International Broadband Deployment: The Impact of Unbundling

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Abstract: This paper shows that 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. Our statistical analysis of approximately 100 countries showed that GDP per capita, population, competition and unbundling are all factors that can lead a carrier to provide broadband services in a country. The logit models show that unbundling has a significant positive impact on the availability of broadband services. The OLS analysis indicates that GDP per capita, population size, price, competition, the percentage of dial-up Internet users, and hosts all have positive effects on the number of subscribers. One implication of these results is that if a policy is to be implemented to promote broadband, it should either foster competition through unbundling and/or reduced prices. Efforts to develop local content can also improve broadband adoption.
Key words: broadband, unbundling, competition.

Both broadband and unbundling have been subject to debate among policy makers. Increasing content, commercial activity, and services provided by governments have prompted policy-makers to design policies aimed at promoting broadband. One of the policies commonly used to promote broadband is telecommunications unbundling. Its objective is to facilitate the entry of new operators in the hope that greater competition will oblige carriers to upgrade their infrastructure to provide services such as broadband. The policy is nonetheless controversial. Views differ greatly about the extent to which governments should attempt to "jump-start" competition by requiring incumbent providers to rent their networks as unbundled network elements. Academics criticize this because it diminishes incumbents' incentives to improve their infrastructure, thus leading to the opposite result of the policy's goal. In spite of criticism, many governments require carriers to unbundle their networks for entrants perceived to be more innovative.

This study contributes to the debate over broadband and unbundling regulatory requirements. It addresses this controversial issue by presenting the results from an international empirical analysis. This data set provides

some useful insights about unbundling and other factors that may affect the provision and adoption of broadband. The data set permits us to explore two issues: firstly, how unbundling policies affect decisions to offer broadband access to the internet and the factors that contribute to the adoption of broadband.

The results of this research can help governments design policies that foster the deployment of broadband. In particular, this research finds evidence of the positive effects of broadband on the provision of the service, although it is not yet clear that prices have dropped to an affordable level for the majority of the population.

The following sections present the factors that other scholars have identified as determinants of broadband deployment. The empirical section of the paper provides a descriptive analysis of the data and then proceeds with logit and OLS regressions. The final part of the paper offers conclusions and recommendations for policy makers.

■ Theoretical context

This section covers the factors identified in previous works as determinants of telecommunications infrastructure investment. Although much has been written on this issue, there is little consensus. As we are interested in the factors that lead to the provision of broadband by carriers, as well as the number of subscribers, the hypotheses presented at the end of each section are formulated in terms of these two issues.

Unbundling policies

While there is almost universal agreement that markets should be open to facilities-based competition, views differ greatly about the extent to which governments should attempt to favor new entrants by requiring incumbent providers to rent their networks as unbundled network elements[1] at low prices established by a government regulatory agency.

[1] The term 'network element' means facility or equipment used in the provision of a telecommunications service. This term also includes features, functions and capabilities that are provided by means of such facility or equipment, including subscriber numbers, databases,

For example, in a discussion of the impact of the 1996 *Telecommunications Act*, CRANDALL (1999) notes that: "… by creating ample opportunities for entrants to use incumbents' network facilities, the Act discourages investment in new facilities" [2]. In addition, JORDE, SIDAK & TEECE (2000) further support the argument made by Crandall, stating that mandatory unbundling of various network components of an incumbent local exchange carrier (ILEC) at TELRIC-based prices discourages ILECs from investing in new facilities and services.

Similar skepticism has been expressed about requiring the provision of unbundled network elements in developing and transitional economies. Since these countries are busy trying to upgrade and build out their infrastructures, it is difficult to coordinate the requirements of the incumbent and the entrant wanting to rent a portion of the incumbent's network. KESSIDES (2003, p. XII) suggests that the introduction of new services requires investments in infrastructure that can be best handled by a vertically integrated firm.

Despite the numerous arguments documented over the comparative benefits of policies, a consensus has not emerged regarding what constitutes the optimal regulatory policy. A 2001 OECD report stated that governments should adopt policies that spur entry because rivalry among firms will compel them to innovate. The authors of the paper stated that: "[p]olicies such as unbundling local loops and line sharing are key regulatory tools available to create the right incentives for new investment in broadband access". (p. 4).

The lack of consensus results from the paucity of empirical studies that either validate or belie the analysts' positions. Indeed the D.C. Circuit in *USTA v. FCC*, 290 F.3d 415 (D.C. Cir. 2002) encouraged the FCC to base its decisions on which unbundled network elements need to be available on "something a bit more concrete than its belief in the beneficence of the widest unbundling possible" [3].

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signaling systems, and information sufficient for billing and collection, or used in the transmission, routing, or other provision of a telecommunications service (47 U.S.C. 153).

[2] See also R.W CRANDALL & J.A. HAUSMAN (2000), *Competition in US Telecommunications Service: Effects of the 1996 Legislation*. In S. Peltzman, & C. Winston (Eds.), *Deregulation of Network Industries: What's Next*, Washington, DC: AEI-Brookings Joint Center for Regulatory Studies.

[3] "In the end, then, the entire argument about expanding competition and investment boils down to the [Federal Communication] Commission's expression of its belief that in this area more unbundling is better."

Ownership and competition

Outside of North America, most telephone companies have traditionally been owned by the State. Over a period of two decades starting in the late 1970s many governments began to privatize their state-owned enterprises. Ownership issues are of concern in this research because of the potential impact that either a privatized or a government-owned company can have on the deployment and upgrade of infrastructure. From a theoretical perspective it is not easy to predict the impact of privatization on infrastructure expansion. There are two possibilities with different potential outcomes. When privatization occurs the management structure of the company changes and, with it, the organization's objectives. Given the new structure of the firm, a privatized carrier will aim to maximize profits. Governments, in contrast, aim to maximize the welfare of society (ADAM *et al.*, 1992). Based on this rationale one could thus expect government to try to expand the infrastructure to serve all sectors of society, while private companies are more likely to focus on the most profitable segments, ignoring isolated regions and scattered population. When the company moves from state to private ownership we would not necessarily expect expansion, although upgrades are likely to occur.

Expansion of infrastructure under state control can happen but there are several reasons why this is not observed in practice. Firstly, provision of telecommunication services is only one of many government objectives and this may not necessarily be a high priority. In the absence of abundant resources, governments have to decide where to invest funds. For some countries this investment may be in infrastructure, but for others it could be in even more basic needs such as water, sanitation, and electricity. Furthermore, the state telecommunications operator may have generated cash that, instead of being reinvested in the network, is diverted to fund other programs. This view was recently expressed by the lead economist with the World Bank's Development Research Group, Ioannis Kessides:

> "Few - if any - sustainable improvements in utility performance can be achieved simply by replacing a state-owned monopoly with a private one" (2003, p. II).

Therefore the effect on ownership is an issue that policy makers can best evaluate through empirical analysis. Investment in telecommunications infrastructure has often been a low priority for governments. It is consequently unsurprising that research suggests privatization has a positive impact on telecommunications infrastructure. In their examination of twelve companies, including three telecommunications players, GALAL *et al.*

(1992) find that privatization leads to overall positive welfare effects. Similarly RAMAMURTI (1996) finds that in the four years following privatization in Argentina, Jamaica, Mexico, and Venezuela, these countries experienced a rapid expansion in their networks, averaging 15% growth per year.

VICKERS & YARROW (1988), in contrast, argue that network expansion has multiple components. They find that privatization only exhibits positive effects when the market is competitive. In their view a company's efficiency is affected by multiple factors. Privatization is only one such factor, and thus can only partially explain increased efficiency. In spite of evidence from several countries that infrastructure deployment was limited under state ownership, one could argue that, in their efforts to provide utilities for the population, states have an interest in making a telecommunications infrastructure as widely available as possible. Even in areas of the world where resources are especially limited, governments may conclude that modernization of the telecommunications infrastructure is essential. This implies that some governments may succeed in effectively providing telecommunications services.

Although state participation should theoretically have a positive impact on infrastructure, previous empirical research indicates that this has not been the case. Privatization has generally improved infrastructure deployment and modernization. (GALAL *et al.*, 1992; RAMAMURTI, 1996; VICKERS & YARROW, 1988). We would thus expect privatization to have a positive impact.

H_1: Broadband access is positively related to the full or partial privatization of the incumbent carrier.

Content and broadband

In the mid-1990s, when deregulation was about to be implemented in many places, companies concerned about the impact of emerging competition began efforts to expand the spectrum of services. Companies in the United States were pioneers in setting up trials to deliver video on demand. Similar efforts took place in countries such as Singapore and New Zealand. As it turned out, video on demand was not ready to deliver high margin revenues and thus telecommunications operators abandoned these projects. Cable companies have achieved near video on demand by using compression technology.

This was nonetheless a prelude to other developments. In the process of deregulation and liberalization, carriers realized that they could expand the capacity of their networks to offer other services such as data and multimedia content distribution. Once it became clear that broadband was a feasible alternative, carriers recognized the value of content. Several media articles alluded to the need for content to increase demand for broadband. In these early days telecommunications carriers began to sign agreements with content providers and set up multimedia divisions such as the Bell Atlantic Video Services unit or the GTE Interactive Media unit (WILSON, 1994, p. 23).

In other countries both governments and private sector officials also recognized that compelling content would drive demand for broadband. In 2000 the director of the Cable and Satellite Broadcasting Association of Asia (CASBAA) stated that as broadband began to emerge in that region, if there were no substantial value added in the form of more specialized applications as well as entertaining content, users would not be willing to pay for high-speed connections (WILHELM & BICKERS, 2000, p. 35). In Taiwan, a survey by the Ministry of Transportation and Communication found that internet users in the country were dissatisfied with the amount of content available on government sites (CHANG, 1999). In the United States representative Mike HONDA of California stated that users need to find internet content and applications compelling enough to make them pay for these services (HONDA, 2002, p. 14) [4].

An additional inhibitor to the expansion of broadband networks is the price that some internet service providers pay U.S. companies. The disproportionate amount of content stored at sites in the United States compared to other countries results in asymmetric traffic flow. Since this traffic has to be routed through backbones that are, for the most part, owned by U.S. carriers, ISPs in other countries have to pay for such connections. In Australia the National Bandwidth Inquiry Report (TERRY, 1999) calculated that connection costs were between USD 133 million and USD 177 million per year higher than the report thought that they should be. Such high connection charges for the internet backbone are increasing prices for users in those countries, thus inhibiting adoption. Local content is consequently an element that could minimize the amount of payments to foreign carriers.

[4] To the best of our knowledge, there is no academic research that articulates the relationship between content availability and demand for broadband. As noted above, the press has reported on industry and government concerns related to the need for content to stimulate broadband demand.

One of the concerns in this analysis is the direction of causality. In the relationship between content and broadband infrastructure there is potentially bidirectional causality. Without content, broadband cannot take off, but at the same time, if people are not willing to pay for this service, there is no incentive to develop content. Optimism during the dot-com bubble led to large investments in telecommunications infrastructure, which has resulted in unused capacity, but perhaps only in the USA. Broadband arguably now needs content. We hypothesize a positive relationship between domestic content and broadband adoption

H_2: Broadband access/subscription is positively related to the availability of domestic content.

Other variables

There are several other factors that determine the level of broadband subscription. Disposable income is a key determinant of a person's decision to purchase goods or services. It is not surprising to see that almost 60% of the countries that reported having broadband subscribers are in the high-income category. Income is related to price. In addition to monthly fees, users have to pay connection and equipment charges. Price thus can be a major barrier to adoption of the technology in the poorer regions of the world. We will test the following hypothesis:

H_3: Higher income levels have a positive impact on broadband access/subscription.

Population density is another variable that affects technology adoption. Regions with high population density can be served more cheaply. More sparsely populated areas could only be served at higher prices. We will thus test the following hypothesis:

H_4: Higher population density has a positive impact on broadband access/subscription.

The education level of the population is also included in the model. People with higher education should be more familiar and comfortable with using information technology. They may also be interested in having access to more information from the internet. We will thus test the following hypothesis.

H_5: Higher average levels of education have a positive impact on broadband access/subscription.

Other technological aspects of importance are the availability of personal computers and the number of people with internet access. Whether using broadband or narrowband, personal computers are the most common method of accessing the internet. It follows that the higher the number of computers in a country, the higher the probability that its inhabitants are connected to the internet. Similarly, internet access, even using dial-up, can be a factor that leads to the adoption of broadband. A person familiar with the internet could, over time, receive greater value from the resource and may consider switching to a faster connection. We will thus test the following hypothesis:

H_6: Higher penetration of personal computers has a positive impact on broadband access/subscription.

H_7: Higher use of dial-up internet has a positive impact on broadband access/subscription.

Figures 1, 2 and 3 show the relationship between these variables and the number of broadband subscribers.

Figure 1 – Relationship between GDP per capita and subscribers to broadband

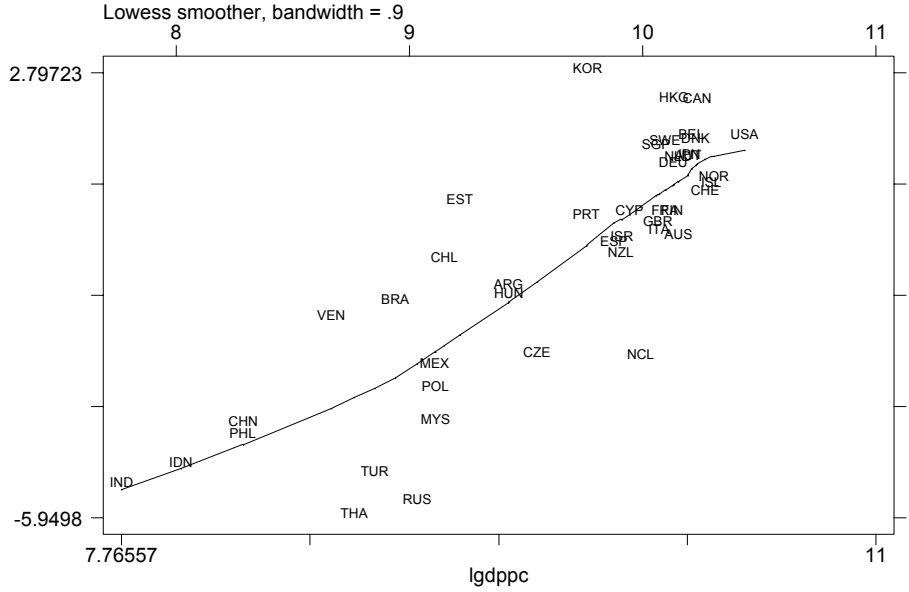


Figure 2 - Relationship between percentage of personal computers and subscribers to broadband

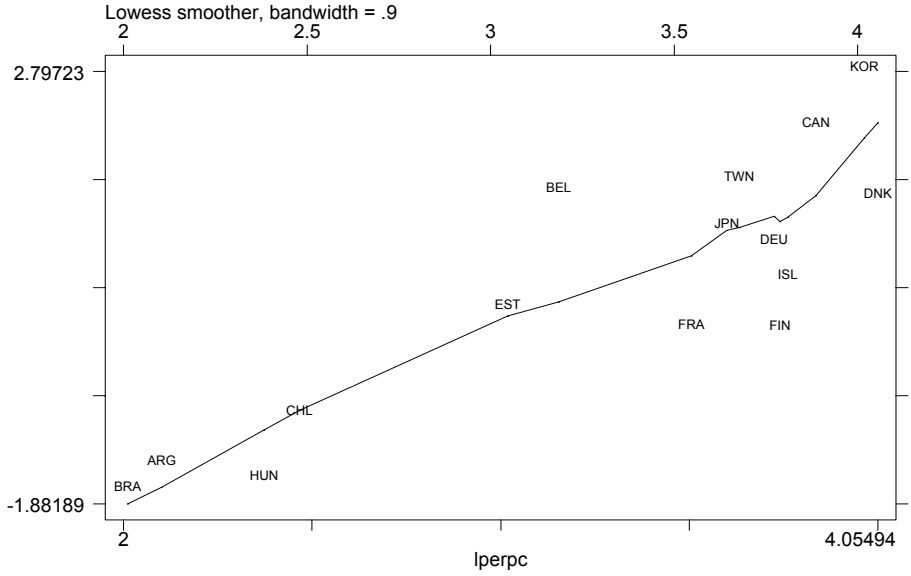


Figure 3 - Relationship between percentage of internet users and subscribers to broadband

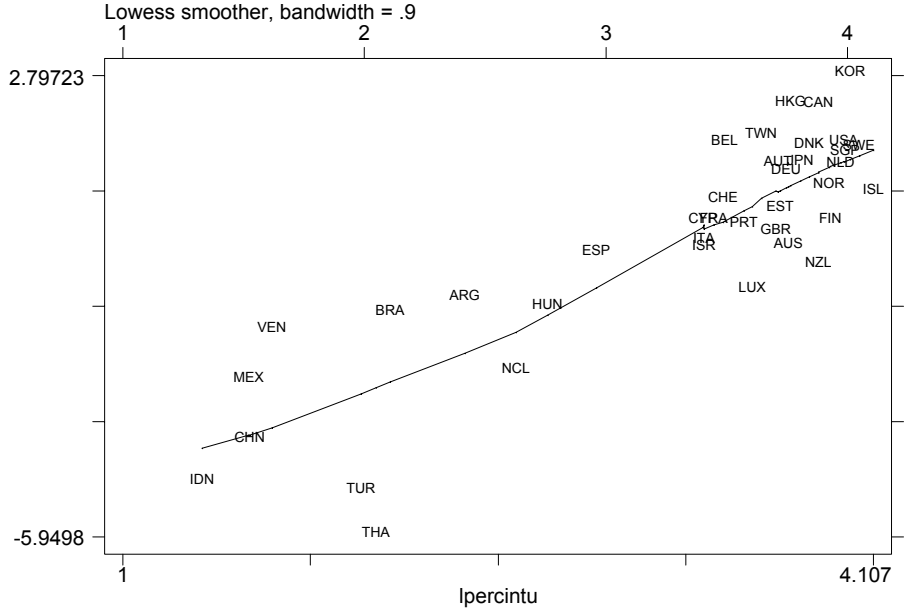
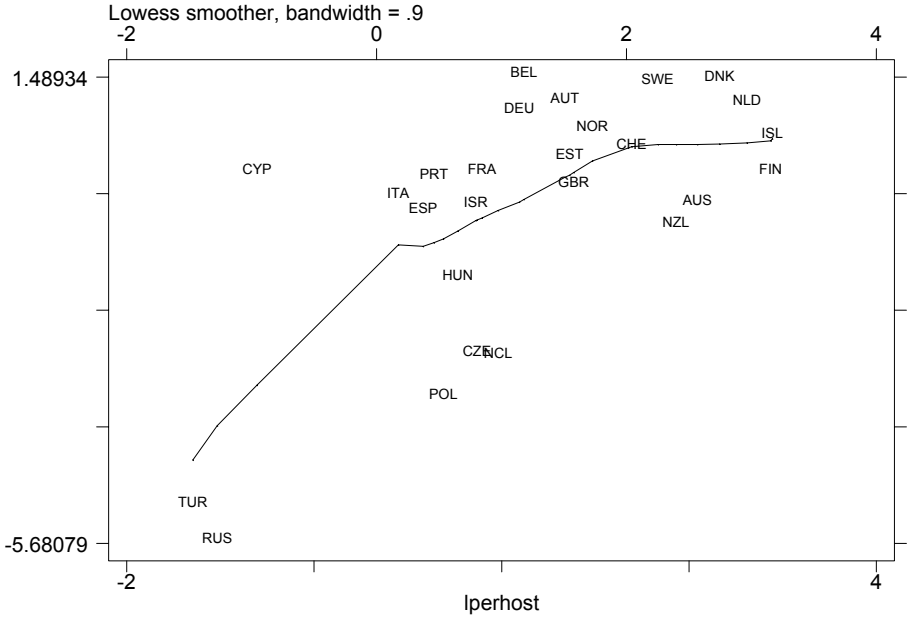


Figure 4 - Relationship between percentage of internet hosts and subscribers to broadband



■ Data analysis and methodology

The purpose of this study is to determine the factors that affect broadband access and the number of subscribers. This section is divided into three subsections. The first part includes a description of the variables used in the data analysis as well as a detailed description of the price variable calculation. The second part presents initial findings from descriptive statistics, while the third section examines the results of the logit and OLS regression analysis.

Data

The database used for this study covers approximately 100 countries, but the number of countries varies depending on the model because some variables have missing data. Only the year 2001 is included because it is the only data currently collected on broadband. The data used in this study

comes from several databases. The ownership and competition variables come from the ITU Trends in Telecommunications Reform 2002 report. Unbundling data comes from the ITU regulatory database.

Prices for broadband were obtained from carriers' websites and OECD documents. The variables internet users, content, and personal computers were obtained from the ITU World Telecommunications Database. The variables population density, income, and education are from the World Bank's World Development Indicators 2002.

Table 1 - Description of variables

Variable	*Description*	*Expected sign*
Unbundling	Dummy: unbundling required by government	+
Ownership	Dummies: privatized, state-owned, semi-privatized	+ (with privatization)
Competition	Dummies: monopoly, duopoly, partial competition, full competition	+ (with higher competition)
Population density	Number of people per square KM	+
Income	GDP per capita	+
Prices	Monthly price per MB	- (with higher prices)
Education	Illiteracy rate / average education level of the population in years	+
Content	Number of domain name servers registered	+
Personal computers	Number of PCs in the country	+
Internet access	Percent of people that have access to the Internet not broadband	+
Broadband Access	Percent of population with broadband access	Dependent variable

The price variable was constructed on a price per megabyte (MB) basis because different carriers offered multiple options for capacity and speed. We selected the 512 kbps download stream speed because it is the most common alternative for DSL users around the world. That speed is comparable to cable connections. Based on HORRIGAN (2002), we assume that the typical subscriber to flat-rate service is online for 50 hours per month. The number of megabytes downloaded per hour is between 5 and 10 MB for average web surfing. With this information we calculated that a broadband user would need approximately 500 MB per month and thus decided that a typical two person household would require 1,000 MB per month [5]. We use this information to calculate the price per megabyte of

[5] This is an assumption because there are no available statistics on the average number of household members using broadband. We decided to use 10MB, the higher number of MB, because average browsing does not include streaming media, which is an important broadband

those households whose broadband provider offers unlimited downloads. For those countries where the carriers have limits, we used the limit imposed to calculate the price per megabyte.

Table 1 identifies the variables included in the model, and the effect we expect them to have on both the dependent variables of access to broadband services and number of subscribers.

Descriptive results

Table 2 presents descriptive statistics on the variables of interest. Income levels and the availability of technology are highly correlated with broadband subscriptions. After adjustment for population size, differences between low and high-income countries are highly pronounced. The number of computers in the country is less than 2% in poor countries, while almost 40% of the population has access to computers in high-income countries. Upper middle income countries have 10 times as many internet users as low income ones. In high income countries this figure is 30 times higher.

Table 2 - Descriptive statistics with means and standard deviations

Variable	*Low income*	*Lower-middle income*	*Upper-middle income*	*High-income*
GDP per capita/PPP	1782.316 (1937.77)	4906.024 (1557.69)	9552.607 (2995.18)	24391.03 (6439.88)
Population density	96.03743 (145.79)	101.8773 (147.68)	166.6773 (254.10)	349.4403 (1086.72)
Illiteracy rate	37.553 (21.61)	15.729 (12.44)	9.277 (8.26)	7.750 (6.71)
Residential monthly telephone subscription	4.046 (1.47)	4.238 (3.08)	6.856 (4.62)	12.459 (4.16)
% of PCs in the country	1.507 (1.52)	3.761 (3.49)	13.229 (5.11)	36.901 (13.44)
% of Internet users	1.136 (1.26)	4.041 (2.32)	12.510 (9.15)	37.565 (13.69)
% of hosts in the country	0.023 (0.04)	1.054 (4.01)	1.404 (1.26)	6.162 (7.03)
% of the population with broadband	0.005 (0.001)	0.006 (0.006)	0.253 (0.36)	2.736 (3.47)

A similar pattern is observed in the production of internet content, which we operationalized as the number of hosts registered for the country. Finally,

application. HORRIGAN (2003) calculates that about one in every five people used streaming media with their broadband connections.

descriptive statistics suggest that the deployment of broadband networks is still quite limited throughout the world. The majority of broadband subscribers are located in high-income countries.

Table 3 shows access to broadband and the privatization status of the carrier. In those countries where broadband was available in 2001, almost 50% of the carriers were privatized. In countries where no broadband was available, 76% of the carriers were state-owned. A significant χ^2 also indicates that the relationship between the ownership status of the carrier and the availability of broadband connections is not by chance. Perhaps because of their lack of resources, state carriers seem to be unable to upgrade their networks to provide these services.

Table 3 - Summary tabulation: relationship between broadband access and ownership of the incumbent carrier

	Carrier ownership	
	State	*Privarized*
Broadband Not Available	76.12	23.88
Available	54.76	45.24

Pearson chi2(1) = 7.0874 Pr = 0.008

As far as market conditions and prices are concerned, table 4 provides a summary of the level of competition in countries where broadband is available and those where it is not. 66% of the countries that do not have broadband services also have single carriers providing local telephony services, while 73% of countries in which services are available have a competitive local market. Because we have a significant χ^2, we can thus conclude that this relationship is not accidental. After calculating the odds ratio, it emerges that the likelihood of having access to broadband is 24 times greater in countries with competitive local markets.

Table 4 - Summary tabulation: Broadband competition prices and subscribers in countries with broadband (means and standard deviations)

Variable	*Monopoly*	*Partial competition*	*Full competition*
Price (cents)	0.010 (0.01)	0.006 (0.004)	0.0076 (0.005)
% of the population with broadband	1.293 (2.28)	1.365 (1.74)	2.359 (2.72)

Pearson chi2(1) = 21.9147 Pr = 0.000

In doing this simple analysis we have to take into consideration that other factors may also lead to competition. It could be the case, for example, that competition exists in larger and wealthier markets. What appears to be a relationship between competition and access to broadband may actually represent the income level of the population. The regression analysis in the next section will help to elucidate these relationships more clearly.

The price for broadband varies from slightly more than half a cent per megabyte downloaded in Belgium to 21 cents per megabyte in Turkey. Table 5 shows the average prices and percentage of the population using broadband service for countries with different levels of competition. The percentage of broadband subscribers is slightly higher in those countries that experience competition in the provision of this service. As the differences are so small, it is difficult to determine if they are significant at this point.

The impact of unbundling requirements on the availability of broadband services is an issue facing regulators. Many have been concerned about the impact that lack of unbundling will have on the level of competition in the market. Because infrastructure deployment is expensive, there are few carriers with the resources to replicate these networks. The introduction of wireless technologies such as microwave, satellite, and WiFi are making these investments more feasible. The local loop nonetheless is mostly wired and, in this study, broadband access is defined as being provided through wired means. Both the cable and the telephone infrastructure that is necessary for broadband services mainly belong to incumbent carriers. As a result of the dominant position held by these companies, their brand recognition and control over essential facilities, a lack of unbundling requirements could potentially impair the number of entrants and impede the deployment of these networks at reasonable prices.

Table 5 - Unbundling requirements for countries with and without access to broadband services

	No unbundling required	*Unbundling required*
No broadband access	75.86	24.14
Broadband access	32.5	67.5

Pearson chi2(1) = 21.9147 Pr = 0.000

Table 6 presents the percentage of carriers required to unbundle in countries with and without broadband services. The table shows that 76% of countries that don't require their carriers to unbundle also do not have broadband access, while 67% of countries with broadband services require unbundling. Here again the χ^2 is significant.

Regression models

The descriptive analysis section has provided some insights about the factors that can affect the access and deployment of broadband networks. Per capita income, privatization of the incumbent carrier, market conditions such as level of competition, and regulatory factors such as unbundling seem to influence the availability of broadband. In this section we present the results of two statistical analyses. The goal of the first analysis is to determine the factors that affect the availability of broadband services in a country. This analysis uses a logit regression. The second set of models uses an OLS regression analysis that shows the factors influencing the number of broadband subscribers.

Logit regression analysis

We ran a logit and standard regression to determine the factors that contribute to the deployment of broadband. The purpose of the first logit regression is to see whether market conditions and government actions affect the availability of broadband independently of the number of people subscribing to the service. This regression is important because broadband services are relatively new and not available in many countries.

Where a service is available, there is still a relatively small number of subscribers. The dependent variable in these models is coded as 1 if there are broadband services in the country and 0 if there are not. We fitted three models. The first two include only market variables, while the third model includes regulatory variables to determine whether public intervention is necessary to make such services available.

The logit equation is:

$$broadband = \beta_0 + \beta_3(\lg\ dppc) + \beta_2(\ln\ population) + \beta_1(\ln\ perc\ \text{int}\ u) + \beta_6(\ln\ illiteracy) + \beta_4(broadbandc\ ompetition) + \beta_5(privatizat\ ion) + \beta_5(unbundling) + \varepsilon$$

Table 6 - Robust logit regression models of broadband availability (market variables)

Variable	*Model 1*	*Model 2*	*Model 3*
GDP per capita	169.529** (-355.57)	47.683*** (-64.269)	193.426*** (-348.949)
Population	13.695*** (-7.474)	2.667*** (-0.929)	12.316*** (-6.379)
Percentage of Internet users	6.022 (-10.872)	1.315 (-0.768)	10.332* (-14.571)
Illiteracy rate	1.482 (-0.717)		
Broadband competition		6.857** (-6.506)	
Privatization			0.828 (-2.037)
Unbundling			34.545*** (-47.062)
Observations	61	92	72
Pseudo R2	.831	.824	.903

* significant at 10%; ** significant at 5%; *** significant at 1% Robust standard errors in parentheses

Table 7 shows the results of the logit regressions. These three models help identify the factors contributing to the availability of services in the country. The variables corresponding to the percentage of personal computers, percentage of dial-up internet users and percentage of internet hosts are highly correlated and thus cannot all be included in a single model. Of those three variables, we decided to include only internet users because this implicitly includes the number of computers. We also expected that dial-up internet users would be likely to switch to broadband.

The three models provide some evidence in favor of and against the hypotheses outlined for this paper. We hypothesized that the effect of all variables except illiteracy would be positive. For all of the models fitted, we find that both the population size and the per capita income positively affect the probability of a country having access to broadband services, which is consistent with what we had hypothesized. The first model suggests that the illiteracy rate and the percentage of Internet users have not had an effect on the availability of broadband services in the country. We had hypothesized that illiteracy would have a negative effect and dial-up Internet users a positive effect. These two hypotheses are thus not supported.

We eliminated the illiteracy rate from the second regression because of its lack of significance, but left the internet users variable because it was significant at the 15% level. We also added the number of broadband providers. This second model suggests, as one would expect, that competition among broadband providers positively affects the probability of service availability. Once again, the level of internet usage was not significant.

The third logit regression includes policy related variables: privatization of the incumbent carrier and unbundling. We find that the variable privatization is not significant and is therefore unrelated to the availability of broadband services. The variable "unbundling" was highly significant.

From the logit regression results we calculated the probabilities for each of the country income levels with and without an unbundling policy. We are interested in the effect of unbundling on the probability of broadband services being offered in the country. The table shows that country income level has a substantial impact on the probability of having access to broadband services. This is not surprising, as these services remain a luxury for most people in developing nations. The other significant result from these calculations is the effect of unbundling. For low income countries, unbundling shows hardly any impact, but for middle income countries an unbundling policy increases the probability of having access to this service from 2% to 41%. High income countries are not affected as drastically. It is possible that in high income countries the market is sufficiently attractive for companies to offer such services, even if unbundling is not required. This is in itself an interesting result, as a country such as South Korea is able to reach high broadband penetration even though carriers have has not implemented local loop unbundling (KELLY, GRAY & MINGES, 2003, pp. 12 and 64). The South Korean case has led some people to believe that unbundling is not necessary, but this may not apply to less developed countries.

Table 7 - Probability of broadband services being provided

	Unbundling required	*No unbundling required*
Low income	0.0029	0.0001
Lower middle income	0.4163	0.0202
Higher middle income	0.9413	0.3172
High income	0.9989	0.9637

OLS regression analysis

The dependent variable for these OLS regression models is the percentage of internet users in the country that subscribe to a broadband service. The variable "price" was also added. The difference between these results and those of logit regression results is that in logit analysis we are only concerned with the factors that affect availability of broadband services in the country. In the regression analysis we want to determine the effect that each factor has on the actual number of subscribers.

We fitted three models and the only difference among them is that the first two include the total population variables, while the third incorporates population density instead. The second of the first two regressions includes the variable lpop_15. This is because we identified a break in the data at point 15 when we plotted the log of the population and broadband subscribers. The OLS regression models include the following variables:

$$l(perctot\quad 01) = \beta_0 + \beta_1(\ln\ gdppc\ ) + \beta_2(\ln\ population\quad) + \beta_3(\ sqrprice\quad)$$
$$+ \beta_4(\ sqrbroadco\quad mpet\ ) + \beta_5(\ln\ \text{int}\ ernethosts\quad) + \beta_5(\ln\ \text{int}\ ernethosts\quad q)$$
$$+ \beta_6(\ privatizat\quad ion\ ) + \beta_7(unbundling\quad) + \varepsilon$$

We find that GDP per capita is not significant in any of the three models. While this is not what we hypothesized, it is consistent with the data. The majority of the countries that have broadband are high income. We find that its provision is related to income, but the level of subscribership is not.

Population and population density are both significant. This is consistent with what we hypothesized and it is also intuitively consistent with experiences in some countries. Countries that have bigger populations are more likely to have more subscribers, even if the percentage of subscribers is the same. Similarly, more densely populated areas may enjoy a higher rate of broadband subscription either due to lower prices in those areas or a contagion effect. If a city is densely populated, broadband users are more likely to influence their neighbors to get broadband too. Population density in this case may not necessarily reflect infrastructure upgrading, but rather diffusion. The variable "price" is significant although it has a positive connotation, i.e. the higher the price, the higher the number of subscribers. This is a counterintuitive result, but it is possible that while per byte and time-based pricing make these services expensive in some countries, people are still adopting.

Table 8 - Robust logit regression models of broadband availability

Variable	*Model 1*	*Model 2*	*Model 3*
Log GDP per capita	0.525 (-0.37)	0.453 (-0.289)	0.69 (-0.385)
Population	0.351** (-0.108)	0.190** (-0.073)	
Price	9.920* (-4.755)	10.320** (-3.508)	12.060* (-5.826)
Competition of broadband providers	2.847*** (-0.606)	2.999*** (-0.697)	1.941*** (-0.327)
Log Percentage of Internet Hosts	1.809*** (-0.393)	1.996*** (-0.456)	1.404*** (-0.311)
Percentage of Internet Hosts Squared	-0.472*** (-0.091)	-0.519*** (-0.096)	-0.395*** (-0.085)
Percentage of Internet users	1.102** (-0.407)	1.049* (-0.457)	1.191*** (-0.337)
Privatization	-0.375 (-0.214)	-0.405 (-0.234)	-0.168 (-0.189)
Unbundling	0.457 (-0.333)	0.338 (-0.31)	0.516** (-0.188)
lpopt_15		0.272 (-0.177)	
Population density			0.262*** (-0.076)
Constant	-19.225*** (-2.883)	-16.239*** (-2.757)	-15.930*** (-3.033)
Observations	18	18	18
R-squared	0.97	0.98	0.98

Robust standard errors in parentheses * significant at 10%; ** significant at 5%; *** significant at 1%

The number of broadband providers in the country, which measures the level of competition, is significant. This can be interpreted as greater willingness to subscribe, potentially as a result of increased choice that enables selection of a plan best suited to subscriber needs.

The percentage of domestic internet hosts also appears to positively contribute to the broadband subscriber base. There is consequently a positive relationship between local content available to the population in their own language and the number of people that contract broadband services.

The percentage of internet users is also significant and consistent with our initial hypothesis. This is also unsurprising because a subscriber that accesses the internet with a dial-up connection is likely to consider switching to broadband if available.

The policy related variables included in the model are privatization and unbundling. We find that privatization is not significant. State-owned monopolies, whose relationship with the dependent variable is captured in

the constant term, have a significant and negative relationship with broadband demand. State monopolies that provide broadband services are possibly not as attractive as those provided by private carriers in a competitive environment.

Unbundling, the variable of greatest interest in this study, is not significant in two of the OLS models. Only when population density is included in the model is unbundling significant with the expected sign. This means that an unbundling policy does not necessarily correlate with the number of subscribers. From the logit regression we know that unbundling has a positive influence over whether broadband services are made available in a country.

It is important to note some of the limitations of this study. International statistical analysis has several weaknesses. Only data aggregated at a national level is available, making it impossible to identify internal differences within countries. It is likely, for example, that people in countries with greatest broadband infrastructure live mostly in the largest cities. We do not have data about the level of competition in different regions and differing regulatory regimes within countries. We are thus unable to determine more specific features of the population that could be helpful for policy. This study, however, is appropriate for policy at a more general level.

■ Conclusion and policy recommendations

It is clear that income is an important determinant of infrastructure in general, but much more so for broadband. There are several reasons why broadband is more likely to be available in high-income than low income countries. Firstly, the price of a computer as a percentage of income is smaller. Similarly, broadband is a value added service and its price, especially in the early years of rollout, tends to be high. High-income economies are also more likely to have greater content available to the population because of the greater availability of resources such as software required to produce materials for the internet. In addition to income, population size also contributes to the likelihood of having broadband services provided in the country.

Of the factors that governments can control, competition and unbundling show a positive relationship to the availability of the service. We also find that the relationship between unbundling and access to broadband services

is more pronounced among middle-income countries. This means that governments in less developed countries can promote the deployment of broadband networks by both fostering competition and requiring unbundling of local loops. Unbundling will allow other carriers to enter the market and pressure from competition should force them to provide advanced services.

The OLS regression results are consistent with the hypotheses formulated for this study. They show that competition positively affects the number of subscribers. Price also shows a positive relationship, although the opposite was expected. In the early years of the technology richer users may contract the service, even at high prices. Due to the high price of the service, it is likely that large segments of the population in less developed countries will not be able to afford it. Governments should thus aim to find mechanisms that allow the general population to have broadband access to the internet. Some solutions have been implemented using community centers. Local content could also be produced in these settings. The regression results also show that having national content also positively affects broadband subscriptions. The number of dial-up users is another factor that positively influences the demand for the service. From a policy perspective, regulations that foster competition, including unbundling, can lead to price reductions that further boost the number of dial-up, and subsequently of broadband subscribers.

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