Examining broadband adoption factors: an empirical analysis between countries

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Abstract

Purpose – *The purpose of this paper is to explore influential factors of global broadband adoption by examining adoption factors – such as platform competition, information and communication technology (ICT) use, content, broadband speed, income, population density, education, price, and local loop unbundling (LLU).*

Design/methodology/approach – *The paper examines influential factors of global broadband adoption; it also employs regression analysis and one-way ANOVA (Analysis of Variance). A total of 110 observations were employed for multiple regression analysis and 159 observations were used for one-way ANOVA.*

Findings – *The findings in the paper show that platform competition, LLU, broadband speed, information and communication technology use, and content contribute to global broadband adoption. The impacts of platform competition are strong when market share of dominant technology and non-dominant technology is similar.*

Originality/value – *The main findings of this paper suggest policy and strategy implications to policy-makers and broadband service providers. This is unsponsored research that adds to the growing scholarship addressing broadband deployment factors on a comparative, international level.*

Keywords *Broadband networks, Communication technologies*

Paper type *Research paper*

Introduction

Communication technologies that provide high-speed, always-on connections to the Internet for large numbers of residential and small-business subscribers are commonly referred to as ''broadband'' (Crandall, 2005). Broadband infrastructure is a key component of the knowledge economy. Widespread and affordable broadband access encourages innovation, contributes to productivity and growth in an economy, and attracts foreign investment (International Telecommunication Union, 2003a). The provision of advanced internet protocol (IP)-based services such as telephony and video will be impossible without the successful diffusion of broadband.

In the US alone, it was estimated that the increase in capital expenditures associated with the ubiquitous adoption of current of broadband technologies will result in a cumulative increase in the US gross domestic product (GDP) of $179.7 billion and will sustain an additional 61,000 jobs per year (Criterion Economics, 2003). Lehr *et al.* (2005) found that communities in which mass-market broadband were available experienced more rapid employment and business growth, especially those in IT-intensive sectors.

In spite of the overall rapid growth in broadband diffusion, many countries are still in the early stages of broadband deployment and are assessing policy strategies to promote faster adoption. The current deployment of broadband is significantly more advanced in some

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countries than others. According to the latest Organization for Economic Co-operation and Development (OECD) penetration data (December 2006), Denmark, The Netherlands, Iceland, Korea, and Switzerland are leading broadband economies among OECD countries (see Table I).

On the supply side, many countries have considered local loop unbundling regulation and facilities-based competition 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). It is also widely held that platform, inter-modal 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 (Lee, 2006). In spite of a growing body of literature about broadband adoption, only a few cross-cultural empirical studies about the important factors of global broadband adoption exist.

Through statistical analysis of 110 observations, this study examines factors influencing global broadband adoption. Using regression and one-way ANOVA, this study assesses whether or not platform competition, LLU policy, broadband speed, Information and Communication Technology (ICT) use, income, education, population density, broadband price and content are drivers of global broadband adoption. Based upon the results of this empirical research, this paper suggests policies that may promote greater broadband adoption as well as areas for further inquiry.

Research on Broadband adoption

Broadband adoption has been steadily growing throughout the world. According to the International Telecommunication (ITU), there were about 215.5 million total broadband subscribers and 3.3 subscribers per 100 inhabitants in the world in 2005 (International Telecommunication Union, 2006). Broadband adoption rates over the first ten years is faster than other offerings like cellular and dial-up services across OECD countries (OECD, 2006). Internationally, the dominant broadband access platforms are DSL (64.34 percent) and cable modem (29.89 percent), though other platforms, such as fiber-to-the-home and wireless broadband access serve around 6 percent (International Telecommunication Union, 2006).

As of December 2006, Denmark, The Netherlands, Iceland, Korea, and Switzerland were the top five OECD countries in terms of broadband penetration rates (Organization for Economic Co-operation and Development, 2007; Table I). Despite the recent growth of broadband access and the largest raw number of broadband subscribers, with a 19.6 percent national broadband penetration rate per 100 inhabitants, the US ranks only fifteenth among 30 OECD countries (Organization for Economic Co-operation and Development, 2007).

In terms of overall global broadband market share by subscribers, the US leads the group, garnering about 22.9 percent of the global broadband subscribers. Nevertheless, the region of Asia trumped all others in broadband adoption with 38.47 percent of the world broadband market share (International Telecommunication Union, 2006). Evidently significant regional

Table I Broadband penetration (top OECD countries) by technology, December 2006

	DSL	*Cable*	*Fibre/LAN*	*Total*	*Rank*	*Total subscribers*
Denmark	19.6	9.4	2.8	31.9	1	1,590,539
The 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

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

differences exist in the number of broadband subscribers. A growing body of scholarship details contributing factors that may lead to broadband adoption. Specifically, as detailed and categorized in the following, research demonstrates that factors involving policy, industry, demographic and information and communication technology (ICT) characteristics might influence broadband deployment.

Policy factors: local loop unbundling policy and platform competition

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, line sharing and bitstream access – 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 (International Telecommunication Union, 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 on broadband deployment. Hausman (2001, 2002) claims LLU regulation in the US 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 pending relaxation of unbundling provisions in the Telecommunications Act of 1996, Glassman and Lehr (2001) found incumbents would possess a greater ability and incentive to exercise anticompetitive tactics to protect their monopoly profits and leverage their strong market position into adjacent services.

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, which may imply governments in less developed countries can promote broadband deployment through LLU. However, the result of Garcia-Murillo's study employed year 2001 data in the initial broadband markets. Through data analysis of 14 European countries, Distaso *et al.* (2006) also found LLU price is an explanatory variable of fixed broadband adoption. Recently through regression analysis of OECD countries' data, Grosso (2006) found LLU influences fixed broadband deployment.

Beyond the policy factor of LLU, several studies argue that platform competition increase broadband adoption. Platform competition, also referred to as intermodal competition, occurs when policy allows different facility-based technologies to provide broadband services to end-users (Church and Gandal, 2005). Platform competition in network industry involves competition between technologies that are not only differentiated, but also are competing networks (Church and Gandal, 2005). Strong platform competition among different technologies may lead to lower prices, increased feature offerings, and more extensive broadband networks (International Telecommunication Union, 2003a).

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 US 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 and 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 US. Lee (2006) finds that platform competition rather than access-based market entry increases the adoption of broadband in the USA. The result of Lee's empirical study suggests broadband penetration tends to be high when DSL and

non-DSL platforms have similar market share (Lee, 2006). Through panel data analysis, Denni and Gruber (2005) find that inter-platform competition, intra-platform competition in the DSL markets, and telecommunication density have positive impacts on broadband diffusion in the USA. Based upon analysis of data from 14 European countries, Distaso *et al.* (2006) demonstrate that inter-platform competition drives broadband adoption, but that competition in the DSL market does not play a significant role. Cava-Ferreruela and Alabau-Munoz (2006) suggest technological competition, along with low cost of deploying infrastructures, and prediction of the use of new technologies might be key factors for broadband supply and demand, respectively.

Industry factors: broadband price and speed

In addition to policy factors, industry factors like price and speed might influence broadband penetration. Fixed broadband price might be a key industry factor in promoting broadband demand (International Telecommunication Union, 2003a). In general, lower prices can contribute to higher broadband adoption. A competitive market structure leads to low prices (International Telecommunication Union, 2003a). Through statistical analysis of approximately 100 countries, Garcia-Murillo (2005) found fixed broadband price and competition have been influential factors of fixed broadband adoption. Through data analysis of a national sample of US households, Rappoport *et al.* (2001) found that price elasticity of demand for broadband service is much greater than narrowband service. Chaudhuri *et al.* (2005) find substantial variation observed in access price may largely have a spatial explanation of internet access.

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. As a product differentiation strategy in the broadband access market, broadband speed might influence broadband demand. Higher speed may even be a key driver of broadband adoption (International Telecommunication Union, 2003b). But thus far, no empirical study exists that measures the relationship between broadband speed and broadband adoption.

Demographic factors: population density, education, and income

Existing research on fixed broadband deployment also suggest demographic factors like income and population density have influenced fixed broadband adoption. Using an estimation of an economic model based on statistical data from 2000 to 2001, Crandall *et al.* (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 *et al.* (2003) suggests population density as a cost condition of deploying advanced networks is a consistent factor in explaining broadband uptake in OECD countries. 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. Recently Grosso (2006) found income measured by GDP per capita is related to the broadband penetration among OECD countries.

Chaudhuri *et al.* (2005) found the influences of traditional socio-demographic variables like income and education on broadband deployment are strong. Recently, through a household-level analysis, Clements and Abramowitz (2006) suggest income, age, educational attainment, and the presence of children influence adoption of broadband service in the USA. Through a US nationwide survey, Savage and Waldman (2005) discovered that preference for high-speed access is apparent among higher income and college-educated households. Through data analysis of US 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 internet.

ICT factors: ICT use and content

Recent studies on broadband diffusion suggest 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 USA, Frieden (2005b) argues the role of government in Information and Communication Technology (ICT) incubation is important for rapid broadband deployment. Using panel data analysis of the US states, Denni and Gruber (2005) also found that telecommunication density has been an influential factor of broadband deployment in the USA. Kim *et al.* (2003) suggest the preparedness of a nation is a factor of broadband deployment. 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, c). Garcia-Murillo (2005) found the number of domain name servers registered is positively correlated with the number of broadband subscribers. The result of Garcia-Murillo's study suggests internet content can be a main driver of broadband adoption.

Research questions

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, ICT use, broadband price, content, and broadband speed – have not been clearly understood in a single systematic study (see Table II). Table II

Table II International empirical studies examining broadband adoption factors

Study	*Independent variables*	*Countries*	*Number of observations*	*Significant variables*
Kim *et al.* (2003)	Broadband price Dial-up service price Income Preparedness of a nation Competition Population density Policy (unbundling, cross-ownership, Government funding)	OECD 30 countries	30	Preparedness of a nation Population density
Garcia-Murillo (2005)	Broadband price Income Education Competition Population density Policy (unbundling, cross-ownership) Content Personal computers Internet access	ITU approximately 100 countries	Observations varies depending on the model (18-92)	Broadband price Income Population density Competition Internet access Unbundling
Distaso *et al.* (2006)	Intra-modal competition Inter-modal competition Rights of way LLU price Price of leased line Price of ten minutes call	EU 14 countries	158 (15 time periods)	Inter-modal competition LLU price
Cava-Ferreruela and Alabau- Munoz (2006)	Broadband price Competition Infrastructure investment Telecom services penetration Internet indicators Economic indicators Demographic indicators Education indicators Social indicators	OECD 30 countries	90 (three years: 2000-2002)	Technological competition Cost of deploying infrastructures Economic indicators Demographic indicators
Grosso (2006)	Competition Income Unbundling Fixed internet penetration	OECD 30 countries	117 (four years: 2001-2004)	Competition Income Unbundling

illustrates the variables and findings of empirical, international broadband deployment studies. As previously discussed, most empirical studies have employed a single-country level or regional level (e.g. Europe) approach. Those studies that do examine factors on a comparative level among countries have used small numbers of observations or excluded important variables like broadband speed and platform competition for statistical analysis.

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

RQ1. Do policy factors such as LLU policy and platform competition influence global broadband adoption?

RQ2. Do industry factors such as broadband price and broadband speed influence global broadband adoption?

RQ3. Do demographic factors such as population density, income, and education influence global broadband adoption?

RQ4. Do ICT factors such as Information Communication Technology (ICT) use and content influence global broadband adoption?

The model, method and data

To examine influential factors of global broadband adoption, this study employs regression analysis and one-way ANOVA (Analysis of Variance). For *RQ2*, *RQ3*, and *RQ4* multiple regression analysis was used. For *RQ1* one-way ANOVA was employed.

Regression analysis

The empirical model and methodology

To capture influential factors of global broadband adoption, a multiple regression analysis was implemented. To examine the influences of quantifiable variables on the diffusion patterns of broadband, this paper formulated the following multiple regression model:

$$\begin{aligned} Y_t(BPR) = \beta_0 \quad & +\beta_1(\text{Platform competition}) + \beta_2(\text{Price}) + \beta_3(\text{Speed}) \\ & +\beta_4(\text{Income}) + \beta_5(\text{ICT use}) + \beta_6(\text{Education}) \\ & +\beta_7(\text{Population} \quad \text{density}) + \beta_8(\text{Content}) + \varepsilon_t \end{aligned}$$

The empirical model (1) for multivariate analysis was a composite model from previous empirical studies. In the empirical model, the dependent variable (Y_t) is broadband penetration rate (110 observations). From the previous studies of broadband adoption, independent variables were identified. Platform competition, price, broadband speed, income, ICT use, education, population density, and content are important quantifiable variables included in the multiple regression analysis.

Measurement and data sources

Broadband penetration rate (BPR: dependent variable) was measured by the number of broadband subscribers per 100 inhabitants. Platform competition (PLATFORM) is an important variable in which the broadband market is served by different technologies compete to provide broadband services to broadband users. Higher level of platform competition among different technologies such as DSL, cable modem, and fiber-to-the-home may lead to the higher level of broadband adoption (Lee, 2006). Platform competition also may bring differentiated services and lower price to broadband subscribers.

Level of platform competition (PLAFORM) might be is measured by (100 – (|market share of dominant technology – market share of non-dominant technologies|). In the previous literature, Lee (2006) found broadband penetration in the USA is highly correlated with 100 – (|DSL market share – non-DSL market share|). Using more generalized measurement, we adopt (100 – (|market share of dominant technology – market share of non-dominant

technologies|) as a measurement of platform competition. When there is strong platform competition in the markets, market share difference between dominant technology and other non-dominant technologies could be small.

Broadband price arguably has been a key 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 (International Telecommunication Union, 2003a). Broadband price (PRICE) was measured by broadband monthly charge (in US dollars). Broadband speed (SPEED) was also considered important independent variable that might influence global broadband adoption. SPEED was measured by broadband download speed (kilobit per second). As a product differentiation strategy in the broadband access market broadband speed might influence broadband demand. Broadband penetration rates can be higher where bigger gaps exist between the speed of narrowband and broadband.

Level of information/communication technology infrastructure is closely related to broadband demand. To reflect the level of information and communication technology infrastructure, ICT use (ICT) was measured by personal computer penetration per 100 inhabitants. Level of education (EDU) was measured by the United Nations Development Program (UNDP) Education Index, and population density (P-DENSITY) was measured by population density per km^2. For the measurement of income (INCOME), GDP per capita was used. Internet content (CONTENT) may be related to the diffusion of broadband. For the proxy measurement of content, internet hosts per 100 inhabitants was employed.

Table III shows variables, measurement and data sources of the multiple regression analysis. Data collected primarily from the ITU (2005b, 2006), and the UNDP (2004, 2005). In all, 110 observations from countries were available for all dependent and independent variables.

One-way ANOVA

The empirical model, methodology, and data

LLU policy has the potential to assist in the development of intra-modal competition for broadband service as well as in its diffusion (OECD, 2003). To assess the impact of LLU

Table III Variables, measurement and data sources for regression analysis

Variables	*Measurement*	*Data sources*
Broadband penetration (BPR)	Broadband subscribers per 100 inhabitants	International Telecommunication Union (2006), International Telecommunication Union (2005b)
Platform competition (PLATFORM)	100 – (|market share of dominant technology – market share of non-dominant technologies|)	International Telecommunication Union (2006), International Telecommunication Union (2005b)
Price of Broadband (PRICE)	Broadband monthly charge (USD)	International Telecommunication Union (2006), International Telecommunication Union (2005b)
Broadband speed (SPEED)	Broadband download speed (kbit/s)	International Telecommunication Union (2006), International Telecommunication Union (2005b)
Income (INCOME)	GDP per capita	International Telecommunication Union (2006), International Telecommunication Union (2005b)
ICT use (ICT)	Estimated PCs per 100 inhabitants	International Telecommunication Union (2006), International Telecommunication Union (2005b)
Education (EDU)	UNDP Education Index	United Nations Development Program (2005), United Nations Development Program (2004)
Population density (P-DENSITY)	Population density (per km^2)	International Telecommunication Union (2006), International Telecommunication Union (2005b)
Content (CONTENT)	Internet hosts per 100 inhabitants	International Telecommunication Union (2006), International Telecommunication Union (2005b)

policy on global broadband adoption, one-way ANOVA was used. LLU policy was not employed in the multiple regression model because platform competition and LLU are not mutually exclusive policy tools. The former is about free-market competition, which is brought about by facility-based entrants to a given telecommunication segment. The latter seeks to simulate the competitive effect by opening up an incumbent network for competitive access. Both approaches work toward the same common goal – a more market-driven environment that advances competition and deployment of a telecommunications service. But, the effects of LLU and platform competition are not interchangeable with each other.

For this reason, this study employed one-way ANOVA to examine the effect of LLU policy on global broadband adoption. The effects of LLU were analyzed by one-way ANOVA by comparing two groups of countries (countries with and without LLU policy). If a country has full unbundling or line sharing or bitstream access, the country was categorized a country with LLU policy. If a country does not have any of these policies, the country was categorized a country without LLU policy. In many European countries line sharing and bitstream access have been considered a type of LLU, which has a large potential as a means to offer broadband services to end-users for entrants who do not own local networks that reach the first and last mile (Bijl and Peitz, 2005). Though full unbundling may reduce incumbent's investment incentives for new telecommunication technologies, in general, it is believed LLU policy may lead to more competition in broadband access markets (Bijl and Peitz, 2005).

To assess the effect of LLU policy, a total of 159 observations were available for one-way ANOVA. Specifically, ITU broadband penetration and LLU policy data from 2002 to 2005 was analyzed.

Results and analysis

Results of regression analysis

Results of the multiple regression analysis identified important variables that affect global broadband adoption. Over 110 observations were available for all regression models. Two models were identified from the multiple regression analysis.

The extended model

Initially, all eight independent variables were employed for the multiple regression analysis. In general, in a regression model, multicollinearity, the existence of a high degree of linear correlation among two or more explanatory variables, might make it difficult to separate the effects of independent variables on the dependent variable. A correlation analysis was conducted first to assess potential multicollinearity problems. Table IV shows the correlation matrix among independent variables. To evaluate the strength of correlations, the 0.65 benchmark was used. Based on this benchmark, no highly correlated independent variables revealed themselves.

Note the collinearity statistic also shows that no independent variable reaches a VIF (Variance Inflation Factor) value above 4 (VIF = 4.55) or a tolerance value below 0.25. Table V shows the ANOVA table of the first regression model, which illustrates the model's significance at the 1 percent level (*F*-statistic: 40.965, $p < 0.001$).

Table IV Correlation matrix (Pearson correlations)

	Platform	*Price*	*Speed*	*Income*	*ICT*	*Edu*	*P*-density	*Content*
Platform	1							
Price	−0.169	1						
Speed	−0.252	−0.092	1					
Income	0.113	−0.090	0.045	1				
ICT	0.407	−0.224	0.273	0.344	1			
EDU	0.376	−0.121	0.223	0.237	0.582	1		
P-density	0.280	0.011	0.001	0.012	0.305	−0.095	1	
Content	0.373	−0.158	0.125	0.270	0.623	0.444	0.069	1

Table V ANOVA table (the first model)

Model	*Sum of squares*	*Df*	*Mean square*	*F*	*Sig.*
Regression	5143.160	8	642.895	40.965	$p < 0.001$***
Residual	1585.068	101	15.694		
Total	6728.229	109			

Notes: *** Significant at the 1 percent level, *R*-square =0.764

The independent variables PRICE, INCOME, EDU, and *p*-DENSITY were related to global broadband adoption, but were not statistically significant (*p*-value of PRICE: 0.166; *p*-value of INCOME: 0.296; *p*-value of EDU: 0.118; *p*-value of *p*-DENSITY; 0.124). PLATFORM was statistically significant at the 10 percent level, and CONTENT was statistically significant at the 5 percent level. SPEED and ICT were statistically significant at the 1 percent level. In the first model, PLATFORM, SPEED, ICT, and CONTENT were factors influential to global broadband adoption. Table VI provides the result of the first model from the regression analysis.

The final reduced model

To check the stability of results in the empirical study, non-significant variables were removed from the second model. In the final reduced model, PRICE, INCOME, EDU, and *p*-DENSITY were removed.

Table VII shows the ANOVA Table of the final reduced model and illustrates that the model is significant at the 1 percent level (*F*-statistic: 78.984, *p*-value < 0.001). In the final reduced model, CONTENT was statistically significant at the 5 percent level, and PLATFORM, SPEED, and ICT were statistically significant at the 1 percent level. In the final reduced model, PLATFORM, SPEED, ICT, and CONTENT were influential factors of global broadband adoption. Table VIII provides the results of the final reduced model from the regression analysis.

Table VI Results of multiple regression analysis (the extended model)

	Unstandardized coefficients		*Standardized coefficients*		
Model	*B*	*Std. error*	*Beta*	*T*	*p*-value
(Constant)	−11.700	7.016		−1.668	0.098
PLATFORM	0.028	0.015	0.114	1.949	0.054*
PRICE	−0.009	0.006	−0.070	−1.395	0.166
SPEED	0.001	0.001	0.217	4.198	$p < 0.001$***
INCOME	0.001	0.001	0.055	1.051	0.296
ICT	0.45	0.024	0.482	5.920	$p < 0.001$***
EDU	12.828	8.133	0.104	1.577	0.118
P-DENSITY	0.001	0.001	0.090	1.550	0.124
CONTENT	0.119	0.046	0.167	2.592	0.011**

Notes: * Statistically significant at the 10 percent level; ** Statistically significant at the 5 percent level; *** Statistically significant at the 1 percent level

Table VII ANOVA table (the final reduced model)

Model	*Sum of squares*	*Df*	*Mean square*	*F*	*Sig.*
Regression	5049.915	4	1262.479	78.984	$p < 0.001$***
Residual	1678.314	105	15.984		
Total	6728.229	109			

Notes: *** Significant at the 1 percent level, *R*-square = 0.751

Table VIII Results of multiple regression analysis (the final reduced model)

Model	*Unstandardized coefficients B*	*Std. error*	*Standardized coefficients B*	*T*	*p*-value
(Constant)	– 1.455	0.750		– 1.940	0.055
PLATFORM	0.039	0.014	0.155	2.819	0.006***
SPEED	0.001	0.001	0.209	4.056	$p < 0.001$***
ICT	0.178	0.020	0.593	9.036	$p < 0.001$***
CONTENT	0118	0.045	0.162	2.548	0012**

Notes: ** Statistically significant the 5 percent level; *** Statistically significant the 1 percent level

Results of one-way ANOVA

To examine the effect of LLU policy, one-way ANOVA was implemented. The dependent variable was broadband penetration rate and the independent factor was LLU policy. Table IX shows the result of the one-way ANOVA. Mean difference between countries with LLU policy and without LLU policy was very significant ($p < 0.001$). Mean broadband penetration rate of 106 countries with LLU policy was 10.38 per 100 inhabitants while mean broadband penetration rate of 53 countries without LLU policy was 3.25 per 100 inhabitants. These results of one-way ANOVA suggest LLU policy has contributed higher level of global broadband adoption in many countries. Note that this finding does not necessarily mean LLU stimulated investment for broadband services.

Main findings

The regression study suggests platform competition was an influential factor for global broadband adoption. The impact of platform, inter-modal competition is strong when the market shares of dominant technology and non-dominant technology are similar. Figure 1 shows how the result of this regression analysis is consistent with the case of Denmark. From June 2003 to June 2006, Denmark's performance of platform competition measured by 100 – (|DSL (dominant technology) market share – non-DSL (non-dominant technologies) market share|) has increased from 68.8 percent to 81.22 percent. Interestingly, during the same period, Denmark's broadband penetration rate increased from 11 percent to 29.3 percent, moving from fourth to first in terms of broadband penetration rate (subscribers per 100 inhabitants) among 30 OECD countries.

In addition to platform competition, the result of the regression study also shows broadband speed, ICT use, and content were influential factors for global broadband adoption. This result may imply a higher level of broadband speed could be a driver of global broadband adoption. The result also may imply, in the supply side of broadband market, a product differentiation strategy that markets fast download speeds could lead to more broadband subscribers in the market. This result may imply consumers will more readily migrate to costly broadband services if the throughput speed is more abundant.

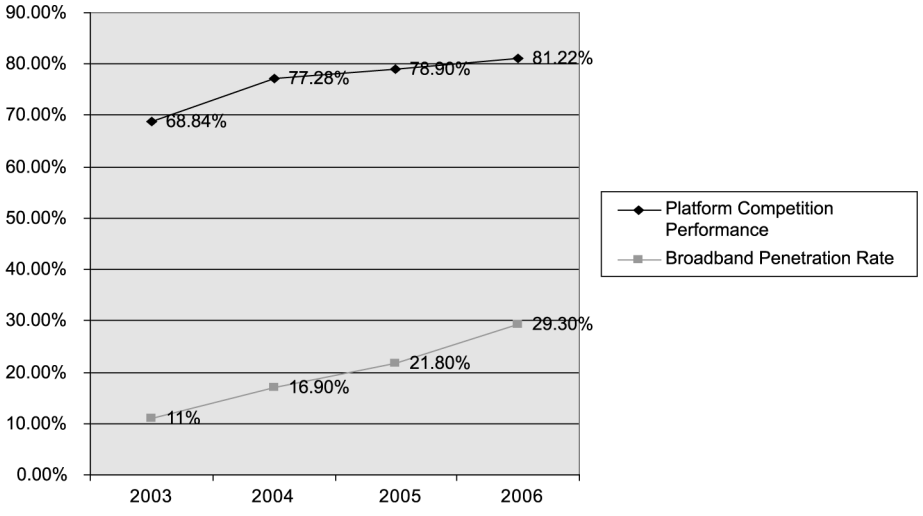
These findings also point to the importance of an established infrastructure for relevant ICT technologies. A higher level of existing information and communication infrastructure like personal computers in a country may lead to a higher level of demand for broadband service in the market. Content was also an influential factor of global broadband deployment. This

Table IX Results of one-way ANOVA analysis

Groups	*Sum of squares*	*Df*	*Mean square*	*F*	*Sig.*
Between groups	1,796.998	1	1,796.998	47.863	$p < 0.001$***
Within groups	5,894.452	157	37.544		
Total	7,691.450	158			

Notes: Dependent variable: Broadband penetration rate; Factor: local loop unbundling; *** Significant at the 1 percent level

Figure 1 Platform competition and broadband penetration rate in Denmark (2003-2006)



Source: OECD (2006)

result suggests that innovative internet content, services and applications within a nation may be one of the key demand-side drivers of global broadband diffusion.

Finally, one-way ANOVA analysis shows that LLU policy is another influential factor of global broadband adoption. Significant mean differences were revealed among countries with and without LLU policy. Considering that DSL is typically the major source of residential broadband delivery in most countries, intra-modal competition in the DSL market through LLU policy has contributed to a greater take-up of broadband.

Conclusion: implications and further inquiry

This study adds to the existing research that has employed a macro-level, international approach to empirically understanding broadband adoption. Specifically through statistical analysis of 110 observations, this study examined whether platform competition, LLU policy, broadband speed, ICT use, content, and other factors have had any real effect on global broadband diffusion. Because of the methodology employed and its findings, this study contains important policy and research implications that are discussed in the following.

The result of this cross-country empirical study demonstrates that, on the supply side of broadband services, platform competition (inter-modal competition) and intra-modal competition through LLU policy are both influential factors for global broadband adoption. These findings suggest that those nations striving to increase broadband penetration should seriously consider LLU as well as facilities-based competition policies. Competition may bring real choice for customers and downward pressure on costs in the broadband access market (Lee, 2006; International Telecommunication Union, 2003b). The existence of strong platform competition among DSL, cable modem, fiber, and wireless broadband in a market may ensure prices remain low (International Telecommunication Union, 2003b). In this context, in the broadband access market, regulation across platforms should be as competitively neutral as possible for sustaining strong platform competition. In spite of some disadvantages, LLU policy is an influential factor for broadband adoption in many countries, especially when one takes into account that DSL is often the dominant broadband platform (International Telecommunication Union, 2005a). LLU encourages competition by reducing the economic barriers to entry, thereby allowing new entrants to construct some components of their networks and obtain other components from the incumbent DSL operator (Organization for Economic Co-operation and Development, 2001).

Beyond facilities-based and intra-modal competition promoted through LLU, the results of this empirical study also show that broadband speed may lead to greater broadband diffusion. Previous empirically-based, cross-country studies have failed to examine speed as a variable in broadband adoption. The finding that faster speeds may increase broadband adoption are significant, not only in terms of nations and providers that wish to increase broadband diffusion but also because of the anticipated growth of high-bandwidth content and services like IP video and telephony. Internet service providers wishing to garner additional market share may roll out faster broadband speeds as a way to distinguish themselves from their competition. By way of illustration, broadband companies in Japan and Korea already have employed this strategy for their customers, and as a result some households with fiber connections enjoy throughput speeds as high as 100 Mbps (compared to 1.5 Mbps for normal DSL) (Williams, 2006). When connected to this study's findings regarding competition, government policymakers may wish to embrace platform competition as another way to induce providers to offer subscribers with greater speeds and utility, thereby giving greater motivations for consumers to adopt broadband.

This study also found content, measured as the number of Internet hosts per 100 habitants, as a factor that contributes to broadband adoption. Internet hosts are computers that possess their own Internet Protocol (IP) address and are permanently and directly connected to the internet. Internet hosts offer a range of content and services, including e-mail and web site storage and retrieval, as well as facilitating applications like streaming and IP telephony. The aforementioned result implies that, from the perspective of broadband users, the amount of compelling content, services and applications within a nation is an important driver of broadband diffusion.

ICT use, as measured by the number of personal computers in a household, was also found to be a factor in broadband adoption. This finding should not come as a surprise, because more often than not, personal computers are required if a household wishes to subscribe to broadband. Countries that wish to ensure their citizens are prepared for broadband may consider programs that help increase affordability of personal computers as one step to creating broadband demand. The potential development of the $100 computer may quickly help in this effort, but such diffusion does not take into account the literacy that may be necessitated. As a result, countries that possess low broadband and computer household penetration rates may also wish to integrate computer and internet literacy initiatives into schools and community centers.

Several limitations to this study present areas for further inquiry. While the above findings indicate a positive overall effect of LLU policy on broadband adoption, this study does not differentiate between the various types of LLU and their respective prices. If the data is available, future comparative research between nations may take into account the different types of LLU, specifically how full unbundling versus line sharing and bitstream access influence broadband adoption. This is particularly important in lieu of scholarship that suggests full unbundling may retard broadband investment and cooperation by incumbents (e.g. Frieden, 2005a). This study also employed linear regression to assess a number of broadband adoption factors. While price and population density were not found to be statistically significant, non-linear regression modeling and analysis may reveal a different outcome with these particular variables. On the demand side of the broadband access market, important variables like socio-cultural characteristics of households, innovative broadband rollouts, applications that may stimulate broadband demand and other factors that are difficult to measure among multiple countries were not included in this empirical study. To examine these factors, the integration of quantitative and qualitative research would be desirable in future research. In this context, this empirical study is only a preliminary step to better understand all of the factors influencing global broadband adoption. In a similar vein, this study utilizes empirical modeling to explain generalized factors across countries and therefore does not undertake a case-study approach to holistically examine and compare the various markets and social and political influences that may exist in given countries that affect broadband adoption. Although some recent case-study work in this area exists (Fransman, 2006), additional variables may be drawn

from these types of studies and incorporated into future international, empirically-based broadband adoption research.

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