REGULATION OF TELECOMMUNICATIONS IN THE BROADBAND AGE

by

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ABSTRACT OF THE DISSERTATION

Regulation of Telecommunications in the Broadband Age

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Broadband is becoming important to both the economic and social progress of a nation. Commerce and social interaction are increasingly conducted "on line." The economic importance of broadband has been theoretically framed in terms of the "network effect." Additionally, broadband may produce significant positive externalities in areas such as education, healthcare, and the environment. For these reasons, policymakers have been closely monitoring the progress of broadband diffusion.

I examine a decade of hard data on the rollout of first generation broadband in the context of policies employed by different administrations around the world. My primary focus is in the use of industrial policy and loop unbundling. As in previous studies in the literature, the dependent variable modeled is broadband subscribers per 100 inhabitants. The impact of industrial policy is consistently a statistically significant predictor of broadband density, with a stable value and positive sign over all regressions. The use of an unbundling policy is found to be statistically significant when lagged by one or two years, and it is always positive.

I use these results to predict policy impacts on the rollout of Next Generation Network (NGN) broadband, which will be characterized by heavy investment in fiber optic facilities supporting access speeds of 100 megabits per second and above. I conduct a benefit-cost analysis for U.S. NGN broadband deployment using predicted increases in NGN availability to drive the compilation of associated costs and benefits. To monetize benefits, I estimate private producer and consumer surpluses. I also include benefits to the economy by virtue of the network effect. Additional positive externalities can be optionally added in the areas of healthcare and the environment.

A number of different scenarios are run in order to get a sense of the impact of the two policies and the sensitivity to different study parameters. The results show that both policies have the potential to be justified on the basis of a benefit-cost analysis. The more that we can attribute positive externalities to a modern, high speed broadband network, the stronger the case there is to justify policies which promote and invest in broadband.

Preface

I have spent my adult working life in the field of telecommunications and have been witness to truly remarkable advances. When I began my career, a 2400 baud dial-up modem was state-of-the-art, and today we have broadband connectivity at work, in our homes, and increasingly in our pockets. It has been a privilege to participate in some small way in the technological advances that have made our connected world possible.

The U.S. has been a leader in many of the pioneering aspects of telecommunications, a source of both pride and employment for professionals like myself. Today telecommunications is a global endeavor, and this has led to inevitable adjustments in industry structure. But the extent of this adjustment has left me uneasy. With the upcoming sale of my current company, the last vestige of the formerly dominant Bell System design and manufacturing arms will no longer be domestically owned. As a front row observer of this process, I wonder why the U.S. can't maintain a larger profile in telecommunications hardware and software. I firmly believe our scientists and engineers continue to be among the best in the world, so I began to seek answers elsewhere: in the social changes of globalization and in the accompanying government policies that attempt to shape outcomes. Thus began my interest in the social sciences.

As I tentatively explored the notion of pursuing a degree in a new field, I was greeted with warmth and encouragement by the professors at the Rutgers Bloustein School. I am very grateful to have worked with the accomplished and dedicated faculty there. I would especially like to thank my committee for sharing their knowledge and expertise and pointing me in the right directions at numerous forks in the road. I came to

Bloustein as an engineer, but I leave viewing the world in a different, and I believe, a better and more holistic way.

Finally I would like to thank my darling wife Susan, who was unwaveringly supportive of my studies. Without her encouragement and understanding I would not have succeeded in my quest, and my life would be poorer as a result.

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1 Introduction

Broadband access to the Internet is a major new technological capability. Since its initial deployment at the turn of the century, the number of broadband lines worldwide now exceeds 500M.[1, 2] Wired broadband access is a relatively recent development of the telecommunications network. In less than a decade broadband has displaced dial-up modems for accessing the Internet, reading email, making phone calls, and other new applications such as downloading videos. Because of its importance in a modern information society, the rollout of broadband in the U.S. has been monitored closely by policymakers.

The main technologies used to provide broadband access are digital subscriber line (DSL) over traditional copper phone lines, cable modems over coaxial cable television networks, and new fiber-based networks. China and the U.S. lead the world in total number of broadband subscribers, as shown in Figure 1.1.

Broadband availability is becoming important to both the economic and social progress of a nation. Commerce and social interaction is increasingly conducted "on line." To name just a few examples, Internet-based shopping, downloadable music and video, and on-line news services have dramatically impacted traditional commercial business models and have altered social behavior.

Broadband is becoming an important infrastructure that supports and contributes to economic activity:

> "Broadband networks are increasingly recognized as fundamental for economic and social development. They serve as a communication and transaction platform for the entire economy and can improve productivity

[1] "Broadband Use In China Soars, U.S. Slows," W. David Gardner, InformationWeek, September 21, 2010

across all sectors. Advanced communication networks are a key component of innovative ecosystems and support economic growth." (Reynolds, 2009)

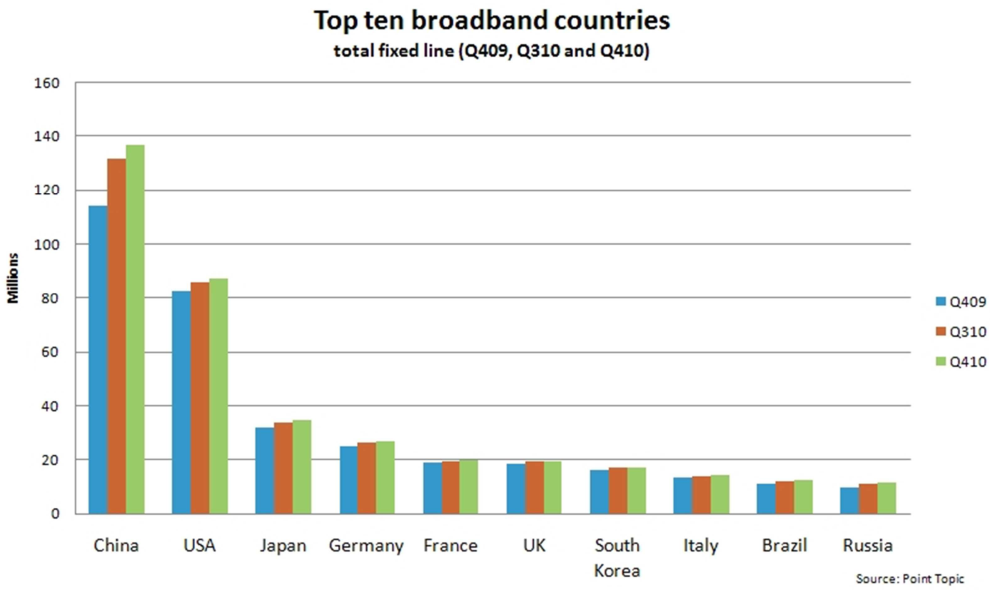

Figure 1.1 - Broadband Subscribers in the World's Largest Countries
(Point Topic[2], used with permission)

Quantitative studies have shown that increased availability of broadband can increase GDP (see for example Koutroumpis, 2009) and employment (see for example Crandall, Lehr, Litan, 2007). Additionally, broadband may produce significant positive externalities in areas such as education, healthcare, and the environment. (OECD, 2008) (FCC, 2010)

One motivation for this dissertation stems from a concern that the U.S. is falling behind in the rollout of broadband. According to the Organization for Economic Cooperation and Development (OECD), in 2009 the United States ranked fifteenth among thirty OECD nations in number of subscribers per capita, as shown in Figure 1.2,

[2] Point-Topic: 523M Broadband Subscribers Worldwide, 24 March, 2011, Posted by: BBC Wires, http://bbpmag.com/wordpress2/2011/03/point-topic-523m-broadband-subscribers-worldwide/, (last viewed November 2011)

dropping from fourth place in 2001. In recent years there has been a general call for policy initiatives to accelerate U.S. broadband deployment. While not everyone agrees that the metric of subscribers per 100 inhabitants is the solely accurate yardstick against which to measure progress, many believe that the U.S. should strive to do better. Deshpande and Elmendorf consider the evidence and conclude:

> "To be sure, the OECD data have well-documented deficiencies, including a failure to separate residential broadband use from commercial use (Wallsten, 2008) … Still, these and other estimates indicate the opportunity for progress in broadband availability in the United States." (Deshpande and Elmendorf, 2008)

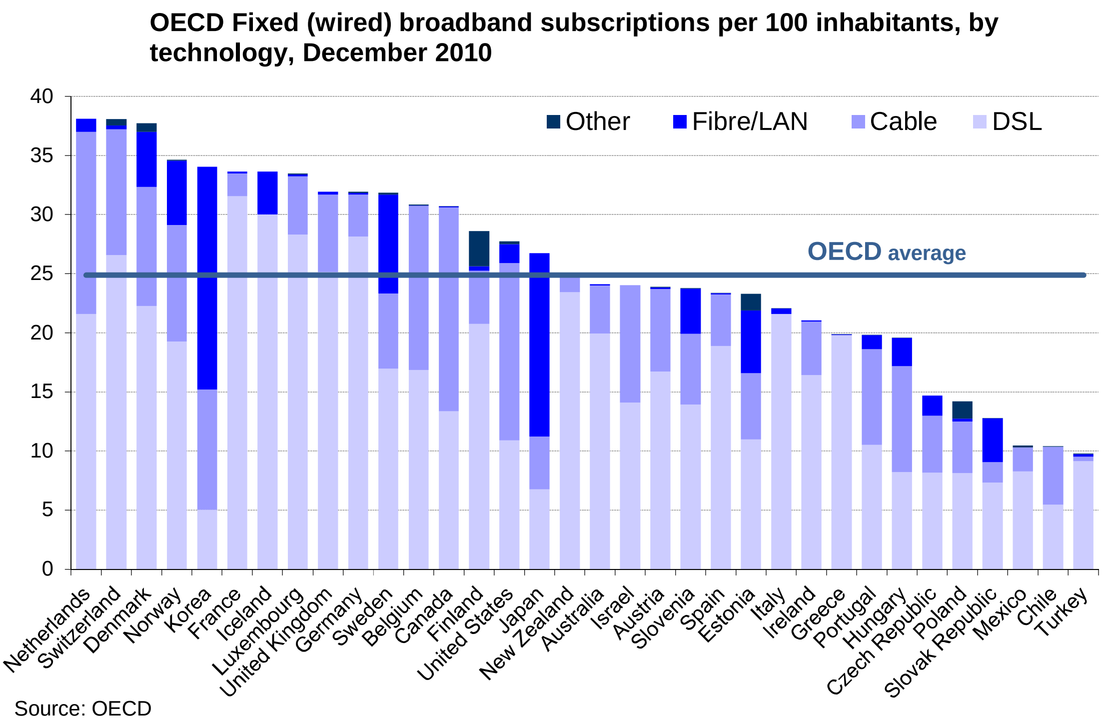

Figure 1.2 - Terrestrial Broadband Subscribers per 100 Inhabitants
(OECD Broadband Portal[3])

[3] OECD Key ICT Indicators, Broadband subscribers per 100 inhabitants in OECD countries, 4a, http://www.oecd.org/document/23/0,3746,en_2649_34449_33987543_1_1_1_1,00.html, (last viewed November 2011)

Another view that more needs to be done was expressed at the release of the FCC National Broadband Plan, mandated by Congress in 2009 as part of the Stimulus Act:

> "But broadband in America is not all it needs to be. Approximately 100 million Americans do not have broadband at home. Broadband-enabled health information technology (IT) can improve care and lower costs by hundreds of billions of dollars in the coming decades, yet the United States is behind many advanced countries in the adoption of such technology. Broadband can provide teachers with tools that allow students to learn the same course material in half the time, but there is a dearth of easily accessible digital educational content required for such opportunities." (FCC, 2010)

In the U.S. the deployment of broadband has been primarily left to free market forces, wherein incumbent telephone companies have rolled out DSL, cable companies have rolled out cable modems, and most recently Verizon has begun to deploy its FiOS® fiber-based broadband offering. Some studies find that broadband is becoming available to citizens at about the same pace as other new technologies. (Crandall, 2004) But because broadband is acknowledged to be critically important for economic and social reasons, (Firth and Mellor, 2005)[4] much attention has been given to how broadband is being deployed, what the impediments are to its deployment, and whether policy mechanisms should be applied to accelerate deployment.

Researchers and policymakers seek ways to evaluate and assess the potential for improvement in the performance of the free market model for broadband diffusion. Researchers have quantified the positive impacts of increased competition, particularly so-called facilities-based competition that comes about when both DSL and cable modems coexist in a single market. But there are still areas of the U.S. where there is only one service provider. And because of the heavy investment required to build a broadband network, there are significant barriers to entry that can deter competitors. To

[4] For example, the comments of FCC commissioner Michael Copps, p. 224

address this, policymakers proposed a number of approaches intended to lower barriers to entry and correct for the market failure of a monopoly. The most extensive of these policies was “loop unbundling” enacted under the Telecommunications Act of 1996.

Under conditions of an open, competitive marketplace, there may be areas where provision of broadband is simply unprofitable, and as a result communities are unserved. And although prices for broadband subscription have declined as the market has matured, and some providers offer “no frills” economy subscriptions with limited bit rates, many citizens still cannot afford the monthly subscription fees. These concerns have led to equity issues, commonly referred to as the “digital divide.” These equity issues have become a policy concern of the Obama administration, and the Stimulus Act of 2009 included billions of dollars to increase broadband deployment to unserved and underserved communities (Act, 2009).

A policy of more equitable access could potentially be justified on a purely philosophical basis, with the knowledge that costs must be borne by other segments of society through redistribution of wealth. Such policy is often further justified by the social benefits that come about through increased broadband connectivity, including “advancing consumer welfare, civic participation, public safety and homeland security, community development, health care delivery, energy independence and efficiency, education, worker training, private sector investment, entrepreneurial activity, job creation and economic growth” (Act, 2009).

The U.S. is not alone in its desire to promote broadband availability, and there is an active literature on market dynamics and potential policies that lead to improved outcomes. Original research in this dissertation focuses on policies intended to promote broadband diffusion. I conduct an empirical analysis on broadband rollout during the last decade, testing quantifiable metrics that reflect broadband policies employed at the time. The need for such research was suggested by Cava-Ferreruella:

> "[T]he following improvements can be implemented in practise to tackle the problem of broadband development modelling in future work … capturing of the effects of government policy on broadband development by the coding of government initiatives and their inclusion as independent variables." (Cava-Ferreruelaa and Alabau-Mun, 2006)

Several researchers have since implemented and tested such metrics, although studies to date are found to have limitations: the raw data tends to be privately held, limited to European countries, and focused on the early years of broadband rollout. In this study, I use a panel data set across 30 OECD countries for the years 2003 through 2008 to determine the impact of two policies on broadband availability. The policies are "industrial policy," where governments direct public funds toward investments in broadband infrastructure, and the aforementioned loop unbundling, where incumbent operators must make their local loops available to competitors on a lease basis. Both policies were found to be statistically significant and to have a positive influence on broadband density, measured in terms of broadband lines per 100 inhabitants.

First generation wired broadband was primarily based on DSL technology, which reuses existing copper telephone lines, and on cable modems, which are added to existing cable television (CATV) networks. These technologies support average sustained throughputs on the order of several megabits per second. This represents a very significant advance from the prior state-of-the-art, where dial-up modems and ISDN Basic Rate Access were the predominant means to access the Internet with speeds on the order of 64 kilobits per second.

As significant as this advance has been, speeds of single-digit megabits per second are now starting to be considered too slow. Commonly available residential broadband speeds in Japan are 200 megabits per second[5] and South Korea has announced plans to deploy 1 gigabit per second residential access.[6] The recently released FCC National Broadband Plan sets as its number one goal, "At least 100 million U.S. homes should have affordable access to actual download speeds of at least 100 megabits per second …" (FCC, 2010)

These next generation speeds will be supported by fiber, either largely (fiber to the curb telephony systems and fiber reinforced cable systems, commonly called hybrid fiber cable or HFC systems) or completely (fiber to the home). This represents an almost complete rebuilding of the access network, as new cables must be placed in underground conduits and along telephone poles, and new electronics must be placed in central offices and homes. For cable systems that are already HFC, the changes are less dramatic but these must be upgraded to the latest standards (DOCSIS 3.0) with new electronics. It is now common in the literature to refer to such networks as next generation networks (NGNs), and the term is used herein to denote networks that provide fiber-based broadband access of at least 100 megabits per second.

NGNs will constitute the second generation of broadband access. Because of the considerable capital expense required to construct them, NGNs will grow slowly over time, coexisting with first generation broadband networks. This evolution has already begun, for example in Japan where DSL and fiber to the home services are both available. Here in the U.S. the incumbent operator Verizon currently offers both DSL and

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5 http://506506.ntt.com/english/ocn/hikari/hikari_flets/ (last viewed July 2011)

6 Mark McDonald, "Home Internet Access May Get Even Faster in South Korea," New York Times, February 21, 2011

all-fiber FiOS® services while major cable operators are well on the way to upgrading their systems to DOCSIS 3.0.

This technology replacement is predicted to occur throughout this decade, in a similar way that first generation broadband based on DSL and cable modems slowly but inevitably replaced dial-up modems and ISDN. Although more and more citizens will have access to basic broadband, the focus will shift to higher speeds. Thus, policy will begin to focus on availability of NGNs. Investments in NGNs are too recent for their impact to be measured by empirical studies. Bit it behooves policymakers to predict the effectiveness of such investments based on lessons learned from the first generation of broadband deployment. If industrial policy or loop unbundling in fact encouraged first generation broadband deployment, then their use for NGN deployment could have a large positive impact. Conversely, if they were not effective, then their application could have large net costs.

Potential positive externalities attributable to widespread broadband availability have been studied in the literature, although somewhat unevenly. This literature will be reviewed, including “network effects” that positively impact economic growth and productivity, as well as specific spillovers in the areas of education, healthcare, and the environment. Quantitative assessment of these benefits is a first step toward conducting a benefit-cost analysis, to determine the potential impact of policy that promotes broadband availability.

It is assumed that in the same way first generation broadband using DSL and cable modems displaced dial-up modems, NGN broadband using fiber will displace first generation broadband. The model for rollout is assumed to be similar, and the lessons learned regarding the impact of industrial policy and unbundling are assumed to carry over as well. On this basis, I create a model for NGN broadband deployment starting in 2013 and extending to 2025.

There are a number of critical assumptions involved in this model, the two most important of which are that the rollout of NGN broadband will be as rapid and robust as the rollout of first generation broadband, and that unbundling applied to fiber will produce positive outcomes. Although supporting arguments are given to defend these positions, it is prudent to additionally assess more pessimistic scenarios. The impact of both policies when there is a slower rollout of NGN broadband is therefore considered. An option that reduces the positive impact of unbundling is included, and it is also possible to consider that unbundling has no positive impact and therefore is not used (i.e., only consider the impact of industrial policy).

The benefit-cost analysis uses increases in NGN broadband availability to drive the compilation of costs and benefits. If industrial policy is applied, public funds will be directed toward increasing broadband infrastructure. And there will be agency implementation costs at the FCC. These costs are compared to the benefits of the additional broadband produced. To monetize these benefits, I estimate private producer and consumer surplus. Benefits to the economy by virtue of the network effect are also included. Finally, the impact of including additional positive externalities in the areas of healthcare and the environment is discussed.

If unbundling is applied, there will be associated overhead costs upon the incumbent operator, as well as enforcement costs at the FCC. These costs are again compared to the benefits of the additional broadband produced, including increased social surplus, economic benefits, and potential healthcare and environmental externalities.

I compute the costs and benefits and determine the net present value, the internal rate of return, and the benefit cost ratio. The discount rate and other study parameters can be varied. I run a number of different scenarios in order to get a sense of the impact of the two broadband policies and the sensitivity to different study parameters.

The remainder of this dissertation is organized as follows. In Chapter 2 I give a detailed review of literature relating to regulation of telecommunications, with particular focus on broadband and previous empirical research. In Chapter 3 I describe original empirical research on the impacts of industrial policy and unbundling on the rollout of first generation broadband. Chapter 4 reviews literature on broadband private and public benefits. Then in Chapter 5, I use the model from Chapter 3 to predict the impact of industrial policy and unbundling on the rollout of NGN broadband, and a benefit-cost analysis is conducted using the benefits from Chapter 4. Chapter 6 is a summary and discussion of findings, and includes conclusions and recommendations for future research.

2 Review of the Literature on Broadband Telecommunications Regulation

The discussion of literature begins with a brief review of the regulated Bell System and its breakup in 1984 into more deregulated entities. Then in 1996 the U.S. instituted the so called “loop unbundling” policy which was subsequently emulated by most administrations around the world. I cover both theoretical discussions and empirical studies on the impact of unbundling, as well as a mostly qualitative review of the application of industrial policy to broadband.

2.1 The Regulated Bell System Monopoly

Telecommunications began at the end of the 19th Century with the invention and patenting of the telephone and its commercialization through a classic market-based scenario where entrepreneurs scrambled to build networks and extend them to as many customers as possible. By the beginning of the 20th Century demand for service was strong and growth of lines was rapid. There was an obvious advantage to move from isolated “islands” of connectivity to a more interconnected network, and companies responded by expanding their networks through growth and acquisition.

After telephone service appeared in a significant number of households, and AT&T had grown through acquisitions to become the dominant player, the model of a regulated monopoly emerged. This model has its theoretic basis in the notion of a “natural monopoly” which, even after achieving a large scale, continues to grow and provide service at decreasing marginal cost. For example, as aggregate traffic increases on the backbone network, larger transmission and switching facilities can be introduced at lower per-subscriber costs. As separate telephone operators merge, their two billing centers can be combined into a single, more cost-effective billing center. Thus the theoretically most efficient way to provide telephone service to society was to allow a single provider to become very large, and then to put regulatory safeguards in place to assure this “chosen instrument” did not abuse its monopoly power. Nadiri and Nandi describe how governments have traditionally dealt with natural monopolies:

> “Natural monopolies pose the same problem as all monopolies: lack of competition drives up prices for consumers and may stifle innovation. The government has two options in this situation: it can provide the good itself, as it does with most roads, or it can regulate private providers, as it does with telecommunications and electricity distribution facilities.” (Nadiri and Nandi, 2001)

For much of its history, the Bell System was a regulated monopoly, and access to the network was considered a right guided by the philosophy of “universal service.” Jean-Jacques Laffont, a scholar of the history of telecommunications, describes the situation:

> “For decades, telecommunications services have been provided by a secure monopolist, a public enterprise in most of the world and a private regulated corporation (AT&T) in the United States. The absence of competition was motivated by the existence of large fixed costs in several parts of the network, whose duplication was neither privately profitable nor socially desirable; the telecommunications industry was deemed to be a ‘natural monopoly.’” (Laffont, 2000)

One of the seminal regulatory scholars during the late 20th Century is Alfred Kahn. Kahn reflects on why certain industries may benefit more from a regulated than a competitive model:

> “[Regulation is appropriate when] the technology of certain industries or the character of the service is such that the customer can be served at least cost or greatest net benefit only by a single firm or by a limited number of chosen instruments. In such circumstances, so the argument runs, unrestricted entry will be wasteful and productive of poorer service, with cycles of excessive investment followed by destructive rivalry - the effect may be to push rates down so close to short-run marginal costs as to impair the ability of the surviving companies to maintain their plant in good working order, to introduce needed renovations, or to continue to give good service.” (Kahn, 1988, p. 2)

Toward the end of the 20^{th} Century the focus shifted toward criticisms of regulation, including higher prices, bureaucracy, inefficiency, and less innovation. Regulating a technological and rapidly evolving economy came to be viewed as simply too complex a task, whereas free enterprise could naturally select the products and services desired and needed and bring them to market at the lowest possible competitive prices (Crandall, 2005). Thus the free market view places confidence in individual consumer and firm decisions that will lead to an optimal allocation of resources, superior to anything that can be crafted by bureaucrats. There was also a growing belief that many industries which had previously exhibited characteristics of a natural monopoly were becoming more competitive, for example due to changes and advances in technology, and were therefore no longer appropriate subjects of regulation. Nicholas Economides (2004) summarizes potential problems with the regulatory process:

> "I should also note that there are significant drawbacks and costs created by regulation. First, regulators generally do not have the latest technological information. In an industry with fast technological change, such as telecommunications, this can lead to significant divergence between costs and prices as costs fall much faster than prices. … Second, regulated firms may be able to use the regulatory setup to create barriers to entry and thereby perpetuate their profitable existence. … Third, the regulatory setup is slow, cumbersome, bureaucratic, and, in many cases, politically influenced. Fourth, because of the public interest provision, there can be significant rent-seeking activity by various groups … Fifth, in an industry with fast technical change, it is hard to define the appropriate array of regulated products … Thus regulation should be used sparingly, and only when there are no good alternatives." (Economides, 2004, p. 52)

Evidence shows that regulated industries performed reasonably well during the mid-20^{th} Century compared to their unregulated counterparts in terms of things like prices to consumers, modernization, and executive pay. Kahn believes that regulated firms will often pursue behaviors comparable to unregulated industry, due to various pressures of oversight. Kahn notes the Bell System's persistent frugal financial performance (e.g. lower Western Electric profits compared to other manufacturers) and reductions in long distance rates as evidence of some regulatory success.

But Kahn, like Economides, also sees the limitations of regulation and calls for its selective application:

> "In my judgment, regulation does do a great deal of good - notably in providing a public forum for continuing scrutiny of the performance of companies that do still have too much monopoly power … Regulation also does a great deal of harm - mainly because of its association with restraints on competition. … Competition is far more powerful than regulation in forcing businesses to explore the slope of their cost functions and elasticity of their demands, and to push down costs, if they are to prosper. In those situations in which competition is feasible, regulatory commissions clearly should welcome it rather than rush to restrict it."
> (Kahn, 1988, p. 111-112)

Richard Posner argues that deregulation is a preferred approach in part because the dangers of natural monopolies are overstated; monopolistic firms are often tempered by market forces, and the regulatory process used to correct for market failure is often ineffectual. Posner believes that the disadvantage of allowing industries to compete in an unbridled and possibly monopolistic fashion is more than offset by the benefits of a competitive marketplace that allows choice to prevail (Posner, 1969, 1999).

Some advocates of competition argue that policy intervention will prevent the free market from operating efficiently, thus reducing total social surplus. For example, Crandall argues that excessive regulation will reduce and delay the availability of broadband in the U.S. and create a significant economic loss.

> "Regulating a new service can generate large losses in economic welfare if such regulation increases the risk of investing in the facilities required to deliver the service. The consequent delay in the introduction of a new service or in the rate at which a new service is introduced denies consumers the opportunity to consume this service. In such cases, the

economic costs to consumers can be quite high, particularly when the demand for these services is price inelastic." (Crandall, 2005)

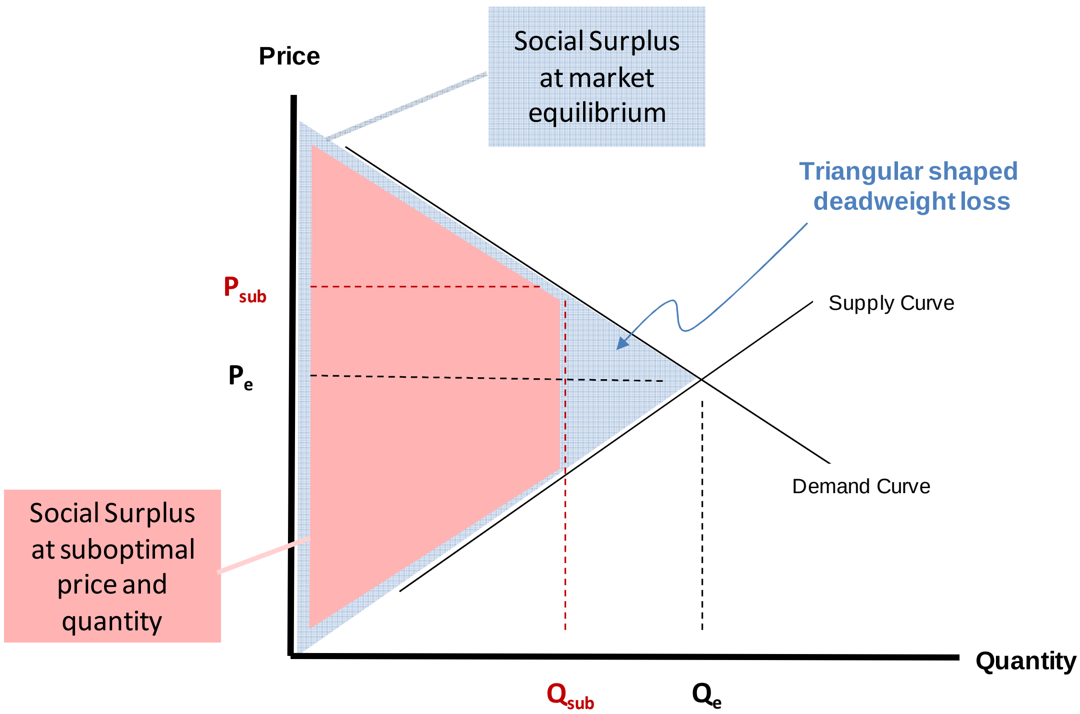


Figure 2.1 - Crandall's Hypothesized Loss of Economic Welfare due to Regulatory Intervention

Figure 2.1 is used to explain Crandall's argument. Using a classic microeconomic model of an efficient private sector marketplace, telecommunications should have the features of rivalry, excludability, no barriers to entry, and full information (Callan and Thomas, 2007). This allows us to model the marketplace using supply and demand curves, along with the concept of equilibrium and associated social surplus, composed of consumer and producer surplus. Crandall argues that government regulation deters suppliers, reducing the quantity of broadband offered. This will result in a new equilibrium point for the marketplace, at a higher price and lower total volume of broadband and a "deadweight loss" of economic welfare. Crandall goes on to estimate the magnitude of the loss in social surplus.

> "Charles Jackson and I have estimated that the benefits of universal broadband service in the United States could be as high as $300 billion a year to consumers and producers. If broadband rollout is delayed by regulatory disincentives to invest, these gains - measured in terms of consumers' and producers' surplus - are likewise delayed. Even if the delay is just a few years, the present value of the losses to consumers and producers could be enormous, easily in the neighborhood of $500 billion." (Crandall, 2005)

AT&T was a "vertically integrated" company that controlled local telephone service, long distance lines, and equipment design and manufacturing. In 1974 the U.S. Department of Justice filed an antitrust suit against AT&T for monopolistic practices (United States v. AT&T). The case was settled in 1982 (552 F.Supp. 131, DDC 1982) with the dramatic break-up of the Bell System into the so-called Regional Bell Operating Companies (RBOCs) or "Baby Bells." AT&T continued to control long distance service and equipment manufacturing. By breaking up local and long distance service, new competitors such as MCI could now compete on an equal footing with AT&T.

2.2 The 1996 Telecommunications Act and Loop Unbundling

Wired broadband networks exhibit a number of features characteristic of a natural monopoly. These networks require substantial capital investment in facilities, particularly cables to homes and businesses. And in order to place these facilities, telephone companies need to obtain public right-of-way to run cables under streets or along telephone poles. Laffont reflects on this point:

> "The telecommunications industry is one with large fixed costs. Some of its segments are, technologically, natural monopolies. And, to the extent that they are produced by one or a small number of operators, these segments become bottlenecks to which other operators must have access." (Laffont, 2000)

This characteristic of the telecommunications network is generally recognized, and leads to the concern of high barriers to entry. It is expensive and difficult for a new entrant to build its own network to compete with the incumbent telephone company. Eun-A Park (2009) has examined this issue and finds that “[T]elecommunications networks are distinguished by economies of scale with sunk costs.” This allows incumbents to maintain their dominant position by leveraging their size and market power. New, small entrants are handicapped in their attempt to compete on price, not only by start-up and scale costs, but by the ability of large incumbents to heavily advertise.

> “[I]t seems evident that the incumbents in the local telecommunications network market … are more likely to respond to [small entrant competition] by employing intense advertising or other leverage for the purpose of erecting barriers rather than to compete on price directly.” (Park, 2009)

Even new, large entrants might be disadvantaged.

> “If an entrant enters with a large production capacity, it poses a serious threat to the incumbents. In such circumstances, incumbents are more likely to react aggressively to the entrant, for example by lowering their prices.” (Park, 2009)

The implication is that the new entrant can be thwarted by a temporary lowering of prices.

The Telecommunications Act of 1996 amended the Communications Act of 1934 and addressed the cable television, over the air broadcast, and telephone industries. One focus of the legislation was to further increase competition and customer choice for traditional land line telephone service. Recognizing that access facilities create barriers to entry and discourage competition, the U.S. Congress instituted measures to level the playing field and promote entry of new local telephone companies, dubbed Competitive

Local Exchange Carriers (CLECs). The 1996 Telecommunications Act was followed by an FCC Report and Order later that year. An important element of the Report and Order was provision for network "unbundling" wherein competitors could lease physical infrastructure from the incumbent:

> "[L]egislators viewed a large part of the distribution network in telecommunications … as a natural monopoly. As a result, the 1996 act instructed regulators to determine which incumbent-carrier facilities should be made available to entrants and to establish the cost basis for wholesale rates for such facilities..." (Crandall, 2005)

As Laffont explains,

> "Its key focus is thus the creation of competition by the so-called Competitive Local Exchange Carriers (CLECs) to eliminate the incumbent local exchange carriers' ability to use their bottleneck monopoly to impede competition ..." (Laffont, 2000)

Under an unbundling regime, if an entrepreneur wishes to form a new telephone company, and if this company has a willing new customer, the local telephone company has to make available the existing physical telephone line of that customer. This is depicted in Figure 2.2, where the phone line is physically removed from the incumbent's local switch and rerouted to the equipment of a competing operator, co-located in the telephone exchange.

Other regulators around the world quickly followed the example of the U.S. and began introducing local loop unbundling. The Commission of European Communities established a policy on unbundling in 2001, requiring incumbent operators throughout Europe to offer unbundled access to their local loops (EC 2887, 2000). Japan has imposed unbundling obligations on the incumbent NTT since the late 1990s (Kamino, 2009). In 2002, local loop unbundling went into effect in Korea (Speta, 2004). Okamoto has compiled the dates when loop unbundling was first introduced, shown in Table 2.1. Subsequently, most countries continued the unbundling policy throughout the last decade.

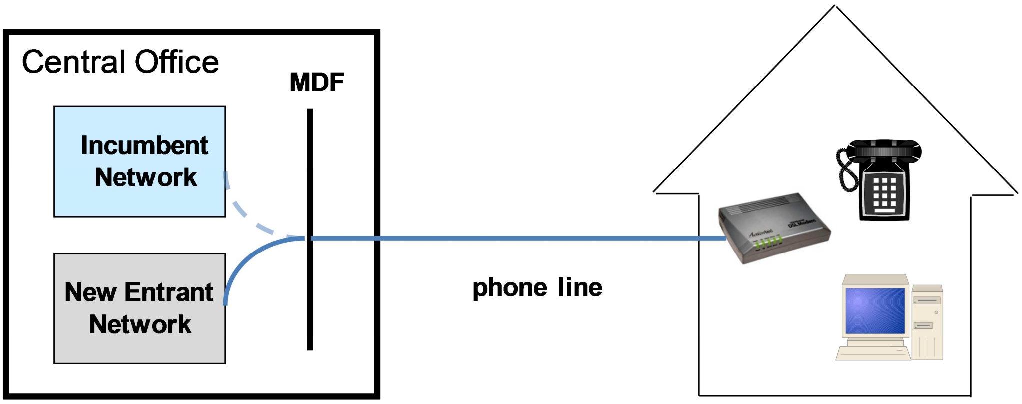


Figure 2.2 - Physical Loop Unbundling

The result of this restructuring and deregulation was expected to be a robust marketplace providing consumers with a choice of local telephone service providers. In the U.S. the result was initially positive, but then turned negative after the “dot-com” bubble and subsequent downturn beginning in 2000. A description of events is given by Crandall:

> “The first four years after the passage of the 1996 act were exhilarating for many participants in the telecommunications sector. Investment soared as stock market valuations rose at remarkable rates. … By the middle of 2000, it was apparent that the very large rise in stock market values in Internet-related companies, including telecommunications carriers, could not be sustained.” (Crandall, 2005)

The rise and fall of the CLEC marketplace in the U.S. is depicted in Figure 2.3. Incumbent operators had been arguing that unbundling was unnecessarily burdensome as well as ineffective. With most of the new competitors failing financially, the FCC rolled back unbundling requirements by 2005.

Table 2.1 - Year when Local Loop Unbundling was Introduced
(Okamoto, 2007)

Year when a Country imposed Local Loop Unbundling on the Incumbent Operator					
Australia	2000	Hungary	2002	Norway	2001
Austria	2001	Iceland	2000	Poland	2005
Belgium	2001	Ireland	2000	Portugal	2001
Canada	1997	Italy	2001	Slovak Rep.	2005
Czech Rep.	2003	Japan	2000	Spain	2001
Denmark	2000	Korea	2002	Sweden	2001
Finland	1997	Luxembourg	2001	Switzerland	N/A
France	2001	Mexico	N/A	Turkey	2004
Germany	1998	Netherlands	1997	UK	2001
Greece	2001	New Zealand	N/A	US	1996

Why did unbundling and the CLECs in the U.S. fail? Incumbent Local Exchange Carriers (ILECs) complained that regulators were setting the wholesale rates for unbundled local loops too low, to the point where they were not only losing a customer, but they were forced to maintain the loop at a loss. Kahn claims that as a result CLECs quickly abandoned attempts to build their own access networks and leased facilities from the ILECs instead. This shifted business from the ILECs to the CLECs, but did not result in any real additional network construction:

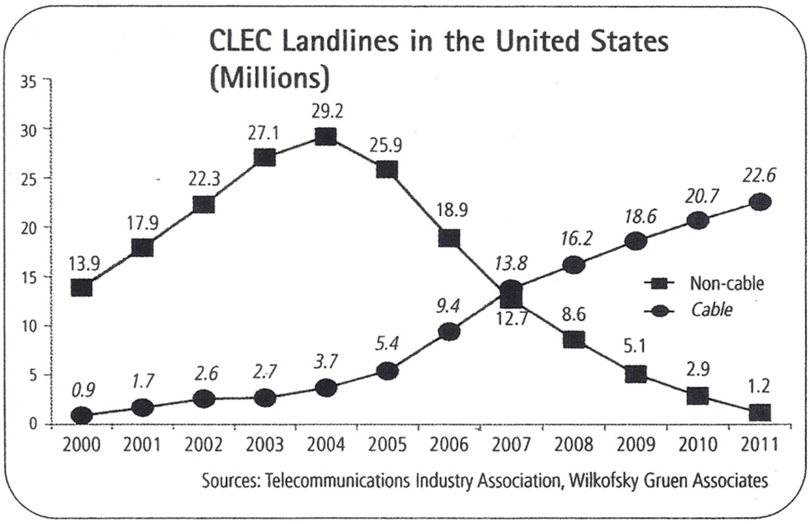


Figure 2.3 - Growth and Decline of U.S. CLECs
(TIA, 2008, used with permission)

> "Why would CLECs be expected to take the risk of constructing their own facilities … when the FCC required the ILECs to make their own network elements available to them at the hypothetical lowest prices …?" (Kahn, 2004)

Not only did the CLECs fail, but the seven Baby Bells have consolidated to the point where AT&T and Verizon now control the majority of the traditional telephone network. Economides notes the near full-cycle that has occurred since the original break-up of the regulated Bell System monopoly in 1984:

> "The failure of the goals of the 1996 act is immense. … Already, we have seen a series of mergers leading to the remonopolization of local telecommunications. … Twenty years after the government broke up the longstanding Ma Bell monopoly, the remonopolization of telecommunications is almost here." (Economides, 2004)

2.3 Competition from Cellular Services and Cable Modems

Some argue that changes and advances in technology are now making competition possible in markets that were previously natural monopolies. Kahn articulates this view:

> "[T]he march of technology has made most of the traditional public utilities, even the most naturally monopolistic among them, increasingly subject to competition." (Kahn, 1970, 1988)

Over the last decade the U.S. has seen the rollout of cellular service. Competition among wireless carriers has stimulated a range of creative feature packages and has kept prices low. And recently cable television providers developed new technology and began offering telephone service over their existing cable networks directly to households. Growth in cable telephony is shown in Figure 2.3. Competition from wireless and cable services has put pressure on the incumbent telephone companies to lower costs of traditional land line service.

Thus, despite the failure of the CLECs, one might still argue that the U.S. telecommunications industry is effectively providing competition through new technology that enables new entrants, resulting in social surplus according to basic microeconomic theory. Crandall notes

> "The diffusion of broadband, particularly over cable television systems, and the rapid growth of cellular wireless systems created a competitive environment that could not have been foreseen in early 1996, when the new act was signed into law. … These cable and wireless companies, not the new entrants, are likely to provide the most potent competition for the established telephone companies." (Crandall, 2005)

With respect to broadband availability, a number of empirical studies support this observation. Several studies find that "facilities-based competition" between cable modem and DSL networks is correlated with increased broadband penetration. In those areas where both exist, the number of broadband lines per capita is on average higher than those areas with only a single provider. For example, Cava-Ferreruelaa and Alabau-Mun analyze OECD data from 30 countries over a three year period of 2000 to 2002: "[A]nalysis of the panel data available has only clearly demonstrated the positive effects of competition between different technologies (technological competition)." (Cava-Ferreruelaa and Alabau-Mun, 2006) A study in the U.S. based on FCC, Rural Utilities Service and National Telecommunications and Information Administration (NTIA) data, shows that "after controlling for the demand and cost influences on adoption, intermodal[7] competition drives increased penetration in a state." (Aron and Burnstein, 2003)

[7] Intermodal competition is defined as competition between DSL and cable modems.

2.4 Broadband Equity Issues - the Digital Divide

Broadband availability has been growing rapidly in the U.S. Horrigan reports that at the end of 2009, 78% of adults in the U.S. were Internet users and 65% of adults had home broadband access (Horrigan, 2010). Figure 2.4 shows this growth graphically.

Despite this growth, there is general agreement that broadband deployment in rural areas is lagging:

> "Though broadband is becoming an increasingly important part of modern life, firms have little incentive to expand broadband services to rural areas since deployment costs are at least 50 percent higher per subscriber in these areas than in urban areas (Kruger 2008; Office of Management and Budget [OMB] 2005)." (Deshpande and Elmendorf, 2008, p. 16)

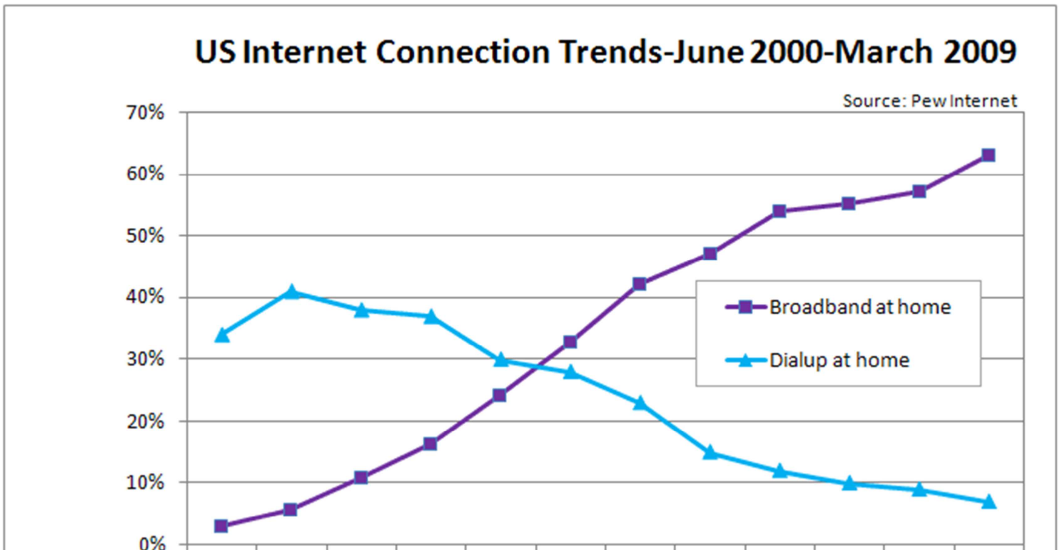
There is also general consensus that the poor are participating less in the broadband revolution:

> "For many households in urban and suburban areas, the problem is affordability of services; 76 percent of households with incomes greater than $75,000 subscribe to broadband, but this number is only 30 percent for households with incomes under $30,000." (Deshpande and Elmendorf, 2008, p. 32)

These two equity issues have come to be known as the "digital divide." The digital divide in some sense replaces the issue of universal service that existed for the traditional public telephone network. In part because of this history, there is strong sentiment that policy is needed to make broadband more widely available to all Americans.

Recent empirical research has focused on the potential benefits of policy that would reduce the digital divide. Avi Goldfarb and Jeff Prince find that, if given the opportunity, low income Americans would benefit as much or more than other segments of society.

> “Our findings indicate that this group would spend a great deal of time online and likely use the internet for activities that policymakers often view positively (e.g., news, health information). … While this prediction does not necessarily mean that access subsidies are a worthwhile policy (that depends on a full cost/benefit analysis and on any perceived negative benefit of subsidizing activities like online gaming), it does suggest that some important benefits will ensue from such subsidies.” (Goldfarb and Prince, 2008)



	June 2000	April 2001	March 2002	March 2003	April 2004	March 2005	March 2006	March 2007	Dec. 2007	April 2008	August 2008	March 2009
Broadband at home	3%	6%	11%	16%	24%	33%	42%	47%	54%	55%	57%	63%
Dialup at home	34%	41%	38%	37%	30%	28%	23%	15%	12%	10%	9%	7%

Figure 2.4 - Growth of Broadband in the U.S.
(Horrigan, 2009, used with permission**)**

There is a great diversity of proposals for addressing these equity issues. Some call for investments to lower the digital divide but not completely eliminate it, due to the high costs associated with a universal strategy:

> “The government should not attempt to provide broadband to every community, and should recognize that some isolated rural areas will have to depend on satellite as their sole source of broadband access until better forms of broadband become cost effective in these areas.” (Deshpande and Elmendorf, 2008, p. 34)

Jon M. Peha proposes a hybrid strategy that leverages market forces to address the underserved rural community (Peha, 2008). He estimates the magnitude of the problem at around 10 million households. He proposes a policy that leverages low-cost technologies that are better suited to rural areas, such as wireless. He calls upon regulators to make more spectrum available for this purpose. He recognizes that even with wireless technology the business case is marginal, and some encouragement will be needed to entice commercial entities to build out rural areas.

To address this Peha proposes a “reverse auction” wherein the price would be lowered until a commercial entity finds it attractive enough to bid. Peha recognizes potential problems with this approach. “For example, reverse auctions in Australia and India were won by the incumbent phone company at the maximum possible subsidy because there were no rival bidders.” (p. 16) This indicates some of the challenges of addressing equity issues.

2.5 Industrial Policy Applied to Broadband Networks

The term “industrial policy” refers to government intervention, investment and promotion in private markets in order to achieve a policy objective. Although recent telecommunications policy has been characterized by the trends of privatization and deregulation, there are several counterexamples of direct government involvement in broadband markets in order to promote its availability.

South Korea is perhaps the best known example of the application of broadband industrial policy. It has been widely cited as a broadband leader, in part due to policies of the government:

> “The government of Korea has intervened consistently in both the supply- and the demand-side of broadband diffusion with more than six major programmes since 1985. Initially, the government funded a backbone national network that connected public institutions throughout the country and provided incentives to operators to expand fiber optic networks. It also developed an extensive e-government programme that digitized and connected public institutions. Finally, the government also provided funds to foster demand through multiple policies, such as ICT training and promotion of local applications.” (Kelly et al, 2009)

France, the Czech Republic, and Greece have also supported the rollout of broadband:

> “In 2008, the French regulator ARCEP undertook an impact analysis of public investment amounting to approximately €1 billion, concluding that it enhanced private investment, fostered local operators, and reduced the price of rural coverage (ARCEP, 2008).” (Cave and Hatta, 2009)

> “The Czech Republic provides direct support to municipally owned networks which follow the “town owns the infrastructure” principle but where outside operators provide services. … Only public bodies such as municipalities, regions or nongovernmental non-profit organisations are allowed to apply for funds.” (OECD, 2008)

> “Policy makers in Greece … focused on backbone networks in around 75 metropolitan areas. The government finances projects with the condition that they interconnect at least 20 spots of public interest in the given metropolitan area. In actuality, the metropolitan networks interconnect an average of 45 public-interest sites in each metropolitan network.” (OECD, 2008)

Because the recent history of telecommunications policy has followed a global trend toward reliance on free market forces, not much attention has been focused on the use and effectiveness of industrial policy. Other than largely qualitative statements about investment on the part of the Korean government, few studies exist.

2.6 Next Generation Network (NGN) Broadband

The initial rollout of broadband is beginning to reach saturation (at least among middle and higher income households). It might therefore appear that arguments about industrial policy and loop unbundling are becoming somewhat academic as we near the end of deployment and there is less opportunity to influence diffusion by means of policy. However, there will be a second phase of broadband deployment, providing substantially higher speeds. Already speeds provided by first generation broadband are being viewed as too slow. The recent FCC National Broadband Plan cites both availability and speed as concerns for the U.S. The first goal of the plan states:

> "At least 100 million U.S. homes should have affordable access to actual download speeds of at least 100 megabits per second and actual upload speeds of at least 50 megabits per second." (FCC, 2010)

Recent literature has begun to refer to networks with access speeds in the tens or hundreds of megabits per second as Next Generation Networks (NGNs).[8] NGNs will require a new round of investment. As an example, over the last decade the U.S. carrier Verizon widely deployed DSL over existing copper telephone lines, but more recently has been deploying its all-fiber FiOS® service. This deployment requires both construction to place new fiber cables as well as new electronics, and is essentially a complete replacement of the existing access network.

Telecommunications is one of the most capital intensive industries in general, and this will be particularly true for deployment of NGNs. Using OECD data from 2004 to 2007, Reynolds finds:

> "Telecommunication investment by some firms was larger than the capital investment of Wal-Mart (the world's largest retailer), leading energy companies such as Exxon Mobile or Conoco Phillips, large automobile manufacturers such as GM and Ford and consumer product companies such as Johnson and Johnson. The firms with the largest capital expenditure over the previous four years were NTT and Verizon, each of which is in the process of deploying fibre-to-the-home connections. AT&T and Deutsche Telekom were also large investors …" (Reynolds, 2009)

[8] NGNs also include very high speed packet-based switching technologies in the backbone network, but use of the term here will be in the context of broadband access at speeds significantly above single digit megabits per second.

Therefore one of the primary reasons to study the success and failure of policies to expand the use of first generation broadband is to see if there are any lessons for policymakers hoping to speed the adoption of NGN.

2.7 Broadband Stimulus Programs

As a result of the recent economic downturn, governments around the world have introduced stimulus programs to counteract the recession, many of which involve broadband infrastructure investments. Kelly has collected data, shown in Figure 2.5, on recently announced investment programs:

> "Most recently, broadband investment has featured in fiscal stimulus plans around the world. … Broadband is seen as providing a quick win in these stimulus plans because, on the supply side, it stimulates investment and employment while, on the demand side, it creates opportunities for entrepreneurship and spillover effects that benefit the general economy." (Kelly et al, 2009)

The figure shows total planned spending, and the equivalent per capita total investment levels over time.

Cave and Hatta reflect on the policy motivations behind this recent trend to invest in broadband infrastructure:

> "Two distinct objectives can be discerned for choosing the communications sector as the recipient of government investment in NGAs.[9] The first is the 'industrial policy' goal of installing NGAs. This can be presented in several ways: as the provision of a transforming infrastructure offering considerable and beneficial network effects to the economy in question; or as a means of bringing investment forward to an efficient date in circumstances where the natural provider, with market power, has a private incentive to defer investment." (Cave and Hatta, 2009)

[9] The authors use the term next generation access (NGA) to indicate the access portion of the NGN.

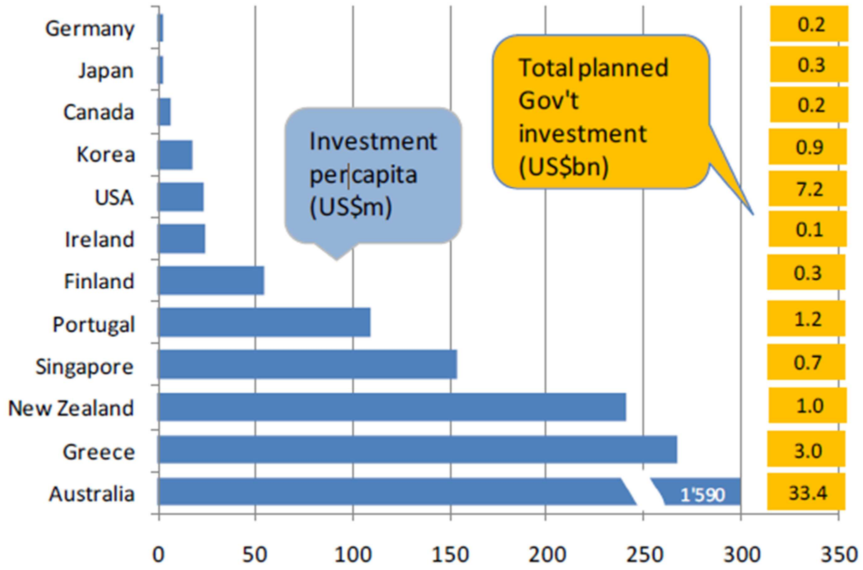


Figure 2.5 - Government Planned Spending on Broadband
(Kelly et al, 2009; *Source:* World Bank, based on data from ITU, Booz and Co and OECD, used with permission)

Reynolds gives economic justification for such programs:

> "Broadband infrastructure, in particular, can be a good target for economic stimulus spending because many projects can be initiated relatively quickly, are labour-intensive, can minimize economic leakages, and may promise stronger marginal impacts on supply and productivity than investing in established networks such as electricity, gas, water and transportation. (Reynolds, 2009)

He also explains how telecommunications investment is vulnerable to economic cycles.

> "Telecommunication investment has been particularly sensitive to changes in the economic climate over the past 20 years. … A 1% change in GDP corresponds roughly to an 8% change in telecommunication investment. …The strongly pro-cyclical nature of communication network investment also means that skilled labour and equipment may be left idle and planned projects shelved until the economy improves. This labour and equipment could be quickly shifted to government-sponsored projects." (Reynolds, 2009)

As Huigen and Cave note, the recent trends in the U.S. have been strongly deregulatory.

> "There is a distinctly deregulatory approach, which is mainly seen in the USA. There is an interventionist approach driven by industrial policy which is typical of many Asian markets; examples are Japan and South Korea. And there is a third or middle way, the European approach, which is focused on regulatory intervention based on competition analysis which is supposed to be devoid of any influence of industrial policy." (Huigen and Cave, 2008)

However it is worth noting that policy may be shifting toward more government oversight and intervention. For example, Senator John D. Rockefeller IV, chairman of the Senate Commerce Committee, recently promoted a broadband regulatory plan similar to the industrial policies seen in Korea and Japan. The plan encouraged aggressive investment in broadband by both offering a tax credit, and also sweetening the credit if the network supported very high speed (100 Megabits per second) access (Hansell, 2009a and 2009b).

The American Recovery and Reinvestment Act of 2009 contains two separate broadband provisions: the Distance Learning, Telemedicine, and Broadband Program, under the Department of Agriculture's Rural Utility Service, in the amount of $2.5B; and the Broadband Technology Opportunities Program, under the National Telecommunications and Information Administration, in the amount of $4.7B. The former program provides grants, loans, and loan guarantees for broadband infrastructure. At least 75% of the funds must go to rural areas that do not have sufficient access to broadband in order to facilitate rural economic development. The latter program grants funds to states to provide broadband service to unserved and underserved areas, including schools, libraries, healthcare facilities, colleges, and organizations serving underprivileged groups. It also requires the development of a broadband inventory map, and a comprehensive national broadband plan overseen by the FCC (Act, 2009).

2.8 Empirical Analyses of Telecommunications Regulation

Scott Wallsten calls for the application of empirical research to determine the effectiveness of different telecommunications regulatory policies.

> "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. Despite the heated debate … remarkably little empirical research attempts to explain these differences." (Wallsten, 2006)

One finding of empirical studies is that higher population density leads to more broadband penetration.

> First, population density matters: it is positively correlated with broadband penetration and with connection speeds. More densely populated countries have higher penetration rates, even controlling for country and year fixed effects." (Wallsten, 2006)

This makes sense because infrastructure investments in high density areas are more efficient due to higher sharing and lower per-subscriber costs.

Several studies find that facilities-based competition between cable and DSL networks is correlated with increased broadband penetration. In those areas where both exist, the number of broadband lines per capita is on average higher than those areas with only a single provider. For example, in an analysis of OECD data from 30 countries over the period 2000 to 2002:

> "[A]nalysis of the panel data available has only clearly demonstrated the positive effects of competition between different technologies (technological competition)." (Cava-Ferreruelaa and Alabau-Mun, 2006)

Recent studies attempt to measure the effectiveness of regulatory requirements for loop unbundling. Wallsten describes the interest:

> "The most contentious policy, both in the U.S. and around the world, has been the role of unbundling regulations. … 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." (Wallsten, 2006, p. 4)

Empirical analyses of loop unbundling provisions have shown mixed results. The effectiveness of unbundling has been controversial from a theoretic point of view as well. Laffont addresses tension inherent in the unbundling policy:

> "There is in general a trade-off between promoting competition to increase social welfare once the infrastructure is in place and encouraging the incumbent to invest and maintain the infrastructure. That is, regulators must encourage entry without expropriating incumbents." (Laffont, 2000)

And Troy Quast concludes that loop unbundling discourages new investment:

> "From roughly 2001-2006, entrants were able to lease all the infrastructure necessary to provide phone service to customers. … It is found that platform entry may have significantly discouraged loop entry." (Quast, 2008)

Wallsten tries to tease apart differences in types of unbundling to explain these differences. The analysis is complicated by the fact that there are many types of unbundling, and they are not consistent across countries. In general, he finds unbundling scenarios that are more onerous to the incumbent can actually slow broadband penetration.

> "[O]f 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. (Wallsten, 2006, p. 16)

These empirical results are consistent with Kahn's (2004) criticisms (see p. 20) that the Telecommunications Act of 1996 simply shifted revenues from one entity to another, but did not necessarily encourage additional investment.

According to another study, empirical evidence on unbundling in Europe shows a negative impact. Grajek and Röller use a sophisticated econometric model in which they allow regulatory policy to be an endogenous variable. The study finds that increased regulation does encourage new entrants, but discourages incumbents from investing and rolling out service as rapidly as they might otherwise. Unfortunately the increase in entrant activity does not appear to compensate for the reduction in incumbent activity. "This adds up to some €16.4 billion lost infrastructure investment for the European Union as a whole, which corresponds to almost 23 percent of the infrastructure stock." (Grajek and Röller, 2009) The study is constrained to countries in Europe, and is dependent upon a regulatory index defined by the authors.

Wallsten and Hausladen show that unbundling negatively impacts fiber investment in Europe (Wallsten and Hausladen, 2009). On the other hand, high level empirical evidence shows that Japan and Korea are currently leaders in fiber penetration, as shown in Figure 2.6. Japan has maintained a consistent and strong unbundling policy, applied to fiber as well as copper access networks. Korea has had unbundling policy in place since 2002, although a fiber access obligation is restricted to facilities built before 2004 (Cave and Hatta, 2009). With about half of broadband subscribers served by fiber, it is hard to argue that an unbundling policy has delayed investment on the part of incumbent operators in these two countries.

As mentioned, one of the prime motivations for empirically examining the impact of regulation on broadband is to try to determine how successful policies such as the Telecommunications Act of 1996 have been, and whether there is a more effective regulatory approach. This is at least in part motivated by claims that the U.S. is behind in broadband, particularly compared to parts of the Pacific Rim. As Wallsten notes

> "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." (Wallsten, 2006, p. 7)

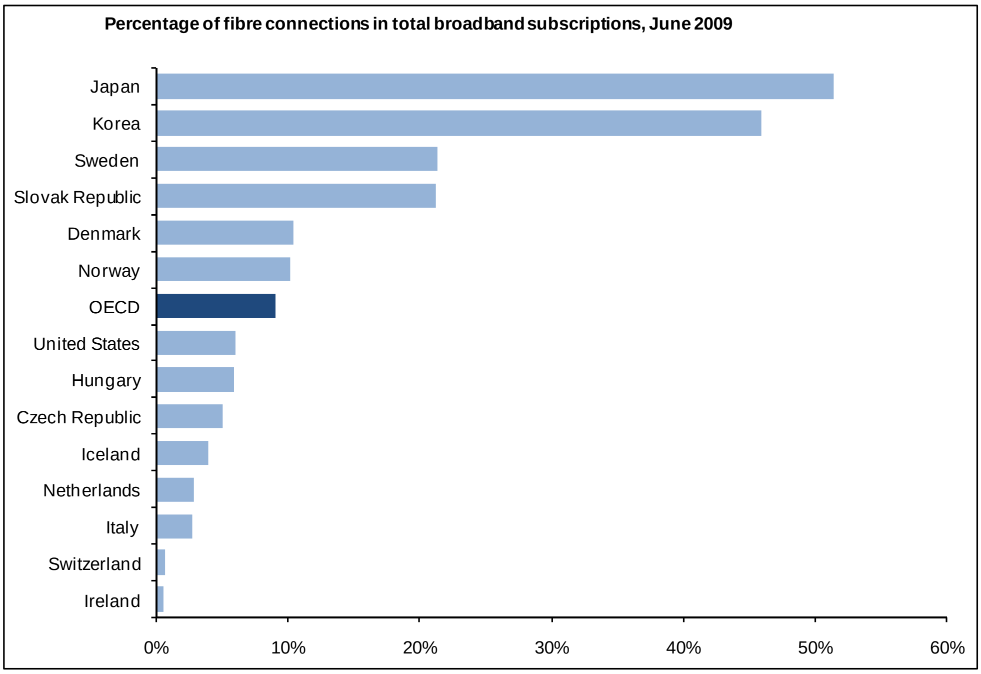


Figure 2.6 - Fiber-based Broadband Penetration
(Cave and Hatta, 2009, used with permission)

One clear explanation for better broadband penetration is the higher population density in Korea and Japan. However, another lesser explored possibility is differences in industrial policy.

> "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 rigorously explores the true impact - or magnitude - of those subsidies. (Wallsten, 2006, p. 7)

In summary, empirical studies to date on the impact of telecommunications regulatory policy on broadband diffusion have found:

- Broadband penetration has been demonstrated to be higher in more densely populated areas.
- Broadband penetration is higher in areas where there is competition between the incumbent telephone company and the cable television company, so called facilities-based competition.
- Broadband penetration under the Telecommunications Act of 1996 in the U.S. has had mixed results, with some evidence that the loop unbundling provisions that were intended to lower barriers to market entry and encourage local competition have in fact discouraged broadband investment and deployment. Also, there is evidence that unbundling has had a negative effect in Europe.
- The impact of industrial policy, such as takes place in Korea and Japan, and was proposed by Senator John D. Rockefeller in the U.S., has not been empirically studied to date.

3 An Empirical Analysis of the Impact of Broadband Policies

There is now a decade of hard data on the diffusion of first generation broadband. This data can be examined in the context of different broadband policies employed by different countries. This chapter is primarily concerned with the use of industrial policy and unbundling. For the 30 OECD countries, I collate indicators for the years when they applied industrial policy, and when they imposed unbundling. These indicators are gathered for the time period 2003 through 2008, a timeframe for which good broadband deployment data is available from OECD and other sources. As in previous studies, the dependent variable is broadband subscribers per 100 inhabitants.

Because a paramount concern of policymakers is to promote broadband connectivity to homes, a better metric might be the number of living units with broadband. However, the manner in which data is collected does not easily support this metric. Operators report the number of broadband lines, but this includes lines to small and medium businesses as well as residences. This problem is addressed in OECD frequently asked questions: “Normalizing subscribers as a percentage of total households would consistently over-estimate broadband penetration.” [10]

I test the unbundling variable in lagged form as well. A number of years may pass between the time loop unbundling is first mandated by a regulatory agency and the time when competitors can begin to actively market unbundled services. The effects of the policy therefore may not become apparent for several years.

Control variables in the dataset include population density and cable competition. Increased population density and the presence of cable competition have both been found

[10] http://www.oecd.org/document/33/0,3343,en_2649_34225_43875169_1_1_1_1,00.html (last viewed April 2011)

to be positively correlated with more rapid broadband deployment in previous studies (Wallstein, 2006) (Aron and Burnstein, 2003) (Cava-Ferreruelaa and Alabau-Mun, 2006). Penetration of computers in households and attainment of advanced educational degrees will also be tested as control variables. Macroeconomic indicators may also partially explain broadband availability and will be tested as potential control variables, including GDP, employment, long term interest rates, and corporate tax rates. Table 3.1 below provides a listing of the variables included in the dataset. The anticipated effects of these variables are discussed in the next section.

Table 3.1 - A Dataset for Investigating Impacts of Broadband Policy

Variables for the Study of Broadband Policy Unless otherwise noted all variables are for 30 OECD countries for years 2003 through 2008				
Variable Theory	**Variable Category**	**Variable Sub-Category**	**Variable Units**	**Variable Name**
Dependent Variables	Broadband subscribers per 100 inhabitants	Total	Number of broadband subscribers per 100 inhabitants	bb_density
Policy Independent Variables	Industrial policy		A “1” if industrial policy applies during the year; otherwise “0”	industrial_policy
	Plant and machinery depreciation	Average and maximum for a country	Depreciation rate (%)	plant_dep_ave plant_dep_max
	Application of unbundling	Starting/stopping the year when policy was enacted/removed	A “1”if unbundling policy applies during the year; otherwise “0”	unbundling
	Application of unbundling - lagged	Starting/stopping N years after policy was enacted/removed	A “1”if unbundling policy applied N years ago; otherwise “0”	l1_unbundling l2_unbundling l3_unbundling
	Interaction terms	Unbundling w/o industrial policy, vice versa, both, and neither	A “1” if the condition applies; otherwise “0”	unbundle_wo_ind ind_wo_unbundle both_unbundle_ind no_unbundle_ind
Control Independent	Population Density		Population density (people per sq km)	pop_density

Variables	Presence of cable	Amount of broadband provided by cable	Percentage of broadband delivered by cable modem	cable_percent
		Cable competition is significant	A “1” if percentage of cable broadband exceeds 20% (40%); otherwise 0	cable_comp_20 cable_comp_40
	Computer Usage	Homes having at least one PC	Percentage of homes with a PC (%)	houses_pc
	Education	Tertiary Type A and Research degrees (BS, MS, PhD)	Percentage of adults with advanced degree (%)	higher_ed_degrees
		Students enrolled in tertiary programs (beyond high school)	Percentage of adults enrolled in tertiary degree programs (%)	tertiary_ed_enrolled
		GDP - US dollars at current prices and current purchasing power parity (PPP)	per capita	gdp_per_capita
			Natural log of per capita	ln_gdp_per_capita
		Employment - adjusted for seasonal variation	Employment rate (%)	employment
			Natural log of employment rate	ln_emp
		Long term rates	Long term interest rates (%)	long_term_interest _rates
		Corporate taxes	Corporate tax rate (%)	corp_tax

Figure 3.1 shows a graph of the data for broadband density. The data is presented as a box plot with 75th, median and 25th percentiles, and the whiskers show upper and lower adjacent values. Country detail can be found in Appendix A, obtained from the OECD Key ICT Indicators.[11]

[11] OECD Key ICT Indicators, item 4a, (last viewed April 2011) http://www.oecd.org/document/23/0,3343,en_2649_34449_33987543_1_1_1_1,00.html

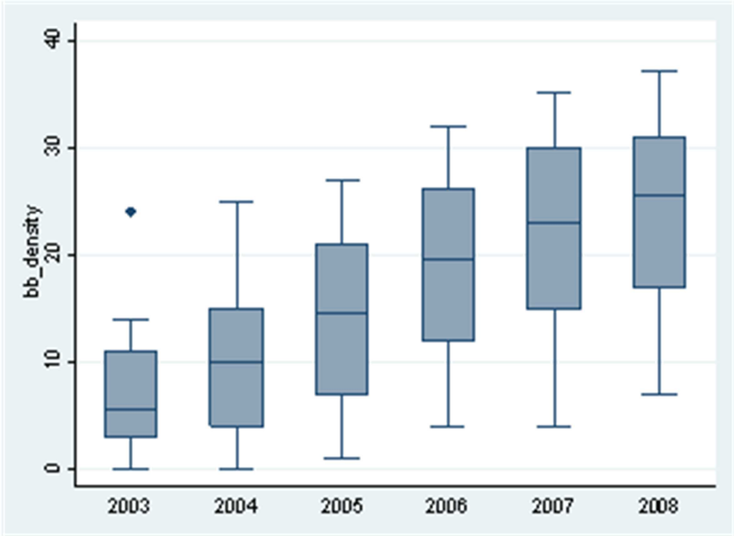


Figure 3.1 - Box Plot of Broadband Density for 30 OECD Countries (subscribers per 100 inhabitants)

Figure 3.2 shows a histogram of population density for the year 2006, the middle year when considering data from 2004 through 2008.[12] The distributions of population density are relatively stable over time. The data is obtained from the OECD Broadband Portal[13] and SourceOECD, Population and Vital Statistics (SourceOECD, 2010).

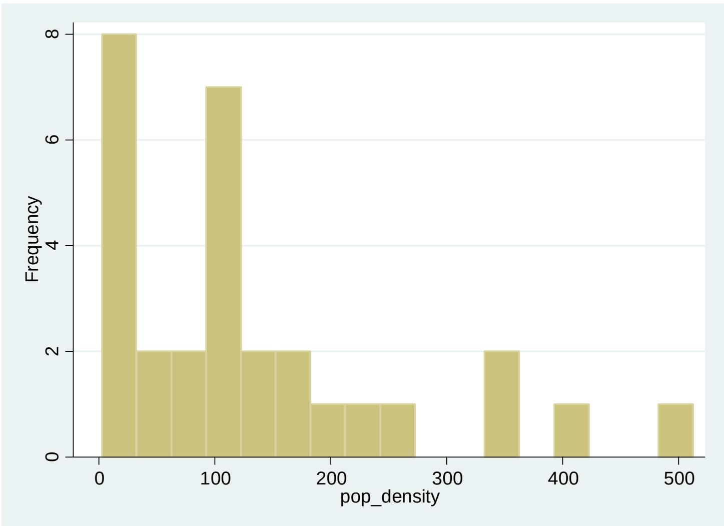


Figure 3.2 - Histogram of 2006 Population Density for 30 OECD Countries (people per square kilometer)

[12] The use of a lagged dependent variable results in the sacrifice of data from year 2003.
[13] OECD Broadband Portal, item 3b, (last viewed April 2011) http://www.oecd.org/document/54/0,3343,en_2649_34225_38690102_1_1_1_1,00.html#Coverage

Figure 3.3 shows a histogram of percentages of homes having one or more personal computers (PCs) in 2006. The scale is fractional, with 1.0 corresponding to 100% penetration. The data is obtained from the OECD Key ICT Indicators.[14] Note that for the year 2006, data is not available for several of the OECD countries.

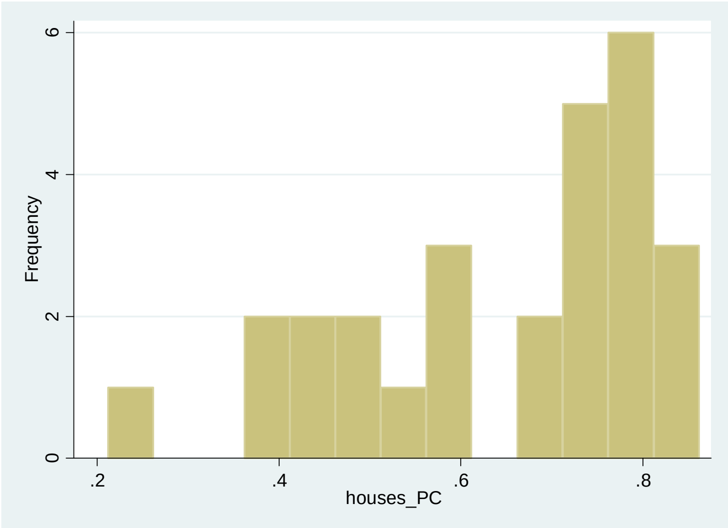


Figure 3.3 - Histogram of 2006 PC Penetration in Households for 30 OECD Countries
(fraction of households with PCs)

Figure 3.4 shows a histogram of long term interest rates in 2006. The scale is fractional, with 0.1 corresponding to a 10% interest rate. The data is obtained from SourceOECD[15] (SourceOECD, 2010). The rates are representative of public sector bonds with a maturity of about 10 years. Note that for the year 2006, data is not available for several of the OECD countries.

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[14] OECD Key ICT Indicators, item 6a, (last viewed April 2011)
http://www.oecd.org/document/23/0,3343,en_2649_34449_33987543_1_1_1_1,00.html
[15] http://oberon.sourceoecd.org/vl=13858182/cl=12/nw=1/rpsv/ij/oecdstats/16081234/v195n1/s2/p1

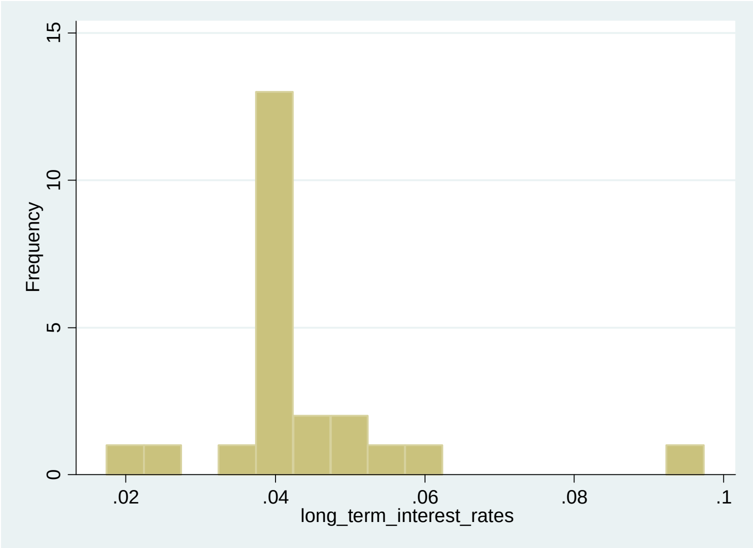

Figure 3.4 - Histogram of 2006 Long Term Interest Rates for 30 OECD Countries (interest rate expressed as a fraction)

Figure 3.5 shows histograms of the industrial policy flags over time. These flags were derived from several sources (Cave and Hatta, 2009) (Kelly et al, 2009) (Kirsch and Von Hirschhausen, 2008) (OECD, 2008) (Speta, 2004). The data is shown in Appendix B.

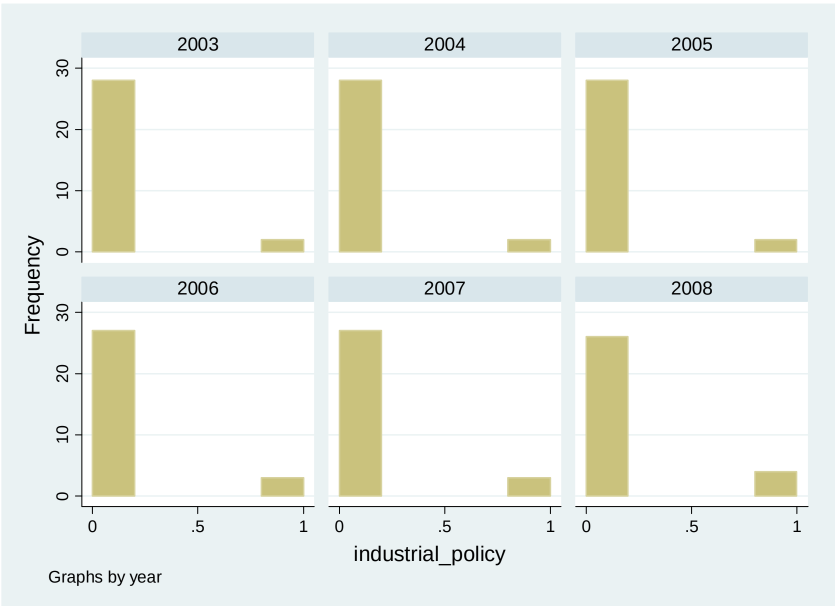

Figure 3.5 - Histograms of Industrial Policy Flags for 30 OECD Countries (“1” if industrial policy applies during the year; otherwise “0”)

Figure 3.6 shows histograms of lagged unbundling flags. The lag is one year. Over time most OECD countries instituted an unbundling policy. The only countries to later drop unbundling as a policy were South Korea, beginning in 2004, and the U.S., beginning in 2005. Because South Korea dropped unbundling requirements on fiber only, the flag is adjusted according to the percentage of broadband provided by copper (for which unbundling still applied), and this results in a fractional value between zero and one. The unbundling data, lagged by one year, is shown in Appendix C.

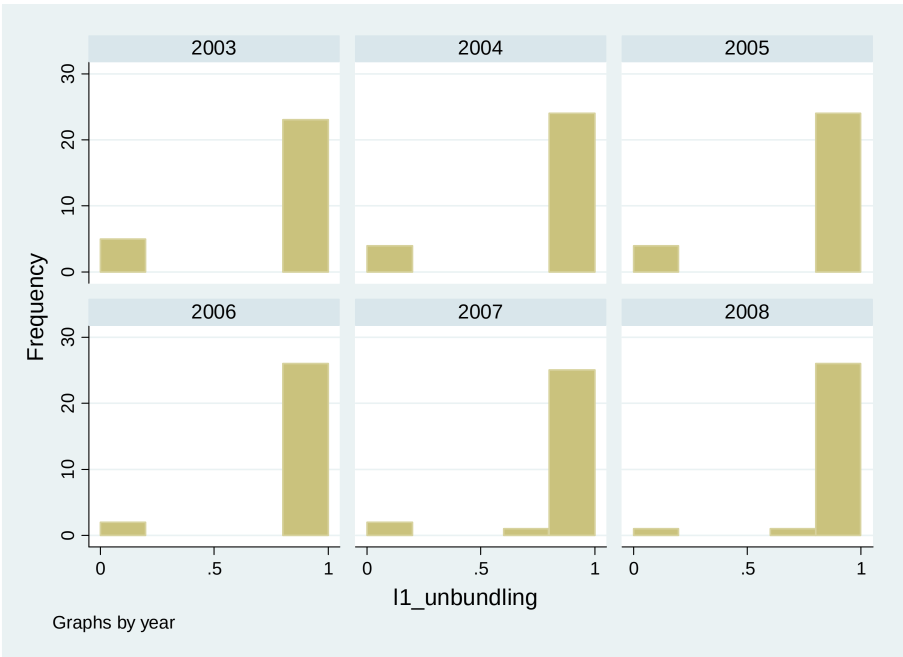

Figure 3.6 - Histograms of Lagged Unbundling Flags for 30 OECD Countries (“1” if industrial policy applied during the previous year; otherwise “0”)

3.1 Model Specification and Research Hypotheses

The independent variables can be used to test theoretical reasoning relative to broadband policy. Two general questions are probed. The first is the impact of industrial policy on broadband diffusion. The second is the impact of unbundling policy on broadband diffusion.

Because broadband came about shortly after telephone companies had been privatized and deregulated, most countries left the diffusion of broadband to free market forces. There were a number of exceptions however. There is a general consensus that investment by the South Korean government contributed to rapid deployment of broadband in that country (Kelly et al, 2009) (Huigen and Cave, 2008). There is also evidence that the French government made large investments in its broadband rollout, and the Czech Republic and Greek governments made investments as well.

Government intervention is now being widely discussed again. There is a general recognition that reliance on commercial forces to produce broadband will also bring about equity issues; there will be unserved rural citizens and underserved poor. This has led to proposals for direct government support to close this "digital divide." Additionally, in response to the economic recession of 2009 many governments have instituted stimulus programs that invest in infrastructure, including broadband next generation networks (NGNs).

How effective these interventions are is a fundamental question. There is an opportunity cost associated with the resources that are directed toward building broadband infrastructure. Policymakers would like to know the effectiveness of these investments, particularly compared to free market forces that will also bring about broadband availability. The dataset will be used to test the impact of industrial policy on broadband penetration. If definitive lessons can be learned relative to industrial policy applied to first generation broadband deployment, then more effective policy for promulgating broadband NGNs can be proposed.

I also examine the impact of loop unbundling. From the literature described in Chapter 2, it is obvious that there are competing theories regarding the impact of unbundling policy. One line of reasoning holds that the existing incumbent telephone company will continue to exhibit tendencies of a regulated monopoly, including lack of innovation and high prices. This market failure needs to be counteracted by competition, which is encouraged through unbundling policy (Laffont, 2000) (EC 2887, 2000).

Counterarguments hold that unbundling will cause the incumbent to drag its feet, resisting competition and postponing any investment in its own network for fear that competitors will unfairly have access to the upgraded infrastructure. Furthermore, unbundling doesn’t bring about a separate competitive network, like a cable television network using cable modems. Rather, unbundling simply shifts market share within a single network and doesn’t create any net addition to the market size or social surplus (Kahn, 2004).

When testing these two competing theories we have, at a high level, mixed empirical evidence. Unbundling in the U.S. was abandoned around 2005, coincident with the bursting of the “dot-com bubble.” Empirical studies examine the period before, but not after unbundling requirements were dropped. Europe has applied unbundling for almost a decade. Some empirical studies point to ambiguous or negative results. But

Japan has had a consistent policy of unbundling, and has the “fastest and cheapest broadband in the world.” (Kamino, 2009)

The dataset will be used to test the impact of unbundling relative to broadband penetration. Unbundling and lagged unbundling indicators will be tested across the 30 OECD countries over time.

Table 3.2 below predicts the impact of the independent variables on broadband diffusion, as measured by the dependent variable broadband subscribers per 100 inhabitants.

Table 3.2 - Predicted Impacts of Independent Variables

Variable Specification	Variable Name	Expected Impact on Dependent Variable	Sign
Dependent Variables	bb_density	Test for independent variables that either increase or decrease the rate of broadband deployment, all other factors being equal	
Policy Independent Variables	industrial_policy	Direct government investment in broadband infrastructure is predicted to have a positive impact on broadband availability	+
	plant_dep_ave	Higher depreciation rates should encourage investment and have a positive impact on broadband deployment	+
	unbundling and lagged unbundling	Unknown - evidence to date is mixed	?
Control Independent Variables	pop_density	Previous empirical studies have found a direct correlation between higher population density and more rapid broadband deployment	+
	cable_percent	Previous empirical studies have found that markets with both cable modems and DSL show more rapid broadband penetration	+
	cable_competition	Previous empirical studies have found that markets with both cable modems and DSL show more rapid broadband penetration	+

	houses_pc	A higher percentage of homes with PCs is likely to generate higher demand for broadband	+
	higher_ed_degrees tertiary_ed_enroll	Pursuit and attainment of a higher educational level will be correlated with greater computer fluency and usage, and make subscription to broadband more likely	+
	gdp_per_capita ln_gdp_per_capita	Higher GDP per capita implies more discretionary funds for consumers, making subscription to broadband more likely	+
	employment ln_emp	Higher employment should be correlated with more consumption, which would tend to increase broadband subscriptions	+
	long_term_interest_rates	Higher long term interest rates make investments in infrastructure more expensive and risky	-
	corp_tax	Higher corporate taxes will reduce funds available for investment in network expansion	-
Panel Data Control Variables - Countries and Regions (relative to Western Europe)	us, ca	The US and Canada, although dropping in ranking over the period, are generally ahead of Western Europe in broadband deployment.	+
	au, nz	The countries of Australia and New Zealand are comparable to Western Europe	?
	scand	Scandinavian countries are consistently leaders in broadband deployment	+
	central_eur	Central European countries generally lag in broadband deployment	-
	jp, kr	Korea has been a leader in broadband deployment, although falling in rank during the period; Japan is comparable to Western European countries	+

Theory predicts that additional incentive or investment on the part of a government in a private industry will promote production. Thus the use of industrial policy to provide government investment in broadband infrastructure should increase broadband availability. Qualitative evidence from South Korea, a broadband leader and a strong supporter of industrial policy, supports this theory.

When governments allow higher depreciation rates for business investments, corporations can claim larger tax deductions and these investments can be written off sooner. This makes investment more attractive from a business case point of view. This leads to a prediction that higher depreciation rates for plant and machinery, a proxy for depreciation rates specific to telecommunications networks, will increase broadband deployment.

Because of the mixed theoretical views on the effectiveness of unbundling to date, no prediction is made about the impact of this independent policy variable.

Previous studies have shown that higher population densities are correlated with higher levels of broadband deployment (Wallsten, 2006). When operators can reach more subscribers over shorter distances for a given level of network investment, they can offer lower subscription fees and take-up is likely to be higher.

Several studies find that “facilities-based competition” between cable modem and DSL networks is correlated with increased broadband penetration (see p. 30-31). In those areas where both exist, the number of broadband lines per capita is on average higher than those areas with only a single provider.

Since the primary mechanism to connect to the Internet during the last decade has been via a computer, higher penetration rates of personal computers (PCs) in homes should lead to higher levels of broadband subscription.

Use of computers and the Internet is becoming increasingly essential in school work, and this is particularly true for advanced levels of education. Therefore populations with higher percentages of individuals pursuing and attaining advanced degrees would be expected to lead to higher levels of broadband usage and subscription.

Higher levels of GDP per capita implies that consumers have more discretionary funds available for purchases, including subscriptions to broadband services, thus driving up broadband penetration levels.

Similarly, higher levels of employment at the macroeconomic level can be expected to increase levels of consumption and increase the take-up of broadband.

As noted by Reynolds, broadband service providers must invest heavily in their networks (Reynolds, 2009). Higher long term interest rates make capital investments more expensive and more risky, and would therefore be expected to decrease the production of broadband.

Higher corporate tax rates will leave broadband service providers with less after-tax income to use for various purposes, including reinvestment in their networks. Higher tax rates would therefore be expected to decrease the production of broadband.

Dummy variables are created and used to reflect regional differences. The regions of Western Europe, Scandinavian, and Central Europe were created. Individual flags were used for the U.S., Canada, Australia, New Zealand, Japan and Korea. Western Europe was dropped and becomes the baseline for comparison. Countries in Western Europe generally fall in the middle of the range of broadband density. Predictions for the signs of the dummies are made by examining the broadband rankings by country in Appendix A. For example, the countries of Scandinavia are consistently ahead in the rankings, leading to a prediction of a positive coefficient. Similarly the countries of Central Europe are consistently behind in the rankings, leading to a prediction of a negative coefficient.

3.2 Estimation and Assessment

A linear regression model (LRM) using ordinary least squares (OLS) is fitted to the panel data for the years 2003 through 2008 and across the 30 OECD countries using the data analysis and statistical software package Stata®. Previous empirical studies have used OLS on the dependent variable broadband density, and the primary intent here is to add explanatory policy variables to these studies.

With 30 countries and 6 time periods, this is considered a shallow panel. Because lagged broadband density is used in the regressions, observations are limited to the years 2004 through 2008. Table 3.3 shows the statistics for the variables used in the regression analysis. Table 3.4 shows correlations between selected variables used in the analysis.

Table 3.3 - Summary Statistics of Variables

Variable	Obs	Mean	Std. Dev.	Min	Max
bb_density	180	15.82778	9.845641	0	37
pop_density	180	133.3418	122.7446	2.59	488.02
houses_pc	156	.619175	.1945418	0	.91922
long_term_~s	138	.0437152	.0134194	.01	.1107
industrial~y	180	.0888889	.2853771	0	1
unbundling	168	.9093058	.2790552	0	1
l1_unbundl~g	168	.8880621	.3104526	0	1
l2_unbundl~g	168	.8543772	.3505497	0	1
l3_unbundl~g	168	.7605801	.4266267	0	1
l1_bb_dens~y	150	14.19333	9.276293	0	35
us	180	.0333333	.1800062	0	1
ca	180	.0333333	.1800062	0	1
au	180	.0333333	.1800062	0	1
nz	180	.0333333	.1800062	0	1
scand	180	.1666667	.3737175	0	1
central_eur	180	.2	.4011158	0	1
jp	180	.0333333	.1800062	0	1
kr	180	.0333333	.1800062	0	1

Table 3.4 - Correlation Table for Variables (118 observations)

	bb_den~y	pop_de~y	houses~c	long_t~s	indust~y	l1_unb~g
bb_density	1.0000					
pop_density	0.1749	1.0000				
houses_pc	0.7999	0.1686	1.0000			
long_term_~s	0.1934	-0.2775	0.1804	1.0000		
industrial~y	0.1279	0.3994	-0.1018	0.0682	1.0000	
l1_unbundl~g	0.1894	0.0208	0.1519	-0.0674	0.0002	1.0000

Table 3.5 shows results from progressively adding policy and control independent variables. The F-test evaluates the null hypothesis H_0 that all regression coefficients are equal to zero. The null hypothesis is easily rejected, and so at least some of the independent variables have predictive value. The value of adjusted R^2 is above 97%, indicating these variables explain much of the behavior of broadband density.

Three control variables were found to be significant and with signs as predicted. Increased population density, as found in previous empirical studies, increases broadband density. An increase in PC penetration explains higher broadband density, as predicted. Higher long term interest rates are correlated with lower levels of broadband density, as predicted.

Industrial policy is always a statistically significant predictor of broadband density, and always with a positive sign indicating that its application has a positive influence on broadband density. Unbundling is often a statistically significant predictor of broadband density, especially in lagged form. The coefficient sign was always positive, indicating that the application of unbundling policy has a positive influence on broadband density.

Table 3.5 - OLS Regression Analysis Results for Broadband Density

	bb_density Coefficient (P>|t|)											
pop_density	.008257 (0.000)	.0081946 (0.000)	.0081355 (0.000)	.0081475 (0.000)	.0073456 (0.001)	.0076028 (0.000)	.0076234 (0.000)	.0076315 (0.000)	.0076843 (0.001)	.0076522 (0.001)	.0078015 (0.001)	.0077243 (0.001)
houses_pc					7.071838 (0.000)	6.771227 (0.000)	6.603953 (0.000)	6.733064 (0.000)	8.810587 (0.000)	9.167443 (0.000)	8.871174 (0.000)	8.888417 (0.000)
long_term_ interest_rates									-24.7147 (0.046)	-25.3544 (0.036)	-24.0180 (0.048)	-25.3001 (0.039)
industrial_policy	1.835735 (0.001)	1.751587 (0.001)	1.716411 (0.002)	1.659857 (0.003)	2.273206 (0.000)	2.148132 (0.000)	2.201793 (0.000)	2.023962 (0.001)	2.555887 (0.000)	2.460941 (0.000)	2.342283 (0.000)	2.359252 (0.000)
unbundling	1.560112 (0.070)				1.236449 (0.170)				0.751081 (0.467)			
l1_unbundling		1.578769 (0.012)				1.746627 (0.007)				1.666333 (0.046)		
l2_unbundling			1.054518 (0.059)				1.147069 (0.050)				1.411641 (0.061)	
l3_unbundling				0.930006 (0.066)				1.077099 (0.042)				.8539386 (0.181)
l1_bb_density	.8837033 (0.000)	.8843149 (0.000)	.8861085 (0.000)	.885618 (0.000)	.8067064 (0.000)	.8045984 (0.000)	.8069913 (0.000)	.8055809 (0.000)	.7816415 (0.000)	.7764305 (0.000)	.7790072 (0.000)	.7802713 (0.000)
us	2.653287 (0.026)	2.337402 (0.013)	1.690765 (0.049)	1.427861 (0.080)	3.527038 (0.045)	4.077624 (0.011)	3.453648 (0.031)	3.395599 (0.031)	3.242413 (0.062)	4.188255 (0.009)	3.927368 (0.012)	3.343733 (0.027)
ca	1.617448 (0.056)	1.594302 (0.056)	1.568749 (0.063)	1.568957 (0.063)	1.175773 (0.147)	1.257462 (0.113)	1.260289 (0.118)	1.252844 (0.120)	1.226682 (0.125)	1.20231 (0.125)	1.23764 (0.115)	1.216136 (0.125)
au	2.16156 (0.007)	2.142904 (0.007)	2.130589 (0.008)	2.127174 (0.008)	1.332041 (0.088)	1.390521 (0.068)	1.406752 (0.069)	1.392206 (0.072)	1.618681 (0.034)	1.574672 (0.035)	1.601172 (0.032)	1.608935 (0.033)
nz	1.949495 (0.038)	2.260917 (0.014)	2.04768 (0.033)	1.917735 (0.039)	2.407061 (0.041)	2.71368 (0.015)	3.003685 (0.016)	2.919015 (0.016)	2.506732 (0.029)	2.921785 (0.007)	3.521158 (0.005)	2.976159 (0.013)
scand	2.991026 (0.000)	2.969068 (0.000)	2.94293 (0.000)	2.943433 (0.000)	2.407061 (0.000)	2.5005 (0.000)	2.507283 (0.000)	2.495169 (0.000)	2.629833 (0.000)	2.602799 (0.000)	2.631996 (0.000)	2.621747 (0.000)
central_eur	-1.83715 (0.000)	-1.67349 (0.000)	-1.60589 (0.000)	-1.48970 (0.001)	-1.07643 (0.015)	-.916632 (0.035)	-.870971 (0.056)	-.715544 (0.136)	-1.10425 (0.028)	-.896594 (0.074)	-.747022 (0.158)	-.771422 (0.172)
jp	-1.96610 (0.010)	-1.96606 (0.009)	-1.96537 (0.010)	-1.97095 (0.010)	-2.90017 (0.000)	-2.89007 (0.000)	-2.87324 (0.000)	-2.89797 (0.000)	-3.82397 (0.000)	-3.89926 (0.000)	-3.84807 (0.000)	-3.87380 (0.000)
kr	-4.53582 (0.000)	-4.57967 (0.000)	-4.70834 (0.000)	-4.52513 (0.000)	-4.95913 (0.000)	-4.87357 (0.000)	-5.01478 (0.000)	-4.78974 (0.000)	-5.16665 (0.000)	-4.97892 (0.000)	-5.04785 (0.000)	-4.96682 (0.000)
cons	2.214425 (0.020)	2.206398 (0.003)	2.719089 (0.000)	2.853557 (0.000)	-.689897 (0.569)	-1.01456 (0.299)	-.342919 (0.710)	-.332484 (0.714)	-.480612 (0.745)	-1.02929 (0.436)	-.698458 (0.575)	-.104998 (0.929)
Number of obs	140	140	140	140	125	125	125	125	99	99	99	99
Prob > F	0.000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Adjusted R^2	0.9737	0.9743	0.9737	0.9737	0.9786	0.9796	0.9790	0.9790	0.9817	0.9825	0.9824	0.9820

Many regressions were run without the lagged dependent variable, broadband density levels lagged by one year. Although some models were found with relatively high predictive value and with statistically significant coefficients, these models were less well behaved in terms of stability and consistency of coefficient signs. Furthermore, all of these models suffered from large time correlation of the residuals. The addition of the lagged dependent variable both reduced residual correlation, and improved the stability of regressions.

Additionally, regressions were run using various forms of the dependent variable, including year-to-year changes, year to year ratios, and logged versions thereof. Although some of these formulations marginally improved the stationarity of the dependent variable, the statistical significance of independent variables degraded substantially. Therefore, as in previous studies, I use the level of broadband density as the dependent variable.

For panel data an appropriate technique is to use a fixed effects regression. Fixed effects will help control for omitted variables that differ between countries, and is one of the most basic techniques used for panel data.[16] A fixed effects regression was run after first sorting the dataset across countries and years. Loop unbundling was only significant at the 20% level.

Because this dataset has 30 countries and only 6 time periods, many degrees of freedom are being used by the country flags in the fixed effects regression. This can lead to larger variances for the coefficients of interest, perhaps making them insignificant. To deal with this, regional flags are created as shown in Table 3.6 below. Geographic

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[16] For example, see http://dss.princeton.edu/online_help/stats_packages/stata/panel.htm (last viewed April 2011) under "Fixed, Between and Random Effects models."

proximities lead to regional economic interdependencies and similarities, including the rate of broadband deployment. Developed countries of Western Europe are grouped together. The less developed countries of Central Europe are grouped together with the similarly less developed countries of Southeastern Europe.

Table 3.6 - Regional Flags

Region	Countries Included	Flag Name
North America	US, Canada	n_america
Down Under	Australia, New Zealand	down_under
Scandinavia	Denmark, Finland, Iceland, Norway, Sweden	scand
Western Europe	Austria, Belgium, France, Germany, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Switzerland, United Kingdom	west_eur
Central Europe	Czech Republic, Greece, Hungary, Poland, Slovak Republic, Turkey	central_eur
Pacific Rim	Japan, Korea	pac_rim

These flags will still control for omitted variables across regions, although not as precisely as individual country flags. The regional flag for Western Europe is dropped, and other flag values are interpreted relative to Western Europe. Using regional flags, the confidence levels of coefficients improved considerably.

Three of the regional flags are made up of only two countries each. These regional flags are replaced by their respective country flags. This represents a fixed effects regression using a compromise between the number of flags used to control for omitted variables between countries/regions, and degrees of freedom left to allow coefficient values to become more significant. Most of these flags are highly statistically significant, with the exception of Canada and Central Europe. And the signs of these flags were consistent across regressions.

Interaction terms between unbundling and industrial policy were tested, including the occurrence of both, the occurrence of one and not the other, and the absence of both. In all cases multicollinearity occurred and Stata would drop one of the variables.

Unlike results reported in the literature, this study found no statically significant relationship between the presence of cable television networks and overall broadband density. This was tested against the percentage of broadband delivered by cable, as well as with flags set to “1” if cable broadband exceeded 20% and 40% levels.

Citizens pursuing or with advanced educational degrees were statistically insignificant as a predictor of broadband density.

The economic indicators, GDP, GDP per capita, employment, industrial production, consumer prices and producer prices were statistically significant in some models. However, use of more than one or two of these control variables would usually result in multicollinearity. GDP and employment were not generally statistically significant by themselves. The logarithm of GDP and employment were sometimes statistically significant. However, they are not included in the final models due to causality issues. Increases in GDP and employment might be expected to generate more broadband take up, but at the same time higher broadband usage is expected to increase GDP and employment through the network effect.

Corporate tax rates were statistically insignificant as a predictor of broadband density.

The model employing the controls population density, households with a PC and long term interest rates, and with unbundling lagged by one year, will be considered the final model for interpretation purposes (See Table 3.5). An examination of the residuals for this final model provides further insight into goodness of fit. Table 3.7 gives an analysis of the residuals provided by Stata. For a normal distribution of residuals, the Kurtosis should be 3.0. The Skewness of 0.34 shows some asymmetry.

Table 3.7 - Analysis of Residuals

Residuals

	Percentiles	Smallest		
1%	-2.287673	-2.287673		
5%	-1.958697	-2.091988		
10%	-1.493661	-2.067085	Obs	99
25%	-.6089706	-2.057072	Sum of Wgt.	99
50%	-.0757044		Mean	-4.08e-09
		Largest	Std. Dev.	1.134793
75%	.6103967	2.187153		
90%	1.560496	2.507279	Variance	1.287756
95%	1.992388	2.667584	Skewness	.3409759
99%	3.532149	3.532149	Kurtosis	3.286854

Figure 3.7 shows how residuals conform to the normal distribution, with emphasis on the distribution tails.

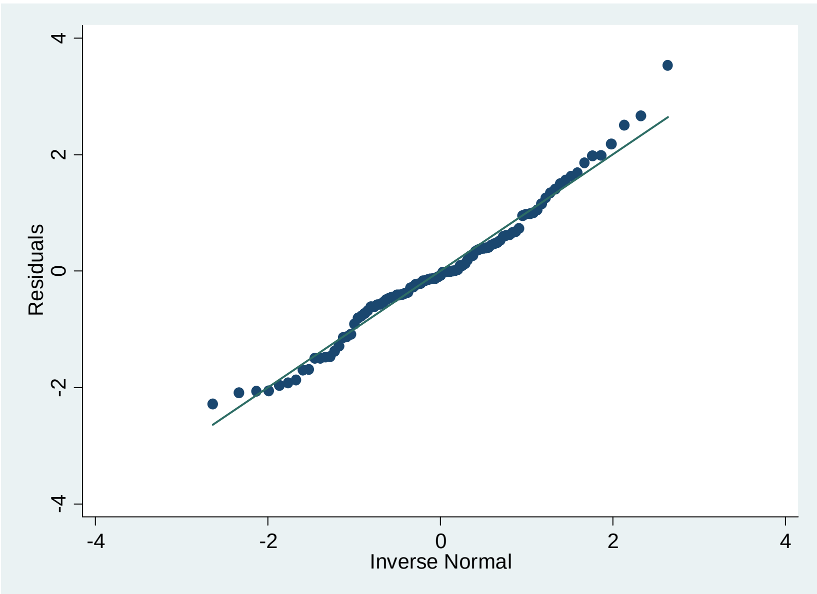

Figure 3.7 - Residual fit to the Normal Distribution

Figure 3.8 shows the predicted vs. the actual values for broadband density. The pattern is relatively linear, indicating that a simple linear specification of the model is appropriate.

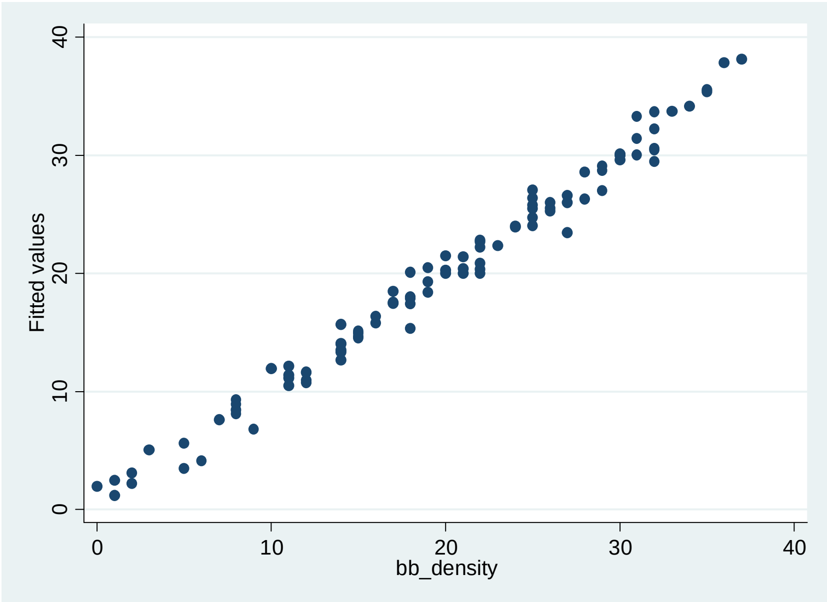

Figure 3.8 - Predicted vs. Observed Values of the Model for Broadband Density

Figure 3.9 shows behavior of the residuals over time, and Figure 3.10 shows behavior of residuals as a function of predicted value. Changes in behavior with time or with magnitude may reflect heteroscedasticity. Some distortion is apparent. I apply Breusch-Pagan/Cook-Weisberg tests of the null hypothesis H_0 that the residuals have constant variance. H_0 cannot be rejected (Prob > chi2 = 0.3757).

Finally, I ran a Ramsey regression specification error test of the null hypothesis H_0 that the model has no omitted variables. H_0 can be rejected at the 5% level (Prob > F = 0.028), indicating there may be omitted variables, even though the R^2 for this model is relatively high.

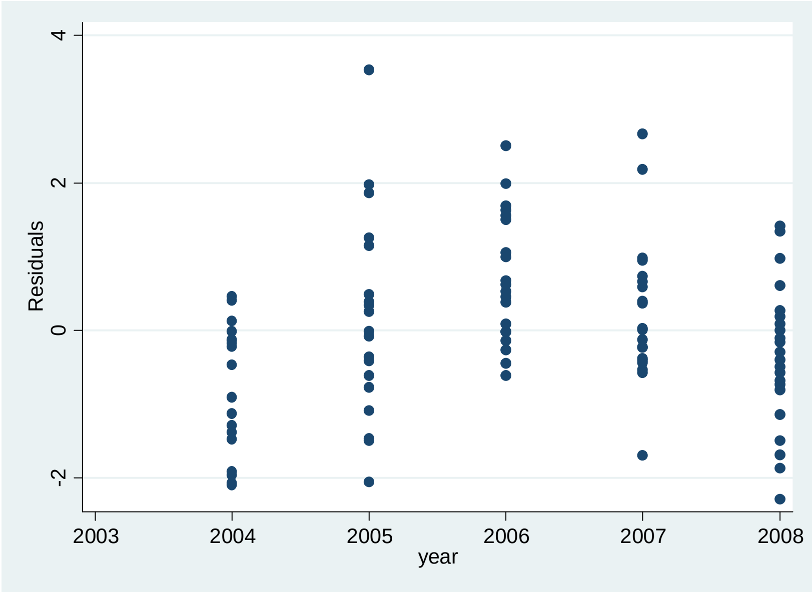

Figure 3.9 - Residuals vs. Time

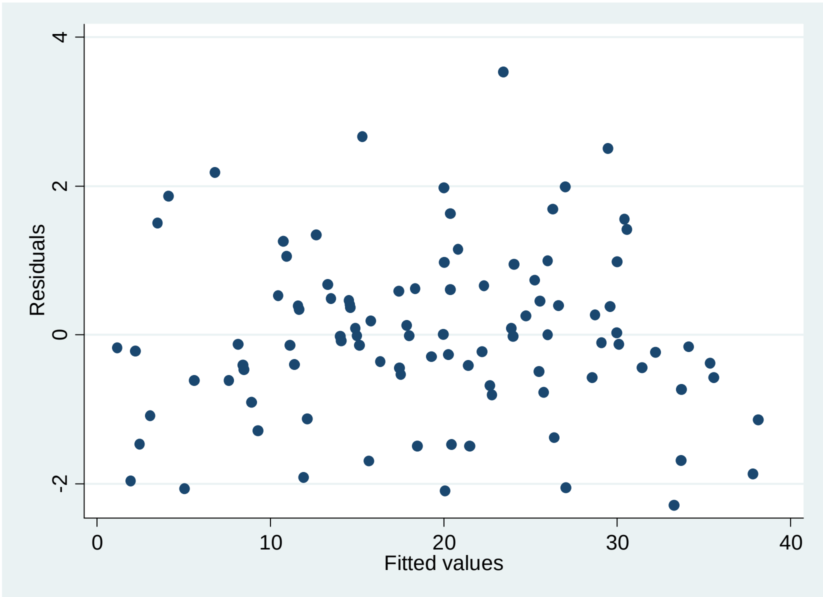

Figure 3.10 - Residuals vs. Predicted Value

Table 3.8 shows correlation in lagged versions of the residuals. Correlation in lags is modest.

Table 3.8 - Serial Correlation in the Residuals

```
             |      res     lres    l2res    l3res    l4res
-------------+---------------------------------------------
         res |   1.0000
        lres |   0.2390   1.0000
       l2res |   0.2137   0.3504   1.0000
       l3res |  -0.6007  -0.2603  -0.2194   1.0000
       l4res |  -0.3001  -0.3730  -0.2158   0.1726   1.0000
```

A type of General Method of Moments (GMM) regression is run for the final model. An Arellano-Bond dynamic panel-data estimation is used to "estimate the parameters of models of the form: $y_{it} = y_{it-1}\gamma + x_{it}\beta + u_i + \varepsilon_{it}$"[17] This is in fact the same lagged dependent variable specification used for the OLS regressions.

Table 3.9 - Comparison of OLS and GMM Regressions

bb_density Coefficient (P>|t|)			
	OLS with lagged dependent variable (country flags not shown)	GMM regression using Arellano-Bond dynamic panel-data estimation	GMM regression using Arellano-Bond dynamic panel-data estimation - robust to heteroskedasticity
pop_density	.0076522 (0.001)	0.5471123 (0.000)	0.547112 (0.017)
houses_pc	9.167443 (0.000)	9.921239 (0.028)	9.921239 (0.344)
long_term_ interest_rates	-25.3544 (0.036)	-51.69933 (0.027)	-51.69933 (0.283)
industrial_policy	2.460941 (0.000)	1.80851 (0.000)	1.80851 (0.000)
l1_unbundling	1.666333 (0.046)	2.632757 (0.000)	2.632757 (0.001)
l1_bb_density	.7764305 (0.000)	.6941396 (0.000)	0.6941396 (0.000)

Results are shown in Table 3.9 above. Results are of the same sign, and with the exception of population density of the same order of magnitude. Statistical significance is similar until robustness to heteroskedasticity is applied, at which point houses with a PC

[17] David M. Drukker, "Econometric analysis of dynamic panel-data models using Stata," StataCorp, Summer North American Stata Users Group meeting, July 24-25, 2008

and long term interest rates lose significance. The Arellano-Bond test for serial correlation is run and shows no autocorrelation.

3.3 Interpretation and Discussion

During the period of study, broadband density ranged from 0 to 37 subscribers per 100 inhabitants. Several countries reported broadband densities of 2 or less in 2004; these were the Czech Republic, Greece, Mexico, the Slovak Republic and Turkey. Broadband availability grew in all countries over the next several years. Denmark reported the highest broadband density of 37 subscribers per 100 inhabitants in 2008. Other countries that had densities greater than 30 that year were Finland, Iceland, Korea, the Netherlands, Norway, Sweden and Switzerland.

Population density ranges from about 2.6 people up to 488 people per square kilometer. Population density is consistently a statistically significant predictor of broadband density, with a stable value and positive sign over all the regressions. In more densely populated areas a given investment can service more potential customers, thus making the business case more attractive for broadband providers and potentially lowering costs to subscribers. This was expected from the literature, for example as reported by Wallstein (Wallstein, 2006).

PC penetration ranged from 10% to 92% during the period. The percentage of households with one or more PCs is consistently a statistically significant predictor of broadband density, with a stable value and positive sign over all the regressions. Going forward, broadband will increasingly be used by cell phones, hand-held devices, in automobiles, television sets, and other devices. But during the period under study the vast majority of residential broadband usage has been via a PC. Therefore higher PC penetration would be expected to stimulate more demand for broadband. During this period it was common to upgrade from a dial-up modem to broadband, retaining an existing PC. It is also possible that the utility of broadband encouraged some to buy a first or a more modern PC, leading to endogeneity problems. Thus this finding should be interpreted with some caution.

Long term rates ranged from 1% to 11% during the period. Higher long term interest rates are correlated with lower levels of broadband density. It is theorized that this is because broadband service providers find it more difficult to invest in and build out their networks when the cost of money is higher.

The impact of industrial policy is consistently a statistically significant predictor of broadband density, with a stable value and positive sign over all the regressions. This is a new finding in the empirical literature, although perhaps not very theoretically startling. Direct investment by a government in a market is intended to increase equilibrium quantity. Most proposed forms of industrial policy are on the production side, although South Korea also influenced consumption through its programs of computer education and the availability of Internet-based government services.

In this study a binary flag was used for industrial policy, saying nothing about the magnitude of investments made. Clearly the opportunity cost associated with such a policy needs to be taken into account. In the case of Korea, these may have totaled as high as tens of billions of dollars over a decade (Speta, 2004). A study by the French regulator ARCEP examined the impact of public investment of over one billion dollars (Cave and Hatta, 2009). Thus, a rough estimate of the opportunity cost for industrial policy would range from $100M to several billions of dollars per year. This rough approximation also points to the need to code a metric that reflects the magnitude of industrial policy investments in future research, if such data can be reliably obtained.

The use of an unbundling policy was generally statistically significant when lagged by one or two years. It was sometimes statistically significant when unlagged, and when lagged by three years. It was always positive. Prior literature has mostly found that unbundling has negative or no impact. Unbundling is expected to influence broadband in a lagged manner, since it may be impractical for the marketplace to immediately react to a newly established unbundling policy. Once the policy is put in place by regulators, new entrants may become motivated to enter the market and will begin making plans. Some time will be required to raise investment, negotiate with incumbents, and purchase and place equipment. This theory was tested by examining unlagged and lagged versions of unbundling. The best model fit was consistently obtained with a lag of one year.

Table 3.10 summarizes model interpretation for the average current year. Because the variables are not logged, elasticities will be a function of the variable values. For a given independent variable, elasticities are evaluated with remaining independent variables at their mean values. Elasticities are also evaluated at the minimum and maximum range of the independent variable in question. Elasticities are evaluated using the final model coefficients and variable mean values as shown in the following equation. This is mathematically equivalent to computing the percent change in broadband density over the percent change in a given independent variable.

$$E_{X_i} = \frac{\Delta Y}{Y} / \frac{\Delta X_i}{X_i} = \frac{dy}{dx} \bullet \frac{X_i}{Y} = b_{X_i} \bullet \frac{X_i}{Y} \qquad \text{(E-3.1)}$$

Table 3.10 - Summary of Current Year Model Interpretation

Impact of Independent Variables on the Dependent Variable Broadband Density during the current year			
	Variable Name	Range of Variable	Broadband Elasticity evaluated at mean (evaluated at min and max)
Control Variables	pop_density	2.6 to 488 - people per sq km	0.058 (0.001 to 0.183)
	houses_pc	0.0 to 0.92 - fractional percent	0.329 (0 to 0.418)
	long term interest rates	0.01 to 0.11 - fractional percent	-0.063 (-0.014 to -0.177)
Policy Variables	industrial_policy	0,1	0.013 (0 to 0.123)
	l1_unbundling	0,1	0.100 (0 to 0.109)

Although carefully researched, the simplicity of the industrial policy data is of some concern. In an attempt to augment this flag data with continuous data, the depreciation rate for plant and machinery was added as a potential predictor of broadband density. It reflects a way for government to encourage or discourage the large investment needed to build a broadband network, and can therefore be considered a form of industrial policy. Unfortunately plant depreciation rates, either their averages or maximums, were not found to be statistically significant in this study. Neither were building depreciation rates. Both were tested as surrogates for the depreciation rates for telecommunications networks, which were given explicitly for a few countries but were generally not available (Ernst and Young, 2009).

Corporate tax rates were used here as a control variable, but they also represent a potential policy variable. For example, Senator John D. Rockefeller IV, chairman of the Senate Commerce Committee, proposed tax credits for networks that support high speed

(100 Megabits per second) access. (Hansell, 2009a and 2009b) Unfortunately, corporate tax rates were found to be statistically insignificant as a predictor of broadband density in this study.

Unlike results reported in the literature, this study found no statically significant relationship between the presence of cable television networks and overall broadband density. This was tested against the percentage of broadband delivered by cable, as well as with flags set to “1” if cable broadband exceeded 20% and 40% levels. One possible explanation might be that the presence of cable competition was important in the early stages of broadband deployment, but became less so as rollout advanced.

Higher education levels were predicted to lead to more broadband consumption. However this study found no statistically significant relationship between higher levels of college degrees and broadband density.

The United States, Canada, Australia, New Zealand, and Scandinavia increase broadband density compared to Western Europe, all other factors being equal, with Scandinavia showing the greatest gains. Central Europe, with its less developed economies, predictably decreases broadband density. The Pacific Rim countries of Korea and Japan fall behind Western Europe. This is reasonable for Japan, which for example always lags Belgium. But Korea was expected to have a positive coefficient due to its high absolute ranking. One possible explanation for its negative coefficient is that during the period Korea steadily lost ground relative to other countries, falling from first to sixth place.

The use of lagged dependent variables has been somewhat controversial in the recent literature. Keele and Kelly address the criticisms of Achen (Achen, 2000) and provide guidelines for use of a lagged dependent variable (Keele and Kelly, 2006). They begin with theory, starting with a linear regression model that includes not only the current values of the independent variables, but also lagged versions, as follows:

$$Y_t = \alpha + \beta_0 \lambda^0 X_t + \beta_1 \lambda^1 X_{t-1} + \beta_2 \lambda^2 X_{t-2} + \cdots + \varepsilon_t \qquad \text{(E-3.2)}$$

The multiplier λ, which is less than 1, creates a geometric decay in the effect of the independent variables on the dependent variable. Keele and Kelly then show that under certain conditions this specification is mathematically equivalent to a single lag of the dependent variable, as follows:

$$Y_t = \alpha + \lambda Y_{t-1} + \beta_0 X_t + \varepsilon_t \qquad \text{(E-3.3)}$$

To make this specification theoretically consistent, the dependent variable should be influenced not only by the current values of the independent variables, but also their previous values, although this influence will fade with time. Thus population density, PC penetration, long term interest rates, loop unbundling policy, and industrial policy should all be plausibly influential over multiple years. These are all reasonable arguments. Areas of high population density will be targeted by broadband providers, as they will remain high density areas in the future. People who acquire a PC at home may not immediately sign up for broadband, but over time the utility of connecting the PC to a broadband network may lead to subscription. Lower long term interest rates over a number of years may encourage investment decisions on the part of broadband network providers. Market players can be expected to deliberate and react to a policy like loop unbundling that is consistently applied over multiple years, whereas policies that are quickly enacted and removed might cause uncertainty and hesitation. Industrial policy should produce results even if it is a one-time event, like the current stimulus programs. However, if a government has a longstanding program of investment, market players may consider this in their long term planning and the public investments may be more effective as a result.

Keele and Kelly also recommend lagging of a dependent variable only if it exhibits stationarity. There are more than a half-dozen different tests for determining stationarity. Some, like the Levin-Lin-Chu test, reject H_0 that broadband density is not stationary with a p-value of 0.000. Similarly most of the Fisher-type tests reject the same H_0. But other tests such as the Harris-Tzavalis and the Hadri Lagrange Multiplier (LM) tests do not indicate stationarity. Thus the dependent variable meets the requirement of stationarity for a number of the tests, but not all. Results are shown in Table 3.11.

Table 3.11 - Stationarity Tests of the Broadband Density Data Set

est	LLC	HT	Breitung	IPS	Fisher-type - pp	Hadri LM
H_0	Not stationary	Not stationary	Not stationary	Not stationary	Not stationary	All panels stationary
H_A	Panels stationary	Panels stationary	Panels stationary	Some panels stationary	At least one panel stationary	Some panels not stationary
bb_density	0.0000	1.000	0.0232 0.1030 0.0023 0.0008	0.9998 0.0000 0.3619	0.0000 0.5307 0.1296 0.0000	0.0000

Keele and Kelly observe “a surprising and counterintuitive fact about OLS with a [lagged dependent variable] … That is, OLS produces the best estimates for modest instead of large sample sizes.” (Keele and Kelly, 2006) This shallow dataset is consistent with the use of OLS.

The impact of applying unbundling in the previous year and industrial policy in the current year can be interpreted according to the elasticities given in Table 3.10. However a better way to interpret the model with a lagged dependent variable is dynamically, over a period of years. Note that if one of the policies is applied during the current year, there will be a delta increase in broadband density. This delta increase will propagate into the following year as a fraction of the lagged dependent variable according to the coefficient of *l1_broadband_density*. Two years hence this delta increase is multiplied by the coefficient squared, three years hence by the coefficient cubed, and so forth. Thus the impact of the policy in the current year is felt for a number of years, and if the policy is maintained over a number of years the contributions all propagate forward and add to broadband growth.

To observe the effects of policy over time, the final model for broadband density is plotted in Figure 3.11 below. Control variables are set to their means according to Table 3.3 above. Broadband density in year 2003 is set to the average across OECD countries. The policy flags for unbundling and industrial policy are held constant over the entire period, in one of four possible states (no unbundling and no industrial policy, unbundling only, industrial policy only, and both unbundling and industrial policy). A fifth projection is made using the OECD averages across the dataset of 0.093 for industrial policy and 0.914 for unbundling. These projections show that the consistent application of unbundling and industrial policy over multiple years can have a large impact on broadband availability. If both policies are applied, broadband density almost doubles.

3.4 Impact of Policies on First Generation Broadband

The impact of industrial policy is consistently a statistically significant predictor of broadband density, with a stable value and positive sign over all regressions. The use of an unbundling policy is found to be statistically significant when lagged by one or two years, and it is always positive. These findings predict that both policies will increase the availability of broadband to citizens. A dynamic multi-year interpretation of the final model shows that application of both policies will almost double broadband density.

As in previous literature, higher population density was found to have a positive influence on broadband availability. But unlike previous studies, the presence of competition from cable networks was not. One possible explanation is that previous studies were from the early years of broadband rollout, for which the influence of cable may have been different. For example, the early presence of cable modems helped to stimulate a competitive response by DSL providers, whereas once the deployment of broadband was well underway, the presence of cable competition may have been less consequential.

Other significant control variables were the percentage of households with personal computers, and long term interest rates. Higher penetration of PCs had a positive influence on broadband availability. It is theorized that the addition of broadband access increases the utility of an existing PC and helps drive service subscriptions. Higher long term interest rates had a negative influence on broadband availability. It is theorized that the higher cost of money inhibits service provider investment in broadband networks.

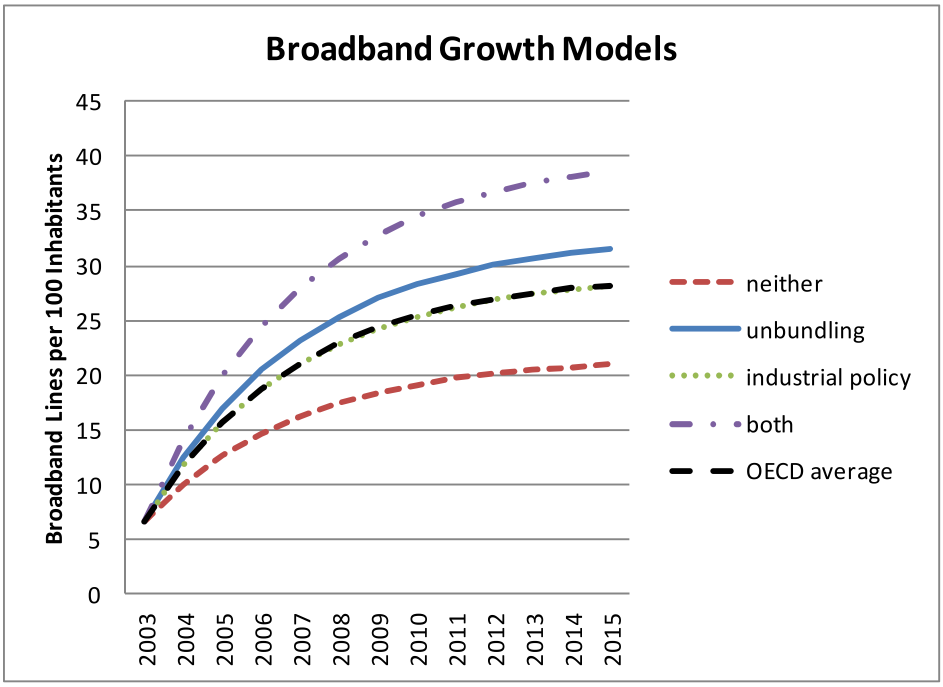

Figure 3.11 - Projections for Broadband Density over Time using the Final Model

4 Literature Quantifying the Benefits of Broadband

This Chapter discusses prior attempts to estimate private and public benefits of a modern broadband network. Greenstein and McDevitt develop a framework for an upper bound on the private social surplus of broadband, from $138M dollars in 1998 to over $18B in 2006 (Greenstein and McDevitt, 2009). Policy that would accelerate the rollout and availability of broadband would thus also accelerate the growth of this private social surplus.

Researchers have argued that broadband exhibits a number of positive externalities which should also be taken into account. The Broadband Technology Opportunities Program articulates specific benefits to be

> "…use of broadband infrastructure and services in advancing consumer welfare, civic participation, public safety and homeland security, community development, health care delivery, energy independence and efficiency, education, worker training, private sector investment, entrepreneurial activity, job creation and economic growth." (Act, 2009)

This theme of positive broadband externalities was reinforced when the National Broadband Plan was issued by the FCC a year later. (FCC, 2010)

4.1 Accounting for Broadband's Impact as a New Good

How should the private benefits of broadband be estimated? First, if we assume that broadband is an entirely new invention, it enters the marketplace and grows over a number of years. The presence of broadband will show up in a number of metrics, including number of households that have broadband and the revenues for broadband access markets. Access market revenues are earned (primarily) by DSL and cable modem service providers who sell broadband access for a monthly fee, and these revenues are collected by the U.S. Bureau of the Census in their Annual Service Survey. These revenues have grown dramatically, from $138M dollars in 1998 to over $18B in 2006. Thus, broadband revenues give some sense of the private benefits being generated by this new good.

Greenstein and McDevitt provide a detailed analysis of these benefits (Greenstein and McDevitt, 2009). Their goal is to determine the social surplus that broadband generates, made up of the two components, producer surplus and consumer surplus.

In order to determine producer surplus, one would need to know the shape of the supply curve which in turn requires removal of the total variable cost. The authors briefly discuss costs, on the order of $150 to $250 to upgrade a phone line or a cable system per subscriber, and on average $100 per year per subscriber to maintain a broadband connection. This is compared to the per subscriber revenues generated, from $36 to $40 dollars per month for an annual total of $432 to $480 dollars per year. Beyond this discussion the analysis is primarily in terms of revenues, which places an upper bound on producer surplus.

The authors point out that broadband is substituting for dial-up connectivity to the Internet. They take this into account by approximating the percentage of subscribers that upgrade from dial-up to broadband (approximately 80% of subscribers), and subtract out the associated loss in producer surplus for dial-up. Additionally, for DSL subscribers, there is often a loss in revenue associated with a dropped second line. Taking these effects into account, the authors calculate new revenue created by broadband (above and beyond what dial-up would have generated) for the period 1999 to 2006, and it ranges from $8.3B to $11.4B. This is about 40% to 50% of the measured broadband GDP revenues. The authors believe this is a more appropriate measure of the producer surplus generated by broadband (Greenstein and McDevitt, 2009).

The authors go on to calculate consumer surplus, making use of survey work by Savage and Waldman wherein dial-up and broadband users were surveyed in 2002 to determine their willingness to pay for upgrading to broadband (Savage and Waldman, 2005). Savage and Waldman identify two components; willingness to pay for the increased speed of broadband, from $11 to $22 per month, and willingness to pay for always-on connectivity and reliability, from $1 to $18 per month. Greenstein and McDevitt then compare these figures to the actual monthly differentials between dial-up and broadband access fees, and calculate consumer surplus created by broadband (above and beyond what dial-up would have generated) for the period 1999 to 2006. It ranges from $4.8B to $6.7B. This is about 31% to 47% of the measured broadband GDP revenues. The authors point out that this consumer surplus is not measured at all in annual GDP figures (Greenstein and McDevitt, 2009). Combining the two results, the upper bound on social surplus ranges from about 70% to 100% of measured broadband GDP.

The authors point out that they are quantifying private benefits, and are not considering any externalities. They give several examples of potential producer externalities, such as additional equipment sold by Cisco, additional sales made by Amazon, and additional advertising revenues collected by Google. They give as a possible example of a consumer externality the ability to access content through peer-to-peer services (Greenstein and McDevitt, 2009).

4.2 Broadband Externalities

In the same way that roads, public transportation and airlines are crucial to the functioning of modern society, so is a telecommunications infrastructure essential to a modern economy. Society has come to depend on the ability to easily make phone calls, and increasingly, to communicate via the Internet.

Many advocate the promotion of broadband due to its benefits. This includes not only the private benefits that accrue to a broadband user and producer, but additionally several public benefits. If these public benefits are significant, they could help justify government policy to more aggressively expand broadband availability. Nadiri and Nandi explain the possible rationale for a policy that would invest in telecommunications infrastructure:

> "[I]nfrastructure often generates costs and benefits that extend beyond users and producers. The existence of these costs and benefits—termed "externalities" by economists—means that private markets alone will not generate the optimal amount of these goods and services. For example, network effects and other positive externalities mean that private markets may not produce a sufficient amount of broadband capacity." (Nadiri and Nandi, 2001)

Firth and Mellor point out the importance of quantifying potential positive externalities in a reliable way. "[T]he literature typically focuses on broadband's economic aspects, but with poor benefit identification and measure difficulties, the findings tend to be steeped in rhetoric." They also correctly point out that "the literature tends to confuse benefit with applications and/or with attributes, and the activities they enable." They call for better research and quantification of such benefits: "[W]hile the need for public policy to be based on identified benefits that are systematically measured is well established … the literature on broadband has failed to achieve those measures largely because the benefits have not been adequately identified." And finally, they give examples of possible *negative* externalities associated with broadband: "While broadband-enabled activities may bring benefits, they may also have negative outcomes such as increased worker isolation and less mentoring (teleworking), financial problems (e-gambling), and displacement of conventional social contacts…" (Firth and Mellor, 2005)

4.3 Quantifying the Network Effect

There have been many studies quantifying the importance of the telephone network to commerce. For example, Nadiri and Nandi conducted an empirical analysis that estimated the contribution of the traditional dial-up network to the growth of output and productivity in the U.S.

> "The estimated value of the marginal benefits … of the communications infrastructure capital is positive in each of 34 industries representing the major industrial sectors of the U.S. economy. This effect captures network externality benefits… [R]esults suggest that an increase in communications infrastructure capital services reduces cost in all the industries and as a consequence that of the entire economy." (Nadiri and Nandi, 2001)

For the purposes of this dissertation the interest is specifically in identifying network effects due to broadband.

> "Broadband networks are increasingly recognized as fundamental for economic and social development. They serve as a communication and transaction platform for the entire economy and can improve productivity across all sectors. Advanced communication networks are a key component of innovative ecosystems and support economic growth." (Reynolds, 2009)

Broadband deployment began in the late 1990's reaching over 75M broadband subscribers in the U.S by 2008 (OECD Broadband Portal). Thus, during the years of deployment, there were areas where broadband was and was not available. This makes possible a quasi-experimental design in which economic indicators can be tested with and without the influence of broadband.

Gillett, Lehr, Osorio, and Sirbu use a panel data set from 1998 to 2002 and run a regression analyses on several indicators of economic development as the dependent variable, in zip codes where broadband either was or was not available, while controlling for other factors that might explain economic trends (Gillett et al, 2006). Dependent variables include employment level and number of businesses. Control regressors include employment growth rate, firm growth rate, salary growth rate, educational level of the population, and average housing rent prices.

The basic regression equation is of the following form:

$$Y(t) = a + \alpha Y(0) + X\beta + \gamma BB + \varepsilon \qquad \text{(E-4.1)}$$

The dependent variable Y(.) is the economic variable of interest (e.g. the employment level). X are the control regressors. The dummy BB is 1 if the community had broadband starting in 1999 and 0 otherwise. Y(0) is the level of the economic variable of interest in 1998, prior to the beginning of broadband deployment. Thus, moving forward into the first four years of broadband deployment, the analysis seeks to determine whether those zip codes with broadband exhibit differences from those without.

The data set matches broadband availability data from the Federal Communications Commission's Form 477, with demographic and other economic data from the U.S. Population Censuses and Business Establishment Surveys. The latter more specifically consisted of employment, establishments, wages (payroll), industry sector and size mix from U.S. Census Bureau ZIP Code Business Patterns (ZCBP), income, rent, educational attainment, and number of households from the U.S. Census Bureau 2000 Decennial Census, and/or from GeoLytics - CensusCD. Finally, the Economic Research Service, U.S. Department of Agriculture - Urban Influence Code (UIC) was used to indicate how urban or rural a zip code is (Gillett et al, 2006).

The coefficient γ is significant and positive, indicating that zip codes with broadband experienced more business growth. The study found that broadband added about 1 to 1.4% to the growth rate in employment, and 0.5 - 1.2% to the growth rate in businesses, over the four year period. The authors interpret these findings as follows:

> "Broadband's impact on the number of jobs and business establishments was particularly large relative to our expectations. While increases on the order of 1% may not appear large at first glance, in fact these figures represent increments to growth rates that are typically in the single digits. For example, in the overall sample of communities we tested, jobs grew on average by only 5.2% between 1998 and 2002. Thus even a 1% increase attributable to broadband represents a noticeably large impact." (Gillett et al, 2006)

Even though controls are used, there is still a significant question of causality. For example, broadband operators are large sophisticated organizations and they will seek attractive markets in which to make their initial investments, and this will include markets with high growth rates. To control for this the authors used a statistical procedure called matched sampling. The two populations, with and without broadband, are further selected so that the control variables are statistically similar, making the quasi-experimental design more likely to reflect the difference of broadband alone.

A similar study was conducted by Crandall, Lehr and Litan. They run a linear regression analysis across U.S. states (Crandall, Lehr, Litan, 2007). Employment and GDP are the independent variables, and they test for broadband penetration as an explanatory variable, using state tax climate, union membership, average hourly earnings and education level, as control variables. They also include mean annual temperature and dummy variables for the nine U.S. census regions as additional controls. They run two separate regressions, testing for change from 2004 to 2005, and also change over two years from 2003 to 2005. Data was obtained from the FCC, the Bureau of Labor Statistics, the Bureau of Economic Analysis, NOAA, the Tax Foundation, and the Bureau of the Census.

Results were not statistically significant for GDP, but were for employment. For the one-year analysis, an increase in broadband of 0.01 lines per capita increased employment by 0.2%. For the two-year analysis an increase of 0.01 lines per capita increased employment by 0.6%. In 2004 the baseline for broadband penetration was about 0.12 broadband lines per capita (or 12 broadband lines per 100 people). Of the control variables, only tax climate was statistically significant, with states of lower taxes seeing more employment. Using these results to project employment growth in 2006, the authors found that an increase in broadband of 0.01 lines per capita would generate almost 300,000 jobs across the nation. Although results for GDP were not significant, the authors did find significant results for some specific sectors such as finance, education and healthcare (Crandall, Lehr, Litan, 2007).

Koutroumpis deals with the simultaneity problem discussed above by explicitly allowing for it in a structural econometric model that expresses growth as a function of broadband (among other things), and broadband as a function of growth (among other things). If such a model can be shown to match empirical evidence in a statistically meaningful way, then the model parameters can be used to interpret the impact of broadband on the economy. In his analysis, which won Best Paper Award at the 17th biennial ITS conference in 2008, Koutroumpis models a production framework as follows (Koutroumpis, 2009):

$$GDP_{it} = f\left(K_{it}, HK_{it}, Broadband_{it}\right) \tag{E-4.2}$$

$$Broadband_{it} = h\left(GDPC_{it}, BBpr_{it}, EDU_{it}, URB_{it}, RND_{it}\right) \tag{E-4.3}$$

$$BBI_{it} = g\left(BBpr_{it}, InterPlatform_{it}, regulation_{it}, RND_{it}\right) \tag{E-4.4}$$

$$Broadband_{it} - Broadband_{it-1} = k\left(BBI_{it}\right) \tag{E-4.5}$$

In this system of equations we are most interested in the relationship between *GDP* and the stock of broadband infrastructure *Broadband*, for which the proxy of broadband penetration level is used. *K* and *HK* are the stock of capital (minus the broadband stock) and the stock of human capital, respectively. There is a rich history in the literature of modeling GDP as a function of capital and human capital stocks.

Demand for broadband infrastructure is modeled next. *GDPC* is GDP per capita, *BBpr* is the average price for obtaining broadband service, *EDU* is the percent of GDP spent on education, *URB* is the percentage of the population that lives in densely populated areas, and *RND* is the percent of GDP spent on public or private R&D.

Supply of broadband infrastructure, *BBI*, is modeled next. *InterPlatform* is a measure of facilities-based competition, and *regulation* is a measure of the level of unbundling within the telecommunications market.

The dataset used annual data from 22 OECD countries between 2002 and 2007 for broadband penetration. GDP, human capital, education and R&D data is obtained from the World Bank. Capital stock is obtained from the Groningen Growth Accounting Database. OECD and ITU data are used to obtain broadband penetration and price data. The urbanization variable data came from the Population Division of the World

Urbanization Project from the United Nations Department of Economic and Social Affairs. The inter-platform and regulation variables are derived from ITU data.

The specific modeling equation used for GDP is as follows:

$$\log(GDP_{it}) = a_0 + a_1 \log(K_{it}) + a_2 \log(LF_{it}) + a_3 \log(Broadband_{it}) + \varepsilon_{it} \quad \text{(E-4.6)}$$

After analysis, the coefficient a_3 has a positive value of 0.025 and is significant at the 1% level. This means that a 1% increase in the broadband penetration rate increases economic growth by 0.025%. Using actual broadband penetration figures during the period, the equivalent annual economic growth rate attributable to broadband is on the order of 0.4% for a typical country (Koutroumpis used Spain as his example). The findings also showed that the level of unbundling is insignificant to the supply of broadband infrastructure.

4.4 Broadband Spillovers to Other Parts of the Economy

The Broadband Technology Opportunities Program articulates specific benefits of the program to be

> "…use of broadband infrastructure and services in advancing consumer welfare, civic participation, public safety and homeland security, community development, health care delivery, energy independence and efficiency, education, worker training, private sector investment, entrepreneurial activity, job creation and economic growth." (Act, 2009)

Here, then, is a list of potential positive externalities that may in part justify the broadband stimulus policy and the associated redistribution of resources. This theme was reinforced when the National Broadband Plan was issued by the FCC a year later (FCC, 2010). Three commonly mentioned externalities are spillovers to education, healthcare and the environment. A concerted attempt to find literature quantifying these benefits was partially successful; benefits to the Medicare and Medicaid program have been reported, as have benefits resulting from telecommuting. There is literature on how programs have increased student access to the Internet, but linking improved access to measurable improvements in educational outcomes has been elusive to date. These findings are described below.

4.4.1 Education

One of the most significant government educational programs to invest in modern network infrastructure is the E-Rate program:

> "As part of the Telecommunications Act of 1996, the government began actively subsidizing Internet and telecommunications access in U.S. classrooms and libraries through a tax on long-distance services as a new, information-age component of the Universal Service Fund. This new initiative, known as the E-Rate program, began in 1998 and provides up to $2.25 billion per year of subsidies… To understand the magnitude of this subsidy, note that Lake (2000) estimates total public school spending on computers in 1999 … was only $3.3 billion. The E-Rate subsidy is, by far, the most ambitious federal technology program in schools…" (Goolsbee and Guryan, 2006)

The E-Rate program subsidizes purchases of technology on a sliding scale that depends on poverty rates and urban-rural status.

> "The subsidy rate ranges from 20% to 90%, depending on the share of students that qualify for the national school lunch program… The subsidy can be used for spending on 'all commercially available telecommunications services, Internet access, and internal connections.' … Schools cannot get subsidies for things like software or computers…Of the E-Rate funds, 80% go to internal connections, 17% go to telecommunications services, and the remaining 3% are used for Internet access." (Goolsbee and Guryan, 2006)

To assess the impact of the program, Goolsbee and Guryan perform an economic analysis over the period 1996 to 2000 in California. They use data on technology owned by each school, administrative data on E-Rate funding applications, and demographic data for each school from the National Center for Education Statistics Common Core of Data (CCD) and the 1990 U.S. Census. California represents 13% of public school enrollment in the U.S.

Figure 4.1 shows trends in classrooms with Internet access per teacher, broken into five groups. Group 1 is composed of school districts with 0% to 20% of their students eligible for federal lunch programs, group 2 is school districts with 20% to 40% eligible, etc. The figure shows the gap in Internet access between richer and poorer districts closing. The data shows that “E-Rate funding went disproportionately to schools with higher poverty rates and fewer Internet classrooms.” (Goolsbee and Guryan, 2006)

In order to confirm that E-Rate funds were an important causal factor in closing the Internet gap between rich and poor districts, a regression analysis is conducted on the following investment equation:

$$\Delta(I/C)_{st} = \beta s_{dt} + \alpha_s + \delta_t + \gamma_1 m_{st} + \gamma_2 m_{st}^2 + \varepsilon_{st} \qquad \text{(E-4.7)}$$

where *I/C* is the fraction of classrooms with Internet access, by school and year, *s* is the E-Rate subsidy received by school district and year, α and δ are dummy variables accounting for school and year fixed effects respectively, and *m* is the fraction of students eligible for the federal school lunch program. It is possible that poorer schools with less Internet access would have invested more heavily, even without the E-Rate funds. This regression analysis specifically measures whether subsidies were a statistically significant factor through the coefficient β. “The estimate of β is positive and significant, implying that schools getting the biggest subsidies starting in 1998 did have larger increases in the growth rate of Internet access.” (Goolsbee and Guryan, 2006)

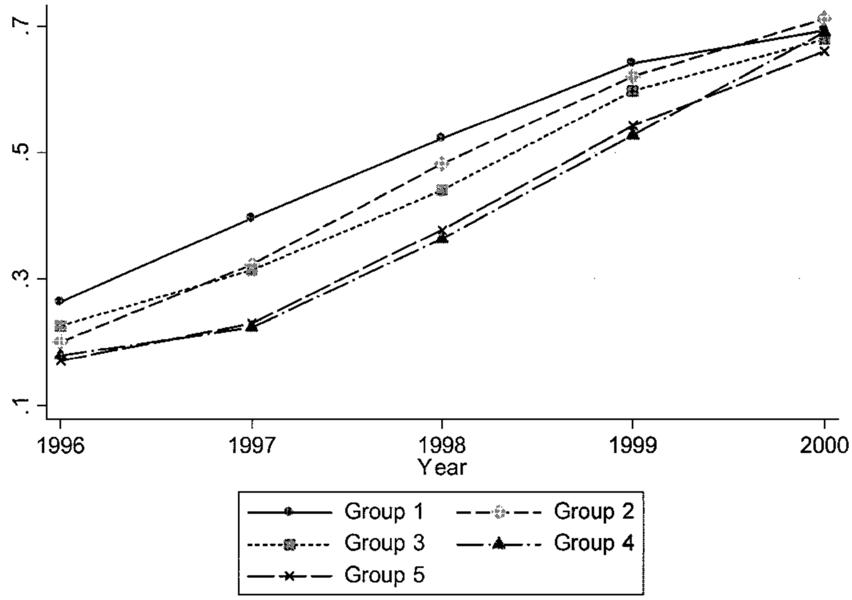

Figure 4.1 - Classrooms with Internet Access per Teacher

(Goolsbee and Guryan, 2006, used with permission)

This analysis quantitatively verifies that the E-Rate program was a significant factor in increasing Internet access in poorer schools, and thus the policy was successful in closing the Internet gap. A presumption of the program is that Internet access is important to the educational advancement of students. Unfortunately, an analysis of the impact of the program on one metric of educational achievement showed no detectable improvement. The metric was test scores, using the Stanford Achievement Test. The test score equation is:

$$\Delta T_{st+1} = \beta' s_{dt} + \alpha'_s + \delta'_t + \gamma'_1 m_{st} + \gamma'_2 m^2_{st} + \varepsilon'_{st} \qquad \text{(E-4.8)}$$

where T is the one year change in test score. This time the regression is intended to measure whether subsidies were a statistically significant factor through the coefficient β'. Results were calculated for math, reading and science test scores. None of the estimates for β' are statistically different from zero. Possible interpretations are that students did not use the Internet, that there may have been improvements in skills that are not captured by traditional testing, or that the impact of Internet availability on learning will take longer to reveal itself (Goolsbee and Guryan, 2006). Of course it is also possible that there is no impact of Internet availability on student achievement.

Park, Sinha and Chong use a qualitative analysis to determine the impact of the E-Rate program. The authors specifically cite the Goolsbee and Guryan finding that E-Rate has had no (yet) measurable impact on educational improvement.

> "On the other hand, digital divide researchers have recognized that without proper support in the school and home environment, computers in the schools probably do not provide much of an educational benefit (Noll, Older-Aguilar, Rosston and Ross, 2000)." (Park, Sinha and Chong, 2007)

The authors seek to answer the question "How have telecommunications and information technology (e.g., Internet connection), established by the E-Rate program, been integrated into the teaching and learning process?" The research was conducted through document analysis using secondary data, primarily using nationwide surveys.

The research clearly identified E-Rate as a program which has had a significant impact on bringing technology to schools. One survey, the National School Boards Foundation (2002), "found that 71% of the respondents identified E-Rate as the most significant outside initiative." However the research also identified continuing problems and concerns, including the need to connect classrooms, not just schools, the need for faster Internet access, and the need for ongoing and adequate technology support (Park, Sinha and Chong, 2007).

Finally, the research showed the need to better utilize the technology:

> "According to one survey conducted in 2003, only 80% of the computers are used each day. Some schools try to combine technologies with their curricula, and sometimes succeed. However, lack of tech-savvy teachers and lack of technical support have made many schools neglect technology … When teachers have no time for developing curricula and no help from technicians, they simply lay technology aside." (Park, Sinha and Chong, 2007)

4.4.2 Healthcare

One of the potential externalities often mentioned with regard to a modern broadband network is savings it will bring to healthcare (Act, 2009) (FCC, 2010) (Deshpande and Elmendorf, 2008). Litan performs a quantitative assessment of these savings (Litan, 2006). This task is complicated by the fact that the healthcare system in the U.S. is made up of a private, for-profit system for many working Americans, and the Medicare and Medicaid systems for older Americans, the disabled, and the poor. Because baseline data and studies of potential savings are more readily available for the latter, Litan confines his study to savings that would accrue to these programs.

Broadband is rolling out and will continue to become more widely available with time. Thus, healthcare savings attributable to the availability of a broadband network will accrue to society. Litan estimates a baseline case for these savings, and then he estimates how these savings will be increased as a result of a robust policy that would accelerate the availability of broadband. All estimates are reported in 2005 dollars and are discounted using a 5 percent interest rate. Savings for both the baseline and accelerated policy cases are made for the years 2010, 2020 and 2030.

In 2005 government medical spending, under the Medicare and Medicaid programs, was about $360 billion, and is projected to increase to $970 billion by 2030 (in

2005 dollars). Government medical spending on non-elderly individuals with disabilities was $186 billion in 2005, and is estimated to climb to $483 billion in 2030 (Litan, 2006).

Litan uses previous studies that show savings attributable to advance electronic connectivity:

> "[T]here are data indicating the magnitude of the possible savings for Medicare (and the elderly portion of Medicaid) programs from … integrated systems of monitoring, clinical information tools and targeted interventions - all enabled by a broadband technology. … The [Veterans Administration] integrated chronic disease monitoring program has produced impressive cost savings, cutting hospital admissions by up to 60 percent. … According to one estimate, if the same disease management system were used for just the 4 million chronically ill Medicare patients posing the highest risks, the number of hospitalizations would decline by 1.7 million per year, producing annual net savings of $30 billion. This would be equivalent to a 10 percent saving of overall Medicare costs." (Litan, 2006)

Litan then set assumptions for accelerated broadband availability:

> "The base case estimates for cost savings for seniors assume only that savings are realized from gradual implementation of chronic disease management, such that Medicare and senior-related Medicaid spending as a whole is 10 percent less than it would otherwise be in 2030. … The broadband policy case assumes that measures are taken to accelerate the use of broadband-based chronic care technologies, such that the 10 percent savings are realized 10 years sooner, or by 2020 … From 2020 to 2030, the 10 percent savings are assumed to continue." (Litan, 2006)

On this basis, Litan estimates savings as shown in Table 4.1 below. In a similar fashion, Litan estimates savings for non-elderly individuals with disabilities, only using a more conservative estimate of 5 percent savings of overall costs, as shown in Table 4.2 below.

Table 4.1 - Savings to Elderly for Chronic Care (2005 $B)
(Litan, 2006, used with permission)

Year	2010	2020	2030
Base	$22.36	$162.76	$401.09
Policy	$37.27	$271.27	$563.65
Difference	$14.91	$108.51	$162.56

In a similar fashion, Litan estimates savings for non-elderly individuals with disabilities, only using a more conservative estimate of 5 percent savings of overall costs, as shown in Table 4.2 below:

Table 4.2- Savings to Non-Elderly with Disabilities for Chronic Care (2005 $B)
(Litan, 2006, used with permission)

Year	2010	2020	2030
Base	$5.23	$39.05	$97.71
Policy	$8.72	$65.08	$136.98
Difference	$3.49	$26.03	$39.27

Litan estimates savings that would result from more independent living enabled by broadband. He again begins by establishing a baseline.

> "In 2004, $135 billion was spent on long-term care for the elderly, of which $92 billion (68 percent) was spent on care provided through nursing homes, and the $53 billion balance (32 percent) spent on home care [CBO, 2004]. Of the total, Medicaid paid 35 percent, Medicare covered 25 percent, and private health insurance picked up 4 percent. The rest, or about 33 percent, of all costs were borne by the individuals and their families [CBO, 2004]." (Litan, 2006)

Litan then assumes that broadband-based monitoring "would save 1 percent of total nursing home costs by 2020, 2 percent by 2030. The policy scenario assumes the savings schedule would be accelerated and magnified a bit: 1 percent by 2010, 2% by

2020, and 3% by 2030." (Litan, 2006) On this basis, Litan estimates savings as shown in Table 4.3 below.

Litan then calculates savings resulting from increased labor force participation by seniors and the disabled.

> "[B]ecause they enable workers to 'telecommute' - that is, to work from home or at locations other than at an employment site - broadband technologies have the potential for increasing labor force participation by both senior citizens and individuals with disabilities." (Litan, 2006)

Table 4.3- Savings in Long Term Home Care (2005 $B)
(Litan, 2006, used with permission)

Year	2010	2020	2030
Base	$0.95	$6.51	$16.73
Policy	$2.86	$15.25	$32.12
Difference	$1.91	$8.74	$15.39

Litan uses Social Security Trustees data to estimate the baseline level of seniors in the labor force at approximately 5.5 million, and average earnings of $29,000 in 2005. "The Social Security Administration's Actuary's Office projects delayed retirement will increase the overall U.S. labor force by 1.5 percentage points by 2080." The Urban Institute projects an increase of 4.4 percent by 2040. For his baseline case, Litan uses an average, "which implies 3.6 million additional workers by 2030, making the total labor force about 2 percent higher than it would be otherwise." For his policy case, Litan uses the more aggressive Urban Institute numbers, which "implies that by 2030, all 6.2 million additional seniors will be in the labor force, making it about 3.4 percent larger than it would be otherwise." (Litan, 2006) On this basis, he estimates output gains as shown in Table 4.4 below:

Table 4.4- Output Gains from Elderly, Half Salary (2005 $B)
(Litan, 2006, used with permission)

Year	2010	2020	2030
Base	$60.75	$223.72	$411.20
Policy	$114.24	$402.19	$726.08
Difference	$53.49	$178.47	$314.89

Altogether, Litan projects total discounted benefits from a policy that accelerates broadband deployment to be in the range of $532 to $847 billion over a 25 year period.

4.4.3 Telecommuting

Telecommuting, in which employees work at home rather than the office, has a positive environmental impact by virtue of reductions in driving and associated automobile emissions. Telecommuting has only recently become more feasible, due to technological change that has both migrated much business activity to computers and the Internet, as well as cost-effective broadband access that makes performance in a home reasonably equivalent to that at the office.

The external benefits that result from telecommuting have been the subject of recent research. One of the earlier works that quantified emission pollution reductions was done by Koenig (Koenig et al, 1996). The study looked at home-based telecommuters who participated in the State of California Telecommuting Pilot Project in the early 1990s.

> "All individuals in the sample worked for the state government and filled out travel diaries before and one year after they began telecommuting. The study analyzed 40 people who chose to telecommute at home and 58 who didn't telecommute at all—that is, a control group. The authors found that the people who telecommuted reduced their average number of daily vehicle trips by 27% and reduced average VMT (vehicle miles traveled)

> by 77%. Using California's EMFAC7 emissions model, the authors calculated that these reductions in driving resulted in substantial emissions reductions: 48% in total organic gases (TOGs), 64% in carbon monoxide (CO), 69% in nitrogen oxides (NO_X), and 78% in particulate matter (PM)." (Walls and Safirova, 2004)

Another study showed that a small increase in telecommuting would result in substantial emissions reductions.

> "We calculate that 25 tons per year of VOCs (and nearly as much NO_X) could be reduced in each city without enormous increases in the number of workers who telecommute. Less than 1% of the workforce working at home one to two days per week would roughly accomplish this goal." (Walls and Nelson, 2004)

A study by Peter Nelson finds that an entirely different positive externality appears to be bigger than emissions reduction, namely reductions in traffic volume and congestion. Reductions in traffic volume reduce wear and tear and lower both vehicle and highway maintenance costs, while reductions in congestion reduce costs associated with lost time (Nelson, 2004, p. 29).

There may also be benefits due to time used in more productive ways than driving. However as these benefits are difficult to compute they are not included in the analysis.

There are indications that additional demand for telecommuting exists. "Workers with relatively lower educational attainment are more enthusiastic about the opportunity to telecommute than better-educated workers, but the latter are more likely to have jobs that make telecommuting possible." (Safirova and Walls, 2004, p. 23) This has implications for a broad-based telecommunications infrastructure that allows a large segment of society to telecommute.

4.5 Summary of Private and Public Benefits of Broadband

A widely recognized externality is the "network effect" which improves the efficiency and breadth of commerce. Gillette et al find that the availability of broadband added about 1 to 1.4% to the growth rate in employment, and 0.5 - 1.2% to the growth rate in businesses, over a four year period (Gillett et al, 2006). Crandall et al found that a 1% increase in broadband penetration would generate almost 300,000 jobs across the nation (Crandall, Lehr, Litan, 2007). Using a more sophisticated structural econometric model that takes into account simultaneity, Koutroumpis finds that a 1% increase in the broadband penetration rate increases economic growth or GDP by 0.025% (Koutroumpis, 2009). Policy that would expand the rollout and availability of broadband would thus in part be justified by this broadband network effect.

Spillovers to other parts of the economy are potentially attributable to broadband. An oft cited positive externality is improved educational outcomes. The E-Rate program is a government program that transfers funds from Universal Service Fund, which is replenished by taxes on telephone bills, to support telecommunications for schools and libraries, particularly in poorer school districts. This includes broadband Internet access to schools. Goolsbee and Guryan show that the program has effectively closed the gap in Internet connectivity between richer and poorer schools. However, attempts to measure an impact on academic performance itself have failed to date (Goolsbee and Guryan, 2006). Qualitative analysis by Park et al identify a number of reasons why Internet access may be underutilized and thus may not positively impact academic achievement (Park, Sinha and Chong, 2007). Many believe that broadband Internet access will be critical to the success of new generations of students, and future research may be able to quantify this effect. If so, policy that would expand the rollout and availability of broadband to students at school and home would thus in part be justified by these educational benefits.

Another example of positive spillovers is improved healthcare. Litan quantifies these benefits for a portion of the general population, namely seniors and the handicapped. Litan projects total discounted benefits from a policy that accelerates broadband deployment to be in the range of $532 to $847 billion over a 25 year period (Litan, 2006). Policy that would expand the rollout and availability of broadband would thus in part be justified by healthcare benefits.

Telecommuting has been enabled by broadband, making home offices nearly as productive as the workplace. Telecommuting reduces automobile emissions and saves wear and tear on road infrastructure. One study showed that an increase of less than 1% of the workforce working at home one to two days per week would result in a reduction of approximately 25 tons per year of VOCs and nearly as much NO_X (Walls and Nelson, 2004). A study by Peter Nelson showed that telecommuting leads to reductions in traffic volume and congestion. Reductions in traffic volume lower highway maintenance costs, while reductions in congestion reduce costs associated with lost time (Nelson, 2004, p. 29). Policy that would expand the rollout and availability of broadband would thus in part be justified by further increases in telecommuting.

5 Broadband Policy Benefit-Cost Analysis

The aim of this Chapter is to determine whether the use of industrial policy or loop unbundling during the upcoming deployment of NGN broadband would have positive net benefits. The analysis first predicts the increase in broadband availability due to application of these policies, based on the findings of Chapter 3, and then conducts a benefit-cost analysis using the findings in the literature surveyed in Chapter 4 to quantify broadband benefits.

Empirical results from first generation broadband deployment will be used to predict impacts of policy on NGN broadband deployment. The final model from Chapter 3 is used. This model is of the following form:

$$y_t = \lambda y_{t-1} + b_0 + b_1 x_{1t} + b_2 x_{2t} + b_3 x_{3t} + ... + \varepsilon \qquad \text{(E-5.1)}$$

Table 5.1 shows the coefficients for the final model, along with their minimum, maximum and mean values. The industrial policy flag will be set to either “1” or “0” to predict the impact of public or no public investment. Similarly the unbundling flag will be set to either “1” or “0” to predict the impact of applying or not applying the unbundling policy. The other independent variables will all be set to their mean values.

This model will be used to predict the impact of policy on NGN deployment in the U.S. The empirical analysis that generated the model was across the 30 OECD countries. Relative to the dependent variable, broadband density, the U.S. currently ranks 15 out of 30 countries, or in other words is about average. Thus the final model with dependent variables held at their mean values should be a good predictor of broadband availability in the U.S.

Table 5.1 - Final Model Coefficients

	units	coefficient	mean	min	max
bb_density	number of broadband subscribers per 100 inhabitants	dependent variable	17.653	0	37
industrial_policy	“1” if industrial policy applies during the current year; otherwise “0”	2.446853	0.0933	0	1
l1_unbundling	“1”if unbundling policy applied 1 year ago; otherwise “0”	1.939502	0.9142	0	1
pop_density	population density (people per sq km)	0.007669	133.64	2.59	488.02
houses_pc	percentage of homes with a PC (100%= 1.0)	9.266385	0.629	0	0.9192
long_term_ interest_rates	long term interest rates (100% = 1.0)	-25.5777	0.043	0.01	0.1107
l1_bb_density	dependent variable lagged by 1 year	0.7743227	14.193	0	35
us	flag for U.S.	4.47993	0.0333	0	1
ca	flag for Canada	1.205087	0.0333	0	1
au	flag for Australia	1.567813	0.0333	0	1
nz	flag for New Zealand	3.05143	0.0333	0	1
scand	flag for Scandinavian countries	2.605652	0.1666	0	1
cent_eur	flag for Central European countries	-0.857585	0.2	0	1
jp	flag for Japan	-3.92279	0.0333	0	1
kr	flag for Korea	-5.22904	0.0333	0	1
cons	constant	-1.32598			

NGN deployment has already begun, and the model will use an initial quantity of NGN broadband assumed in the year 2013. Currently the most significant NGN deployment vehicle in the U.S. is FiOS®. This service had 3.8 million active subscribers in 2010, and “passed” 18 million homes, meaning that the entire fiber infrastructure is in place to serve up to 18 million subscribers. The only remaining step is for the subscriber to sign up for service and for Verizon to perform installation within the home. Thus another 14 million subscribers could be activated with relatively modest additional investment. For the basis of the study herein, it will be assumed that there are 6.7 million NGN subscribers in the U.S. starting in the year 2013. NGN broadband availability will then be modeled for over a decade. The starting conditions for the model, namely the year and the initial quantity of NGN broadband, are somewhat arbitrary and can be easily changed in the following analysis. The impact on results was found to be minor.

Using this framework, the availability of NGN broadband in the U.S. is predicted as shown in Figure 5.1. The application of either industrial policy or unbundling substantially increases NGN broadband availability, and the simultaneous application of both policies almost doubles availability by 2025.

Several questions arise relative to the reliability of this predictive model, which is based on the assumption that the progression from narrowband to first generation broadband will carry over in a similar way to the progression from first generation to NGN broadband.

First, unbundling policy was initially applied to an existing base of access facilities, namely copper telephone lines which were deployed to the majority of homes in developed countries. Thus there was no question of whether the facilities existed. In the case of NGN broadband, a majority of households do not yet have fiber infrastructure, even in developed countries. One of the theoretical debates surrounding unbundling is whether the policy inhibits incumbent investment in the plant, both for maintaining the existing infrastructure as well as to expand and upgrade it. There is some evidence that unbundling inhibits investment, while other evidence indicates that deployment proceeds even in the face of an unbundling requirement. This ambiguity calls into question whether unbundling policy applied to new fiber-based facilities will be as effective as it was when applied to the existing copper loop plant, or even whether it will be effective at all.

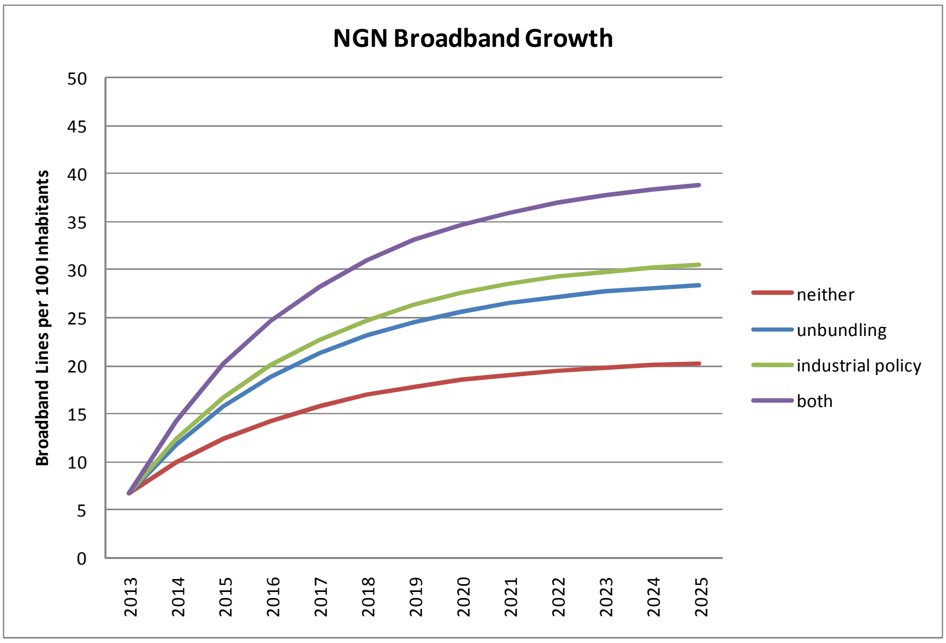

Figure 5.1 - The Baseline (Optimistic) NGN Broadband Availability Model

To deal with this, the analysis will consider an optimistic scenario, where unbundling is assumed to have the same impact as it did for first generation broadband, and a pessimistic scenario, where the impact of unbundling is reduced. For this latter model, the coefficient value for unbundling in the final model will be divided by a factor of 2. The result of this is to lower the impact of unbundling, as shown in Figure 5.2 below. Finally, to consider a very pessimistic scenario, the impact of unbundling can be eliminated completely during analysis. In other words, it can be assumed that unbundling has no positive effect and therefore is not applied. If unbundling has no effect, then analysis is obviously trivial and the policy is not worth pursuing (it would have only costs and no benefits).

Another question regarding the model relates to the contrast between narrowband and first generation broadband as compared to the contrast between first generation and NGN broadband. On the one hand the contrast between narrowband and broadband seems dramatic, explaining the rapid penetration of broadband and providing supporting rationale for consideration of associated positive externalities. People want broadband and can do things they just couldn't do with dial-up modems.

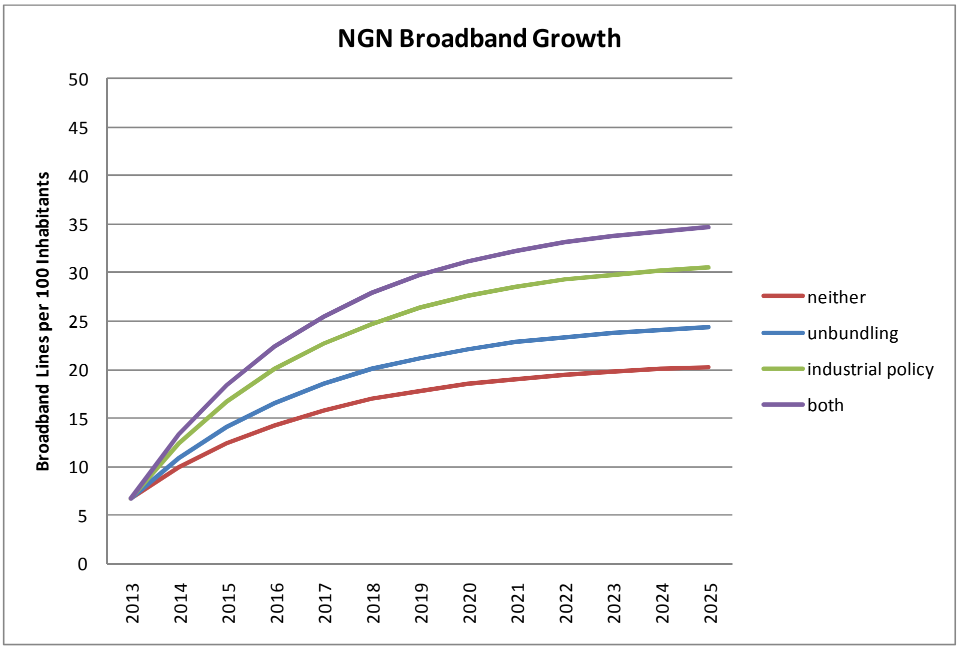

Figure 5.2 - An NGN Broadband Availability Model with Reduced (Pessimistic) Unbundling Impact

But there are several counter arguments that characterize this as more of an evolutionary continuum than a disruptive change. First, in most OECD countries ISDN was in widespread use. The U.S. was relatively unique in the absence of ISDN and the use of dial-up instead. Although the rates were comparable (about 56 kbps), ISDN service was "always on" in the same way that first generation broadband using ADSL or cable modems is always on.[18] Furthermore, there was the possibility of using two ISDN "B" channels to obtain over 100 kbps full duplex data. Thus the transition from ISDN to ADSL might appear more evolutionary than revolutionary in many of the countries

[18] The term digital subscriber line, or DSL, in fact originated with ISDN. Asymmetric Digital Subscriber Line, or ADSL, was a technological extension and enhancement of the ISDN DSL.

studied, lending credence to the argument that this evolution will continue toward NGN broadband.

Another concern is that externalities produced by the change from narrowband to broadband will not carry over or be reflective of externalities produced by the transition from first generation to NGN broadband. Here an argument of obsolescence can be used to justify the assessment of externalities. It is well known that the advent of computers has greatly increased productivity. It is also well known that computers quickly become obsolete, that processor speeds and memory sizes both increase in a seemingly unending fashion, and that a machine that is five years old becomes almost useless. Thus, unless it is replaced with a new machine, the productivity gains will begin to slip away. In a similar fashion it is argued that NGN broadband will become increasingly necessary to generate network effect benefits, to have effective education and healthcare systems, and to telecommute. Research to quantify these benefits generally relies on regional differences during the ramp-up of the new technology. For example areas that received first generation broadband sooner show statistically significant increases in economic activity. A plausible argument is that these quantifiable differences will carry over in an analogous fashion when transitioning from first generation to NGN broadband.

Finally, there is a question as to whether the penetration of NGN broadband will be as robust and rapid as first generation broadband. Steadily advancing technology might be used to argue that broadband must advance as consistently and rapidly as do computers and other high technologies. On the other hand, NGN broadband will require massive investment in fiber infrastructure, and although some administrations appear to be ready to make such commitments, others, including the U.S., are more inclined to rely on free market forces which may be slower and more selective in bringing about these investments. Unlike first generation broadband which leveraged existing copper and cable television facilities, NGN broadband will require new fiber facilities to be placed. These considerations may lead one to conclude that NGN broadband will roll out more slowly.

To deal with this, the analysis considers a baseline optimistic scenario, where NGN broadband will be assumed to roll out at the same rate as first generation broadband, and a more pessimistic scenario, where the rate of rollout is reduced. For this latter model, the coefficient value used to carry over the previous year's broadband density level is adjusted to lower the rate of growth to that shown in Figure 5.3 below.

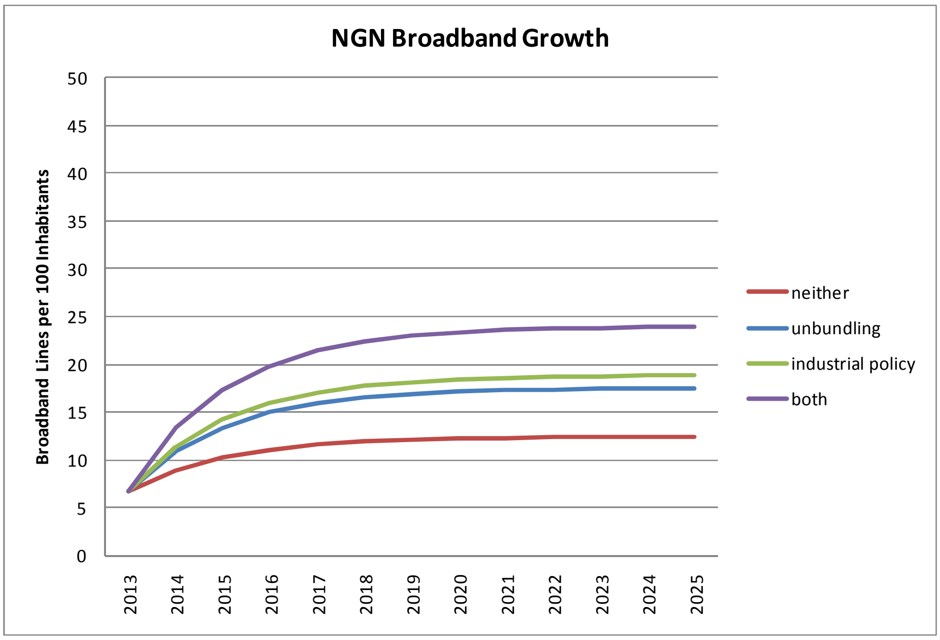

Figure 5.3 - An NGN Broadband Availability Model with Reduced (Pessimistic) Rollout Rate

In the next sections the various components of a benefit-cost analysis are developed. The model for broadband availability has already been introduced. Next, private benefits are articulated, including producer and consumer surplus generated by increased levels of broadband. This is followed by a discussion of costs associated with industrial policy and unbundling. Next follows discussion of the positive spillover to the economy at large resulting from increased broadband availability, due to the network effect. Then the positive benefits that increased broadband brings to one segment of the healthcare sector, the elderly, the disabled and the poor served by the Medicare and Medicaid programs, are quantified. This is followed by the positive benefits that increased broadband brings to environment, economy and infrastructure by virtue of a synergistic relationship with telecommuting. Next all of these costs and benefits are combined and a discount rate is applied to derive net present value and benefit cost ratio. A number of different scenarios are examined and results are tabulated and discussed.

5.1 Benefits of Producer and Consumer Surplus

The approach used to calculate U.S. private social surplus attributable to broadband is to examine available data from several years during the last decade. Using this data, producer and consumer surplus are estimated on an annual basis, and will then be normalized per-subscriber.

To make the initial estimates, data from the U.S. Census Bureau Service Annual Survey is used (Census Bureau, 2010). As part of this survey, figures for employer firm revenues are given. In particular Table 3.3.6 gives “Wired Telecommunications Carriers (NAICS 5171) - Estimated Sources of Revenue for Employer Firms.” The Census Bureau defines "wired telecommunications carriers" to include telephone and cable companies,[19]

[19] Wired telecommunications carriers , 2007 NAICS Definition (last viewed July 2011) http://www.census.gov/econ/industry/def/d517110.htm

the two predominant sources of broadband access. These wired carrier figures provide total operating revenue, including fixed local, fixed long distance, subscriber line charges, private network services, etc. Within these figures “Internet Access Service Revenues” are also provided separately. These figures are extracted and shown in Table 5.2 below for the years 2005 through 2008, along with the percentage of Internet to total revenue.

Census Bureau Service Annual Survey Table 3.6.5 gives “Wired Telecommunications Carriers (NAICS 5171) - Selected Expenses for Employer Firms” (Census Bureau, 2010). It similarly provides total operating expense figures but does not break out Internet access expenses separately. Therefore Internet access expenses are estimated by prorating, using the same ratio as for revenues above. An estimate of profit for Internet access is calculated by subtracting expenses from revenues. Then a per-subscriber estimate is made using total U.S. broadband subscriber figures from the OECD (OECD, 2009). These figures are also shown in Table 5.2.

Note this method assumes that broadband is a long-run constant-cost industry. This is consistent with trends for the industry to be dominated by incumbents with relatively elastic supply curves. For example, Figure 5.4 shows price and quantity data for broadband services in 31 OECD countries in 2010. (Note that OECD only recently began to report price data.) Strictly speaking, the data should be broken out and plotted for each operator firm. But the cumulative country figures do give an indication of the elastic nature of prices. This would imply minimal producer surplus and is an area worthy of additional research. Going forward, price data can be used to better understand broadband supply and demand, and can be added to data sets to explore the relationship between broadband availability and prices.

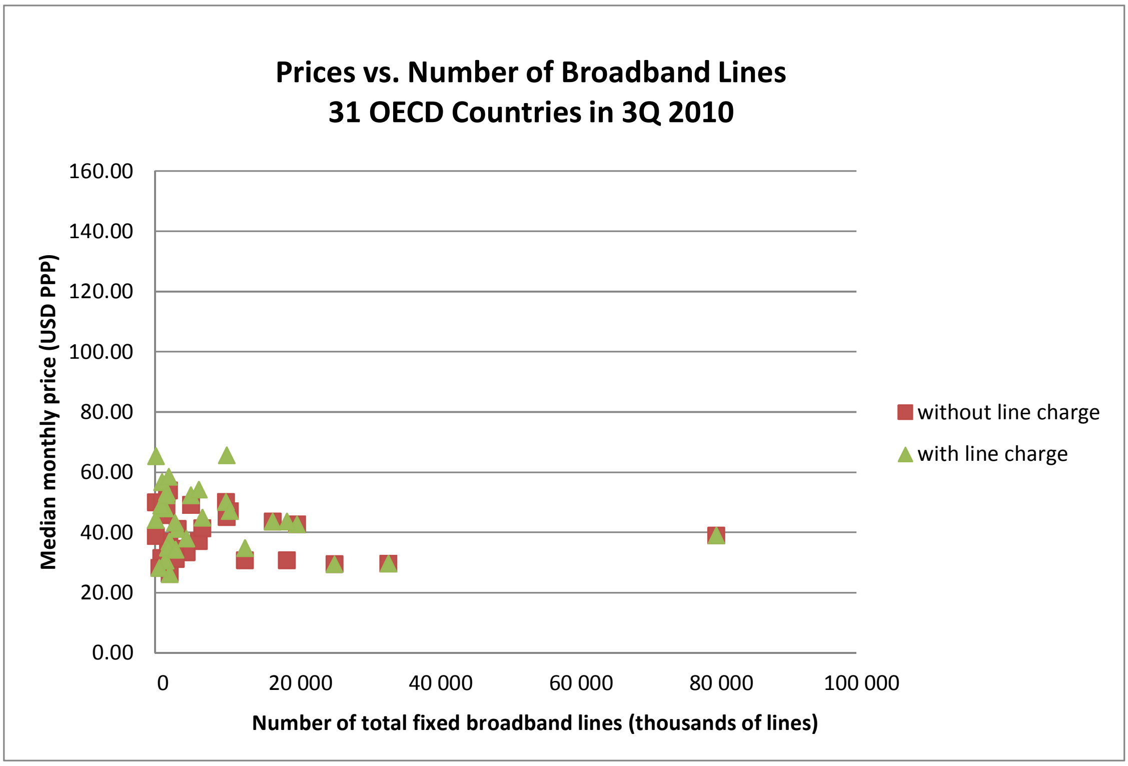

Figure 5.4 - Broadband Price and Quantity Data for 2010

To calculate consumer surplus, simple estimates for the shape of the demand curve are assumed. The demand curve is assumed to be linear. As shown in Figure 5.5, the market equilibrium point is assumed to occur at the average monthly price for broadband Internet subscriptions, and at the quantity of total U.S. broadband subscriptions. For example, in 2008 there were 77.4 million subscribers and the average monthly fee was $25.50.

To calculate the area of the consumer surplus triangle, the willingness to pay at low quantities is needed. One way to speculate as to the marginal demand is to ask the question, “What did people do before DSL was available?” Many businesses leased T1 private lines from the telephone company (also referred to as DS1 service), and there was a persistent urban legend of a small number of technology-oriented individuals who paid to have private lines installed to their residences. Whether such cases actually occurred does not detract from the reasonableness of an argument that the demand curve crosses the origin at something close to the monthly recurring charge for T1 private lines. Monthly rates for local loops providing DS1 service vary substantially by location.[20] Calculations herein are made using rates of $75 and $150 for the monthly recurring charge (MRC). Table 5.2 shows the details for calculating annual consumer surplus when using $75 for the MRC.

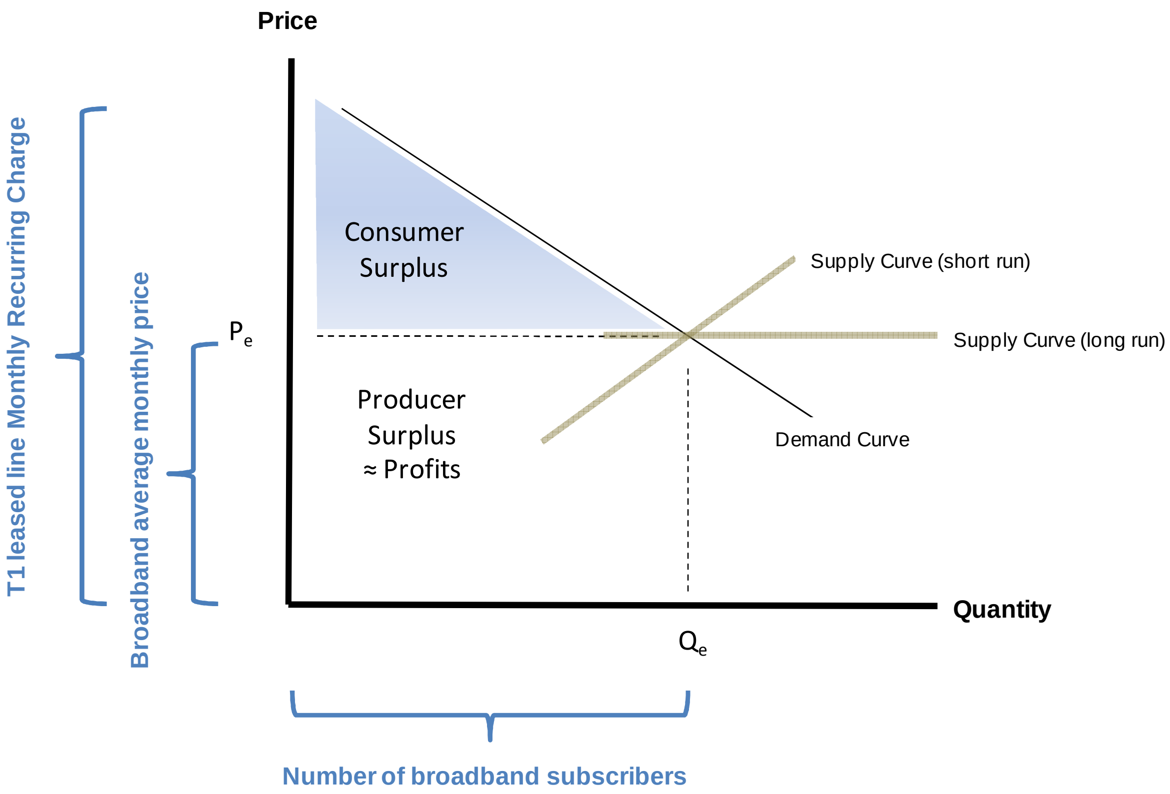

Figure 5.5 - An Estimate of Broadband Consumer Surplus

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[20] See for example state rates quoted by TeleDeal Inc., at http://1800teledeal.com/privateline.pdf (last viewed July 2011)

Table 5.2 - Estimate of Broadband Producer and Consumer Surplus
($75 Monthly Recurring Charge as proxy for willingness to pay at origin)

	Year	2005	2006	2007	2008
A (Census Bureau, 2010)	total annual operating revenues ($B)	$206	$196	$197	$195
B (Census Bureau, 2010)	annual Internet access services revenues ($B)	$16.4	$17.5	$21.1	$23.7
C = B/A	percent revenue from Internet access (%)	8.0%	9.0%	10.7%	12.2%
D (Census Bureau, 2010)	total annual operating expenses ($B)	$181	$174	$166	$162
E = C*D	annual operating expenses prorated for Internet access ($B)	$14.5	$15.5	$17.8	$19.7
F = B-E	estimated annual profit for Internet access ($B)	$1.94	$1.98	$3.38	$3.96
G (OECD, 2009)	U.S. broadband subscribers (millions)	48.5	60.6	70.3	77.4
H = F*1000/G	annual profit per subscriber for Internet access ($)	$40.10	$32.61	$48.00	$51.18
I = B*1000/G/12	average subscriber monthly price ($)	$28.28	$24.07	$25.05	$25.50
J (see discussion)	estimated monthly willingness to pay for first unit ($)	$75.00	$75.00	$75.00	$75.00
K = 1/2(J-I)	monthly consumer surplus per subscriber ($)	$23.36	$25.47	$24.98	$24.75
L = 12*K	annual consumer surplus per subscriber for Internet access ($)	$280.34	$305.58	$299.72	$297.03
M = H+L	annual Social Surplus per subscriber for Internet access ($)	$320	$338	$348	$348

The estimated per-subscriber consumer surplus is added with the per-subscriber profit, an estimate of producer surplus, to yield estimated per-subscriber social surplus. It is relatively stable, and the four year average will be used to make future projections of private benefits.

Interpretation of Internet access service revenues are complicated by a number of factors. They include dial-up modem services, which are not broadband. However, by mid-decade, use of dial-up modems had declined significantly, and the figures discussed will reflect access predominantly provided by DSL and cable modems.

Many DSL customers converted their second phone lines, which previously were dedicated to a dial-up modem, to a DSL line. Thus subscribers additionally had to continue to pay for the second line in order to obtain Internet access. On the other hand, some customers placed DSL on their primary line, and telephone companies began offering low cost data-only DSL services which reduced or eliminated the line fee.

Another factor that can impact assessment of revenues is service bundling, for example the so-called “triple play” package of voice, video and Internet services. Both DSL and cable modem providers increasingly offered bundled services, which reduces total fees and further complicates the task of allocating costs.

Greenstein and McDevitt performed an extensive study of the consumer costs for broadband services by examining actual customer service agreements (Greenstein and McDevitt, 2009). Their conclusions regarding U.S. revenues for the Internet access market are somewhat higher than figures derived from Census Bureau data. In order to align the Census Bureau figures with those of Greenstein and McDevitt, the former would have to be increased by a factor of 1.4. I calculated revenues with and without this adjustment. Only the Internet revenues are adjusted upward; total operating revenues and expenses are left unchanged. The implication of increased revenues is that customers are paying more for their broadband service, and as a result consumer surplus will be reduced.

Another factor that could impact proper estimation of broadband social surplus is the new goods effect. Because broadband largely replaced dial-up modems, counting surplus generated by broadband may overstate the benefit. For if broadband did not exist it is likely that dial-up modems would have continued to generate social benefit, albeit less than broadband. Thus some would argue that only surplus over and above that which would have been generated by dial-up modems should be attributed to broadband.

> “It has been widely accepted since Fogel (1962) that it is an error to focus solely on the demand for and supply of the new good. Instead, attention should be paid to the additional benefits beyond what would have occurred without the deployment of the new good.” (Greenstein and McDevitt, 2009)

Greenstein and McDevitt go on to determine that of broadband GDP, only 40% to 50% was "newly created" over GDP that would have been generated by dial-up modems.

A similar argument might be made for NGN Broadband, operating at significantly higher speeds than first generation broadband. Calculations are run with and without the new goods effect.

Projections of private social surplus attributable to policies applied to NGN broadband are then calculated based on the increase in broadband penetration levels when industrial policy and/or unbundling are applied. These broadband density increases are multiplied by projected U.S. population levels to generate additional broadband subscribers, and then by the per-subscriber social surplus figure derived above.

Population projections for the U.S. are obtained from the OECD (OECD Factbook, 2010). Table 5.3 below shows a portion of the calculations for the case when industrial policy is applied. The calculations continue through 2025.

As will be the case for the entire study, costs and benefits will not include inflation. Rather the discount rate will be inflation indexed and thus will remove inflationary effects when calculating present values. Also, for convenience, 2010 dollars will be used throughout this study.

5.2 Costs Associated with Broadband Policy

The costs associated with industrial policy will be guided by data from Kelly et. al. They collected figures, shown in Figure 2.5 in Chapter 2, on recently announced broadband investment programs enacted by governments around the world as part of stimulus programs intended to counteract the recent recession (Kelly et al, 2009). With the exception of Australia, which is mounting a very substantial public program to deploy fiber nationwide, the investment levels are on the order of tens to hundreds of U.S. dollars per capita.

Table 5.3 - Calculation of Social Surplus Attributable to Industrial Policy (adjusted according to Greenstein and McDevitt, New Goods effect applied)

	Year	2013	2014	2015
N (from final models)	baseline broadband model (subscribers/100 inhabitants)	6.700	9.903	12.383
O (from final models)	with industrial policy (subscribers/100 inhabitants)	6.700	12.350	16.724
P = O - N	increase with policy (subscribers/100 inhabitants)	0	2.4469	4.3415
Q (OECD Factbook, 2010)	projected US population (millions)	319.33	322.423	325.54
R = (P/100)*Q	additional subscribers (millions)	0.000	7.889	14.133
Social $\text{Surplus}_{\text{Ave,Adjusted}}$	average annual per subscriber social surplus, adjusted	\$294	\$294	\$294
$\text{Effect}_{\text{New Goods}}$	new goods effect (%)	50%	50%	50%
S = R*Social $\text{Surplus}_{\text{Ave,Adjusted}}$*$\text{Effect}_{\text{New Goods}}$	additional social surplus (millions of 2010 dollars)	\$0	\$1,160	\$2,078

Table 5.4 - Cost Calculations for Public Investment in Broadband (\$10 per capita investment level, agency staff level of 100)

	year	2013	2014	2015
Q (OECD Factbook, 2010)	projected US population (millions)	319.33	322.423	325.54
T = Q*Investment Level	annual investment in NGN broadband (millions of 2010 dollars)	\$3,193	\$3,224	\$3,255
U = \$250,000*$\text{Number}_{\text{Staff}}$/1,000,000	annual Agency implementation costs (millions of 2010 dollars)	\$25	\$25	\$25
V = T + U	total costs of Industrial Policy (millions of 2010 dollars)	\$3,218	\$3,249	\$3,280

Public investment made for U.S. broadband industrial policy will be examined at $10, $50 and $100 per capita. The total absolute investment levels will therefore be determined by population projections. For example, a $10 per capita level represents about $3.1B in annual investment today. As a point of reference, the Stimulus Act of 2009 allocated about $7B of investment in broadband to be spent over several years (Act, 2009). Analysis of broadband industrial policy suffers from lack of detailed data on investment levels. Therefore I will also test the more expensive levels of $50 and $100 per capita, representing more conservative cases where more public funds are required to achieve a given increase in broadband.These levels are maintained for the years 2013 through 2017, and then begin to slowly taper down so that by 2025 the levels are 20% of the initial levels.

There will be agency costs associated with industrial policy. A regulatory agency must oversee the policy, disbursement of funds, compliance with any requirements, and reporting to congress and the public. In the U.S. this agency would most likely be the FCC. For this cost I assume that a staff of 100 will be required to administer the program at the $10 per capita level. I assume that each staff person will cost the government $250,000 in fully loaded annual recurring expense to cover salaries, benefits and other overhead. When investment levels are increased, agency staff levels are increased as well, with 500 and 1000 staff required for the $50 and $100 per capita levels of investment respectively. Table 5.4 above shows a portion of the calculations, which continue through 2025. The table shows the case where the investment level is $10 per capita and with an agency staff level of 100.

Unbundling is a policy instituted and enforced by a regulatory agency on the private broadband service provider marketplace. In the U.S. the FCC has in the past imposed loop unbundling upon incumbent telephone companies, and it could do so again in the future, for example relative to NGNs and fiber access loops.

As discussed in Chapter 2, the impact of unbundling is controversial from both a theoretic and empirical point of view. On one side of the argument, incumbents will complain that unbundling gives competitors unfair access to facilities that required substantial investment to build out. This represents a cost to the incumbent, in terms of lost business and revenue, and furthermore presents a disincentive to invest in and modernize infrastructure. New entrants will embrace unbundling, claiming that access facilities represent a high barrier to entry. When this barrier is lowered via unbundling, entrants can lease facilities at competitive rates, can establish an alternative choice for consumers, and over time can build a business that competes with the incumbent. These costs to incumbents and benefits to new entrants are not addressed here. Rather, the approach is to use the results of the empirical analysis of 30 OECD countries where, overall, unbundling was found to have a statistically significant and positive influence on total broadband availability. Thus although there will potentially be shifts in production among incumbents and competitors as a result of unbundling policy, the overall impact is appropriately captured and modeled by the empirical analysis and needs no further consideration in terms of costs and benefits. However, the possibility cannot be dismissed that for NGN, unbundling will create a sufficient disincentive for incumbent investment such that rollout is significantly delayed. Obviously the analysis that follows would not apply in that case.

One might argue that if a policy increases market activity and the size of the market, then producers must generate more network infrastructure. And increases in market size are typically accompanied by reductions in prices, in this case for broadband service subscriptions. These changes have already been accounted for by estimates of overall changes in private consumer and producer surplus and are not considered further here.

There will be an enforcement cost associated with unbundling. A regulatory agency must oversee the policy and ensure compliance. In the U.S. this agency would be the FCC. For this cost, I will examine two assumptions. The first assumes a dedicated FCC staff of 50 employees, to manage a national NGN unbundling policy, including monitoring of incumbents, fielding questions and complaints from new entrants, and to interact with Congress and the public. Alternatively a staff of 100 will be examined. Each staff person will be assumed to cost the government $250,000 in fully loaded annual recurring expense to cover salaries, benefits and other overhead.

There has been discussion of costs of co-locating equipment in the incumbent telephone company's central office. Incumbents must make space available for competitors to locate their equipment, and must move lines to the competitor's equipment in order to place subscribers in service. For a given number of broadband users, about the same amount of equipment and cross connects are needed, whether incumbent or entrant provided. Still, there is an overhead associated with managing separate entities in the central office. To account for this additional overhead, the assumption is made that unbundling increases incumbent operational expenses by one, three, or five percent.

In order to estimate increases in operational expenses, figures from Table 5.2 are used. There annual operator expenses (line E) were calculated for broadband Internet access for the years 2005 through 2008. Dividing by the number of broadband subscribers (line G) gives the average annual operator expense per subscriber. The annual values are relatively stable across the four years, and the 2010 cost is assumed to be the average of $266 per-subscriber.

The staff costs and increased operational expenses are calculated for the study period. Table 5.5 below shows a portion of the calculations, which continue through 2025. The table shows a case when the operator overhead is assumed to be 5% and the agency staff level is 100.

5.3 Broadband's Positive Impact on the Economy

In order to estimate the magnitude of the network effect, I rely on the resulting increase in GDP according to Koutroumpis et al. The authors run a structural econometric model using annual data from 22 OECD countries between 2002 and 2007. In order to deal with potential causality concerns between broadband and GDP, a system of equations explicitly expresses economic growth as a function of broadband (among other things), and broadband as a function of economic growth (among other things). Our interest here is in the relationship between GDP and the stock of broadband infrastructure, for which the proxy subscribers per 100 inhabitants is used. After analysis, the coefficient for broadband stock has a positive value of 0.025 and is significant at the 1% level. Thus a 1% increase in the broadband penetration rate increases economic growth by 0.025% (Koutroumpis, 2009).

Table 5.5 - Cost Calculations for Implementing and Enforcing Unbundling
(5% operator overhead, agency staff level of 100)

	Year	2013	2014	2015
W = \$250,000*$Number_{Staff}$/1,000,000	unbundling enforcement costs (millions of 2010 dollars)	\$25	\$25	\$25
X (from final models)	broadband model with unbundling (subscribers/100 inhabitants)	6.7	10.87254	14.10343
Q (OECD Factbook, 2010)	projected US population (millions)	319.33	322.423	325.54
Y = (X/100)*Q	projected broadband subscribers (millions)	21.4	35.1	45.9
Z = Y*Operator Expense per Sub_{AVE}	service provider operating expense (millions of 2010 dollars)	\$7,958	\$13,040	\$17,078
a= Z*$\%_{OVERHEAD}$	increase in operating expenses (millions of 2010 dollars)	\$398	\$652	\$854
b = W + a	Total unbundling costs (millions of 2010 dollars)	\$423	\$677	\$879

Table 5.6 - Calculations of Increased GDP Attributable to Industrial Policy
(1% baseline growth rate, adjusted Koutroumpis estimate)

	Year	2013	2014	2015
N (from final models)	baseline broadband model (subscribers/100 inhabitants)	6.700	9.903	12.383
O (from final models)	with industrial policy (subscribers/100 inhabitants)	6.700	12.350	16.724
c = (O-N)/N	percent change in broadband density with policy (%)	0.00%	24.71%	35.06%
d = (c*100)*%$Koutroumpis_{ADJUSTED}$	percent change in GDP using Koutroumpis (%)	0.000%	0.572%	0.812%
e = 2010 GDP grown at a fixed annual rate	estimated real U.S. GDP (2010 trillions of dollars)	\$15.2	\$15.3	\$15.5
f = (e*1000)*d	increase in GDP (millions of 2010 dollars)	\$0	\$88	\$126

I calculate the benefit based on the increase in broadband penetration levels when industrial policy and/or unbundling are applied. The final model figures are used to expresses these increases in percentage, and each percent increase is then multiplied by 0.025% to determine the percentage increase in GDP. The baseline for GDP begins with 14.72 trillion dollars in 2010 (CIA World Factbook, 2010), and GDP is then grown over the study period using the simple assumption of a 1, 2 or 3 percent annual growth rate. Then I calculate the increase in GDP in dollars by multiplying the baseline GDP by the estimated percentage increase in GDP due to broadband. Table 5.6 above shows a portion of the calculations for the case when industrial policy is applied, and where the annual GDP growth rate is assumed to be 1%. The calculations continue through 2025.

This straightforward calculation suffers from the fact that the Koutroumpis model captures all GDP growth attributable to increased broadband, both the private and public components. The private component has already been captured as producer surplus, and should therefore be removed. This is the reason for the use of the adjusted Koutroumpis estimate in Table 5.6.

The adjusted estimate is made as follows. Broadband density in the U.S. is obtained from OECD data, and multiplied by 0.01. This generates the 1% increase in broadband penetration cited by the Koutroumpis study. To convert this into an increase in GDP, the broadband increase is multiplied by the U.S. population (OECD Factbook, 2010) to generate additional subscribers. The additional subscribers are multiplied by the average monthly subscriber prices, as discussed previously, to generate additional revenues. I then compare these additional revenues to U.S. GDP figures (OECD iLibrary) to determine percent increases in GDP. These increases represent the component attributable to producer surplus.

They are small compared to 0.025%, indicating that the bulk of the Koutroumpis GDP increase is due to public benefit from the network effect. Additionally, the private estimate is quite stable from 2003 through 2008. The average of 0.0019% is used, and is subtracted from 0.025% to obtain a lower, adjusted Koutroumpis benefit of 0.0231% that accounts for just the public component of the benefit.

5.4 Broadband Spillovers to the Medicare and Medicaid Programs

As described in Chapter 4, Litan examines Medicare and Medicaid programs that leverage a modern broadband network to achieve efficiencies and he quantifies the associated savings. He then goes on to estimate the impact of accelerated broadband availability, comparing a baseline case to a broadband acceleration case. His baseline assumption is that savings will build to the 10 percent level by 2030. His accelerated case assumes that an unspecified broadband policy is able to accelerate broadband availability such that the 10 percent savings level occurs by 2020, a decade earlier. Then the 10 percent savings level remains in effect from 2020 to 2030. Litan's analysis projects cumulative savings for the years 2010, 2020 and 2030, shown in Tables 4.1, 4.2 and 4.3 in Chapter 4 (Litan, 2006).

Examining the NGN Broadband Model of Figure 5.1, both the industrial policy and unbundling cases reach a level of about 20 broadband lines per 100 inhabitants by the year 2016. However it takes until 2025 for the no policy case to reach this same level, another 9 years. The application of either of the broadband policies thus accelerates broadband availability by about a decade, the condition that Litan uses in his study. The calculations of benefits are arranged so that application of either industrial policy or unbundling triggers Litan's savings. The application of both policies simultaneously does not have any additional effect.

Litan's savings are all in billions of 2005 dollars. Calculation of benefits starts by shifting them forward 5 years using a 2% inflation rate so that they become 2010 dollars. Litan's 2010 cumulative savings then become 2015 cumulative savings, in 2010 dollars. Similarly the 2020 cumulative savings become 2025 cumulative savings, in 2010 dollars. Litan's 2030 savings are not used. The results are shown in Table 5.7.

Table 5.7 - Litan's Savings Moved Forward 5 Years (2010 $B)

Year	2010	2015	2025
Chronic Care - Elderly	$0	$16.139	$117.454
Chronic Care - Poor	$0	$3.777	$28.175
Home Care	$0	$2.067	$9.460

To distribute Litan's cumulative savings over years, first observe the pattern of his savings. Savings accumulate slowly until 2010, then accelerate until 2020, then grow more slowly until 2030. Because this pattern is now shifted out 5 years, only the first two stages need to be modeled. A simple piecewise linear model is used where annual savings are at a lower rate until 2015 and then at a higher rate until 2025. The annual savings levels are adjusted to make the cumulative levels at 2015 and 2025 match Litan's levels. The results of this exercise are shown in Figures 5.6 and 5.7.

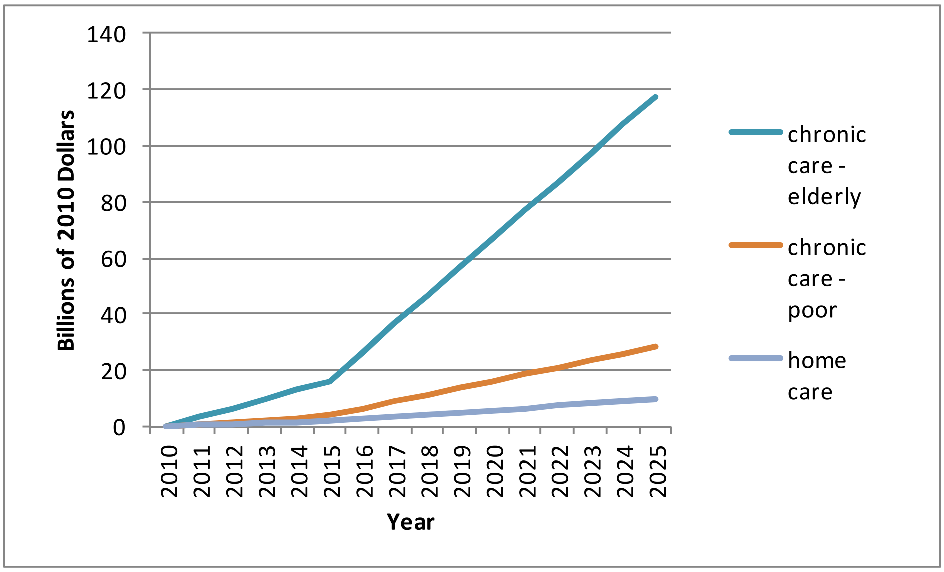

Figure 5.6 - Litan's Cumulative Savings attributable to Increased Broadband

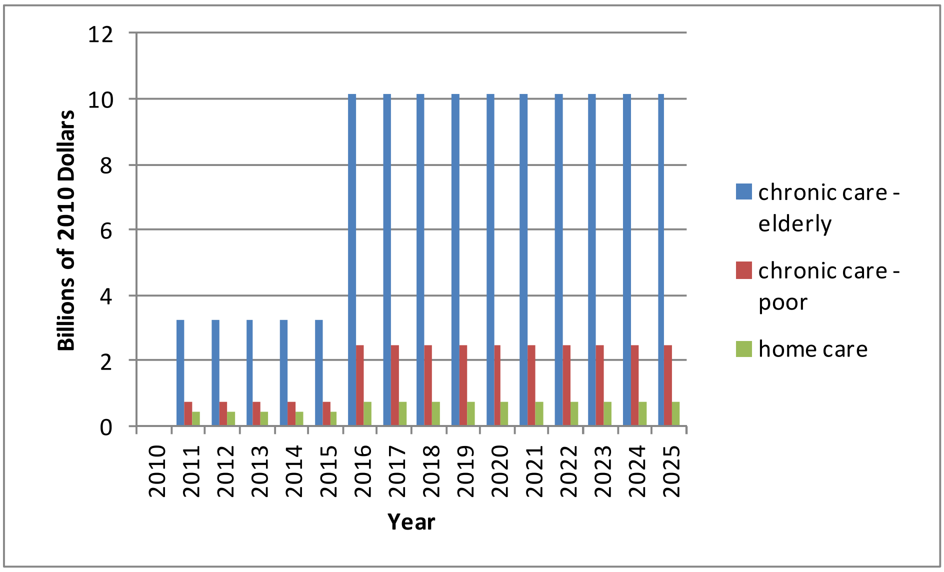

Figure 5.7 - Litan's Savings Annualized

Because Litan's savings are already discounted, and because the analysis conducted later will begin by summing undiscounted benefits, Litan's annual savings are converted to undiscounted figures. The rate used is the discount rate, which will appear in the benefit-cost analysis below and will be used to discount all costs and benefits. The results of this exercise are shown for the annual savings in Figure 5.8 for the case where the discount rate is 7%. These are the benefits that will be attributed to healthcare externalities as a result of increased broadband availability. The chronic care savings will be combined together, and the home care savings will remain separate.

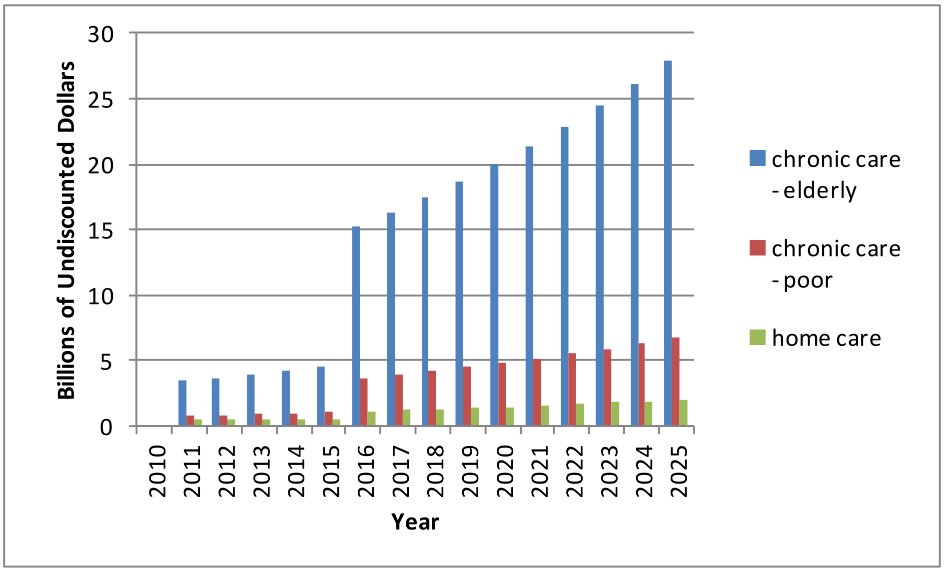

Figure 5.8 - Litan's Savings Annualized and Undiscounted (discount rate 7%)

5.5 Broadband Spillovers to Telecommuting

Telecommuting, in which employees work at home rather than the office, has a positive environmental impact by virtue of reductions in driving and associated decreases in automobile emissions, savings in fuel consumed, and decreased wear and tear on road infrastructure.

In order to identify the potential telecommuter population, data from a telecommuting survey is used. This survey asked a number of questions of workers who are currently *not* telecommuting. In response to the question "Do you have tasks that could be performed at home?" 38% of interviewees responded yes. In response to a question soliciting interest in performing work tasks at home, 34% of interviewees responded “Very interested.” In response to a question regarding employer attitude, 54% of interviewees believed that their employer would be willing to support telecommuting (Telework Trendlines, 2009). Multiplying these three percentages together yields a relatively conservative estimate of individuals who are not currently telecommuting, have jobs amenable to telecommuting, are personally interested in telecommuting, and whose employers are supportive.

Telecommuting has only recently become practical, due to technological change that has both migrated business activity to computers and the Internet, as well as cost-effective broadband access that makes performance in a home reasonably equivalent to that at the office. In the assessment of benefits attributable to broadband, it will be assumed that in the same way first generation broadband became dominant over dial-up modems, NGN broadband will become dominant over first generation broadband. Thus NGN broadband will become increasingly necessary to support contemporary telecommuting.

I calculate benefits based on the increase in NGN broadband penetration levels when industrial policy and/or unbundling are applied. These broadband density increases are converted to the percentage increase in coverage of inhabitants. For simplicity I assume that both the increases in coverage and potential telecommuters are uniformly distributed, such that the product of the two yields additional telecommuters potentially enabled by an increase in NGN broadband availability. It is possible that increases in NGN coverage and pent-up telecommuting demand could either be non-overlapping or highly correlated, leading to lower or higher estimates, respectively. The assumption of uniform distribution is a compromise between these two extremes.

I estimate worker levels as before, by taking the population projections used previously for the U.S. and multiplying by estimates of the percentage that are of working age. The working age population is then multiplied by the estimated percentage increase in broadband coverage and by the estimated percentage of potential telecommuters.

Up to this point, the calculation assumes that the only thing holding back potential telecommuters is access to NGN broadband in their home offices, necessary to provide performance levels sufficient to efficiently work at home. However there may be other reasons that this population is not currently telecommuting. It may be simply due to lack of initiative on the employee's part. Although an employee believes their employer is willing to support telecommuting, the employer may have yet to institute a policy that will allow or encourage telecommuting. The assumption is that NGN broadband will be needed for effective telecommuting, particularly as applications demand more and more bandwidth. But there may still be a subset of users who struggle with slower first generation broadband, in the same way that a diminishing number of employees struggled with dial-up modems in the early 2000s. In order to account for all of these factors, results will be multiplied by an estimate of potential telecommuters who are not currently telecommuting due to lack of NGN broadband in their homes. Levels of 10% and 25% are used in the analysis.

Previous studies have found that the benefits of reduced conventional pollution emissions (NOx, CO, hydrocarbons, and particulate matter) are an order of magnitude less than other benefits, namely reductions in CO_2 emissions, savings in gasoline, and savings in highway maintenance costs. Therefore only the latter benefits are considered here.

The study by Koenig found that each day a worker telecommutes reduces VMT by an average of 34.6 miles (Koenig et al, 1996). For the estimate of benefits accruing from reduction in CO_2 emissions, 1.1 pounds of CO_2 are associated with each vehicle mile of travel (CNT, 2003). Three values for the social cost of carbon are used; the recently proposed U.S. Senate low price of $12 per ton, the high price of $25 per ton, and the UK government 'central case' price of $83 per ton.[21] At $12 per ton, for example, the benefit of one day of telecommuting is then $0.21.

For the estimate of benefits accruing from reduced gasoline consumption, I use an average passenger car fuel efficiency of 22.6 miles per gallon from Table 4-23 of the National Transportation Statistics (National Transportation Statistics, 2010). The benefit of one day of telecommuting is then $4.59, assuming the price of gasoline is $3 per gallon.

For the estimate of benefits accruing from reduction in wear and tear on roads and highways, I use a roadway cost of 7.7 cents per mile driven (Nelson, 2004). The benefit of one day of telecommuting is then $2.66.

Finally, I multiply the number of telecommuters enabled by broadband by zero, one or two days of telecommuting a week to determine annual benefits. Table 5.8 below shows a portion of the calculations, which continue through 2025. The table shows a case where the percentage of potential telecommuters who would be enabled by NGN broadband is assumed to be 10% and they telecommute 2 days a week.

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[21] "The social cost of carbon," Kate Sheppard, Washington Post, June 1, 2010, http://voices.washingtonpost.com/ezra-klein/2010/06/the_social_cost_of_carbon.html, last viewed September 2011

Table 5.8 - Calculation of Telecommuting Externalities Attributable to Industrial Policy (10% of potential telecommuters enabled by NGN, telecommute two days/week)

	Year	2013	2014	2015
N (from final models)	baseline broadband model (subscribers/100 inhabitants)	6.7	9.9027856	12.382775
O (from final models)	with industrial policy (subscribers/100 inhabitants)	6.7	12.349639	16.724282
P = O - N	increase with policy (subscribers/100 inhabitants)	0.000	2.447	4.342
g= P / 100	increased broadband coverage (%)	0.0%	2.4%	4.3%
Q (OECD Factbook, 2010)	projected US population (millions)	319	322	326
h (U.S. Census Bureau, 1996)	percent working age (extrapolate 59% down to 55%)	59%	59%	58%
i = Q * h	working age population (millions)	188	190	189
j (Telework Trendlines, 2009)	have tasks that could be perfomed at home (%)	38%	39%	40%
k (Telework Trendlines, 2009)	very interested in performing tasks at home (%)	34%	35%	36%
l (Telework Trendlines, 2009)	employer is willing to support telecommuting (%)	54%	55%	56%
m = i*j*k*l	additional potential telecommuters (millions)	13.14	14.28	15.23
n = g * m	candidate telecommuters served by additional NGN broadband (millions)	0.000	0.349	0.661
$o = n*Enabled_{NGN}$	employees who will telecommute if NGN broadband is available (millions)	0.000	0.035	0.066
$p = o*days*50*benefit_{CO2}$	benefits due to reductions in CO2 emissions (millions of 2010 dollars)	$0	$1	$1
$q = o*days*50*benefit_{FUEL}$	saved fuel costs (millions of 2010 dollars)	$0	$16	$30
$r = o*days*50*benefit_{ROADS}$	benefits due to reductions in roadway costs (millions of 2010 dollars)	$0	$9	$18

5.6 Benefit-Cost Analysis

To conduct the benefit-cost analysis, I first tally the annual costs and benefits in 2010 undiscounted dollars. For costs, the previously discussed costs for unbundling and industrial policy are added as appropriate. For benefits, the previously discussed private social surplus, public network effect, Medicare and Medicaid savings, and telecommuting benefits are added as appropriate.

Next, costs and benefits have to be discounted. I use both a social rate of time preference at 3%, and an opportunity cost of capital at 7%. A base year of 2010 is used. A spreadsheet inspired by Armitage Consulting calculates the net present value, the internal rate of return, and the benefit cost ratio (Armitage Consulting, 2009). Figures 5.9 and 5.10 show plots of the discounted payback schedule and cash flows. The case shown in these figures is the first case shown in Table 5.9 below, when using the optimistic model for the NGN deployment rate.

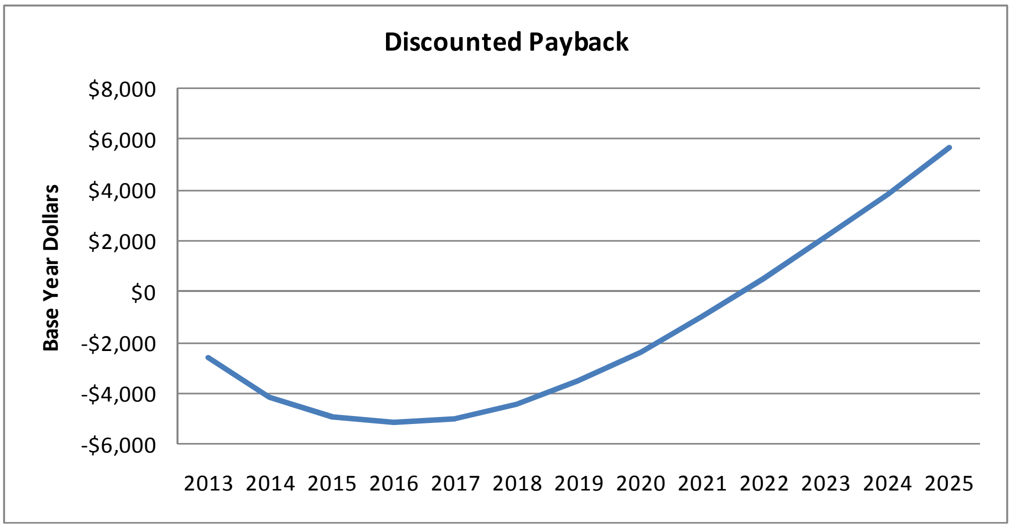

Figure 5.9 - Example Discounted Payback Schedule

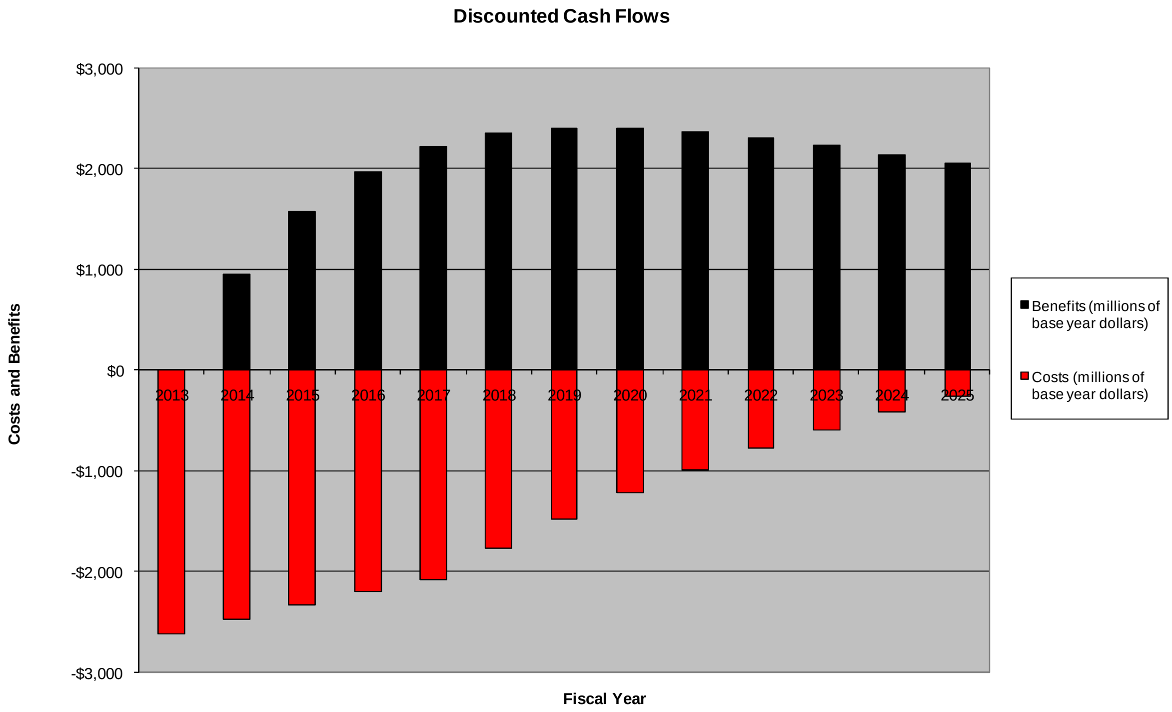

Figure 5.10 - Example Discounted Cash Flows by Year

I present a number of scenarios for the case of industrial policy, as shown below in Table 5.9. For the optimistic NGN rollout scenario, the baseline case uses an opportunity cost of capital for the discount rate, assumes a $10 per capita investment level in broadband infrastructure, uses a conservative estimate for private consumer surplus invoking the new goods effect, uses the adjusted Koutroumpis GDP increase to estimate the network effect, and does not consider other positive externalities. This baseline case has a benefit cost ratio of 1.29. If telecommuting benefits are added, the benefit cost ratio increases to 1.33. I assume two days of telecommuting a week and the more conservative estimate for the percentage of potential telecommuters enabled by NGN broadband. Alternatively, if home care monitoring benefits are added to the baseline scenario the benefit cost ratio increases to 1.60. If chronic care benefits are added to the baseline scenario the benefit cost ratio grows to 5.9.

Table 5.9 - Industrial Policy Benefit-Cost Analysis Scenarios

Discount Rate	Cost Factors	Private Benefit Factors	Network Effect	Externality Factors	NPV (billions of dollars)	IRR	Benefit Cost Ratio (optimistic/ pessimistic rollout)
7%	$10 per capita investment level	calibrate to Greenstein;T 1 MRC of $75, new goods effect	Koutroumpis GDP assumption; annual GDP growth 1%	none	$6.9 ($1.1)	17% 5%	1.29 0.95
"	"	"	"	telecommute two days a week; 10% enabled by NGN; $12 per ton CO_2	$7.8 ($0.2)	18% 7%	1.33 0.99
"	"	"	"	home care monitoring	$14.1 $6.1	26% 17%	1.60 1.26
"	"	"	"	chronic care	$115 $107	112% 108%	5.86 5.52
"	$50 per capita investment level	"	"	none	($87.6) ($95.6)	- -	0.26 0.19
"	"	"	"	telecommute two days a week; 10% enabled by NGN; $12 per ton CO_2; home care monitoring; chronic care	$28.6 $20.5	14% 12%	1.24 1.17

The $10 per capital investment level is equivalent to about $3B per year in NGN broadband investment. A larger level of infrastructure investment of $50 per capita, or about $16B per year, drives the baseline benefit cost ratios to below unity. Upon addition of both health and telecommuting externalities, the benefit cost ratio is brought back above unity.

Lowering the expectations for the rollout of NGN broadband, by moving from the optimistic scenario to a more pessimistic scenario, lowers all of the benefit cost ratios, and the benefit cost ratio for the baseline case now dips below unity.

I also run a number of scenarios for the case of unbundling policy, as shown in Table 5.10. For the optimistic unbundling scenario, the baseline case again uses an opportunity cost of capital for the discount rate, assumes the highest overhead upon incumbents to implement the requirements of unbundling, uses a conservative estimate for private consumer surplus invoking the new goods effect, uses the adjusted Koutroumpis GDP increase to estimate the network effect, and does not consider other positive externalities. This baseline case has a benefit cost ratio of 2.06.

If telecommuting benefits are added, the benefit cost ratio increases to 2.14. Two days of telecommuting a week are assumed and the more conservative estimate for the percentage of potential telecommuters enabled by NGN broadband is used. Alternatively, if home care monitoring benefits are added to the baseline scenario the benefit cost ratio increases to 2.68. Alternatively, if chronic care benefits are added to the baseline scenario the benefit cost ratio grows to over 11.

Returning to the baseline case, lowering the overhead incurred by incumbents to meet unbundling requirements to 3% increases the benefit cost ratio, up to 3.4. This shows the importance of better understanding the costs associated with an unbundling policy.

Lowering the expectations for the effectiveness of unbundling, by moving from the optimistic scenario to a more pessimistic scenario, lowers all of the benefit cost ratios. However they are all still greater than unity, including the baseline case.

Table 5.10 - Unbundling Benefit-Cost Analysis Scenarios

Discount Rate	Cost Factors	Private Benefit Factors	Network Effect	Externality Factors	NPV (billions of dollars)	IRR	Benefit Cost Ratio (optimistic/ pessimistic unbundling)
7%	5% unbundling overhead	calibrate to Greenstein; T1 MRC of $75, new goods effect	Koutroumpis GDP assumption; annual GDP growth 1%	none	$12.5 $1.8	136% 31%	2.06 1.18
"	"	"	"	telecommute two days a week; 10% enabled by NGN; $12 per ton CO_2	$13.4 $2.8	143% 40%	2.14 1.27
"	"	"	"	home care monitoring	$19.7 $9.1	219% 105%	2.68 1.88
"	3% unbundling overhead	"	"	none	$17.1 $5.8	280% 106%	3.39 1.94
"	5% unbundling overhead	"	"	chronic care	$120 $110	1085% 976%	11.26 11.69

5.7 Benefit-Cost Analysis Results

Industrial policy directs public funds towards the broadband marketplace in order to increase quantity. This might be justified on the basis of positive externalities that are not accounted for by the private market, and thus the socially optimal quantity of broadband is not produced. It is well established in the literature that broadband provides spillovers into the general economy through the network effect. Additionally there may also be spillovers to education, healthcare and the environment. In this study, only spillovers that could be quantified are used. This included the network effect, savings to the Medicare and Medicaid programs, and benefits attributable to reductions in vehicle miles traveled (VMT) through telecommuting. Other externalities may exist, but await further research that quantifies their impacts sufficiently to be included in a benefit-cost analysis. Additionally, as Firth and Mellor note (see p. 70), negative externalities may also exist and should be included.

A baseline scenario for industrial policy assumes an investment level of $10 per capita, or a level of about $3B per year invested in NGN broadband infrastructure. This level is roughly equivalent to the funds released under the 2009 stimulus act (Act, 2009). Agency enforcement and implementation costs are also included. With a discount rate of 7%, private benefits and the network effect are sufficient to raise the benefit cost ratio above unity. As additional positive externalities are added, the benefit cost ratio increases further.

Under a more pessimistic scenario the predicted deployment rate for NGN broadband is lowered to account for the possibility that the need for massive investment in fiber facilities and tempered demand for higher speeds will lead to a slower rollout. Under this more cautious scenario, benefit cost ratios go down with the baseline case dipping below unity.

Increasing the assumed investment level to $50 per capita drives many of the benefit cost ratios below unity, although the addition of multiple externalities will still bring the ratio back above unity. This highlights the need to better calibrate the magnitude of industrial policy investments needed to produce a given increase in broadband quantity in future research.

The opportunity cost of spending government resources to increase broadband availability should be compared to other possible uses, such as national defense, national parks or tax reductions. One way to make such evaluations is by comparing benefit cost ratios of each option. Although the social value of other opportunities is beyond the scope of this dissertation, clearly higher benefit cost ratios for broadband industrial policy will make its use more attractive.

Litan's estimates of chronic care savings push many of the benefit cost ratios well above unity. The savings in home care monitoring are recommended for use, because they are more conservative and directly dependent on network connectivity.

Unbundling is a policy that attempts to lower barriers to entry for new entrants by forcing the incumbent to lease bottleneck access facilities at a fair price. The empirical analysis in Chapter 3 shows that over time, this policy is effective in expanding broadband availability. There are two main costs associated with unbundling. In the U.S. the FCC would have to dedicate staff to oversee compliance, and there would be an associated enforcement cost. And the mechanics of unbundling and co-locating equipment from several competitors in central offices would create overhead costs for the incumbent operator.

A baseline scenario for unbundling policy assumes an FCC enforcement staff of 100 employees and an incumbent overhead cost of 5%. With a discount rate of 7%, private benefits and the network effect are sufficient to raise the benefit cost ratio above unity. As additional positive externalities are added, the benefit cost ratio increases further.

Under a more pessimistic scenario the predicted impact of unbundling is reduced. This accounts for the possibility that an unbundling policy applied to a yet-to-be built NGN fiber access network may not be as effective as was unbundling applied to the existing copper network. Under this more cautious scenario, benefit cost ratios go down but still remain above unity. If unbundling causes disinvestment or has no effect, then it would fail a benefit-cost test.

The scenarios examined for industrial policy and unbundling can be expanded. A spreadsheet used to calculate benefit cost ratios, net present value, and internal rate of return allows for “what if” experiments to be rapidly conducted. The results given herein indicate that both policies have the potential to be justified on the basis of a benefit-cost analysis. It is clear that the more positive externalities that can be quantitatively attributed to a modern, high speed broadband network, the more potential there is to justify policies which promote and invest in broadband. Relative to the wide range of positive externalities that are qualitatively discussed in the literature, I only used a small subset. This is due to the difficulty in obtaining empirical findings of broadband spillovers. For example, educational benefits are often cited, but meaningful quantitative data are yet to emerge.

6 Discussion and Recommendations

The regulatory environment for telecommunications in the U.S. has evolved from one of a government monitored monopoly to that of a competitive free market. Policy for bringing about widely available broadband in the U.S. must confront the question of whether the telephone network is best modeled as a natural monopoly or a free market commodity. Unlike other public goods such as national defense, interstate highways, and perhaps other utilities such as water and sewer systems, the question as to whether telecommunications is a natural monopoly or a private good is not straightforward. Telecommunications in fact exhibits aspects of both models. And the question depends in part on which portion of the network is being discussed. In the case of wired broadband access, the capital-intensive cable facilities running to homes and offices are one of the most difficult network elements to move toward competition.

This leads to policy arguments supporting both sides of the debate. Crandall points out that improperly matched policy could discourage broadband investment with a resultant significant loss in social surplus, and he advocates for a free market approach (Crandall, Lehr, Litan, 2007). But Nadir and Nandi point out that private markets may under-produce broadband because of insufficient consideration of positive externalities, including network effects and other spillovers (Nadiri and Nandi, 2001).

It appears that after decades of a strong free market philosophy, U.S. telecommunications policy may be shifting back toward more government intervention; not a returning to a regulated monopoly, nor a total reliance on the free market, but rather policy that provides loans and grants to increase broadband availability, particularly to the unserved and underserved citizens on the wrong side of the so called "digital divide." This recent trend in policy direction is articulated by Firth and Mellor:

> "The mantra of the preceding two decades has been that free markets will deliver the desired outcomes in terms of private investment and consumer welfare, without direct government participation. Broadband has brought about a change in direction, if not a turn around in policy. Governments around the world that had given up a direct stake in the telecommunications industry by privatizing their incumbent operators … have also been active in creating and implementing policies aimed at realizing the benefits of the information economy." (Firth and Mellor, 2005)

The broadband stimulus program, included in the stimulus act of 2009 (Act, 2009) with funding of over $7B, is an example of this trend.

This may be an opportune time to reexamine U.S. broadband policy and to look for the most effective balance of free market forces and selective government intervention. In a recent report to Congress, Kruger and Gilroy frame a range of possibilities:

> "If one assumes that governmental action is appropriate to spur broadband deployment in underserved areas, which specific approaches, either separately or in combination, would likely be most effective? Targeted grants and loans from several existing federal programs have been proposed, as well as tax credits for companies deploying broadband systems in rural and low-income areas. … How might the impact of federal assistance compare with the effects of regulatory or deregulatory actions? And finally, how might any federal assistance programs best complement existing 'digital divide' initiatives by the states, localities, and private sector?" (Kruger and Gilroy, 2008)

Chapter 2 describes how the history of telecommunications regulation in the U.S. evolved from a regulated monopoly to a free market. Broadband reaches more Americans every year under this contemporary market-driven approach. But there are acknowledged problems with stimulating sufficient competition to lower prices and encourage widespread availability, particularly in poor and rural communities.

Chapter 2 also reviews industrial policy as applied to broadband networks and empirical studies that measured the effectiveness of unbundling policy. In Chapter 3 a dataset covering the years 2003 through 2008 is assembled and analyzed. Results of a regression analysis show that the application of industrial policy and unbundling increase broadband availability.

The rollout of first generation broadband in the U.S. is about two-thirds complete, if we assume that it will ultimately reach the same high level of penetration (approximately 98%) as did ordinary telephone service. Contemporary broadband policy has been focused on accelerating this deployment, which in turn accelerates associated economic and social benefits. A common metric is to calculate the net present value of such acceleration.

Eventually broadband will be widely deployed, and such discussion will appear to be less relevant. However, "broadband" is not a static technology, and in particular the speed of broadband is important. Already new video applications are stressing the bandwidths of currently available broadband offerings. Commercial broadband services in the U.S. currently provide throughputs of single-digit Megabits per second, while Korea and Japan now offer speeds of 100 Megabits per second (Reynolds, 2009). Thus, even after most Americans have access to some form of broadband, there will likely be a need to upgrade the speed as time goes on, and this will require additional investments in the network. Thus better methodology to inform debate about broadband policy will be needed for many years to come.

Chapter 4 reviews literature which quantifies the value of broadband, including private and public benefits. Chapter 5 conducts a benefit-cost analysis that predicts the utility of applying industrial policy and unbundling during the rollout of fiber-based broadband access this decade. Although results are sensitive to a number of underlying assumptions, I find that both policies have the potential for benefit cost ratios greater than unity, particularly when broadband positive externalities are included.

This work identifies the need for several areas of ongoing research. First, a limitation of the analysis herein is that only flags were used to reflect countries employing industrial policy. The use of actual annual investment levels, if such data could be obtained, would enhance the accuracy of subsequent benefit-cost analysis. Rather than bounding investment levels assumed to yield an increase in broadband quantity, for example the $10 and $50 per capita levels used herein, a regression analysis based on an independent variable that was continuous would tie a specific investment level to a specific predicted increase in broadband quantity.

Additionally, more consensus is needed on the magnitude of positive externalities produced by broadband. The research herein began that process, moving from largely qualitative statements found in both the research literature and government policy documents, toward quantitative assessment of individual benefits. As scholars and policymakers come to agreement on these levels, or at least bounds for these levels, they can be used with more confidence to inform policy. For example, I show that under a pessimistic next generation network (NGN) rollout scenario, industrial policy still has a benefit cost ratio above unity if spillovers to healthcare and the environment are included.

This work highlights one of the difficulties in trying to perform an analysis of broadband costs and benefits, namely the diverse nature of measures and metrics used in studies to date. This increases the difficulty of conducting a calibrated comparison of costs and benefits, and is an area worthy of future effort. If a consensus can be reached among researchers on methodology to calculate broadband costs and benefits, this will improve the accuracy of analyses and may lead to better agreement on the appropriate level of government intervention.

We are in the midst of a contemporary debate regarding the proper role for government, and this relates directly to the building and maintaining of infrastructure, including broadband. Clearly there is a wide range of theoretic opinion and policy practice. The recent U.S. stimulus investment in broadband may not be repeated anytime soon, and policy is still dominated by a dependence on market mechanisms, with little or no government partnership. Australia, on the other hand, is in the midst of a large government funded and managed national broadband rollout. Broadband benefit-cost analysis may not resolve this diversity of approaches, and may not settle a policy debate within a given country. But it can help inform the discussion and perhaps lead to more consensus on what role the U.S. government should play in building of this nation's broadband infrastructure.

Ironically, there may be more opportunity to reach policy consensus at the margins of society. In the U.S. there is already a rich history of telecommunications subsidies for rural communities. First generation broadband is now penetrating the last third of U.S. households, and Peha estimates the magnitude of the unserved rural population at around 10 million households (Peha, 2008). Policies directed at closing the digital divide are inherently understood to involve reallocation of resources in order to achieve a social goal, and the "bar" for policy effectiveness may not be set as high as that of a policy applied globally across all of society. Benefit-cost analysis is a particularly good tool to inform such discussion. For example, a benefit cost ratio of greater than unity when carefully quantifying and including broadband externalities could help lead to agreement for investments intended to close the digital divide.

Even if benefit cost ratios are less than unity, analysis can still be useful. Elected officials may choose to close the digital divide for reasons of equity and social justice, and quantification of the net costs can help inform that decision.

Perhaps the most surprising result of regression analysis conducted herein is that unbundling was found to have a positive impact on broadband deployment whereas the presence of cable competition did not. Earlier empirical research showed that the so called “facilities based” competition, wherein there are literally two separate physical networks in place and competing for broadband customers, increased broadband penetration. The same body of literature showed mixed outcomes for the application of unbundling policy, with the bulk of the findings showing neutral or negative results.

A possible explanation for both findings is that much of the literature examined the rather early days of broadband rollout. Broadband penetration accelerated until about 2006, after which strong growth continued but at a slower rate. This roughly conforms to the “S-curves” predicted by diffusion of innovation theory, and suggests that in order to make judgments about what impacts the rollout of a new technology, data should be studied over a substantial segment of the technology life cycle. The data set used herein covers years 2003 through 2008 and captures a critical portion of first generation broadband deployment. This could explain the different findings; facilities based competition may have less impact as deployment matures, and the impact of unbundling may not manifest itself until it is consistently applied over a number of years.

Although the unbundling results have been carefully vetted and are believed to be accurate, because they represent a relatively new finding yet to be confirmed by others, they are used with some caution. To this end, results using the estimated positive impact of unbundling on broadband availability are used in the benefit-cost analysis, as well as a more conservative estimate of unbundling impact.

Some may choose to discount unbundling altogether. With time, more data on first generation broadband rollout will become available and future empirical research may confirm or contradict my findings. If nothing else, the findings show that *if* unbundling is effective, then from a benefit-cost point of view it is highly effective due to its relatively low costs. Further research on the impact of unbundling is therefore warranted, to determine if it in fact has positive impacts on broadband availability when sustained over a substantial portion of a technology's life cycle.

A baseline scenario for unbundling policy assumes an FCC enforcement staff of 100 employees and an incumbent overhead cost of 5%. With a discount rate of 7%, private benefits and the network effect are sufficient to raise the benefit cost ratio above unity. As additional positive externalities are added, the benefit cost ratio increases further. Under the more pessimistic scenario the predicted impact of unbundling is reduced to account for the possibility that an unbundling policy applied to a yet-to-be built NGN fiber access network will not be as effective as unbundling applied to the existing copper network. Under this more cautious scenario, benefit cost ratios go down but still remain above unity. In general the benefit cost ratios of unbundling are higher than those of industrial policy. This is due to the lower costs of the unbundling policy.

A second critical assumption is that unbundling policy, when applied to fiber infrastructure, will have similar results as did unbundling applied to the in-place copper phone line network. Although this is not out of the question - Japan may be a good example - it is also not easily proven. It appears that in the U.S. the threat, real or imagined, of negative impacts of unbundling policy on fiber investment led to a pullback by the FCC and unbundling was abandoned. An interesting question is whether, in the face of a sustained regulatory application of unbundling such as that of The Commission of European Communities, operators will react to its inevitability by resuming investment. This would suggest the need for more qualitative research of the type conducted by Böllhoff on the dynamics of interactions between regulators and industry players (Böllhoff, 2002).

The U.S. is unique in that current broadband deployment is roughly split between the historically highly regulated telecommunications industry, and the less regulated cable television industry. These are physically and technically different infrastructures, and they have different regulatory legacies. Both industries will have an important role to play in NGN broadband. The impacts of policies on each might be different. For example, the impact of an unbundling policy applied to a cable network is relatively unstudied and unknown.

An inherent assumption in all of this work is that wired broadband will continue to provide higher speeds and capacities than wireless services. Although this is likely to be true, both wired and wireless access speeds will increase over time. As a result, some of the applications and services that previously could only be effectively supported over wired broadband will migrate to wireless networks and devices. Thus the benefits of wired broadband for some set of customers may instead be delivered over wireless broadband in the future, particularly in rural areas.

The impact of both industrial policy and unbundling on the rollout of NGN broadband was predicted on the basis of the final model from the empirical analysis, and assuming that if a policy is applied, it is applied over an extended period of time. This is a simplifying assumption that may not match the complexities of the real world. In the U.S. both loop unbundling and broadband stimulus investments were applied over shorter periods. Furthermore, both policies may suffer from declining returns over time.

The thread of this dissertation follows the growth of first generation broadband, using the metric of subscribers per 100 inhabitants, empirically determines policy impacts on the speed of this diffusion, uses these findings to predict similar policy impacts on NGN broadband, and conducts a benefit-cost analysis which determines whether the costs of policies that accelerate NGN broadband availability are outweighed by private benefits and positive externalities. Implicit in this thread is the assumption that the higher speeds supported by NGN broadband will be desired, demanded, and ultimately be a required attribute of the infrastructure. In this sense, broadband is a somewhat different infrastructure than, say, the electrical grid which has delivered 120 VAC in the U.S. since its inception, or the interstate highway network which has allowed 65 mph travel since its construction. Although these infrastructures do grow, they do not exhibit the dramatic technological change that broadband has seen and will continue to see. This suggests that use of a single metric like broadband density warrants reflection, and additional metrics, like speed of access, should be examined. Data on access speeds has been difficult to obtain for first generation broadband, but more comprehensive data collection is an important focus of the U.S. National Broadband Plan. As better data becomes available, it will be informative to conduct empirical analysis to test the impact of policies and other explanatory variables on broadband speeds available to citizens.

Broadband will take its place alongside road, air and rail networks and electric and water utilities as infrastructures that are necessary for a modern developed nation to prosper economically and socially. Not providing the socially optimal amount of broadband will come at an increasingly higher price - too little broadband will slow business development and blunt global competitiveness; too much broadband will strand resources that could be better used elsewhere. Some might argue that the U.S. is an example of a country in danger of making the former mistake, and Australia the latter. Determining the “right” quantity of broadband and the necessary levels of public investment and related policy to bring it about is not a trivial subject. This dissertation is a step in the direction of using empirical findings and benefit-cost analysis to develop a consensus position for broadband policy that will meet this goal.

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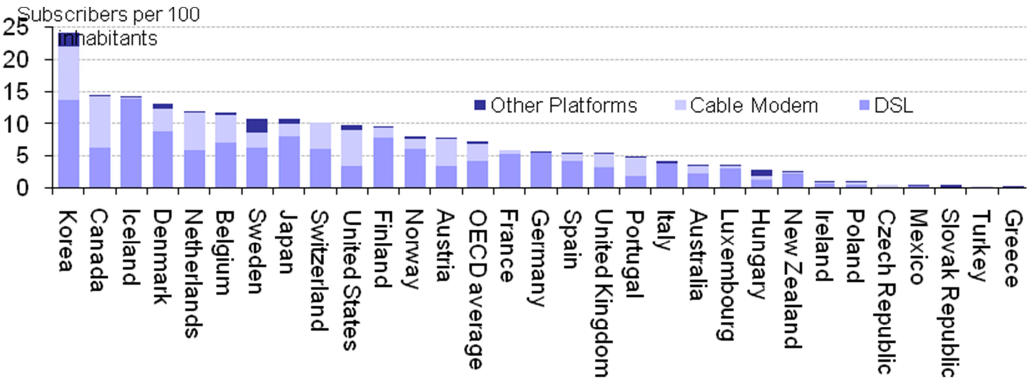
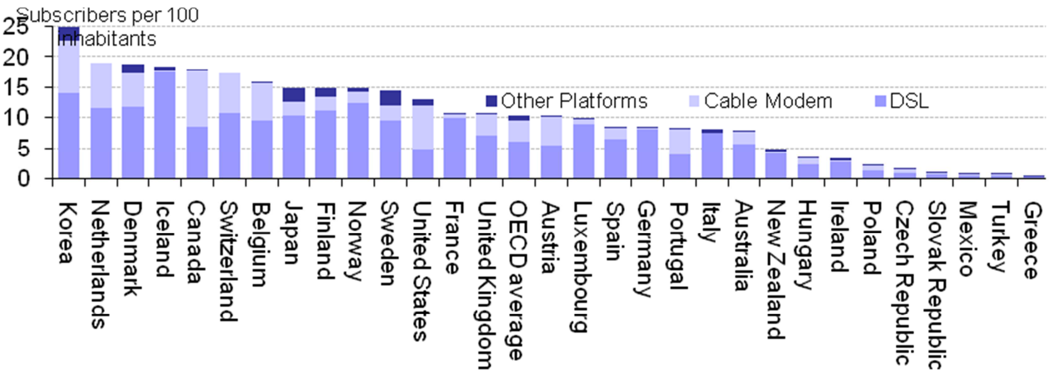
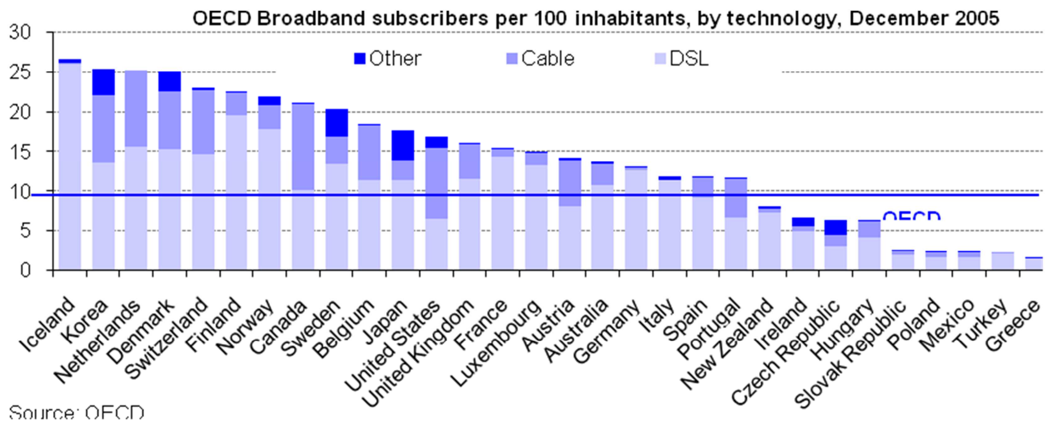
Appendix A - Annual OECD Broadband Rankings

Broadband subscribers per 100 inhabitants in OECD countries, December 2003

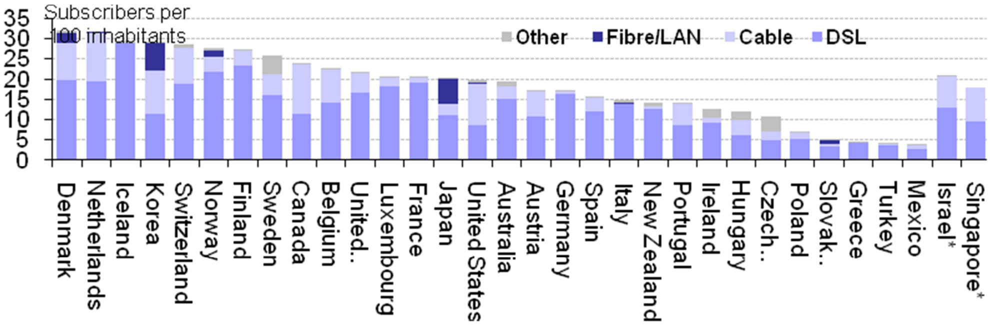


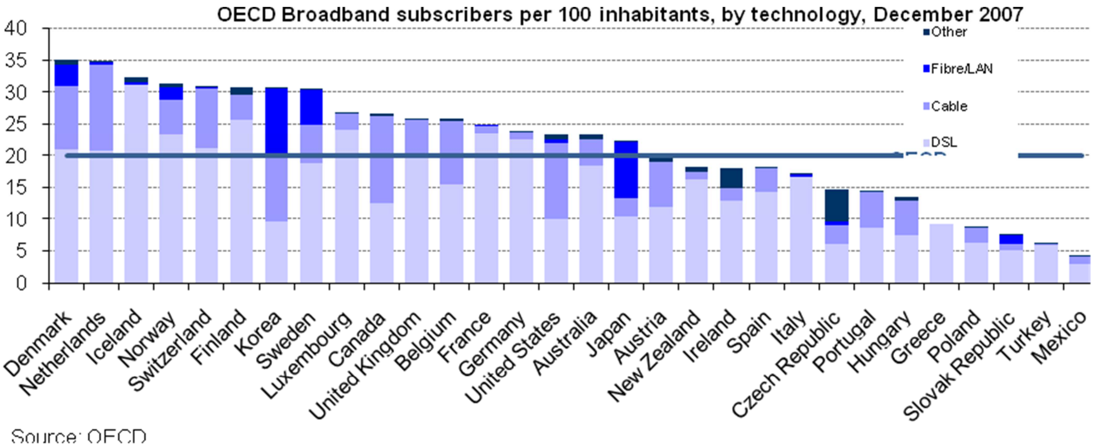
Broadband subscribers per 100 inhabitants in OECD countries, December 2004

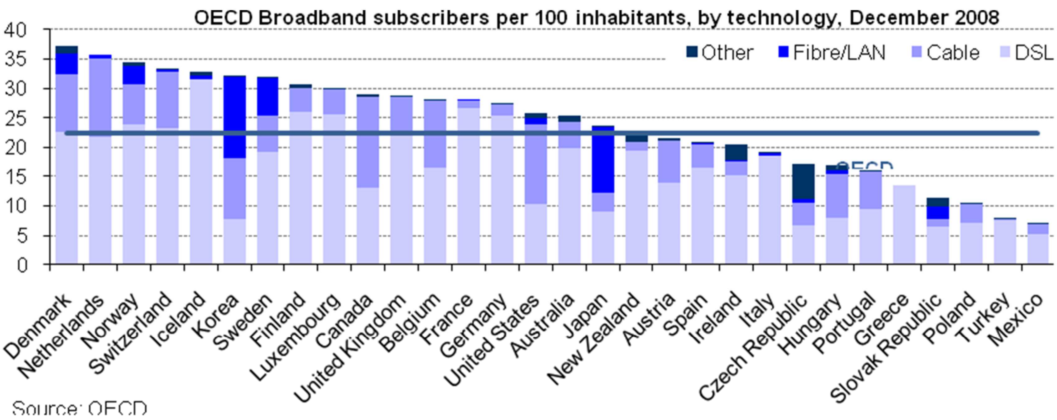




Broadband subscribers per 100 inhabitants in OECD countries and ICCP Committee observers countries, December 2006







Appendix B - Industrial Policy Flag Data

	2003	2004	2005	2006	2007	2008
Australia	0	0	0	0	0	0
Austria	0	0	0	0	0	0
Belgium	0	0	0	0	0	0
Canada	0	0	0	0	0	0
Czech Republic	0	0	0	1	1	1
Denmark	0	0	0	0	0	0
Finland	0	0	0	0	0	0
France	1	1	1	1	1	1
Germany	0	0	0	0	0	0
Greece	0	0	0	0	0	1
Hungary	0	0	0	0	0	0
Iceland	0	0	0	0	0	0
Ireland	0	0	0	0	0	0
Italy	0	0	0	0	0	0
Japan	0	0	0	0	0	0
Korea	1	1	1	1	1	1
Luxembourg	0	0	0	0	0	0
Mexico	0	0	0	0	0	0
Netherlands	0	0	0	0	0	0
New Zealand	0	0	0	0	0	0
Norway	0	0	0	0	0	0
Poland	0	0	0	0	0	0
Portugal	0	0	0	0	0	0
Slovak Republic	0	0	0	0	0	0
Spain	0	0	0	0	0	0
Sweden	0	0	0	0	0	0
Switzerland	0	0	0	0	0	0
Turkey	0	0	0	0	0	0
United Kingdom	0	0	0	0	0	0
United States	0	0	0	0	0	0

Appendix C - Unbundling Flag Data Lagged by 1 Year

	2003	2004	2005	2006	2007	2008
Australia	1	1	1	1	1	1
Austria	1	1	1	1	1	1
Belgium	1	1	1	1	1	1
Canada	1	1	1	1	1	1
Czech Republic	0	1	1	1	1	1
Denmark	1	1	1	1	1	1
Finland	1	1	1	1	1	1
France	1	1	1	1	1	1
Germany	1	1	1	1	1	1
Greece	1	1	1	1	1	1
Hungary	1	1	1	1	1	1
Iceland	1	1	1	1	1	1
Ireland	1	1	1	1	1	1
Italy	1	1	1	1	1	1
Japan	1	1	1	1	1	1
Korea	1	1	0.91	0.87	0.76	0.66
Luxembourg	1	1	1	1	1	1
Mexico						
Netherlands	1	1	1	1	1	1
New Zealand	0	0	0	0	0	1
Norway	1	1	1	1	1	1
Poland	0	0	0	1	1	1
Portugal	1	1	1	1	1	1
Slovak Republic	0	0	0	1	1	1
Spain	1	1	1	1	1	1
Sweden	1	1	1	1	1	1
Switzerland						
Turkey	0	0	1	1	1	1
United Kingdom	1	1	1	1	1	1
United States	1	1	1	0	0	0