expenditure, household PC access rate, Internet penetration, and fixed phone penetration are factors of fixed-broadband deployment in EU countries.

Despite existing research efforts to better understand broadband adoption, the influence of important variables on global broadband adoption across countries — such as platform competition, LLU, population density, urban population, ICT infrastructure, broadband price, content, age and broadband speed — have not been clearly understood in a single systematic study (see Table 2-1). However, there is no empirical study which test effects of institutional environment, international bandwidth, and telecommunication infrastructure investment. Also, there is no empirical work, which tests network effects and digital divide related to the diffusion of fixed-broadband.

Research on Mobile Broadband Adoption

Policy Factors

Many stakeholders in the mobile industry such as policymakers, mobile service operators, content providers, and end-users play an influential role in shaping mobile broadband deployments at different phases. Saugstrup and Henten (2004) propose that regulation and market competition are important factors affecting the deployment of the new 3G technology.

Table 2-1. Cross-National empirical studies on fixed-broadband adoption factors

Study	Main independent variables	Significant variables
Kim et al. (2003) 30 countries 30 observations	Broadband price Dial-up service price Income Preparedness of a nation Competition Population density Policy (unbundling, cross ownership, government funding)	Preparedness of a nation Population density
Garcia-Murillo (2005) Approximately 100 countries Observations varies depending on the model (18-92)	Broadband price Income Education Competition Population density Policy (unbundling, cross ownership) Content Personal computers Internet access	Broadband price Income Population density Competition Internet access Unbundling
Distaso et al. (2006) EU countries 158 observations (15 time periods)	Intra-modal competition Inter-modal competition Rights of way LLU price Price of leased line Price of ten minutes call	Inter-modal competition LLU price
Cava-Ferreruela and Alabau-Muňoz (2006)	Broadband price Competition Infrastructure investment Telecom services penetration	Technological competition Cost of deploying infrastructures Economic indicators

Table 2-1 Continued.

30 countries 90 observations (3 years: 2000-2002)	Internet indicators Economic indicators Demographic indicators Education indicators Social indicators	Demographic indicators
Grosso (2006) 30 countries 117 observations (4 years: 2001-2004)	Competition Income Unbundling Fixed Internet penetration	Competition Income Unbundling
Wallsten (2006) 30 countries 179 observations (5 years: 1999-2003)	Income Unbundling Teledensity Urbanization	Income Unbundling Teledensity Urbanization
Turner (2006) 30 countries 30 observations (2005)	Price Income Population density Education Poverty rate Urbanization	Income Poverty rate
Ridder (2007) 30 countries 30 observations (2005)	Price Income Age Education Saturation Weather Urbanization Competition Policy	Price Age Urbanization Saturation
Atkinson et al. (2008) 30 countries 30 observations (2007)	Market concentration Urbanicity Home ownership Income Temperature Median age Internet users Education Income inequality Price Internet users	Urbanicity Income Internet users Price Median age

Table 2-1 Continued.

Trkman et al. (2008) 25 countries 23 observations (2006)	Electronic purchasing Internet users Information technology expenditures Communication technology expenditures Household Income Household PC access PC users Internet penetration GDP per capita Price Fixed phone penetration Population density Education	Communication technology expenditures Household PC access Internet penetration GDP per capita Fixed phone penetration Population density Education

Specifically, Gans, King, and Wright (2004) suggest that "standardization" policy plays a significant role in the success of wireless communication. From a historical perspective, regulations such as standardization with the intent to safeguard consumers have sometimes confined the development of new telecommunications services. Maeda, Amar, and Gibson (2006) argue that because of the typical progression of a new media technology market from the initial monopoly dominance of a large firm, to the addition of many smaller competitors in the growth stage, to the few, surviving strong competitors after a phase of consolidation, inflexible regulation such as mandated standardization may not actually benefit the consumers.

Many studies in the economics of standards have focused on the private and social incentives for standardization (Gandal, 2002; David & Greenstein, 1990). Most of the literature suggests that compatibility and standardization may lead to efficient outcomes in the market. Theoretically, a single standard tends to deliver better economies of scale and network externalities. Nevertheless, Gandal et al. (2003) claim that the aforementioned benefits of standardization are unclear in the mobile market. It was argued that as long as the mobile networks are interconnected and coverage is effective, there is little need for compatibility (Gandal et al., 2003). Roaming (i.e., using one's cellular phone outside the provider's coverage area) is a main network benefit for mobile communication. Thus, there are few network externalities that may justify a government mandated standard in the mobile market (Gans et al., 2004). In essence, there are both advantages and disadvantages in market mediated multiple standards and government mandated single standard. Though market-mediated standards might lead to limited network externalities and economies of scale, multiple wireless standards and different types of services across technologies enable the existence of diverse competing systems which may lead to more and better mobile services (Gruber & Verboven, 2001).

There are a few empirical studies addressing the standardization policy in the mobile industry. Gruber and Verboven (2001) find that the early diffusion of digital technologies in mobile markets was faster in Europe where most countries had adopted a single standard. Kioski and Kretschmer (2002) empirically estimate the effects of standardization through two alternative approaches. They conclude that standardization has a positive but insignificant effect on the timing of initial entry of 2G services but can also lead to higher prices because it dampens competition. It seems that while a government-mandated standard was useful in stimulating mobile adoption in the initial stage (e.g., first generation mobile), as the mobile technology becomes more advanced, standardization policies become less relevant and even limiting (Cabral & Kretschmer, 2004). Cabral and Kretschmer (2004) examine the effectiveness of public policy in the context of competing standards with network externalities and discovered that current mobile diffusion levels are quite similar between the United States (multiple standards) and Europe (mostly single standards). Recently Kauffman and Techatassanasoontorn (2005) found that market-mediated standardization policy is a contributing factor of international diffusion of digital mobile technology. More recently, Rouvinen (2006) investigate the factors affecting the diffusion of digital mobile telephony across developed and developing countries. It was concluded that mandated standards actually hinder competition in both groups. The review of literature thus far points to the changing role of standardization policy as mobile technology and markets continue to develop. It also reveals that while there have been studies on the effects of standardization in early 1G and 2G mobile industry, no empirical work has ventured into the new 3G mobile markets concerning the effects of standardization policy.

In regards to 3G licensing policy, since the methods of licensing adopted by a country impact the nature and number of service providers in a mobile market, an effective policy framework for licensing 3G operators is important to the diffusion of 3G mobile services. Xavier (2001) suggests that, for the 3G mobile to develop successfully in a country, the licensing framework must reflect the high levels of investment required for a 3G-network rollout and nurture the growth of new and innovative 3G services.

Granting individual 3G licenses typically involves some form of selection process. As the wireless business becomes more attractive to investors, the competition for the right to operate a certain 3G spectrum has intensified. In general, three main selection approaches — auctions, beauty contests, and a hybrid system — have been used to choose licensees by governmental agencies (Xavier, 2001; ITU, 2001; Bauer, 2003). Many countries like Canada, Germany, and the U.K. used auctions to assign 3G licenses. Supporters of the auctioning approach argue that auctions are transparent and fair, and can be designed to incorporate a wide range of public policy goals (McMillan, 1995). In addition, the auctioning of 3G spectrum licenses can generate substantial revenues for governments and may increase competition with existing services (Kwerel & Strack, 2001). Auctioning also allocates 3G spectrums to those operators that value the spectrum most highly, and who can thus be expected to make the most economically efficient use of the spectrum (Xavier, 2001). However, it is difficult to translate theoretically efficient auction designs into practice because they assume that all potential bidders have full access to information on 3G markets (Xavier, 2001). Additionally, government control over spectrum allocation means there are strong government incentives to manage the resource in a way that maximizes their own revenue and the procedure of auction design could be quite complex (ITU, 2004). Noam (2003) also argues that the U.S. spectrum auctioning system generated costs of deployment delay far in excess of any efficiency gains and permitted other countries to leapfrog the United States in mobile technology, applications, and consumer satisfaction.

In other countries such as Japan, Korea, Norway, and Sweden, the "beauty contest" or comparative evaluations method has been used for 3G licensing (ITU, 2001; Xavier, 2001). With the beauty-contest method, the government accepts applications from eligible applicants and decisions to award licenses are typically based on multiple criteria (ITU, 2004). The advantage of the beauty contest is that it awards 3G licenses to those applicants that would make the best use of the license from a social point of view (ITU, 2004). However, the beauty-contest method can be time-consuming and unfair.

Some countries such as Austria, Italy, and Hong Kong adopted a combined or hybrid method for awarding 3G licenses (ITU, 2001; Xavier, 2001). The hybrid method requires applicants to pre-qualify under multiple criteria similar to those established for the conventional beauty contest in order to bid (Xavier, 2001). Licenses are then allocated on the basis of an auction. It is plausible that the selection process that a country chose to select 3G mobile licensees might play a role in the adoption of these services.

Institutional environment might also influence mobile broadband deployment. Employing regression analysis, Andonova (2006) finds institutional environment such as political rights and civil liberties are correlated with deployment of mobile. In spite of these previous studies, there was no empirical study, which tests the influences of institutional environment on fixed-broadband diffusion.

Industry Factors

In addition to policy issues, the characteristics of the mobile industry in a country affect the marketing of 3G services in that country and thus its rate of deployment. Steinbock (2003) suggests that the thrust of change in the mobile industry has shifted from technology to markets in the 3G era. In a separate study, Lee (2006) finds that market-based standardization policy and competition empirically correlate with mobile growth rates. Furthermore, through a longitudinal analysis of 25 Asian countries from 1986 to 1998, Burki and Aslam (2000) find that digital mobile competition did indeed promote mobile diffusion. More recently, in his investigation of the factors affecting the diffusion of digital mobile telephony across developed and developing countries, Rouvinen (2006) conclude that market competition promotes mobile diffusion in both groups.

It is intuitive that the cost of mobile services would affect the demand for such services. A number of empirical studies have investigated the possible causal relationship between mobile service cost and mobile deployment. Ahn and Lee (1999) study the determinants of demand for mobile telephone networks using observations from 64 ITU member countries and found that price was not a strong predictor of demand. On the other hand, using a panel data set of 56 countries, Madden et al. (2004) examine the economic factors that affect the growth of global mobile telephony and conclude that lower cost contributes to mobile diffusion. There seems to be conflicting results concerning the role of pricing in the development of mobile phone services.

Similar to the factor of mobile phone cost, the prices of non-voice mobile applications in each country may also affect the consumer acceptance and usage of enhanced mobile services in that country. Studies have suggested that mobile applications and services that exploit the value of a wide-area wireless network and customers' needs and desires are important drivers of success for 3G mobile systems (Foster, 2003). The availability of appealing, diverse mobile applications such as multimedia messaging and mobile internet is likely to contribute to the growth of 3G mobile (Wilska, 2003; Nobel, 2004). Specifically, Foster (2003) proposes that the development of mobile applications and services that leverage the unique capabilities of the wireless environment such as personal and ubiquitous capabilities would directly promote 3G mobile deployment.

More recently using multivariate analysis of 55 countries' data, Lee et al. (2007) find lower pricing of mobile application such as SMS services is correlated with the higher level of 3G mobile deployment.

Demographic Factors

Many studies have empirically supported the importance of national economic health in stimulating the demand for mobile services. Ahn and Lee (1999), in their study of the determinants of demand for mobile telephone networks, find that the probability of subscribing to the telephone networks was positively correlated with per capita GDP. Using a panel data set of 56 countries to investigate the economic factors influencing the growth of mobile phone services, Madden et al. (2004) conclude that higher income and a large user base tend to promote mobile diffusion. In a separate empirical study about the same topic, Andonova (2006) also find GDP per capita to be major contributing variable to mobile diffusion.

Communication research has long identified the importance of demographic factors as antecedents in new media adoption (Atkin and LaRose, 1994). It was suggested that early adopters tend to have higher socio-economic status (Rodgers, 2003). Various studies have reported a positive relationship between education and new media technology adoption (Lin, 1998; LaRose &Atkin, 1992). Wareham et al. (2004) report that education is a steady indicator of wireless phone diffusion because achieving higher education has a positive association with being comfortable with higher technology use.

In addition to socioeconomic factors, there seems to be a positive linkage between population density and mobile penetration rates as evidenced in areas like Hong Kong and Luxemburg that have been garnering mobile penetration rates over 120 and 150 percent (ITU, 2005). Through data analysis of approximately 100 countries, Garcia-Murillo (2005) finds that population density has positive effects on the number of broadband subscribers. Kim and et al. (2003) also suggest that population density should be considered the cost conditions of deploying advanced networks and is one of the influential factors in explaining broadband uptake. However, some empirical studies examining the relationship between mobile diffusion and share of urban population find no significant correlation between the two variables (Gruber, 2001; Koski & Kretschmer, 2002). Some studies emphasize the role of socio-cultural factors in explaining broadband deployment. In his comparative study of broadband deployment in Asia, Aizu (2002) argued social and cultural factors were important explanatory variables for widely differing diffusion rates in Asian countries. He suggests killer applications like online gaming is an influential factor of broadband adoption in Korea (Aizu, 2002).

ICT Factors

The existing information and communication infrastructure in a country is also a potential factor that might affect the adoption of 3G mobile services. Some countries might be more prepared than others to adopt new communications technology because of their existing information and communications technology (ICT) development and consumers' experience with relevant information/communication services. Some ITU

Internet reports have suggested that the countries that already have high PC and Internet penetration have seen users embrace broadband services more readily (ITU, 2003b; ITU 2003c). Kim et al. (2003) found that the preparedness of a nation, which is measured by the attitudes of a nation towards advanced information technology and the availability of complementary technologies, such as computers, is one of the important factors in explaining new media technology adoption like broadband services. Specifically, through a panel data analysis, Denni and Gruber (2005) find that telecommunication density has a positive impact on broadband diffusion. In spite of a growing body of literature that addresses the factors contributing to mobile adoption at the country level, few empirical studies have focused on the factors that affect mobile broadband adoption globally (see Table 2-2). In addition, mobile broadband is not a brand new innovation, but an evolving new communication/media technology that might be affected differently by policy, industry, ICT and demographic factors than fixed-broadband.

There is no empirical work, which tests whether fixed-broadband is a complement to or substitute for mobile broadband. Also, there is no empirical study regarding the potential mobile broadband digital divide.

Table 2-2. Cross-National empirical studies on mobile adoption factors

Study	Main independent variables	Significant findings
Gruber (2001) 140 countries	Income Urban population Fixed penetration Wait time Digital mobile competition Number of mobile operators Market transition index	Late mobile adoption Multiple operators High fixed penetration Wait time
Gruber and Verboven (2001) 140 countries	Income Fixed penetration Digital mobile Standard Competition	Competition Single standard Incumbent pre-empt sequential entry
Koski and Kretschmer (2002) 32 countries	Income Urban population Competition Analog mobile penetration Dominant digital mobile standard Mobile operators (dummy)	Between and within standards Competition Lower user cost
Liikanen et al. (2004) 80 countries	Income Uraband population Fixed penetration Number of analog/digital standards Years since introduction Standard (dummy) Mobile telephony operation Age-dependency ratio	Digital mobile introduction hinders analog mobile diffusion Generation-specific results differ from generic results
Kauffman and Techatassanasoontorn (2005) 46 countries	Years since introduction Standard (dummy) Mobile telephony operation	Income Number of digital mobile phone standards Mobile service price Analog mobile phone penetration Analog mobile phone service prices Standardization policy Licensing Policy

Table 2-2 Continued.

	Age-dependency ratio Income Fixed phone penetration	Income Number of digital mobile phone standards
Rouvinen (2006) 165 countries	Income Population Standard Fixed Penetration/user cost Development Technology Democracy	Standards Competition Network effects

CHAPTER 3
ANALYTICAL FRAMEWORK AND RESEARCH QUESTIONS

This section discusses the analytical framework and proposed research questions for this study. This study examines adoption factors of fixed, mobile, and ubiquitous broadband that collapses both fixed and wireless into one category. This empirical study proposes four different empirical models based on the four different sets of proposed research questions.

Analytical Framework and Research Questions

This study tests adoption factors of fixed, mobile and ubiquitous broadband deployment. This study mainly examines whether policy, industry, demographic, and ICT factors influenced broadband deployment (see figure 3-1, 3-2, and 3-3). The first analytical framework employs both non-linear and linear regression and tests whether macro-national level factors have influence fixed-broadband deployment (see figure 3-1).

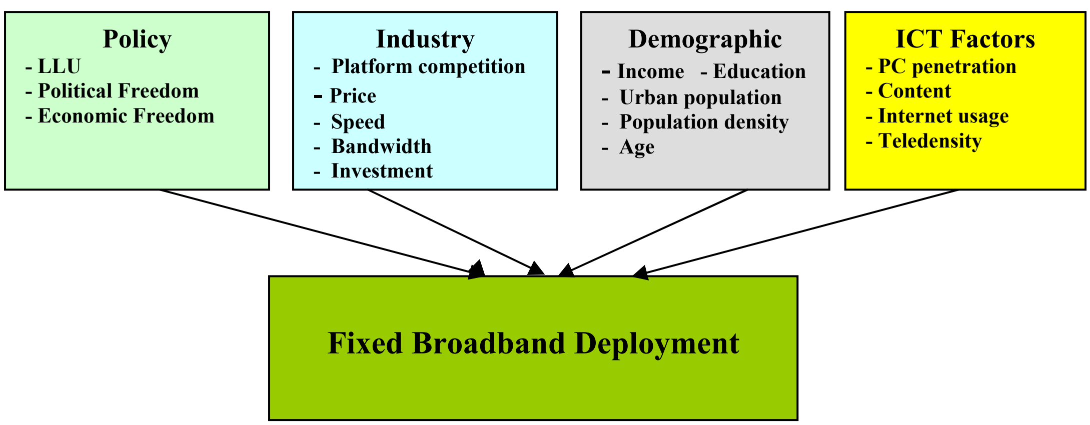


Figure 3-1. Analytical framework for fixed-broadband deployment

The second analytical framework employs linear regression to test the adoption factors of mobile broadband deployment. The second analytical framework empirically tests whether macro-national level factors have influenced mobile broadband deployment (see figure 3-2).

The third analytical framework employs linear regression to test the adoption factors of ubiquitous broadband deployment. The third analytical framework empirically tests whether macro-national level adoption factors have influenced ubiquitous broadband deployment (see figure 3-3).

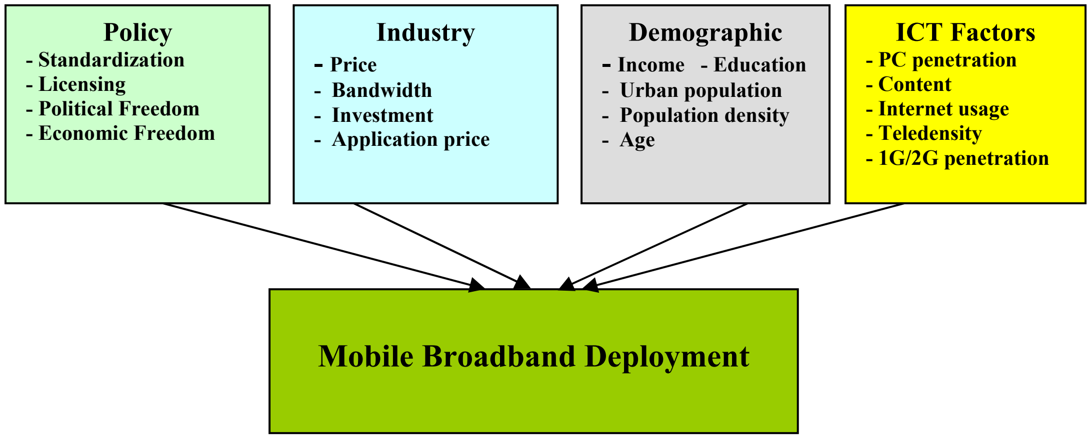


Figure 3-2. Analytical framework for mobile broadband deployment

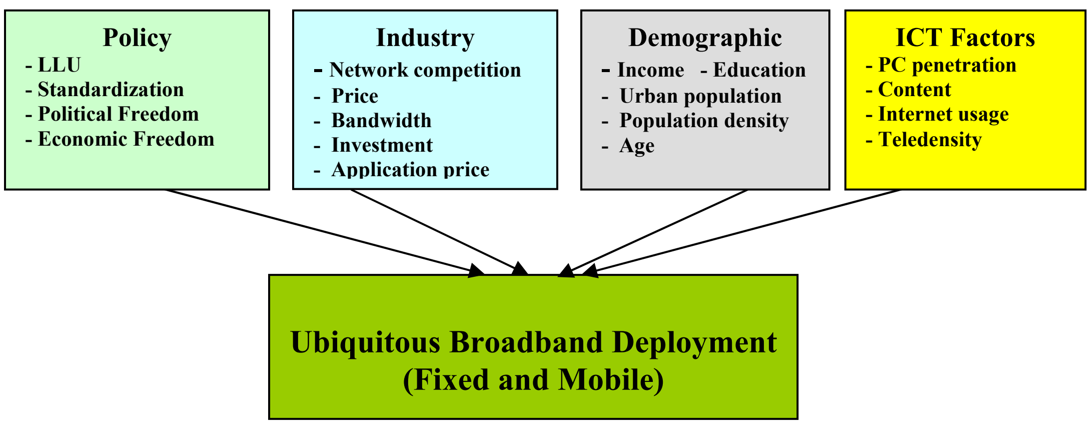


Figure 3-3. Analytical framework for ubiquitous broadband deployment

These three analytical frameworks include four categories of independent variables: (1) policy factors, (2) industry factors, (3) demographic factors, and (4) ICT factors. Choice of individual independent variables is based on previous empirical studies. Most of the independent variables are similar. Technology-specific independent variables are LLU for fixed and ubiquitous broadband, platform competition for fixed-broadband, standardization policy for mobile broadband and ubiquitous broadband, network competition for ubiquitous broadband, mobile application price for mobile and ubiquitous broadband, and 1G and 2G penetration for mobile broadband.

Policy Factors

For policy factors, LLU policy (for fixed and ubiquitous broadband), political freedom (for all broadband technologies), economic freedom (for all three models), and standardization policy (for mobile broadband and ubiquitous broadband) were selected for the empirical test.

Many countries have considered local loop unbundling policy as important policy tools for promoting rapid broadband adoption. Though LLU may reduce their incentives to invest in advanced telecommunication technologies (Frieden, 2005a), some previous empirical studies suggest LLU policy might be positively correlated with broadband deployment (Grosso, 2006; Garcia-Murillo, 2005; Distaso et. al., 2006, Lee & Brown, 2007). Considering fixed-broadband is the dominant type of broadband technology, LLU also might be positively correlated to the ubiquitous broadband deployment.

Institutional environment such as political freedom and economic freedom might be positively correlated to the higher level of fixed, mobile and ubiquitous broadband deployment. In the previous empirical study, Andonova (2006) suggest political rights and civil liberties are correlated with deployment of the Internet. With political freedom this study also tests the relationship between economic freedom and broadband deployment.

Multiple standardization policy might be positively related to rapid mobile broadband. Though multiple standardization policy might lead to limited network externalities and economies of scale, multiple standards and different types of services across technologies may lead to better and differentiated services in the market (Church & Gandal, 2005). One recent empirical study suggests that multiple standardization policy contributes to the higher level of mobile broadband deployment (Lee, et. al, 2007). Based on this previous study, it is also expected that with the effects of platform competition standardization policy might lead to the higher level of ubiquitous broadband diffusion.   Also, different 3G licensing methods might also affect mobile broadband deployment (Lee, et al., 2007).

Based on the literature reviewed, following research questions (RQs) are proposed:

RQ1: Have policy factors, specifically Local Loop Unbundling (LLU), and institutional environment such as political and economic freedom contributed to the adoption of fixed-broadband services?

RQ2: Have policy factors, market mediated standardization policy, and institutional environment such as political and economic freedom contributed to the adoption of mobile broadband services?

RQ3: Have policy factors, specifically Local Loop Unbundling (LLU) and standardization policy, and institutional environment such as political and economic freedom contributed to the adoption of ubiquitous broadband services?

Industry Factors

For industry factors, platform (network) competition (for fixed and ubiquitous broadband), price (for all broadband technologies), speed (for fixed-broadband), bandwidth (for all broadband technologies), telecommunication network investment (for all fixed and ubiquitous broadband), mobile network investment (for mobile broadband) and multiple strategy (for all broadband technologies) were selected for the empirical test.

Platform (network) competition among different technologies (networks) might be positively correlated with the fixed and ubiquitous broadband adoption. A growing body of previous literature suggests that facilities-based competition among several different broadband platforms (networks) may lead to improved quality of service, higher level of broadband adoption and network investment (ITU, 2003b; DotEcon and Criterion Economics, 2003; Aron & Burnstein, 2003; Lee, 2006; Distaso et. al, 2006). However, there was no empirical study which tests the relationship between network competition between fixed and mobile broadband and ubiquitous broadband adoption.

Lower price for fixed, mobile and ubiquitous broadband could be negatively related to the broadband diffusion. However, there is no empirical study, which found relationship between price variables and fixed-broadband adoption. Recent OECD report suggests there is a non-linear relationship between price variables and broadband adoption (OECD, 2007e). Recently an empirical study found lower levels of mobile application price could be correlated with higher levels of mobile broadbanf diffusion (Lee et al, 2007). Also fixed and mobile broadband service could be a substitute for or complementary to one another. It is necessary to test whether price of fixed or price of mobile broadband have influenced mobile or fixed-broadband diffusion.

Higher speed, bandwidth, and higher level of telecommunication (mobile network investment for mobile broadband) network investment might be positively correlated with the fixed, mobile and ubiquitous broadband adoption. However, data for the speed variable were available only for fixed-broadband. One recent empirical study found higher speed is positively correlated with the fixed-broadband deployment (Lee & Brown, 2007). Growth in demand for higher capacity and telecommunication infrastructure investment from private and public sector might lead to higher level of broadband diffusion (ITU, 2003b; ITU, 2006). But there was no empirical work yet.

Also, multiple play strategy might be a key driver of broadband adoption. As an ITU report suggested, corporate strategy is an influential factor of broadband deployment (ITU, 2003b). It is interesting to examine whether triple-play strategy have influenced the growth of fixed-broadband and quadruple-play strategy have influenced the growth of mobile broadband. Also, triple-play and quadruple-play strategy might influence the diffusion of ubiquitous broadband.

RQ4: Have industry factors, specifically platform competition, fixed-broadband price, broadband speed, bandwidth, telecommunication infrastructure investment, mobile service price, and triple-play strategy influenced the adoption of fixed-broadband services?

RQ5: Have industry factors, specifically platform competition, fixed-broadband price, bandwidth, mobile network investment, mobile service price, mobile application price, and quadruple-play strategy influenced the adoption of mobile broadband services?

RQ6: Have industry factors, specifically network competition, fixed-broadband price, bandwidth, telecommunication infrastructure investment, mobile service price, mobile application price, and multiple play strategy influenced the deployment of ubiquitous broadband services?

RQ7: Is mobile broadband a complement to or substitute for fixed-broadband?

RQ8: Is fixed-broadband a complement to or substitute for mobile broadband?

Demographic Factors

For demographic factors, income, education, urban population, population density, and age were selected for the empirical test. All these demographic factors are employed for fixed, mobile, and ubiquitous broadband. Previous studies on new media technology adoption suggest higher level of income, education, urban population share, and population density might be positively correlated with the higher levels of fixed, mobile, and ubiquitous broadband. Some empirical studies on fixed-broadband find high level of population density is related to rapid fixed-broadband deployment (Kim et al., 2003; Garcia-Murillo, 2005; Lee & Brown, 2007). An empirical study suggests high level of income contributed to high level of mobile adoption (Madden et al., 2004). Most of studies on the communication sector suggest younger age is correlated with the higher level of new media technology adoption. Recently De Ridder finds the 35-39 and 40-44 year old groups were positively correlated with fixed-broadband adoption (OECD, 2007e). Based on this previous OECD study, it is interesting to examine whether age groups such as 15-24, 25-34, and 35-44 are correlated with fixed, mobile, and ubiquitous broadband diffusion.

RQ9: Have demographic factors, specifically income, education, urban population share, population density and age influenced the deployment of fixed-broadband services?

RQ10: Have demographic factors, specifically income, education, urban population share, population density and age influenced the deployment of mobile broadband services?

RQ11: Have demographic factors, specifically income, education, urban population share, population density and age influenced the deployment of ubiquitous broadband services?

ICT Factors

For ICT factors, PC penetration, content, Internet usage, and teledensity were selected for the empirical test. These ICT factors are employed for fixed, mobile, and ubiquitous broadband. For mobile broadband deployment, to capture the effects of previous generation mobile technology, 1G and 2G penetration was also selected for the empirical test. Liiknen et al. (2004) found that 1G has a positive effect on 2G. The existing information communication infrastructure in a country might be important factor that might affect the adoption of fixed, mobile and ubiquitous broadband services. Frieden (2005b) suggests ICT incubation is a key driver of broadband adoption. Kim et al. (2003) suggest the preparedness of a nation is a driver of fixed-broadband deployment. A recent empirical study suggests content is factor of fixed-broadband deployment (Lee & Marcu, 2007). It is expected that high level of PC penetration, content, Internet usage, and teledensity are positively correlated with the high level of fixed, mobile, and ubiquitous broadband deployment. 1G and 2G penetration could be positively or negatively correlated to the mobile broadband diffusion.

RQ12: Have ICT factors, specifically PC penetration, content, Internet usage, and teledensity influenced the deployment of fixed-broadband services?

RQ13: Have ICT factors, specifically PC penetration, content, Internet usage, and teledensity, 1G and 2G mobile penetration influenced the deployment of mobile broadband services?

RQ14: Have ICT factors, PC penetration, content, Internet usage, and teledensity influenced the deployment of ubiquitous broadband services?

Factors of Digital Divide and Network Effect

For factors of digital divide, this study selects income and region for the empirical test. These factors are employed for fixed, mobile, and ubiquitous broadband. Previous studies suggest income and region might be factors of digital divide (Crandall, 2003; Rice & Katz , 2003; Madden et al., 1996; Chinn and Fairlie, 2006). Also, to capture the different contributing factors of broadband diffusion for developed and developing countries, it is interesting to examine whether there are common or different factors in the diffusion of broadband in developed and developing countries. Based on the previous literature, this study also examines generation as a factor of digital divide.

RQ15: Is there digital divide in fixed-broadband deployment among group of countries originated from income and region?

RQ16: Is there digital divide in mobile broadband deployment among group of countries originated from income and region?

RQ17: Is there digital divide in ubiquitous broadband deployment among group of countries originated from income and region?

RQ18: Are there common or different factors in the diffusion of fixed and ubiquitous broadband in developed and developing countries?[1]

By using log linear regression model, this study also test whether previous broadband subscription has influenced current broadband subscription. If network effect exists, current subscription might be positively correlated with the previous subscription of new media (Economides & Himmelberg, 1995). Network effect also might exist in the adoption of mobile broadband and ubiquitous broadband, but limitation of data, this study examines whether previous subscription has influenced current subscription for fixed-broadband technology.

[1] Currently only small number of data mobile broadband related data for developing countries are available. Therefore, this study excluded this research question for mobile broadband.

Based on the literature reviewed, the following research question (RQ) is proposed:

RQ19: Have previous subscription of fixed-broadband influenced current subscription?

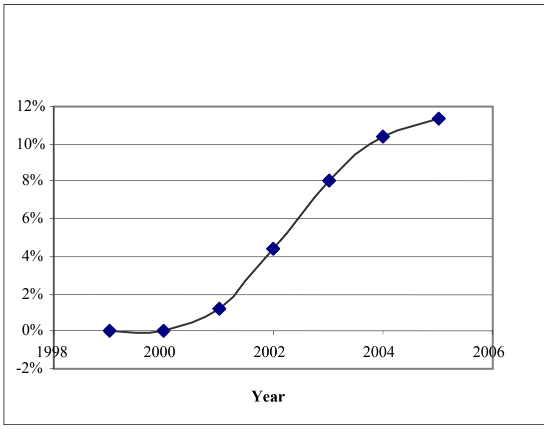
Proposed Empirical Models

Fixed-Broadband

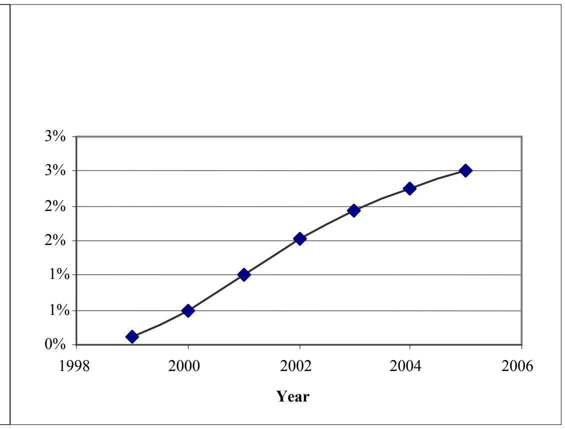
To examine determinants of the global fixed-broadband deployment, this study employs both non-linear and linear regression models. This logistic regression model[2] (non-linear regression model) employs 240 observations for broadband services from OECD (Organization for Economic Co-operation and Development) countries. This study also estimates a linear regression model of fixed-broadband penetration. The linear regression model employs approximately 380 observations for fixed-broadband services from the ITU (International Telecommunication Union) membership countries.

Non-linear model of fixed-broadband diffusion. For the estimation of fixed-broadband diffusion, a logistic model of technology diffusion is employed. Gruber and Verboven's (2001b) logistic model of mobile diffusion is applied to the diffusion model for fixed-broadband. The logistic specification is appropriate for capturing the existence of network externalities (Gruber and Verboven, 2001b). With network externality, higher adoption of fixed-broadband services makes subscribers more valuable. In some countries fixed-broadband penetration pattern is nonlinear and standard S-shaped curve (see figure 3-4).

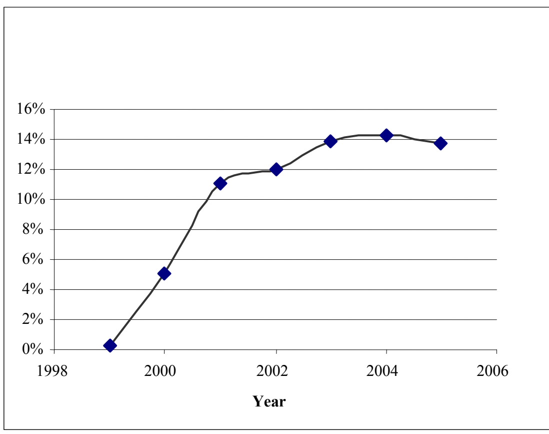
[2] This logistic regression model is based on the previous study by Lee and Marcu (2007).



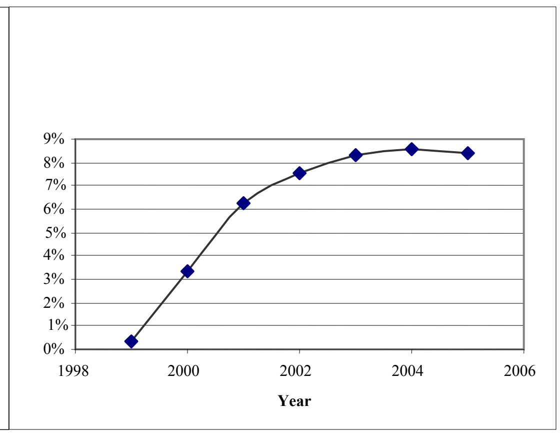
A)



B)



C)



D)

Figure 3-4. Broadband penetration 1999-2005 in Japan and Korea. A) DSL in Japan. B) Cable-Modem in Japan. C) DSL in Korea. D) Cable-Modem in Japan

Letting y_{it} denote the percentage of country *i*'s population that has broadband access to the Internet by time *t*, the standard logistic diffusion equation is:

$$y_{it} = \frac{y_{it}^{*}}{1+\exp(-a_{it} - b_{it}t)} \tag{3-1}$$

where a_{it}, b_{it}, and y_{it}^{*} are parameters, as discussed below.

Not all individuals in a country adopt a new media technology, such as broadband, regardless of how inexpensive the technology may become. This is captured in the model by y_{it}^{*}, the long run expected fraction of subscribers (the ceiling parameter, or saturation point).[3] The parameter a_{it} in equation (3-1) is a constant of integration that gives the initial value of fixed-broadband penetration.[4] A positive value shifts the S-shaped function upwards while a negative one shifts it downwards, without modifying the S-shape.

The parameter b_{it} in equation (3-1) captures the speed of fixed-broadband diffusion. This can be seen by differentiating equation (3-1) with respect to time:

$$\frac{dy_{it}}{dt}\frac{1}{y_{it}} = b_{it}\frac{y_{it}^{*} - y_{it}}{y_{it}^{*}} \tag{3-2}$$

Equation (3-2) shows that b_{it} is equal to the growth rate in the number of adopters, relative to the fraction of potential subscribers who have not yet adopted the technology.

The speed of fixed-broadband diffusion varies with policy variables D_{it}^{j} and country socio-economic characteristics X_{it} in linear fashion. In the previous literatures two broad classes of logistic diffusion models have been proposed: the variable-ceiling logistic and the variable-speed logistic (Fernandez-Cornejo & McBride, 2002). Letting the ceiling vary with country characteristics poses significant estimation problems. There is no guarantee that the parameter will stay at theoretically justifiable levels, or that the model will converge. The variable-speed

[3] Note that $y_{it} \to y_{it}^{*} \quad as \quad t \to \infty$.

[4] Note that $y_{it} \to \dfrac{y_{it}^{*}}{1+e^{-a_{it}}} \quad as \quad t \to 0$.

logistic model is easier to estimate and the speed of adoption can be positive or negative, depending on the movement of exogenous factors.

The logistic regression is symmetric and imposes an inflection point halfway between zero and the saturation point. The inflection point is crucial in determining the saturation point (Bewley and Griffiths, 2003). The saturation point is estimated from the observations of early adopting countries that have passed the midway point, such as Japan and South Korea. To the extent the saturation points of lagging countries differ from those of forerunners, holding the ceiling parameter fixed across countries may bias the expected saturation point for lagging countries. This is somewhat mitigated by the addition of an error term to equation (3-1) for the purpose of estimation.

$$b_{it} = \beta^0 + \sum_{j=1}^{J} \beta^j D_{it}^j + X_{it}\beta \qquad (3\text{-}3)$$

The country characteristics included in X_{it} are variables that may influence the supply and demand for fixed-broadband services. The demand for fixed-broadband services is expected to increase with the higher level of income, education, PC penetration, bandwidth and Internet content. Higher population density and percentage of urban population decrease deployment cost, increasing the supply of broadband. The effects of policy variables on fixed-broadband penetration are main interests of this nonlinear regression. The main policy variables included in this study are dummy variables capturing the effects of different types of LLU such as full bundling, line sharing, bit stream access, LLU price regulation (regulatory approval for line rental charges). Interaction dummy variables of these different types of LLU with LLU price regulation are included in this model with platform competition and institutional environments such as political and economic freedom.

Linear model of fixed-broadband diffusion. To capture more diverse determinants of global broadband deployment, a multiple regression analysis (linear model) is also implemented. To examine the influences of quantifiable variables on the diffusion patterns of fixed-broadband, this study formulates the following linear regression model. Since the distribution of dependent variable and many independent variables in this linear regression model is positively skewed, data transformation with logarithm was employed.

$$\begin{aligned}
\textbf{Ln } \mathbf{Y_t} \textbf{ (BPR)} = {} & \boldsymbol{\beta_0} + \boldsymbol{\beta_1}\textbf{(ln Platform Competition)} + \boldsymbol{\beta_2}\textbf{(ln Previous Penetration)} + \\
& \boldsymbol{\beta_3}\textbf{(ln Political Freedom)} + \boldsymbol{\beta_4}\textbf{(ln Economic Freedom)} + \\
& \boldsymbol{\beta_5}\textbf{(ln Fixed-broadband Price)} + \boldsymbol{\beta_6}\textbf{(ln Mobile Price)} + \boldsymbol{\beta_7}\textbf{(ln Speed)} + \\
& \boldsymbol{\beta_8}\textbf{(ln Bandwidth)} + \boldsymbol{\beta_9}\textbf{(ln Investment)} + \boldsymbol{\beta_{10}}\textbf{(ln Income)} + \\
& \boldsymbol{\beta_{11}}\textbf{(ln Education)} + \boldsymbol{\beta_{12}}\textbf{(ln Population Density)} + \\
& \boldsymbol{\beta_{13}}\textbf{(ln Urban Population)} + \boldsymbol{\beta_{14}}\textbf{(ln Age)} + \\
& \boldsymbol{\beta_{15}}\textbf{(ln PC Penetration)} + \boldsymbol{\beta_{16}}\textbf{(ln Content)} + \boldsymbol{\beta_{17}}\textbf{(ln Internet usage)} + \\
& \boldsymbol{\beta_{18}}\textbf{(ln Teledensity)} + \boldsymbol{\varepsilon_t} \qquad (3\text{-}4)
\end{aligned}$$

The empirical model (3-4) for multivariate analysis was a composite model from previous empirical studies. In the model, the dependent variable (Y_t) is fixed-broadband diffusion. This study included independent variables such as platform competition, previous penetration, political freedom, economic freedom, fixed-broadband price, speed, bandwidth, telecommunication network investment, income, education, population density, urban population, age, PC penetration, content, Internet usage, and teledensity. To examine whether mobile broadband is a complement to or a substitute for fixed-broadband, mobile price was also included in the linear regression model.

One-way ANOVA is used to test the digital divide research questions. The digital divide between high/medium/low income countries and between regions is analyzed by the one-way ANOVA by comparing a few groups of countries. One-way ANOVA is also used to test the effects of LLU and triple-play strategy. 159 observations were available to test the effects of LLU and 29 observations were available to test the effects of triple-play strategy on the growth rate of fixed-broadband penetration. Also, based on the result of regression analysis, significant factors of fixed-broadband diffusion for developed countries (high income countries) and developing countries (medium or low income countries) are compared.

Mobile Broadband

To examine determinants of global mobile broadband deployment, this study employs a log linear regression model. In the model, the dependent variable (Y_t) is mobile broadband diffusion. The linear regression model employs approximately 106 observations for mobile broadband services from the ITU (International Telecommunication Union) membership countries.

Linear model of mobile broadband diffusion. To examine the influences of quantifiable variables on the diffusion patterns of mobile broadband, this study formulates the following log linear regression model. Since the distribution of dependent variable and many independent variables in this linear regression model is positively skewed, data transformation with logarithm was utilized.

$$\begin{aligned}
\mathbf{Ln\ Y_t\ (MBPR)} = {} & \boldsymbol{\beta_0 + \beta_1(\text{Standardization Policy}) + \beta_2(\ln \text{Political Freedom}) +} \\
& \boldsymbol{\beta_3(\ln \text{Economic Freedom}) + \beta_4(\ln \text{Fixed-broadband Price}) +} \\
& \boldsymbol{\beta_5(\ln \text{Mobile price}) + \beta_6(\ln \text{Bandwidth}) +} \\
& \boldsymbol{\beta_7(\ln \text{Investment}) + \beta_8(\ln \text{Mobile Application Price}) +} \\
& \boldsymbol{\beta_9(\ln \text{Income}) + \beta_{10}(\ln \text{Education}) + \beta_{11}(\ln \text{Population Density}) +} \\
& \boldsymbol{\beta_{12}(\ln \text{Urban Population}) + \beta_{13}(\ln \text{Age}) + \beta_{14}(\ln \text{PC Penetration}) +} \\
& \boldsymbol{\beta_{15}(\ln \text{Content}) + \beta_{16}(\ln \text{Internet usage}) + \beta_{17}(\ln \text{Teledensity}) +} \\
& \boldsymbol{\beta_{18}(\ln \text{1G and 2G Penetration}) + \varepsilon_t} \qquad (3\text{-}5)
\end{aligned}$$

The empirical model (3-5) for multivariate analysis was a composite model from previous empirical studies about mobile diffusion. This study includes independent variables such as standardization policy, political freedom, economic freedom, mobile price, bandwidth, telecommunication investment, mobile application price, income, education, population density, urban population, age, PC penetration, content, Internet usage, teledensity, and 1G and 2G penetration. To examine whether fixed-broadband is a complement to or a substitute for mobile broadband, fixed-broadband price was also included in the linear regression model.

One-way ANOVA is also used to test the influence of licensing policy and determinants of digital divide. The digital divide between high/medium/low income countries and between regions is analyzed by the one-way ANOVA by comparing a few groups of countries. One-way ANOVA is also used to test the effects of quadruple-play strategy on the growth of mobile broadband penetration. 69 observations were available to test the effects of licensing policy and 29 observations were available to test the effects of quadruple-play strategy on the growth rate of mobile broadband penetration.

Ubiquitous Broadband

As already discussed in the previous chapters, underlying forces of the notion of ubiquitous broadband are convergence in services, technology, industry, and policy and consumer demand. These underlying forces may influence the macro-level adoption factors of "ubiquitous broadband." A vision of ubiquitous broadband is that broadband access is possible anytime, anywhere, by anyone and anything through both fixed and mobile broadband. In this context, examination of adoption factors of "ubiquitous broadband" is necessary.

To examine determinants of broadband adoption, this study employs a log linear regression model. The linear regression model employs approximately 216 observations for broadband services from the ITU (International Telecommunication Union) membership countries.

Linear model of ubiquitous broadband diffusion. To examine the influences of quantifiable variables on broadband adoption, this study formulates the following log linear regression model. Since the distribution of many variables in this linear regression model is positively skewed, data transformation with logarithm was utilized.

$$\begin{aligned}\mathbf{Ln\ Y_t\ (BPR)} = {} & \boldsymbol{\beta_0} + \boldsymbol{\beta_1}\textbf{(ln Network Competition (or Standardization Policy Type)} + \\ & \boldsymbol{\beta_2}\textbf{(ln Speed)} + \boldsymbol{\beta_3}\textbf{(ln Political Freedom)} + \boldsymbol{\beta_4}\textbf{(ln Economic Freedom)} + \\ & \boldsymbol{\beta_5}\textbf{(ln Fixed-broadband Price)} + \boldsymbol{\beta_6}\textbf{(ln Mobile price)} + \\ & \boldsymbol{\beta_7}\textbf{(ln Bandwidth)} + \boldsymbol{\beta_8}\textbf{(ln Telecommunication Investment)} + \\ & \boldsymbol{\beta_9}\textbf{(ln Income)} + \boldsymbol{\beta_{10}}\textbf{(ln Education)} + \boldsymbol{\beta_{11}}\textbf{(ln Population Density)} + \\ & \boldsymbol{\beta_{12}}\textbf{(ln Urban Population)} + \boldsymbol{\beta_{13}}\textbf{(ln Age Group)} + \boldsymbol{\beta_{14}}\textbf{(ln PC Penetration)} + \\ & \boldsymbol{\beta_{15}}\textbf{(ln Content)} + \boldsymbol{\beta_{16}}\textbf{(ln Internet usage)} + \\ & \boldsymbol{\beta_{17}}\textbf{(ln Teledensity)} + \boldsymbol{\varepsilon_t} \end{aligned} \tag{3-6}$$

The empirical model (3-6) for multivariate analysis was a composite model from previous empirical studies about fixed and mobile broadband deployment. In the empirical model, the dependent variable (Y_t) is broadband adoption that accounts for both fixed and mobile services. Independent variables are policy factors such as standardization policy type, political freedom, and economic freedom. Three different standardization policy types (Policy Type I: platform competition for fixed-broadband without mobile broadband services, Policy Type II: platform competition with single standard for mobile broadband services, Policy Type III: platform competition with multiple standards for mobile broadband services) are examined in the model. Also industry factors such as speed, network competition, telecommunication infrastructure investment, fixed-broadband price, bandwidth, and mobile service price, demographic factors such as income, education, population density, urban population, and age, and ICT factors such as PC penetration, Internet usage, content, and teledensity. Since some of policy types for standardization policy might be conceptually and empirically correlated, only one variable (network competition or policy types for standardization policy) were included in an empirical model. One-way ANOVA is also used to test the digital divide research questions. The digital divide between high/medium/low income countries and between regions is analyzed by the one-way ANOVA by comparing a few groups of countries. The effects of multi-play strategy also were analyzed by one-way ANOVA by comparing two groups of countries (countries with triple-play and without triple-play and countries with quadruple play and without quadruple-play). One-way ANOVA is also used to test the effects of LLU policy. 83 observations were available to test the effects of LLU and 29 observations were available to test the effects of multiple-play strategy on the growth rate of fixed-broadband penetration.

CHAPTER 4
RESEARCH METHOD

This chapter discusses data, measurement, and statistical methods to test the adoption factors of global broadband deployment. This study uses secondary datasets and employs quantitative methodologies such as non-linear and linear regression analysis, and one-way ANOVA to investigate the role of the contributing factors in affecting fixed, mobile, and ubiquitous broadband adoption at the national level. Employing secondary analysis may save time, money, and personnel and it is efficient (Wimmer & Dominick, 2006). Secondary analysis[1] also allows researcher to expend the scope of the study considerably (Stewart, 1984).

Measurement, Data and Statistical Methods for Fixed-broadband Deployment

Table 4-1 and 4-2 shows the variables, their measurement, and the corresponding data sources for fixed-broadband deployment. The dependent variable, fixed-broadband deployment, was measured by the number of broadband subscribers per 100 inhabitants. As detailed in the literature review, there are many potential independent variables involving policy, industry, ICT and demographic factors that may influence fixed-broadband adoption.

Policy Factors

LLU (Local loop unbundling) might be a key driver of the fixed-broadband deployment (ITU, 2003b; Garcia-Murillo, 2005; Distaso et. al., 2006). To capture the effects of different types (full unbundling, line sharing, and bit stream access) of LLU and LLU price regulation (regulatory approval for line rental charges), dummy variables (1 for with full unbundling 0 for otherwise; 1 for with unbundling 0 otherwise; 1 for with bit stream access 0 for otherwise; 1 for with price regulation 0 for no price regulation) are also employed. Some previous studies used

[1] Not all information obtained from secondary sources is equally reliable or valid. For evaluation of secondary data, information must be evaluated according to its recency and credibility (Stewart, 1984).

dummy variable as a measure of LLU (Garcia-Murillo, 2005; Lee & Brown, 2007). For the actual nonlinear model of regression, interaction variables of these dummy variables are used to prevent multicollinearity issue. Three types of LLU policy were identified from the interactions of these dummy variables- LLU Policy I (full unbundling, line sharing and bit stream access without price regulation), LLU Policy II (full unbundling, line sharing, no bit stream access with price regulation), and LLU Policy III (full unbundling, line sharing and bit stream access with price regulation). For the one-way ANOVA, dummy variable (1 for with LLU, 0 for no LLU) is used. Political freedom is measured by the inverse of the score on civil liberties (originally ranging from 1 to 7; Andonova, 2006). For the measurement of economic freedom, the index of economic freedom index has been used. The index of economic freedom is defined by multiple rights and liberties such as business freedom, trade freedom, monetary freedom, and freedom from government (Beach & Kane, 2007).

Industry Factors

Platform competition is an important industry variable in which the broadband market is served by competing platforms. In the previous studies platform competition could be measured by HHI (Herfindahl-Hirshman-Index) or dummy variable (0 or 1) (Distaso et. al., 2006; Lee & Marcu, 2007). A report from DotEcon & Criterion Economics (2003) suggested broadband penetration tends to be higher in European countries where DSL and non-DSL platforms have similar market share. This study employs more generalized measures for platform competition by the HHI (Herfindahl-Hirshman-Index) between different fixed-broadband technologies.

Fixed-broadband price arguably has been a key industry factor in promoting broadband demand. Successful broadband economies are characterized by low prices as a result of flourishing competition and innovative pricing schemes to attract a wide variety of customers (ITU, 2003a). Broadband price is measured by broadband monthly charge (in U.S. Dollars).

Broadband speed is also considered important independent variable that might influence global broadband adoption. It is measured by broadband download speed (kilobit per second). As a product differentiation strategy in the broadband access market, broadband speed might influence broadband demand. For the measurement of bandwidth, international Internet bandwidth (bits per inhabitant) is employed. For the measurement of telecommunication infrastructure investment, annual telecommunication investment is employed. For mobile price, per minute charge (in U.S. Dollars) for a local call during peak time is used.

Demographic Factors

Demographic variables such as income, education, population density, urban population and age might influence fixed-broadband deployment. For the measurement of income, GDP per capita is used. Many studies employed GDP per capita for the measurement of income (Kim et al., 2001; Garcia-Murillo, 2005; Grosso, 2006; Ridder, 2007). Level of education is measured by the UNDP education index. The United Nations Development Programme (UNDP) education index measures a country's relative achievement in both adult literacy and combined primary, secondary and tertiary gross enrolment. Initially an index for adult literacy and one for combined gross enrollment are calculated and then these two indices are combined to create the education index, with two-thirds weight given to adult literacy and one-third weight to combined gross enrolment (UNDP, 2005).

Population density is measured by population density per km^2. Urban population is measured by the percentage of urban population. This study has interest in particular segment of age groups, so age is measured by percentage of age between 15 and 34.

ICT Factors

Internet content may be related to the diffusion of broadband. For the proxy measurement of content, Internet hosts per 10000 inhabitants is employed. Internet usage is measured by

Internet users per 100 inhabitants. Teledensity is measured by main telephone lines per 100 inhabitants. To measure the PC infrastructure, estimated PCs per 100 inhabitants is used.

Other Factors

This study also examines the independent variable of income and regions using categorical variable. Previous subscription could influence the diffusion of fixed-broadband. To test the influence of network effects on the fixed-broadband deployment, this study includes previous year's fixed-broadband subscribers per 100 inhabitants in the model.

This study employs different samples for non-linear and linear regression model for fixed-broadband deployment. Through employing two different samples, this study can include more independent variable for the model. For non-linear regression model 30 OECD country's data from 1999 to 2006 are used. A total 240 observations are employed for non-linear model. For linear model ITU membership countries' data from 2002 to 2006 are employed. Approximately 380 observations are available for the linear model.

One-way ANOVA is also used test the digital divide research questions and the effects of triple-play strategy. The digital divide between high/medium/low income countries and between regions (Africa, Americas, Asia, Europe, and Oceania) is analyzed by the one-way ANOVA by comparing a few groups of countries. This category of regions is based on the categorization of regions by the ITU (International Telecommunication Union). For the one-way ANOVA approximately 380 observations are available. Dummy variable is used for the measurement of triple-play strategy (1 for country with triple-play strategy, 0 for country without triple-play strategy). 29 observations are available for the one-way ANOVA analysis. To capture common and different factors of broadband diffusion, this study also compares significant factors of broadband diffusion for developing and developed countries. 214 observations were available for

Table 4-1. Variables, measurement and data sources for fixed-broadband deployment (Non-linear regression model)

Variables	Measurement	Data Sources
Fixed-broadband deployment	Fixed-broadband subscribers per 100 inhabitants	OECD (1999-2006)
Income	GDP per capita	ITU (1999-2006)
PC Infrastructure	Estimated PCs per 100 inhabitants	ITU (1999-2006)
LLU Policy I	Dummy (1 for with full unbundling, line sharing, bit stream access, no LLU price regulation, 0 for otherwise)	OECD (1999-2006)
LLU-Policy II	Dummy (1 for with full unbundling, line sharing, bit stream access, with LLU price regulation, 0 for otherwise)	OECD (1999-2006)
LLU-Policy III	Dummy (1 for with full unbundling, line sharing, bit stream access, with LLU price regulation, 0 for otherwise)	OECD (1999-2006) OECD (1999-2006)
Population density	Population density (per km^2)	ITU (1999-2006)
Internet content	Internet hosts per 10000 inhabitants	ITU (1999-2006)
Platform Competition	HHI (Herfinall-Hirschman Index) for different fixed-broadband platforms	OECD (1999-2006)
Education	UNDP Education index	UNDP (1998-2007)
Bandwidth	International Internet Bandwidth (Bits per inhabitant)	ITU (1999-2006)
Political freedom	Inverse of the score on civil liberties	Freedom House (1999-2006)
Economic freedom	Index of economic freedom	Heritage Foundation (1999-2006)

Table 4-2. Variables, measurement and data Sources for fixed-broadband (Loglinear regression model)

Variables	Measurement	Data Sources
Fixed-broadband deployment	Fixed-broadband subscribers per 100 inhabitants	ITU (2002-2005)
Income	GDP per capita	ITU (2002-2005)
PC Infrastructure	Estimated PCs per 100 inhabitants	ITU (2002-2005)
Platform Competition	HHI (Herfinall-Hirschman Index) for different fixed-broadband platforms	ITU (2002-2005)
Population Density	Population density (per km^2)	ITU (2002-2005)
Internet Usage	Internet user per 100 inhabitants	ITU (2002-2005)
Internet Content	Internet hosts per 100 inhabitants	ITU (2002-2005)
Mobile Price	Per minute local call (USD) peak charge	ITU (2002-2005)
Speed	Broadband speed (Kbit/s)	ITU (2002-2005)
Education	UNDP education index	UNDP (2002-2005)
Urban Population	Percentage of urban population	Euromonitor (2002-2005)
Telecommunication Infrastructure Investment	Annual telecommunication investment (USD)	ITU (2002-2005)
Teledensity	Main telephone lines per 100 inhabitants	ITU (2002-2005)
Previous Penetration	Previous year's fixed-broadband subscribers per 100 inhabitants	ITU (2001-2004)
Bandwidth	International Internet bandwidth (Bits per inhabitant)	ITU (2002-2005)
Age	Percentage of age between 35-44	World Bank (2002-2005)
Political Freedom	Inverse of the score on civil liberties	Freedom House (2002-2005)
Economic Freedom	Index of economic freedom	Heritage Foundation (2002-2005)
Fixed-broadband Price	Lower speed monthly charge (USD)	ITU (2002-2005)

developing countries and 166 observations were available for developed countries. Most of data were collected from ITU, OECD, and World Bank.

Measurement, Data and Statistical Methods for Mobile Broadband Deployment

Table 4-3 shows the variables, their measurement, and the corresponding data sources. Mobile diffusion can be measured either at the household or individual level. Wareham and Levy (2002) used the proportion of households that owned a mobile telephone to measure mobile diffusion. Most other mobile studies (Madden et al. 2004; Koski & Kretschmer, 2002; Gruber 2001; Ahn & Lee, 1999) used mobile penetration rates at the individual level for such a measurement. In the context of this study, mobile broadband diffusion rate (dependent variable) is measured by the number of mobile broadband subscribers per 100 inhabitants in a country.

Policy Factors

To examine the standardization policy factor, a dummy variable (0 or 1) is employed (i.e., if a country employed multiple standards, 1 was coded). Licensing approaches is coded as a categorical variable of beauty contest, auction, or hybrid licensing system. Political freedom is measured by the inverse of the score on civil liberties (originally ranging from 1 to 7; Andonova, 2006). For the measurement of economic freedom, the index of economic freedom index has been used.

Industry Factors

Because of the variability of mobile services and thus their pricing, this study adopted per minute local call peak charge (USD) to measure the cost of mobile services in each country. Previous studies have used the local call peak charge (USD) per minute (or per month) measure to indicate the relative level of prices for residential mobile voice services (ITU, 2005; Rouvinen, 2006). Regarding the factor of non-voice mobile applications, the cost of short message services (SMS) is employed as the price proxy for mobile broadband relevant applications. SMS is a feature available in many new digital phones that lets users receive and send short text messages. Fixed-broadband price is measured by broadband monthly charge (in U.S. Dollars). This study also includes telecommunication infrastructure investment in the empirical model. It is measured by annual telecommunication investment (USD). For the measurement of bandwidth, international Internet bandwidth (bits per inhabitants) is used.

Demographic Factors

In terms of demographic variables, level of education could be measured by illiteracy rate and average education/degree level (Garcia-Murillo, 2005; Clements & Abramowitz; 2006). For the measurement of education, this study uses the UNDP education index. The UNDP education index measures a country's relative achievement in both adult literacy and combined primary, secondary and tertiary gross enrollment. Studies have used a share of urban population to measure the demographic aspect of population density (Gruber, 2001; Liikanen et. al, 2004; Koski & Kretschmer, 2002). In this study, population density is measured by population per km^2. Urban population is measured by the percentage of urban population and age is measured by percentage of age between 35 and 44. In the previous study, Ridder (2007) suggested only age groups 35-39 and 40-44 were correlated with fixed-broadband deployment in his correlation study. For the measurement of income, the typical GDP per capita is used.

ICT Factors

Teledensity is measured by main telephone lines per 100 inhabitants. To assess PC infrastructure, estimated PCs per 100 inhabitants are used. For the proxy measurement of content, Internet hosts per 10000 inhabitants is employed. Internet usage is measured by Internet users per 100 inhabitants. Previous study by Liikanen et al. (2004) suggested 1G (2G) has a positive(negative effect) on 2G (1G) diffusion. Based on this empirical result, this study examines relationship between 3G (mobile broadband) mobile penetration and 1G and 2G penetration. 1G and 2G penetration is gauged by 1G and 2G mobile subscribers per 100 inhabitants in a country.

This study also examines the independent variable of income and regions using categorical variable to examine the digital divide issue. For the measurement of quadruple play strategy, dummy variable (1 for country with quadruple-play- 0 for country no multiple play strategy) was used.

Data were collected from ITU, OECD, World Bank, IDATE, Haritage Foundation and Freedom House. This study applied the statistical analyses of log linear regression analysis, and one-way ANOVA to assess the influential factors of mobile broadband deployment. A total of 106 observations were available for regression analysis and one-way ANOVA.

Table 4-3. Variables, measurement and data sources for mobile broadband adoption

Variables	Measurement	Data Sources
Mobile broadband deployment	Mobile broadband subscribers per 100 inhabitants	ITU (2004-2006), IDATE (2006)
Economic Freedom	Index of economic freedom	Haritage Foundation (2004-2006)
Political Freedom	Inverse of the score on civil liberties	Freedom House (2004-2006)
Licensing Policy	Categorical variable (Auction, beauty contest, Hybrid approach)	ITU (2001)
Standardization Policy	Dummy (1 for multiple standard, 0 for single standard)	ITU (2004-2006)
Price of Fixed-broadband Service	Lower speed broadband monthly charge (USD)	ITU (2004-2006)
Mobile Service Price	Per minute local call (USD) peak charge	ITU (2004-2006)
Income	GDP per capita	ITU (2004-2006)
PC Infrastructure	Estimated PCs per 100 inhabitants	ITU (2004-2006)
Education	UNDP education index	UNDP (2004-2006)
Population Density	Population density (per km^2)	ITU (2004-2006)
Internet Usage	Internet user per 100 inhabitants	ITU (2004-2006)
Urban Population	Percentage of urban population	Euromonitor (2004-2006)
Telecommunication Infrastructure Investment	Annual telecommunication investment (USD)	ITU (2004-2006)
Teledensity	Main telephone lines per 100 inhabitants	ITU (2004-2006)
Mobile Application Cost	Cost of SMS service	ITU (2004-2006)
Age	Percentage of Age between 35-44	World Bank (2004-2006)
Content	Internet hosts per 100 inhabitants	ITU (2004-2006)
Bandwidth	International Internet bandwidth (bits per inhabitant)	ITU (2004-2006)
1G and 2G Penetration	1G and 2G mobile subscribers per 100 inhabitants	ITU (2004-2006)

Measurement, Data and Statistical Methods for Ubiquitous Broadband Deployment

Table 4-4 shows the variables, their measures, and the corresponding data sources for ubiquitous broadband adoption. In this study broadband services can be deployed through fixed and mobile networks. Therefore this study also examines adoption factors of total broadband deployment (fixed plus mobile). Total broadband subscribers are obtained by summing the totals of fixed and mobile broadband subscribers. Total broadband subscribers per 100 inhabitants are the broadband penetration obtained by dividing by the total population and multiplying by 100 (ITU, 2006).

Policy Factors

DSL is a dominant fixed-broadband technology in most of countries. Open access policy (LLU) in DSL markets might be a main driver of the ubiquitous broadband deployment (ITU, 2003b). For the measurement of standardization/platform competition policy, three different types were categorized: platform competition only in fixed-broadband market and no mobile broadband services (Policy I); platform competition in fixed-broadband markets and single standardization policy in mobile broadband markets (Policy II); and platform competition in fixed-broadband markets and multiple standardization policy in mobile broadband markets (Policy III). For all three types of LLU policy, dummy variables are employed (1 for with LLU, 0 for no LLU). Political freedom is measured by the inverse of the score on civil liberties (Andonova, 2006). For the measurement of economic freedom, the index of economic freedom index has been used.

Industry Factors

Network competition between fixed and mobile networks might be an influential factor of ubiquitous broadband deployment. Ubiquitous broadband access means broadband access anytime, anywhere with anything through fixed and mobile broadband (ITU, 2006). In the empirical model, network competition is measured by dummy variable (1 for DSL and cable modem is available for fixed-broadband and multiple standards for mobile broadband, 0 for otherwise). This study adopted per minute local call (USD) peak charge to measure the cost of mobile services in each country. Regarding the factor of non-voice mobile applications, the cost of short message services (SMS) is used as the price proxy for mobile broadband relevant applications. Fixed-broadband price is measured by broadband monthly charge (in U.S. Dollars). Telecommunication infrastructure investment is measured by annual telecommunication investment. For the measurement of bandwidth, international Internet bandwidth (bits per inhabitant) is employed.

Demographic Factors

In terms of demographic variables, level of education could be measured by illiteracy rate and average education/degree level. For the measurement of education, this study employs the UNDP education index. A share of urban population is used to measure the demographic aspect of population density (Gruber, 2001; Liikanen et. al, 2004; Koski & Kretschmer, 2002). In this study, population density is measured by population per km^2. Age is measured by percentage of age between 35-44. For the measurement of income, the GDP per capita is used.

ICT Factors

To measure the PC infrastructure, estimated PCs per 100 inhabitants are used. Teledensity is measured by main telephone lines per 100 inhabitants. For the proxy measurement of content, Internet hosts per 10000 inhabitants is employed. Internet usage is measured by Internet users per 100 inhabitants. This study also examines the independent variable of income and regions using categorical variable. For the measurement of multiple play strategy, dummy variable (1 for country with multiple play strategy – triple-play or quadruple-play – 0 for country no multiple play strategy) was used.

Most of the secondary data has been collected from the International ITU, OECD, World Bank, Heritage Foundation, and Freedom House. This study employs the statistical analyses of linear regression analysis and one-way ANOVA to assess the influential factors of broadband deployment. A total of 216 observations were available for log linear regression analysis and one-way ANOVA.

Table 4-4. Variables, measurement and data sources for ubiquitous broadband deployment

Variables	Measurement	Data Sources
Total broadband deployment	Total broadband subscribers per 100 inhabitants	ITU (2004-2005)
Policy I	Dummy (1 for with platform competition in fixed-broadband markets and no standardization in mobile broadband markets, 0 for otherwise)	ITU (2004-2005)
Policy II	Dummy (1 for with platform competition in fixed-broadband markets and single standardization policy in mobile broadband markets, 0 for otherwise)	ITU (2004-2005)
Policy III	Dummy (1 for with platform competition in fixed-broadband markets and multiple standardization policy in mobile broadband markets, 0 for otherwise)	ITU (2004-2005)
LLU	Dummy (1 for with LLU, 0 for no LLU)	OECD (2004-2005)
Economic Freedom	Index of economic freedom	Haritage Foundation (2004-2005)
Political Freedom	Inverse of the score on civil liberties	Freedom House (2004-2005)
Network Competition	Dummy (1 for DSL and cable modem for fixed-broadband and multiple standards for mobile broadband are available, 0 for otherwise)	ITU (2004-2005)
Price of fixed-broadband Service	Broadband monthly charge (USD)	ITU (2004-2005)
Mobile Service Price	Per minute local call (USD) peak charge	ITU (2004-2005)
Income	GDP per capita	ITU (2004-2005)
PC Infrastructure	Estimated PCs per 100 inhabitants	ITU (2004-2005)
Education	UNDP Education Index	UNDP (2004-2005)
Population Density	Population density (per km^2)	ITU (2004-2005)

Table 4-4 Continued.

Internet Usage	Internet user per 100 inhabitants	ITU (2004-2005)
Urban Population	Percentage of urban population	Euromonitor (2004-2005)
Telecommunication Infrastructure Investment	Annual telecommunication investment	ITU (2004-2005)
Teledensity	Main telephone lines per 100 inhabitants	ITU (2004-2005) ITU (2004-2005)
Age	Percentage of Age between 35-44	World Bnak (2004-2005)
Content	Internet hosts per 10000 inhabitants	ITU (2004-2005)
Bandwidth	International Internet bandwidth (bits per inhabitant)	ITU (2004-2005)
Speed	Broadband speed (Kbit/s)	ITU (2004-2005)

CHAPTER 5
RESULTS

This chapter provides the results of the data analysis. The first part provides the description of the secondary data set and descriptive statistics for fixed, mobile and ubiquitous broadband. In the second part of this chapter, the result of regression analysis for fixed broadband deployment is provided. The third part provides common and different factors of fixed broadband deployment for developed and developing countries. In the fourth part of this chapter, the result of one-way ANOVA for fixed broadband deployment is provided. The fifth part provides the result of regression analysis for mobile broadband deployment. In the sixth part of this chapter, the result of one-way ANOVA for mobile broadband is provided. The seventh part provides the result of regression analysis for ubiquitous broadband deployment. The eighth part provides common and different factors of ubiquitous broadband deployment for developed and developing countries. In the final part of this chapter, the result of one-way ANOVA for ubiquitous broadband deployment is provided.

Data and Descriptive Statistics

This study employs secondary data for all different empirical models of broadband deployment. Data are mostly collected from international organizations such as the ITU (International Telecommunication Union), OECD (Organization for Economic Co-operation and Development, and World Bank. For the nonlinear regression model of fixed broadband deployment, a total of 240 observations were available, which covers data from 1999 to 2006. This nonlinear model of fixed broadband deployment is based on the observations from 30 OECD countries. This data set has advantages and disadvantages for the data analysis. This OECD data set allows more years of observations (e.g. 8 years period), but the variation of data by country income is small since OECD countries consist of 30 comparatively developed countries. However, this data set allows us to examine variables such as different types of LLU policies such as full unbundling, line sharing, and bit stream access, which other data sets (e.g, ITU membership countries) cannot provide. Data set for the nonlinear model allows 12 different independent variables.

For the linear regression model of fixed broadband diffusion, 380 observations were available. This linear regression model is based on the ITU data set, which allows 4 years of observations. For the ITU data set, the variation of data by country income is larger than that of data from the OECD countries. Table 5-4 provides the list of selected countries examined for the linear model of fixed broadband deployment. This sufficient variation of data by country allows us to examine differences in the significant factors of fixed broadband deployment between developed and developing countries. The data set for the linear regression model allows observations of 18 different independent variables. Table 5-1 provides descriptive statistics for the linear model of fixed broadband deployment. Mean of the fixed broadband penetration among ITU membership countries between 2002 and 2005 is 4.33 per 100 inhabitants and the standard deviation for the fixed broadband penetration is 6.16.

For the linear regression model of mobile broadband, a total of 106 observations were available. This linear regression model of mobile broadband is based on the ITU data set, which allows 3 years of observations. Table 5-5 provides the list of selected countries examined for the linear model of mobile broadband deployment. For this data set, the number of observations for low income countries was small, since mobile broadband is comparatively new media technology for developing countries. This insufficient variation of data by country income didn't allow for the examination of differences in the significant factors of mobile broadband deployment between developed and developing countries. The data set for the linear regression model of mobile broadband provides observations of 18 different independent variables. Table 5-2 offers descriptive statistics for the linear model of mobile broadband deployment. Mean of the mobile broadband penetration among ITU membership countries (for countries which mobile broadband is available) 4.65 per 100 inhabitants (standard deviation for the mobile broadband penetration: 9.10).

For the linear regression model of ubiquitous broadband deployment, 216 observations were available. This linear regression model of ubiquitous broadband diffusion is also based on the ITU data set, which allows 2 years of observations between 2004 and 2005. Table 5-6 provides the list of selected countries examined for the linear model of ubiquitous broadband diffusion. This data set provides sufficient variation of data by country income and allows us to examine differences in the significant factors of ubiquitous broadband diffusion between developed and developing countries. The data set for the linear regression model allows observations of 17 different independent variables. Table 5-3 offers descriptive statistics for the linear model of ubiquitous broadband diffusion. Mean of the ubiquitous broadband penetration among ITU membership countries between 2004 and 2005 is 6.96 per 100 inhabitants and the standard deviation for the ubiquitous broadband penetration is 10.79. For all empirical models, some observations for a portion of the independent variables were missing. Therefore the number of observations employed for the real regression analysis was smaller than the number of observations proposed.

Regression Analysis of Fixed Broadband Deployment

Nonlinear Regression Model

Data for nonlinear regression model covers all 30 OECD countries from 1999 to 2006. This study estimates the variable-speed logistic model described in equations (1) and (3) by

Table 5-1. Descriptive statistics for fixed broadband deployment

Variables	Mean	Standard Deviation
Fixed broadband deployment	4.33	6.16
Income	11973.28	12316.92
PC Infrastructure	23.59	21.64
Platform Competition	7181.97	2603.45
Population Density	520.07	2390.51
Internet Usage	26.62	21.36
Internet Content	435.36	877.99
Mobile Price	0.35	0.33
Speed	896.48	2285.13
Education	0.88	0.10
Urban Population	67.91	20.34
Telecommunication Investment	5E+010	3.5930E+011
Teledensity	31.25	18.85
Previous Penetration	2.86	4.76
Bandwidth	1997.81	4336.00
Age	14.19	2.37
Political Freedom	2.49	1.64
Economic Freedom	64.81	9.71
Fixed Broadband Price	100.09	343.76

Table 5-2. Descriptive statistics for mobile broadband deployment

Variables	Mean	Standard Deviation
Mobile broadband deployment	4.65	9.10
Economic Freedom	67.83	9.17
Political Freedom	1.89	1.41
Standardization Policy	0.27	0.44
Price of Fixed Broadband Service	67.83	123.61
Mobile Service Price	0.35	0.19
Income	21252.75	16057.63
PC Infrastructure	38.18	25.93
Education	0.92	0.087
Population Density	344.40	1124.79
Internet Usage	39.48	22.09
Urban Population	72.70	14.78
Telecommunication Investment	1E+010	6.452+010
Teledensity	70.15	32.10
Mobile Application Cost	0.10	0.07
Age	14.79	2.04
Content	854.53	1246.77
Bandwidth	4253.74	6442.72
1G and 2G Mobile Penetration	73.60	30.79

Table 5-3. Descriptive statistics for ubiquitous broadband deployment

Variables	Mean	Standard Deviation
Total Broadband Deployment	6.96	10.79
Policy I	0.26	0.44
Policy II	0.32	0.47
Policy III	0.11	0.32
Economic Freedom	64.00	9.60
Political Freedom	2.51	1.64
Network Competition	0.43	0.49
Price of Fixed Broadband Service	118.54	446.53
Mobile Service Price	0.30	0.21
Income	11955.70	13275.03
PC Infrastructure	24.91	23.85
Education	0.87	0.10
Population Density	503.73	2506.82
Internet Usage	27.72	21.69
Urban Population	66.82	20.26
Telecommunication Infrastructure Investment	6E+010	4.2800E+011
Teledensity	29.45	18.45
Age	14.09	2.31
Content	455.77	959.82
Bandwidth	2247.34	4886.65
Speed	918.18	2012.05

Table 5-4. Selected countries examined for fixed broadband deployment (ITU, 2005)

Country	Total fixed broadband subscribers per 100 inhabitants	Country	Total fixed broadband subscribers per 100 inhabitants	Country	Total fixed broadband subscribers per 100 Inhabitants
Algeria	0.59	Germany	13.06	Panama	0.54
Andorra	15.4	Greece	1.44	Peru	1.26
Antigua	7.02	Guatemala	0.22	Philippines	0.15
Argentina	2.4	Guyana	0.27	Poland	2.45
Aruba	12.34	Hong Kong, China	23.56	Portugal	11.11
Australia	8.87	Hungary	6.45	Puerto Rico	2.99
Austria	14.36	Iceland	26.54	Qatar	3.23
Bahrain	2.95	India	0.12	Romania	3.48
Barbados	11.87	Ireland	7.77	Russia	1.11
Belgium	19.13	Israel	17.82	San Marino	4.52
Belize	1.86	Italy	11.74	Saudi Arabia	0.28
Bermuda	28.81	Jamaica	1.7	Senegal	0.15
Bosnia	0.35	Japan	18.19	Seychelles	1.18
Brazil	2.35	Jordan	0.42	Singapore	15.3
Brunei	2.17	Korea	25.24	Slovak Republic	3.36
Canada	19.84	Kuwait	0.93	Slovenia	10
Cape Verde	0.2	Latvia	2.63	South Africa	0.35
Chile	4.54	Lebanon	3.63	Spain	11.79
China	2.84	Liechtenstein	24.76	St. Vincent	3.06
Colombia	0.7	Lithuania	6.83	Suriname	0.25
Costa Rica	1.08	Luxembourg	15.08	Sweden	21.21
Croatia	2.55	Macau	14.79	Switzerland	21.77
Cyprus	3.82	Malaysia	1.95	TFYR Macedonia	0.61
Czech Republic	6.94	Maldives	1.08	Taiwan, China	19.06
Denmark	24.75	Malta	11.14	Thailand	0.16
Dominica	0.74	Mauritius	0.25	Tonga	0.64
Ecuador	0.2	Mexico	1.8	Trinidad & Tobago	0.83
Egypt	0.13	Moldova	0.25	Tunisia	0.17
El Salva	0.61	Morocco	0.82	Turkey	2.17
Equatorial Guinea	0.04	Netherlands	25.15	Tuvalu	1.43

Table 5-4 Continued.

Estonia	13.48	New Caledonia	4.05	United Arab Emirates	2.88
Faroe Islands	12.48	New Zealand	8.22	United Kingdom	16.58
Fiji	0.83	Nicaragua	0.18	United States	16.1
Finland	22.37	Norway	21.46	Uruguay	1.88
France	15.66	Oman	0.32	Venezuela	1.33

Note. Data were derived from the International Telecommunication Union (2006).
Source: ITU Internet Reports 2005. Geneva: ITU.

Table 5-5. Countries examined for mobile broadband deployment (ITU, 2005)

Country	3G mobile subscribers per 100 inhabitants (2004)	Number of 3G mobile subscribers	Country	3G mobile subscribers per 100 inhabitants (2004)	Number of 3G mobile subscribers
Angola	1.598	225000	Latvia	.044	1000
Argentina	.052	20000	Luxembourg	.828	3810
Australia	3.862	76900	Mauritius	.041	500
Austria	2.488	20200	Mexico	.019	20000
Bahrain	.128	950	Moldova	.070	3000
Belgium	.013	1391	Netherlands	.166	27000
Brazil	.945	1706660	New Zealand	18.721	732000
Canada	23.314	7400000	Nicaragua	.357	20000
Chile	.485	74730	Norway	.154	7000
China	.066	8711300	Peru	1.088	300000
Colombia	.011	5000	Poland	.003	1000
Czech Republic	.479	49000	Portugal	.983	99000
Denmark	2.317	124650	Romania	1.254	279408
Ecuador	1.516	200000	Russia	.127	181000
Finland	.141	7361	Slovenia	.318	6300
France	.063	38000	South Africa	.007	3000
Germany	.297	245000	Spain	.187	77000
Greece	.084	9250	Sweden	3.241	288150
Guatemala	.395	50000	Switzerland	.140	10000
Hong Kong	2.949	210000	Taiwan	1.318	300000
Indonesia	.022	50000	Thai	.969	615000
Ireland	.075	3000	UAE	.176	5370
Israel	27.790	1823000	UK	4.765	2832000
Italy	4.882	2800000	USA	16.681	49550000
Japan	20.110	25700000	Uruguay	.006	193
Kazakh	.649	100000	Venezuela	.764	200000
Korea	57.370	27509000			

Note. Data were derived from the International Telecommunication Union (2005).
Source: ITU Internet Reports 2005. Geneva: ITU.

Table 5-6. Selected countries examined for ubiquitous broadband deployment (ITU, 2005)

Country	Total broadband subscribers per 100 inhabitants (2005)	Country	Total broadband subscribers per 100 inhabitants (2005)	Country	Total broadband subscribers per 100 inhabitants (2005)
Algeria	0.7	Greece	2.5	Paraguay	0.1
Andorra	14.8	Grenada	0.6	Philippines	0.1
Argentina	2.2	Guyana	0.3	Poland	3.3
Australia	14.4	Hong Kong, China	31.8	Portugal	20.3
Austria	21.2	Hungary	6.5	Puerto Rico	0.6
Bahamas	4	Iceland	26.5	Qatar	3.2
Bahrain	4.3	India	0.12	Reunion	7.2
Barbados	11.8	Ireland	11.5	Romania	4
Belgium	19.3	Israel	20.5	Russia	1.1
Belize	1.6	Italy	29.4	Senegal	0.15
Bolivia	0.1	Japan	31.4	Seychelles	0.7
Bosnia	0.3	Jordan	0.2	Singapore	18.4
Brazil	1.9	Korea (Rep)	51.2	Slovak Republic	2.6
Bulgaria	0.5	Kuwait	0.9	Slovenia	9.9
Canada	20.9	Kyrgyzstan	0.05	Solomon Islands	0.09
Cape Verde	0.2	Latvia	2.3	Spain	13.9
Chile	4.5	Lebanon	3.6	Sri Lanka	0.1
China	2.9	Lithuania	6.8	St. Kitts and Nevis	1.1
Colombia	0.5	Luxembourg	21	St. Vincent	3.1
Costa Rica	0.9	Macao, China	14.8	Suriname	0.2
Croatia	2	Malaysia	2.1	Sweden	27.6
Cyprus	3.2	Maldives	0.6	Switzerland	24.5
Czech Republic	5.1	Malta	11.1	Taiwan, China	20.6
Denmark	27.1	Martinique	1.5	TFYR Macedonia	0.6
Dominica	4.6	Mexico	2.2	Thailand	0.1
Dominican Rep.	0.6	Moldova	0.19	Trinidad & Tobago	0.8
Ecuador	0.2	Morocco	0.8	Tunisia	0.2
Egypt	0.2	Netherlands	27.2	Turkey	2.2
El Salvador	0.6	New Caledonia	4	United Arab Emirates	3.1

Table 5-6 Continued.

Country	Total broadband subscribers per 100 inhabitants (2005)	Country	Total broadband subscribers per 100 inhabitants (2005)	Country	Total broadband subscribers per 100 inhabitants (2005)
Estonia	13.5	New Zealand	10.5	United Kingdom	23.6
Faroe Islands	11.7	Nicaragua	0.12	United States	18
Finland	23.8	Norway	23.9	Uruguay	0.8
France	18.3	Palestine	0.2	Venezuela	0.8
French Polynesia	4.2	Panama	0.6	Vietnam	0.25
Germany	15.7	Peru	1.2	Zimbabwe	0.09

Note. Data were derived from the International Telecommunication Union (2006).
Source: ITU Internet Reports 2005. Geneva: ITU.

nonlinear least squares, after adding disturbances to equation (1) (see pp. 66-68). Table 5-7 provides the results (see nonlinear model part in table 5-7).

PC penetration was associated with higher broadband penetration levels. PC penetration was statistically significant at the .01 level. High level of education, population density, and Internet content (the number of Internet hosts per 10000 inhabitants) were statistically significant at the .05 level. The main interest of this nonlinear model of fixed broadband diffusion is the effect of LLU policy. All three types of LLU policy variables are statistically significant at the 1 percent level. This may mean that LLU policy I (with full unbundling, line sharing, bit stream access and without LLU price regulation), LLU policy II (with full unbundling, line sharing, no bit stream access and with LLU price regulation) and LLU policy III (with full unbundling, line sharing, bit stream access and with LLU price regulation) have contributed high level of fixed broadband penetration.[1]

[1] Most of OECD countries have two types of LLU policy. One major type of LLU was LLU policy, which has full unbundling, line sharing, and bit stream access and the other major type of LLU in OECD countries was LLU policy, which has full unbundling and line sharing without bit stream access. With two different types of LLU, for this empirical study, interaction of these two types and LLU price regulation. Only three cases of LLU policies were

Table 5-7. Results of regressions of fixed broadband deployment

	Nonlinear Model		Log linear (Extended Model)		Log linear (Reduced Model)	
	Coefficients		Coefficients		Coefficients	
Variable	B	t-stat	B	t-stat	B	t-stat
Constant	-	-	.62	.92	.02	.13
Ceiling	26.14	19.85***	-	-	-	-
Initial level Parameter	-3.52	-13.08***	-	-	-	-
Speed	-	-	.04	.80	-	-
Fixed broadband price	-	-	-.09	-.03*	-.10	-1.9*
Mobile price	-	-	.08	1.8*	.06	1.4
Education	.47	2.11**	-.08	-1.7	-	-
Internet use	-	-	.35	3.98***	.31	4.28***
Population density	B<.001	2.07**	.002	.067	-	-
Bandwidth	1.07E-06	0.30	.13	3.75***	.13	4.15***
Content	B<.001	2.77**	-.05	-1.47	-	-
Political freedom	-.023	-.40	-.18	-1.85*	-.10	-1.3
Economic freedom	-.004	-1.61	-.60	-1.58	-	-
Urban population	-	-	.07	.58	-	-
Age (35-44)	-	-	.27	.78	-	-
Platform competition	B<-.001	-1.07	-.07	-1.84*	-.08	-2.1**
Previous penetration	-	-	.65	21.5***	.63	23.01***
Telecom investment	-	-	-.007	-.41	-	-
Teledensity	-	-	-	-	-	-
Income	-1.13E-06	-0.63	-	-	-	-
PC Penetration	.004	3.09***	-	-	-	-
LLU Policy Type I	.21	3.39***				
LLU Policy Type II	.19	2.81***				
LLU Policy Type III	.15	3.00***				
R-Squared	0.93		0.92		0.91	
Number of observations	217		255		282	

* Statistically significant at the 10% level
** Statistically significant at the 5% level
***Statistically significant at the 1% level

High level of platform competition, which is measured by HHI (Herfindall-Hirschman Index) was related to high level of fixed broadband penetration, but it was not statistically

identified and included in the model after careful check of correlation between these different types of LLU cases, which might not lead to multicollinearity in the model.

significant at the .10 level (p-value:.29). Bandwidth, political freedom, and economic freedom were not significant in the model. To check multicollinearity issue in this model, correlation analysis was also conducted. Based on the .80 benchmark, there were no highly correlated independent variables in the model. R-squared for this model was .932 and adjusted R-squared was .930.

Linear Regression model

A total of 380 observations were analyzed employing the multiple regression analysis. Extended and reduced model were identified from the data analysis. Note that dependent variable and independent variables were transformed using logarithmic function since data were positively skewed.

Extended model. Initially, all eighteen independent variables were included for the multiple regression analysis. Multicollinearity issue might occur when independent variables are highly correlated, a correlation analysis conducted to check potential multicollinearity problems. To assess the strength of correlations, the .80 Pearson correlation criterion was employed. PC penetration, teledensity, and income were removed from the initial model because of its high correlation with other independent variables. Table 5-7 shows the ANOVA table of the extended regression model, which illustrates the model's significance at the .01 level (F statistic: 199.15, P <. 001).

Specifically, Internet use, bandwidth, and previous penetration were statistically significant at the .01 level. Other independent variables such as fixed broadband price, political freedom, mobile price, and platform competition were statistically significant at the .1 level. Other variables such as speed, education, population density, content, urban population, age (35-44), telecommunication investment were not statistically significant. R-squared for the extended model was .926.

Reduced model. To check the stability of results in the empirical study, non-significant variables such as speed, education, population density, content, urban population, age (35-44), and telecommunication investment were removed from the reduced model. The reduced model is significant at the .01 level (F statistic: 357.76). In this model, mobile price was positively related to the dependent variable, but it was not statistically significant at the .1 level. Internet use, bandwidth, and previous penetration were statistically significant at the .01 level, and platform competition was significant at the .05 level. Also, lower price of fixed broadband was associated with higher level of fixed broadband penetration. R-squared for the reduced model was .915. Table 5-7 provides the results of the reduced model from the regression analysis.

Results of Fixed-Broadband Deployment for Developed and Developing Countries

A total of 132 observations were analyzed employing the multiple regression analysis for developed countries and a total of 148 observations were analyzed for developing countries. R-squared for the model for developed countries was .90, and R-squared for the model for developing countries was .81. Dependent variable and independent variables were transformed using logarithmic function since data were positively skewed.

Regression Analysis: Developed Countries

In the initial model, all eighteen independent variables were included for the multiple regression analysis. PC penetration, teledensity, and Internet use were removed from the initial model because of its high correlation with other independent variables. For the extended model, some insignificant variables such as political freedom, economic freedom, urban population, age (35-44), and telecommunication investment were removed from the model. In the reduced model, other insignificant variables such as speed, fixed broadband price, bandwidth, and platform competition were also removed from the model. Table 5-8 provides the ANOVA table of the reduced regression model, which illustrates the model's significance at the .01 level (P <. 001).

In the reduced model, education and previous penetration were statistically significant at the .01 level. Other independent variables such as income, population density, and content were statistically significant at the .05 level. Mobile price was negatively associated with high level of fixed broadband diffusion at the .1 level in the developed countries. The results of analysis of developed countries were consistent with the results of analysis of OECD countries. In both models, high level of education, population density, and Internet content were statistically significant.

Regression Analysis: Developing Countries

Initially, all eighteen independent variables were included for the multiple regression analysis. PC penetration, teledensity, and income were removed from the initial model because of its high correlation with other variables. For the extended model, some insignificant variables such as education, population density, content, economic freedom, urban population, age (35-44), and telecommunication investment were removed from the model. For the reduced model, other insignificant variable such as speed was also removed from the model. Table 5-8 provides the results of the extended and reduced regression model, which illustrates the model's significance at the .01 level (P <. 001).

The result of analysis for developing countries was very different from the result of developed countries. In the reduced model, bandwidth and previous penetration were statistically significant at the .01 level. Internet use was statistically significant at the .05 level. Mobile price was positively associated with high level of fixed broadband diffusion at the .1 level in the developing countries instead of negative association in the developed countries. Fixed broadband price and HHI was negatively associated with the high level of fixed broadband penetration.

Table 5-8. Results of regressions of fixed broadband penetration for developed and developing countries

	Developed Countries				Developing Countries			
	Extended model		Reduced model		Extended model		Reduced model	
Variable	Coefficients B	t-stat	Coefficients B	t-stat	Coefficients B	t-stat	Coefficients B	t-stat
Constant	-.17	-.40	-.48	-1.52	-.28	-.66	-.20	-.70
Speed	.04	1.46	-	-	.18	1.35	-	-
Fixed broadband price	-.10	-1.61	-	-	-.14	-1.80*	-.13	-1.67*
Income	.13	1.43	.16	2.13**	-	-	-	-
Mobile price	-.06	-1.79*	-.06	-1.69*	.13	1.75*	.14	1.83*
Education	1.91	2.96***	2.28	3.79***	-	-	-	-
Internet use	-	-	-	-	.19	1.66*	.24	2.14**
Population density	.03	1.68*	.04	2.50**	-	-	-	-
Bandwidth	.03	.90	-	-	.11	1.97*	.15	2.71***
Content	.05	1.90*	.06	2.55**	-	-	-	-
Political freedom	-	-	-	-	-.23	-1.55	-.23	-1.54
Economic freedom	-	-	-	-	-	-	-	-
Urban population	-	-	-	-	-	-	-	-
Age (35-44)	-	-	-	-	-	-	-	-
Platform competition	-.05	-.74	-	-	-.10	-1.90*	-.09	-1.72*
Previous penetration	.62	20.71***	.65	24.27***	.61	13.89***	.61	14.09***
Telecom investment	-	-	-	-	-	-	-	-
Teledensity	-	-	-	-	-	-	-	-
PC Penetration	-	-	-	-	-	-	-	-
R-Squared	0.90		0.90		0.81		0.81	
Number of observations	132		132		148		148	

* Statistically significant at the 10% level. ** Statistically significant at the 5% level. ***Statistically significant at the 1% level

One-way ANOVA Analysis of Fixed-Broadband Deployment

Table 5-9 provides the data analysis employing one-way ANOVA. Mean difference of fixed-broadband penetration between high, medium, and low income countries was statistically significant (F-statistic: 123.49, P <.01). Higher income countries tend to have higher fixed-broadband penetration. This result may suggest that there is digital divide between countries by income.

Mean difference of fixed-broadband penetration between regions (Africa, America, Asia, Europe, and Oceania) was also statistically significant (F-statistic: 11.75, $P < .01$). European and Asian countries tend to have higher fixed-broadband penetration than other countries in Africa, America, and Oceania. This result suggests that there is digital divide between countries by region.

Mean difference of fixed-broadband penetration growth rate between countries with triple-play strategy and without triple-play strategy was also significant (see table 5-9). This result may suggest that triple-play is a contributing factor of global fixed-broadband deployment. Also, mean difference of fixed-broadband penetration between countries with LLU policy and without LLU policy was also significant (see table 5-9). This result suggests that LLU policy is a contributing factor of global fixed-broadband deployment.

Table 5-9. Difference in fixed broadband penetration and fixed broadband penetration growth rate by income, region, triple-play offerings and LLU

Dependent Variable	Source	SS	*df*	MS	*F*	Variable	Mean
Fixed Broadband Penetration	Income	5702.61	2	2851.30	123.49**	High Income	8.72
	Error	8704.38	377	23.09		Medium Income	1.06
						Low Income	.06
	Region	1605.32	4	401.33	11.75**	Africa	.59
	Error	12801.67	375	34.13		America	2.43
						Asia	4.59
						Europe	6.67
						Oceania	2.64
Fixed Broadband Penetration Growth Rate	Triple-play	13.94	1	13.94	8.23**	Triple-play	4.47
	Error	47.40	28	1.69		No Triple-play	2.86
Fixed Broadband Penetration	LLU	1796.99	1	1796.99	47.86**	LLU	6.90
	Error	5894.45	157	37.54		No LLU	4.13

Note. Categorization of countries by income and region are based on the ITU's categorization of countries by income and region.
**Statistically significant at the 1% level

Regression Analysis of Mobile Broadband Deployment

A total of 106 observations were analyzed employing the multiple regression analysis. Extended and reduced model were identified for the analysis. Note that dependent variable and independent variables were transformed using logarithmic function since data were positively skewed.

Extended Model

In the initial model, all eighteen independent variables were included for the multiple regression analysis. A correlation analysis was conducted to check potential multicollinearity problems. To assess the strength of correlations, the .80 Pearson correlation benchmark was employed. PC penetration, Internet use, bandwidth, and content were removed from the initial model because of its high correlation with other independent variables. Some independent variables, which have unexpected sign, such as teledensity, mobile price, political freedom, and urban population were removed from the model. Also, some insignificant variables such as education and cost of mobile application were removed from the initial model. Table 5-10 provides the ANOVA table of the extended regression model, which illustrates the model's significance at the .01 level.

Specifically, multiple standardization policy and income were statistically significant at the .01 level. 1G and 2G mobile penetration was statistically significant at the .1 level, which suggests mobile broadband is a substitute of 1G and 2G mobile. Other variables such as fixed broadband price, telecommunication investment, economic freedom, population density, and age (35-44) were not statistically significant. R-squared for the extended model was .46.

Reduced Model

To check the stability of results in the empirical study, non-significant variables such as fixed broadband price, telecommunication investment, economic freedom, population density, and age (35-44) were removed from the reduced model. The reduced model is significant at the .01 level. In the reduced model, multiple standardization policy, and income were statistically significant at the .01 level. 1G and 2G mobile penetration was negatively correlated to the dependent variable and was significant at the .05 level. Also, higher level of population density was associated with higher level of mobile broadband penetration. R-squared for the reduced model was .44 (see Table 5-7).

Table 5-10. Results of regression analysis of mobile broadband deployment

	Log linear (extended model)		Log linear (reduced model)	
	Coefficients		Coefficients	
Variable	B	t-stat	B	t-stat
Constant	-3.71	-1.23	-4.54	-7.19
Standardization policy	.89	4.85***	.86	5.03***
1G and 2G penetration	-.85	-1.68*	-.95	-2.12**
Income	1.28	4.33***	1.33	5.63***
Fixed broadband price	-.06	-.22	-	-
Age (35-44)	1.69	.93	-	-
Telecom investment	.07	.86	-	-
Economic freedom	-1.81	-1.01	-	-
Population density	.19	1.50	.21	1.82*
R-Squared	0.46		0.44	
Number of observations	101		105	

* Statistically significant at the 10% level. ** Statistically significant at the 5% level.
***Statistically significant at the 1% level

One-Way ANOVA Analysis of Mobile Broadband Deployment

Table 5-11 offers the data analysis employing one-way ANOVA. Mean difference of mobile broadband penetration between high, medium, and low income countries was statistically significant at the .1 level (F-statistic: 2.75, P <.1). Higher income countries tend to have higher mobile broadband penetration. This result may suggest that there is digital divide between countries by income (see Table 5-11).

Mean difference of mobile broadband penetration between regions (Africa, America, Asia, Europe, and Oceania) was also statistically significant at the .1 level (F-statistic: 2.38, P <.1).

Asian countries have the highest mobile broadband penetration than other countries in other regions. This result suggests that there is digital divide between countries by region. Mean difference of mobile broadband penetration growth rate between countries with quadruple-play strategy and without quadruple-play strategy was not significant (see Table 5-11). This result suggests that quadruple-play is not a contributing factor of global mobile broadband deployment yet. Also, mean difference of mobile broadband penetration between countries which have different licensing policy system was not significant (see table 5-11).

Table 5-11. Difference in mobile broadband penetration and mobile broadband penetration growth rate by income, region, quadruple-play offerings and licensing policy

Dependent Variable	Source	SS	*Df*	MS	*F*	Variable	Mean
Mobile Broadband Penetration	Income	442.06	2	221.03	2.75*	High Income	6.14
	Error	8262.58	103	80.21		Medium Income	2.06
						Low Income	.51
	Region	750.29	4	187.57	2.38*	Africa	.39
	Error	7954.34	101	78.75		America	3.10
						Asia	9.44
						Europe	3.55
						Oceania	7.19
Mobile Broadband Penetration Growth Rate	Quadruple-play	73.17	1	73.17	.86	Quadruple-play	7.14
	Error	2394.72	28	85.53		No quadruple-play	10.86
Mobile Broadband Penetration	Licensing Policy	654.67	3	218.22	2.09	Auction	4.18
						Beauty Contest	9.15
						Hybrid	11.97
	Error	6662.07	64	104.09		Other	.48

Note. Categorization of countries by income and region are based on the ITU's categorization of countries by income and region.
* Statistically significant at the 10% level

Regression Analysis of Ubiquitous Broadband Deployment

A total of 216 observations were analyzed employing the multiple regression analysis. For the ubiquitous broadband deployment, this study examines both the model with network competition variable and the model with different platform completion-standardization policy type variable.[2] Extended and reduced model were identified from the data analysis for both models. Note that dependent variable and independent variables were transformed using logarithmic function since data were positively skewed. The results of both models show similar results.

Model with Network Competition Variable

Extended model. In the initial model, seventeen independent variables were included for the multiple regression analysis. Multicollinearity problem might occur when independent variables are highly correlated, a correlation analysis conducted to check potential multicollinearity problems. To assess the strength of correlations, the criterion of .80 Pearson correlations was employed. PC penetration, teledensity, Internet use, and bandwidth were removed from the initial model because of its high correlation with other independent variables. The extended regression model was significant at the .01 level.

Specifically, network competition, income, and content were statistically significant at the .01 level. Fixed broadband price, speed, and political freedom were statistically significant at the .05 level. Other variables such as mobile price, education, population density, urban population, age (35-44), telecommunication investment, and economic freedom were not statistically significant. R-squared for the extended model was .81.

Reduced model. In the reduced model, non-significant variables such as mobile price, education, age (35-44), telecommunication investment, and economic freedom were removed from the reduced model. The reduced model was significant at the .01 level. In the reduced

[2] One goal of this empirical model was to examine effective policy variables, which might influence higher level of ubiquitous broadband diffusion. Network competition variable and different platform competition-standardization policy could be included in a single model. However, network competition variable and some of platform competition-standardization policy type were correlated with each other. Therefore this study examines two different models –the model with network competition variable and the model with platform competition-standardization policy variable.

model, income and political freedom were statistically significant at the .01 level. Fixed broadband price, speed, content, urban population, and network competition were statistically significant at the .05 level. Also, population density was statistically significant at the .1 level. R-squared for the reduced model was .79. Table 5-12 provides the results of the regression analysis.

Model with Different Platform Competition-Standardization Policy Variables

Extended model. Main interest of this model is the effects of different platform competition-standardization policy types. Three different types were categorized for the platform competition-standardization policy types: platform competition only in fixed-broadband markets and no mobile broadband services (Policy type I); platform competition in fixed- broadband markets and single standardization policy in mobile broadband markets (Policy type II); and platform competition in fixed-broadband markets and multiple standardization policy in mobile broadband markets (Policy type III). For the extended model, initially, all nineteen independent variables were included for the multiple regression analysis. A correlation analysis conducted to check potential multicollinearity issues. Based on the benchmark of .80 Pearson correlations, PC penetration, teledensity, Internet use, and bandwidth were removed from the initial model because of its high correlation with other independent variables. Also, for the extended model, other insignificant independent variables such as mobile price, education, age (35-44), and economic freedom were removed from the initial model. The extended model was significant at the .01 level.

In particular, Policy type III (platform competition in fixed-broadband markets and multiple standardization policy in mobile broadband markets) and income were statistically significant at the .01 level. Policy type II (platform competition in fixed- broadband markets and single standardization policy in mobile broadband markets), speed, political freedom, and population density were statistically significant at the .05 level. Policy type I (platform competition only in fixed-broadband markets and no mobile broadband services) was significant at the .1 level. Other independent variables such as fixed broadband price, content, telecommunication investment, and urban population were not statistically significant. R-squared for the extended model was .80.

Reduced model. To check the stability of results in the empirical study, non-significant independent variable telecommunication investment was removed from the reduced model. The reduced model is significant at the .01 level. In the reduced model, Policy type III, income, and political freedom were statistically significant at the .01 level. Policy type II, speed, and population density were statistically significant at the .05 level. Policy type I, fixed broadband price, and urban population were significant at the .1 level. Content was not statistically significant. R-squared for the reduced model was .80. A total of 190 observations were available for this model. Table 5-12 provides the results of the reduced model from the regression analysis.

Table 5-12. Results of regressions of Total (Ubiquitous) broadband deployment

	Model 1 (with network completion variable)				Model 2 (with policy I, II, III)			
	Extended model		Reduced model		Extended model		Reduced model	
Variable	Coefficients B	t-stat	Coefficients B	t-stat	Coefficients B	t-stat	Coefficients B	t-stat
Constant	-4.74	-3.50***	-4.11	-7.74***	-4.61	-7.64***	-4.41	-8.29***
Speed	.23	2.16**	.25	2.55**	.22	2.03**	.23	2.36**
Fixed broadband Price	-.19	-2.11**	-.17	-2.11**	-.12	-1.45	-.13	-1.69*
Income	.67	5.65***	.71	7.48***	.76	7.42***	.79	8.32***
Mobile price	-.04	-.491	-	-	-	-	-	-
Education	-.89	-1.16	-	-	-	-	-	-
Content	.20	3.05***	.12	2.34**	.09	1.62	.07	.17
Political freedom	-.37	.18**	-.50	3.27***	-.40	-2.42**	-.50	-3.35***
Age (35-44)	.32	.43	-	-	-	-	-	-
Telecom investment	.02	.03	-	-	.03	1.08	-	-

Table 5-12 Continued.

Economic freedom	.06	.08	-	-	-	-	-	-
Population density	.08	1.54	.09	1.96*	.11	2.24**	.12	2.48**
Urban population	.40	1.50	.49	2.05**	.41	1.64	.45	1.96*
Teledensity	-	-	-	-	-	-	-	-
PC Penetration	-	-	-	-	-	-	-	-
Internet use	-	-	-	-	-	-	-	-
Bandwidth	-	-	-	-	-	-	-	-
Network competition	.23	2.67***	.18	2.32**	-	-	-	-
Policy Type I	-	-	-	-	.18	1.86*	.16	1.84*
Policy Type II	-	-	-	-	.25	2.46**	.21	2.28*
Policy Type III	-	-	-	-	.56	4.33**	.53	4.33**
R-Squared	0.81		0.79		0.80		0.80	
Number of observations	169		191		177		191	

* Statistically significant at the 10% level
** Statistically significant at the 5% level
***Statistically significant at the 1% level

Results of Ubiquitous Broadband Deployment for Developed and Developing Countries

A total of 73 observations were analyzed employing the multiple regression analysis for developed countries and a total of 120 observations were analyzed for developing countries. R-squared for the final reduced model for developed countries was .77, and R-squared for the final reduced model for developing countries was .56. To examine effects of different platform competition-standardization policy types, Policy type I, II, and III were included for the model. Dependent variable and independent variables were transformed using logarithmic function since data were positively skewed.

Regression Analysis: Developed Countries

In the initial model, all nineteen independent variables were included for the multiple regression analysis. PC penetration was removed from the initial model because of its high

Table 5-13. Results of regressions of total (Ubiquitous) broadband penetration for developing and developed Countries

Variable	Developing Countries				Developed Countries			
	Extended model		Reduced model		Extended model		Reduced model	
	Coefficients B	t-stat	Coefficients B	t-stat	Coefficients B	t-stat	Coefficients B	t-stat
Constant	-2.71	-1.12	-3.48	-6.57	-1.53	-.75	-.20	-5.73***
Speed	.08	.33	-	-	.13	1.69*	.14	2.15**
Fixed broadband price	-.18	-1.60	-.11	-1.11	-.04	-.25	-	-
Income	.57	2.62**	.79	4.24***	.30	1.19	-	-
Mobile price	.17	1.08	-	-	-.05	-.65	-	-
Education	-	-	-	-	.41	.21	-	-
Content	-	-	-	-	.07	.95	-	-
Political freedom	-.03	-.12	-	-	-.23	-.96	-.29	-2.18**
Age (35-44)	-.94	.84	-	-	-	-	-	-
Telecom investment	.01	.31	-	-	.004	.07	-	-
Economic freedom	.11	.10	-	-	-1.25	-1.22	-	-
Population density	-	-	-	-	.14	2.94***	.09	2.58**
Urban population	.12	.35	-	-	.24	.44	-	-
Teledensity	.25	1.02	-.001	-.005	-	-	-	-
PC Penetration	.05	.29	-	-	-	-	-	-
Internet use	-	-	-	-	.86	2.90***	.91	3.65***
Bandwidth	.31	2.62**	.25	2.96***	.14	1.3	.21	3.05***
Network competition	-	-	-	-	-	-	-	-
Policy Type I	.23	1.86*	.19	1.74*	.37	1.85*	.25	1.75*
Policy Type II	.36	2.66***	.33	2.73***	.29	1.50	.23	1.72*
Policy Type III	.36	1.96*	.39	2.13**	.59	2.94***	.54	4.01***
R-Squared	0.69		0.56		0.79		0.77	
Number of observations	94		120		69		73	

* Statistically significant at the 10% level. ** Statistically significant at the 5% level. ***Statistically significant at the 1% level.

correlation with other independent variables. Also, for the extended model, some insignificant variables, which have unexpected sign like teledensity and age, were removed from the model. In the reduced model, other insignificant variables such as fixed broadband price, income, mobile price, education, content, telecommunication investment, urban population, and economic freedom were also removed from the model. Table 5-13 provides the ANOVA table of the reduced regression model, which illustrates the model's significance at the .01 level (P <. 001). In the reduced model, Policy type III, bandwidth, and Internet use were statistically significant at the .01 level. Speed, political freedom, and population density were statistically significant at the .05 level. Also, policy type I and policy II were significant at the .1 level in the developed countries.

Regression Analysis: Developing Countries

Initially, all nineteen independent variables were included for the regression model. Some insignificant variables such as education, content, and population density, which have unexpected sign, were removed from the model. Also, insignificant independent variable Internet usage was removed from the model. In the reduced model, other insignificant variables such as speed, political freedom, age (35-44), telecommunication investment, economic freedom, urban population, and PC penetration were removed from the model. Table 5-13 provides the results of the extended and reduced regression model.

The result of analysis for developing countries was different from the result of developed countries. In the reduced model, policy type II, income, and bandwidth were statistically significant at the .01 level. Policy type III was statistically significant at the .05 level. Policy type I was significant at the .1 level in the developing countries. Considering significance level of Policy type II and policy type III, it appears that in the developing countries policy type II (platform competition in fixed-broadband market and single standard for mobile broadband market) is more effective than policy type III (platform competition in fixed-broadband market and multiple standards for mobile broadband market). In the developed countries, policy type III was more significant variable than policy type II.

One-Way ANOVA Analysis of Ubiquitous Broadband Deployment

Table 5-14 provides the result of one-way ANOVA analysis of ubiquitous broadband deployment. Mean difference of ubiquitous broadband penetration between high, medium, and low income countries was statistically significant (F-statistic: 69.80, P <.01). Higher income countries tend to have higher ubiquitous broadband penetration. This result may suggest that there is digital divide in the ubiquitous broadband access between countries by income.

Mean difference of ubiquitous broadband penetration between regions (Africa, America, Asia, Europe, and Oceania) was also statistically significant (F-statistic: 5.87, P <.01). European and Asian countries tend to have higher ubiquitous broadband penetration than other countries in Africa, America, and Oceania. This result suggests that there is digital divide between countries by region.

Mean difference of ubiquitous broadband penetration between countries with multi-play strategies such as triple-play and quadruple-play offerings without multi-play strategies was also significant (see table 5-14). This result suggests that multi-play strategy such as triple-play and quadruple-play offerings is a contributing factor of global ubiquitous broadband deployment including fixed and mobile broadband. Also, mean difference of broadband penetration between countries with LLU policy and without LLU policy was also significant (see table 5-14). This suggests that LLU policy is a contributing factor of global ubiquitous broadband deployment.

Table 5-14. Difference in total (ubiquitous) broadband penetration and total broadband penetration rate by income, region and multiple play offerings

Dependent Variable	Source	SS	*df*	MS	*F*	Variable	Mean
Total Broadband Penetration	Income	9917.05	2	4958.52	69.80***	High Income	15.12
	Error	15130.59	213	71.03		Medium Income	1.52
						Low Income	.22
	Region	2509.46	4	627.36	5.87***	Africa	.88
	Error	22538.19	211	106.81		America	3.63
						Asia	8.17
						Europe	10.53
						Oceania	7.89
Total Broadband Penetration	Triple-Play	1192.75	1	1192.75	14.20**	Triple-play	21.67
	Error	2351.61	28	83.99		No Triple-play	6.76
	Quad-play	517.88	1	517.88	4.791*	Quad-play	24.53
	Error	3026.47	28	108.09		No Quad-play	15.47
Total Broadband Penetration	LLU	2441.22	1	2441.22	17.40***	LLU	537.05
	Error	11362.21	81	140.27		No LLU	914.11

Note. Categorization of countries by income and region are based on the ITU's categorization of countries by income and region.
* Statistically significant at the 10% level. ** Statistically significant at the 5% level.
***Statistically significant at the 1% level

CHAPTER 6
DISCUSSION AND CONCLUSION

This study examines adoption factors of fixed, mobile, and ubiquitous broadband and helps explains why there are differences in the diffusion of broadband communication technology between countries. This chapter summarizes the empirical results and analysis. Implications of this study and limitations and suggestions for future research are also discussed in this chapter.

Summary of Results and Analysis

Effects of Policy Factors on Broadband Deployment

This study examined several policy factors of broadband diffusion. For fixed-broadband, the effects of interactions of different types of LLU policies and LLU price regulation on fixed-broadband deployment were examined. For mobile broadband, the effects of market-mediated standard policy and the influence of different 3G licensing assignment types on mobile broadband diffusion were tested. For ubiquitous broadband, the effect of LLU policy (LLU dummy variable) and influences of different types of platform competition-standardization policies on the diffusion of ubiquitous broadband were examined. Also, for all broadband technologies, the effects of institutional environment such as political and economic freedom were tested.

Effects of LLU policy on broadband deployment. The results of nonlinear regression analysis suggests the effects of interactions of different types of LLU and LLU price regulation were very significant factors of fixed broadband diffusion in OECD countries (see Table 6-1). Most OECD countries adopted two types of LLU. The first type of LLU in OECD countries is implementation of full unbundling, line sharing, and bit stream access all together. Some OECD countries adopted full unbundling and line sharing only without bit stream access (OECD, 2003). Also, many OECD countries have LLU price regulation such as regulatory approval for line rental charges (OECD, 2003). The result of nonlinear regression study suggests that LLU policy type I (full unbundling, line sharing, and bit stream access without LLU price regulation for line rental charges), LLU policy type II (full unbundling, line sharing, and no bit stream access with LLU price regulation for line rental charges), and LLU policy type III (full unbundling, line sharing, and bit stream access with LLU price regulation for line rental charges) were significant factors of fixed broadband diffusion in OECD countries. The result of one-way ANOVA also suggests LLU policy has been a key driver of fixed broadband diffusion in many ITU membership countries (see Table 6-1). Also, the result of one-way ANOVA suggests ubiquitous broadband penetration of countries with LLU policy is higher than that of countries without LLU policy (see Table 6-1). Considering fixed broadband is more popular in most of countries and competition effect of LLU policy might influence other platforms' (e.g. cable) market behavior for competition, it is expected result.

Based on these results, in general, LLU policy can be an effective policy tool for improving broadband diffusion.[1] Considering that DSL is the major source of residential broadband delivery in most countries, intra-modal competition in the DSL market through LLU policy might have contributed to a greater adoption of fixed-broadband (Lee & Brown, 2008). LLU policy might simulate the competitive effect by opening up an incumbent network for competitive access. Effective intra-modal competition through LLU policy may bring real choice for customers and reduce DSL prices (Lee, 2006; DotEcon & Criterion Economics, 2003). However, implementation of LLU policy and LLU price widely differs among countries (OECD, 2003). In spite of significance LLU policies' effect on broadband deployment, strong LLU

[1] These results are consistent with the results of other previous studies by Ridder (2007), Wallsten (2006), and Grosso (2006).

regulation may confiscate incumbents' property and reduce their investment incentives in new telecommunication technologies (Frieden, 2005a). Considering these costs and benefits of LLU policy, more refined LLU policy should be recommended.

Effects of other policy factors on mobile and ubiquitous broadband deployment. The log linear regression results of mobile broadband penetration for all countries suggest that a market-based multiple standards policy significantly contributes to the diffusion of mobile broadband services (see Table 6-1). This finding is consistent with the findings by Cabral and Kretschmer (2004), which assert, as mobile technology becomes more mature, standardization and its scale and efficiency benefits seem to become less relevant. This finding might also suggest that the importance of market- mediated multiple standards when a new technology evolves into a different stage of development characterized by more advanced, differentiable features (Lee et al., 2007b).

Also, the log linear regression results of ubiquitous broadband penetration for all countries suggest that both the interactions of DSL-cable platform competition availability in fixed-broadband markets and single and multiple standardization policy significantly contributes to the diffusion of ubiquitous broadband penetration (see Table 6-1). However, can these results of log linear regression of mobile broadband penetration and ubiquitous broadband penetration for all countries be applied to both developed and developing countries? Unfortunately, since mobile broadband is a very new medium for most developing countries, only a small number of observations for mobile broadband penetration were available. In spite of the small number of observations for the mobile broadband penetration, the result of log linear regressions of ubiquitous broadband penetration for developed countries and developing countries gives us more ideas about this policy issue. The log linear regression results of ubiquitous broadband penetration for developed countries suggest that the interaction variable (Policy type II) of DSL-cable platform competition availability in fixed-broadband markets and single standardization policy in mobile broadband markets was not statistically significant (see Table 6-1). However, the interaction variable (Policy type III) of DSL-cable platform competition availability in fixed-broadband markets and multiple standardization policy in mobile broadband markets was statistically significant (see Table 6-1). In the developing countries, the situation seems different. In the developing countries both interaction variables (Policy type II and Policy type III) were statistically significant (see Table 6-1). Moreover, in developing countries, considering the P-value and t-statistic for Policy type II and Policy type III variables, Policy type II variable (with DSL-cable platform competition in fixed-broadband markets and single standardization policy in mobile broadband markets) was more significantly associated with the diffusion of ubiquitous broadband (see Table 6-1). Considering that in most of developed countries currently DSL-cable modem platform competition is available, the results of these empirical studies for mobile broadband diffusion and ubiquitous broadband diffusion at least suggest that in the initial status of mobile broadband deployment, market-mediated standardization policy is more effective for developed (high income) countries, which basic ICT infrastructure is already deployed and might have more mature mobile industry and consumers.

Table 6-1. Significant policy factors of broadband deployment*

Model/Policy Factors	LLU Policy I**	LLU Policy II	LLU Policy III	LLU Dummy	Multiple Standards	P-S Policy I***	P-S Policy II	P-S Policy III	Political Freedom	Economic Freedom	Type of Licensing
Fixed-Broadband Nonlinear(N=217) OECD Countries	Yes (p<.01)	Yes (p<.01)	Yes (p<.01)						No	No	
Fixed-Broadband Linear(N=282) All Countries									No	No	
Fixed-Broadband Linear(N=132) Developed Countries									No	No	
Fixed-Broadband Linear(N=148) Developing Countries									No	No	
Fixed-Broadband One-way ANOVA (N=158) All Countries				Yes (p<.01)							
Mobile Broadband Linear (N=105) All Countries					Yes (p<.01)				No	No	
Mobile Broadband											

Table 6-1 Continued,

One-way ANOVA (N=65) All Countries											No
Total Broadband Linear (N=191) All Countries						Yes (p<.1)	Yes (p<.1)	Yes (p<.05)	Yes (p<.01)	No	
Total Broadband Linear (N=73) Developed Countries						Yes (p<.1)	Yes (p<.1)	Yes (p<.01)	Yes (p<.05)	No	
Total Broadband Linear (N=120) Developing Countries						Yes (p<.1)	Yes (p<. 01)	Yes (p<.05)	No	No	
Total Broadband One-way ANOVA (N=82) All Countries				Yes (p<.01)							

*For the significant variables, variables which are statistically significant at the .1 level were included in this table. This result is based on the final reduced model.

** LLU Policy Type I: Full unbundling + line sharing + bit stream access + No LLU price regulation
LLU Policy Type II: Full unbundling + line sharing + no bit stream access + LLU price regulation
LLU Policy Type III: Full unbundling + line sharing + bit stream access + LLU price regulation

***P-S Policy Type I: Cable modem-DSL platform competition + no standardization policy for mobile broadband
P-S Policy Type II: Cable modem-DSL platform competition + single standardization policy for mobile broadband
P-S Policy Type III: Cable modem-DSL platform competition + multiple standardization policy for mobile broadband

It appears that, in developed countries, technological diversity, in a new medium's early stage, is likely to foster innovative applications and better consumer choices, which initially lead to faster deployment of technology like mobile broadband.

This study also found high level of political freedom, which is measured by the level of civil liberty in a country, is associated with the high level of diffusion of ubiquitous broadband. This result suggests, in the diffusion of 4G mobile technology, political freedom might be an influential factor. Also, the result of one-way ANOVA of mobile broadband diffusion suggests 3G mobile licensing assignment method is not a significant factor of mobile broadband diffusion (see Table 6-1).

Effects of Industry Factors on Broadband Deployment

Platform/network competition is a significant factor of broadband deployment. The result of log linear regression of fixed-broadband diffusion suggests the higher level of platform competition measured by HHI (Herfinall-Hirschman Index) is associated with the higher level of fixed broadband penetration. Though coefficient B of platform competition shows its relationship with fixed-broadband diffusion, it was not a significant factor of fixed-broadband diffusion in developed countries (see Table 6-2) in the log linear model. This result is consistent with the result of the nonlinear model of fixed broadband diffusion for OECD countries. Considering OECD countries consist of 30 developed countries, this result appears robust (see Table 6-2). However, in developing countries, platform competition was an influential factor of fixed-broadband diffusion. With these results, considering most of developed countries have higher level of fixed-broadband penetration, it appears platform competition is mainly effective for countries in the initial diffusion stage of fixed-broadband deployment.

Also, for ubiquitous broadband, network competition between fixed and mobile broadband, which is measured by a dummy variable, was a significant factor of ubiquitous broadband deployment (see Table 6-2).

In the log linear model of fixed-broadband deployment, this study also found fixed broadband price, which is measured by lower speed monthly charge (USD), was negatively associated with the higher level of fixed-broadband diffusion. As Ridder (2007) suggested, many previous empirical studies on fixed broadband couldn't find this negative association between fixed-broadband price and fixed-broadband deployment.[2] Considering the relationship between price and normal goods, negative association between fixed-broadband price and fixed-broadband deployment is an expected result. Interestingly, the result of log linear model of ubiquitous broadband also provides that negative correlations of price and ubiquitous broadband deployment (see Table 6-2). Considering fixed-broadband technology is a dominant technology in most of countries for broadband access, this is a plausible result.

The result of log linear regression analysis also suggests download speed, which is measured by the Kbit/s, is a significant factor of ubiquitous-broadband deployment (see Table 6-2). The result suggests that fast download speeds could lead to more broadband subscribers in the market. This result also may imply consumers who want fast broadband speed will more readily migrate to costly broadband services, if there are higher levels of throughput speed offered by broadband service providers (Lee & Brown, 2008).

The log linear regression of fixed-broadband deployment also suggests that bandwidth, which is measured by bits per inhabitants, is a driver of fixed broadband deployment.

[2] Garcia-Murillo (2005) found association of fixed broadband price, which is measured by monthly price per megabite, with the number of fixed broadband subscribers. However, in the study, fixed broadband price was positively correlated to the number of subscribers.

Considering bandwidth may determine the quantity of information transmitted and the offering of diverse broadband applications, the positive association between bandwidth and fixed broadband deployment is an expected result.

The effect of mobile price on fixed-broadband deployment is very interesting. In the linear regression analysis for all ITU membership countries, mobile price is not a significant factor of fixed-broadband diffusion. Also, the result of linear regression analysis of mobile broadband suggests fixed-broadband price is not a significant factor of mobile-broadband diffusion. Based on these results, in the linear regression model for all countries, mobile service (and mobile-broadband service) is not a complement or substitute to fixed-broadband services and fixed-broadband service is not a complement or substitute to mobile-broadband service. However, surprisingly, in developed countries, mobile price is negatively associated with the higher level of fixed broadband, but, in developing countries, mobile price is positively associated with the higher level of fixed broadband. This result might suggest that in developed countries mobile service is a complement to fixed-broadband services, but in developing countries mobile service is a substitute to fixed broadband. Considering consumers in low-income countries tend to have limited budget for media and telecommunication services, this result is possible.

This finding may also suggest that when mobile broadband services become popular in most countries, this trend could be continued for both developed countries and developing countries. If the data for mobile broadband services in developing countries become sufficiently available, this relationship should be tested in the future research.

The result of one-way ANOVA for fixed and mobile broadband suggests triple-play strategy have contributed higher level of fixed broadband penetration growth rate, but quadruple-play strategy have not significantly influenced the growth rate of mobile penetration yet. This

Table 6-2. Significant industry factors of broadband deployment*

Model /Industry Factors	Platform Competition	Fixed Broadband Price	Speed	Bandwidth	Telecom Investment	Mobile Price	Mobile Application Cost	Network Competition	Triple-Strategy	Quadruple -Strategy
Fixed-Broadband Nonlinear(N=217) OECD Countries	No			No	No					
Fixed-Broadband Linear(N=282) All Countries	Yes $(p<.05)$	Yes $(p<.1)$	No	Yes $(p<.01)$	No	No				
Fixed-Broadband Linear(N=132) Developed Countries	No	No	No	No	No	Yes $(p<.1)$				
Fixed-Broadband Linear(N=148) Developing Countries	Yes $(p<.1)$	Yes $(p<.1)$	No	Yes $(p<.01)$	No	Yes $(p<.1)$				
Fixed-Broadband One-way ANOVA All Countries(N=158)									Yes $(p<.01)$	
Mobile Broadband Linear (N=105) All Countries		No		No	No	No	No			
Mobile Broadband One-way ANOVA All Countries(N=65)										No
Total Broadband Linear (N=191) All Countries		Yes $(p<.05)$	Yes $(p<.05)$	No	No	No		Yes $(p<.05)$		
Total Broadband										

Linear (N=73) Developed Countries		No	Yes (p<.05)	Yes (p<.01)	No	No				
Total Broadband Linear (N=120) Developing Countries		No	No	Yes (p<.01)	No	No				
Total Broadband One-way ANOVA All Countries(N=29)									Yes (p<.05)	Yes (p<.1)

*For the significant variables, variables which are statistically significant at the .1 level were included in this table. This result is based on the final reduced model.

result may suggest that in the initial multiple play markets the quadruple-play strategy is not as successful as triple-play strategy.[3] The result of one-way ANOVA for ubiquitous broadband also suggests quadruple-play strategy have not significantly influenced the ubiquitous broadband penetration yet as triple-play strategy.[4]

Effects of Demographic/ICT Factors on Broadband Deployment

The results of both linear regression analysis of mobile broadband and ubiquitous broadband suggest higher level of income measured by GDP per capita is associated with higher levels of mobile and ubiquitous broadband deployment (see Table 6-3).[5] These results suggest consumers with higher incomes are more likely to purchase broadband services. Broadband service providers in high-income markets may consider possible segmentation strategies by income. Also, higher levels of education are associated with higher levels of fixed-broadband deployment in both nonlinear and linear regression models. As Rodgers (2003) suggests, many early adopters tend to have higher socio-economic status (e.g. high level of education).

High level of population density and urbanization are considered as supply factors for broadband diffusion (Ridder, 2007). The results of nonlinear and linear regression analysis of fixed broadband suggests higher levels of population density are associated with higher levels of fixed-broadband deployment and linear regression analysis of ubiquitous broadband shows population density is also a significant factor of ubiquitous broadband deployment. This result

---

[3] One of the reasons might be the high switching cost for mobile services. To switch over mobile providers, the consumer should pay high cancellation fee.

[4] Table 5-14 provides this result. The result of one-way ANOVA suggests that the effects of triple-play strategy on the diffusion of ubiquitous broadband are statistically significant at the .05 level, while the effects of quadruple-play strategy on the diffusion of ubiquitous broadband are statistically significant at the .1 level only.

[5] This result is consistent with the result by Madden et al. (2004) and Andonova (2006), which suggested income is a significant factor of mobile diffusion. Also, some previous studies on fixed broadband suggested income is an influential factor of broadband diffusion (see Wallsten (2006); Grosso (2006); Garcia-Murillo (2005)).

may imply more densely populated country have advantages in the cost conditions for network deployment. Also, higher levels of urban population share are associated with higher levels of ubiquitous broadband deployment, which may imply that more urbanized countries have better cost conditions for broadband deployment.

The result of nonlinear regression analysis suggests that higher levels of PC penetration are associated with the higher levels of fixed broadband penetration in OECD countries (see Table 6-3). This result might suggest that an already well-established ICT infrastructure may lead to more rapid fixed-broadband deployment. Also, the result of linear regression for all ITU membership countries suggests high levels of Internet usage in a country is correlated with high levels of fixed broadband diffusion (see Table 6-3). As Frieden (2005) contends, these results of ICT factors might suggest that ICT incubation, which is supported by ICT infrastructure or ICT use such as PC infrastructure and Internet use, may be key drivers of broadband deployment.

In addition, Internet content, as measured by the number of Internet hosts per 10000 inhabitants, was a significant factor for fixed broadband penetration in OECD countries (see Table 6-3). This result implies that the amount of compelling content, services and applications within a nation is an important factor of fixed-broadband diffusion (Lee & Brown, 2008).

This study also examined the causal relationship between 1G and 2G mobile penetration and mobile broadband penetration. Considering the negative relationship between these two variables in the final reduced model of mobile broadband diffusion, mobile broadband can be considered a substitute of 1G and 2G mobile services. While this result of inter-generation effects on mobile diffusion is different from the previous study by Liiknen et al. (2004), which found that 1G has positive effect on 2G, it is nevertheless an expected result because many mobile users prefer 3G mobile services that offer more diverse mobile applications than 1G or 2G mobile services.

Also, the result of linear regression analysis of fixed-broadband diffusion suggests previous fixed-broadband penetration is positively associated with current fixed-broadband penetration, which may imply existence of network effects. As Economides and Himmelberg (1995) suggest, if there are network effects, current subscription of new media is positively correlated with previous subscription of new media. Based on the result of log linear regression study of fixed-broadband deployment, this study at least suggests that between 2002 and 2005, new fixed-broadband subscribers joined broadband network influenced the utility of current fixed-broadband subscribers.[6]

Digital Divide and Broadband Deployment in Developed and Developing Countries

The result of one-way ANOVA for fixed, mobile, and ubiquitous broadband diffusion, suggests there are significant differences in the diffusion of broadband by income (between high, medium, and low income countries) and by region (between Africa, America, Asia, Europe, and Oceania). This result is consistent with the result of previous by Chinn and Fairlie (2006), which found that the global digital divide is mainly explained by income differentials.

This study also examined common and different factors of broadband deployment in developing and developed countries.[7] Table 6-4 provides summary of the results for developing and developed countries. For fixed-broadband deployment, common significant factors of broadband diffusion for both developing and developing countries are fixed-broadband price and

[6] If more broadband penetration data, which covers more periods, are available, using different nonlinear model, more refined research to test the impact of network effect on broadband deployment will be possible.

[7] Because of very small number of observations of mobile broadband for developing countries, this study examined only fixed and ubiquitous broadband deployment for developing and developed countries.

Table 6-3. Significant demographic/ICT factors of broadband deployment*

Model /Factors	Income	Education	Urban Population	Population Density	Age (35-44)	PC Penetration	Content	Internet Usage	Teledensity	1G/2G Penetration	Previous Penetration
Fixed-Broadband Nonlinear(N=217) OECD Countries	No	Yes (p<.05)		Yes (p<.05)		Yes (p<..01)	Yes (p<.05)				
Fixed-Broadband Linear(N=282) All Countries	No	No	No	No	No	No	No	Yes (p<.01)	No		Yes (p<.01)
Fixed-Broadband Linear(N=132) Developed Countries	Yes (p<.05)	Yes (p<.01)	No	Yes (p<.1)	No	No	Yes (p<.05)	No	No		Yes (p<.01)
Fixed-Broadband Linear(N=148) Developing Countries	No	No	No	No	No	No	No	Yes (p<.05)	No		Yes (p<.01)
Fixed-Broadband One-way ANOVA All Countries(N=158)	Yes (p<.01)										
Mobile Broadband Linear (N=105) All Countries		No		No	No	No	No			Yes (p<.05)	
Mobile Broadband One-way ANOVA All Countries(N=65)	Yes (p<.1)										
Total Broadband Linear (N=191) All Countries	Yes (p<.01)	No	Yes (p<.1)	Yes (p<.05)	No	No	No	No	No		
Total Broadband Linear (N=73)	No	No	No	Yes	No	No	No	Yes	No		

Developed Countries				(p<.05)				(p<.01)			
Total Broadband Linear (N=120) Developing Countries	Yes (p<.01)	No	No	No	No	No	No	No	No		
Total Broadband One-way ANOVA All Countries(N=82)	Yes (p<..01)										

*For the significant variables, variables which are statistically significant at the .1 level were included in this table. This result is based on the final reduced model.

previous fixed-broadband penetration. For both developing and developed countries, fixed-broadband price is negatively associated with fixed-broadband deployment and previous fixed-broadband penetration is positively associated with current fixed-broadband penetration (see Table 6-4). This result implies lower pricing and network effects contributed to more rapid fixed-broadband diffusion in both developing and developed countries. Mobile price was positively associated with fixed-broadband diffusion in developing countries, but negatively associated with fixed-broadband diffusion in developed countries. This result implies that in developing countries mobile service is a substitute for fixed broadband service, but in developed countries it is a complement for fixed broadband service. Table 6-4 also suggests that Internet use, bandwidth and platform competition are significant factors of fixed-broadband diffusion only for developing countries and income, education, population density, and content are significant factors only for developed countries. This result implies for fixed-broadband diffusion, ICT infrastructure (Internet use), industry competition (HHI), and technological factors such as bandwidth are more important variables in developing countries.

For ubiquitous-broadband deployment, common significant factors of broadband diffusion for both developing and developing countries are bandwidth and Policy type III (A country which platform competition between cable modem and DSL platform is available and has multiple standardization policy for mobile broadband).[8] Table 6-4 also suggests that income is a significant factor of ubiquitous broadband diffusion only for developing countries and speed, political freedom, population density, and Internet use are significant factors only for developed countries. Policy type II (A country which platform competition between cable modem and DSL platform is available and has single standardization policy for mobile broadband) is a significant

[8] Policy type I was a significant factor for both developing and developed countries at the .1 level.

factor for developing countries, but significant only at the .1 level for developed countries. This result may imply the impacts of a single standard and its benefits such as network externalities for mobile broadband may be larger in developing countries than in developed countries.

Table 6-4. Common and Different Significant Factors of Broadband Deployment**

Broadband Technology	Common Significant Factors	Significant Factors: Developing Countries Only	Significant Factors: Developed Countries Only
Fixed Broadband	Fixed broadband price Previous broadband penetration	Mobile price (+)* Internet use Bandwidth Platform competition*	Mobile price (-)* Income Education Population density Content
Ubiquitous Broadband	Bandwidth Policy Type III (p <.05) Policy Type I* (p < .1)	Income Policy Type II (p < .01)	Speed Political freedom Population density Internet use Policy Type II* (p <.1)

**For the significant variables, variables which are statistically significant at the .05 level were included in this table. This result is based on the final reduced model.
Variable with * is significant at the level .1
***Policy Type I: Cable modem-DSL platform competition + no standardization policy for mobile broadband
Policy Type II: Cable modem-DSL platform competition + single standardization policy for mobile broadband
Policy Type III: Cable modem-DSL platform competition + multiple standardization policy for mobile broadband

Implications

Theoretical Implications

One of the main goals of this study is to examine the effects of platform (or standard/network competition) on broadband deployment. Platform competition occurs when different technologies (platforms) compete to provide similar or differentiated telecommunication services to end-users (Church & Gandal, 2005). Platform competition in network industry involves competition between technologies that are not only differentiated, but also involve competing networks (Church & Gandal, 2005). Using ITU membership countries data, this study tested the impacts of platform competition between cable modem, DSL and other platforms on fixed-broadband penetration. The result provides competition between different fixed-broadband platforms is an influential factor of fixed-broadband deployment in ITU membership countries.[9] Interestingly, the result of nonlinear regressions of fixed-broadband penetration suggest high levels of platform competition are related to high levels of fixed-broadband penetration, but the effects of platform competition are not statistically significant in OECD countries. This result is consistent with the result of linear regression analysis of developed countries (high income ITU membership countries). Considering OECD countries are composed of 30 developed countries with comparatively high GDP per capita, it seems this result is robust.

Considering all results of statistical analysis of fixed-broadband and previous empirical studies on fixed broadband deployment, it appears the effects of platform competition are strong in the initial deployment (e.g. a developing country with low level of fixed broadband penetration) of fixed-broadband, but the effects of platform competition are decreasing when the broadband market size is sufficiently large or broadband market is mature.[10] Strong platform competition among different technologies may lead to lower prices, increased feature offerings, and more extensive broadband networks (ITU, 2003a), but, it seems, after the initial deployment of fixed-broadband, these effects of platform competition are decreasing. In the future, with

[9] It appears this result was similar in developing countries (see Table 5-8).

[10] In some OECD countries such as Korea and Japan, the diffusion pattern of fixed broadband already shows s-shape curve, as Rodgers (2003) suggested in the diffusion of innovations theoretical framework.

larger numbers of data and observation periods, the effects of platform competition should be continuously examined.[11]

In spite of this observation of the effects of platform competition on fixed-broadband diffusion, the results of log linear regression analysis of ubiquitous broadband and mobile broadband suggest theoretical framework of platform competition are still useful in explaining the deployment of broadband. The result of data analysis of ubiquitous broadband suggests network competition between mobile and fixed broadband is a significant factor of ubiquitous broadband deployment. Also, this study also suggests competition between different mobile standards (e.g. competition between W-CDMA and CDMA 2000) in mobile industry is a significant factor of mobile broadband diffusion. Considering the status of mobile and ubiquitous broadband deployment is still in early stage in most of countries, these results support the result of fixed broadband deployment research, which the effects of platform (or network competition) are strong in the initial deployment of broadband deployment. With greater numbers of data and observation periods, the results of this study should be further assessed as mobile and ubiquitous broadband continues to grow.[12]

This study also examined whether network effects are involved in the diffusion of broadband. For the test of network effect, a long period of observations with sufficient number of data is necessary. For the nonlinear model of fixed broadband, this study employs Gruber and Verboven (2001)'s model. Since nonlinear model of fixed- broadband diffusion already assume network externality, this study tested whether previous subscription of fixed-broadband is a

[11] Hőffler (2007) found negative side of platform/network competition. He suggested that comparing additional social surplus attributable to cable competition with the cable investments, without significant positive externality, infrastructure competition has probably not been welfare enhancing (Hőffler, 2007).

[12] However, considering very initial deployment status of mobile broadband in most of countries, this new hypothesis can be tested after significant time period is passed.

significant factor of current subscription in the log linear regression model of fixed broadband.[13] As expected, previous fixed- broadband penetration was an influential factor of current fixed-broadband deployment in all ITU membership countries, whether characterized as developed or developing countries. Considering impacts of platform competition in ITU membership countries, it appears currently in many countries that network effects and the effects of platform competition co-exist. The result of log linear regression analysis suggests, for fixed broadband, new subscribers joining a broadband network might influence the utility of current subscribers. This network effect in fixed-broadband markets might become significant after a certain broadband subscription percentage has achieved critical mass. This study has not examined critical mass point for fixed-broadband deployment; however, network effect and critical mass point may be captured in fixed-broadband deployment pattern in some countries like Korea, Japan and UK (Lee & Marcu, 2007). Research should continue to examine network effects and the effects of platform competition, thereby capturing how broadband diffusion patterns change over time.

Path dependence theory, which refers to the dependence of a system or network on past decisions of producers and consumers, is also related to mobile broadband deployment. The result of log linear regression analysis of mobile broadband suggests that market-mediated standard policy is a significant factor of mobile broadband diffusion. It appears that market-mediated multiple standards are important when a new technology evolves into a different stage of development characterized by more advanced, differentiable features (Lee et al., 2007). The result of the regression study of mobile broadband suggests that, in spite of EU's success story of mandated standard (GSM) in initial stage of 2G, the 3G standard policy that may have

[13] Because of short period of observations, this hypothesis was not tested for mobile and ubiquitous broadband.

assumed WCDMA or locked operators into WCDMA might be a very costly public policy decision (Gandal et al., 2003). However, considering the positive effects of platform competition on broadband diffusion decrease as the market matures, the applicability of path dependence theory is limited and the effect of EU's mandated single standard policy on mobile broadband diffusion is not clear in the long term.

Also, the result of this empirical study suggests that an established infrastructure (e.g. PC penetration, ICT use, previous fixed broadband penetration) for relevant information and communication technologies is an influential factor for fixed-broadband diffusion (Lee et al., 2007). This result may imply the phenomenon of leapfrogging in developing countries cannot be easily applied to the diffusion of fixed-broadband. More refined studies about the applicability of leapfrogging theory to broadband diffusion are necessary in the future.

Policy Implications

This study examined the effects of LLU policy on fixed-broadband diffusion. There have been a lot of debates on the effects of LLU policy, but the type of LLU policy and LLU price are very different across countries. The result of nonlinear regression study suggests that LLU policy type I (full unbundling, line sharing, and bit stream access without LLU price regulation for line rental charges), LLU policy type II (full unbundling, line sharing, and no bit stream access with LLU price regulation for line rental charges), and LLU policy type III (full unbundling, line sharing, and bit stream access with LLU price regulation for line rental charges) were all significant explanatory variables of fixed broadband diffusion in OECD countries. Apparently it seems this result supports the effectiveness of LLU on fixed broadband in many countries. Effective LLU policy may generate consumer benefits in the near future through open access to competitors (Frieden, 2005a). Considering the result of this study, countries fostering broadband deployment need consider adopting LLU policy for the fixed-broadband market. However, LLU might reduce incumbent's incentives to invest in new telecommunication technologies (Frieden, 2005a). Considering these costs and benefits of LLU policy, it may be better if countries might pursue light-touch regulation such as line-sharing and/or bit stream access instead of full unbundling at a reasonable LLU price. A previous study suggests, the uptake of these light forms of LLU has been relatively successful (de Bijl & Peitz, 2005).

This study also found significant effects of platform competition on fixed-broadband diffusion in the initial deployment of fixed broadband and initial success of market-mediated standard policy in mobile broadband markets. Also, this study found positive effects of network competition and interactions of platform competition and multiple standards policy on ubiquitous broadband deployment. This result implies, at least in the initial broadband markets, regulation across different platforms should be as competitively neutral as possible for sustaining strong platform competition. Considering positive effects of network externality and the possibility of decreasing effects of platform/network/standard competition on broadband diffusion in the long term, it is still important to note that concepts of efficiency and ease of integration are critical for future broadband markets.

These discussions on policy factors of broadband deployment have policy implications for the diffusion of 4G mobile technologies (or pre 4G mobile technologies). The result of this study implies in the initial 4G mobile markets, governments need to be open to diverse standards for competition instead of government-mandated standards. In the long term, as Noam (2003) suggested, industry-wide coordination and mutual learning processes is important. In this cooperative voluntary standard setting situation, compatibility is achieved by agreeing to a standard (Church & Gandal, 2005). In doing so, in the long term, broadband service providers may suppress competition between networks in favor of competition on a network.

Also, this study has different policy implications for developed and developing countries. The results of fixed broadband deployment study suggest that mobile service could be a substitute for fixed broadband service in developing countries, but it could be a complement for fixed broadband service in developed countries. This result may imply, in the long term, when mobile broadband services are mature in many countries, deployment of fixed (mobile) broadband might positively influenced mobile (fixed) broadband in developed countries. Considering leapfrogging theory cannot easily applied to broadband deployment in the developing countries, this result of statistical analysis for developing countries may suggest without sufficient previous ICT experiences and better economic status[14], it is not easy to deploy fixed and mobile broadband at the same time. Also, this study suggests, for the ubiquitous broadband deployment, policy type II (platform competition in fixed broadband plus single standard for mobile broadband) or policy type III (platform competition in fixed broadband plus multiple standards for mobile broadband) would be recommendable in the developing countries, but, only policy type III would be recommendable for developed countries.[15]

Limitations and Suggestions for Future Research

This study has some limitations. For the fixed-broadband diffusion model, because of data availability, more diverse independent variables cannot be included for the nonlinear regression model. Also, since the nonlinear model already assumes network externality, the impacts of network effects on fixed broadband could not be tested in the model. When more data and observations over a longer period are available, and, with different nonlinear model such as Gompaz model, more refined analysis on the effects of platform competition and network effects

[14] It appears that insufficient income and limited budget for mobile and fixed broadband services are reasons of substitute relationship between mobile service and fixed broadband services in developing countries.

[15] In spite of this general policy recommendation, each country's situation and environment such as size of a country should be considered for the best policy choice.

will be possible. Also, for the analysis of the effects of LLU policy, if diverse data about the effects of line sharing and bit stream access are available with sufficient observations, more refined comparison of the effects of different type of LLU policies are possible.

For the mobile broadband diffusion model, data for developing countries were not sufficient to analyze the difference between developing countries and developed countries. Also, with a small number of observations over comparatively short period, nonlinear nature of broadband diffusion was not easily captured for mobile and ubiquitous broadband diffusion. When more observations over a longer time period are available, more refined analysis will be possible. Also, if different multiple measurements for ubiquitous broadband deployment and data are available, more improved research for the diffusion of ubiquitous broadband deployment, which has greater implications for 4G mobile deployment, will be available.

Finally, this study could not include any impacts of socio-cultural variables and other policy variables on broadband deployment in a country. For instance, a country's culture such as life style and policy factors such as cross-ownership regulation of media and spectrum availability[16] could be another influential factors of broadband deployment. When more refined measurement and data for these variables are available, these variables can be included in the empirical model.

[16] For instance, the scarcity of frequency spectrum may influence the performance of the mobile telecommunications industry (Gruber, 2001c). Efficient use of spectrum and optimal licensing fee could be important for the deployment of 3G mobile and mobile price.

LIST OF REFERENCES

Ahn, H. & Lee, M. (1999). An econometric analysis of the demand for access to mobile telephone networks. *Information Economics and Policy*, *11*, 297-305.

Aizu, I. (2002). A comparative study of broadband in Asia: Development and policy. Paper presented at RIETI Symposium, Tokyo.

Andonova, V. (2006). Mobile phones: the Internet and the institutional environment. *Telecommunications Policy*, *30*, 29-45.

Aron, D. J. & Burnstein, D. E (2003). Broadband adoption in the United States: An empirical analysis. In A.L. Shampine (Ed.), *Down to the wire: Studies in the diffusion and regulation of telecommunications technologies* (pp.119 -138). Haupaugge, NY: Nova Science Publishers.

Atkinson, R.D., Correa, D.K. & Hedlund, J.A. (2008). Explaining international broadband leadership. Washington, DC: The Information Technology and Innovation Foundation.

Cabral, L. M. B. & Kretschmer, T. (2007). Standards battle and public policy. In S. Greenstein & V. Stango (Eds.), *Standards and public policy* (pp.329 -344). Cambridge, MA: Cambridge University Press.

Cava-Ferreruela, I. & Alabau- Muňoz, A. (2006). Broadband policy assessment: A cross-national empirical analysis. *Telecommunications Policy*, *30*, 445-463.

Church, J. & Gandal, N. (2005). Platform competition in telecommunications. In M., Cave, S., Majumdar & I. Vogelsang (Eds.), *The handbook of telecommunications vol. 2.: Technology evolution and the Internet*., Armsterdam, The Netherlands: North-Holland.

Clements, M & Abramowitz, A. (2006, September). The development and adoption of broadband service: A household level analysis. Paper presented *35th Research Conference on Communication, Information and Internet Policy*, Arlington, VA.

Chang, B., Lee, S. & Kim, B. (2006). Exploring factors affecting the adoption and continuance of online games among college students in South Korea. *New Media and Society 8*(2), 295-319.

Chaudhuri, A., Flamm, K.S. and Horrigan J. (2005), An analysis of the determinants of internet access. *Telecommunications Policy*, *29*(9-10),731-55.

Chinn, M.D. & Fairlie, R.W. (2006). The determinants of the global digital divide: A cross-country analysis of computer and Internet penetration. *Oxford Economic Papers*, *59*, 16-44.

Collis, D.J., Bane, P.W., & Bradley, S. P. (1997). Winners and losers: Industry structure in converging world of telecommunications, computing and entertainment. In D.B. Yoffie (Ed.), *Competing in the age of digital convergence* (pp.159-200). Boston: Harvard Business School Press.

Crandall, R. W., Sidak, J.G. & Singer, H.J. (2002). The empirical case against the regulation of broadband access. *Berkeley Technology Law Journal*, *17*(3), 953-87.

Crandall, R. W. (2005). Broadband Communications. in Cave, M., Majumdar, S. and Vogelsang, I. (Eds.), *Handbook of telecommunications economics, Volume 2: Technology evolution and the Internet*(pp.156 -191), Amsterdam, Netherlands: North-Holland.

David, P., & Greenstein, S. (1990). The economics of compatibility standards: An introduction of recent research. *Economics of Innovation and New Technology*, *1*, 3-41.

Davis, F.D. (1989). Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Quarterly*, *13*(3), 319–340.

De Bijl, P.W.J. & Peitz, M. (2005). Local loop unbundling in Europe: Experience, prospects and policy challenges. *Communications & Strategies*, *57*, 33-57.

Denni, M. & Gruber, H. (2005). The diffusion of broadband telecommunications: The role of competition. Paper presented at International Telecommunication Conference, Pontevedra.

Distaso, W., Lupi, P & Maneti, F.M. (2006). Platform competition and broadband uptake: theory and Empirical evidence from the European Union. *Information Economics and Policy*, *18* (1). 87-106.

DotEcon & Criterion Economics (2003). Competition in broadband provision and its implication for regulatory policy: A report for the Brussels Round Table. London: DotEcon & Criterion Economics. Retrieved July 7, 2006, from http://www.dotecon.com

Dowling, M., Lechner, C., &Thielman, B. (1998). Convergence – Innovation and change of market structures between television and online services. *Electronic Markets*, *8*(4).

Economides, N. & Himmelberg, C. (1995). Critical mass and network size with application to the US fax market. Discussion paper EC-95-11, Stern School of Business, New York University.

Fernandez-Cornejo, J & McBride, W. D. (2002). Adoption of bioengineered crops. US Department of Agriculture Agricultural Economics Report, 810.

Fransman, M. (2006). Introduction. In M. Fransman (Ed.), *Global Broadband Battles; Why the U.S. and Europe Lag While Asia Leads* (pp. 1-58). Standford University Press, Stanford, CA.

Freedom House (2007). Freedom in the world country ranking. Retrieved May 10 from http://www.freedomhouse.org

Frieden, R. (2005a). Unbundling the local loop: A cost/benefit analysis for developing nations. *Info*, *7*(6), 3-15.

Frieden, R. (2005b). Lessons from broadband development in Canada, Japan, Korea and the United States. *Telecommunications Policy*, *29*(8), 595-613.

Friedman T.L. (2006). *The world is flat: A brief history of the twenty first century*. New York, NY: Farrar, Straus and Giroux.

Gandal, N. (2002). Compatibility, Standardization, and network effects: Some policy implications. *Oxford Review of Economic Policy*, *18* (1), 80-91.

Gandal, N., Salant, D. & Waverman, L. (2003). Standards in wireless telephone networks. *Telecommunications Policy, 27*, 325–332.

Garcia-Murillo, M. (2005). International broadband deployment: The impact of unbundling. *Communications & Strategies*, *57*. 83-108.

Glassman, J. & Lehr, W. (2001). The economics of Tauzin-Dingell: Theory and evidence. Retrieved December 3 from http://ebusiness.mit.edu/research/papers

Grosso, M. (2006). Determinants of broadband penetration in OECD nations. Paper presented to the Australian Communications Policy and Research Forum.

Gruber, H. (2001a). Competition and innovation: The diffusion of mobile telecommunications in Central and Eastern Europe. *Information Economics and Policy*, *13*(1), 19-34.

Gruber, H. & Verboven F. (2001b). The evolution of markets under entry and standards regulation: The case of global mobile telecommunications. *International Journal of Industrial Organization 19*, 1189-1212.

Gruber, H. (2001c). Spectrum limits and competition in mobile markets: the role of license fees. *Telecommunications Policy, 25*, 59-70.

GSMA (2007). How to realize the benefits of mobile broadband today. Retrieved November 26, 2007 from http://hspa.gsmworld.com

Haring, J., Rohlfs, J.H. & Shooshan, H.M. (2002). Propelling the broadband bandwagon. Bethesda, MA; Strategic Policy Institute.

Heritage Foundation (2008). 2008 Index of economic freedom. Retrieved May 10, 2008 from http://www.heritage.org/research/features/index/downloads.cfm

Hausman, J. A. (2001). Regulation by TSLRIC: Economic effects on investment and innovation in Sidak, J., Engel, C. and Knieps, G. (Eds.), *Competition and Regulation in Telecommunications: Examining Germany and America* (pp. 51-68). Boston, MA: Kluwer Academic.

Hausman, J. A. (2002). Internet related services: The results of asymmetric regulation, in Crandall, R.W. and Alleman, J.H. (Eds.), *Broadband: Should we regulate High-Speed Internet* (pp.129-56), AEI-Brookings Joint Center for Regulatory Studies, Washington, DC.

Horrigan, J.B. (2005). Broadband adoption at home in the United States: Growing but slowing. Paper presented at 33rd Research Conference on Communication, Information and Internet Policy, VA: Arlington.

Horrigan, J.B. (2007). Home broadband adoption 2007, Retrieved November 26, 2007 from http://www.pewinternet.org

International Telecommunication Union (2001). *3G mobile licensing policy: From GSM to IMT-2000- a comparative analysis*. ITU Workshop on Licensing 3G Mobile, September 19-21, 2001, Geneva: International Telecommunication Union.

International Telecommunication Union (2003a). Promoting broadband: Background paper for workshop on promoting broadband. Retrieved November 11, 2005 from http://www.itu.int

International Telecommunication Union (2003b). *Birth of broadband*. Geneva, Switzerland: ITU.

International Telecommunication Union (2003c). Mobile overtakes fixed: Implications for policy and regulation. Geneva, Switzerland: Author.

International Telecommunication Union (2004). *The portable Internet*. Geneva, Switzerland: Author.

International Telecommunication Union (2005). *The Internet of Things*. Geneva, Switzerland: Author.

International Telecommunication Union (2006). *Digital.life*. Geneva, Switzerland: Author.

Jang, S., Dai, S. & Sung, S. (2005). The pattern and externality effect of diffusion of mobile telecommunications: The case of OECD and Taiwan. *Information Economics and Policy*, *17*, 133-148.

Kang, M.H. (2002). Digital Cable: Exploring Factors Associated with Early Adoption. *Journal of Media Economics*, *14*(3), 193–207.

Katz, Michael & Shapiro, C. (1985). Network Externalities, Competition and Compatibility. *The American Economic Review*, *75* (3), 424-440.

Kauffman, R.J. & Techatassanasoontorn, A.A. (2005). International diffusion of digital mobile technology: A couple-hazard state-based approach. *Information Technology and Management*, *6*, 253-292.

Kim, D. (2005). Direction of mobile communication in the age of convergence. Retrieved October 13, 2007 from http://www.etri.re.kr

Kim, J. H., Bauer, J.M. & Wildman, S.S. (2003). Broadband uptake in OECD countries: Policy lessons from comparative statistical analysis. Paper presented at the 31st Research Conference on Communication, Information and Internet policy. VA: Arlington.

Koski, H. & Kretschmer, T. (2002). Entry, standards and competition: Firm strategies and the diffusion of mobile telephony. ETLA Discussion Papers, 827.

Krauss, J. (2006). Market drivers for triple play. Retrieved March 14, 2008, from http://www.keymile.com

Lee, C. & Chan-Olmsted, S.M. (2004).Competitive advantage of broadband Internet: A comparative study between South Korea and the United States. *Telecommunications Policy*, *28* (9-10), 649-677.

Lee, S. (2006). Broadband deployment in the United States: Examining the impacts of the platform competition. *The International Journal on Media Management*, *8*(4), 173-181.

Lee, S. (2006, August). The Impacts of Market-based Standardization Policy on Mobile Deployment in OECD Countries: An Empirical Analysis. Paper presented *Association for Education in Journalism and Mass Communication* Annual Convention, San Francisco, CA.

Lee, S., Chan-Olmsted, S.M. & Kim, H. (2007, August). The Deployment of Third-Generation Mobile Services: A Multinational Analysis of Contributing Factors. Paper presented to the 2007 *Association for Education in Journalism and Mass Communication* Annual Convention, Washington D.C.

Lee, S., & Marcu, I. M. (2007, August). Fixed and mobile broadband deployment: An empirical analysis of adoption factors. Paper presented *to the 35th Research Conference on Communication, Information and Internet Policy*, Arlington, VA.

Lee, S., Brown, J. (2008). Examining Broadband Adoption Factors: An Empirical Analysis between Countries. *Info: the Journal of Policy, Regulation, and Strategy for Telecommunication, Information, and Media*, *10* (1), 25- 39.

Lee, W. (2006, August). Mobile phone diffusion in developed and developing countries: Digital divide, factor, and difference. Paper presented *Association for Education in Journalism and Mass Communication* Annual Convention, San Francisco, CA.

Lehr, W., Osorio, C., Gillett, S. & Sirbu, M. (2005). Measuring broadband's economic impact. Paper presented at 33rd Research Conference on Communication, Information and Internet Policy, Arlington, VA.

Liebowitz, S.J. & Margolis, S. (1990). The fable of the keys. *Journal of Law & Economics*, *30*(1), 1-26.

Liebowitz, S.J. & Margolis, S. (1994). Network externality: An uncommon tragedy. *Journal of Economic Perspective*, *8* (2). 133-150.

Liikanen, J., Stoneman, P. & Toivanen, O. (2004). Intergenerational effects in the diffusion of new technology: The case of mobile phones. *International Journal of Industrial Organization*, *22* (8/9). 1137-1154.

Lin, C.A. (1998). Exploring personal computer adoption dynamics. *Journal of Broadcasting and Electronic Media*, *42* (1). 95-112.

Madden, G., Coble-Neal, G. & Dalzell, B. (2004). A dynamic model of mobile telephony subscription incorporating a network effect. *Telecommunications Policy*, *28*, 133-144.

Noam, E. M. (2003). The next frontier for openness: Wireless communications. In E. M. Noam, & D. Steinbock (Eds.), *Competition for the Mobile Internet* (pp. 21-37). Norwell, MA: Kluwer Academic Publishers.

Oh, S., Ahn, J. & Kim, B. (2003). Adoption of broadband Internet: The role of experience in building attitudes. *Journal of Information Technology*, *18*, 267-280.

Organization for Economic Co-operation and Development (2001). *The development of broadband access in OECD countries*. Paris: OECD.

Organization for Economic Co-operation and Development (2003). *Development in local loop unbundling*. Paris: OECD.

Organization for Economic Co-operation and Development (2005). *Communications outlook 2005*. Paris: OECD.

Organization for Economic Co-operation and Development (2006a). OECD broadband statistics. Paris: OECD. Retrieved July 5, 2006 from http://www.oecd.org/document

Organization for Economic Co-operation and Development (2006b). Multiple play: Pricing and policy trends. Paris: OECD.

Organization for Economic Co-operation and Development (2007a). OECD broadband statistics. Paris: OECD. Retrieved July 26, 2007 from http://www.oecd.org/document

Organization for Economic Co-operation and Development (2007b). *Communications outlook 2007*. Paris: OECD.

Organization for Economic Co-operation and Development (2007c). Mobile multiple play: New service pricing and policy implications. Paris: OECD. Retrieved October 29, 2007 from http://www.oecd.org

Organization for Economic Co-operation and Development (2007d). Fixed-Mobile convergence: Market development and policy issues. Paris: OECD. Retrieved October 29, 2007 from http://www.oecd.org

Organization for Economic Co-operation and Development (2007e). Catching-up in broadband: What will it take?. Paris: OECD. Retrieved October 2, 2007 from http://www.oecd.org

Owen, B. M. (2002). Broadband mysteries. In Crandall, R.W. and Alleman, J.H. (Eds.), *Broadband: Should we regulate High-Speed Internet* (pp.9-38), AEI-Brookings Joint Center for Regulatory Studies, Washington, DC.

Pagani, M. (2004). Determinants of adoption of third generation mobile multimedia services. *Journal of Interactive Mobile Marketing*,*18* (3),46-59.

Picard, R.G. (2000). Changing business models of online contents services: There implication for multimedia and other content producers. *International Journal on Media Management*, *2*, 60-68.

Prieger, J.E. (2003). The supply side of the digital divide: Is there equal availability in the broadband Internet access market. *Economic Inquiry*, *41*(2), 346-363.

Rappoport, P. N., Kridel, D. J., Taylor, L. D. and Alleman, J. (2001). Residential demand for Access to the Internet. In Madden, G. (Ed.), *Emerging telecommunications networks: The international handbook of telecommunications economics, Volume II*. (pp.1-20), Edward Elgar Publishers, Cheltenham, UK.

Reese, S.D. (1988). New Communication Technologies and the Information Worker: The Influence of Occupation. *Journal of Communication*, *38*(2), 59–70.

Rice, R.E. & Katz, J.E. (2003). Comparing Internet and mobile phone usage: Digital divides of usage, adoption, and dropouts. *Telecommunications Policy*, *27*, 597-624.

Ridder, J. D. (2007, August). Catching-up in broadband: What will it take?. Paper presented *to the 35th Research Conference on Communication, Information and Internet Policy*, Arlington, VA.

Rohlfs, J.H. (2001). *Bandwagon Effects in High-Technology Industries*. Cambridge, MA: The MIT Press.

Rogers, E. M. (2003). *Diffusion of innovations*. New York, NY: Free Press.

Rouvinen, P. (2006). Diffusion of digital mobile telephony: Are developing countries different? *Telecommunications Policy*, *30*, 46-63.

Savage, S. J. & Waldman, D. (2005). Broadband Internet access, awareness, and use: Analysis of United States household data. *Telecommunications Policy*, *29* (8), 615-633.

Shapiro, C. & Varian, H. R. (1999). *Information Rules*. Boston, MA: Harvard Business School Press.

Time Warner (2007). Time Warner cable news. Retrieved March 29, 2008, from http://www.timewarnercable.com

Turner, S.D. (2006). Broadband reality check II: The truth behind America's digital decline.Washington, DC: The Free Press.

United Nations Development Program (2004). *Human development report 2005.* New York, NY: UNDP.

United Nations Development Program (2005). *Human development report 2006.* New York, NY: Author.

Viard, B., (2007). Do switching costs make markets more or less competitive: The case of 800-number portability. *Rand Journal of Economics, 38*, 146-163.

Wallsten, S. (2006). Broadband and unbundling regulations in OECD countries. Working paper 06-16, AEI-Brookings Joint Center for Regulatory Studies.

Warschauer, M. (2003). *Technology and social incursion: Rethinking digital divide*. Cambridge, MA: The MIT Press.

Weiser, M. (1991, September). The computer for the 21st Century. *Scientific American*.

Wikipedia. (n.d.). Retrieved October 11, 2007, from http://en.wikipedia.org

Williams, M. (2006). Cutting the cord to analog phone. Retrieved March 31, 2006, http://www.networkworld.com/news/2006/081006-no-analog-phone.html

Wirth, M. (2006). Issues in media convergence in Albarran, A., Chan-Olmsted, S.M., & Wirth, M. (ed). *Handbook of Media Management and Economics*. Mahwah, New Jersey: Lawrence Erlbaum & Associates.

Sawng,Y., Lee, J. & Han, H.(2005). Market expansion and customer acceptance for IT convergence related new business. *Information and Telecommunication Policy Research*, *12* (1), 189-221.

Shelanski, H. (2003). Competition policy for 3G wireless services. In E. M. Noam & D. Steinbock (Eds.), *Competition for the Mobile Internet* (pp. 39-54). Norwell, MA: Kluwer Academic Publishers.

Xavier, Patrick (2001). *Licensing of third generation (3G) mobile: Briefing Paper*. ITU Workshop on Licensing 3G Mobile, September 19-21, 2001, Geneva, International Telecommunication Union.

BIOGRAPHICAL SKETCH

Sangwon Lee received his bachelor's degree in public administration at Yonsei University in Seoul, Korea. He also earned a master's degree in telecommunication at George Washington University in Washington, DC. He has worked for consultant and analyst in telecommunication sector. Lee conducted research in the area of telecommunication policy, media economics, media management, and new media technology and regulation. His work has been published in journals such as International Journal on Media Management, Info: the Journal of Policy, Regulation, and Strategy for Telecommunication, Information and Media, and International Journal of Mobile Marketing.