International Broadband Deployment: The Impact of Unbundling

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Introduction

Broadband and unbundling regulatory requirements have received much attention. Scholars and regulators have a variety of views about the optimal policy for promoting the deployment of broadband networks. This paper addresses the controversy by presenting the results from an empirical analysis of 135 countries. We believe that this heterogeneous data set provides some useful insights into the benefits of different policy options. The data set permits us to explore how unbundling affects investment in telecommunications infrastructure. Before presenting our results, we first summarize the literature on how such factors as state ownership, competition, and content may affect investment in infrastructure.

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 "jump-start" competition by requiring incumbent providers to rent their networks as unbundled network elements[2] at low prices established by a government regulatory agency.

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."[3] In addition, Jorde, Sidak, and Teece (2000) further support the argument made by Crandall and state that mandatory unbundling of various network components of an 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 infrastructure, it is difficult to coordinate the requirements of the incumbent and the entrant that wants to rent a portion of the incumbent's network. Kessides (2003, p. XII) suggests that the introduction of new

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[2] 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, 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).

[3] 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.

services requires investments in infrastructure that can be best handled by a vertically integrated firm.

Despite the numerous arguments written about the comparative benefits of different 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 of the paucity of empirical studies that can 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."[4]

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. This was a period of broad state privatization programs that included several sectors. 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 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 objectives for the organization. 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 that the government would try to expand the infrastructure to serve all sectors of society while the private company would focus instead on the most profitable segments and ignore isolated regions and scattered population. When the company moves from state to private ownership we would not necessarily expect expansion.

Expansion of infrastructure under state control can happen but there are several reasons why this is not observed in practice. First, 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, a government would have to decide where to invest its funds. For some countries this may be for infrastructure but for others it could be 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, were diverted to fund other programs.

Therefore the effect on ownership is an issue that policy makers can best evaluate through empirical analysis. Investment in telecommunications infrastructure has often not been a high priority for governments It is thus not surprising that researchers have found

[4] "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."

that privatization has a positive impact on telecommunications infrastructure. Galal et al. (1992), in their examination of twelve companies, of which three were in telecommunications, find that privatization leads to overall positive welfare effects. Similarly Ramamurti (1996) finds that in the four years that followed privatization in Argentina, Jamaica, Mexico, and Venezuela, these countries experienced a rapid expansion in their networks, averaging 15% growth per year. Wellenius (1994) reached a similar conclusion. He found that state owned companies undersupplied services and generally exhibited network and service quality deficiencies.[5]

Vickers and 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 of which privatization is only one and thus can only partially explain increased efficiency. A similar 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).

Even though there is evidence from multiple countries that infrastructure deployment was limited under state ownership, one could argue that states in their efforts to provide utilities to the population would have an interest in making a telecommunications infrastructure as widely available as possible. This is especially the case in recent years, as the information sector of the world's economy has become increasingly important. Even in areas of the world where resources are especially limited, the governments may conclude that it is essential for the telecommunications infrastructure be modernized. This thus implies that there may be governments that can succeed in effectively providing telecommunications services.

There is another alternative in the ownership structure of a company. Some firms have partial private participation. Scholars that have analyzed mixed ownership corporations have focused primarily on the impact this shared arrangement has on the enterprise itself. Megginson et al. (1994) show that less state ownership is associated with higher productivity and superior operating returns. This happens because the new management has a strong incentive to innovate and create value for shareholders (Boycko, et al.1996; Shleifer and Vishny, 1998; Hart et al., 1994; Hart et al., 1997). This view suggests that there should be limited state participation in the corporation. Government officials could jeopardize investment if they are seen as imposing a political agenda (Guislain, 1997). State intervention is thus seen as impeding the overall managerial tasks and objectives of the corporation.

Perotti (1995), in contrast, believes that state participation has a positive impact on the privatized corporation. The government signals to the new owners that they have a stake in the success of the company and will thus facilitate investment and enhance growth. Having the government take a stronger role could, for example, provide guarantees on long-term debt and limit competition (Guislain, 1997). A recent empirical study by Vaaler (2003), nonetheless, argues that the impact depends on the level of a country's development. In LDCs companies derive greater benefits from having the government involved because this reduces the risk to their assets. In a developed country

[5] This was not a problem unique to telecommunications. State enterprises were often poorly managed and thereby harmed the country's economy.

government participation has little impact on the company and thus having only private control with little intervention is often preferred.

Although theoretically state participation should have a positive impact on infrastructure, previous empirical research indicates that this has not been the case. Privatization has generally improved infrastructure deployment (Galal et al., 1992; Ramamurti, 1996; Vickers and Yarrow, 1988). We would thus expect privatization to have a positive sign.

H1: Broadband subscription is positively related to the 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 was 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 and 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 content and applications on the Internet compelling enough to pay for these services (Electronic News, 2002, p. 14).[6]

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

[6] To the best of our knowledge there is no scholarly work that points to the relationship between the availability of content and the 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.

the most part, owned by American carriers, ISPs in other countries have to pay for such connections. In Australia the National Bandwidth Inquiry Report (1999) calculated that connection costs were between $133 million and $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 thus an element that could minimize the amount of payments to foreign carriers.

In this analysis one of the concerns is the direction of causality. In the relationship between content and broadband infrastructure there is potentially bidirectional causality. Without content, broadband would not 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 US. Arguably broadband now needs content. We hypothesize a positive relationship between domestic content and broadband adoption.

H2: Broadband 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 for adoption of the technology in poorer regions of the world.

Population density is another variable that affects technology adoption. Regions with high population density can be served more cheaply through cable, which can serve multiple dwellings. More sparsely populated areas could only be served at higher prices.

The educational level of the population is also included in the model. People with higher education should be more familiar with and feel more comfortable using information technology. They may also be interested in having access to more information from the Internet.

Other technological aspects of importance are the availability of personal computers and the number of people that have access to the Internet. Whether using broadband or narrowband, personal computers are the most common method of accessing the Internet. Obviously then, the higher the number of computers in the country the higher the probability that people would be connected to the Internet. Similarly, access to the Internet, 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.

Data analysis and methodology

The purpose of this study is to determine the factors that affect broadband demand. This section is divided in three sections. The first part includes a description of

the variables that are used in the data analysis. The first part presents some conclusions from basic statistical analysis. The second presents the results of the regression analysis.

Data

The database used for this study includes 135 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. The data used in this study comes from several databases and some of it self-constructed from various sources. 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 World Development Indicators 2002.

Table 1 identifies the variables included in the model, and the affect that we expect them to have on the dependent variables.

Table 1
Description of variables

Variable	Description	Expected sign
Unbundling	Dummy: unbundling required by government = 1	+
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

Price variable calculation

Prices. The price variable was constructed on a price per megabyte (MB) basis. We did this 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 (2003) 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.[7] We use this information to calculate the price per megabyte of 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.

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 adjusting for the size of the population, the differences between low and high-income countries is highly pronounced. The number of computers in the country is less than 1% in poor countries while almost 30% 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. High income countries have 30 times more. A similar pattern is observed in the production of Internet content, which we operationalize as the number of hosts registered for the country. Finally, the 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 2
Descriptive statistics means and standard deviations

Variable	Low income	Lower-middle income	Upper-middle income	High-income
% of Internet users	0.005 (0.009)	0.03 (0.02)	0.101942 (0.078)	0.29689 (0.15)
Population density	95.51 (143.09)	96.44 (142.83)	152.9516 (206.91)	356.8048 (1035.83)
GDP per capita	1569.8 (760.98)	5102.37 (2252.29)	9097.52 (2391.01)	22901.19 (7549.16)
Illiteracy rate	37.98 (21.84)	16.23 (13.61)	10.73509 (7.86)	7.560235 (6.55)
Residential monthly telephone subscription	3.5 (2.79)	4.68 (7.60)	7.3125 (3.30)	10.27778 (4.40)
% of the population with broadband	1.91E-06 (1.08E-05)	6.50E-06 (2.79E-05)	0.000689 (0.002)	0.009282 (0.01)
% of hosts in the country	0.00022 (.0008)	0.0055 (0.02)	0.006279 (0.007)	0.040241 (0.04)
% of PCs in the country	0.006 (.0008)	0.037 (0.03)	0.098169 (0.05)	0.285651 (0.15)

Table 3 shows access to broadband and the privatization status of the carrier. In those countries, where broadband is available, 90% of the carriers are either privatized

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

(54%) or semi-privatized (37%). In countries where no broadband was available in 2001, 50% 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 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	Privatized	Partial privatization
Broadband Not Available	50.34	8.84	40.82
Available	9.76	36.59	53.66

Pearson chi2(2) 30.5048 Pr = 0.000

With respect to the market conditions, such as level of competition and prices, Table 4 provides a summary of the level of competition for countries where broadband services are available and those where it is not. This refers to the level of competition for local telecommunications services. It is assumed that DSL providers will be using this type of infrastructure to provide service.

67% of the countries that do not have broadband services available also have single carriers providing local telephony services while 73% of those with these services available have a competitive local market. Because we have a significant χ^2, we can thus conclude that this relationship did not happen by chance. After calculating the odds ratio we find that those countries whose local markets are competitive have a 24 times greater odds of having access to broadband. In doing this type of simple analysis we have to take into consideration that there may be other factors that lead to competition. It could be, for example, that competition exists in larger and wealthier markets. What appears to be a relationship between competition and access to broadband is actually representing the income level of the population. The regression analysis in the next section will help to elucidate these relationships more clearly.

Table 4
Summary tabulation: relationship between broadband access and level of competition at the local level

	Monopoly	Duopoly	Partial competition	Full competition
No broadband available	66.9	2.07	14.48	16.55
Broadband available	12.2	2.44	12.2	73.17

Pearson chi2(3) = 52.8726 Pr = 0.000

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. It does not seem as if the level of competition has had any noticeable affect on the prices of the service. The percentage of broadband subscribers is not different for all levels of competition except for full competition, which appears to lead to a greater number of subscribers. Because the differences are so small, it is difficult to determine at this point if they are significant.

Table 5
Summary tabulation: Competition prices and subscribers in countries with broadband (means and standard deviations)

Variable	Monopoly	Partial competition	Full competition
Price (cents)	.068 (.08)	.026 (.016)	.05 (.035)
% of the population with broadband	.009 (.011)	.009 (.019)	.021 (.033)

Regulatory aspects

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 belong for the most part to the incumbent carriers. Thus because of the dominant position of these companies, brand recognition, and control over essential facilities, lack of unbundling requirements could potentially impair the number of entrants and impede the deployment of these networks at reasonable prices. Table 6 presents the percentage of carriers for which unbundling is required in countries with and without broadband services. The table shows that more than two thirds (72%) of countries that do not require their carriers to unbundle also do not have broadband access while more than two thirds (67%) of those countries where broadband services are available require unbundling. Here again the χ^2 is significant.

Table 6
Unbundling requirements for countries with and without access to broadband services

	No unbundling required	Unbundling required
No broadband access	72.37	27.63
Broadband access	32.5	67.5
Pearson chi2(1) = 17.1727	Pr = 0.000	

Regression Models

The descriptive analysis section has provided some insights about the factors that could be affecting the 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.

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 determine if market conditions and government actions affect the availability of broadband independently of the number of people that have access to it. We do this because broadband services are relatively new and there are many countries where they are not available while in others there are still a 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 separate the models into those where only market variables are explored. The purpose is to determine if market factors alone facilitate broadband. Another model includes the regulatory variables to determine if public intervention is necessary to make these technologies available.

The logit and standard regression equations for the market models are:

$$broadband = \beta_0 + \beta_1(perc\,\mathrm{int}\,u) + \beta_2(popden) + \beta_3(\lg dppc) + \beta_4(partialcompe) + \beta_5(fullcomp) + \beta_6(literacy) + \varepsilon$$

$$l(pertot01) = \beta_0 + \beta_1(perc\,\mathrm{int}\,u) + \beta_2(perchost) + \beta_3(popden) + \beta_4(\lg dppc) + \beta_5(partialcompe) + \beta_6(fullcomp) + \beta_7(literacy) + \varepsilon$$

Table 7
Robust Logit Regression Models of Broadband Availability (market variables)

Variable	Coefficient	Coefficient	Coefficient
Illiteracy rate			-.0183078 (.0334681)
Percentage of Internet Hosts		19.4715 (21.4105)	24.46214 (51.49905)
Percentage of Internet users	6.803664** (3.079164)	4.410105 (4.181391)	2.180358 (4.347737)
Population density	.0000543 (.0005062)	.0000545 (.0005418)	3.35e-06 (.0004446)
Log GDP per capita	1.302226** (.5052994)	1.313044** (.4873187)	1.348913** (.5767674)
Partial competition	2.149687** (.8724228)	2.077866** (.8569633)	2.385617** (.9704235)
Full competition	2.165475** (.7805632)	2.086531** (.7675441)	2.229824** (.8294199)
Constant	-14.36001** (4.47246)	-14.34651 (4.293928)	-14.21247 (5.365007)
	Pseudo R2 =.56 No. of observations: 135	Pseudo R2 =.56 No. of observations: 134	Pseudo R2 =.42 No. of observations: 101

*Significant at .10 ** Significant at .05

Table 7 shows the results of three separate logit regressions. The first model does not include the variables hosts and education. In the first two regressions the percentage of Internet users was significant. By including the illiteracy rate we intended to determine if illiteracy would influence the percentage of Internet subscribers. The assumption was that countries with high levels of illiteracy will have lower Internet access. This was not the case because the coefficient was not significant. As shown in Table 7 the first two models include 134 and 135 observations while the third only has 101. We lost many observations. When testing to determine if missing variables in the illiteracy rate had any systematic bias we found that they did.

Because the logit regression does not capture demand but simple availability of the service in the country we find that the percentage of Internet use does not necessarily mean that broadband service will or will not be available.

As expected the relationship between broadband and GDP per capita is significant. Descriptive statistics as well as the simple logit regression indicate that income level of the population and availability of broadband have an effect on the availability of the service.

Similarly the level of competition matters in the availability of broadband services. This is also expected because a monopoly provider will have little incentive to upgrade the network to allow for faster connections. Thus competition forces the carriers to attract users by introducing new services.

Table 8 includes similar models to those done using logit regression. There are two differences. The dependent variable is the percentage of Internet users in the country and the variable price was also added.

Table 8
Robust regression results models of the effect of market variables on the percentage of broadband users in the country

Variable	Coefficient	Coefficient	Coefficient
Illiteracy rate			449605.9 (317177.4)
Percentage of Internet Hosts		-4.36148 (3.040854)	70.97307 (84.25317)
Price		-11.57043*** (2.389153)	-1.944671 (4.338315)
Percentage of Internet users	5.193984** (2.037038)	4.676029** (1.916061)	11.21495 ** (3.028178)
Population density	.0001747** (.0000513)	.000072** (.0000319)	-.0005062 (.0005109)
Log GDP per capita	1.737674*** (.4152277)	1.817025*** (.3350875)	.4217719 (1.040875)
Partial competition	.7482297 (.8345824)	-.2562345 (.7133348)	.47958 (.9113241)
Full competition	.6207386 (.4901851)	.3202431 (.2164298)	.8524417** (.3924552)
Constant	-24.23855*** (3.518144)	-23.51718 (2.828595)	-13.36849 (8.128219)
	R2 =.82 No. of observations: 39	Pseudo R2 =.91 No. of observations:36	Pseudo R2 =.89 No. of observations: 18

*Significant at .10 ** Significant at .05

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 the technology in the country and not the actual demand for it. In the regression analysis we want to determine the effect that each factor has on the actual number of subscribers.

The first simple model that includes the main economic variables that were included in the logit regression. Model two improves by including price, which, as one would expect, is an important determinant of demand. The percentage of Internet users is also significant, which is also not surprising because a subscriber that accesses the Internet with a dial-up connection is likely to consider switching to broadband if it is available. Population density is significant but the coefficient is too small to be of importance. Population density should have been significant in the logit regression and not on the OLS regression. Upgrading the infrastructure to provide this service is more attractive to do if the carrier can provide service to a large number of people with few lines. If a city is densely populated broadband users are more likely to influence their neighbors to also have broadband. Population density in this case may not necessarily reflect infrastructure upgrade but rather diffusion.

GDP per capita as expected is significant. Demand for broadband services is higher in those countries with wealthier individuals. The variables related to competition produce a surprising result. While competition can foster the provision of the service, having competition per se does not affect the level of demand. Although competition is

not significant, it is likely to affect prices, which is highly significant in our model. Thus competition can enable the product to be provided and can also reduce prices.

The effect of regulatory decisions

The models in this section include two policy related variables: (1) ownership status of the incumbent carrier and (2) unbundling requirements.

The logit and standard regression models including regulatory factors are:

$$broadband = \beta_0 + \beta_1(perc\,\mathrm{int}\,u) + \beta_2(perhost) + \beta_3(popden) + \beta_4(\lg dppc) + \beta_5(partialcompe) + \beta_6(fullcomp) + \beta_7(privateowned) + \beta_8(mixowned) + \beta_9(unbu) + \varepsilon$$

$$l(perctot01) = \beta_0 + \beta_1(perc\,\mathrm{int}\,u) + \beta_2(perhost) + \beta_3(popden) + \beta_4(\lg dppc) + \beta_5(partialcompe) + \beta_6(fullcomp) + \beta_7(privateowned) + \beta_8(mixowned) + \beta_9(unbu) + \varepsilon$$

Table 9
Robust Logit Regression Models of Broadband Availability (market and policy variables)

Variable	Coefficient	Coefficient
Unbundling		.0645864 (.7757379)
Percentage of Internet Hosts	30.28683 (27.16575)	23.27919 (23.92829)
Percentage of Internet users	2.346071 (3.765944)	3.551521 (3.987648)
Population density	.0001564 (.0006259)	.0002295 (.0009029)
Log GDP per capita	1.190647* (.4655606)	1.027314** (.5141863)
Partial competition	2.252738* (.8930273)	1.682343* (.959921)
Full competition	1.901638* (.8040594)	1.662098* (1.013072)
Private owned carrier	1.252409 (.8750365)	.9065505 (1.01749)
Mixed owned carrier	.7604586 (.803437)	.421622 (.8893807)
Constant	-13.84318 (3.990479)	-11.69996** (4.186842)
	R2 =.58 No. of observations: 132	Pseudo R2 =.90 No. of observations:56

*Significant at .10 ** Significant at .05

The second logit regression includes two additional policy related variables: privatization of the incumbent carrier and unbundling. In both models these variables are not significant. The only variables that were significant in this model were once again GDP per capita and level of competition. This means that as long as there is competition in the market it does not matter if the incumbent is fully or partially privatized. The other significant variable was the constant, which in this case represents a state owned carrier with a monopolized local market. The sign is negative as expected. Under these circumstances we would expect broadband to be negatively affected.

Table 10
Robust regression results models of the effect of market and policy variables on the percentage of broadband users in the country

Variable	Coefficient	Coefficient
Unbundling		.0443199 (.3222689)
Percentage of Internet Hosts	-4.478218 (2.766234)	-4.357201 (2.887176)
Percentage of Internet users	5.31298 (1.771435)	5.276914** (1.842812)
Population density	.000123** (.000034)	.000124** (.000038)
Log GDP per capita	1.604445** (.3140789)	1.605664** (.3623978)
Price	-9.192805** (3.283556)	-8.973361** (3.519241)
Partial competition	-.0156094 (.56528)	.0198411 (.6083771)
Full competition	-.0327158 (.3374054)	-.0262273 (.3703)
Private owned carrier	1.775226** (.8616836)	1.741934** (.9256339)
Mixed owned carrier	1.250638 (.8960818)	1.241969 (.9477803)
Constant	-22.92288 (2.813818)	-22.97543** (3.219821)
	R2 =.78 No. of observations: 35	Pseudo R2 =.81 No. of observations:34

*Significant at .10 ** Significant at .05

The two regression models that include now policy related variables show similar results to those that include market variables alone. Unbundling is not significant, which means that this policy does not affect the level of broadband demand. Among the countries where broadband is available are some where unbundling is not required. Although this policy does not affect broadband demand it is not clear if broadband affects the level of competition, which is a significant variable in all of the models. The variable mixed owned carriers, which are those operators that still have state participation, is not

significant but the variable private owned carrier is significant. This result could mean that a private owned operator, because of the way it is organized, is able to generate more demand than a mixed owned or a state owned operator.

This study cannot determine the exact elements that a private carrier is able to do that the other two types of carriers do not. State owned monopolies, which are represented again in the constant term, have a significant impact on demand. Of all the significant factors that are included in the model, the ones that have the greatest impact are state monopolies, which result in 22% fewer broadband users. Price is the second most important variable. An increase in price of one cent per megabyte will decrease demand for broadband by 9%. The third most important element is the percentage of Internet users. A percentage increase in dial up usage will eventually lead to a 5% increase of broadband use. This thus means that one effective way of increasing broadband is to simply have people be exposed to the Internet since it is likely that a good portion of them will move to broadband. GDP per capita is important but the impact is smaller than price and Internet use. The variable hosts was not significant, which means that content is not an issue. This is also not surprising because the Internet is an international network and people can access content from sites located in other countries.

Limitations

International statistical analysis has several weaknesses. First because we only have aggregated data for a country we cannot determine the internal differences within the country. It is likely, for example, that people in those countries that have a broadband infrastructure live mostly in the largest cities. We do not have data about the level of competition in different regions of countries and about differing regulatory regimes within countries. This does not allow us 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. A company may be more interested in individual characteristics for marketing purposes.

Conclusion and Policy Recommendations

It is clear that the income level of a country, price, privatization of the incumbent carrier, and the presence of competition are all factors that can facilitate and promote the deployment of broadband. This means that if a policy is to be implemented a government should either foster competition or reduce prices. It is possible that once competition is introduced lower prices will follow and no intervention may be necessary. In low income countries a government may consider some level of subsidy for broadband.

Unbundling is not significant in our models but this does not mean that the policy will not affect the level of competition. A follow up study could look at the relationship between these two variables.

While privatization is can foster competition, there are conditions that may inhibit a government from doing so. In Honduras, for example, is a small market that has unsuccessfully tried to privatize the state operator. Similarly it is not surprising that small markets are not able to attract many players. Governments that face these circumstances

could benefit from a study that analyzes low income countries with a state carrier and limited competition that have been able to foster the deployment of broadband. There are three countries with broadband access under those circumstances: Turkey, Thailand, and China. In Thailand and China however there is competition for the local loop. A follow up study could thus look at these countries to determine how carriers have been able to foster demand for broadband.

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