Examining Broadband Adoption Factors: An Empirical Analysis between Countries

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Sangwon Lee
Ph.D. Student and Alumni Graduate Fellow
Department of Telecommunication
College of Journalism and Communications
University of Florida
Gainesville, FL 32611
United States
Tel. 1-352-281-4951
sangwon@ufl.edu

Justin S. Brown, Ph.D.
Assistant Professor
Department of Telecommunication
College of Journalism and Communications
University of Florida
Gainesville, FL 32611
United States
Tel. 1- 352-846-1428
jbrown@jou.ufl.edu

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Abstract

This study explores influential factors of global broadband adoption. 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) — are examined. This study also assesses whether mobile broadband is a complement to or a substitute for fixed broadband. To examine influential factors of global broadband adoption, this study employs regression analysis and one-way ANOVA (Analysis of Variance). A total of 110 observations were employed for statistical analysis. The results of this empirical study 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. This study also finds that mobile broadband is neither a complement nor a substitute for fixed broadband yet.

Keywords: Broadband diffusion, Platform competition, Unbundling, Broadband Speed, ICT use, Content

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 (ITU, 2003a). The provision of advanced IP-based services such as IP telephony and IP video will be impossible without the successful diffusion of broadband.

In the United States 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 U.S. gross domestic product (GDP) of $179.7 billion and will sustain an additional 61,000 jobs per year (Criterion Economics, 2003). Lehr, Osorio, Gillett, S. and Sirbu (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 Internet is significantly more advanced in some countries than others. 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, pg. 3).

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 (DotEcon & Criterion Economics, 2003). 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, content, and mobile broadband price 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 (ITU, 2006). Broadband adoption rates over the first 10 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 %) and cable modem (29.89 %), though other platforms, such as fiber-

to-the-home and wireless broadband access serve around 6 % (ITU, 2006).

Table 1 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
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 broadband statistics. Paris: OECD.

As of December 2006, Denmark, the Netherlands, Iceland, Korea, and Switzerland were the top five OECD countries in terms of broadband penetration rates (OECD, 2007; Table 1). 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 United States ranks only 15th among 30 OECD countries (OECD, 2007).

In terms of overall global broadband market share by subscribers, the United States 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 (ITU, 2006). Evidently significant regional differences exist in the number of broadband subscribers.

A growing body of empirical research details broadband adoption. A few studies argue that inter-modal competition (platform competition among different technologies), LLU and other factors in the supply side of the broadband market increase broadband adoption. Likewise, other studies purport that demand-side variables like income and education affect broadband adoption. As discussed below, broadband adoption research either examines variables at a

micro, national-level, or within a macro, cross-country framework.

In an effort to improve overall penetration rates, many scholars have provided statistical analyses of various broadband adoption factors in the U.S. Recently, through two different econometric analyses (time-series analysis and multiple-regression analysis) using data from 50 states, Lee (2006) suggests platform competition, the availability of different broadband platforms and level of income have all 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. 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 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). Meanwhile, 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. 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.

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. More recently, through a nationwide 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 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. Chaudhuri, Flamm and Horrigan (2005) found the influences of traditional socio-demographic variables like income and education on broadband deployment are strong. 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.

Beyond research that assesses 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). 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. Through a comparative study of broadband deployment in Canada, Japan, Korea, and

the United States, Frieden (2005) argues the role of government for Information and Communication Technology (ICT) incubation is important for rapid broadband deployment. 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.

While the above macro, cross-national studies utilize mostly qualitative, case-study comparisons, a growing body of recent studies are empirically-based. Several international empirical analyses of data from 30 OECD countries explore factors influencing broadband supply, demand, and 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, LLU, and income influence broadband penetration among OECD countries. 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. In addition, 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. 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.

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 2).

Table2. International empirical studies examining broadband adoption factors

Study	Indepentdent variables	Countries	Number of Obeservation	Significant variables
Kim et. al. (2003)	Broadband price Dial-up service price Income Preparedness of a nation Competition Population density Policy (undundling, 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 (undundling, 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-Muňoz (2006)	Broadband price Competition Infrastructure investment Telecom services penetration Internet indicators Economic indicators Demographic indicators Education indicators Social indicators	OECD 30 countries	90 (3 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 (4 years: 2001-2004)	Competition Income Unbundling

Also, no published empirical study examines whether mobile broadband is a complement to or a substitute for fixed broadband. Based upon research that suggest cell phones serve as a substitute for wireline phone service (e.g., ITU, 2003c), one might expect a similar relationship between broadband wireless services and fixed broadband.

Table 2 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: Does platform competition influence global broadband adoption?

RQ2: Does LLU policy influence global broadband adoption?

RQ3: Do factors such as income, population density, broadband price, broadband speed, Information Communication Technology (ICT) use, education, and content significantly influence global broadband adoption?

RQ4: Is mobile broadband a complement to or a substitute for fixed broadband?

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 RQ1, RQ3, and RQ4 multiple regression analysis was used. For RQ2 one-way ANOVA was employed.

1. 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.

$$\begin{aligned} \mathbf{Y_t\ (BPR)} = {} & \mathbf{\beta_0 + \beta_1(Platform\ Competition) + \beta_2(Price) + \beta_3(Speed) + \beta_4(Income)} \\ & \mathbf{+ \beta_5(ICT\ Use) + \beta_6(Education) + \beta_7(Population\ Density) + \beta_8(Price\ of\ Mobile)} \\ & \mathbf{+ \beta_9(Content) + \varepsilon_t} \qquad \mathbf{(1)} \end{aligned}$$

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. To examine whether mobile broadband is a complement to or a substitute for fixed broadband, mobile price was included in the regression model.

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 competing platforms. PLATFORM is measured by (100 – market share of dominant technology – market share of non-dominant technology). In the previous literature, 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. 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 (ITU, 2003a). Broadband price (PRICE) was measured by broadband monthly charge (in U.S. 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 exists between the speed of narrowband and broadband.

Table 3 Variables, Measurement and Data Sources for Regression Analysis

Variables	Measurement	Data Sources
Broadband Penetration (BPR)	Broadband subscribers per 100 inhabitants	ITU (2006), ITU (2005b)
Platform Competition (PLATFORM)	100 – market share of dominant technology – market share of non-dominant technology	ITU (2006), ITU (2005b)
Price of Broadband (PRICE)	Broadband monthly charge (USD)	ITU (2006), ITU (2005b)
Broadband Speed (SPEED)	Broadband download speed (kbit/s)	ITU (2006), ITU (2005b)
Income (INCOME)	GDP per capita	ITU (2006), ITU (2005b)
ICT Use (ICT)	Estimated PCs per 100 inhabitants	ITU (2006), ITU (2005b)
Education (EDU)	UNDP Education Index	UNDP (2005), UNDP (2004)
Population Density (P-DENSITY)	Population density (per km^2)	ITU (2006), ITU (2005b)
Price of mobile (MPRICE)	Per minute local call (USD) peak	ITU (2006), ITU (2005b)
Content (CONTENT)	Internet hosts per 100 inhabitants	ITU (2006), ITU (2005b)

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. For mobile price, per minute charge (in U.S. Dollars) for a local call during peak time was used. Internet content may be related to the diffusion of broadband. For the proxy measurement of content, Internet hosts per 100 inhabitants was employed.

Table 3 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.

2. One-Way ANOVA

The Empirical Model, Methodology, and Data

To assess the impact of LLU policy on global broadband adoption, one-way ANOVA was used. LLU could not be included in the multiple regression analysis for two reasons. First, 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 telecom 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 a telecommunications service. The effects of LLU and platform competition are not interchangeable with each other. Second, though LLU can be included in the multiple regression models, the observations were smaller than those of other

independent variables (60 observations for LLU; more than 110 observations for other variables).

For these reasons, 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).

Results and Analysis

1. 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 First Model

Initially, all nine independent variables were employed for the multiple regression analysis. Since multicollinearity might occur when independent variables are highly correlated, a correlation analysis was conducted first to assess potential multicollinearity problems. Table 4 shows the correlation matrix among independent variables. To evaluate the strength of correlations, the .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 value above 4 (VIF=4.55) or a tolerance value below .25. Table 5 shows the ANOVA table of the first regression model, which illustrates the model's significance at the 1% level (F statistic: 36.147, P<.001).

Table 4. Correlation Matrix (Pearson Correlations)

	PLATFORM	PRICE	SPEED	INCOME	ICT	EDU	P-DENSITY	MPRICE	CONTENT
PLATFORM	1								
PRICE	-.169	1							
SPEED	.252	-.092	1						
INCOME	.113	-.090	.045	1					
ICT	.407	-.224	.273	.344	1				
EDU	.376	-.121	.223	.237	.582	1			
P-DENSITY	.280	.011	.001	.012	.305	-.095	1		
MPRICE	.061	.096	.214	.256	.197	.310	-.285	1	
CONTENT	.373	-.158	.125	.270	.623	.444	.069	.144	1

Table 5. ANOVA Table (The First Model)

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	5146.315	9	571.813	36.147	P<.001***
Residual	1581.914	100	15.819		
Total	6728.229	109			

*** Significant at the 1% level, R-Square = .765

Table 6. Results of Multiple Regression Analysis (The First Model)

	Unstandardized Coefficients		Standardized Coefficients		
Model	B	Std. Error	Beta	T	P-Value
(Constant)	-11.813	7.048		-1.676	.097
PLATFORM	.029	.015	.114	1.952	.054*
PRICE	-.008	.006	-.065	-1.272	.206
SPEED	.001	.001	.221	4.200	P<.001***
INCOME	.001	.001	.059	1.115	.268
ICT	.146	.025	.486	5.905	P<.001***
EDU	13.234	8.216	.108	1.611	.110
P-DENSITY	.001	.001	.082	1.330	.187
MPRICE	-1.029	2.305	-.025	-.447	.656
CONTENT	.118	.046	.166	2.556	.012**

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

The independent variables PRICE, INCOME, EDU, P-DENSITY, and MPRICE were related to global broadband adoption, but were not statistically significant (P value of PRICE:

.206; P value of INCOME: .268; P value of EDU: .110; P value of P-DENSITY; .187, P value of MPRICE: .656). PLATFORM was statistically significant at the 10% level, and CONTENT was statistically significant at the 5% level. SPEED and ICT were statistically significant at the 1% level. In the first model, PLATFORM, SPEED, ICT, and CONTENT were factors influential to global broadband adoption. Table 6 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, P-DENSITY, and MPRICE were removed.

Table 7. ANOVA Table (The Final Reduced Model)

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	5049.915	4	1262.479	78.984	P<.001 ***
Residual	1678.314	105	15.984		
Total	6728.229	109			

*** Significant at the 1% level, R-Square = .751

Table 7 shows the ANOVA Table of the final reduced model and illustrates that the model is significant at the 1% level (F statistic: 78.984, p-value < 0.001). In the final reduced model, CONTENT was statistically significant at the 5% level, and PLATFORM, SPEED, and ICT were statistically significant at the 1% level. In the final reduced model, PLATFORM, SPEED, ICT, and CONTENT were influential factors of global broadband adoption. Table 8 provides the results of the final reduced model from the regression analysis.

Table 8. Results of Multiple Regression Analysis (The Final Reduced Model)

Model	Unstandardized Coefficients B	Std. Error	Standardized Coefficients B	T	P-Value
(Constant)	-1.455	.750		-1.940	.055
PLATFORM	.039	.014	.155	2.819	.006***
SPEED	.001	.001	.209	4.056	P<.001***
ICT	.178	.020	.593	9.036	P<.001***
CONTENT	.118	.045	.162	2.548	.012**

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

2. 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 9 shows the result of the one-way ANOVA. Mean difference between countries with LLU policy and without LLU policy was very significant (P<.01). One-way ANOVA suggests LLU policy has been an influential factor for global broadband adoption.

Table 9. Results of One-way ANOVA Analysis

Groups	Sum of Squares	Df	Mean Square	F	Sig.
Between groups	890.663	1	890.633	21.399	P<.001***
Within groups	2455.630	59	41.621		
Total	3346.262	60			

Dependent Variable: Broadband Penetration Rate
Factor: Local Loop Unbundling
*** Significant at the 1% level

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. Facilities-based competition in the broadband access market has brought diverse choices for broadband customers (DotEcon & Criterion Economics, 2003). To help illustrate this trend, 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 technology) 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 4th to 1st in terms of broadband penetration rate (subscribers per 100 inhabitants) among 30 OECD countries.

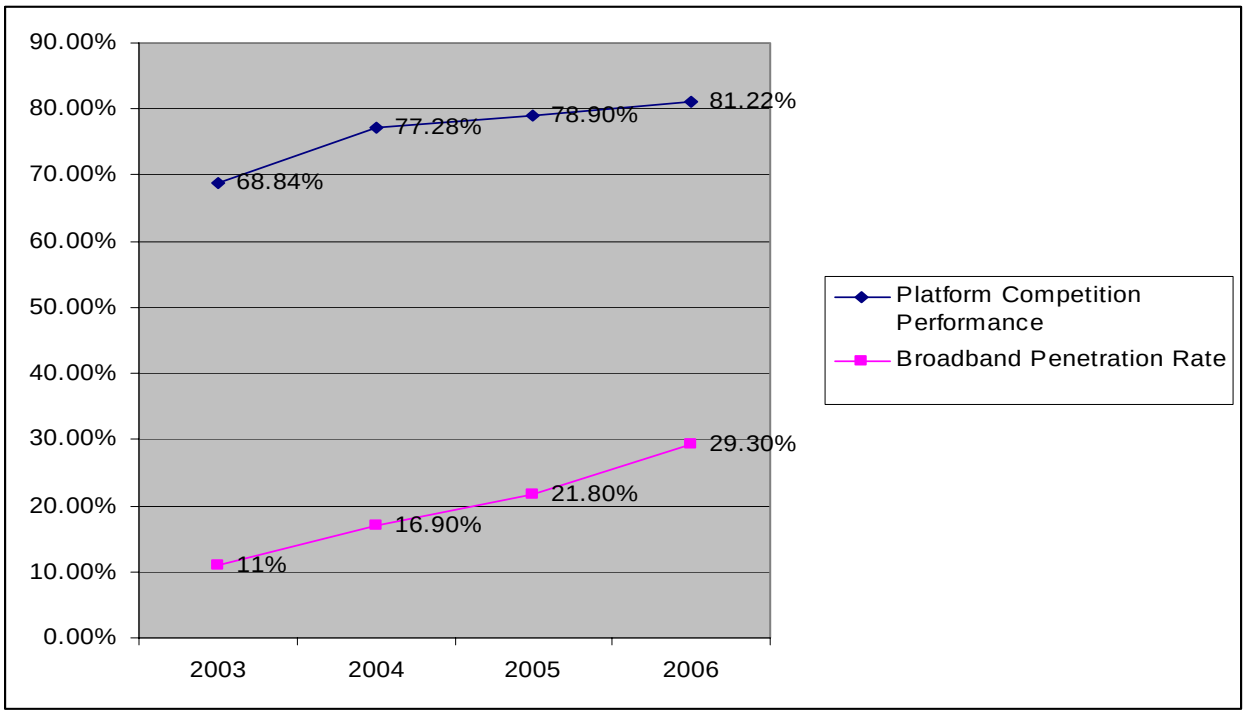

Figure 1. Platform competition and broadband penetration rate in Denmark (2003-2006)
Source: OECD (2006)

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. These findings also point to the importance of an established infrastructure for relevant information and communication 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 result suggests that innovative Internet content, services and applications within a nation may be one of the key drivers of global broadband diffusion.

The result of the regression analysis also shows that mobile broadband is neither complementary to nor a substitute for fixed broadband. If either of these trends were present, a causal relationship could exist between mobile price and fixed broadband diffusion. Admittedly, this finding may change with the continued development of third-generation (3G) and fourth-generation (4G) mobile technology that enables faster Internet connectivity. Nevertheless, in the initial wireless broadband market, mobile broadband is neither complementary to nor a substitute for fixed broadband.

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 may be considered one of the main drivers of broadband diffusion.

Conclusion: Implications & 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 below.

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; DotEcon & Criterion Economics, 2003). The existence of strong platform competition among DSL, cable modem, fiber, and wireless broadband in a market may ensure prices remain low (ITU, 2003b). In this context, in the broadband access market, regulation across platforms should be as competitively neutral as possible for sustaining strong platform competition and LLU should be made available at cost-based prices. 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 (ITU, 2005). 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 (OECD, 2001).

Beyond competition, 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.

This study also made a preliminary finding that broadband wireless is neither a complement to nor substitute for fixed broadband. Based upon studies that suggest cell phones serve as a substitute for wireline phone service (ITU, 2003c), one might expect a similar relationship between broadband wireless services and fixed broadband. This finding is based upon 2004-05 data and therefore it may be premature to indicate a permanent result considering that 3G wireless is relatively new in the marketplace compared to fixed broadband. If this does indicate a long-term result, the lack of substitution suggests that policymakers may wish to concentrate current deployment efforts on fixed broadband.

Several limitations to this study present areas for further inquiry. This study 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 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 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.

References

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

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

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

Cava-Ferreruela, I. & Alabau- Muňoz, A. (2006), "Broadband policy assessment: A cross-national empirical analysis", *Telecommunications Policy*, Vol. 30 No.8-9, pp. 445-463.

Chaudhuri, A., Flamm, K.S. and Horrigan J. (2005), "An analysis of the determinants of internet access", *Telecommunications Policy*, Vol. 29 No.9-10, pp. 731-55.

Crandall, R. W., Sidak, J.G. & Singer, H.J. (2002), "The empirical case against the regulation of broadband access", *Berkeley Technology Law Journal*, Vol. 17 No. 3, pp. 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*, North-Holland, Amsterdam, Netherlands, pp.156 -191.

Criterion Economics (2003), "The effects of ubiquitous broadband adoption on investment, jobs, and the U.S. economy", 13 June, available at: www.newmillenniumresearch.org/archive/bbstudyreport_091703.pdf

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*, Vol. 18 No. 1, pp.87-106.

DotEcon & Criterion Economics (2003), "Competition in broadband provision and its implication for regulatory policy: A report for the Brussels Round Table" 7 July, available at: www.dotecon.com/publications/BRTfull15-10-03.pdf

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

Frieden, R. (2005), "Lessons from broadband development in Canada, Japan, Korea and the United States", *Telecommunications Policy*, Vol. 29, No. 8, pp. 595-613.

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

Glassman, J. & Lehr, W. (2001), "The economics of Tauzin-Dingell: Theory and evidence," 3 December, available at: ebusiness.mit.edu/research/papers/128%20Lehr,%20Tauzin-Dingell.pdf

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

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,* Kluwer Academic, Boston, MA, pp. 51-68.

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*, AEI-Brookings Joint Center for Regulatory Studies, Washington, DC, pp.129-56.

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, Arlington.

International Telecommunication Union (2003a), "Promoting broadband: Background paper for workshop on promoting broadband" 11 November, available at: www.itu.int/osg/spu/ni/promotebroadband/PB03-PromotingBroadband.pdf

International Telecommunication Union (2003b), *Birth of Broadband*, ITU, Geneva.

International Telecommunication Union (2003c), "Mobile overtakes fixed: Implications for policy and regulation", 3 November, available at: www.itu.int/osg/spu/ni/mobileovertakes/Resources/Mobileovertakes_Paper.pdf

International Telecommunication Union (2004), *The Portable Internet*, ITU, Geneva.

International Telecommunication Union (2005a), *Year Book of Statistics: Telecommunication services 1994~2003*, ITU, Geneva.

International Telecommunication Union (2005b), *The Internet of Things*, ITU, Geneva.

International Telecommunication Union (2006), *Digital.life*, ITU, Geneva.

Kim, J. H., Bauer, J.M. & Wildman, S.S. (2003), "Broadband uptake in OECD countries: Policy lessons from comparative statistical analysis," Paper presented at 31st Research Conference

on Communication, Information and Internet Policy, Arlington.

Lee, C. & Chan-Olmsted, S.M. (2004), "Competitive advantage of broadband Internet: A comparative study between South Korea and the United States', *Telecommunications Policy*, Vol. 28 No. 9-10, pp. 649-677

Lee, S. (2006), "Broadband deployment in the United States: Examining the impacts of the platform competition", *The International Journal on Media Management,* Vol. 8, No. 4, pp. 173-181.

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.

Organization for Economic Co-operation and Development (2001), *The Development of Broadband Access in OECD Countries,* OECD, Paris.

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

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

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

Organization for Economic Co-operation and Development (2007), "OECD broadband statistics", 5 June, available at: www.oecd.org/document/7/0,3343,en_2825_495656_38446855_1_1_1_1,00.html

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

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*., Edward Elgar Publishers, Cheltenham, UK, pp.1-20.

Savage, S. J. & Waldman, D. (2005), "Broadband Internet access, awareness, and use: Analysis of United States household data", *Telecommunications Policy*, Vol. 29. No. 8, pp. 615-633.

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

United Nations Development Program (2005), *Human development report 2006*, UNDP, New

York.

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