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Whence Competition in Network Industries?
Broadband and Unbundling Regulations in OECD Countries

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December 2007

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Abstract

Policymakers generally hope to encourage competition, but often do not agree on what form competition should take. In network industries with high sunk costs and low marginal costs some believe that competition is best encouraged by requiring incumbent firms to allow entrants to use the incumbent's infrastructure to offer competing services. Others argue that such rules can discourage investment in that infrastructure. In telecommunications, these so-called "unbundling" regulations are controversial. The original unbundling controversy was concerned with voice communications, but now focuses on broadband. While the United States has moved away from unbundling regulations in recent years, the European Union has increasingly adopted them in order to stimulate broadband investment.

This paper assembles a unique panel dataset to test the effects of different types of unbundling regulations on broadband penetration and speeds. I find that unbundling regulations do not promote broadband investment and may even reduce it. I also find, however, that complementary collocations regulations—rules on how entrants can interconnect with the incumbent's network—matter. Rules that make it easier for an entrant to interconnect are positively correlated with broadband penetration and speed while rules that make it more difficult to interconnect are negatively correlated with penetration and speed.

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I. Introduction

Competition is the essence of a market economy. It generates economic growth, technological change, and overall welfare improvements. It is now considered a primary driver of investment even in industries once considered natural monopolies, like telecommunications.[1] But what is the source of competition? Identifying competition is often not straightforward. Most antitrust cases, for example, begin with a detailed discussion of the correct market definition and of which firms compete in those markets. Such cases focus in particular on how competing firms will react to, say, a merger and how the merger is likely to affect entry of new firms.

In some industries, it is especially difficult to determine the type of entry necessary to create market discipline and encourage innovation and investment. In network industries with high sunk costs and low marginal costs competition can come from at least two sources. One source includes competing infrastructure or platforms. As in other industries, competitors enter the market by investing in capital and labor. But in many network industries the sunk cost of capital may represent a high barrier to entry. Thus, a second source of competition includes competing services on the same platform. For example, some consumers can choose a preferred electricity generator, which then delivers its power over the incumbent utility's wires. Similarly, consumers may choose a telephone service offered by an alternate provider using the incumbent's lines. Intra-platform competition often requires regulatory intervention to compel the incumbent infrastructure operator to allow competitors to access its network.

Mandating access to a firm's infrastructure can have two possible—and opposing—effects. It could introduce competition by giving additional firms access to consumers. Such access could stimulate price and service competition among the firms jockeying to serve customers on the same platform. Policymakers sometimes hope that mandatory access regulations will provide a "stepping stone" for entrants to build a subscriber base and then invest in their own facilities. On the other hand, forcing an incumbent to lease access to its facilities at regulated rates could reduce incentives to invest in the infrastructure, ultimately reducing total welfare. As a result, the debate over whether government should mandate such access and, if so, to what extent, remains unresolved.

[1] See, for example, Stiglitz (1999).

In telecommunications this debate has focused on what type of access competitors should have to an incumbent's infrastructure. So-called "unbundling" regulations generally require incumbents to make their facilities available to competitors at regulated rates. While the U.S. has been moving away from mandatory unbundling in recent years, other OECD countries are increasingly adopting it. Unbundling regulations have traditionally been debated with respect to voice communications. Today, however, the debate has extended to the role of unbundling in the development of high-speed Internet, or broadband, connections.

This paper explores the effects of unbundling regulations on broadband development, improving on existing work in several ways. First, it recognizes that there are many types of unbundling regulations and explicitly incorporates these differences into an empirical analysis of panel data. Second, it explicitly incorporates the reality that complementary regulations may be necessary for unbundling to be effective. Third, 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, a crucial outcome of investment. Finally, it uses two different estimates of broadband penetration to test the robustness of results. It uses data from the OECD on the number of broadband connections and survey data on household penetration.

Overall, I find no evidence that unbundling promotes either broadband penetration or speed. One type of unbundling, subloop unbundling, is negatively correlated with broadband penetration, suggesting that unbundling could harm broadband development. Interconnection (collocation) regulations also matter. Requiring incumbents to allow competitors to connect their equipment directly to the incumbent's is positively correlated with broadband penetration and speed. Contrarily, making it more difficult for a competitor to interconnect (through "virtual collocation") is negatively correlated with penetration and speed.

II. Broadband Overview

Simple comparisons across countries do not provide much useful information. A better way to evaluate broadband is to empirically control for factors policy cannot change, like population density, and test the effects of factors that policies might affect. 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.

First, as one would expect, population density is a strong predictor of broadband penetration since more densely populated areas are less costly to serve. Korea, for example, achieved high levels of broadband penetration more quickly than any other country. 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.

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 that conclusion is controversial. 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.

There is little research on the effectiveness of government policies in promoting broadband. For example, the Korean government offered financial incentives to promote 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 Internet 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.

In sum, relatively uncontroversial factors affecting broadband penetration include population density, income, and facilities-based competition. Few government policies in the U.S. appear to have had robust impacts. Flamm (2005) found that the eRate program, intended to help connect schools and libraries to the internet, had little effect 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 contributed somewhat to broadband expansion, but the data made it impossible to determine whether those investments were cost-effective. Nonetheless, these 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]

III. Unbundling

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. Unbundling policies first focused on voice telecommunications, but have more recently targeted broadband as countries look for ways to increase competition for high speed Internet connections.

Because "unbundling" comes in so many different forms, 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

[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.

has implemented unbundling requirements, the type of unbundling, and the year in which the regulation came into effect, if at all.[3]

This paper focuses on three types of unbundling: local loop unbundling (LLU), sub-loop unbundling (SLU), and bitstream unbundling. Each type of unbundling, described below, requires different types of investment by an entrant and different types of cooperation from the incumbent.

LLU is probably the most common type of mandatory unbundling (Figure 1). LLU unbundling generally requires the firm that owns the copper lines connecting customers' premises to allow other firms to provide competing services over those lines, typically at regulated rates. LLU gives entrants access to the 'last mile,' but to offer broadband services the entrant must still invest in its own equipment. In particular, to offer DSL service over the copper loop it must install a DSLAM (digital subscriber access line), which receives the data signals from customers and transfers those signals to an Internet backbone. In order to serve customers an entrant must also gain access to the incumbent's local exchange facility.

Unlike LLU, in which an entrant makes use of the entire copper loop, with SLU "other operators can interconnect with the local access network at a point between the incumbent's site and the end user."[4] Under SLU, the entrant installs its equipment at the "primary connection point," which is generally a small box on the street close to the customer (Figure 2). Ofcom notes that "Sub-loop unbundling can be used for emerging technologies such as VDSL where the equipment needs to be much closer to the home to deliver very high bandwidth services. An optical fibre would deliver the high-speed services to the local green cabinet and VDSL used to send them along the copper pair to the consumer's premises." Umino (2004) notes that subloop unbundling is a more "far reaching and complicated regulatory measure" than LLU.

SLU is likely to be more complicated than LLU because of the expense and difficulty of connecting to the primary connection point (PCP). A PCP is typically a small box by the side of a street. Each PCP serves a relatively small number of people, meaning that an entrant must connect to a large number of PCPs if it wants to build a good-sized subscriber base. In addition, the entrant may not be able to collocate in the PCP itself, depending on the PCP's size and the number of other entrants also wishing to connect. In that case it may have to build its own PCP

[3] We searched for any changes to unbundling regulations that have occurred since the Umino (2004) publication and updated the data accordingly.
[4] http://www.ofcom.org.uk/static/archive/oftel/publications/broadband/dsl_facts/LLUbackground.htm

box nearby, which then must connect to the incumbent's. Some estimate that sub-loop unbundling is unlikely to be profitable for an entrant, regardless of regulated access prices (Analysys Consulting 2007;Spiller and Ulset 2003).

Bitstream unbundling differs from the full- or sub-loop unbundling in that it requires less investment by the entrant and more cooperation from the incumbent. The New Zealand Ministry of Economic Development (2004) noted that

> The main difference between copper based unbundled access and bitstream based unbundled access is the provisioning of the DSLAM. In the case of copper circuit unbundled access the DSLAM connected to the unbundled circuit is always installed and operated by the new entrant. In the case of bitstream access, the DSLAM is installed and operated by the incumbent who also configures the DSLAM and sets up the required technical parameters (speed and QOS attributes) of each user's DSL access link.

In other words, bitstream unbundling gives the competitor access to more of the incumbent's facilities than do the other types of unbundling considered here.

One justification for 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 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 without 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.

Unbundling and Broadband

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 made it less likely that broadband providers will 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. Verizon's FiOS fiber optic service, for example, can currently sustain speeds up to 100Mbps to end-users' homes in some markets and, unlike most DSL or cable connections, can offer symmetric download and upload speeds.

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 "Competition based on bitstream access and/or resale cannot bring about all these benefits, and risks crowding out facilities-based benefits." Yet their conclusions are based on case-studies, 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 less extensive unbundling regulations. Likewise, Korea did not require unbundling until 2001.

Not everyone agrees that unbundling always has negative effects, 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.[5]

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

[5] Frieden does not test his thesis empirically.

broadband providers. They find that states with lower regulated prices for local loop access have higher shares of zip codes with more providers.

Japan and France: Unbundling Success Stories?

Because the world broadband situation changes so quickly, it is worth discussing recent developments in unbundling that have not yet been subject to rigorous investigation. Some countries, notably France and Japan, have used unbundling regulations to promote broadband. And some measures suggest their efforts have been successful. While the U.S., Japan, and France have similar levels of broadband penetration, consumers in France and Japan generally have access to services that advertise much faster speeds than are available in the U.S. Critics of U.S. policies often cite unbundling as a crucial factor in this difference.[6] Indeed, in France, nearly half of all DSL lines are sold via unbundled loops or bitstream,[7] while in Japan more than half of all DSL lines are unbundled. Although unbundling policies were clearly important in encouraging competition over the incumbent's existing copper lines, the details paint a more complicated picture.

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). Softbank was among the most successful users of unbundling policies, amassing nearly 40 percent of the DSL market and 20 percent of the entire broadband market by 2007 through its Yahoo!BB brand (Softbank 2007). It advertises download speeds up to 50 Mbps.

The story with fiber, which is beginning to supplant DSL in Japan (Figure 3), is different. While providers are required to give competitors access to their fiber, the regulated price for a fiber loop is higher than for a copper loop. The current (2007) regulated price for a fiber loop is ¥5,074 (about $40) per month, while the price for a copper loop is about $15 per month.[8]

Perhaps as a result of these higher loop prices, nearly all fiber connections are provided by facilities-based carriers using their own lines. The incumbent telecommunications company,

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[6] See, for example, http://www.thinkbroadband.com/news/3185-14-25-million-broadband-subscribers-in-france.html.

[7] http://globaltechforum.eiu.com/index.asp?layout=rich_story&doc_id=10300&title=France%3A+Unbundling+FT%3F&channelid=4&categoryid=29

[8] Slide 26, www.itu.int/osg/spu/ngn/documents/presentations/**seki**-23-march-2006.ppt

NTT, and the electric power utilities are the main providers of residential fiber broadband. As of the end of 2006, NTT provided 67.5 percent of FTTH lines, electric utilities provided 14.6 percent, and the cable company USEN provided 6.7 percent.[9] Thus, while unbundling played an important role in bringing DSL service to Japanese consumers, to date it appears to be largely irrelevant in competition for fiber broadband services.

Other regulations particular to Japan make it difficult to know precisely the importance of unbundling regulations. 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).[10] In 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.

French regulators have also used unbundling as a tool to promote broadband, and new entrants have taken advantage of these regulations to provide DSL service. Companies including France Telecom, Free, and Neuf Cegetel are beginning to lay fiber to offer faster broadband connections to consumers.[11] Unbundling regulations currently apply only to copper, not to fiber, although the French regulator has announced its intention to apply unbundling rules to fiber.[12] The main point here is that while unbundling may have been a factor in stimulating DSL, it has not been a factor in fiber investments.

The French experience to date alone leads to ambiguous conclusions. Unbundling proponents might conclude that France is witnessing a successful version of the "stepping stone" theory—new entrants used unbundling rules to build subscriber bases and then began to invest in

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[9] http://www.stat.go.jp/english/data/figures/zuhyou/1608.xls

[10] 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).

[11] See, for example, http://news.bbc.co.uk/2/hi/technology/6936325.stm. It is unclear, however, exactly how much fiber has actually been installed to date (http://www.zdnet.fr/actualites/telecoms/0,39040748,39376497,00.htm).

[12] http://lw.pennnet.com/display_article/293410/63/ARTCL/none/none/European-trends-favour-FTTX/

their own facilities. Opponents of unbundling would note that new investment is occurring, as they would predict, in the infrastructure that is not subject to sharing regulations.

Korea is also known as a broadband success story, and some attribute that success to unbundling policies. While unbundling policies undoubtedly stimulated growth of DSL in France and Japan, such attribution may not be warranted for Korea. 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.[13] Hanaro decided to offer broadband services as a way to entice consumers to change providers, since at that time KT did not offer DSL service. KT began providing ADSL in 1999 (International Telecommunications Union 2003). As a result, Koreans benefited from facilities-based competition and actual choices among a number of competing networks.

In short, the unbundling debate remains unresolved.

Collocation

Certain complementary regulations are necessary for unbundling to have any chance of success. As Figure 1 and Figure 2 show, competitors must also be able to connect their equipment to the incumbent's network. The way in which the entrant connects with the incumbent is governed by collocation regulations. Collocation can be accomplished in different ways. The OECD collects information on different types of collocation regulations across OECD countries.[14] In particular, the OECD notes whether a country has implemented caged, co-mingled, remote, and virtual collocation.

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

[13] 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.
[14] The descriptions in this paragraph are derived largely from Umino (2004).

> 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" Umino (2004).

Price Regulation

Unbundling regulations are not likely to be meaningful without regulated prices since an incumbent could deny an entrant access simply by setting a high price for the unbundled network elements. How to set those prices will always be controversial. The incumbent has an incentive to claim that its costs are high in order to guarantee a higher price and entrants have an incentive to argue that the costs are low so that they can buy cheap wholesale access. Indeed, Spiller and Ulset (2003) note

> A naïve reader of regulatory proceedings may come to the conclusion that opportunistic behavior characterizes incumbents and not entrants. More often than not, it is the incumbent who is accused of regulatory misconduct. These accusations have some theoretical support. Since the incumbent has significantly more to lose and therefore more to hide than the entrant, the incumbent will also have stronger incentives and more opportunities to behave opportunistically...
>
> New entrants, however, have similar incentives to behave opportunistically vis-à-vis the regulator. Since it is normally difficult to ascertain costs and behavioral intent, new entrants will have all the incentives to claim misconduct by the incumbent as well as overcharge. New entrants will use regulatory threats as leverage to achieve better performance by the incumbent. Although the use of regulatory threats is not costless, costs fall unevenly on the incumbent and the regulator, rather than the new entrant. Incumbents must show that their costs are proper, that their conduct is flawless. Entrants must show none of the above. Faced, then, with opportunistic behavior by new entrants, the optimal strategy for incumbents is to behave similarly. Thus, opportunism is the dominant strategy of both entrants and incumbents. p.17

Development of the telecom network can depend crucially on these regulated prices. On one hand, the lower the regulator sets the price, the less incentive the incumbent has to invest in the network. On the other hand, the higher the regulator sets the price, the less likely it is that an entrant can be competitive.

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

III. Empirical Analysis

I combine data from many sources to create an original dataset for testing the effects of unbundling policies on broadband. The OECD compiles information from country regulators and broadband provides on the number of DSL, cable, and, more recently, fiber connections in each country over time. Data on household penetration come from a number of sources, including the European Commission and the Pew Internet and American Life Foundation. Data on broadband speeds are from speedtest.net. Data on unbundling and collocation policies come from Umino (2004) and updated through 2006.

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 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). I combine data from various sources to construct a panel dataset of 30 OECD countries over five years (1999-2003).

Summary statistics

Before proceeding to the model it is useful to consider summary statistics of the most important variables. Table 1 shows some of the time series for OECD broadband penetration. The table reveals the fast increase in the number of connections in nearly all countries. Data on household penetration are more difficult to compile, as discussed. Table 2 shows the data on household penetration. The countries’ relative positions differ substantially depending on the metric. For example, the United States is fifteenth among OECD countries in total penetration per capita, but seventh in household penetration.[15]

Finally, another indicator of broadband development is speed, usually measured as a flow rate in bits per second. It is not obvious, however, how best to measure speeds at a country level.

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[15] The U.S. may, in fact, be fourth in household penetration. Some surveys showed the U.S. with more than 50 percent household penetration by 2007.

Most countries have several broadband providers and each offers different plans with different speeds. The OECD handles the issue by presenting the average of advertised speeds in each OECD country, as well as the fastest speed available by the incumbent operator. One problem with the OECD's approach is that the average is unweighted—that is, it does not reflect the share of consumers that could access services with such speeds. Another problem is that the speeds consumers receive may differ from the advertised speed. One study found that the higher the advertised speed, the bigger the gap between the advertised and actual speed (Kende 2006).

One alternative is to use data on the actual speeds consumers obtain. Such data are available from speedtest.net, a website on which consumers can test the speed of their connections.[16] Unfortunately, the data are available only for 2006, meaning that the empirical analysis will be cross-sectional. Figure 4 shows the average of the tests from users in each country. The figure shows that Japan has the fastest connections, at over 10 megabits per second (Mbps) on average, followed by Sweden, the Netherlands, Germany, and the United States.

Our policy variables of interest include local loop, subloop, and bitstream unbundling, as well as on-site and virtual collocation. Table 3 shows the years that OECD countries implemented the three types of unbundling regulations. Table 4 shows the years that these countries adopted different collocation regulations.

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

$$y_{it} = f(\boldsymbol{unbundling_{it}}, \boldsymbol{collocation_{it}}, \boldsymbol{collocation\ price\ reg_{it}}, \boldsymbol{Z_{it}}) + \gamma_i + \alpha_t + \varepsilon_{it} \qquad (1)$$

where y_{it} is a measure of broadband development; ***unbundling***$_{it}$ is a vector of three unbundling dummy variables (full unbundling, bitstream, and subloop); ***collocation***$_{it}$ is a vector of dummies indicating the types of collocation implemented (co-mingling and virtual); and ***collocation price reg***$_{it}$ is a dummy variable indicating whether regulatory approval is required for collocation charges.[17] It is also important to control for other factors that affect broadband development.

[16] Speedtest.net claims more than 200 million users from around the world have used the service to test their speeds. Speedtest.net uses servers around the world to minimize the possible measurement error that can be introduced by using testing servers far from the end-user. One exception is that, to date (November 2007), speedtest.net did not yet have a server in Korea, making its results unreliable.

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

Several studies discussed above, for example, show that income and population density affect broadband. $\boldsymbol{Z}_{it}$ thus includes GDP per capita, population density (in the cross-sectional analysis), and the number of fixed telephone lines 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 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. Because population density changes so little from year to year the analysis of panel data omits the variable for population density, since the country fixed effects absorb most of that variation.

Broadband Penetration

I first estimate the equation using measures of broadband penetration as the dependent variable. In particular, I run each regression initially using the OECD numbers for total penetration as the dependent variable, and then again using the measures of household penetration. Estimating the equation separately with both variables serves as a robustness check.

Table 5 shows the results of these regressions. The first two columns omit the fixed effects while the second two include them. Column 1 shows the results of using broadband connections per capita as the dependent variable and column 2 shows the results when using household penetration. Similarly, column 3 uses broadband connections per capita as the dependent variable and column 4 uses household penetration.

Without the fixed effects, LLU is positively and significantly associated with per capita broadband connections and household penetration. This correlation, even when controlling for population density, income, and telephone lines, is consistent with the belief many hold that unbundling is crucial to broadband penetration.

Incorporating fixed effects, however, changes these results. In particular, with the country and year fixed effects included LLU is no longer statistically significantly associated with per capita broadband connections and the coefficient on LLU is considerably smaller in magnitude.

Other results remain consistent across the two approaches. Subloop unbundling is negatively and significantly correlated with both per capita broadband connections and household penetration. The collocation variables appear to be important, as well. Co-mingling collocation is positively and significantly associated with broadband penetration, and virtual collocation is negatively and significantly associated with penetration.

Broadband Speeds

Table 6 shows the results of these regressions when using measures of download and upload speeds as the dependent variables. The results are similar to those obtained using the measures of broadband penetration. None of the unbundling variables are statistically significant, though the signs of the coefficients are the same as in the previous regressions. Comingled collocation is positively and significantly associated with download speed, just as it was with penetration. It is also positive but not quite significant at conventional levels for upload speeds. Virtual collocation is negatively and significantly correlated with both download and upload speeds.

IV. Discussion

While this paper cannot fully explain why broadband penetration varies across countries, a few results are robust. First, population density matters: consistent with earlier research, it is positively correlated with broadband penetration and with connection speeds. Second, regulations also matter. Full local loop unbundling is not obviously correlated (positively or negatively) with broadband penetration. Subloop unbundling—generally thought to be costly—is robustly negatively correlated with broadband penetration. Commingled collocation is generally positive, virtual collocation negative.

The negative result on subloop unbundling is curious, especially because its high cost means that it is rarely used, even where it is required. It turns out that while some countries mandate LLU and not subloop unbundling, no country has required subloop unbundling without also requiring LLU. As a result, the subloop variable indicates not just that a country requires subloop unbundling, but that it requires subloop unbundling *and* LLU.   It is possible, then, that mandating both subloop and LLU indicates a stronger commitment to unbundling. Under that interpretation, the results could indicate that stronger unbundling rules reduce incentives to invest in broadband.

These results may have some useful policy implications. First, mandatory unbundling does not appear to improve broadband outcomes. One type of unbundling—subloop unbundling—may even reduce investment. This may not be surprising given that subloop unbundling can be costly both to the incumbent and to the entrant. Nevertheless, some countries that did not mandate subloop unbundling, such as Germany, are now planning to implement it.[18] Those countries may want to think carefully about such a decision given these results.

While unbundling may not be effective, the collocation results suggest that regulation can help promote broadband. Comingled collocation is positively associated with both broadband penetration and speeds, while virtual collocation is negatively associated with these measures. Collocation is akin to interconnection issues that have faced competitors in telecommunications services throughout history.[19] If an entrant cannot connect to the incumbent's network it has almost no chance of succeeding.

Comingled 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.

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 own equipment. The results here suggest that countries that require comingled 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 comingled collocation.

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. An incumbent has every incentive to increase the costs to a competitor wishing to

[18] See, for example, http://www.iqpc.de/cgi-bin/templates/document.html?topic=586&event=11817&document=85774.
[19] See Wallsten (2005) for an analysis of telecommunications in Europe at the turn of the 20th Century.

connect to its network. Collocation rules can mitigate this problem or make it easier for the incumbent to act on this 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 2006). 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 its central offices to collocation in 2000.

One general interpretation of these empirical results is that regulations that reduce returns to investment (costly 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 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. 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.

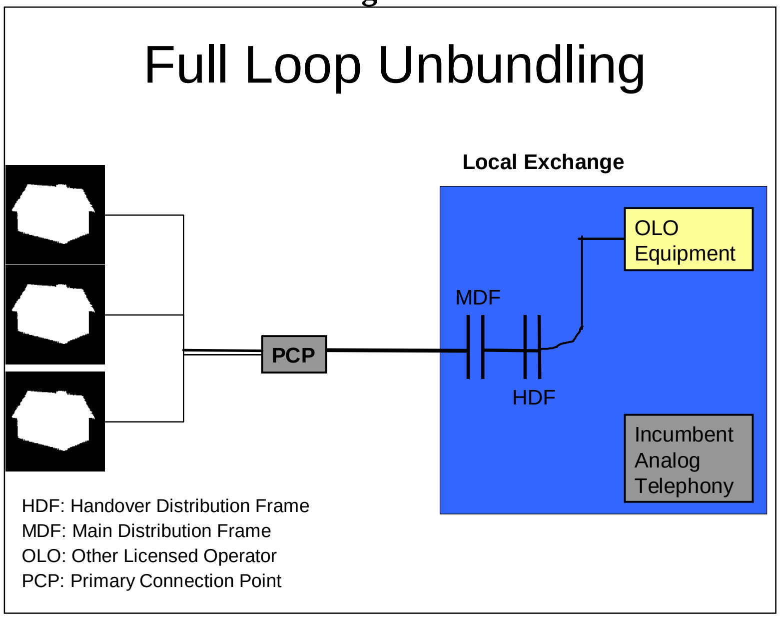
Indeed, according to data from the Pew Internet Project, as late as January 2005 nearly half of all Internet users in the U.S. still used dialup modems to access the Internet.[20] A survey by Parks Associates, meanwhile, finds that about 80 percent of narrowband (dialup) subscribers have no intention 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.[21]

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

It is also becoming increasingly difficult to measure broadband. Although broadband is still relatively new, the relevant technologies and the way people use broadband change quickly. For example, while the majority of users receive broadband over DSL or cable lines, an increasing number obtain broadband wirelessly or over fiber connections. Wireless connections, in particular, are difficult to analyze in comparison to traditional wired connections. As cellular mobile companies roll out high-speed networks, an increasing number of handsets are available that can use these networks. But how many do? And how do most mobile broadband uses compare to broadband used at home or in the office? The degree to which wireless and wireline broadband are substitutable remains a hotly contested issue. This paper excludes data on wireless connections, but it is becoming an increasingly important source of broadband.

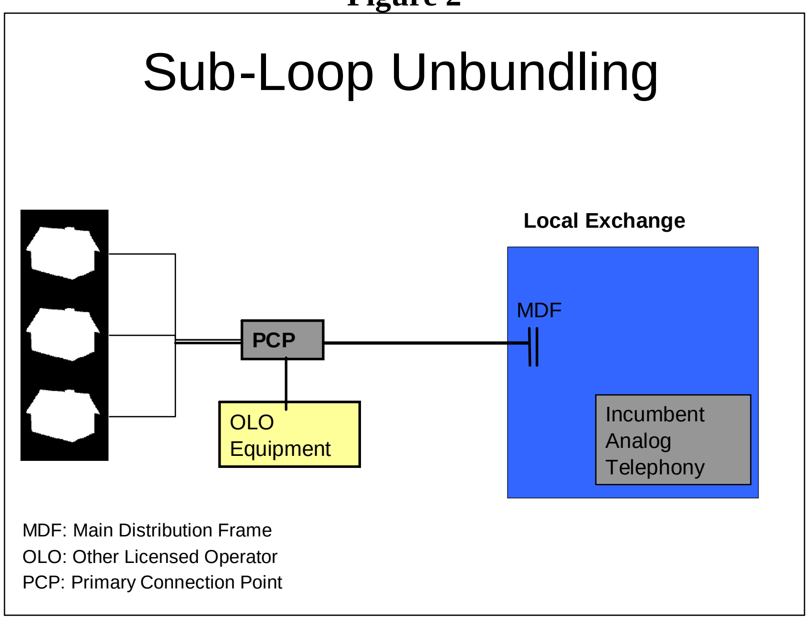
To conclude, this paper examined the effects of unbundling and collocation policies on broadband penetration—both number of connections and household penetration—and on download and upload speeds. The results suggest that unbundling policies do not promote broadband. Subloop unbundling, in fact, may reduce broadband investment. Collocation regulations, however, may be crucial. Comingled collocation is positively associated with broadband penetration and speeds, while virtual collocation is negatively associated with both measures. Together, these results suggest it remains crucial for new entrants to have access incumbent's facilities for interconnection purposes, but that access to the incumbent's network itself does not stimulate investment.

Figure 1



Source: Ofcom.[22]

Figure 2



Source: Ofcom.[23]

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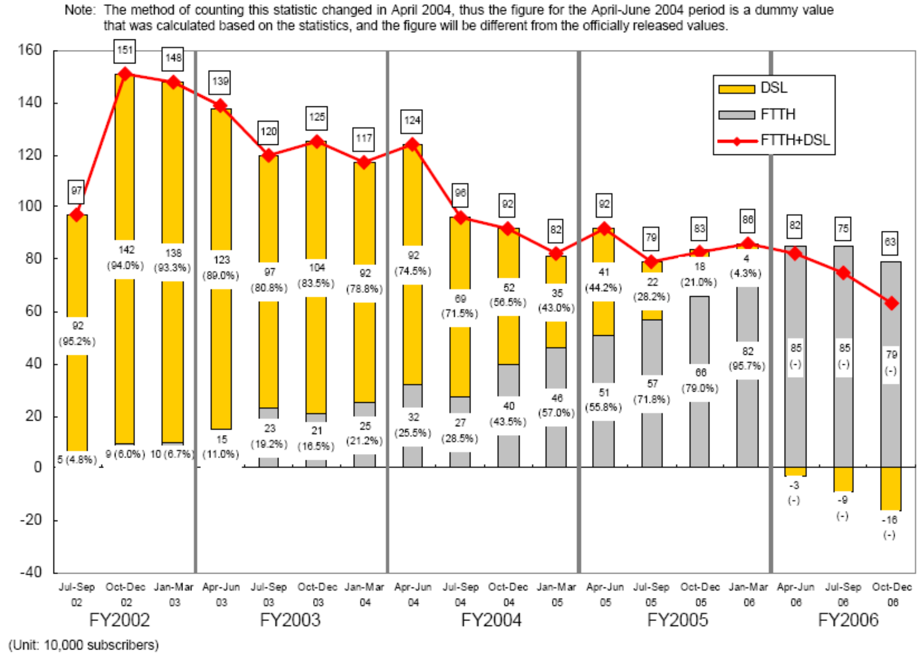
[22] http://www.ofcom.org.uk/static/archive/oftel/publications/broadband/dsl_facts/LLUbackground.htm
[23] http://www.ofcom.org.uk/static/archive/oftel/publications/broadband/dsl_facts/LLUbackground.htm

Figure 3
Net Changes in Subscribers to Different Broadband Technologies in Japan



Source: Japan Ministry of Internal Affairs and Communication.
http://www.soumu.go.jp/joho_tsusin/eng/Statistics/pdf/070313_1.pdf

Figure 4
Broadband Speeds Measured by Speedtest.net in 2006

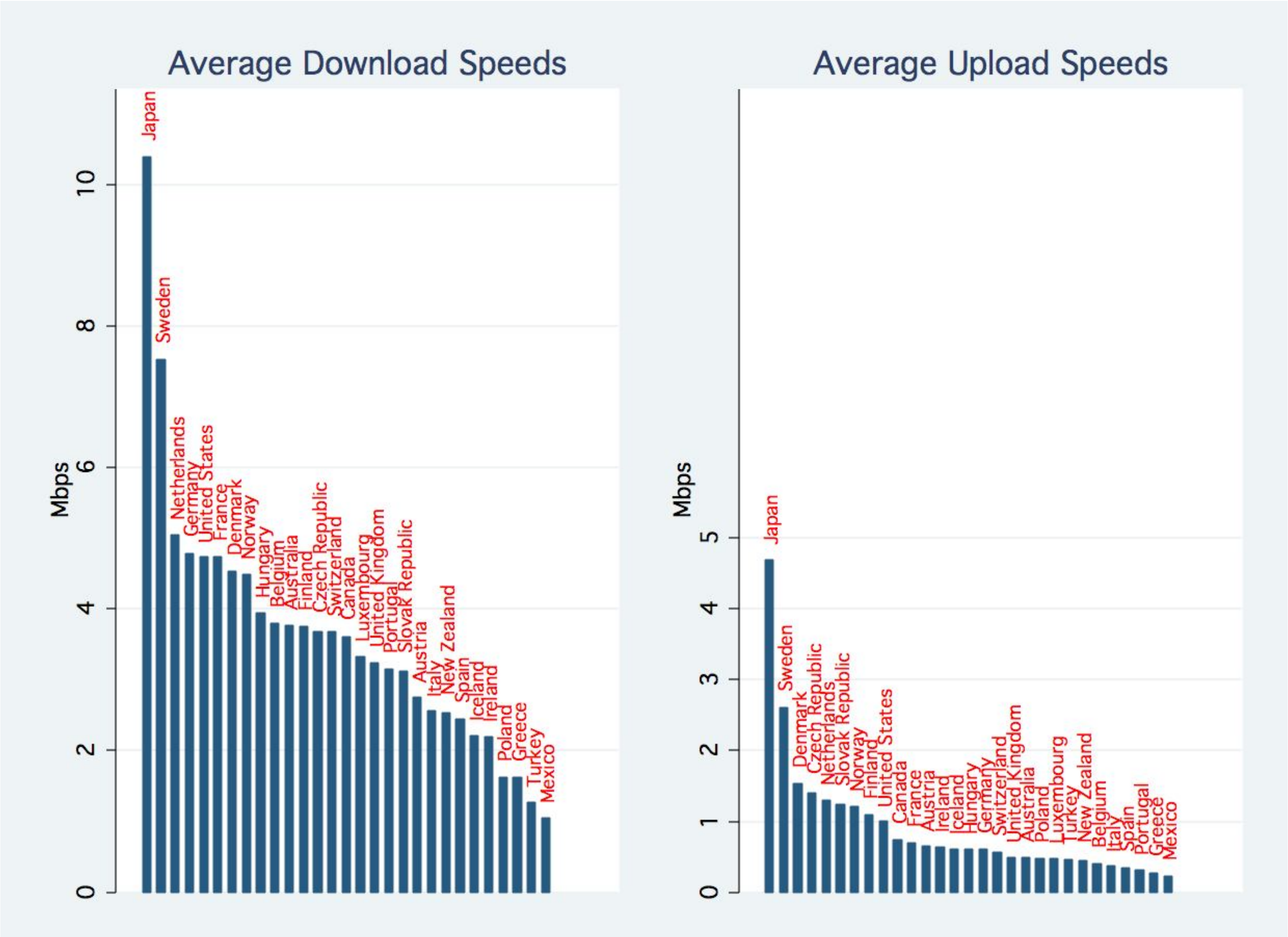


Table 1
Broadband Connections Per 100 People, OECD Estimates

	2002-Q2	2003-Q2	2004-Q2	2005-Q2	2006-Q2	2007-Q2
Australia	1.31	2.58	5.19	10.66	16.96	22.66
Austria	4.57	6.48	8.65	12.38	15.66	18.64
Belgium	6.24	10.23	14.18	17.35	19.20	23.82
Canada	10.25	13.14	16.39	18.97	21.89	24.96
Czech Republic	0.12	0.28	0.75	4.12	9.37	12.20
Denmark	6.64	11.05	16.90	21.71	29.25	34.33
Finland	3.49	5.34	10.93	18.66	24.87	28.84
France	1.57	3.97	7.87	12.63	17.57	22.55
Germany	3.20	4.83	6.56	10.24	15.11	21.21
Greece	0.00	0.02	0.23	0.84	2.70	7.07
Hungary	0.43	1.15	2.52	4.68	9.73	11.62
Iceland	5.29	10.82	15.19	21.48	26.51	29.78
Ireland	0.05	0.39	1.61	4.23	8.75	15.35
Italy	1.19	2.80	6.02	9.70	13.08	15.81
Japan	3.93	8.57	12.67	16.40	18.95	21.25
Korea	20.26	22.89	24.18	25.47	26.44	29.90
Luxembourg	0.61	2.27	5.57	11.38	17.20	22.24
Mexico	0.16	0.31	0.74	1.67	2.82	4.59
Netherlands	4.93	9.07	15.43	22.32	28.80	33.47
New Zealand	1.09	2.08	3.48	6.96	11.56	16.50
Norway	2.99	6.15	11.26	18.09	24.41	29.78
Poland	0.15	0.45	1.19	2.19	5.33	7.97
Portugal	1.46	3.62	6.35	9.68	12.71	14.70
Slovak Republic	0.01	0.01	0.62	1.61	4.02	6.83
Spain	2.07	4.18	6.46	9.10	13.31	16.98
Sweden	6.75	9.17	12.26	16.69	22.53	28.59
Switzerland	3.83	9.17	14.55	20.20	26.19	30.73
Turkey	0.02	0.06	0.29	1.20	2.91	5.16
United Kingdom	1.27	3.67	7.36	13.25	19.20	23.73
United States	5.49	7.90	10.86	14.16	17.88	22.08
OECD	3.82	5.93	8.48	11.63	15.11	18.76

Source: OECD http://www.oecd.org/dataoecd/22/12/39574779.xls

Table 2
Percentage of Households with Broadband Connections

Country	2000	2001	2002	2003	2004	2005	2006
Austria			0.08		0.1	0.2	0.21
Belgium			0.15		0.32	0.38	0.47
Bulgaria						0.05	0.1
Canada							0.63
Czech Republic						0.1	0.15
Denmark			0.17		0.3	0.49	0.6
Finland			0.06		0.14	0.41	0.49
France	0.01		0.03	0.06	0.1	0.34	0.4
Germany	0.01		0.03		0.06	0.19	0.25
Greece						0.02	0.06
Hungary						0.11	0.18
Ireland						0.07	0.11
Italy			0.01		0.03	0.12	0.14
Japan			0.15	0.2	0.33	0.37	
Korea	0.27	0.53	0.69	0.73	0.77	0.77	0.87
Latvia						0.13	0.19
Luxembourg			0.02		0.07	0.29	0.33
Netherlands			0.12		0.36	0.62	0.65
Poland						0.13	0.21
Portugal			0.03		0.07	0.13	0.17
Romania						0.06	0.09
Slovak Republic						0.05	0.08
Spain			0.04		0.12	0.16	0.25
Sweden			0.13		0.25	0.45	0.43
Turkey						0.03	0.06
United Kingdom			0.04		0.13	0.32	0.41
United States	0.03	0.07	0.12	0.15	0.25	0.34	0.43

Sources: Europe 2003-2004 from Telecoms Service Indicators, Produced for the European Commission, DG Information Society by Ipsos.
Europe 2005-2006 from European Commission E-Communications Survey.
Japan estimated from Ministry of Internal Affairs and Communications http://www.johotsusintokei.soumu.go.jp/tsusin_riyou/data/eng_tsusin_riyou02_2005.pdf
Italy, FR, UK Germany, Sweden 2003: http://answers.google.com/answers/threadview?id=177744
Germany, France 2000 from http://answers.google.com/answers/threadview?id=177744, citing http://cyberatlas.internet.com/big_picture/geographics/article/0,,5911_738531,00.html
United States from Pew Internet and American Life Project. U.S. data are share of adults online at home, not household penetration (unclear if those numbers would differ). For 2007, estimates range from .50 to .55.

Table 3
Year Unbundling Regulations Implemented

`	Local loop	Subloop	Bitstream
Australia	1999		2000
Austria	1998	1999	1999
Belgium	2000	2001	2001
Canada	1997		
Czech Republic	2003		
Denmark	1998	1999	1999
Finland	1997		
France	2001	2002	2002
Germany	1996		
Greece	2001	2002	
Hungary	2001		
Iceland	2001		
Ireland	2000	2001	2001
Italy	1998	1999	1999
Japan	1997	1997	1997
Korea	2001		2002
Luxembourg	2000	2001	
Mexico			
Netherlands	1997		
New Zealand			
Norway	2000	2001	2001
Poland	2003		
Portugal	2000	2003	
Slovak Republic			
Spain	2000	2001	2001
Sweden	2000	2001	2001
Switzerland	2003		
Turkey			
United Kingdom	2000	2001	2001
United States	1996	1996	

Note: Empty cells in the table indicate that the country does not have the particular regulation.

Table 4
Year Collocation Regulations Implemented

Country	Comingled	Virtual	Remote
Australia	2000	2000	
Austria	1999		
Belgium	2001	2001	
Canada	1997	1997	
Czech Republic			
Denmark	1999	1999	1999
Finland	1997		
France	2002	2002	2002
Germany	1996		1996
Greece	2002		2002
Hungary	2002		
Iceland	2002		
Ireland	2001	2001	2001
Italy	1999		1999
Japan		1997	
Korea	2002	2002	
Luxembourg	2001	2001	2001
Mexico			
Netherlands	1997		
New Zealand			
Norway	2001	2001	
Poland			
Portugal	2001		
Slovak Republic			
Spain	2001	2001	2001
Sweden	2001	2001	
Switzerland			
Turkey			
United Kingdom	2001	2001	2001
United States	1996	1996	

Note: Empty cells in the table indicate that the country does not have the particular regulation.

Table 5
Broadband Penetration and Unbundling Regulations

	Broadband connections per 100 people	Share of households with broadband	Broadband connections per 100 people	Share of households with broadband
Full LLU mandated	0.03	0.11	0.01	-0.02
	(1.87)+	(1.94)+	(0.74)	(0.37)
Sub-loop unbundling mandated	-0.03	-0.14	-0.05	-0.15
	(3.01)**	(3.30)**	(2.31)*	(2.73)**
Bitstream access mandated	0.01	0.05	-0.01	0.07
	(0.54)	(1.35)	(0.40)	(0.90)
Co-mingling collocation implemented	0.01	0.15	0.08	0.28
	(1.37)	(4.11)**	(3.27)**	(4.99)**
Virtual collocation implemented	-0.03	-0.16	-0.05	-0.16
	(2.52)*	(4.57)**	(2.45)*	(2.96)**
Regulatory approval for collocation charges	0.00	-0.10	0.00	-0.08
	(0.23)	(2.73)**	(0.16)	(0.66)
GDP per capita ($000s per person)	0.04	0.07	0.04	-0.02
	(11.40)**	(4.78)**	(7.15)**	(0.59)
Fixed telephone lines per 10,000 people	-0.89	-1.40	-0.64	-2.43
	(4.56)**	(2.24)*	(2.76)**	(1.93)+
Population per square kilometer	0.16	0.52		
	(4.78)**	(4.43)**		
Constant	-0.05	-0.04	-0.18	-0.05
	(4.74)**	(0.68)	(7.19)**	(0.27)
Country and year fixed effects	NO	NO	YES	YES
Observations	237	95	237	95
R-squared	0.50	0.63	0.90	0.94

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

Table 6
Broadband Speeds and Unbundling Regulations

	Download speed kbit/sec	Upload speed kbit/sec
Full LLU mandated	643.13	219.06
	(0.62)	(0.40)
Sub-loop unbundling mandated	-152.88	201.20
	(0.19)	(0.46)
Bitstream access mandated	-237.91	-282.27
	(0.29)	(0.65)
Co-mingling collocation implemented	1855.14	719.04
	(2.23)*	(1.63)
Virtual collocation implemented	-1529.02	-756.59
	(1.97)+	(1.83)+
Regulatory approval for collocation charges?	165.08	-55.68
	(0.21)	(0.13)
GDP per capita ($000s per person)	52.79	-20.19
	(0.26)	(0.19)
Population per square kilometer	6855.19	2566.76
	(2.18)*	(1.53)
Constant	1884.41	463.76
	(2.34)*	(1.08)
Country and year fixed effects	NO	NO
Observations	29	29
R-squared	0.46	0.32

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

Note: Korea excluded because speedtest.net data for Korea are inaccurate due to the lack of a testing server in-country.

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