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Executive Summary

Broadband penetration and available speeds vary widely across OECD countries. Policymakers around the world, and especially in countries like the U.S. that lag in the rankings, are searching for policies to narrow those gaps. Relatively little empirical work tests possible reasons for these differences. In this paper I test the impacts of regulations and demographics on broadband development in a panel dataset across countries. In addition to adding to the meager empirical literature on broadband across countries, this paper is novel in two ways. First, it explicitly takes into account the many different types of unbundling regulations that countries have implemented. Second, in addition to studying the impacts of policies on broadband penetration, it also studies the impact of policies on available connection speeds. Controlling for country and year fixed effects, I find that local loop unbundling has no robustly significant impact on broadband penetration. More extensive "subloop" unbundling, however, is negatively correlated with penetration. Requiring the incumbent to allow on-site collocation is positively correlated with penetration, though regulating collocation charges is negatively correlated with penetration. None of the unbundling regulations are correlated with connection speeds, though regulated collocation prices are generally negatively correlated with speed. In sum, it appears that very extensive unbundling mandates and some types of price regulation can reduce broadband investment incentives, though regulations ensuring easier interconnection with the incumbent can increase investment.

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1. Introduction

Policymakers, academics, and others have expressed concern about what many perceive to be poor broadband service in the U.S. relative to some other countries. According to the OECD, by December 2005 the United States ranked 12th among OECD countries in terms of broadband penetration per capita (Figure 1).[1] Faster speeds are more widely available in some other countries, as well, ranging up to 100 Mbps in Japan, far faster than is generally available in the U.S. (Figure 2). Despite the heated debate over whether these comparisons are meaningful and whether the U.S. does, in fact, have a "broadband problem," as some have called it, remarkably little empirical research attempts to explain these differences.

This paper explores some of the determinants of broadband differences across countries, including the impact of unbundling regulations. This paper improves on existing work in two ways. First, it recognizes that there are many types of unbundling and explicitly incorporates these differences into an empirical analysis of panel data. Second, it studies the effects of unbundling not just on broadband penetration, which is the most commonly studied indicator, but also on the speed of available Internet connections.

In particular, I compile a unique country-level panel dataset to test the effects of different types of unbundling and collocation regulations as well as other demographic characteristics on broadband penetration and connection speeds. First, I find that population density is positively correlated with broadband penetration and speed. In addition, regulations also matter. The most extensive form of mandatory unbundling included here—so-called "subloop unbundling"—appears to slow penetration growth. Requiring incumbents to allow on-site collocation by their competitors is correlated with faster penetration growth. None of the unbundling variables were significantly correlated with connection speeds, though regulating collocation charges is negatively correlated with speed.

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[1] Exact rankings vary by source as calculating the number of broadband connections is inherently imprecise and changes quickly. The OECD ranks the U.S. 12th as of December 2005 http://www.oecd.org/document/39/0,2340,en_2649_201185_36459431_1_1_1_1,00.html.

2. Broadband Overview and Literature

Supporters of government intervention argue that broadband in the U.S. lags some other countries in three respects: penetration, speed, and price. While the U.S. does lag in penetration and in available speeds (as discussed above), it is less clear if broadband is actually more expensive in the U.S. than elsewhere. Prices are difficult to compare and interpret, given their endogeneity. Nonetheless, the ITU (2005) surveyed broadband ISPs in every country and derived a range of prices for each country. Based on these data, the ITU calculated the price per kilobit-per-second to facilitate cross-country comparisons. The ITU's figures should be considered cautiously, as the document does not describe the derivation method completely nor does it discuss whether these prices reflect those generally available. Moreover, as Ismail and Wu (2003) note, these estimates assume that all bits have the same value, regardless of the speed with which they are delivered.

The ITU's data, while error-prone, is among the only sources of comparable information. Claims that other countries have cheaper access than the U.S. are generally based on anecdotes. The ITU at least attempts to create a reasonable tool for comparison. Figure 3 shows the prices for the countries that also appear in Figure 1. The figure reveals that while the U.S. does not have the least expensive broadband access, it compares favorably to other countries.

What affects broadband penetration?

While the U.S. lags in several measures of broadband service availability and adoption, not everyone believes that these comparisons are meaningful. As demonstrated in Figure 4, the number of U.S. broadband subscribers is growing quickly, and the growth rate appears to have increased after certain legal changes, discussed below. And according to a survey by the Pew Internet and American Life Project, the number of Americans with broadband access at home increased by 40 percent between March 2005 and March 2006 (Horrigan 2006). Indeed, American consumers seem to be adopting high-speed Internet services at least as quickly as previous new technologies (Crandall 2004; Faulhaber 2002). Thus, it is not necessarily correct to conclude, as some have (e.g., Ferguson 2002; Hundt 2002), that the U.S. has a "broadband problem."

Nonetheless, we can gain some insights into the issue by reviewing the small literature on factors affecting broadband adoption. The literature consists of brief case studies, cross-country empirical analyses, and analyses of U.S. broadband penetration over time. The literature reaches some broadly consistent conclusions, though some countries or regions are exceptions to these general results. First, as one would expect, population density is a strong predictor of broadband penetration since more densely populated areas are less costly to serve. Second, competition across platforms (i.e., facilities-based competition) strongly affects penetration. Access competition (i.e., reselling another firm's services via unbundling laws) does not generally seem to have a positive impact on penetration, though many disagree with that conclusion. Third, no particular government policy has been empirically shown to have a strong positive impact on penetration.

Demographics and competition affect deployment

Flamm (2005), in a careful zip-code level U.S. study, finds that geographic terrain, income, and population density all affect broadband penetration. Bauer, et al (2003) reach identical conclusions in a cross-section of OECD countries. Recognizing the importance of these factors, other studies control for them.

Using a state-level cross-section of U.S. states, Aron and Burnstein (2003) find that intermodal (e.g., DSL versus cable) competition between providers is the most effective catalyst for increased penetration after controlling for demographic and geographic factors that affect demand and supply. Denni and Gruber (2005) use a panel of data across U.S. states and similarly conclude that competition across platforms (i.e., cable versus DSL) strongly affects penetration. They also find that intra-platform competition (mostly DSL providers competing via access to the incumbent's copper wires) has a positive effect initially, but that the effect disappears over time.

Maldoom, *et al.* (2003) confirm the important role of cross-platform facilities-based competition in a report on broadband in OECD countries. Distaso, *et al*. (2004) also conclude, in an empirical study of European Union countries, that inter-platform competition drives broadband adoption.

In sum, relatively uncontroversial factors affecting broadband penetration include population density, income, and facilities-based competition. The effects of policies, including unbundling regulations, intended to boost competition and broadband penetration continue to be debated internationally. The next section discusses those issues.

Policies and unbundling regulations

Few government policies in the U.S. seem to have had robust impacts. Flamm (2005) found that the eRate program, intended to help connect schools and libraries to the internet, had little impact on broadband penetration. Wallsten (2006) found that few state-level policies had any impact on broadband penetration. Some subsidies for providers in rural areas may have had some positive impacts, but the data made it impossible to determine whether those investments were cost-effective. Nonetheless, those results are consistent with Goolsbee's (2002) argument that if policymakers want to employ subsidies to increase broadband penetration, then subsidies should be targeted at encouraging investment in unserved areas rather than at individual consumers.[2]

The most contentious policy, both in the U.S. and around the world, has been the role of unbundling regulations. Broadly speaking, unbundling regulations require owners of telecommunications facilities to make parts of their networks available to competitors at regulated rates. Unbundling comes in many forms, ranging from local loop unbundling, in which a competitor must be given access to the 'last mile' connection to end-users' homes, to the unbundled network element – platform (UNE-P) in the U.S. that required incumbent telecom firms to open their entire networks to competitors at regulated rates.

One justification for these unbundling regulations, especially in the U.S., was what became known as the "stepping-stone theory." Proponents argued that network externalities and the relatively high sunk costs of entering telecommunications markets were barriers to entry, and that new competition was feasible only if entrants had access to incumbents' networks. According to the theory, the entrants would use this access as a "stepping stone" to building their

[2] The generally negative effect of government interventions in broadband reflects the little thought that has generally gone into such programs. Faulhaber (2002) notes that state and local policies could impede broadband rollout by, for example, imposing costly requirements on infrastructure providers. Crandall, et al. (2004) agree that state policies can affect broadband investment and should be sure not to inhibit competition.

own networks—once they had attracted subscribers, they would begin building their own facilities, resulting in real facilities-based competition.

Many economists believe that approach, as implemented in the U.S., reduced incentives for telecom companies to invest by requiring them to share new facilities with competitors, thereby lowering the returns to investments. Hausman and Sidak (2004), for example, argue that

> Telecommunications regulators offered four major rationales for mandatory unbundling: (1) competition in the form of lower prices and greater innovation in retail markets is desirable, (2) competition in retail markets cannot be achieved with mandatory unbundling, (3) mandatory unbundling enables future facilities-based investment ('stepping-stone' theory), (4) competition in wholesale access markets is desirable. An empirical review of the unbundling experience in the United States, the United Kingdom, New Zealand, Canada, and Germany suggests that none of the four rationales is supported in practice.

Empirical research on the effects of unbundling on broadband generally reaches the same negative conclusions. Hazlett (2005) notes that cable companies, whose broadband services were largely unregulated, invested more quickly in their broadband networks than did telephone companies, who were required to share their broadband facilities with competitors.

In 2003, the FCC ended the mandatory line sharing agreements, and further Court decisions, such as *Verizon v Trinko*, have guaranteed broadband providers that they will not be forced to share new investments with competitors. Hazlett (2005) notes that once the line sharing regulations were lifted, the number of DSL subscribers began to grow more quickly. In addition, after these decisions the incumbent telecommunications companies such as AT&T (née SBC) and Verizon increased their investment in "fiber to the home."[3] Verizon's FiOS fiber optic cable, for example, can currently sustain speeds up to 30Mbps to end-users's homes.

The cross-country literature on the effects of unbundling is largely consistent with these results. Maldoom, *et al* (2003) observe that facilities-based competition yields positive results, while access-based competition (via unbundling regulations) does not. They conclude that

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[3] To my knowledge, there is no rigorous study of the impact of legislation on this type of investment. Thus, while investments in FTTH increased following these FCC and Court decisions, it is not possible to reject the possibility that the timing is coincidence.

"Competition based on bitstream access and/or resale cannot bring about all these benefits, and risks crowding out facilities-based benefits." Their conclusions are based on case-studies, though, not empirical analysis. Garcia-Murillo, *et al.* (2003) find in a 2001 cross-section of countries no effect of unbundling but positive effects of facilities-based competition.

Case-study approaches generally reach similar conclusions regarding unbundling regulations and broadband. Crandall (2005), for example, contends that the primary difference between the U.S. and Canada is that Canada had much less extensive unbundling regulations. Likewise, Korea did not require any unbundling until 2001.

Not everyone agrees that unbundling always has negative impacts, however. As discussed in more detail below, many credit Japan's strict enforcement of local loop unbundling for its high investment in broadband. Frieden (2004), comparing Canada, Japan, Korea, and the U.S., argues that it is the failure of U.S. regulators to fully open the RBOC's lines to competitors that caused the U.S. to fall behind in broadband penetration. However, Frieden offers no empirical analysis or other evidence supporting his argument.

One empirical study finds evidence supporting a positive correlation between unbundling and broadband in the U.S. Ford and Spiwak (2004) examine the correlation between the regulated rates for unbundled loops and the share of zip codes in a state with certain numbers of broadband providers. They find that states with lower regulated prices for local loop access have higher shares of zip codes with more providers.

Ford and Spiwak (2004) [FS] is similar to Aron and Burnstein (2003) [AB] in that they both explore the effects of local loop pricing on broadband. The dependent variable in FS, however, is the share of zip codes in a state with at least a certain number of broadband providers, while in AB the dependent variable is the number of subscribers in a state. AB have far more controls in their analysis than do FS. FS have a short panel (exactly how long is not clear) while AB have a cross-section. FS's panel may not be an advantage, though, since most of their variables, including their measuring of loop price, appear to cover only one time period.[4]

In sum, there is still debate about the effects of unbundling policies. Most economists and most studies conclude that unbundling in the U.S. reduced incentives to invest in high-speed

[4] Indeed, it is difficult to determine what, precisely, an observation is in the FS study. They include three time fixed effects and note that they have "semester" data, but do not indicate which variables vary over time. They also do not report the number of observations in the dataset, further complicating interpretation.

Internet infrastructure. Unbundling, however, comes in many forms and there is still much debate regarding what impact different types of unbundling may have on investment.

The outliers: Japan and Korea

Critics of the state of U.S. broadband typically point to Japan and Korea as prime counterexamples. Korea has among the highest penetration rates and available download speeds in the world. Broadband penetration in Japan is not especially impressive—it has only slightly more broadband users per capita than does the U.S., but has much faster available download speeds. Little research convincingly explains these differences. A few points, however, are noteworthy.

First, Japan and Korea are more densely populated than the U.S., reducing the relative cost of broadband investments there. Speta (2004) notes that

> Korea's population density is more than 16 times that of the U.S. (471 people per square KM versus 29). Nearly half of all Koreans live in cities of more than one million people, compared to 37 percent of Americans. And more than half of Koreans live in large apt buildings. This difference in multi-unit dwellings is particularly sharp, for roughly 75 percent of housing in the U.S. is in single-family structures, and only 3.2 percent of all housing units are in structures with more than 50 units.

That countries with higher population density than the U.S. would have faster broadband buildout is consistent with the literature on determinants of broadband penetration.

In addition to high population density, the Korean government has subsidized broadband investment. As Speta (2004) notes, the Korean government subsidized construction of the country's Internet backbone and provided subsidized loans to broadband providers. While true, no analysis (to my knowledge) rigorously explores the true impact—or magnitude—of those subsidies. Few U.S. broadband critics complain about the state of the Internet backbone in the U.S., which for more than a decade has been almost entirely privately owned (though the original Internet was built by the Defense Department's Defense Advanced Research Projects Agency and the backbone later run and managed by the National Science Foundation before being handed off to the private sector). In addition, Wallsten (2006) finds that some direct government provision of Internet services in the U.S. seems to have slowed penetration growth.

Notably, Korea did not require local loop unbundling until 2002, when Korea was already the world's leader in broadband connections per capita. In some ways, the lack of forced local loop unbundling spurred broadband investment. Korea Telecom (KT), the incumbent telecommunications company, long dominated traditional telephony. Thrunet was the first to offer broadband, and did so over cable. Hanaro wanted to enter the telephony market, but could not access KT's local loops while problematic number portability rules made consumers reluctant to switch.[5] Hanaro decided to offer broadband services as a way to entice consumers to switch, since at that time KT did not offer DSL service. KT began providing ADSL in 1999 (International Telecommunications Union 2003b). As a result, Koreans benefited from facilities-based competition and actual choices among a number of competing networks.

Some have suggested that Koreans have an especially strong demand for broadband-intensive applications. One survey showed that nearly 54 percent of all Korean Internet users used the Internet for games, second only to the share using it for "information searches" and more than the share that use it for email (National Computerization Agency 2005). Online games can require very large amounts of bandwidth, and would thus increase demand for broadband. International comparisons are difficult, as this survey did not include other countries. Nonetheless, while 54 percent of Korean users rated gaming as their second-most frequent use, a January 2005 survey by the Pew Internet and American Life Project found that only one-third of Internet users in the United States had ever played online games at all.

In 2002 the Korean Entertainment System Industry Association estimated that the Korean video game market—much of which involves online activity—was worth \$3.2 billion and expected it to increase to \$5.2 billion. By mid-2004 there were estimated to be about 28,000 "gaming parlors" around the country and three cable television channels devoted exclusively to gaming (Paul Budde Communications 2006b).

Finally, it is not clear that Korea's lead will last. Broadband penetration in Korea has barely changed over the past few years, and the country lost its first place ranking (to Iceland) according to the December 2005 OECD statistics. In addition, the full explanation for Koreans'

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[5] Consumers could take their telephone numbers to new competitors, but could not take their numbers back to KT. This rule discouraged consumers from trying new competitors for fear of being unable to return to KT.

switch to broadband is unclear. The number of *Internet* (as opposed to broadband) users per capita is similar in Korea and in the United States. In Korea, however, fewer than one percent of Internet users access the Internet through dialup connections while nearly half of all Americans go online that way (International Telecommunications Union 2005). It is not entirely clear what caused the shift from dialup. Part of the reason was the system of metered telephone calls, which increased the cost of dialup connections. But most other countries have metered telephone calls and no other country experienced a similar decline in dialup users. Even in Japan, more than half of Internet users still use dialup connections (International Telecommunications Union 2005). Perhaps, as discussed above, Koreans have a stronger taste for broadband than do others. Even so, the bottom line is that the broadband revolution in Korea succeeded in delivering broadband connections, but not in increasing the share of the population online relative to other countries.

Japan is held up as the prime example of the potentially positive effects of unbundling. The Japanese government mandated local loop unbundling in 1997, and in 2001 extended these regulations to include unbundling of fiber optic facilities, including FTTH (Umino 2004). Today, many firms compete to provide very high speed (up to 100 Mbps) broadband connections to consumers.

Other regulations particular to Japan make it difficult to know precisely the importance of unbundling there. For example, the government allows broadband providers to provide cable television services over their high-speed networks (Takada and Shinohara 2003). An amendment to the Telecommunications Business Law in 2004 made such provision possible by eliminating the distinction between facilities and service providers "in recognition of the convergence of wireline, wireless and cable technologies, platforms and networks" (Telecommunications Research Project 2003).[6] By contrast, in the United States firms wishing to offer cable television services over broadband lines must negotiate separately with each municipality. Given that broadband providers apparently expect large returns from such services in the U.S., it is plausible that the ability to provide cable TV services has stimulated broadband investment and adoption in Japan.

[6] The Telecommunications Research Project (2003) discusses this issue, but the regulation was not abolished until 2004 (http://www.ebusinessforum.com/index.asp?layout=newdebi&country_id=JP&country=Japan&channelid=6&title=Doing+e-business+in+Japan).

While available download speeds in Japan are, indeed, high, it is not clear if the Japanese approach will ultimately be considered successful. Yahoo!BB, the main broadband provider in Japan (in partnership with Softbank), consistently posted losses on its broadband investments, though it may begin turning a profit in 2006. While providers have been rolling out ever-faster service, it remains unclear how much consumers are really willing to pay for it. Shinohara (2005) observes that "So far, no killer application has emerged for these higher-speed ADSL services." Ida (2004) notes that no particular services exist to fully take advantage of the very high speeds and that broadband provision does not yet appear to be very profitable.

The issue of how particular policies are likely to affect broadband investment clearly remains largely unsettled. The remainder of this paper explores empirically the impacts of various regulatory policies on broadband in OECD countries.

3. Empirical Analysis

I combine data from the OECD and the International Telecommunications Union (ITU) to create an original dataset for analyzing the determinants of various broadband measures across countries. Both the OECD and the International Telecommunications Union (ITU) compile some cross-country broadband data over time. In particular, they both have estimates of broadband penetration (number of subscribers) by country-year. They also each collect information on available connection speeds, though the type of speed data they collect differs and cannot easily be analyzed in the form presented. I discuss the connection speed data in depth below.

Because there are so many ways to mandate unbundling, comparable data across countries are difficult to compile. Fortunately, a 2004 OECD report documents all OECD countries' experiences with unbundling (Umino 2004). In particular, it notes whether a country has implemented unbundling requirements, the type of unbundling (local loop, bitstream, or subloop unbundling), and the year in which the regulation came into effect, if at all. In addition, the report also notes the type of collocation required: caged, co-mingled, remote, and virtual. Finally, the report notes whether regulatory approval is required for line rental charges and for collocation charges.

The types of unbundling and collocation require further explanation.[7] The 2004 OECD report classifies three types of unbundling: local loop (LLU), bitstream, and subloop. LLU gives an entrant access to the copper wires that connect subscribers' homes. While the incumbent remains responsible for maintaining the wires, the competitor must invest in a good deal of its own infrastructure. Bitstream unbundling gives the competitor access to more of the incumbent's facilities. The competitor could still invest in some of its own infrastructure to provide differentiated services, but it could also lease much of the necessary infrastructure from the incumbent. Subloop unbundling is a much more "far reaching and complicated regulatory measure" (Umino 2004) than the other types of unbundling considered here. The extensive UNE-P system in the U.S., for example, included subloop unbundling. In other words, of the types of unbundling considered here, LLU is the least demanding in terms of regulatory obligations, bitstream more demanding, and subloop unbundling the most.

Collocation, which is how a competitor connects to the incumbent's network, is an important component of unbundling and can be accomplished in several ways.[8] Caged and co-mingled collocation are both physical connections to the incumbent's equipment. Umino (2004) notes

> Caged collocation can provide greater security for new entrants within their own separated space as well as for the incumbent within the building. Effective collocation requires that new entrants have easy access to their equipment in the incumbents' switching offices. Co-mingling is cheaper in terms of collocation, but if the incumbent insists on caged collocation, care must be taken that the space should be provided on a basis which does not treat new entrants in a discriminatory way in terms of cost.

Remote collocation involves placing competitors' equipment near the incumbent's location, while with virtual collocation "the new entrants' equipment is installed and maintained by the incumbent on its premises and new entrants do not have access to these premises."

The OECD has also been collecting data on broadband penetration since 1999. There is no single definition of broadband. The FCC defines it as speed of at least 200 Kbps in at least

[7] The definitions in this paragraph are largely derived from Umino (2004) and Maldoom, *et al* (2003).
[8] The descriptions in this paragraph are derived largely from Umino (2004).

one direction. The ITU initially defined it as speeds faster than "primary rate ISDN," though the OECD specified at least 256 Kbps as broadband (Paltridge 2001). This information, combined with other data from the ITU and elsewhere, should allow us to test the effects of unbundling laws on broadband development. In particular, I combine data from various sources to construct a panel dataset of 30 OECD countries over five years (1999-2003).

With these data I can explore the effects of unbundling by estimating versions of equation (1):

$$y_{it} = f(\boldsymbol{unbundling}_{it}, \boldsymbol{collocation}_{it}, \boldsymbol{price\ regulation}_{it}, \boldsymbol{Z}_{it}) + \gamma_i + \alpha_t + \varepsilon_{it} \qquad (1)$$

where y_{it} is broadband subscribers per capita, $\boldsymbol{unbundling}_{it}$ is a vector of three unbundling dummy variables (full unbundling, bitstream, and subloop), $\boldsymbol{price\ regulation}_{it}$ is a vector of two dummy variables representing types of wholesale price regulation in place (regulatory approval for line rental charges and regulatory approval for collocation charges), and $\boldsymbol{collocation}_{it}$ is a vector of dummies indicating the types of collocation implemented (co-mingling, remote, and virtual).[9] $\boldsymbol{Z}_{it}$ includes variables acting as demand-shifters, including the number of fixed telephone lines per capita and GDP per capita.

The panel nature of the data allows me to include two important additional controls. The first is year fixed effects to control for time trends, which is especially important given the extremely fast increase in broadband penetration over this time period. The second is country fixed effects, which controls for country-specific factors that affect broadband penetration.

I begin by estimating a simple ordinary least squares regression without any fixed effects. The first three columns of Table 1 show the results of this series of regressions. Full unbundling (LLU) is significantly positively correlated with broadband penetration. Including also bitstream and subloop unbundling changes the results somewhat: LLU remains positive and significant, bitstream is not statistically significant, and subloop unbundling is negative and significant. Including year fixed effects to control for the general increasing trend in broadband penetration has little impact on the other coefficients. This series of regressions seems to suggest that local loop unbundling is correlated with higher broadband penetration over time, while the more extensive subloop unbundling reduces growth in broadband penetration.

[9] I exclude caged co-location from the list because it exists in all OECD countries with unbundling except for Japan.

It is also noteworthy that the coefficient on population density remains significantly positive, and its magnitude is not much affected by the other variables. This result has two implications. First, population density explains a good deal of the variation in broadband penetration, which is not surprising: it is easier to connect people through wires, cables, or spectrum if they live closer together. Second, other country-specific factors that are not captured in the data may also be important, implying that the regressions should include country fixed effects in addition to year fixed effects.

Table 2 shows the results of a similar, but more extensive, set of regressions controlling for country and year fixed effects. Here, LLU by itself is not significant. The results on the LLU coefficient are, in general, ambiguous in this set of regressions. Under some specifications it is positive and significant, under some it is insignificant, and under one it is negative and significant. Bitstream access is positive, but is not always statistically significant. Subloop unbundling—the most extensive type of unbundling included here—is negative and statistically significant under all specifications.

Unbundling regulations typically coincide with other regulations on collocation and wholesale pricing. Including these additional regulation variables causes the coefficient on LLU to become insignificant (and in one case negative and significant), while bitstream access becomes just barely significant at the 10 percent level or insignificant. Subloop unbundling remains negative and significant. The coefficient on commingling is positively correlated with broadband penetration though it is insignificant in a few cases. Virtual collocation is negatively correlated with penetration. Regulatory approval of line rental charges is positively correlated with penetration though not always significantly, and approval of collocation charges is negatively correlated, though again, not always significantly.

Download speeds

Broadband penetration is only part of the debate. Another is the connection speed, as discussed above. Speed is more difficult to handle empirically than is penetration. Speeds vary across companies within a country and across plans offered by any given company, making it difficult to identify a variable that represents typical speed available in a country. Ideally, one would have detailed information on firms and plans at relatively small geographic levels. An OECD report does provide data at the firm-plan level (Paltridge and Matsui 2004). The publication includes information on plans offered by broadband providers in OECD countries, including provider, plan name, download and upload speeds, maximum monthly data transfer, and technology used (e.g., xDSL, Cable, Satellite, etc), and prices.

Unfortunately, the data have limitations that make it difficult to analyze at this disaggregated level. While the firms included in the list average nearly 80 percent of all broadband subscribers in each country, the data include no firm-level measure of coverage or demand.[10] The U.S., for example, includes the expected major broadband providers like Verizon, Comcast, and others, but also includes a company called "Wheatland Broadband." Wheatland provides wireless coverage in parts of rural Kansas and in April 2003 reportedly had about 1,000 customers.[11] Presumably the data for other countries include similarly small, non-representative firms. In addition, the number of firms listed is not consistent across countries and the number of available plans is not consistent across firms. As a result, it is inappropriate to analyze these data at the firm-plan level, though that type of analysis, if possible, would likely yield results that could be interpreted with more confidence

To compile a dataset that can be merged with the country-level policy variables, I collapse the firm-level information into a single observation for each country. In particular, for each country I calculate the median download speed and price of plans that allow at least 1Gb of monthly data transfer and are offered by incumbents. The 1Gb minimum data transfer is to ensure that the plans are broadly comparable in that they do not require large additional payments each month and to make these data consistent with other data provided by the ITU (discussed below).[12] Including only incumbents ensures that the plans are available to some reasonable segment of the population.

As a robustness check, I also use data on download speeds provided by the ITU (2003a). It is not completely clear how the ITU calculated representative speeds. While there is no precise description of their methodology, the ITU report notes that "prices were gathered looking for the most 'common' or cost-efficient broadband offer" (p. A-56). It also notes that plans had to offer close to 1 Gb of monthly data transfer. Presumably, the ITU's method for choosing representative download speeds is similar.

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[10] The most poorly represented country is Turkey, where the listed firms represent "60+" percent of subscribers, and the best represented is the Czech Republic, where the listed firms represent 96 percent of broadband subscribers.
[11] http://www.alvarion.com/RunTime/CorpInf_30130.asp?fuf=304&type=item
[12] Changing the minimum download criterion has no qualitative effect on the empirical results.

Consistent results across the two methods of identifying speed would lend additional credibility to the conclusions, though I cannot rule out the possibility that results would be similar if the ITU's methodology for calculating representative download speeds was similar to mine. Accounting for missing data, I end up with 29 observations (countries) using the data imputed from firm-plans, and 27 observations using ITU data.

One final, though relatively minor, problem is that download and upload speeds usually differ. I focus on download speeds because it is reported more regularly than upload speeds, and users often care more about download speeds because more data is generally transferred into a user's computer than out of it (indeed, for this reason download speeds are generally faster than upload speeds).

To analyze the data, I estimate equations similar to equation (1), with a few exceptions. First, in this case an observation is a country in 2003, rather than a country-year, so it is not possible to control for fixed effects. Second, the ITU published data on prices of dialup service by country.[13] Because dialup is a substitute (albeit imperfect) for broadband, I control for dialup prices in the speed equation. Third, because I have data on download speeds for only one year, I change the unbundling variables from dummies to years of unbundling, under the rationale that these regulations can be implemented on the ground slowly. One would thus expect them to have more of an effect the longer they have been in place.

Unlike the penetration results, which are sensitive to included and excluded variables, the speed results are broadly consistent across specification and across dependent variable source (Tables 3 and 4). No type of unbundling appears to affect download speeds. Some evidence suggests that regulatory approval for collocation charges is negatively correlated with download speeds. The only variable with consistent explanatory power is population density: denser countries have much faster typical download speeds.

4. <u>Discussion</u>

While this paper cannot fully explain what accounts for broadband differences across countries, a few results are robust. First, population density matters: it is positively correlated

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[13] Actually the cheapest price for 20 hours of Internet use, which presumably represents dialup charges. http://www.itu.int/newsarchive/press_releases/2003/30.html

with broadband penetration and with connection speeds. More densely populated countries have higher penetration rates, even controlling for country and year fixed effects. Second, regulations also matter, and some appear to be beneficial while others are harmful. Full local loop unbundling is not obviously correlated with broadband penetration. Its estimated coefficient ranges from positive and significant to negative and significant depending on the specification. Subloop unbundling—the most extensive type of unbundling studied here—is robustly negatively correlated with broadband penetration. Commingling collocation is generally positive, virtual collocation negative, and regulatory approval for collocation charges negative. Regulatory approval for collocation charges may have a negative effect on typical download speeds, if we assume causality.

Subloop unbundling, the most extensive form of unbundling examined here, probably gives companies wishing to gain access to the incumbents' lines the most flexibility in how to do so. In other words, of the types of unbundling considered here, subloop unbundling gives the greatest relative advantages to new entrants and the greatest obligations on the incumbents. The results suggest that these extensive obligations on the incumbent reduce broadband penetration. These results support opponents' view of unbundling by suggesting that extensive unbundling (like the sort mandated in the U.S.) has a deleterious effect on broadband investment.

Likewise, if regulators price collocation charges below cost, then the incumbents have little incentive to upgrade equipment when they have to provide access at a loss.
These results suggest that regulating the prices that incumbents charge for collocation slows the growth of broadband penetration.

Other results, however, suggest that regulation can also be an important tool in promoting broadband adoption. Rules that might be interpreted as making it more difficult for the incumbent to exercise market power—but without putting the incumbent at a disadvantage—seem to foster broadband adoption. Consider the collocation results. An incumbent has every incentive to increase the costs to any competitor wishing to connect to its network. Collocation rules can mitigate this problem or make it easier for the incumbent to act on the incentive. Indeed, this result is consistent with the Japanese experience. The incumbent, NTT, was slow both to open its lines to competitors, even though it was required to, and to offer DSL services (Paul Budde Communications 2006a). When first ordered to share its facilities, it created high entry barriers: only a limited amount of space in a limited number of offices was available for collocation. Investment in broadband began to increase once NTT was forced by the Ministry of Posts and Telecommunications to open all of its central offices to collocation in 2000.

Commingled collocation is typically the least expensive way for a competitor to connect to the incumbent's network, as the competitor's equipment is placed with the incumbent's, rather than in a physically separate space. Competitors should prefer this type of collocation because it reduces their costs, while incumbents may dislike it because it gives competitors better access to the incumbents' equipment. The results here suggest that countries that require commingling collocation see faster broadband adoption while countries that allow virtual collocation see slower broadband adoption. That is, broadband penetration grew more quickly in countries that allow competitors to keep their costs down by requiring incumbents to allow commingled collocation.

With virtual collocation, the incumbent is responsible for installing and maintaining the competitor's equipment, but the competitor has no access to this equipment. Such an arrangement gives the incumbent real advantages over an entrant, who has no control over his equipment. Countries that allow virtual collocation experienced slower growth in broadband penetration than countries that did not.

One general interpretation of these empirical results is that regulations that can reduce returns to investment (more extensive unbundling) or increase costs to entrants (allowing incumbents to insist on off-site collocation) reduce broadband investment. In other words, market rules that keep costs low but allow firms to earn returns on investments are good for broadband growth.

This paper does not, of course, include all possible explanations of broadband differences. For example, Chaudhuri and Flamm (2005) find that dialup and broadband service are (imperfect) substitutes—lower prices for dialup Internet service reduce demand for broadband. While I include dialup prices in the speed equations, I do not have time series data on dialup prices across countries, so cannot control for it in the penetration equations. This substitutability leads to a third possible explanation for differences between broadband adoption in U.S. and other countries.

In particular, in many other countries local telephone service was metered, while unlimited local calling for a flat rate has long been available in the U.S. It thus remains less expensive to have dialup service and use the Internet than in other countries. In addition, dialup providers have continued to compete for consumers in the U.S. through lower prices and improvements such as “accelerators,” which makes Internet content available to end-users more quickly than a standard dialup connection would otherwise allow. This competition and innovation, while good for consumers, is likely to suppress broadband adoption.

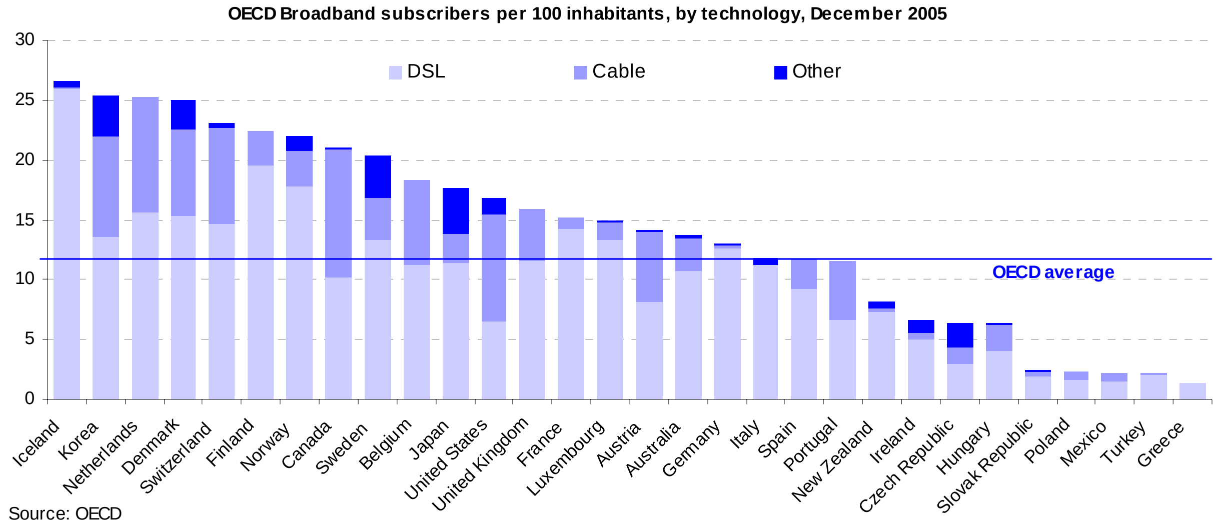
Indeed, according to data from the Pew Internet Project, even in January 2005 nearly half of all Internet users in the U.S. still used dialup modems to access the Internet.[14] A survey by Parks Associates, meanwhile, finds that about 80 percent of narrowband (dialup) subscribers have no intention of upgrading to broadband. And nearly one-third of people without Internet access at home claim not to subscribe because they have access at work.[15]

In other words, some Americans do not subscribe to broadband services because they are content with narrowband services or because they have adequate Internet access elsewhere. While I have no information on how these survey data compare to similar evidence in other countries, it is clear that some Americans do not have broadband simply because they do not want it, not because they cannot afford it or because it is not available.

Finally, economists generally agree that U.S. broadband investment has been slowed by inefficient local regulations and spectrum policy (Bailey*, et al.* 2006). It is true that most broadband users around the world use either DSL or cable technologies. Nonetheless, Hazlett (2004) notes that many European countries have allocated far more spectrum to mobile wireless technologies than has the U.S. It is possible that this lack of available spectrum in the U.S. has slowed the development of competition, keeping broadband availability artificially low.

[14] Pewinternet.org Jan 2005 tracking crosstabs.doc
[15] http://www.clickz.com/stats/sectors/demographics/article.php/3587496 (Accessed March 25, 2006).

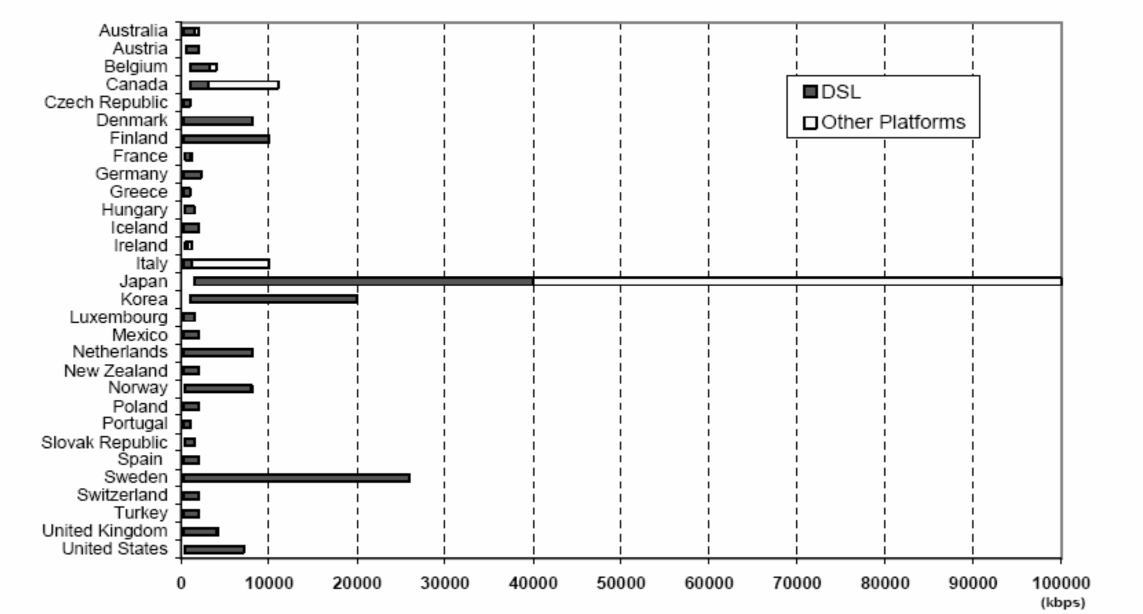
Figure 1



http://www.oecd.org/document/39/0,2340,en_2649_201185_36459431_1_1_1_1,00.html

Figure 2
The Range of Capacity across all Offers/Platforms in OECD (2004) Report

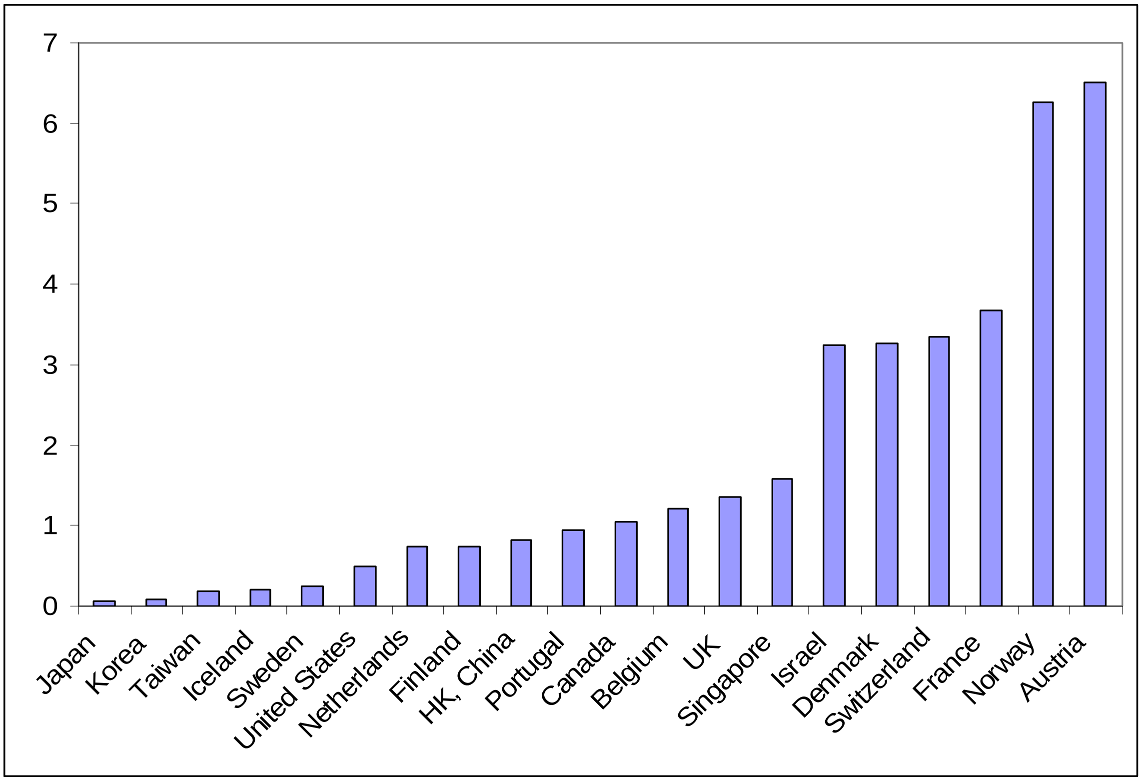
As of October 2003*



Source: Paltridge and Matsui (2004), Figure 1

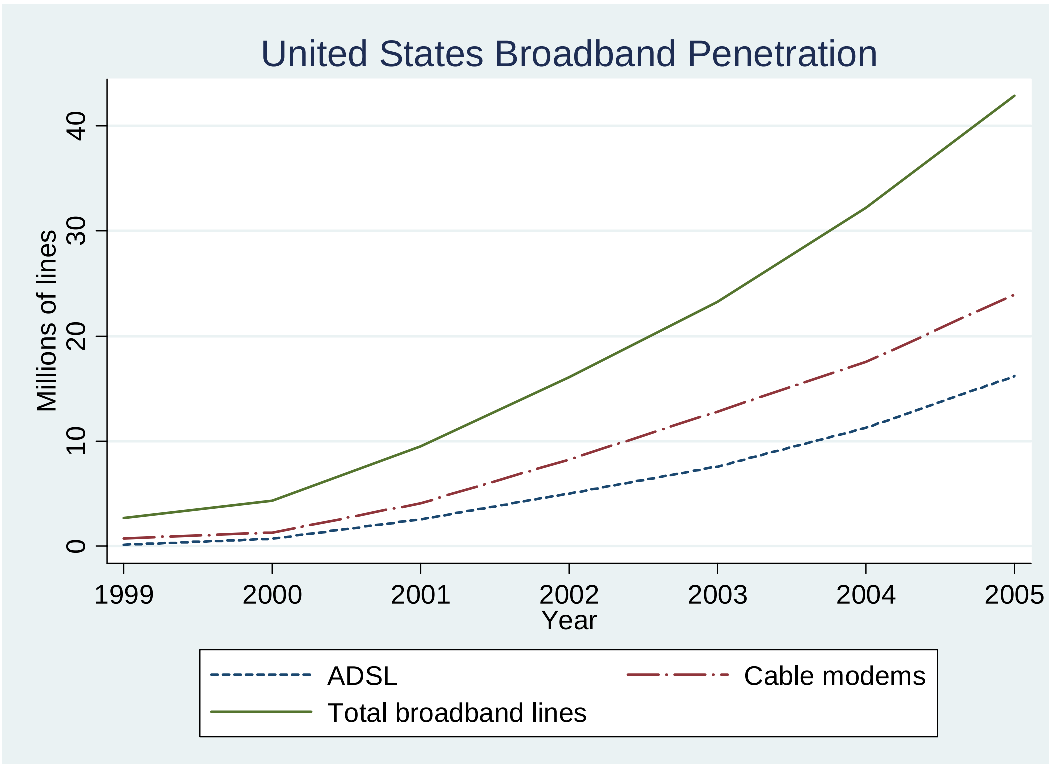
* Available speeds in the U.S. have increased substantially in the past two years. Download speeds up to 10 Mbps are often available from cable broadband providers, and Verizon's FiOS service offers speeds up to 30 Mbps.

Figure 3
Broadband prices, selected OECD Countries
USD per 100 kbps



Source: ITU (2005), Table 8.
Note: The ITU's method of calculating these prices is not immediately transparent. It appears to be the best price/speed combination available. The report notes that the "Lowest sampled cost US$ per 100 kbit/s gives the most cost-effective subscription based on criteria of least cost per 100 kbit/s." The report does not mention whether these prices should necessarily be considered indicative of prices available to large segments of the population.

Figure 4
Broadband Penetration in the U.S.



Source: FCC, "High Speed Services for Internet Access," various years.
http://www.fcc.gov/wcb/iatd/comp.html

Table 1
Broadband Penetration and Unbundling
No fixed effects

Dependent variable: Broadband subscribers per 100 people			
Mean of dependent variable: 3.9			
Full LLU	2.522	2.418	4.491
	(2.94)**	(2.33)*	(4.13)**
Bitstream access		0.159	0.728
		(0.18)	(0.86)
Sub-loop unbundling			-4.083
			(4.51)**
Main telephone lines per 100 people	-7.934	-7.890	-11.736
	(2.03)*	(2.01)*	(3.07)**
GDP per capita	2.01	2.02	2.66
	(4.21)**	(4.20)**	(5.57)**
Population per square kilometer	0.011	0.011	0.011
	(3.80)**	(3.80)**	(3.90)**
Constant	0.229	0.210	0.929
	(0.16)	(0.15)	(0.69)
Observations	179	179	179
R-squared	0.27	0.27	0.35
Fixed effects		None	

Number of cntrycod
Absolute value of t statistics in parentheses
+ significant at 10%; * significant at 5%; ** significant at 1%

Table 2
Broadband Penetration and Unbundling
Country and year fixed effects included

Dependent variable: broadband subscribers per 100 people Mean of dependent variable: 3.9													
Full LLU mandated	0.395	-1.232	4.891	3.133	-1.115	-3.790	2.747	3.532	1.047	0.895	1.080	0.632	0.982
	(0.47)	(1.06)	(3.80)**	(2.41)*	(0.81)	(2.29)*	(2.12)*	(2.17)*	(0.46)	(0.39)	(0.46)	(0.28)	(0.43)
Bitstream access mandated		2.718		5.314			2.805	2.185	3.818	3.543	3.825	1.199	1.684
		(1.98)*		(4.03)**			(1.55)	(1.11)	(1.79)+	(1.67)+	(1.66)+	(0.54)	(0.71)
Sub-loop unbundling mandated			-6.339	-8.345			-8.515	-8.583	-8.119	-7.808	-8.371	-4.950	-5.962
			(4.42)**	(5.75)**			(5.92)**	(5.95)**	(5.40)**	(5.18)**	(3.60)**	(2.76)**	(2.47)*
Co-mingling collocation implemented					3.399	3.713	3.618	4.044	2.897	3.054	2.806	5.437	5.018
					(2.44)*	(2.72)**	(2.00)*	(2.14)*	(1.46)	(1.55)	(1.32)	(2.59)*	(2.27)*
Regulatory approval for line rental charges?						5.683			1.610	3.538	3.302	4.587	4.158
						(2.81)**			(0.91)	(1.65)	(1.45)	(2.16)*	(1.86)+
Regulatory approval for collocation charges?					-0.675	-3.865		-1.077		-2.586	-2.524	-3.789	-3.698
					(0.49)	(2.21)*		(0.80)		(1.60)	(1.54)	(2.31)*	(2.24)*
Virtual collocation implemented												-4.467	-4.573
												(2.80)**	(2.84)**
Remote collocation implemented											0.638		1.223
											(0.32)		(0.63)
Main telephone lines per 100 people - ITU data	-20.036	-21.759	-19.539	-22.751	-21.981	-21.353	-23.286	-23.037	-23.389	-22.913	-22.718	-22.431	-22.047
	(2.71)**	(2.95)**	(2.81)**	(3.42)**	(3.00)**	(2.98)**	(3.54)**	(3.49)**	(3.55)**	(3.49)**	(3.44)**	(3.50)**	(3.42)**
GDP per capita (divided by 10m)	3.66	3.64	4.00	4.09	3.23	3.26	3.60	3.62	3.64	3.73	3.75	3.81	3.84
	(3.87)**	(3.90)**	(4.49)**	(4.83)**	(3.38)**	(3.50)**	(4.14)**	(4.15)**	(4.17)**	(4.29)**	(4.28)**	(4.49)**	(4.51)**
Constant	9.180	10.017	5.940	8.877	7.202	10.994	5.381	6.599	8.551	10.065	9.870	7.881	9.273
	(1.95)+	(2.14)*	(1.36)	(2.10)*	(1.63)	(2.38)*	(1.35)	(1.66)+	(2.04)*	(2.37)*	(2.29)*	(1.94)+	(2.21)*
Observations	179	179	179	179	179	179	179	179	179	179	179	179	179
R-squared	0.72	0.73	0.75	0.78	0.73	0.75	0.79	0.79	0.79	0.79	0.79	0.80	0.80
Number of countries	30	30	30	30	30	30	30	30	30	30	30	30	30

Absolute value of t statistics in parentheses
+ significant at 10%; * significant at 5%; ** significant at 1%

Table 3
Download speed and unbundling
Speed derived from firm-plan data

Dependent variable: Download speed Mean of dependent variable:	1	2	3	4	5	6	7	8
Number of years of LLU	355.577			755.715	503.246	520.031	462.278	781.739
	(0.77)			(1.46)	(0.93)	(0.98)	(0.80)	(1.22)
Number of years of bitstream unbundling		-425.024		-781.142	-756.287			-823.973
		(0.96)		(1.58)	(1.55)			(1.62)
Number of years of subloop unbundling			834.120		755.402			783.646
			(1.60)		(1.35)			(1.22)
Co-mingling collocation implemented						2,210.805	1,929.248	1,224.288
						(1.20)	(0.91)	(0.58)
Regulatory approval for collocation charges?						-939.664	-1,639.908	-2,508.082
						(0.49)	(0.53)	(0.84)
Regulatory approval for line rental charges?							1,106.530	687.173
							(0.29)	(0.19)
Main telephone lines per 100 people	-125.998	-122.409	-67.102	-116.988	-63.748	-125.237	-143.714	-65.113
	(1.15)	(1.12)	(0.60)	(1.10)	(0.57)	(1.13)	(1.11)	(0.48)
GDP per capita	0.180	0.223	0.077	0.161	0.061	0.125	0.162	0.043
	(1.15)	(1.49)	(0.46)	(1.06)	(0.37)	(0.76)	(0.77)	(0.20)
Population per square kilometer	17.386	17.951	16.926	16.481	15.941	16.968	16.530	15.959
	(2.77)*	(2.91)**	(2.81)**	(2.70)*	(2.65)*	(2.64)*	(2.45)*	(2.48)*
Price of 20 hours of Internet use, presumably dialup	-84.741	-109.300	-99.017	-64.130	-72.580	-43.373	-63.654	-47.727
	(0.65)	(0.87)	(0.81)	(0.51)	(0.58)	(0.32)	(0.41)	(0.32)
Constant	3,248.223	3,958.828	2,454.967	3,013.501	2,182.255	2,717.703	3,294.228	1,940.619
	(0.71)	(0.88)	(0.55)	(0.68)	(0.50)	(0.58)	(0.64)	(0.39)
Observations	29	29	29	29	29	29	29	29
R-squared	0.32	0.33	0.37	0.39	0.44	0.37	0.37	0.49

Absolute value of t statistics in parentheses
+ significant at 10%; * significant at 5%; ** significant at 1%

Table 4
Download speed and unbundling
Speed from ITU

Dependent variable: Download speed Mean of dependent variable: 2540 Kbps	1	2	3	4	5	6	7	8
Number of years of LLU	134.477			392.024	154.332	476.075	359.908	715.349
	(0.24)			(0.59)	(0.22)	(0.74)	(0.53)	(0.91)
Number of years of bitstream unbundling		-290.105		-485.398	-500.771			-860.470
		(0.53)		(0.75)	(0.78)			(1.31)
Number of years of subloop unbundling			749.997		808.728			1,152.682
			(1.14)		(1.11)			(1.36)
Co-mingling collocation implemented						3,328.788	2,537.584	1,150.257
						(1.54)	(1.01)	(0.44)
Regulatory approval for collocation charges?						-2,027.562	-4,334.551	-7,607.103
						(0.83)	(1.01)	(1.66)
Regulatory approval for line rental charges?							3,317.648	4,521.791
							(0.66)	(0.91)
Main telephone lines per 100 people	-185.944	-177.498	-115.136	-165.412	-89.746	-158.692	-192.230	-20.748
	(1.24)	(1.18)	(0.72)	(1.07)	(0.53)	(1.04)	(1.18)	(0.11)
GDP per capita	0.303	0.311	0.161	0.263	0.119	0.176	0.246	-0.032
	(1.29)	(1.38)	(0.62)	(1.08)	(0.43)	(0.72)	(0.91)	(0.10)
Population per square kilometer	29.084	29.206	28.125	28.332	27.475	28.421	26.873	24.953
	(3.81)**	(3.88)**	(3.79)**	(3.64)**	(3.53)**	(3.76)**	(3.34)**	(3.16)**
Price of 20 hours of Internet use, presumably dialup	-344.025	-342.199	-310.092	-300.467	-270.961	-229.720	-244.841	-78.339
	(1.60)	(1.63)	(1.49)	(1.33)	(1.20)	(1.01)	(1.05)	(0.32)
Constant	8,331.588	8,421.427	6,506.697	7,464.794	5,682.095	6,288.153	6,803.664	1,532.213
	(1.26)	(1.30)	(0.99)	(1.10)	(0.82)	(0.94)	(0.99)	(0.21)
Observations	27	27	27	27	27	27	27	27
R-squared	0.45	0.46	0.48	0.47	0.50	0.52	0.53	0.61

Absolute value of t statistics in parentheses
+ significant at 10%; * significant at 5%; ** significant at 1%

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