Fixed and Mobile Broadband Deployment: An Empirical Analysis of Adoption Factors

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Abstract

Broadband communications lie at the heart of the developing information society. We employ 1999-2005 OECD data to analyze the primary determinants of fixed broadband adoption. We find that local loop unbundling, ICT infrastructure, population density, and Internet content are all influence fixed broadband adoption. Platform competition is a significant driver of cable modem broadband, but not DSL adoption. Multiple standards policy, mobile application price, and population density also influence the diffusion of mobile broadband. We also find that fixed broadband is neither a complement nor a substitute for mobile broadband yet.

1. Introduction

Broadband communications lie at the heart of the developing information society. Widespread broadband adoption encourages innovation, contributes to productivity and growth, and attracts foreign investment (ITU, 2003a). As of December 2005, more than 166 countries had launched fixed broadband services and a further 68 or so economies had 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). “Mobile broadband”, provided by 3G mobile systems, support data transport rates of at least 144 kbit/s for all radio environments (which exceed the rates under second generation wireless networks). (ITU, 2006; ITU, 2003b; Shelanski, 2003). The 3G mobile systems enable many advanced video applications such as mobile videoconferencing, video phone/mail, mobile TV/Video player, and digital audio/video delivery (Xavier, 2001; ITU, 2001).

In spite of the overall rapid growth in broadband diffusion, many countries are still in the early stages of fixed and mobile broadband deployment and are assessing policy strategies to promote faster adoption. 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 the quality of service, increasing the number of customers and promoting investment and innovation (DotEcon & Criterion Economics, 2003). Regarding mobile, there have been debates on whether single or multiple standards promote faster adoption of mobile communications.

There is a growing body of literature on fixed broadband adoption, but there are still very few cross-cultural empirical studies examining the important influential factors of global broadband adoption. In addition, the existing studies provide contrasting findings (see table 3). In spite of its significance and implications, there is no empirical study about influential factors of mobile broadband adoption because mobile broadband deployment began only in recent years. For the same reason, there is no study investigating whether fixed broadband is a complement or a substitute for mobile broadband.

Using 1999-2005 OECD (Organization for Economic Cooperation and Development) data, the longest available panel to date, we estimate a logistic regression to capture the nonlinear nature and examine the influential factors of fixed broadband adoption. We find that local loop unbundling, ICT infrastructure, population density, and Internet content are all influential factors of fixed broadband adoption. Interestingly, while insignificant in the overall regression of fixed broadband adoption, platform competition appears to be a significant driver of cable modem broadband, though not DSL adoption.

Using linear regression analysis of mobile broadband adoption in 51 countries, we also assess whether standardization policy, Information and Communication Technology (ICT) infrastructure, teledensity, income, education, population density, mobile service price, mobile application cost, and fixed broadband price are influential factors of global mobile broadband deployment.[1] We find that multiple standards policy, mobile application price, and population density contributed significantly to the diffusion of mobile broadband. Our results indicate that fixed broadband is neither a complement nor a substitute for mobile broadband yet.

The paper is organized as follows: Section 2 summarizes the existing literature on fixed

1 We are constrained to use linear regression to analyze mobile broadband diffusion by the small number of years of data available. Previous studies of first and second generation mobile communications diffusion have evidenced the nonlinear nature of the adoption process (see Gruber and Verboven (2001) and Marcu (2004), for example).

and mobile communications adoption, Section 3 presents the methodology and data, Section 4 presents the results, and Section 5 concludes.

2. Literature Review

There has been a steady growth of fixed and mobile broadband adoption in the world. There were some 216 million fixed broadband subscribers and just over 60 million mobile broadband subscribers at the end of 2005 (ITU, 2006). The adoption of fixed broadband service during the first 10 years of its availability has proceeded more rapidly than the corresponding adoption of previous services such as cellular and dial-up services across OECD countries (OECD, 2006). The dominant fixed broadband access platforms are DSL (Digital Subscriber Line) (with 61.85 % of the market) and cable modem (32.29 %). Other platforms such as fiber-to-the-home (FTTH) and wireless broadband access serve approximately 6 % of the market (ITU, 2005). As of December 2006, Denmark, Netherlands, Iceland, Korea, and Switzerland had thehighest broadband penetration rates among OECD countries (OECD, 2007; see Table 1).

Table 1 about here

There exists a wide range of mobile broadband diffusion levels across countries. As of November 2005, Korea, Israel, Canada, Japan, and the United States were the top five mobile broadband economies in terms of the percentage of 3G subscribers (ITU, 2005; see Table 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 2 about here

2.1. Empirical Studies on Global Fixed Broadband Deployment

There is a growing body of empirical research about fixed broadband deployment. Some empirical studies find that inter-modal competition, local loop unbundling (LLU), and demographic variables on the supply-side increase fixed broadband adoption. On the demand side, higher income and lower broadband price increase fixed broadband adoption.

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 might be key factors for broadband supply and demand. Analyzing data from 14 European countries, Distaso et al. (2006) argue that inter-platform competition drives broadband adoption, but that competition in the DSL market does not play a significant role. Using logit regression analysis, 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 explaining broadband uptake in OECD countries. Using generalized least squares, Grosso (2006) finds that competition, income, and unbundling increase broadband diffusion (see Table 3).

2.2. Empirical Studies on Global Mobile Deployment

Many previous empirical studies on global mobile diffusion find that standardization policy, competition, and low user cost are influential factors of global mobile deployment (Gruber, 2001; Gruber & Verboven, 2001; Liikanen et. al., 2001; Kioski and Kretschmer 2002; Rouvinen, 2006; see Table 3). Many studies in the economics of standards have focused on the private and social incentives for standardization (Gandal, 2002; David & Greenstein, 1990). A single standard can deliver better economies of scale and network externalities. However, as long as mobile networks are interconnected and coverage is effective, there is little need for compatibility (Gandal et al., 2003). In essence, there are both advantages and disadvantages to market-mediated multiple standards relative to a 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). Through empirical study of 140 countries, 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 as it dampens competition. It appears 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) examined the effectiveness of public policy in the context of competing standards with network externalities and concluded that current mobile diffusion levels are quite similar between the United States (multiple standards) and Europe (mostly single standard). More recently, Rouvinen (2006) investigated the factors affecting the diffusion of digital mobile telephony across developed and developing countries, finding that standards competition hinders and market competition promotes diffusion in both groups. Table 3 summarizes the variables and findings of empirical studies on global broadband deployment.

In spite of a growing body of literature that addresses the factors contributing to fixed broadband diffusion at the national level, the results of empirical studies are not consistent (see table 3). In addition, few empirical studies have focused on the factors that affect mobile broadband adoption globally. Also, there is no empirical study concerning whether mobile broadband is a complement or a substitute for fixed broadband.

Accordingly, based on the literature reviewed, this paper proposes the following research questions (RQs):

RQ1: Does platform competition influence global fixed broadband adoption?

RQ2: Does LLU policy influence global fixed broadband adoption?

RQ3: Do other factors such as income, population density, ICT infrastructure, urban living population, and broadband content significantly influence global fixed broadband adoption?

RQ4: Does standardization policy influence the adoption of mobile broadband services?

RQ5: Do other factors such as income, Information and Communications Technology infrastructure, mobile service price, mobile content price, population density, and education affect mobile broadband deployment?

RQ6: Is fixed broadband a complement or a substitute for mobile broadband?

3. The Model, Method, and Data

3.1. Fixed Broadband

The diffusion of new technologies is usually nonlinear, and this is most likely also the case with broadband diffusion, as acknowledged by Kim et al (2003), and Cava-Ferreruela and Alabau-Muňoz (2006). We follow Gruber and Verboven (2001) and estimate a logistic model of fixed broadband penetration. In many OECD countries the standard S-shaped pattern of the logistic curve appears to approximate well the diffusion of fixed broadband (see graphs in the appendix).

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:

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

where a_{it} and b_{it} are parameters, as discussed below, and y_{it}^{*} is the penetration ceiling or percentage of potential adopters.

The parameter a_{it} in equation (1) is a constant of integration that gives the initial value of broadband penetration.[2] A positive value shifts the S shaped function upwards while a negative one shifts it downwards, without modifying the S-shape. Not all individuals in a country adopt a new technology, such as broadband, regardless of how inexpensive the technology may become. This is captured in the model by the ceiling parameter y_{it}^{*}. The parameter b_{it} in equation (1) captures the speed of adoption. This can be seen by differentiating equation (1) with respect to time.

The parameters in equation (1) can vary with characteristics such as income, prices, the percentage of urban population, and other socio-economic variables, as well as a result of policy

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2 Note that $y_{it} \to \frac{y_{it}^{*}}{1+e^{-a_{it}}} \quad as \quad t \to 0$.

decisions. Two broad classes of logistic diffusion models have been proposed: the variable-ceiling logistic and the variable-speed logistic (Fernandez-Cornejo and 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 logistic model is easier to estimate and the speed of adoption can be positive or negative, depending on the movement of exogenous factors. We therefore allow the speed of diffusion to vary with policy variables D_{it}^{j} and country socio-economic characteristics X_{it} in linear fashion:

$$b_{it} = \beta^0 + \sum_{j=1}^{J} \beta^j D_{it}^j + X_{it}\beta . \qquad (2)$$

The parameter β^0 captures the natural speed of broadband adoption. The country characteristics included in X_{it} are variables that are likely to influence the supply of and the demand for broadband. They are: real GDP per capita expressed in constant 2000 US Dollars as a measure of income, the number of computers per 100 inhabitants, population density and the percentage of urban population as determinants of deployment cost, and the number of Internet hosts per 10000 inhabitants as a proxy for Internet content.

We are mainly interested in the impact of policy variables on broadband penetration. The policy variables included in our study are dummy variables capturing the unbundling of the local loop and the existence of platform competition. Our measure of platform competition equals one for years in which both cable and DSL subscriber existed in the country. The local loop unbundling dummy equals one for years when unbundling was in effect and zero otherwise. The dummy variables thus change over time, depending on the timing of the introduction of competition and the year when unbundling began. Some of the previous studies have found that inter-modal competition and local loop unbundling are important determinants of broadband penetration (Cava-Ferreruela & Alabau-Muňoz, 2006). A third policy variable, the share of state ownership in the incumbent telecommunications operator tuned out to be insignificant and did not affect the qualitative results of our estimations, so we excluded it from the reported results and estimations. Table 4 shows the variables, their measures, and the data sources.

Table 4 about here

3.2. Mobile Broadband

To examine the influential factors of global mobile broadband deployment this study utilizes a secondary dataset and employs linear regression analysis. Because of the relatively early stage of mobile broadband deployment, data is available only for a cross-section of countries.

Table 5 shows the variables used, their measures, and the data sources. Most mobile studies (Madden et al. 2004; Koski & Kretschmer, 2002; Gruber 2001; Ahn & Lee, 1999) used mobile penetration rates at the individual level for the measurement of mobile deployment. In this study, the 3G mobile diffusion rate (dependent variable) was also measured by the number of 3G mobile subscribers per 100 inhabitants in a country. To examine the effect of standardization policy, we employ a dummy variable equal to one if a country had multiple standards, and zero otherwise. Because of the variability of mobile services and thus their pricing, measuring mobile service prices is notoriously difficult. We use the price per minute of a local call during peak hours in US Dollars collected by the ITU to measure the cost of mobile services in each country. This measurement refers to the average cost of one-minute mobile calls within the same network, off-net, and to a fixed line during peak hours (ITU, 2005). Regarding non-voice mobile applications, we adopted the cost of short message services (SMS) as a proxy for the price of mobile broadband relevant applications. SMS is a feature available in many new digital phones that lets users receive and send short text messages. For the measurement of fixed broadband price, we employ USD per 100kbit/s.

The level of education may play a significant role in the adoption of mobile broadband, and could be measured by literacy rates and average education/degree levels (Garcia-Murillo, 2005; Clements & Abramowitz; 2006). For the measurement of education, this study uses the UNDP education index, which is based both on the adult literacy rate and the combined gross enrollment ratio for primary, secondary and tertiary schools (UNDP, 2005). Previous studies have used the share of urban population to capture demographic factor (Gruber, 2001; Liikanen et. al, 2004; Koski & Kretschmer, 2002). In this study, population density was measured by population per km^2. We use GDP per capita expressed in US dollars as a measure of disposable income. Finally, to assess the information and communication technology infrastructure, we adopted the usual ICT measures of estimated PCs per 100 inhabitants (ITU, 2006) and teledensity (i.e., main telephone lines per 100 inhabitants). Data has been collected from the International Telecommunication Union and UNDP. A total of 51 observations were available for multiple regression analysis.

Table 5 about here

In summary, the linear regression composite model we employ to examine the influence of quantifiable variables on the diffusion patterns of 3G mobile in individual countries is:

$$\begin{aligned} \mathbf{Y_t\ (3G\ Mobile\ Penetration\ Rate)} = {} & \beta_0 + \beta_1(\text{Dummy-Standardization Policy}) \\ & + \beta_2(\text{ICT Infrastructure}) + \beta_3(\text{Mobile Price}) \\ & + \beta_4(\text{Population Density}) + \beta_5(\text{Education}) \\ & + \beta_6(\text{Teledensity}) + \beta_7(\text{Income}) + \beta_8(\text{Fixed Broadband Price}) \\ & + \beta_9(\text{Cost of Mobile Application}) + \varepsilon_t \qquad (3) \end{aligned}$$

4. Results and Analysis

4.1. Fixed Broadband

Our data covers all 30 OECD countries. To our knowledge, no other study employs data as recent as 2005 when examining broadband diffusion. We estimate the variable-speed logistic model described in equations (1) and (2) by nonlinear least squares regression, after adding disturbances to equation (1). The disturbances are allowed to be potentially heteroskedastic, as well as serially correlated within country. The results are presented in Table 6. In addition to the results of fixed broadband penetration estimations, Table 6 also presents results of separate estimations for DSL and cable penetration.[3]

Table 6 about here

Per capita disposable income is highly correlated with our ICT infrastructure indicator, the number of personal computers per 100 inhabitants (the correlation is close to 0.8). While this may lead to multicollinearity and imprecise estimates of the coefficients, theory suggests they are both very important determinants of broadband penetration. For this reason we opted to report results with both variables included in the estimations. This did not appear to qualitatively change our results or affect our ability to precisely estimate the other parameters. The use of personal computers was associated with higher broadband and cable penetration levels, though

[3] Other high speed technologies such as WiFi and fiber to the home (FTTH) played a relatively insignificant role in broadband Internet penetration for the countries and years in our sample.

not with DSL penetration. Income was significant only in the cable equation, and had an unexpected negative sign. It is possible however that we are unable to adequately disentangle the effects of these variables.

Our proxy for available Internet content (the number of Internet hosts per 10000 inhabitants) is positively associated with the dependent variables in all our models. However, this result should be interpreted with care, as higher broadband penetration may in turn lead to a larger number of Internet hosts. That is, the variables may be endogenous. The same can be said about the number of PCs per 100 inhabitants.

We include both the percentage of urban population and population density in the estimations, as there is little correlation between them in our sample. Theoretically they are both drivers of cost, and hence the supply of broadband. The relatively low correlation is probably due to the existence of two types of countries in our sample: large countries like the US, Canada, and Australia, with a high percentage of urban population yet relatively low population density, and smaller countries, like most European countries, that have both a relatively high population density and a high percentage of urban population. We find that higher population density increases the speed of broadband penetration. However, the percentage of urban population is insignificant in all three equations. In light of the recent debates and allegations that some countries have fallen behind while others are ahead in the broadband adoption race, our results suggest that larger, less densely populated countries are indeed at a disadvantage when it comes to the deployment of broadband communications. One should therefore exercise caution and conduct a careful analysis before concluding that some countries are ahead or are falling behind.[4]

LLU encourages competition by reducing the economic barriers to entry, thereby

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4 In a policy paper written at the same time as this paper, Ford and others [2007] propose a policy-relevant method for comparing broadband adoption among countries.

allowing new entrants to build some components of their networks and obtain other components from the incumbent DSL operator (OECD, 2001). Competition may bring real choice for customers and downward pressure on costs in the broadband access market (Lee, 2006; DotEcon & Criterion Economics, 2003). However, LLU may also result in lower broadband penetration by reducing the incentives of incumbent suppliers to invest in broadband infrastructure. There is great variation in the ways local loop unbundling has been implemented in different countries. Unfortunately, we were unable to find measures such as leased line prices or the share of leased lines in total lines for a large enough number of observations in our sample. Nevertheless, the dummy variable capturing the implementation of local loop unbundling is significant in all our estimations. Local loop unbundling appears to have significantly increased the speed of broadband adoption.

The most interesting result concerns the effect of platform competition on broadband penetration. According to an ITU report, the existence of strong platform competition among DSL, cable modem, fiber, and wireless broadband in a market may ensure that prices remain low (ITU, 2003b). In this context, in the broadband access market, regulation across platforms should be as competitively neutral as possible to sustain strong platform competition. While platform competition is insignificant in our estimations of overall broadband penetration, a closer look at the equations we estimated separately for cable and DSL penetration reveals the fact that platform competition is significantly associated with a higher speed of cable modem broadband diffusion.

4.2. Mobile Broadband

Our examination of mobile broadband diffusion employed 51 observations using linear regression analysis. Two models were identified from the multiple regression analysis.

Initially, all nine independent variables were employed. As multicollinearity is usually a concern with a relatively low number of observations, Table 7 in the appendix shows the correlation matrix among independent variables. Multicollinearity does not appear to be an issue in our sample. The left panel in Table 8 provides the results of this first extended regression. The regression model is significant at 1% level.

Table 8 about here

The multiple standards dummy variable, population density, and the proxy for the cost of mobile applications (cost of SMS service) are all statistically significant at the 1% level. Mobile service price, income, teledensity, ICT infrastructure, education, and the price of fixed broadband service were not statistically significant.

To check the stability of the results, the most insignificant variables were removed and a second, reduced model was estimated.[5] Teledensity, fixed broadband price, ICT infrastructure, and mobile service price were removed. The right panel in Table 8 provides the results of the resulting reduced model. The regression is still significant at the 1% level. The multiple standards dummy variable, population density, and the proxy for the cost of mobile applications (cost of SMS) were again statistically significant at the 1% level. Furthermore, the estimates appear to be very stable when comparing the two regressions. We therefore conclude that multiple standards, higher population density, and lower mobile application prices were all significant drivers of mobile broadband adoption.

Our findings here support the assertion of Cabral and Kretschmer (2004) that, as mobile

[5] The removed variables had p-values above 25%, and with the exception of fixed broadband price they all had p-values above 40%.

technology becomes more mature, standardization and its scale and efficiency benefits seem to become less relevant. This illustrates the importance of market mediated multiple standards when a new technology evolves into a different stage of development characterized by more advanced, differentiable features. In this context, technological diversity is likely to foster innovative applications and better consumer choices.

5. Concluding Remarks

This study examines influential adoption factors of fixed and mobile broadband. The results of logistic regression show that ICT infrastructure, population density, and broadband content are associated with faster fixed broadband adoption. Our results also indicate that LLU policies have been successful in promoting fixed broadband adoption in many OECD countries. The effects of platform competition on fixed broadband diffusion are very interesting. We found that platform competition contributed mainly to cable modem adoption. A high level of ICT infrastructure and country-specific broadband content are also important drivers of fixed broadband deployment. This result might imply use of interesting contents and killer applications such as online game and MP3 music download could drive broadband deployment.

Higher population density contributes significantly to fixed broadband adoption. This implies that the costs of deploying fixed broadband services differ significantly among countries. Caution should therefore be exercised and a careful analysis conducted when assessing the relative success or failure of countries' broadband policies.

Our linear regression results suggest that a market-based multiple standards policy significantly contributes to the adoption of mobile broadband services. The cost of mobile broadband applications and is also an influential factor of mobile broadband adoption. It appears that a lower cost for popular mobile applications is critical in attracting the consumers to the more advanced non-voice mobile services. In other words, a competitive pricing system for applications that can leverage the unique characteristics of mobile broadband networks encourages rapid and widespread deployment of mobile broadband. Just like in the case of fixed broadband, population density contributes significantly to mobile broadband adoption.

This study is limited by the relatively small number of observations in our sample, particularly on mobile broadband. As more data becomes available it may be possible to capture the potentially nonlinear nature of mobile broadband diffusion and to construct better measures of broadband policies such as LLU and platform competition. Based upon studies that suggest mobile telephony serves as a substitute for fixed phone services (ITU, 2003c), one might expect a similar relationship between fixed and mobile broadband. Our preliminary findings did not support the hypothesis that fixed and mobile broadband are substitutes, nor did they support the hypothesis that they are complements. It may be too early to indicate a permanent result, considering that mobile broadband is relatively new in the marketplace compared to fixed broadband. Further research is necessary to better assess the nature of the relation between fixed and mobile broadband, as well as the effects of broadband policies on broadband adoption.

Appendix

Table1. Broadband Penetration Rate (Top 5 OECD Countries), by Technology, December 2006

	DSL	Cable	Fibre/LAN	Other	Total	Rank	Total Subscribers
Denmark	19.6	9.4	2.6	0.4	31.9	1	1,728,359
Netherlands	19.5	12.0	0.4	0	31.8	2	5,192,200
Iceland	28.8	0	0.2	0.6	29.7	3	87,738
Korea	11.4	10.7	7.0	0	29.1	4	14,042,728
Switzerland	18.8	8.8	0	0.9	28.5	5	2,140,309

Note. Data were derived from Organization for Economic Co-operation and Development (2007).
Source: OECD broadband statistics. Paris: OECD.

Table2. Mobile Broadband (3G Mobile) Penetration (Top 5 OECD Countries), 2005

	3G Mobile Penetration	3G as % of all mobile subscribers	Rank	Total 3G Subscribers
Korea	57.37	75.2	1	27,509,000
Israel	27.78	25.4	2	1,823, 000
Canada	23.31	49.4	3	7,400,000
Japan	20.10	28.1	4	25,700,000
United States	16.68	27.4	5	49,550,000

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

Table3. Main Empirical Studies on Fixed and Mobile Broadband Deployment

Fixed broadband			Mobile		
Study	**Main independent variables**	**Significant findings**	**Study**	**Main independent variables**	**Significant findings**
Kim et. al. (2003) 30 countries	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	**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
Garcia-Murillo (2005) 92 countries	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	**Liikanen et al. (2001)** 80 countries	Income Urban population Fixed penetration Analog/digital 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
Distaso et. al. (2006) 14 countries	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	**Gruber and Verboven (2001)** 140 countries	Income Fixed penetration Digital mobile Standard Competition	Competition Single standard Incumbent pre-empt sequential entry
Cava-Ferreruela and Alabau-Muňoz (2006) 30 countries	Broadband price Competition Infrastructure investment Telecom services penetration Internet indicators Economic indicators Demographic indicators Education indicators Social indicators	Technological competition Cost of deploying infrastructures Economic indicators Demographic indicators	**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
Grosso (2006) 30 countries	Competition Income Unbundling Fixed Internet penetration	Competition Income Unbundling	**Rouvinen (2006)** 165 countries	Income Population Standard Fixed Penetration/user cost Development Technology Democracy	Standards Competition Network effects

Table 4. Variables, Measurement and Data Sources for Statistical Analysis (Fixed Broadband)

Variables	Measurement	Data Sources
Fixed broadband deployment	Fixed broadband subscribers per 100 inhabitants	OECD (1999-2005)
Cable modem deployment	Cable modem subscribers per 100 inhabitants	OECD (1999-2005)
DSL deployment	DSL subscribers per 100 inhabitants	OECD (1999-2005)
Income	GDP per capita	UN (1999-2005)
ICT Infrastructure	Estimated PCs per 100 inhabitants	ITU (1999-2005)
LLU	Dummy (1 for with LLU, 0 for no LLU)	OECD (1999-2005)
Population density	Population density (per km^2)	ITU (1999-2005)
Urban population	Percentage of urban population	Euromonitor (1999-2005)
Broadband content	Internet hosts per 10000 inhabitants	ITU (1999-2005)
Platform Competition	Dummy (1 for with DSL and cable modem, 0 for only DSL or cable modem)	OECD (1999-2005)

Table 5. Variables, Measurement and Data Sources for Statistical Analysis (Mobile Broadband)

Variables	Measurement	Data Sources
3G mobile deployment	3G mobile subscribers per 100 inhabitants	ITU (2005), ITU (2006)
Standardization Policy	Dummy variable (1 for multiple standards or 0 for mandated standard)	www.3gtoday.com, ITU (2005), ITU (2006)
ICT Infrastructure	Estimated PCs per 100 inhabitants	ITU (2005), ITU (2006)
Mobile service price	Per minute local call (USD) peak	ITU (2005), ITU (2006)
Population density	Population density (per km^2)	ITU (2005), ITU (2006)
Cost of Mobile Application	Cost of SMS service	ITU (2005), ITU (2006)
Income	GDP per capita	ITU (2005), ITU (2006)
Education	UNDP Education Index	UNDP (2004), UNDP (2005)
Teledensity	Main telephone lines per 100 inhabitants	ITU (2005), ITU (2006)
Fixed broadband price	USD per 100kbit/s	ITU (2005), ITU (2006)

Table 6. Logistic Regressions of Broadband Penetration

	Broadband Penetration		Cable Penetration		DSL Penetration	
Variable	Coefficients	t	Coefficients	t	Coefficients	t
Ceiling	21.35162	10.35***	10.22267	6.8***	13.36406	6.07***
Initial level parameter	-3.52229	-6.66***	-1.96148	-4.72***	-4.63713	-5.28***
Natural speed	-0.18011	-0.86	-2.33559	-5.34***	0.052397	0.21
Income	-3.14E-06	-0.58	-1E-05	-2.49**	1.83E-06	0.28
ICT Infrastructure	0.609149	1.98*	0.861186	2.92***	0.451714	1.14
LLU	0.241145	3.89***	0.345326	2.6**	0.184515	2.94***
Population density	0.00091	1.97*	0.000834	1.94*	0.000875	1.74*
Urban population	0.00107	0.36	0.000343	0.09	0.002213	0.58
Internet hosts	0.0001	2.46**	5.23E-05	1.75*	0.000116	1.83*
Platform competition	0.035929	0.67	1.774471	4.12***	-0.04641	-0.52
R-Squared	0.8871		0.7513		0.8512	
Number of observations	205		205		205	

Nonlinear regression with robust standard errors
* Statistically significant at the 10% level
** Statistically significant at the 5% level
***Statistically significant at the 1% level

Table 7. Sample Correlation Matrix of Variables Used in Mobile Broadband Analysis

	ICT Infrastructure	Mobile Price	Population density	Cost of Mobile Application	Income	Education	Teledensity	Fixed Broadband price
ICT Infrastructure	1							
Mobile service price	.273	1						
Population density	.044	.041	1					
Cost of Mobile Application	-.094	.263	-.037	1				
Income	.135	.301	-.080	.335	1			
Education	.435	.022	-.059	.110	-.016	1		
Teledensity	.049	-.076	.014	.293	.147	.208	1	
Fixed broadband price	-.135	-.033	-.082	-.149	.007	-.001	.348	1

Table 8. Linear Regressions of Mobile Broadband Penetration

	Extended Model		The Reduced Model	
Variable	Coefficients B	t-stat	Coefficients B	t-stat
Constant	-70.648	-1.487	-54.936	-1.340
Multiple Standards Policy	9.580***	3.582	9.328***	3.766
Mobile Service Price	3.837	.579	-	-
Income	.001	1.511	.001	1.527
Population Density	.030***	3.662	.031***	3.908
Fixed Broadband Price	-.073	-1.165	-	-
ICT Infrastructure	-.053	-.851	-	-
Cost of Mobile Application	-51.276***	-3.051	-41.587***	-2.871
Education	77.324	1.528	60.867	1.435
Teledensity	.040	.611	-	-
R-Squared	.553		.534	
Number of observations	51		51	

***Statistically significant at the 1% level

Figures 1-10 DSL and Cable-Modem Broadband Penetration 1999-2005 (Selected Countries)

Fig. 1 DSL Penetration - Australia

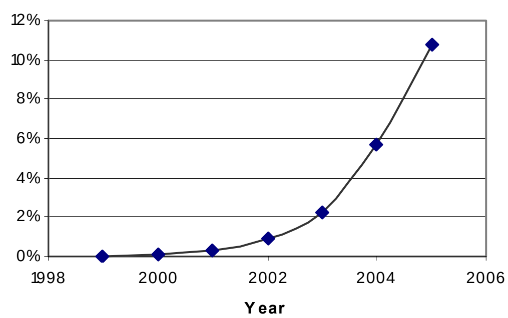


Fig. 2 Cable-Modem Penetration - Australia

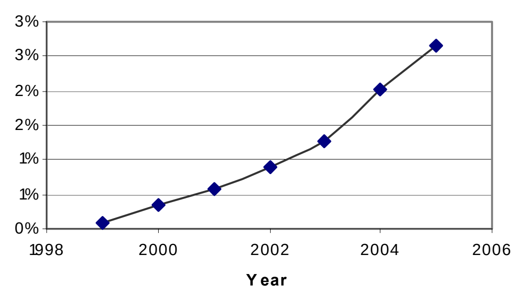


Fig. 3 DSL Penetration - Austria

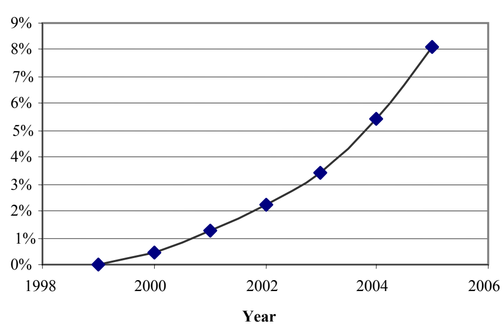


Fig. 4 Cable-Modem Penetration - Austria

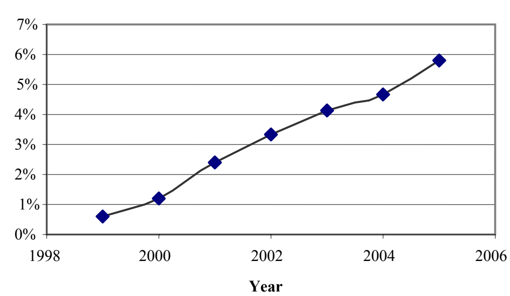


Fig. 5 DSL Penetration - Japan

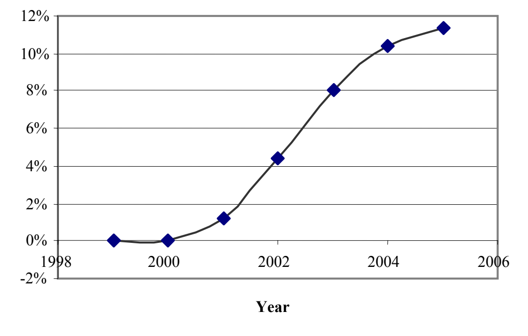


Fig. 6 Cable-Modem Penetration - Japan

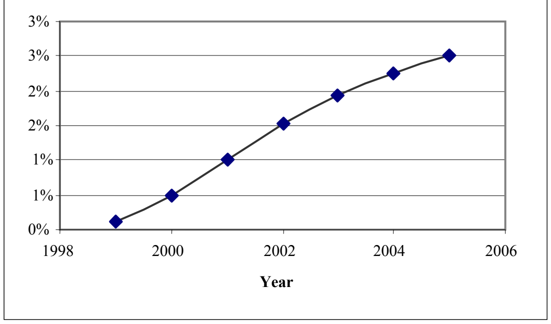


Fig. 7 DSL Penetration - South Korea

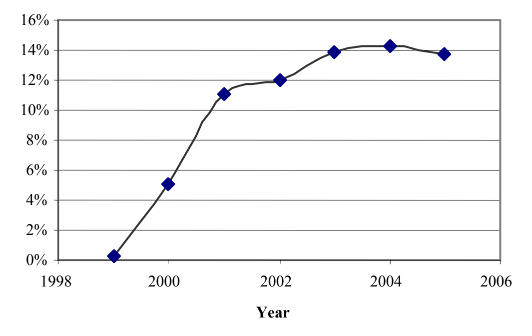


Fig. 8 Cable-Modem Penetration - South Korea

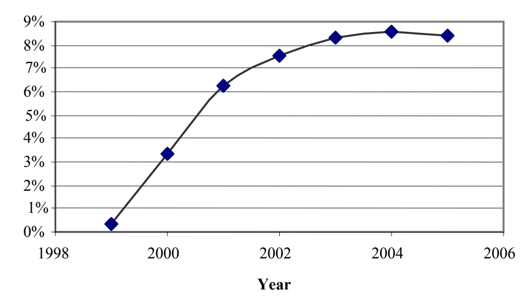


Fig. 9 DSL Penetration - USA

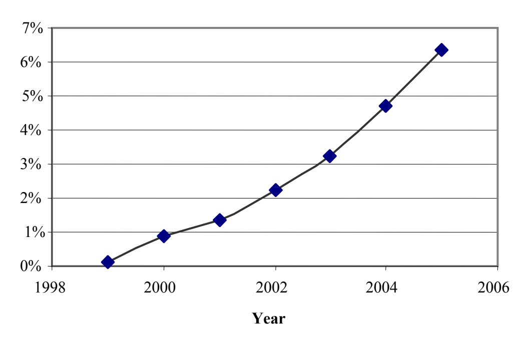
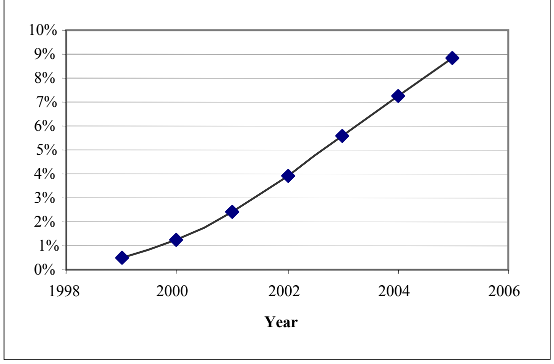


Fig. 10 Cable-Modem Penetration - USA



The nonlinear nature of broadband diffusion is readily apparent. Countries like Japan and South Korea have a relatively high penetration level. Faster technologies like FTTH have begun replacing DSL and cable-modem broadband in these countries. Their adoption patterns already exhibit a slowdown in the adoption of DSL and cable-modem broadband, a characteristic of the logistic S-shaped curve.

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