

# Broadband Growth and its Determinants

– Determining the Effects of Socio-Economic, ICT and Industry, and  
Policy Factors on Broadband Penetration in OECD Countries

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## Abstract

This study attempts to contribute to the literature by evaluating the effects of various Socio-Economic, Information and Communication Technology (ICT) and Industry, and Policy factors on Broadband Penetration rates through pooling data across 30 OECD countries between years 2005 to 2008. By utilizing the fixed effect model, the study estimates that socio-economic factors such as income, size of urban population, life expectancy, and unemployment rates are statistically significant in determining the broadband penetration rate within a country. Additionally, the study finds that except broadband speed, all ICT and industry factors are also statistically significant. It also finds that full unbundling, and sub-loop unbundling have a positive impact on broadband penetration, while bitstream access and lack of inter-platform competition have a negative impact on broadband penetration rates.

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## Glossary of Terms<sup>1,2</sup>

<b>Technical Term</b>	<b>Definition</b>
ADSL	Asymmetric Digital Subscriber Line - DSL technology that provides much greater downstream than upstream bandwidth
Bitstream	A type of Local Loop Unbundling (LLU), where the preferred ADSL equipment and configuration is installed by the incumbent on its local access network, which is then made accessible to the entrants for providing various services to the consumers
Bottleneck Activity	A bottleneck is a feature within the value chain, whose control could allow the firm to exercise its market power at the retail level
DSL	Digital Subscriber Line – Type of technology that allows for provision of high bandwidth services over the copper wires
ICT	Information and Communication Technology Sector
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol – Set of codes and conventions that allow for transfer of digital information over the internet
ISP	Internet Service Provider – A firm that provides the consumers with data connection for accessing internet
LLU	Local Loop Unbundling – Access-based policy that allows new entrants access to the network elements used in the local loop. Full LLU is the situation where entrants are allowed to install their equipments and configure their own local access network
Local Loop	It is the connection between the end-user and the local exchange
Modem	Modeulator-Demodulator – A peripheral that allows the computer to transmit data over telephone and cable lines
Unbundling	Access-based policy to provide access to the entrants to the elements used for delivering communication services
xDSL	Term for describing all types of DSL technologies

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1 Using: DotEcon and Criterion Economics (2003)

2 Using: “Glossary of Statistical Terms”. OECD

## I. Introduction

The term broadband, as defined by the International Telecommunication Union (ITU, 2009), is generally used to identify high-speed network connections with download speeds faster than some minimum level such as dial-up connections (64 Kbit/s). As suggested by Welsum (2008), the broadband market has become one of the most important markets, crucial to today's economic growth. For example, in their report for the World Bank, Kim et al. (2010) estimated that there were 1.04 billion broadband subscribers worldwide by late 2009. Figure 1 shows the breakdown for different regions. Additionally, the same report also estimates that a 10 percentage point increase in broadband penetration leads to a 1.21 percentage point and 1.38 percentage point increase in the economic growth for the high income, and low and middle income countries respectively.

In addition to the above statistics, various studies have also shown the importance of broadband for the economy. For instance, Röller and Waverman (2001) find that about one third of the economic growth in the OECD countries, after controlling for the simultaneities for telecommunication infrastructure investments and economic growth and fixed effects, is due to telecommunications. In particular, recent studies suggest that the broadband sector has also played an important role in both Canadian and American economic growth. For example, Koutroumpis (2009) estimates that 6.8 percent of Canada's economic growth between 2002 to 2007 is attributed to the broadband infrastructure. Likewise, Greenstein and McDevitt (2009) estimate that approximately \$4.8 billion to \$6.7 billion of consumer surplus was generated by broadband. Thus it can be seen that any regulatory policy affecting broadband will also affect the economy of the country. Moreover, the regulation of broadband will also have significant impact on the integration of global economies. This is because, the information technology, such as electronic communications, is one of the drivers of globalization. For example, Ferguson (2004) suggests that information technology allows increased mobility of people, capital and

technology worldwide and thus allows for greater integration of world economies.

Finally, as suggested by various researchers such as Welsum (2008), broadband not only causes economic growth but it also impacts other social factors. For example, Ferguson (2004) finds that broadband development has enabled both the governments and the population to become more energy efficient, provide better health care, and provide a medium to express oneself and thus become socially more active.

Given the importance of broadband technology, it has therefore become utmost important for the policy makers of various countries to pay special attention to the growth and development of broadband market in their countries. However, the development of broadband is significantly different from country to country – requiring policy makers to evaluate various regulatory options. As a result, the need of regulatory participation within these countries has become even more crucial. Generally, the regulator would be required to ensure efficiency in the broadband market. In particular, Intven et al. (2000) suggest that the regulator would be required to ensure efficient supply of the broadband services, the quality of the service, and more importantly efficient prices.

The two key policy initiatives currently under investigation include local-loop unbundling regulation and platform competition. As Wallsten (2007) suggests, local-loop unbundling regulation generally requires an incumbent telecommunication firm to make part of their network available for the competing firms to use. See Figure 2 for a visual representation of the method by which local loop unbundling is implemented. This provides the new entrants with an opportunity to compete with the incumbent firm by using various techniques such as provision of differentiated services. Furthermore, by using one-way access pricing theory, Cave (2006) also suggests that an increase in product variety and additional price pressures due to unbundling of local loop tends to also increase broadband uptake. On the other hand, as explained by Church and Gandal (2004), inter-modal competition usually takes

place when policies promote different technologies to compete for providing the end-users with the telecommunications services.

In this respect, the current study attempts a modest contribution to the existing literature in identifying various factors contributing to broadband growth in various economies. More specifically, the study explores the effect of two key policy initiatives – the unbundling regulation and platform competition on broadband growth. This is accomplished by exploring the effect of these two factors on broadband growth in 30 OECD countries from 2005 to 2008. Furthermore, by utilizing various statistical tools and regression techniques, the study will empirically verify any effect on broadband growth within the panel dataset.

Such a study has apparent benefits from the perspective of various policymakers worldwide. Firstly, by differentiating between different types of unbundling regulation (Full Local-Loop Unbundling, Bitstream Access and Sub-Loop Unbundling), the study will allow to analyze the effect of each type of unbundling regulation independently. This is very important as different types of unbundling policies affect broadband growth differently. For example, Wallsten (2007) finds that full loop unbundling has a positive impact on broadband penetration rates while sub-loop unbundling has negative impact on the penetration rates. In addition to testing the effect of unbundling on broadband growth, this study also tests the effect of inter-modal competition on broadband growth. This is carried out by calculating the Herfindahl-Hirschman Index for each country for all the years – which is pertinent as it gives more weight to larger firms and thus tests the hypothesis that promoting single technology over different technologies is beneficial. Hence, from the above arguments, the study will test whether access based competition or facility based competition is the principle driver of broadband growth. Moreover, the study also incorporates the most recent available data for all the factors, especially for the unbundling regulation. Finally, the study analyzes data utilizing the Fixed-effect

estimation technique, thus enabling a policymaker to make decisions based on robust results.

Overall, the study finds that of all the Socio-Economic factors, income, urban population size, life expectancy, and unemployment rates are statistically significant in determining broadband penetration rates. Also, most of the ICT and Industry factors are found to be statistically significant in explaining the broadband growth for the sample countries. Moreover, of all the policy options available, bitstream access is found to be the only statistically significant factor that affects the broadband growth negatively; that is, broadband penetration rates are found to be negatively correlated with this policy. Finally, the study suggests that inter-platform competition is economically significant in determining penetration levels.

The remainder of this paper is structured as follows: Section II describes the two broad regulatory policies in more detail. Section III reviews the existing literature on factors affecting broadband growth. The description of data and the theoretical model for the study are then introduced in Sections IV and V respectively, while the main model itself is empirically tested in Section VI. Finally, Section VII discusses the limitations of the model and concludes the study with a summary of key findings.

## **II. Regulatory Policy Options for Promoting Broadband Growth**

The two (most widely debated and usually considered opposite ends of the spectrum of policies) policy options dealing with unbundling regulations are policies promoting access-based competition, and policies that promote platform competition (facilities-based competition). This section discusses these policy options in further detail to provide a better understanding of the issue.

### ***Access-Based Competition (Unbundling) Policies***

At present, DotEcon and Criterion Economics (2003) identify that the most dominant feature of any telecommunication regulatory regime is access regulation. Usually, access based regulation can be used to promote competition for activities that are not subject to natural monopoly within the value chain. Additionally, DotEcon and Criterion Economics (2003) also explain that this type of regulation also reduces the bottleneck and encourage competition. Assuming local loops are bottlenecks for broadband provision, the local-loop unbundling is a form of access regulation. Generally, the local loop unbundling strategies can be further divided into various forms: full unbundling, bitstream access, and sub-loop unbundling. Umino (2003) also identifies that each type of unbundling is dependent of services provided by new entrants and various other factors such as the Main Distribution Frame (MDF) size of the telecommunication operator and availability of collocation space.

As explained by Umino (2003) and The Local Loop Unbundling Committee (2007), the three main types of unbundling policies available to policymakers are:

#### ***(A) Full Unbundling***

Full unbundling usually occurs when the new entrant leases the copper pairs that connect a subscriber to the MDF from an incumbent. In this form of unbundling, the incumbent not only owns the unbundled loop but also maintains it; while the entrant has total control of the copper pairs to provide all telecommunication services (including data and voice) to subscribers. Additionally, new technologies such as ADSL can also be added to improve the copper wire. Finally, the relationship between the two operators is regulated. Figure 3 provides a visual representation of a Full Unbundled Network.

#### ***(B) Bitstream Access***

Bitstream access unbundling usually occurs when an incumbent firm provides a whole data service for the Internet Service Providers (ISP) to satisfy the need of fast growing internet markets.

Generally, the incumbent provides the ISPs with wholesale xDSL services. Unlike full unbundling, the incumbent also maintains the control of the line and only allocates the spectrum to the entrant. Additionally, the entrant is only allowed to offer telecommunication services which are approved by the incumbent and use equipments and technology that are provided by the incumbent; thus restricting any competition for the actual physical layer and discouraging any installations of new technology by the incumbent. Moreover, the incumbent also manages the spectrum between the operators and hence there is no need for regulating the spectrum. Generally, this method is also avoided by the entrants but favoured by the ISPs. Finally, service based competition can occur at lower level depending on the amount of access to the system provided by the incumbent. See Figure 4 for the visual representation of a network under bitstream access.

### ***(C) Sub-Loop Unbundling***

Sub-loop unbundling generally occurs when an entrant or another operator is allowed to interconnect with the local access network between the incumbent's site and the end consumer. Generally, the incumbent leases some of the copper loop between the network termination point at the end user and a specified intermediate access point within the local network. As a result, this policy allows an entrant to possibly gain access to the incumbent's network much closer to the end consumer. However, this policy is considered to be very complicated because of the expenses and difficulty to create such a connection closer to the consumer. Moreover, as Wallsten (2007) notes, there are various estimates suggesting that sub-loop unbundling is less profitable for an entrant. Figure 5 presents a graphic representation of the network showing the Sub-loop Unbundling characteristics.

### **Facilities-Based (Platform) Competition Policy**

The second type of policy initiative under investigation within this study promotes platform competition – more specifically inter-platform competition, which implies a type of facilities-based competition. According to DotEcon and Criterion Economics (2003), inter-platform competition

usually occurs when there are several platforms utilizing different technologies but providing end users with closely substitutable retail services. Moreover, the report also suggests that promoting facilities-based competition is advantageous as building infrastructure to provide services provides more control over those services as opposed to access-based regulating strategies. However, there are various barriers in promoting facilities-based competition; chief among these barriers is the requirement for a new entrant to provide upfront large investments to develop the infrastructure. As a result, facilities-based competition may or may not be beneficial to broadband growth – this hypothesis will be tested later empirically.

Since both access-based competition and facilities-based competition are present in the broadband market, the study will allow to empirically observe the effect of these two market forces on the development of broadband. The next section provides a brief review of the existing research that has been performed to empirically identify various sources of influences on broadband growth.

### **III. Review of the Literature**

Due to its growing influence on both the economic and social aspects of a country, a considerable amount of research is being carried in the field of broadband development. Most importantly, in the past two decades various studies are being conducted to determine some of the key factors that affect the broadband growth in a given country. These empirical studies, that analyze the effect of the given factors on the growth of broadband, vary in terms of: both (i) regression methodology used – some employ the usual multivariate OLS estimation, IV estimation technique or ANOVA regression techniques; and (ii) the type of data set used – cross sectional, time series or panel data series.

Similar to this study, much of the recent analyses are designed to evaluate the effects of regulatory policy (chiefly the local loop unbundling), and inter-modal or intra-modal competition on broadband penetration rate. In their pivotal paper, Distaso et al. (2006) find that greater competition across different technologies (DSL and cable) stimulates broadband adoption significantly; while increased competition within the DSL segment of the market in itself does not have the same effect. Additionally, they also find that policies directed towards local loop unbundling have a positive effect on broadband adoption. Simply stated, the authors find that both inter-platform competition and local loop unbundling policy have a significant impact on broadband growth while intra-platform competition is not that important. Specifically employing cross panel unbalanced data from the fourth quarter of 2000 to second quarter of 2004 for 14 European countries, they find that a one point increase in the intra-platform competition will lead to a 0.08% increase in broadband penetration rate (when accounting for GDP per capita and using IV estimation technique). Similarly, a one point increase in the inter-platform competition will lead to a 1.98% decrease in broadband penetration rate. However, it should also be noted that the authors assume a simple oligopolistic market for broadband technologies (due to lack of data availability), which could be one of the shortcomings of this particular study.

Wallsten (2007) focuses on the effect of different types of unbundling regulations (full Local Loop Unbundling, Sub-loop unbundling and Bitstream access) on broadband penetration and speed for 30 OECD countries over five years (1999-2003). The study also tests the effect of different types of collocation techniques on broadband penetration and speed. In order to do so, the author incorporates binary variables for each type of unbundling regulation in his two regression models – (i) where broadband penetration rate is the dependent variable, and (ii) where broadband speed is a dependent variable. In the first regression model, the results suggest that without the fixed effects and when controlling for population density, income, and telephone lines, LLU (Local-Loop Unbundling) is significant and positively related to broadband penetration; this result however does not hold true when

fixed effects are integrated into the regression. When country and year fixed effects are integrated, it is found that a fully mandated LLU will result in 1% increase in broadband penetration, a mandated sub-loop unbundling will result in a decrease of 5% in broadband penetration and a mandated bitstream access will result in a 1% decrease in broadband penetration. Similarly, in the second regression model, the study finds that none of the unbundling variables are statistically significant (with same signs as the previous model). Additionally, comingled collocation is found to be positively and significantly correlated to the download speed (not significant for upload speed); while virtual collocation is negatively and significantly correlated with both download and upload speeds.

Grosso (2006) also tests the effect of various factors on broadband penetration in 30 OECD countries from 1999 to 2005 using generalized least squares multiple regression analysis. These factors include the Herfindahl-Hirschman Index of concentration, gross domestic product (GDP) per capita, fixed internet penetration and an unbundled local loop dummy variable. Incorporating cross-section fixed effect in the model, the study estimates that a 1% decrease in concentration leads to 0.18% increase in broadband penetration and is statistically significant. Additionally, it also finds that GDP per capita is also statistically significant and a 1% increase in GDP per capita leads to 5.5% increase in broadband penetration. Finally, countries where local-loop are unbundled tend to have 0.32% higher penetration rate than countries with no local-loop unbundling. In general, the study finds that broadband is a superior good and all factors are significant in determining broadband penetration.

In another study, Cava-Ferreruela and Alabau-Muñoz (2006) utilize cross-national empirical analysis to identify factors affecting broadband supply, demand and adoption. In particular, the study uses panel dataset for 30 OECD countries from 2000 to 2002, and includes variables for telecommunications, social, economic and demographic factors. This study finds that promoting technological competition and public funding for infrastructure will promote broadband supply in a

given country. Similarly, increasing people's disposition and skills for using new technologies and promoting relevant local content can result in increased broadband demand. Finally, the study also suggests that having both supply and demand-side policies will also promote broadband adoption. More specifically, they find that access to DSL networks is on average 10 times greater in countries with competing broadband infrastructures as opposed to those who do not have such competition. Additionally, the dummy variable used to incorporate the competition between technologies is also statistically significant. On the other hand, the study also finds that DSL coverage, on average, is 1.8 times greater for countries where local loop unbundling is mandatory. Lastly, it also suggests that urban population and household density are positively and significantly related to DSL and cable coverage.

Garcia-Murillo (2005) analyzes the role of unbundling policies and various other regulatory policies. By using a logit modelling technique, and cross-sectional data for 2001 and for approximately 100 countries, the author estimates the impact of unbundling on broadband access. Additionally, an OLS analysis is also used to find the effect of GDP per capita, population size, price, and competition on broadband access. In general, the study finds that income, population size, competition and unbundling have a significant effect on broadband access. In the first analysis (analyzing factors affecting availability of broadband services in a country), the author finds that broadband competition is significant at the 5% level and positively affects the probability of broadband service availability. Furthermore, the study also estimates that middle income countries are drastically affected depending on unbundling policy (unbundling policy increases the probability of having access to broadband service from 2% to 41%). Thus implying that less developed countries can improve broadband growth by using LLU regulatory policies. Similarly, in the second analysis (analyzing the effects of various factors on broadband subscribers), the author estimates that unbundling is only significant and positively related when population density is included in the model.

By employing a weighted least-squares logit regression for 46 U.S. States, Aron and Burnstein

(2003) find that the effect of direct inter-modal competition results with households increasing their subscriptions to broadband services. Additionally, in the restricted model, they find that both access to internet (INTERNET) and percentage of population with Bachelor's degree or higher (EDUCATION) have positive effects but only the education level is statistically significant; the model estimates that one standard deviation increase in EDUCATION increases the level of per capita penetration by 96%. Likewise, it is also estimated that one standard deviation increase in the density of switched access lines results in 0.0016% increase in penetration. Moreover, in the unrestricted model, the authors find that having access to more than one technology (DSL or cable modem) is positive and statistically significantly- with one standard deviation increase in this variable resulting in 6.5% increase in penetration. On the other hand, the variable for only having access to one technology is not statistically significant. Overall, the authors find that facilities-based (inter-modal) competition between DSL and cable technologies has significant impact on broadband penetration. However, it should also be noted that the model estimated is cross-sectional and hence is a static model.

In their paper, Bauer et al. (2003) use cross-sectional dataset for 30 different OECD countries for the year 2001 to estimate the effect of various factors such as the price of broadband, competition level and relative income levels on broadband penetration. By utilizing a multivariate OLS regression method, they estimate that the price of broadband, the price of dial-up, income and competition are statistically insignificant. Although surprising, this is probably due to the fact that the model is cross-sectional and not time series (which the authors explain is due to lack of comparative data); thereby, not accounting for the dynamic process by which the broadband adoption usually evolves.

In addition to competition and regulatory factors, various studies are also conducted to identify various demographic factors that affect broadband adoption. One such study is conducted by Stanton (2004). In this study, the author attempts to analyze the socio-demographic factors influencing the

adoption of broadband services. To do so, the author uses the Current Population Survey data from September 2001 for the United States. Furthermore, the study utilizes three multivariate logit regression models with binary dependent variables. The key model of interest is the third model, which examines the likelihood of broadband access within a home. Within the model, the author estimates that all races except American Indian and Asian are statistically significant and also living in a metropolitan area increases the likelihood of access to broadband by 222% over rural areas.

Similarly, one of the most important studies (on which the current study is based) is that of Lee and Brown (2008). The study focuses on estimating the effect of various factors (policy factors, industry factors, demographic factors and ICT factors) on broadband adoption. Specifically, the study includes factors such as platform competition, ICT use, content, broadband speed, income, population density and local loop unbundling. In order to examine these effects, the authors use 110 observations from various countries between 2002 and 2005 for the regression analysis and 159 observations for the same period for one-way ANOVA analysis. In the final reduced regression model, platform competition, broadband speed, number of estimated computers per 100 inhabitants (ICT), and number of internet hosts per 100 inhabitants (CONTENT) are found to be statistically significant. Moreover, a 1% increase in platform competition is estimated to increase broadband adoption by 11.4%. On the other hand, using one-way ANOVA to examine the effect of LLU policy on broadband penetration, the study suggests that differences between countries with and without LLU policy are statistically significant; likewise, the mean penetration rate for 106 countries with LLU policy was 10.38 per 100 inhabitants which is greater than the mean broadband penetration rate of 53 countries without LLU policy (3.25 per 100 inhabitants).

Finally, Kum (2008) examines the effect of government role in promoting broadband growth within a country. In particular, the study conducts a pooled Time Series and Cross Section analysis and

an OLS regression using a sample of 60 countries (28 developed countries and 32 developing countries) between 2000 and 2006. Additionally, the study incorporates five explanatory factors that affect broadband penetration rates: Political Factors, Technological Factors, Economic Factors, Demographic Factors, and Cultural Factor. Overall, LLU policy implementation is found to be significant in determining broadband growth, while market competition is found to be statistically insignificant. Moreover, the author also finds that the number of internet subscribers is also positively significant. Surprisingly, the study also finds income (as measured by GDP per capita) to be insignificant for developed countries. The study also finds urbanization to be statistically significant but negatively related to broadband penetration rates. More specifically, a 1% increase in urban population is found to reduce broadband penetration rates by 0.71% in developed countries when including policy variables. However, similar to various other studies in this literature, the author also identifies lack of sufficient data as one of the shortcomings of the analysis.

#### **IV. The Data**

This panel dataset is formed by joining data collected from various sources<sup>3</sup> that concern three main categories: Socio-Economic, Industrial and ICT, and the Regulatory Policy that promotes facilities-based competition or access-based competition. Additionally, all data described here are for the period 2005-2008 inclusive.

The list of the OECD countries and a summary of some of the key indicators for 2008 are provided in TABLE 1 of the appendix. The table suggests that countries with higher gross domestic product in 2008 also tend to have higher broadband penetration rates; this relationship is demonstrated

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<sup>3</sup> Primary Sources: OECD Broadband Portal, and World Development Indicators & Global Development Finance database.

in Figure 6. On the other hand, in 2008 ICT expenditures have a very weak relationship with the broadband penetration rates. Finally, the Herfindahl-Hirschman Index also suggests that in 2008 more than fifty percent of the sample countries had at least more than one dominating technology to provide broadband within the market. Additionally, the descriptive statistics for each of the variables included in this study are provided in TABLE 2. The table provides summary information such as number of observations, the range of values, mean and standard deviation. For example, this table shows that on an average the broadband penetration rates (Broadband\_Rate) for the sample countries is 19.42%; thus suggesting that on an average only 19 people out of 100 had access to broadband within each country. However, the standard deviation for the same variable also suggests that there is large variance amongst countries. Similarly, the table also suggests that on average the advertised broadband speed is 12289.67 kbit per second; while the average price of the average broadband subscription is 51.39 U.S. dollars PPP. Also, approximately 63% of total population are internet users (Internet\_Users) within each country. Likewise, on average the ICT expenditure (ICT\_Expenditure) is found to be approximately 6% of the country's gross domestic product. Finally, the mean for the Herfindahl-Hirschman Index (HHI) is reported to be approximately 62.71 - suggesting that most of the countries have at least more than one dominating technology within the market.

A correlation analysis is also conducted to verify any multicollinearity problems that may arise within the study. As it can be seen from Table 3, there are no problems of perfect collinearity within the independent variables; which would otherwise void the Gauss-Markov assumption for estimating an Ordinary Least Squares (OLS) model. However, multicollinearity could exist between certain variables such as ICT expenditures and GDP (ICT is found to be 71% correlated to GDP); nevertheless, since ICT expenditure is an important component for this study, it will be included to determine its effect on the level of broadband growth.

**TABLE 3: Correlation Matrix for each of the Variables**

	BB	BBS	BBP	INU	INH	GDP	ICTE	LEXP	PDEP	PDEN	UER	PURB	HHI	FLLU
BB	1.0000													
BBS	0.3628	1.0000												
BBP	-0.6124	-0.3114	1.0000											
INU	0.8654	0.3218	-0.5593	1.0000										
INH	0.6613	0.0718	-0.3609	0.6194	1.0000									
GDP	0.7295	0.2684	-0.5379	0.6931	0.5228	1.0000								
ICTE	0.1643	0.2365	-0.0953	0.2206	-0.1416	-0.0882	1.0000							
LEXP	0.6297	0.3655	-0.5907	0.5252	0.4143	0.7106	-0.0858	1.0000						
PDEP	0.1858	0.0471	-0.1197	-0.0150	0.3183	0.4203	-0.4625	0.2886	1.0000					
PDEN	0.3078	0.4706	-0.1997	0.1920	-0.0091	0.0489	0.3481	0.1500	-0.1140	1.0000				
UER	-0.5138	-0.2738	0.2110	-0.4062	-0.4294	-0.5058	-0.1034	-0.3930	-0.2478	-0.1610	1.0000			
PURB	0.5218	0.0409	-0.1562	0.4298	0.2248	0.3305	-0.0281	0.3056	0.3411	0.1811	-0.4063	1.0000		
HHI	-0.2677	-0.2091	-0.0042	-0.3810	-0.0530	-0.1591	-0.4983	0.0350	0.3878	-0.2212	0.3543	-0.1441	1.0000	
FLLU	0.5743	0.3028	-0.4734	0.5092	0.3435	0.5498	0.0596	0.5315	0.1901	0.1710	-0.1849	0.1413	-0.0977	1.0000
SLU	0.2346	0.2470	-0.3213	0.1730	0.0619	0.5503	-0.2673	0.4143	0.4329	-0.0030	-0.1562	0.0994	-0.0656	0.5014
BSA	0.4267	0.4578	-0.3933	0.3653	0.3660	0.5151	-0.2267	0.5344	0.3416	0.1336	-0.2811	0.2302	-0.0618	0.4501
		SLU	BSA											
SLU		1.0000												
BSA		0.6319	1.0000											

***Broadband Penetration (Broadband\_Rate)***

Broadband penetration is the dependent variable in this empirical study. It is defined as the number of broadband subscribers per 100 inhabitants within each of the 30 OECD countries. Additionally, these data are collected from the OECD's Broadband Portal - within the Information and Communications section of the website. Since most of the other variables used in this paper are on an annual basis, only yearly figures are used in the dataset.

**Category: Socio-Economic Factors**

***Gross Domestic Product per capita (GDP)***

The Gross Domestic Product per capita is the proxy variable used for measuring the per capita income of all residents within an OECD country. Arithmetically, it is the sum of gross value added by all resident producers divided by midyear population in constant 2000 US\$ prices. Also, these data are collected from the World Development Indicators (WDI) & Global Development Finance (GDF)

database. Although it can be argued that GDP is endogenous – that is, there is a two way causality between GDP per capita and Broadband Penetration<sup>4</sup>, this paper assumes GDP to be exogenous; this is because the development of broadband is still in its early stages and hence its impact on the economy is likely to be negligible. Since, broadband is a normal good, this study tests the hypothesis that broadband penetration is positively and significantly related to higher income levels as suggested by Grosso (2006).

H<sub>1</sub>: Coefficient of GDP<sub>i</sub> > 0

#### ***Population Density (Pop\_Density)***

Population density is the number of people living in a per square kilometre of land. Arithmetically, it is calculated by dividing the midyear population by the total land area in square kilometres of an OECD country. Like the GDP variable, these data are also collected from the World Development Indicators (WDI) & Global Development Finance (GDF) database. As Garcia-Murillo (2005) suggests, given that less populated regions could only be served through higher prices - which will reduce the demand for broadband, this study tests the hypothesis that higher population density has a positive effect on the broadband penetration rates.

H<sub>2</sub>: Coefficient of Pop\_Density<sub>i</sub> > 0

#### ***Percentage of Urban Population (Pop\_Urban)***

The Percentage of Urban Population is a factor used to measure the percentage of people that live in urban areas as defined by national statistical offices. It is collected from the World Development Indicators (WDI) & Global Development Finance (GDF) database. The primary reason for using this variable is that various studies such as Cava-Ferreruela and Alabau-Muñoz (2006) find it significant in explaining the broadband penetration rates. On the other hand, it can be expected that building new

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<sup>4</sup> As mentioned in the Introduction, Broadband is found to be a significant factor in growth of an economy as it facilitates faster means of communication and transactions over the internet. For example, Atkinson and McKay (2007) report that Cisco saves \$360 million per year using the internet for e-business.

infrastructures in very populated urban areas is both difficult and costly as it would require more space and overhaul of older infrastructure; thus suggesting that having more urban population can also have a negative impact on broadband penetration. As a result, this study tests the hypothesis that higher percentage of urban population has an ambiguous effect on the broadband penetration rates.

H<sub>3</sub>: Coefficient of Pop\_Urban<sub>i</sub> ≠ 0

#### ***Life Expectancy at Birth (Life\_Expectancy)***

The Life Expectancy at Birth is a proxy variable to measure the quality of life for the residents within an OECD country. It is defined as the number of years a newborn will live given the prevailing mortality rate in that year. Similar to the above socio-economic factors, the data are obtained from World Development Indicators (WDI) & Global Development Finance (GDF) database. Also, since this variable measures the quality of life of the individuals within a country, it can be assumed that the higher quality of life should have a positive effect on the demand for broadband (a normal good). Thus, this study tests the hypothesis that higher life expectancy at birth has a positive effect on broadband penetration rates.

H<sub>4</sub>: Coefficient for Life\_Expectancy<sub>i</sub> > 0

#### ***Unemployment Rate (Unemployment)***

The Unemployment Rate represents the share of the total labour force that is without work but are actively seeking employment and available for work. The data are collected from the World Development Indicators (WDI) & Global Development Finance (GDF) database. Given that most of the previous literature has not focused on the impact of unemployment rates, this study incorporates it for the following two reasons: (1) Due to unemployment, an individual will see a reduction in their income and will reduce their demand for normal goods such as broadband. (2) On the other hand, it will also provide an individual with more leisure time in which the demand for normal goods such as broadband can increase. This study therefore hypothesizes that unemployment rate has a significant and

an ambiguous effect on broadband penetration.

H<sub>5</sub>: Coefficient for Unemployment<sub>*t*</sub> ≠ 0

### ***Dependent Population (Pop\_Dependent)***

Dependent Population is defined as the ratio of population within the age group of 0-14 and 65 and over divided by the population that is within 16-64. Alternatively, it is the ratio of dependent population to the working age population. Moreover, these data are collected from the World Development Indicators (WDI) & Global Development Finance (GDF) database. Similar to the unemployment rate, this variable is a new addition to the model estimating the effect of various factors on the broadband penetration rate. Given that most of the dependent population do not have resources to subscribe for broadband or lack technology expertise to use it efficiently,<sup>5</sup> this study hypothesizes that the ratio of dependent population will have a negative impact on the broadband penetration rates.

H<sub>6</sub>: Coefficient for Pop\_Dependent<sub>*t*</sub> < 0

### **Category: Information and Communication Technology, and Industry Factors**

#### ***Internet Users (Internet\_Users)***

Internet Users is the variable that measures the number of internet users per 100 inhabitants within a country. It is one of the independent variables in this study used to measure the effect of Information and Communication Technology infrastructure (ICT) on broadband demand. More specifically, it is used as a proxy for ICT use (which is one of the measures for level of ICT infrastructure). Additionally, the data are collected from the International Telecommunications Union (ITU) statistics database for the years 2005 through 2008. Moreover, it should also be noted that unlike Lee and Brown (2008), this variable is chosen over the personal computer rates. This is because (1) with the advancement in technology, there are more tools such as tablet computers and smart phones by

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<sup>5</sup> For example, children within the age group of 0-14 cannot usually subscribe for internet services as they have no or very little income to pay for those services.

which an individual can use internet; and (2) the data for more recent personal computer penetration rates are unavailable for many of the countries in the sample. Given that most of the literature, such as Lee and Brown (2008)<sup>6</sup>, find that the level of ICT use has a positive effect on broadband demand, this study will test the hypothesis that higher internet use has a positive effect on broadband penetration rates.

H<sub>7</sub>: Coefficient for Internet\_Users<sub>i</sub> > 0

### *Internet Hosts (Internet\_Hosts)*

Internet hosts are domain names that have an IP address associated with them. Thus it includes any computer or device connected to the internet using various connection techniques. This variable measures the number of internet hosts originating within a country for every 100 inhabitants. Additionally, similar to the *Internet Users* variable, it measures the effect of Information and Communication Technology content on the demand for broadband. More specifically, it is an indication of internet growth within a country and thus acts as a proxy to measure the diffusion of broadband. The data for the number of Internet Hosts per country are derived from the Telecommunications Database of the OECD statistical database for the years 2005 through 2008. In addition to the existing literature (example - Garcia-Murillo, 2005), the governments and the private sector of various countries have also acknowledged that region specific content can increase demand for broadband. For example, in Honda (2002) the United States representative of California – Mike Honda, also suggests that internet users would only pay higher prices for these services if the internet content is compelling. As a result, this study tests the hypothesis that an increase in the number of internet hosts (which is a measure of the effect the ICT content has on broadband demand) originating within a country will have a positive effect on broadband penetration rates.

H<sub>8</sub>: Coefficient for Internet\_Hosts<sub>i</sub> > 0

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<sup>6</sup> Lee and Brown (2008) find that a 1% increase in ICT use increases broadband penetration by 0.45% and is statistically significant at 1 percent significance level.

### ***Information and Communication Technology Expenditure (ICT\_Expenditure)***

The Information and Communication Technology Expenditure variable measures the amount of expenditure on computer hardware, computer software, computer services, communications services, and wired and wireless communication equipment as a percentage of Gross Domestic Product. Additionally, these data are collected from the World Development Indicators (WDI) & Global Development Finance (GDF) database for the years 2005 through 2008. One of the key reasons for incorporating this variable is that research in this field is very limited. Moreover, the existing literature also suggests that ICT infrastructure has a positive influence on broadband adoption. For example, Arnun and Conti (1998) find that infrastructure development is positively correlated to internet penetration. Likewise, Cava-Ferreruela and Alabau-Muñoz (2006) also find that modernization of the networks also contributes to broadband growth. Given these results, this study tests the hypothesis that an increase in investment within the Information and Communication Technology infrastructure has a positive effect on broadband penetration rates.

H<sub>9</sub>: Coefficient for ICT\_Expenditure<sub>i</sub> > 0

### ***Broadband Price (Broadband\_Price)***

Broadband Price is the average price of all available (and advertised) offers for the residential consumers within each OECD country and is measured in U.S. dollars PPP. It is collected from the OECD Communications Outlook publication for years 2006 and 2008. As suggested by the existing literature (for example: Lee and Brown, 2008), broadband price could be an important factor in promoting broadband growth. Additionally, since broadband is a normal good, it is expected that *Broadband Price* negatively affects the demand for broadband within a country. However, one of the primary issues when incorporating such a variable is the direction of causality. This arises because on one hand prices negatively affect the broadband demand but on the other hand a lower demand could result in service providers to charge higher prices. Hence, following the argument provided by Bauer et

al. (2003),<sup>7</sup> *Broadband Price* is assumed to be an exogenous variable as there is no reverse causality suspected due to the early developmental stage of broadband. Therefore, this study tests the hypothesis that a higher price for the broadband service has a negative impact on broadband penetration rates.

H<sub>10</sub>: Coefficient for *Broadband\_Price*<sub>*i*</sub> < 0

### ***Broadband Speed (Broadband\_Speed)***

Broadband Speed is the average speed of all available (and advertised) offers for the residential consumers within each OECD country and is measured in kbit per second. Similar to the Broadband Price, these data are also collected from OECD communications Outlook publication for years 2006 and 2008. As suggested by Lee and Brown (2008), broadband speed may stimulate demand when used as a product differentiation technique by providers. Simply stated, it can be argued that higher speed for accessing internet could attract more consumers and therefore increase demand for broadband, which in turn can foster the growth of the broadband market. Therefore, this study tests the hypothesis that a higher broadband speed is positively related to broadband penetration rates.

H<sub>11</sub>: Coefficient for *Broadband\_Speed*<sub>*i*</sub> > 0

## **Category: Policy Factors**

### ***Full Local Loop Unbundling (Full\_LLU)***

This is a proxy variable used to study the effect of full local loop unbundling policy on broadband penetration. In particular, this variable measures the number of years that full local loop unbundling has been available within a country, thus allowing policymakers to see the impact of full local loop unbundling over a period of time. This information is collected and updated through various sources. Firstly, it uses information available in Atsushi (2004), and is then updated using OECD Communications Outlook publication (2007 and 2009). Since recent literature such as Aron and

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<sup>7</sup> Bauer et al. (2003) argue that companies may compete using other dimensions such as service quality instead of price competition in a market which is in its early stage of development.

Burnstein (2003), and Garcia-Murillo (2005) find a positive relationship between unbundling policies and broadband penetration, the study tests the hypothesis that a full local loop unbundling policy has a positive impact on the growth of broadband within the country.

H<sub>12</sub>: Coefficient for Full\_LL*U*<sub>*i*</sub> > 0

#### ***Sub-Loop Unbundling (Sub\_Loop)***

Similar to the *Full Local Loop Unbundling* variable, Sub-Loop Unbundling is also a proxy variable used to study the effect of sub-loop unbundling policy on broadband penetration. In particular, this variable measures the number of years that sub-loop unbundling has been available within a country. Once again, this information is collected and updated through various sources such as Atsushi (2004), and OECD Communications Outlook publication (2007 and 2009). Similar to full local loop unbundling policy, sub-loop unbundling policy is also a policy measure to increase competition and therefore promote broadband development. However, since recent literature such as Wallsten (2007) finds contradicting evidence, this study tests the hypothesis that a sub-loop unbundling policy has an ambiguous impact on the growth of broadband within the country.

H<sub>13</sub>: Coefficient for Sub\_Loop*i* ≠ 0

#### ***Bitstream Access (Bitstream)***

This is the last proxy variable used to study the effect of unbundling on broadband penetration. More specifically, this variable measures the number of years that bitstream access policy has been available within a country. Also, this information is collected and updated through various sources such as Atsushi (2004), and OECD Communications Outlook publication (2007 and 2009). Similar to the above mentioned policies, *Bitstream Access* policy is also utilized to promote broadband development by promoting competition.<sup>8</sup> However, like Sub-Loop Unbundling policy, studies such as Wallsten (2007) find contradicting evidence. Hence, this study tests the hypothesis that Bitstream Access has an

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<sup>8</sup> See Section II. for explanation.

ambiguous impact on broadband growth.

H<sub>14</sub>: Coefficient for Bitstream<sub>i</sub> ≠ 0

### ***Herfindahl-Hirschmann Index (HHI)***

The Herfindahl-Hirschmann Index is the variable utilized in this study to measure the degree of inter-modal competition. Generally, the HHI index is given by:

$$HHI_{inter} = \sum_{i=1}^n s_i^2$$

Where  $s_i$  represents the market share of firm  $i$  in a market of  $n$  firms. However, for this study a modified version of this index is used<sup>9</sup>:

$$HHI_{inter} = \sum_{i=1}^n \left( \frac{B_i}{TB} \right)^2$$

where  $B_i$  represents the number of broadband access lines of platform  $i$  (DSL, Cable, and Others), and  $TB$  represents the total number of broadband access lines within a country.

This modified version can be interpreted as the concentration index derived by using the sum of squared market shares for each platform within the country. This index has a range between zero and one hundred. For example, a market characterized by only one platform for broadband services (a pure monopoly) will have an HHI of 100, a perfect duopoly market will have an HHI of 50 and a perfectly competitive market will have an HHI of 0. The data for creating this index are collected from the Telecommunications Database of the OECD statistical database for the years 2005 through 2008. Given that increase in competition within technologies should enable broadband growth, the hypothesis tested is that an increase in facilities-based competition has a positive impact on the growth of broadband within a country. As a result, this variable is expected to have a negative coefficient.

H<sub>14</sub>: Coefficient for HHI<sub>i</sub> < 0

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<sup>9</sup> This is similar to the  $HHI_{inter}$  index used in Distaso et al. (2006) - the only difference between the two indices is that unlike Distaso et al.'s paper, this paper incorporates all types of platform technologies through which broadband is provided.

**TABLE 4: Summary of Expected Signs**

Variable	Description	Expected Sign
<i>Socio-Economic Factors</i>		
GDP	Gross Domestic Product per capita	+
Pop_Density	Population Density	+
Pop_Urban	Percentage of Urban Population	+ or –
Life_Expectancy	Life Expectancy at Birth	+
Unemployment	Unemployment Rate	+ or –
Pop_Dependent	Dependent Population	–
<i>Information and Communication Technology, and Industry Factors</i>		
Internet_Users	Internet Users	+
Internet_Hosts	Internet Hosts	+
ICT_Expenditure	Information and Communication Technology Expenditure	+
Broadband_Price	Broadband Price	–
Broadband_Speed	Broadband Speed	+
<i>Policy Factors</i>		
Full_LLU	Full Local Loop Unbundling	+
Sub_Loop	Sub-Loop Unbundling	+ or –
Bitstream	Bitstream Access	+ or –
HHI	Herfindahl-Hirschmann Index	–

## V. The Model

The above list of variables and descriptive statistics form the basis on which the empirical model will be built. More specifically, this study hypothesizes the following function for estimating Broadband Penetration Rates:

$$\text{Broadband\_Rate}_i = f \{ \text{GDP}_i, \text{Pop\_Density}_i, \text{Pop\_Urban}_i, \text{Life\_Expectancy}_i, \text{Unemployment}_i, \text{Pop\_Dependent}_i, \text{Internet\_Users}_i, \text{Internet\_Hosts}_i, \text{ICT\_Expenditure}_i, \text{Broadband\_Price}_i, \text{Broadband\_Speed}_i, \text{Full\_LLU}_i, \text{Sub\_Loop}_i, \text{Bitstream}_i, \text{HHI}_i \}$$

Furthermore, in order to test the above relationship between broadband and various factors, the

following three models are estimated:

Model 1: 
$$\text{Broadband\_Rate}_{i,t} = W_{i,t} \alpha + \varepsilon_{i,t}$$

where,  $W = [\text{GDP}, \text{Pop\_Density}, \text{Pop\_Urban}, \text{Life\_Expectancy}, \text{Unemployment}, \text{Pop\_Dependent}]$

Model 2: 
$$\text{Broadband\_Rate}_{i,t} = X_{i,t} \beta + \varepsilon_{i,t}$$

where,  $X = [\text{Internet\_Users}, \text{Internet\_Hosts}, \text{ICT\_Expenditure}, \text{Broadband\_Price}, \text{Broadband\_Speed}]$

Model 3a: 
$$\text{Broadband\_Rate}_{i,t} = Z_{i,t} \gamma + \varepsilon_{i,t}$$

where,  $Z = [\text{GDP}, \text{Pop\_Density}, \text{Pop\_Urban}, \text{Life\_Expectancy}, \text{Unemployment}, \text{Pop\_Dependent}, \text{Internet\_Users}, \text{Internet\_Hosts}, \text{ICT\_Expenditure}, \text{Full\_LLU}, \text{Sub\_Loop}, \text{Bitstream}, \text{HHI}]$

Model 3b: 
$$\text{Broadband\_Rate}_{i,t} = Z_{i,t} \delta + \varepsilon_{i,t}$$

where,  $Z = [\text{GDP}, \text{Pop\_Density}, \text{Pop\_Urban}, \text{Life\_Expectancy}, \text{Unemployment}, \text{Pop\_Dependent}, \text{Internet\_Users}, \text{Internet\_Hosts}, \text{ICT\_Expenditure}, \text{Broadband\_Price}, \text{Broadband\_Speed}, \text{Full\_LLU}, \text{Sub\_Loop}, \text{Bitstream}, \text{HHI}]$

Note:  $\alpha$ ,  $\beta$ ,  $\gamma$  and  $\delta$  are regression coefficients for the explanatory variables

$\varepsilon_{i,t}$  is the error term, and

$i$  is the subscript for country and  $t$  is the subscript for year

Model (1) is an estimated model controlling for the effects of various socio-economic factors on broadband penetration.

Model (2) is an estimated model controlling for the effects of Industry and ICT factors on broadband penetration. This model is estimated using data from 2006 and

2008 only – as information on key variables (speed and price) are only available for these years.

Model (3) is an estimated model controlling for all socio-economic, Industry and ICT, and Policy factors (Unbundling and facilities-based competition). Thus, it is the complete model that tests the hypotheses as stated earlier. Additionally, due to lack of data for some variables (speed and price), this model is estimated for (a) all four years (2005-2008) without the speed and price variables and (b) only 2006 and 2008 with speed and price variables included.

Moreover, the panel data also allows for incorporating Fixed Effects - this specification is utilized in this study to control for various explanatory factors that are constant over time for all countries. Finally the model assumes the following conditions:

A1. For each  $i$ , the model follows the following specification:

$$Y_{i,t} = \beta_1 X_{i,t1} + \dots + \beta_k X_{i,tk} + a_i + u_{i,t}$$

Where  $t = 1, \dots, T$  is time

$\beta$  is the parameter to estimate

$a_i$  is the fixed effect and  $u_{i,t}$  is the time-varying error

A2. For each  $t$ ,  $E(u_{i,t}|X_i, a_i) = 0$ ; that is, given the explanatory variables in all time periods and the fixed effect, the expected value of the time-varying error is zero.

A3. The time-varying error is independent and identically distributed as normal  $(0, \sigma^2 u)$ , conditional on  $X_i$  and  $a_i$ .

## VI. Results and Discussion

The results from the empirical analysis of the models as mentioned in *Section V* are reported in TABLE 5 on the next page. This section will now analyze the individual effect of each variable on Broadband Penetration rates holding other variables constant. It should also be noted that a variable is considered economically significant if a one unit change in that variable causes broadband penetration to change by one percentage point or more. Lastly, it should also be noted that both Iceland and Luxembourg have data for ICT expenditures missing and hence all models that include the variable *ICT Expenditures* utilize information from the rest of the 28 countries. As a result, Model 1 and Model 2 have 120 and 56 observations respectively while Model 3a and Model 3b have 112 and 56 observations respectively.

**TABLE 5: Panel Regression Estimates of regressing Socio-Economic, ICT and Industry and Policy factors on Broadband Penetration Rates**

Dependent Variable: Broadband Penetration rates				
Method: Fixed-Effect Panel				
Panel Observations: 120				
	56	112	56	
VARIABLES	(Model 1) Broadband_ Rate	(Model 2) Broadband_ Rate	(Model 3a) Broadband_ Rate	(Model 3b) Broadband_ Rate
GDP	0.002628**** (0.000)		0.001733**** (0.001)	0.000969** (0.001)
Pop_Density	0.265681 (0.320)		0.045250 (0.266)	-0.159376 (0.250)
Pop_Urban	2.200871* (1.413)		-1.382729 (1.154)	-2.425544*** (0.986)
Life_Expectancy	3.863244*** (1.458)		0.565691 (1.121)	3.339932*** (1.415)
Unemploy~ment	-0.254366 (0.199)		0.343231** (0.184)	0.562420*** (0.208)
Pop_Dependent	0.166553 (0.521)		-1.017760** (0.501)	-0.070323 (0.797)
Internet_Users		0.275400**** (0.056)	0.149426**** (0.049)	0.192978**** (0.047)
Internet_Hosts		0.319749**** (0.048)	0.233654**** (0.068)	0.313352**** (0.055)
ICT_Expen~ture		1.325856* (0.847)	1.097721 (0.876)	2.422647** (1.188)
Broadband_Price		-0.026656*** (0.012)		-0.028362** (0.015)
Broadband_Speed		-0.000008 (0.000)		-0.000014 (0.000)
Full_LLU			1.385015**** (0.458)	0.901567* (0.569)
Sub_Loop			0.888908* (0.529)	0.628616 (0.632)
Bitstream			-1.095322*** (0.508)	-1.025149** (0.504)
HHI			0.016044 (0.070)	-0.122243* (0.077)
_cons	-5.57e+02*** (92.053)	-1.09e+01 (6.797)	50.210534 (111.949)	-9.12e+01 (109.975)
R-sq	0.808	0.887	0.910	0.952

Note: Robust Standard errors in parentheses; \* p<0.15 \*\* p<0.10, \*\*\* p<0.05, \*\*\*\* p<0.01

## **Category: Socio-Economic Factors**

### ***Gross Domestic Product per capita (GDP)***

The real gross domestic product per capita is statistically significant and has a positive sign across various tested models. Furthermore, this factor is also economically significant – a \$1000 per capita/per annum increase in GDP results in broadband penetration to increase by 2.7 percent (in the model controlling only socio-economic factors), 1.7 percent (in the model controlling all factors except broadband speed and price), and approximately 1 percent in the model where all factors are controlled for. This result is similar to various studies within the field (e.g. Grosso, 2006) and also fails to reject the stated null hypothesis.

### ***Population Density (Pop\_Density)***

The population density within a country is found to be statistically insignificant across various tested models (with positive signs for model 1 and 3a while negative for model 3b). This insignificant result could be attributed to the lack of sufficient data for the tested models – as only 30 countries over a 4 years' time span are included.

### ***Percentage of Urban Population (Pop\_Urban)***

The factor controlling for the percentage of urban population within the OECD countries shows mixed results depending on the model used. It is found to be weakly statistically significant (at 15 percent confidence level), and both positive and economically significant when only socio-economic factors are controlled for. The coefficient suggests that 1 percent increase in urban population increases broadband penetration by 2.2 percent. On the other hand, when all variables except broadband speed and price are controlled for (model 3a), it is found to be statistically insignificant (with a negative sign). Finally, when all variables are controlled for, this variable is found to be both statistically and economically significant with a negative impact on broadband penetration. Moreover, the coefficient

suggests that 1 percent increase in urban population results in broadband penetration to decrease by 2.4 percent. This result could occur because building new infrastructures in very populated urban areas is both difficult and costly as it would require more space and overhaul of older infrastructure. It is also similar to the result found by Kum (2008), where a negative relationship between urbanization and broadband penetration rates is observed. However, the magnitude of changes within these results suggests that this factor is very sensitive to model specification and hence any inference drawn from this factor could be misleading.

#### ***Life Expectancy at Birth (Life\_Expectancy)***

This variable, which is unique to the study, provides interesting results. Firstly, the life expectancy at birth is both statistically and economically significant in models 1 and 3b respectively. Additionally it has a positive coefficient suggesting that an increase in life expectancy will increase broadband penetration. More specifically, within the unrestricted model (model 3b), an increase in life expectancy by 1 year raises the broadband penetration by 3.3 percent. One of the key reasons could be that given broadband is a normal good, an increase in quality of life increases the demand for broadband (as more people will use broadband for various purposes such as leisure activities).

#### ***Unemployment Rate (Unemployment)***

Unemployment rate is positively related and statistically significant for both models 3a and 3b. However, it is insignificant (and negative) when only controlling for socio-economic factors (model 1). The surprising positive coefficient for this variable suggests that broadband penetration increases as unemployment rate increases but at a lower rate (i.e. it is not a 1 to 1 ratio). There are two possible explanations for this effect: (1) as people are unemployed, they resort to internet in order to spend this extra leisure time, and (2) although the data measure broadband penetration in per capita terms, most of the people within a household share the same internet connection. Therefore, a loss in income from unemployment has a negligible impact on the household's budget constraint (when there is more than

one household member generating employment income) – which when combined with the first reason makes a stronger case for the positive effect.

#### ***Dependent Population (Pop\_Dependent)***

The coefficient for the dependent population variable is negative for models 3a and 3b while positive for model 1. However, it is only statistically significant for model 3a (where all variables except speed and price are controlled for). The coefficient for this variable in model 3a suggests that an increase in dependent population by 1 percent will reduce broadband penetration by 1.02 percent. The expected negative sign could be because: (1) most of the dependent population do not make any income to afford broadband and (2) this group of population are not the primary users of internet as they either lack the technical know-how or because their internet use is controlled by population in the age group of 15-59.

### **Category: Information and Communication Technology, and Industry Factors**

#### ***Internet Users (Internet\_Users)***

One of the Information and Communication Technology (ICT) factors that is hypothesized to affect broadband penetration, the number of internet users is found to be statistically significant at 1 percent level for all the tested models. Thus, the estimated result suggests that an increase in ICT use has a positive impact on broadband growth, as suggested by the existing literature (example: Lee and Brown, 2008). Its coefficient show that a 1 percent increase in internet users increases broadband penetration rates by less than 1 percent.

#### ***Internet Hosts (Internet\_Hosts)***

Similar to the number of internet users, the number of internet hosts is also found to be statistically significant at 1 percent level for all the tested models. Moreover, just like the number of internet users, the effect of a 1 percent increase in number of internet hosts has a minuscule effect (0.31

percent for model 3b) on broadband penetration rates. This supports the existing literature, such as Lee and Brown (2008), where internet content is found to be significant in explaining broadband growth. Since it is used as a proxy for broadband diffusion within a country, the results suggest that Information and Communication Technology (ICT) content does have a positive impact on broadband penetration.

#### ***Information and Communication Technology Expenditure (ICT\_Expenditure)***

The coefficient for Information and Communication Technology Expenditure is both positive and economically significant in determining broadband penetration for all tested models. More specifically, 1 percent increase in the share of ICT expenditure in the gross domestic product raises the broadband penetration rate by 1.3 percent (when controlling only for the ICT and industry factors), 1.1 percent (when controlling for all factors except speed and price), and 2.4 percent within the unrestricted model where all variables are controlled for. Additionally, it is also found to be statistically significant at 10 percent confidence level within the same model that controls for all variables (model 3b) and weakly statistically significant for model 2. This result strongly suggests that investment in ICT infrastructure is necessary for broadband growth within a country.

#### ***Broadband Price (Broadband\_Price)***

As expected, the coefficient for average broadband price is both negative and statistically significant at 5 percent and 10 percent for models 2 and 3b respectively. The results are consistent with economic theory which suggests an inverse relationship between the demand for a normal good and its price. Thus a decrease in price will increase the demand for broadband, which will further raise the broadband penetration rates. Lastly, the coefficient for *Broadband Price* shows that an increase in the average broadband price by one dollar will decrease penetration rates by approximately 0.03 percent. However, this result should also be interpreted carefully as this measure is an average of all available offers and hence does not tell us the direct relationship between broadband price and demand.

### ***Broadband Speed (Broadband\_Speed)***

Unlike broadband price, broadband speed is found to be both statistically and economically insignificant in this study. There could be three possible explanations for this result – (1) A very small number of observations could be tested as data on speed are only available for 2006 and 2008, and (2) similar to broadband price, this variable is a measure of average available speed of broadband within the countries, and hence is not a perfect measure as well.

### **Category: Policy Factors**

#### ***Full Local Loop Unbundling (Full\_LLU)***

The coefficient for this variable is positive for both models 3a and 3b. Moreover, it is also statistically significant at 1 percent confidence level in the model where all variables except broadband speed and price are included (model 3a) and weakly statistically significant for model 3b. The coefficient for *Full Local Loop Unbundling* suggests that an increase in one year of provision of this policy raises broadband penetration by 1.4 percent in model 3a and approximately 1 percent in model 3b (where all variables are controlled for). Furthermore, this result is also consistent with various studies such as Lee and Brown (2008) and Wallsten (2007) that suggest that full local loop unbundling raises broadband adoption.

#### ***Sub-Loop Unbundling (Sub\_Loop)***

The coefficient for sub-loop unbundling policy is found to be weakly statistically significant (at 15 percent confidence level) and positive for model 3a only. Moreover, it is moderately significant in terms of economic significance – as 1 year increase in the provision of this policy raises broadband penetration by 0.88 percent and 0.63 percent in model 3a. However, this result is in stark contrast to the results found by Wallsten (2007). This could possibly occur because it takes more time for sub-loop unbundling policy to affect broadband penetration – which could not have been calculated in Wallsten's

study as its data covers the period from 1999 to 2003. Another possible explanation for this result could be that since most of the countries also have full local loop unbundling, this variable could also be capturing some of the combined effects of both full local loop and sub-loop unbundling.

#### ***Bitstream Access (Bitstream)***

The third access-based policy to be tested in this model, bitstream access, is both negative and statistically significant at 5 and 10 percent confidence levels for models 3a and 3b respectively. Additionally, its coefficient suggests that a year increase in the provision of this policy decreases broadband penetration by 1.09 percent and 1.02 percent for models 3a and 3b respectively. This seems intuitive considering that under this policy new entrants are provided direct access to the incumbent's line, which could deter the incumbent from further investing to upgrade their networks.

#### ***Herfindahl-Hirschmann Index (HHI)***

The coefficient for this index is weakly statistically significant for model 3b (at 15 percent confidence level). Additionally, the negative sign for this index in model 3b also supports the economic theory that more competition is beneficial for broadband growth and is concurrent to studies in this literature (example: Distaso et al., 2006). Lastly, the coefficient for this index is also economically significant. More precisely, it is found that a country has a higher broadband penetration rate when using more than one technology to provide broadband.<sup>10</sup>

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<sup>10</sup> For example, a country with two technology platforms (HHI = 50) has a higher broadband penetration rate than a country using only one technology (HHI = 100) ==>  $(50-100)*-0.122 = 6.11$  percent higher.

**TABLE 6: Summary of Results**

Variable	Description	Expected Sign	Results			
			Model 1	Model 2	Model 3a	Model 3b
<i>Socio-Economic Factors</i>						
GDP	Gross Domestic Product per capita	+	+		+	-
Pop_Density	Population Density	+				
Pop_Urban	Percentage of Urban Population	+ or -	+*			+
Life_Expectancy	Life Expectancy at Birth	+	+			+
Unemployment	Unemployment Rate	+ or -			+	+
Pop_Dependent	Dependent Population	-			-	
<i>Information and Communication Technology, and Industry Factors</i>						
Internet_Users	Internet Users	+		+	+	+
Internet_Hosts	Internet Hosts	+		+	+	+
ICT_Expenditure	Information and Communication Technology Expenditure	+		+*		+
Broadband_Price	Broadband Price	-		-		-
Broadband_Speed	Broadband Speed	+				
<i>Policy Factors</i>						
Full_LLU	Full Local Loop Unbundling	+			+	+*
Sub_Loop	Sub-Loop Unbundling	+ or -			+*	
Bitstream	Bitstream Access	+ or -			-	-
HHI	Herfindahl-Hirschmann Index	-				-*

Note: Only signs of significant results are reported.

\* Denotes significance at 15% confidence level.

## VIII. Conclusion

Through this study, it can be seen that various key factors play an important role in the development of broadband within a country. More importantly, the study attempts to contribute to this literature by employing very recent data and by adding some variables that were not incorporated in the existing literature. Specifically, the study employs data for 30 different OECD countries from 2005 to 2008 to estimate the effect of Socio-Economic, ICT and Industry, and Policy factors on Broadband Penetration rates.

The results find that of all the Socio-Economic factors affecting broadband penetration, income, size of urban population, life expectancy, and unemployment rates are statistically significant. Additionally, contrary to most of the literature, urban population is found to be negatively affecting broadband growth (where 1 percent increase in urban population reduces broadband penetration rate by 2.4 percent). This factor however is also found to be very sensitive to model specification. On the other hand, it is quite possible that an increase in urban population can create a congestion problem within the networks – leading to poor services causing people to switch networks. Similar to the urban population variable, the life expectancy ratio is also found to be economically significant (where a one year increase in life expectancy raises the broadband penetration rates by 3.3 percent). This could suggest that improvement in quality of life has positive impact on broadband growth.

Unsurprisingly, all but average broadband speeds are found to be statistically significant factors within the ICT and Industry category of variables with expected signs for the coefficients. One of the probable reasons for the average speed to not be statistically or economically significant with a negative sign is that it is very hard to calculate this variable with accuracy. Moreover, since it is the average speed within a country, a lot of factors could have skewed the data for a very little amount of time frame. Lastly, it should be also noted that in addition to being statistically significant, expenditure

on ICT is also economically significant (where 1 percent increase in the share of ICT expenses of the GDP raises the broadband penetration rates by 2.4 percent). This is expected, as investments in telecommunication sectors do tend to improve the overall quality of the industry.

Finally, all four policy instruments adopted within these OECD countries are found to be statistically significant at varying levels. More specifically, Full-local loop unbundling policy is found to be statistically significant at 1 percent confidence level in model 3a and has a positive effect on the growth of broadband within a country – consistent with current literature on the same issue. Likewise, sub-loop unbundling policy is also found to have a positive impact on the broadband penetration rates. This is contrary to Wallsten (2007) but could be explained as this policy may require more time to actually affect the penetration rates. However, it is weakly statistically significant (at 15 percent confidence level). On the other hand, Bit-stream Access is found to be statistically significant in all models and also has the expected negative sign and suggests that a one year increase in the provision of this policy reduces broadband penetration rates by 1 percent. Lastly, this study finds by employing Herfindahl-Hirschmann Index that inter-platform competition does promote broadband growth when taking speed and price into account and is also economically significant as explained in the main results section; this, however does not hold true when speed and price are eliminated from the model.

The above results have important policy implications. Firstly, the study suggests that countries still in the process of determining ways to develop broadband should incorporate policies that promote access-based competition. More specifically, policymakers should include full local-loop unbundling and sub-loop unbundling policies as one of the measures to promote broadband growth. However, adopting bitstream access methodology seems to be inappropriate as it results in reduction of broadband development and hence should be avoided. Additionally, investment in Information and Communication Technology sectors is also very vital for broadband development; as a result, the role

of telecommunication infrastructure should not be overlooked. Finally, policymakers need to develop strategies promoting various technologies as opposed to just a single technology as means of delivering broadband.

However, it is important to point out a few caveats within the study. It should first be noted that the empirical analysis is constrained to a panel data consisting of only 120 observations. Moreover, when factors for speed and price are added the model is further reduced to only 56 observations. As a result, various inferences drawn within the model could have been skewed based on the available data. More importantly, due to lack of data, various tests such as tests for stationarity, could not be performed. Given the data includes variables such as broadband penetration rates and per capita gross domestic product, it is possible for the data to be affected by non-stationarity. Additionally, the model did not control for any time trends. This is because, controlling for time effects was deemed inappropriate for such a small sample size. Likewise, controlling for time effects would also further result in more loss of degrees of freedom – making the statistical results more biased. Finally, some of the key variables, such as the Herfindahl-Hirschmann Index, are found to be weakly statistically significant and hence any inference drawn must be done cautiously.

The following improvements are suggested to overcome these limitations: firstly, future studies could incorporate more data for modelling process. This can be done by increasing the sample size to include more countries and or increase the number of years included. Furthermore, since this study only uses a linear estimation technique, utilizing non-linear modelling techniques can also prove useful to capture the true effect of various factors on broadband penetration rates. Finally, it would also be beneficial to incorporate other factors (such as rate of innovation, intra-modal competition index, and market openness within each country) that could affect broadband penetration rates but are not included in this specific study.

## Appendix of Tables and Figures

**TABLE 1: List of OECD Countries and Key Indicators**

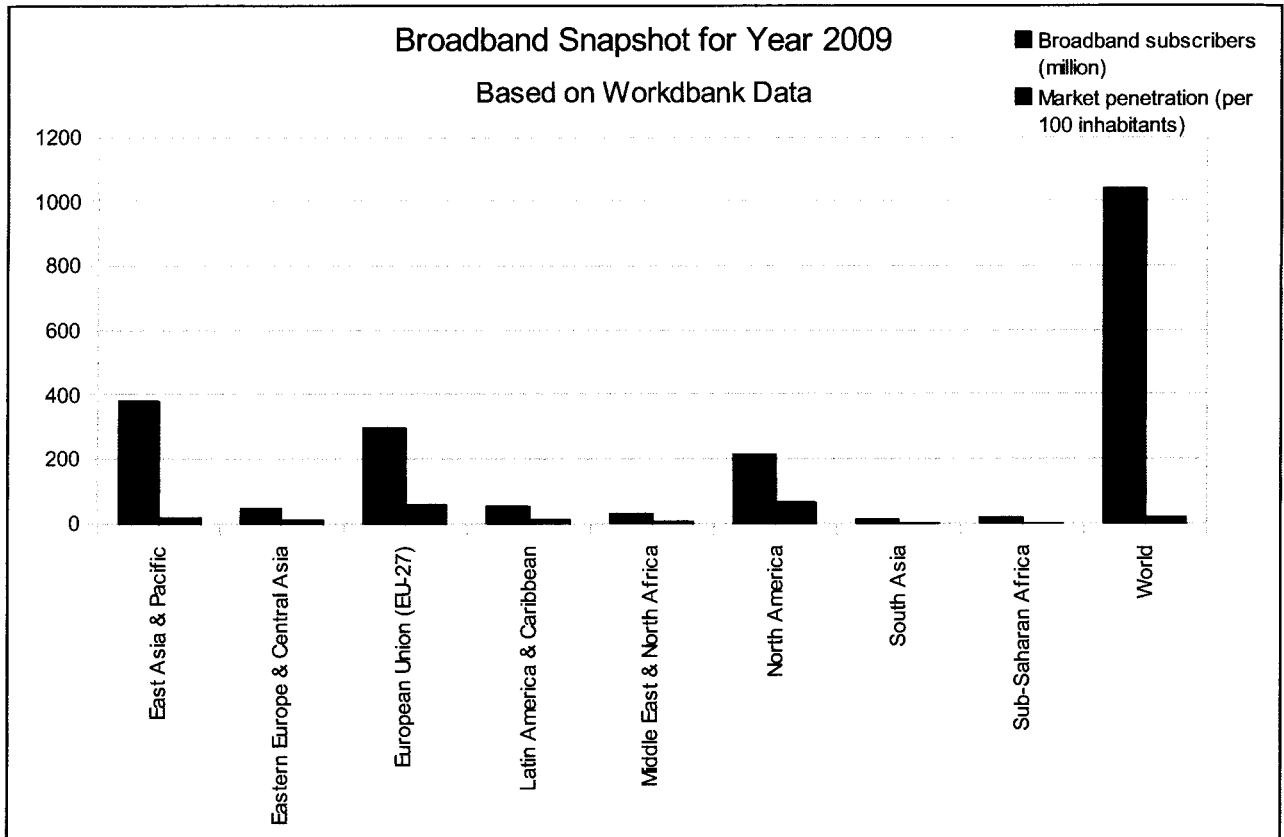
Country	Population	GDP per capita (constant 2000 US\$)	Broadband Penetration	ICT Expenditures (% of GDP)	HHI
Australia	21,431,800	25,248.44	24.8	4.81	64
Austria	8,336,926	27,131.81	21.22	5.5	53
Belgium	10,708,433	25,094.45	27.67	5.16	51
Canada	33,311,400	26,643.10	28.19	6.61	49
Czech Republic	10,424,336	7,593.31	16.97	7.58	35
Denmark	5,493,621	32,326.93	36.81	5.02	46
Finland	5,313,399	28,915.43	30.43	6.59	73
France	62,277,432	23,567.04	27.64	5.18	90
Germany	82,110,097	25,516.76	27.44	5.38	87
Greece	11,237,094	15,203.05	13.41	4.61	100
Hungary	10,038,188	6,215.82	16.9	8.9	43
Iceland	317,414	37,820.31	32.47		91
Ireland	4,425,675	30,926.96	20.17	4.62	58
Italy	59,832,179	19,586.11	18.84	4.96	93
Japan	127,704,000	40,249.18	23.58	6.72	40
Korea	48,607,000	15,457.85	31.84	9.05	35
Luxemburg	488,650	55,639.47	29.42		76
Mexico	106,350,434	6,592.09	7.14	4.54	58
Netherlands	16,445,593	27,319.26	35.61	6.28	51
New Zealand	4,268,900	15,223.48	21.25	6.16	80
Norway	4,768,212	42,132.92	33.72	3.66	53
Poland	38,125,759	6,228.47	10.48	5.5	56
Portugal	10,622,413	11,443.47	15.93	5.98	50
Slovak Republic	5,406,626	8,591.43	11.45	6.19	44
Spain	45,555,716	16,262.57	20.08	4.82	67
Sweden	9,219,637	32,232.47	31.51	5.65	44
Switzerland	7,647,675	38,108.03	32.73	7.07	57
Turkey	73,914,260	5,074.45	8.07	4.08	97
United Kingdom	61,406,928	28,819.73	28.16	6.36	66
United States	304,375,000	37,887.83	25.48	7.22	44

**TABLE 2: Summary of Descriptive Statistics for each Variable**

Variable		Mean	Std. Dev.	Min	Max	Observations
Broadband_ Rate	overall	19.42125	9.136248	1.41	36.81	N = 120
	between		8.416047	4.13	32.3275	n = 30
	within		3.798263	10.83625	26.28125	T = 4
Broadband_ Speed	overall	12289.67	16751.88	960	92846	N = 60
	between		14880.24	1509	70847	n = 30
	within		7934.55	-13610.33	38189.67	T = 2
Broadband_ Price	overall	51.39933	24.16755	28.8	162.3	N = 60
	between		18.54851	30.2	110.91	n = 30
	within		15.67975	0.0093319	102.7893	T = 2
Internet_ Users	overall	62.93125	19.00509	15.46	91.04	N = 120
	between		18.5145	19.9475	89.6175	n = 30
	within		5.200827	48.67625	76.98375	T = 4
Internet_ Hosts	overall	21.76458	17.70881	0.44	72.43	N = 120
	between		16.67752	0.57	62.83	n = 30
	within		6.517229	3.649583	38.30208	T = 4
GDP	overall	23531.78	12485.8	4679.58	56624.73	N = 120
	between		12630.04	4949.135	54563.79	n = 30
	within		631.5612	20949.6	25592.73	T = 4
ICT_ Expenditure	overall	6.09982	1.435458	3.66	10.76	N = 112
	between		1.428306	3.955	9.965	n = 28
	within		0.274989	5.034821	6.894821	T = 4
Life_ Expectancy	overall	78.98208	2.624292	71.39	82.59	N = 120
	between		2.636982	71.645	82.3375	n = 30
	within		0.329447	78.24458	79.85208	T = 4

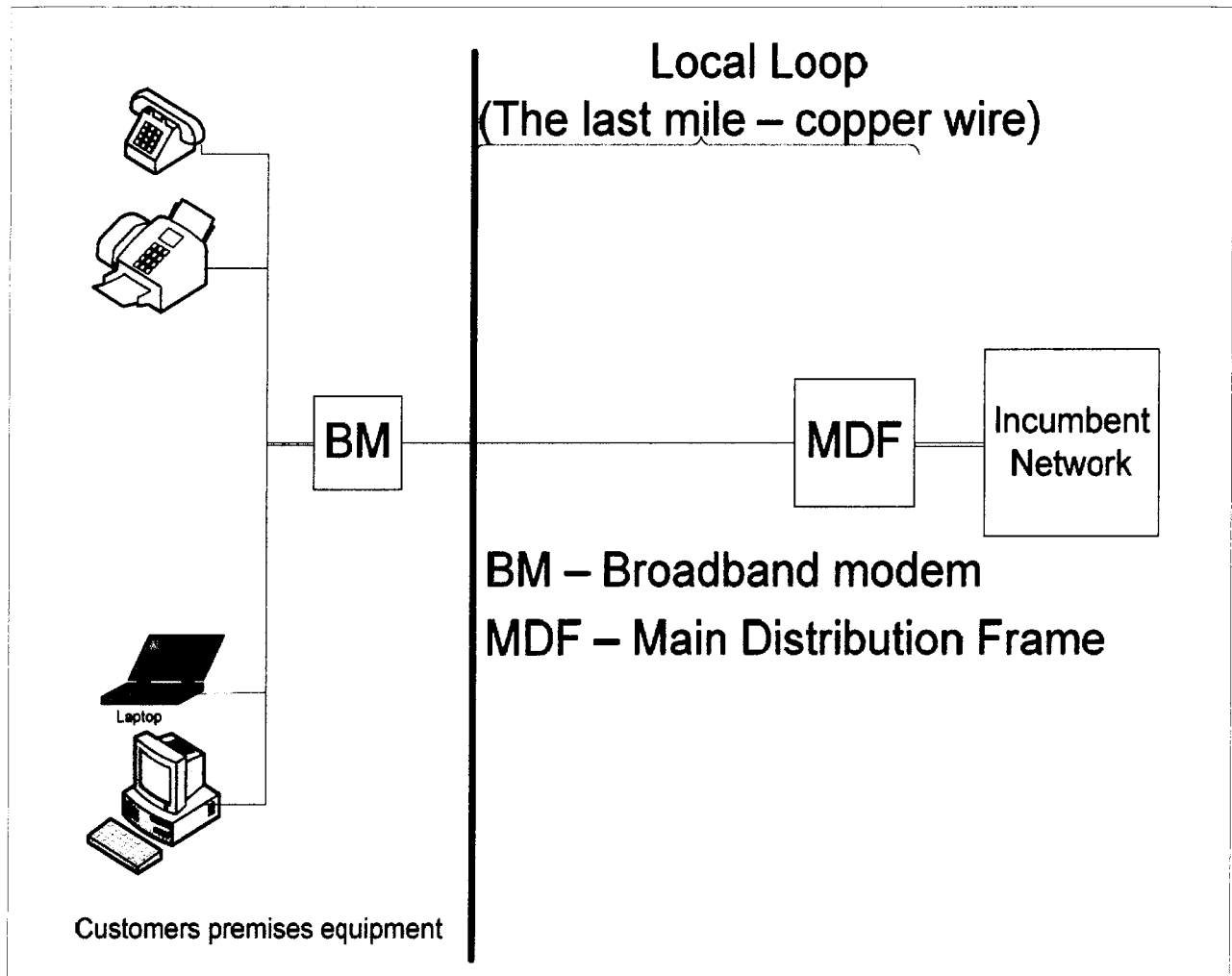
Pop_	overall	48.3085	4.237161	38.15	57.41	N = 120
Dependent	between		4.264975	38.945	55.955	n = 30
	within		0.47127	46.8535	49.7635	T = 4
Pop_	overall	139.4974	132.1354	2.65	501.52	N = 120
Density	between		133.8275	2.7175	499.26	n = 30
	within		1.215268	135.0749	144.1449	T = 4
Unemploy- ment	overall	6.25833	2.802358	2.3	17.7	N = 120
	between		2.620668	2.725	12.5	n = 30
	within		1.076311	1.308333	11.90833	T = 4
Pop_	overall	75.20933	10.73397	56.2	97.36	N = 120
Urban	between		10.86824	56.38	97.33	n = 30
	within		0.277746	74.27933	76.13933	T = 4
Full_LLU	overall	5.95833	3.354154	0	12	N = 120
	between		3.233768	0	10.5	n = 30
	within		1.02797	4.458333	7.458333	T = 4
Sub_Loop	overall	3.11667	3.483897	0	12	N = 120
	between		3.435824	0	10.5	n = 30
	within		0.793884	1.616667	4.616667	T = 4
Bitstream	overall	2.85	3.268515	0	11	N = 120
	between		3.21607	0	9.5	n = 30
	within		0.775139	1.35	4.35	T = 4
HHI	overall	62.70833	18.93882	33	100	N = 120
	between		19.02212	34.75	97	n = 30
	within		2.441328	54.45833	74.45833	T = 4

**FIGURE 1: Breakdown of Broadband Subscribers for 2009**



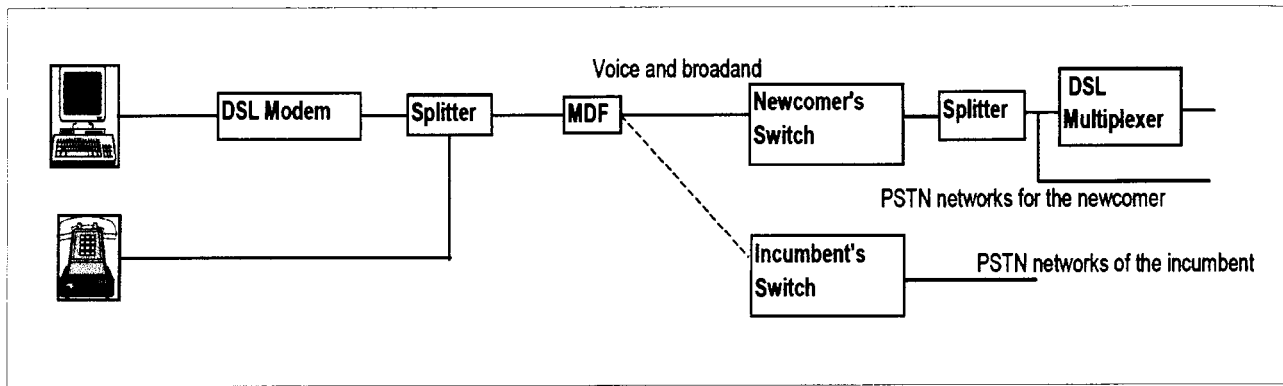
Data Source: Kim et al. (2010)

**FIGURE 2: An Overview of Local-Loop Unbundling**



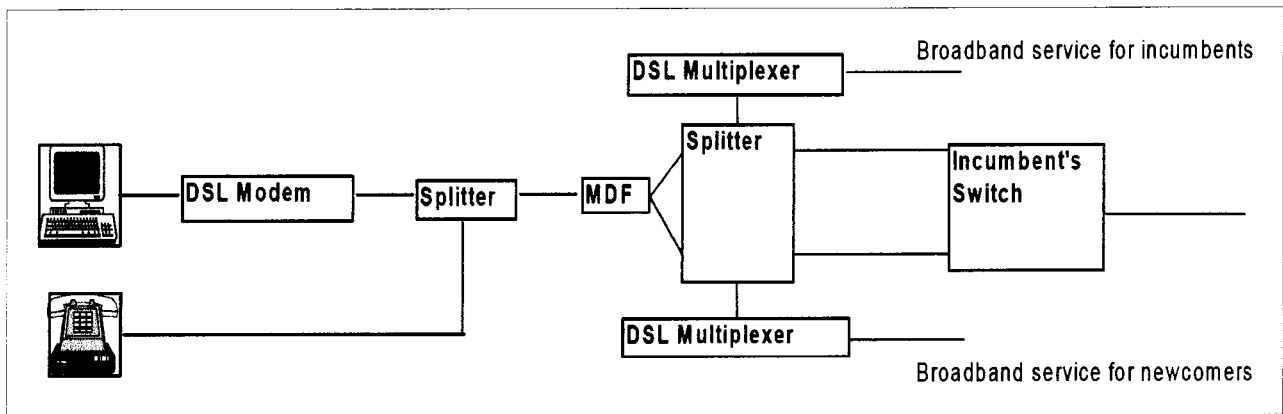
Source: Teddy et al. (2008)

**FIGURE 3: Full Unbundled Network**



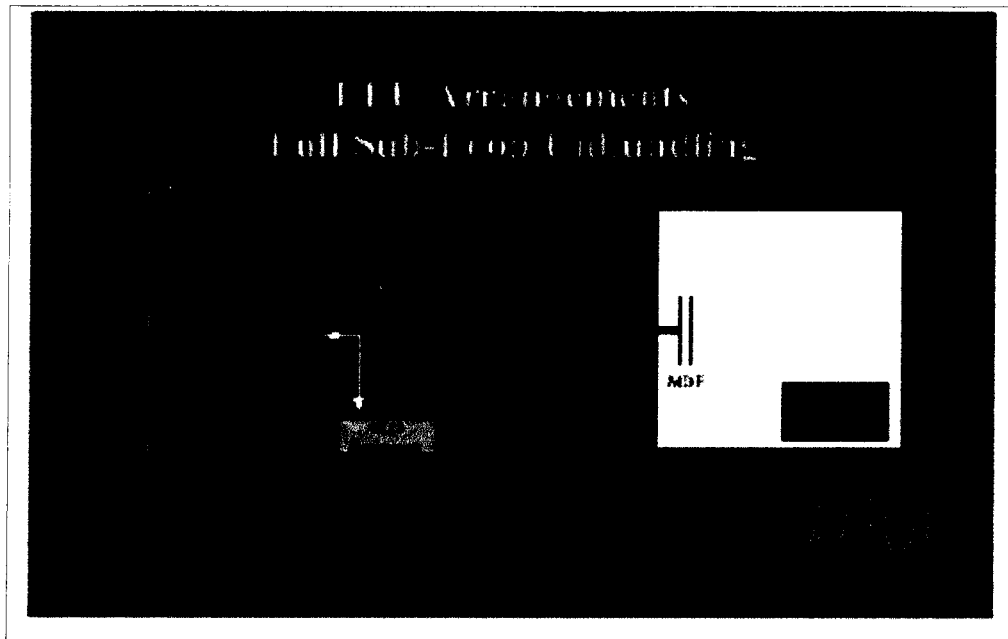
Source: Umino (2003)

**FIGURE 4: Bitstream Access**



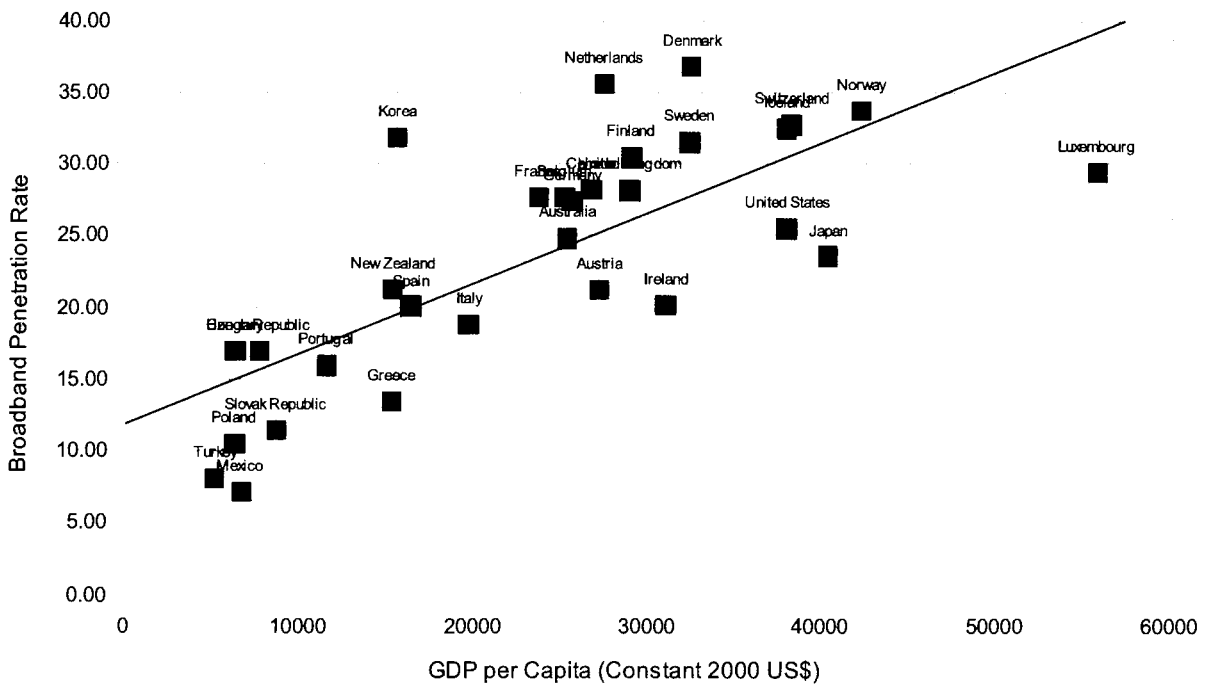
Source: Umino (2003)

**FIGURE 5: Sub-Loop Unbundling**



Source:  
[http://www.ofcom.org.uk/static/archive/oftel/publications/broadband/dsl\\_facts/LLUbackground.htm](http://www.ofcom.org.uk/static/archive/oftel/publications/broadband/dsl_facts/LLUbackground.htm)

**Figure 6 - Relationship between GDP per Capita and Broadband Penetration Rates**



Data Source: OECD's Broadband Portal and World Development Indicators (WDI) & Global Development Finance (GDF) database

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