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Factors Affecting the Availability of Broadband Access to the Internet: Costs, Demographics, Infrastructure, Wire Center Type, and Regulatory Issues

by

Ching-Cheung (Florence) Kwan

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9/19/00 — [signature]

Date — Chair of Examining Committee

9/19/00 — [signature]

Date — Executive Officer

David Gabel

Michael Grossman

Salih Neftci

Supervisory Committee

The City University of New York

Abstract

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Advisor: Professor David Gabel

The main purpose of this thesis is to investigate the factors affecting the availability of broadband access to the Internet in the context of economics and regulation. Based on simple economic theories of supply and demand, I estimate logistic regressions for the availability of Internet services via DSL (Digital Subscriber Line) and cable modem technologies. The explanatory variables include costs, demographics, existing infrastructure, and wire center type. The results have important implications for policy-making and provide interesting insights on the provider's decision to deploy advanced communications technologies.

Using data on availability collected in February of 2000, I find that the percent of population in urbanized area has a significant positive effect on the probability of a wire center area having DSL or cable modem services. I also find evidence suggesting that T1 charges for connecting to an Internet backbone could materially discourage the deployment of these technologies. RBOC ownership of a given wire center does not have any significant effect on the availability of DSL and cable modem services. This indicates that customers served by Regional Bell Operating Companies (RBOCs), all else being equal, have the same opportunity to subscribe to high-speed Internet service as customers served by non-RBOCs. Median household income, which measures the

ability to pay of the market area covered by a wire center, is found to have a significant positive impact on broadband deployment. As for the other demographic factors, such as age, race, and education, I could not obtain any significant result in the different specifications.

Having identified some key factors that determine the deployment of broadband Internet technology, I conclude that although cable modem and DSL services are becoming available faster in some areas than in others, the deployment process is still at its nascent stage, and market forces may soon spread these new services to other areas. I recommend that the FCC continues its data-gathering efforts to track the speed and the extent of broadband deployment, but to hold off on any plans to intervene in the market.

Acknowledgments

I would like to acknowledge the contributions of those without whom this dissertation could not possibly have been completed.

First and foremost, I wish to give thanks to my dissertation advisor, Professor David Gabel, for stimulating my interest in broadband Internet access, for providing valuable direction, for sharing generously his knowledge of economics and telecommunications, and for giving me the confidence to complete this work. My thanks also go to my dissertation supervisors, Professor Michael Grossman and Professor Salih Neftci, for providing valuable econometric and theoretical comments. Professor Grossman and Mrs. Grossman have both been my mentors professionally, academically, and in life. Through my years in New York as a graduate student, they have been supportive and caring. Apart from being my dissertation supervisor, Professor Neftci has also become a friend, making my life as a graduate student more exciting, hence more bearable.

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Having good colleagues and friends is more than one should expect and in that regard, I think myself quite fortunate. I would particularly like to thank Dr. Recai Gunesdogdu. Dr. Gunesdogdu has been my dearest friend, who understands me and loves me for who I am. My sister Helen also deserves special thanks for getting me settled down in Manhattan, putting up with my crankiness as my roommate, and supporting me through my ups and downs. My dear sister Michelle has always been my role model, and I still strive to be more like her.

Above all, my parents deserve a lot of credit for putting up with my self-indulgence for the past 28 years. They have never been quite certain what I was doing with my life, but encouraged and trusted me enough to find my own way. They have also instilled in me strong values which kept me sane. Last but not least, I would like to thank my husband, Paulus, for believing in me and loving me unconditionally. He showed me what living is all about, and gave me the courage to take part in it. To my parents, Grandpa, my sisters, and Paulus, this dissertation is respectfully dedicated.

September 17, 2000
Ching-Cheung Kwan

Table of Contents

List of Tables and Figures

List of tables

Chapter 1

Chapter 2

Chapter 3

List of figures

INTRODUCTION[1]

The latest figures published by Department of Commerce show that at the end of 1998, over 40 percent of American households owned computers, and only one-quarter of all households subscribed to an Internet provider[2]. However, as any casual reader of the daily news knows, more and more information is being digitalized and made available via "packet-switched" networks such as the Internet. The vast increase in the amount of digital information available, the growing numbers of telecommuting employees in the economy, and the increasing dependence of businesses on "packet-switched" networks for communication among employees, customers, service providers, and business units, have made high-speed, advanced access[3] to these networks an important ingredient for economic advancement.[4]

As companies race to roll out technology solutions such as cable modem or xDSL hookups to satisfy the burgeoning demand for high-speed, high-capacity access to advanced data networks[5], there is a growing national concern about the ability of all

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1 I would like to thank StratSoft Inc for providing in-kind research support for this research project. I also would like to thank Steven Burns and Zeng Yu Chen for their able research assistance.
2 National Telecommunications and Information Administration. Falling through the net: - defining the digital divide. Washington, DC: US Department of Commerce, July 1999, p. 5-9 <http://www.ntia.doc.gov/ntiahome/fttn99/FTTN.pdf>.
3 In my study, high-speed, advanced services are available where a customer can obtain either xDSL or cable modem services.
4 For example the FCC has stated that "[t]he ability of all Americans to access these high-speed, packet-switched networks will likely spur our growth and development as a nation." Source: Federal Communications Commission. "First Report and Order and Further Notice of Proposed Rulemaking; In the Matters of Deployment of Wireline Services Offering Advanced Telecommunications Capability." *FCC 99-48* Washington, DC: Federal Communications Commission, Adopted 18 Mar. 1999, Released 31 Mar. 1999, p.5.
5 For example, SBC Communications has announced a $6 billion overhaul of its network, called "Project Pronto," that will allow SBC to provide 80% of its customers broadband access via xDSL technology. Source: Greene, Tim, and Denise Pappalardo. "SBC Pushes Toward Converged Net." *Network World* 25 October 1999 <http://www.nwfusion.com/archive/1999/78877_10-25-

segments of American society to have access to, and benefit from, these solutions. According to the Chairman of the Federal Communication Commission,

> The most important issue on our agenda today is broadband. This debate that we are having in our country about broadband -- that we must have about broadband -- is an important debate. Broadband is going to change America in wonderful ways that no one in this room can predict, certainly not myself.... Fundamentally, we want four things for consumers in the broadband world. We want fast deployment. We want ubiquitous deployment. We want competitive deployment. And we want open deployment.[6]

Just prior to the speech, the FCC adopted rules requiring the further unbundling of network elements by the nation's incumbent local telephone companies.[7] These rules essentially rely upon marketplace forces to create an environment in which new broadband service providers will be encouraged to enter the local exchange market. In a related proceeding,[8] the Commission stated that its market-based approach to stimulating new market entry promotes the goal of Section 706 of the Telecommunications Act of 1996[9] (i.e. the deployment of advanced services to all Americans on a reasonable and timely basis). The FCC has reconfirmed its commitment to a market-based approach in

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1999.html>. While AT&T, through its MediaOne acquisition, is busy rolling out cable modem hookup options to consumers throughout the country.

[6] Kennard, William E. "Consumer Choice Through Competition." *Remarks Before the National Association of Telecommunications Officers and Advisors 19th Annual Conference* 17 Sept. 1999, p.1. It should be noted that the Federal Communications Commission (FCC) defines broadband as the ability to support a data rate of at least 200K bit/sec, both upstream and downstream. Source: Johnston, Margret. "11 Billion needed for rural broadband upgrade." *IDG News Service* 21 June 2000 <http://www.nwfusion.com/news/2000/0621eleven.html.>.

[7] Federal Communications Commission. "Third Report and Order and Fourth Further Notice of Proposed Rulemaking in CC Docket No. 96-98." *FCC 99-238* Washington, DC: Federal Communications Commission, Released 15 Sept. 1999, p.1.

[8] Federal Communications Commission. "Notice of Proposed Rulemaking and Notice of Inquiry in WT Docket No. 99-217 and Third Further Notice of Proposed Rulemaking in CC Docket No. 96-98." *FCC 99-141* Washington, DC: Federal Communications Commission, Released 7 Jul. 1999, p.1.

its recent *First Report and Order and Further Notice of Proposed Rulemaking; In the Matters of Deployment of Wireline Services Offering Advanced Telecommunications Capability*, where it has adopted "...measures that we consider critical steps in encouraging the competitive provision of advanced services."[10]

Congress and the FCC have placed great reliance upon marketplace forces to achieve the dual goals of advanced service competition and universal access. FCC staff, however, have acknowledged the "virtual consensus" that local telephone competition mostly takes place in urban business districts and that "competitors are more likely to enter highly populated urban areas."[11] Given this inconsistency in current policies regarding broadband services, research is warranted to provide a better understanding of the factors that influence providers' decisions to offer advanced services. My dissertation is offered as a step in the development of that understanding.

This study is designed to examine where advanced service is and is not available. In addressing this matter, I recognized that I needed to look at what is happening in different markets. I also recognized that, to be done properly, the analysis should be careful in defining what constitutes access. Some published data reports access at a high level of aggregation, such as the State or city level of observation.[12] A finer level of granularity than the city is used in this study. This is necessary because, as the map from

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[9] Telecommunications Act of 1996 § 706(a), 47 U.S.C. 706 (a) (1996); *see also* S. Conf. Rep. No. 104-230, 104th Cong., 2d Sess. at 1 (1996)..
[10] Federal Communications Commission. "First Report and Order and Further Notice of Proposed Rulemaking; In the Matters of Deployment of Wireline Services Offering Advanced Telecommunications Capability." *FCC 99-48* Washington, DC: Federal Communications Commission, Adopted 18 Mar. 1999, Released 31 Mar. 1999, p.21..
[11] *Id.*, p.17.
[12] See, for example Olbeter, Eric R., and Matt Robison. "Breaking the Backbone: The Impact of Regulation on Internet Infrastructure Deployment." *Iadvance Internet Facts* 27 Jul. 1999 , Appendix A and B <http://www.iadvance.org/background/index.html>.

Time-Warner's web site illustrates, there can be a lot of variation within city (see Figure 1-1).[13]

One could say that Manhattan has cable modems, but this misses the distinctions that are reflected in the map. Firms are making decisions about where to roll-out service first, and where subsequent investments will be made. I have undertaken this analysis to see what influence such factors as costs, income, race, and regulation may have on the availability of high-speed access to the Internet for residential customers.

In order to understand the outcome which is availability, I need to look at firms' private investment decision. I model this decision using factors that a firm considers in deciding whether to and then where to deploy these technologies. Given the current state of things affecting investment decisions, the outcome of availability may not be as efficient and equitable as what our policy-makers consider acceptable. When the outcome does not meet the standards set by the policy-makers, it represents a market failure, and it may be time for the government to take action and intervene in the market.

In this dissertation I analyze the outcome of broadband availability by looking into firms' private investment decision. The analysis provides insights into the factors that affect the availability of broadband Internet services, and provides preliminary recommendation for policies aimed to encourage deployment.

In Chapter One, I provide some background on the development of Internet technology, the current level of Internet usage in the United States, and the regulatory environment in which these markets operate. Also, a review of the literature directly

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[13] Map is from the Time-Warner Website. Source: Time-Warner Cable. "In your Neighborhood." Time-Warner Cable Website accessed on 15 Sept. 2000

related to this study is presented in Section three, laying out what has been done in this area. The objective of this study is restated, and it was linked to the way in which this research intends to fill the gaps in current research in the area.

In Chapter Two, the supply and demand considerations are discussed, and a summary of the testable hypothesis are provided. Then the econometric model is specified, and a description of the data and a discussion of the descriptive statistics are provided.

In Chapter Three, I present the regression results and give my interpretation of them. The results from different model specifications are summarized, and are discussed as they relate to policy-making.

This study aims to provide a better understanding of the investment decisions involving the provision of broadband Internet services and their effect on the availability of these services. In relating the analysis to the government's concern for the widening "digital divide", this study provides some interesting insights into what the regulators may do to encourage the deployment of these technologies when and if market failure is observed.

<Http://www.twcnyc.com/rr/maps/man_base.html>.

CHAPTER 1 OVERVIEW

Section 1 Introduction

In this section, I provide an overview of the current usage trends of the Internet, separating between general narrowband usage and broadband usage. I also discuss the FCC's concern for the widening "digital divide", and provide justifications for this concern.

1-1.1 Computer Ownership and Internet Usage Trends in the United States

The latest report published by the NTIA "Falling Through the Net: Defining the Digital Divide" shows that at the end of 1998, 42.1 percent of American households owned computers, and 26.2 percent of all households had Internet access. ZD Infobeads's study on PC penetration forecasts that from the end of 1998 to the end of 2000, the percentage of homes with at least one PC will grow around 10 percent[14]. Using the NTIA's 42.1 percent PC penetration as a baseline for the end of 1998, we can expect that by the end of 2000, PC penetration would be at least 52 percent and could possibly

[14] Bowman, Lisa. "More households than not have PCs: But corporate computer buying is slowing - blame the Y2K bug." *ZDNet News* 18 March 1999 <http://www.zdnet.com/zdnn/stories/news/0,4586,2228620,00.html>.

reach 60 percent.[15] In fact, a recent poll conducted by Harris Interactive indicates that more than half of U.S. households own a computer by the first quarter of 2000.[16]

The same report states that of those U.S. households with a PC, 90 percent are online. Given the projected household counts for the year 2000 published by the Census Bureau[17], we can estimate that online penetration among U.S. households for the first quarter of 2000 to be about 45 percent.[18] Estimates from Nielsen/NetRatings show that by July 2000, 52 percent of all US *population* use the Internet at home, which is a higher percentage than our first quarter estimate for *household* online penetration of 45 percent. If population penetration rate can be used as a proxy for household penetration rate, we can estimate a 7 percentage point increase in household online penetration from first quarter to second quarter of 2000, which would imply a 15 percent quarter-over-quarter growth rate for household online penetration.[19] E-mail use also gives an indication of how widespread Internet-related technology is. By the end of 1999, there are about 333 million electronic mailboxes in the US. About two-thirds of the US workforce and about

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[15] PC penetration estimates for 1998 reported on several websites are higher than the 42.1percent reported by the NTIA. ZD Infobeads reports 50.3 percent PC penetration for the end of 1998.
[16] Nua Internet Survey. "Harris Interactive: PC Penetration Increases in US." *Nua Internet Survey* 29 Feb 2000 <http://www.nua.ie/surveys/index.cgi?f=VS&art_id=905355625&rel=true>.
[17] U.S. Bureau of the Census. "TABLE 1. Projections of Households by Type: 1995 to 2010, Series 1, 2, and 3." *Census Bureau Website* May 1996 <http://www.census.gov/population/projections/nation/hh-fam/table1n.txt>.
[18] An estimate of US household counts for 2000 reported by the Census Bureau is about 103 million. According to Harris Interactive, PC penetration for 2000 is at least 50%, which means that 52 million U.S. households own a PC. Harris Interactive's estimate for online penetration is about 90% of all households with a computer, making the number of households online 46 million, which is about 45% of all US households. However, on
[19] Percentages based on population and households are not synonymous. For example, elderly households are small in size relative to families with school-age children. These differences make both the denominator and the numerator of the percentages incomparable, but the percentages should not be very different. Hence, using the growth rate of population penetration as a proxy for household penetration should be acceptable.

half of US households now use email. Accounting for the overlap, at least 40 percent of those living in the US are email users.[20]

As these numbers suggest, the computer and the Internet are becoming widespread and penetration is growing fast in the United States. I estimate that household online penetration in the U.S., which was estimated to be 26 percent in the end of 1998, would have grown to about 52 percent in July of 2000.

1-1.2 The digital economy and the "digital divide"

Robert J. Shapiro, Under Secretary for Economic Affairs of the Department of Commerce, wrote,

> "Americans have definitively crossed into a new era of economic and social experience bound up in digitally-based technological changes that are producing new ways of working, new means and manners of communicating, new goods and services, and new forms of community,"[21]

Compared to innovations from the past, Internet technology has a special quality in that it provides new ways of managing and using information. It makes the dissemination of information cheaper, and the updating of information faster. Because of this quality, every sector and aspect of economic life can make use and benefit from it. It has been

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[20] Nua Internet Survey. " Messaging Online: One Billion Email Accounts by 2002. " *Nua Internet Survey* 6 Apr 2000 <http://www.nua.ie/surveys/index.cgi?f=VS&art_id=905355701&rel=true >.Original report is from source: Messaging Online. "Messaging Online 1999 Year-end Mailbox Report - Part 5." *Messaging Online* 14 March 2000 <http://www.messagingonline.com/mt/html/feature031400.html>.

[21] Economics And Statistics Administration, Office of Policy Development. Digital Economy 2000. Washington, DC: U.S. Department of Commerce, June 2000, p.xiii <http://www.esa.doc.gov/de2000.pdf>.

asserted, "the digital economy can produce higher long-term productivity gains and national growth than we knew in the 1970s and 1980s". [22]

A recent study done by the Department of Commerce, *Digital Economy 2000* , presents supporting evidence suggesting that IT (Internet Technology) contributes significantly to the growth of the U.S. economy experienced in the second half of the 1990s. IT industries' share of the economy has climbed from an estimated 6.3 percent in 1994 to 8.3 percent in 2000.[23] More impressive is IT industries' contribution to economic growth. Since, 1995, IT industries accounted for an average 30 percent of total real U.S. economic growth. [24] The importance of IT to the economy is also reflected by the growth in the IT workforce to 7.4 percent of total American workers in 1998. From 1992 to 1998, employment in the IT job categories that require the most education and offer the highest compensation increased by almost 80 percent. [25]

Although the IT industry is growing at a fast pace, and it is benefiting the economy as a whole, the diffusion of it has been uneven. The number of homes with computers and Internet connections has been rising rapidly, but almost half of Americans (Nielsen/NetRatings have estimated about 48 percent of all U.S. households in July of 2000) do not have online connection at home. The "digital divide", the divide between those with access to new technologies and those without, is now one of America's leading economic and civil rights problems.[26] The U.S. Department of Commerce published a study *Falling Through the Net* in July of 1999 which looks at modem

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[22] *Id*, p.xiii
[23] *Id*. p. 24, Figure 3.2
[24] *Id*, p. 27
[25] *Id*, p. 27
[26] National Telecommunications and Information Administration. Falling through the net: -defining the digital divide. Washington, DC: US Department of Commerce, July 1999, p.vii.

ownership, e-mail use, and Internet use as measures of general Internet access among households.[27] It concludes that by the end of 1998, those segments of the society least likely to be connected to the Internet are "low-income, Black, Hispanic, or Native American, senior in age, not employed, single-parent (especially female-headed) households, those with little education, and those residing in central cities or especially rural areas."[28] According to a more recent report by Media Metrix, lower-income households that are online are growing rapidly in 2000, but they still represent only 9.7 percent of overall Internet users.[29] A press release by Jupiter Communications indicates that the wealthiest households (income over $75,000) will continue to represent the biggest single segment online, with 15 million such households expected to be online by the end of 2000. The poorest segment (incomes of under $15,000) will represent only three million online households. Apart from this "divide" associated with differences in income, there is also a pronounced gap in U.S. Internet usage among various ethnic groups. Jupiter reports that in 1999, 60 percent more white households are online than African-American households are. African-American and Hispanic-American segments have the lowest Internet penetration, at 30 percent and 33 percent in 1999, respectively. Significant differences also exist among various age groups, with kids (ages two to 12) and seniors (ages 65 and older) lagging behind the national average in online penetration.

<http://www.ntia.doc.gov/ntiahome/fttn99/FTTN.pdf>.

27 *Id*, p. 85. Internet use data is only available from 1997. Prior to 1997, modem ownership is used as a measured of Internet access. While modems provide a means to access the Internet, they do not necessarily mean that a household actually has Internet access. This measurement therefore does not provide an exact proxy for Internet access. The availability of modem ownership data discontinued in 1998 because nearly all computers contain modems today and because modems, n practice, are not always used to connect to the Internet.

28 *Id.*, p. 85.

29 Nua Internet Survey. "Media Metrix:Lower-income households online growing rapidly." *Nua Internet Survey* 24 Aug 2000 <http://www.nua.net/surveys/index.cgi?f=VS&art_id=905355996&rel=true>.

Kids' penetration is 32 percent in 2000 and senior penetration is 16 percent.[30] These segments of our society that are on the wrong side of the digital divide are missing out on increasingly valuable opportunities for education, job search, and communication with their families and communities.[31]

1-1.3 Telecommunications Act of 1996

In the U.S., the Telecommunications Act of 1996 (the Telecom Act for short) represents the first major revision and addition to domestic communications law since 1934. Recognizing the growing importance of Internet Technology to the U.S. economy, it made a policy of the U.S. to "to promote the continued development of the Internet and other interactive computer services and other interactive media".[32] Also, foreseeing the improvement in technology expanding the capabilities of IT, the Telecom Act contains a section obligating the FCC and each state commission to "encourage the deployment on a reasonable and timely basis of advanced telecommunications capability to all Americans".[33] This section is generally known as section 706 of the Telecom Act.

Advanced telecommunications capability is defined as "switched, broadband telecommunications capability that enables users to originate and receive high-quality

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[30] Press Release, Jupiter Communications, "Income and Age, Not Ethnicity, to remain largest gap for us digital divide, June 15, 2000. http://www.jup.com/company/pressrelease.jsp?doc=pr000615

[31] Telecomm Act of 1996, `SEC. 230.(a1) `(1) The rapidly developing array of Internet and other interactive computer services available to individual Americans represent an extraordinary advance in the availability of educational and informational resources to our citizens.

[32] Telecomm Act of 1996, `SEC. 230`(b1)

[33] Telecomm Act of 1996, `SEC. 706`(a)

voice, data, graphics, and video telecommunications using any technology".[34] To most people, broadband merely means transmission speeds higher than a traditional dial-up connection. However, broadband is strictly defined as a technology allowing for two-way data transmission at a high rate, generally greater than T1 speed (1.544Mbps).[35] In practice, service providers are taking liberties with that definition and ascribing broadband to any technology with higher than narrowband speed. For example, Verizon (formerly Bell Atlantic/GTE) offers "DSL Personal" service in New York City for $39.95 per month for downstream speed of 256kbps-640kpbs and upstream speed of 90kbps. These speeds are much lower than the 1.544Mbps cutoff that technically defines broadband, but many consultant reports and survey results published on broadband websites include these services as broadband. The FCC defines "full broadband" services as having information carrying capacity of over 200 kbps, both upstream and downstream.[36] The speed requirement set by this definition is slower than that for the strict definition of broadband (1.544Mbps), but faster than many DSL and cable modem offerings that could be included in the relaxed definition of broadband (faster than dial-up or above 128kbps[37]). DSL and cable modem services are currently considered the leading residential broadband technologies in the U.S.. They are both "always-on", higher speed, and higher capacity services.

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[34] Telecommunications Act of 1996 § 706(c1), 47 U.S.C. 706 (c1) (1996); *see also* S. Conf. Rep. No. 104-230, 104th Cong., 2d Sess. at 1 (1996)..

[35] ZDWepopedia, ZDNet. "Broadband Transmission." *ZDWebopedia* accessed on 15 Sept. 2000. <http://www.zdwebopedia.com/TERM/b/broadband_transmission.html>. Information Society. "broadband ." *Information Society Website Glossary* accessed on 18 Sept 2000 <http://www.ispo.cec.be/ephos/en/glossary/G883.htm>.

[36] Federal Communications Commission, "Broadband Deployment Hearing." *FCC00-114* Washington, DC: Federal Communications Commission. Released 25 May 2000, p.13.

[37] IDC defines broadband as 128kbps connection to the Internet.. Source: Doyle, Lee. "Broadband to the Home: A Revolution in Internet Access." IDC Opinion January 2000 <http://www.idc.com:8080/EI/content/040600.stm>.

The usage penetration rates for general Internet access reported in sections 1-1 and 1-2 reflect the problem of the digital divide. Section 706 of the Telecom Act focuses on *broadband* access rather than on general Internet access. This is not surprising because according to a study by Downes and Greenstein (1998), "over ninety-two percent of the U.S. population has easy access to a competitive Internet access market".[38] This finding suggests close to universal access for traditional narrowband Internet access, so the digital divide problem is less a results of limiting infrastructure but more a result of consumer preference and affordability. The same cannot be said for broadband access such as that via Digital Subscriber Line (DSL) and cable modem technology. Narrowband Internet access piggy-backs on top of traditional phone networks to connect households to the ISPs. Hence, the availability of ISP service can be translated into the availability of narrowband Internet service[39]. Unlike narrowband dial-up access, high-bandwidth technologies can require removing knots in the network for DSL and upgrading broadcast networks to bi-directional capabilities for cable modems. Because high-bandwidth infrastructure development is still in its nascent stage, the availability of Internet service via these technologies is growing but is far from universal[40]. Due to the fact that consumers are limited by inadequate infrastructure, the government included Section 706 in the Telecomm Act of 1996 to encourage the deployment of *broadband*

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[38] Downes, Thomas A. and Shane M. Greenstein. "Do Commercial ISPs Provide Universal Access?" *Working Paper for the Fall 1998 Telecommunications Policy and Research Conference,* 2 Dec. 1998, p.1. <http://skew2.kellogg.nwu.edu/~greenste/research/papers/tprcbook.pdf>.

[39] U.S. household telephone penetration rate as of December 1998 is estimated at 94.1%. Source: National Telecommunications and Information Administration. Falling through the net: - defining the digital divide. Washington, DC: US Department of Commerce, July 1999, p.2 <http://www.ntia.doc.gov/ntiahome/fttn99/FTTN.pdf>.

[40] Approximately one-third of U.S. homes currently have access to at least one high-speed Internet access service. Source: Doyle, Lee. "Broadband to the Home: A Revolution in Internet Access." IDC Opinion January 2000 <http://www.idc.com:8080/EI/content/040600.stm>.

technologies in a timely and affordable manner to all Americans. According to the Chairman of the Federal Communication Commission,

> The most important issue on our agenda today is broadband. This debate that we are having in our country about broadband -- that we must have about broadband -- is an important debate. Broadband is going to change America in wonderful ways that no one in this room can predict, certainly not myself.... Fundamentally, we want four things for consumers in the broadband world. We want fast deployment. We want ubiquitous deployment. We want competitive deployment. And we want open deployment.[41]

The Telecom Act is known for its pro-competitive and deregulatory strategy. It essentially relies upon marketplace forces to create an environment in which new broadband service providers will be encouraged to enter the local exchange market.[42] One evidence is the FCC's recent adoption of rules requiring further unbundling of network elements by the nation's incumbent local telephone companies.[43] Having placed great reliance upon marketplace forces to achieve the dual goals of advanced service competition and universal access, the FCC, however, have acknowledged the "virtual consensus" that local telephone competition mostly takes place in urban business districts and that "competitors are more likely to enter highly populated urban areas".[44] Given this inconsistency in current policies regarding broadband services, research is warranted to provide a better understanding of the factors that affect the availability of these

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[41] Willia m E. Kennard, *Consumer Choice Through Competition,* Remarks Before the National Association of Telecommunications Officers and Advisors 19th Annual Conference (September 17, 1999).

[42] Note 2, *supra,* at 5.

[43] *Third Report and Order and Fourth Further Notice of Proposed Rulemaking in CC Docket No. 96-98 (FCC 99-238).* Released September 15, 1999.

[44] Federal Communications Commission. "Deployment of Advanced Telecommunications Capability: Second Report," *CC Docket No. 98-146* Washington, DC: Federal Communications Commission, August 2000, p.17 <http://www.fcc.gov/Bureaus/Common_Carrier/News_Releases/2000/nrcc0040.html>.

services. In this dissertation I analyze the outcome of broadband availability by looking into firms' private investment decision. The analysis provides insights into the factors that affect the availability of broadband Internet services, and provides preliminary recommendation for policies aimed to encourage deployment.

1-1.4 Broadband usage and trends–number of subscribers

Broadband penetration is much lower than general online penetration. For year-end 1999, general online penetration is estimated to be 39 percent. Broadband penetration for the same time is between one and two percent, depending on how broadband is defined. By year-end 2000, Internet penetration should be at least 56 percent and broadband penetration is expected to be about 5 percent to 6 percent. [45]

According to a report released by the FCC recently, 1.8 million of residential subscribers of high-speed and advanced services as of December 31, 1999.[46] Again, advanced telecommunications capability is infrastructure capable of delivering a speed of 200 kilobits per second in each direction, while the commission denominates as "high-speed" those services with over 200 kbps capability in at least one direction. The data in

[45] Esimated: Broadband penetration is from IDC opinion,"Broadband to the Home:A Revoluation in Internet Access", http://www.idc.com:8080/EI/content/040600.stm. Online penetration for 2000 and the number of household online for 1999 is from "Home Internet Access Reaches critical Mass in the US, According to Nielsen/Netratings; 52 percent of US population", Business Wire via Dow Jones, August 21,2000 and "Broadband on the Run" by Steven Vonder Haar, Inter@tive Week, May 10,1999, ,http://www.zdnet.com/intweek/stories/news/0,4164,2255139,00.html. Population estimates from Census Bureau at http://www.census.gov/population/projections/nation/summary/np-t3-a.txt

[46] Federal Communications Commission. "FCC Issues Report on the Availability of High-Speed and Advanced Telecommunications Services." *CC Docket No. 98-146* Washington, DC: Federal Communications Commission, 3 August 2000, p.1

the report is based largely on the first systematic, nationwide "Broadband Survey" of subscription to high-speed and advanced services, begun by the FCC in 2000. This nationwide "Broadband Survey" required any facilities-based company that provided 250 or more broadband service lines (or wireless channels) in a given state to report basic information about their service offerings and customers. The survey suggests that there has been appreciable growth in the deployment of high-speed services to residential consumers. The data reveal that, although high-speed services are available in many parts of the country, rural and low-income areas are particularly vulnerable to not receiving timely access to such services.[47]

The penetration rate for advanced services more than tripled from 0.3 percent of households at the end of 1998 to 1.0 percent at the end of 1999.[48] The report also shows that in 1999, cable modem is by far the leading technology for residential broadband service. In 1999, 84 percent of the residential advanced services market was served by Cable MSOs, 11 percent was served by ADSL providers, and 5 percent was served by others including fixed wireless and satellite service providers.[49] Although cable modem was leading in 1999, there is evidence suggesting that DSL is quickly gaining grounds in the year of 2000. In fact, a report by Cahners In-Stat suggests that DSL modem sales have been continuing its 50 percent growth rate quarter-over-quarter into the first half of

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<http://www.fcc.gov/Bureaus/Common_Carrier/News_Releases/2000/nrcc0040.html>.

[47] *Id.*

[48] *Id.*

[49] *Id.*

2000, while the growth of cable modem sales is showing declines in the second quarter of 2000 to only 24 percent.[50]

DSL service is being rolled out in different areas across the country in 2000, but it still has a way to go until it catches up with cable modem service. For example, in Pleasanton, Calif., penetration of AT&T@HOME cable modem service is 22 percent; Fremont, Calif., has 19 percent penetration; and in the Chicago suburb of Winnetka, penetration is 13 percent.[51] Also, cable modem penetration rates have passed 10 percent in MediaOne Group's suburban Boston system and 22 percent in Time Warner, Inc's Portland Me., system.[52] According to Mr. Robert Sachs, National Cable Television Association (NCTA) President and Chief Executive Officer, by year-end, 75 percent of US cable TV systems will be upgraded to provide high-speed bi-directional Internet service.[53].

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[50] While DSL modem sales continued to grow at a 50 percent pace, quarter over quarter, cable modem growth actually slowed from 31 percent growth in Q1 2000 to 24 percent in Q2 2000. Source: Cahners In-stat Group. "DSL Positioned to Overtake Cable Modems; Efficient and Alcatel Set Pace in Market." *Cahners In-Stat Press Release* 29 August 2000 <http://www.instat.com/pr/2000/cq0003m7_pr.htm>.

[51] The penetration applies to all homes the company is marketing to in a given area. Source: AT&T Broadband. "AT&T@HOME now in 300,000 Homes." *AT&T Broadband News Release* 8 May 2000 <http://www.att.com/press/item/0,1354,2868,00.html>.

[52] Telecommunications Reports International, Inc. "Net Apps Seen As Driver For Broadband TV." *TR Daily* 8 May 2000 < http://www.tr.com/ >.

[53] 75% of cable systems will operate at 750 MegaHertz or higher and will be fully two-way. Source: Telecommunications Reports International, Inc. "Net Apps Seen As Driver For Broadband TV." *TR Daily* 8 May 2000 < http://www.tr.com/ >.

1-1.5 Conclusion

The computer and the Internet are becoming widespread and penetration of use in the United States is growing fast. To ensure that all segments of society benefit from this new digital economy, Congress included Section 706 in the Telecom Act of 1996, requiring the FCC to follow the development of broadband Internet technologies and to leave the market to itself except for areas where deployment is unacceptably slow or inexistent, in which case regulatory actions may be appropriate to encourage deployment. This section of the study shows that broadband penetration is still growing but the percentage of household on a broadband Internet connection is still low. Usage trends, which are indicative of the present state of the market, however, is not a direct measure of availability. According to what we know about broadband, availability is far from universal. This study aims to understand the factors affecting the availability of broadband services, and to provide insights into how the government might assist in narrowing the "digital divide".

Section 2 Background

In this section, I will provide some background on the development of the Internet, the technology that makes up the Internet, the difference between the two most popular broadband technologies, and the broadband markets and the major players involved. This section aims to provide answers to basic questions about the Internet and broadband. Knowing the history of the Internet and the way it operates helps to understand the challenges faced by policy-makers in encouraging the deployment of broadband technologies. The explanation on DSL v. cable modem technologies gives an overview of technical challenges faced by providers, which in term limits availability. The paragraphs on the broadband markets and the major players involved give some background on what the providers' strategies are in rolling out DSL or cable modem services, and also provide an idea of the current state of competition in these markets.

1-2.1 The Internet – How It All Started and How It Works

The Internet is a complex series of interconnected computer networks forming a worldwide information infrastructure, commonly described as a "network of networks". These computer networks are connected using a common communication language called TCP/IP. TCP/IP was developed to provide a common language for interoperation between networks that use a variety of local protocols.[54] Some of the computers and computer networks that make up the Internet are owned by governmental and public institutions; some are owned by non-profit organizations, and some are privately owned by corporations. The resulting whole is a decentralized, global medium of communications.[55]

The beginning of the Internet came about in the late 1960's with the creation of ARPANET by the Advanced Research Projects Administration, a division of the U.S. Defense Department. This network connected computers and computer networks owned

[54] Mcknight, Lee W. and Bailey, Joseph P. (ed.). Internet Economics. Cambridge, MA: The MIT Press, 1998, p.28.
[55] Esbin, Barbara. "Internet Over Cable: Defining the Future in terms of the past." FCC's *Office of Plans and Policy Working Paper* No. 30. Washington, DC: August 1998, p.6 <http://www.fcc.gov/Bureaus/OPP/working_papers/oppwp30.pdf>.

by the military defense contractors and university laboratories conducting defense-related research. Several similar networks were established, primarily between universities during the 1970s and early 1980s. In 1985, the NSFNET, a high-speed backbone network, funded by the National Science Foundation, initiated programs intended to serve the entire higher education community. NSF funding for an NSFNET connection were provided to U.S. universities, given that they make the connection available to all qualified users on campus. For this program, the NSF decided to make TCP/IP the standard protocol to be used for the NSF network, which was to ensure that the ARPANET and the NSFNET could be linked up and interoperate. Another reason for the standardization of TCP/IP is to have the two organizations jointly author the formal specifications for the Internet as we know it today. [56]

The NSFNET was originally created so that researchers could submit jobs to supercomputers located at various universities around the United States. It was then became apparent that there were a lot of excess capacity on the NSF for exchanging data among universities that had nothing to do with supercomputing. The NSF sponsored the NSFNET operation for several years, but eventually decided that the technology was mature enough that it could be more effectively provided by the private market.[57] In April 1995, NSF's funding for the NSFNET backbone was terminated. [58]

Before the Internet in the U.S. became "privatized", there was a clear distinction between the backbone[59] (e.g., the NSFNET) and regional network layers (e.g., campus

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[56] *Id.*, p.6.
[57] Mcknight, Lee W. and Bailey, Joseph P. (ed.). Internet Economics. Cambridge, MA: The MIT Press, 1998, p.31.
[58]: *Id.*, p.28.
[59] A backbone is an overarching network to which multiple regional networks connect, and which generally does not serve directly any local networks or end-users. The U.S. backbones

networks). But after funding for the NSFNET terminated, this distinction became blurred as more regional networks are connected directly to each other through network access points (NAPs), and traffic passes through a chain of regionals without any backbone transport. [60]

Also, after the Internet became privatized, the terms of intercconnect agreements need to be defined for the now privately owned networks to connect to one another. Internet service providers (ISPs) transfer data generated by their users to the networks for which they are intended, and the cost of the many disparate networks is spread over a large group of users. All ISPs are not created equal, however. Firms that generate the greatest amounts of traffic also share the greatest economies of scale. In addition, since a small network is more dependent on a large one for access to different points on the Internet, the large network is in a better position to dictate the terms of the interconnect agreements. ISPs are, therefore, often grouped into tiers by size.[61] In this sense, the shared structure of the Internet is still hierarchical. This structure of interconnection agreements allows firms to recover their costs of building the further-reaching networks, and prevents smaller networks from "free-riding" on the larger ones by sending them a lot of traffic.

Although the Internet now operates as a decentralized medium, this section shows that the Internet was actually started by government agencies. The evolution of the Internet to its privatized state took only a short ten years, but there may now be gaps left for the government to fill. I have shown in Chapter One that there is indeed the problem

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connect to other backbone networks around the world. Souirce: Mcknight, Lee W. and Bailey, Joseph P. (ed.). Internet Economics. Cambridge, MA: The MIT Press, 1998, p.28.
[60] *Id.*, p.28.

of the "digital divide". If the privatized Internet is still evolving, there may be hope that the "digital divide" will eventually be eliminated. However, if it is the case that the private market is already matured, and the digital divide is to remain a permanent problem, then government intervention may be warranted to correct for this.

For a list of backbone providers ranked by their size in August 1999, see Table 1-1. Maps of major interconnection points and the numerous networks that use them is available at http://www.cerf.net/cerfnet/Bbone-map.html for AT&T CERFnet, and http://www.uunet.com/network/maps/index.html for MCI/WorldCom's UUNET, http://www.psinet.com/network/connectivitymaps.html for PSINet, and http://www.csmc.edu/pediatrics/cme/inetpeds/sld035.htm for Sprint's IP backbone.

1-2.2 xDSL versus Cable Modem

Section 2-1 explains the underlying technology of the Internet – how the computer networks and backbones are interconnected. This section gives an overview of two technologies which allow high-speed connection to an internet access point from a customer's location. DSL stands for digital subscriber line. The technology uses digital coding to deliver additional capacity over existing telephone lines, enabling telephone companies to offer high-speed data and Internet access in addition to telephone service.[62] The technology utilizes unused frequencies in copper telephone lines, allowing data to

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[61] Morgan Stanley Dean Witter . "Network Services - The Wholesale and Backbone Market." *The Internet Data Services Report* 11 Aug. 1999, p.28 <http://www.msdw.com/techresearch/inetdata/index.html>.
[62] SBC Communications, Inc. "Project Pronto: Glossary of Terms", *SBC Website* accessed on 15 Sept 2000 <http://webcast.sbc.com/media/fact/glossary.doc>.

flow at speeds many times faster than a traditional dial-up analog connection. There are many different variations of xDSL, hence the prefix "x". A more popular and affordable class of this technology called ADSL allows speeds ranging from 128kbps to 8 Mbps.[63] DSL is on all the time, hence there is no need to dial-up, and customers can use their telephones for voice calls without having to pay for a separate line.[64]

Cable modem is another popular broadband technology. The technology uses the same cable lines that carry cable TV signals. In recent years, cable operators have started to upgrade their cable lines to HFC (Hybric Fiber Coaxial) to allow for bi-directional, high-speed transmission of data. The technology uses slices of frequency to carry digital data and to provide the return signals needed for telephony and high-speed data. Traditional coaxial cable systems typically operate with 330 MHz or 450 MHz of capacity, whereas modern hybrid fiber/coax (HFC) systems are expanded to 750 MHz or more. A headend cable modem termination system (CMTS) communicates through these channels with cable modems located in subscriber homes to create a virtual local area network (LAN) connection.[65] Most HFC systems utilize fiber between the headend and the neighborhood "nodes." Between the nodes and the individual end-user homes, signals travel over coaxial cable infrastructure.

Under optimal conditions, and using the best available technology, an upgraded cable system can provide maximum downstream speeds of 27 Mbps and maximum

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[63] Cahners In-stat Group. "Entering the broadband era." Cahners In-stat Report NO.: BB0000CI. May 2000, p.20, Table 3 <http://www.instat.com/catalog/downloads/broadbandera.asp>.
[64] Vicomsoft. "XDSL Q&A" *Knowledge Share Page*, accessed on 15 Sept. 2000. <http://www.vicomsoft.com/knowledge/reference/xdsl1.html >.
[65] Vicomsoft. "XDSL Q&A" *Knowledge Share Page*, accessed on 15 Sept. 2000. <http://www.vicomsoft.com/knowledge/reference/xdsl1.html >.

upstream speeds of 10 Mbps.[66] This upstream and downstream bandwidth is shared by the active data subscribers connected to a given cable network segment, typically 500 to 2,000 homes on a modern HFC network.[67,68] This translates into transmission speeds in the range of 128kbps to 2Mbps for each home.[69]

The shared bandwidth for a cable modem connection distinguishes cable modem from DSL services. DSL uses a dedicated connection but cable modem service uses a shared bandwidth among households connected to the same node. For Cable Data Network Architecture, see Figure 1-2.

Besides the shared versus dedicated bandwidth element, there is not a significant difference between cable modem and DSL service from the consumer's perspective given the current state of the technologies. Higher-end DSL offerings are available for business customers, but cable modem service is primarily residential. Price in the form of a monthly charge is about the same at comparable quality (around $40 per month for the basic, lower-end residential offers). Installation for cable modem service is about $100, whereas for DSL service it is usually free. Due to the G.Lite technology, DSL has become much like a plug-and-play technology. You buy the modem (sometimes came already installed in your PC) and the do-it-yourself installation program comes with it. Cable modem, however, still requires a technician to spend at least a day at the customer

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[66] Federal Communications Commission. "Deployment of Advanced Telecommunications Capability: Second Report," *CC Docket No. 98-146* Washington, DC: Federal Communications Commission, August 2000, p.19 <http://www.fcc.gov/Bureaus/Common_Carrier/News_Releases/2000/nrcc0040.html>.
[67] Vicomsoft. "Cable Modem Q&A" *Knowledge Share Page*, accessed on 15 Sept. 2000. <http://www.vicomsoft.com/knowledge/reference/cable.modems.html>.
[68] "Overview of Cable Modem Technology and Services", cable datacom news,. http://www.cabledatacomnews.com/cmic/cmic1.html
[69] Cahners In-stat Group. "Entering the broadband era." Cahners In-stat Report NO.: BB0000CI. May 2000, p.20, Table 3 <http://www.instat.com/catalog/downloads/broadbandera.asp>.

premise to get the installation done. DSL customers usually have to purchase their own modem, which is about $100, although some get it for free as a promotion (Bell South is currently having such a promotion). For cable modem users, the rental of the cable modem is usually included in the monthly charge.[70]

Only in highly urbanized areas do people actually have a choice of the two technologies. Some people live in areas where neither DSL nor cable modem service is available. There are a few reasons for the slow deployment of these technologies. Although from the user's point of view the two technologies are similar, from a supplier's perspective, deployment of these technologies requires overcoming different problems in the infrastructure. For cable modem, the upgrade process often includes extending optical fiber closer to the end-user and improving system quality to reduce signal leakage. The cable system's transmission capacity needs to be upgraded to 750MHz to allow for greater flexibility in allocating bandwidth for two-way high-speed services.[71] Equipments that enable the transmission of digital data packets such as routers, switches, and a cable modem termination system need to be installed for high-speed Internet service. Further, amplifiers and optical lasers need to be installed in both downstream and upstream direction in order to allow for bi-directional transmission. Without such equipment, providers typically can provide high-speed service only in the downstream direction and must rely on a telephone line return path.[72] For example, in

[70] Cablevision in New Jersey started to provide cable modem service for a monthly fee that does not include the rental of a cable modem. However, the subscriber could easily purchase a cable modem at a discount in stores.
[71] Federal Communications Commission. "Deployment of Advanced Telecommunications Capability: Second Report," *CC Docket No. 98-146* Washington, DC: Federal Communications Commission, August 2000, p.19-20 <http://www.fcc.gov/Bureaus/Common_Carrier/News_Releases/2000/nrcc0040.html>.
[72] *Id.*, p.19-20.

Somerset, New Jersey, RCN offers a high-speed downstream cable modem service, but uploading still requires the use of the telephone line. Once an HFC network is upgraded, new services are available to all homes passed by the upgraded infrastructure.[73]

DSL service, like cable modem, is subject to certain limitations that currently prevent it from being deployed. First, DSL is limited by distance of the customer's premise to the carrier's central office. Currently, an ADSL customer must be within approximately 18,000 feet of the carrier's central office. The FCC in its second report on the deployment of advanced services indicates that eighty percent of the subscriber loop plant falls within these distance limitations, and thus is capable of supporting DSL service, but this factor "remains an impediment to DSL deployment in more sparsely populated and remote locations".[74] The second factor limiting the deployment of DSL to some potential customers is the presence of load coils and bridged taps in their loop. These devices that were used to enhance the quality of voice traffic over the copper are incompatible with DSL, hence need to be removed before the technology can be deployed.[75] The age and quality of the loops also is a factor in the LEC's ability to provide DSL service to a customer. Frayed insulation or poorly spliced loops can cause signal leakage, which can result in poor quality transmission.[76] Digital Loop Carrier (DLC) is another problem for the deployment of DSL. DSL can work with some newer DLC products but most DLC systems are incompatible with DSL.[77]

Hence, suppliers of both cable modem and DSL face challenges in deploying these technologies.

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[73] *Id.*, p.19-20.
[74] *Id.*, p.12-23.
[75] *Id.*, p.12-23.
[76] *Id.*, p.12-23.

1-2.3 Broadband markets and trends –major players

In the market for DSL service, we are starting to see competition among DSL providers in the same area, but we still do not see competition among cable MSOs in rolling out cable modem service. In Verizon (Bell Atlantic/GTE) territories, for example, we see offers by other DSL providers such as Northpoint. But inside Time Warner Cable territory, we do not see any other cable modem offers available in the same area. However, in New York City, where Verizon is the local exchange carrier for telephone service, and Time Warner is the leading cable company, residential customers have a choice between cable modem service from Time Warner and DSL service from Verizon. So far, although there is competition among DSL providers, we see more competition between the two technologies, DSL and cable modem.

The FCC has mandated the unbundling of network elements by Regional Holding Companies in accordance with the Telecom Act.[78] This has allowed CLECs (Competitive Local Exchange Carriers) to provide DSL service to residential customers by leasing the local loop. As a result, CLECs such as Northpoint and Covad are now able to offer DSL services in targeted areas, although the coverage areas of these CLECs are small and most of them focus on the business/wholesale markets. The newly released

[77] *Id.*, p.12-23.
[78] Federal Communications Commission. "Third Report and Order and Fourth Further Notice of Proposed Rulemaking in CC Docket No. 96-98." *FCC 99-238* Washington, DC: Federal Communications Commission, Released 15 Sept. 1999, p.5.

FCC report finds that "competition is emerging, rapid buildout of necessary infrastructure continues, and extensive investment is pouring into this segment of the economy." [79]

Just as there has been little competition in the Cable TV business, the geographical market for cable modem service is divided among the cable companies, each serving their own designated territories. The bigger ISPs have been pushing the cable companies to open up their networks so as to allow cable customers a choice of ISPs, although the FCC is still in the process of considering making the sharing of cable data links a requirement. However, it looks probable that this will happen in the near future since AT&T Broadband (partnering with Excite@home) has announced its commitment to opening up its networks and is set to begin test trials of multiple Internet providers in Boulder, Colorado in November 2000.[80]

According to Kinetic Strategies, Inc., at the end of June 2000, the cable modem market in North America is still dominated by a few multiple system operators (MSOs). AT&T/MediaOne led the industry with 23% of the cable modem market, followed by Time Warner Cable with 19% share, Cox with 11%, Rogers with 9%, Shaw with 8%, and Comcast with 8% share (see Table 1-2).[81] For a list of cities served by Time Warner Cable, see Table 1-3.

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[79] Federal Communications Commission. "Deployment of Advanced Telecommunications Capability: Second Report," *CC Docket No. 98-146* Washington, DC: Federal Communications Commission, August 2000, p.6 <http://www.fcc.gov/Bureaus/Common_Carrier/News_Releases/2000/nrcc0040.html>. <http://www.usda.gov/rus/unisrv/ntia-rusbroad.pdf>.

[80] AT&T Broadband. "AT&T Broadband To Launch Trial Of Multiple Internet Provider." *AT&T Broadband News Release* 7 June 2000 <http://www.att.com/press/item/0,1354,2951,00.html_>.

[81] Cable Datacom News. "Cable Modem Market Stats & Projections." *Cable Datacom News* 16 August 2000 <http://www.cabledatacomnews.com/cmic/cmic16.html >.

Similar market share information is available for DSL (Table 1-4). SBC is the leading DSL provider in the U.S., accounting for 31% of all business and residential customers in the end of 1999. In 2000, SBC continues to be the leading DSL provider. SBC's Project Pronto, implemented in October 1999 launched a $6 billion initiative that is to transform the company over the next three years into the largest single provider of advanced broadband services in America. Through the initiative, SBC will provide an estimated 77 million Americans - about 80 percent of its Southwestern Bell, Ameritech, Pacific Bell, Nevada Bell, and SNET customers - with DSL service than it currently offers by the end of 2002. Ultimately, the company intends to make broadband services available to all of its customers. [82]

Detailed information on the progress of DSL deployment is not available for other providers, but Verizon (Bell Atlantic/GTE) have also rolled out DSL service in some cities since the beginning of 2000. These are examples of the kinds of investments being made in the DSL markets and the plans of deployment for the major players.

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[82] SBC Communications, Inc. "SBC Becomes America's Largest Single Broadband Provider With $6 Billion Initiative." *SBC Website* accessed 15 Sept. 2000 <http://www.sbc.com/data/network/pronto.html>.

1-2.4 Conclusion

Although the Internet started out as a project by government agencies, it has evolved into the hands of for-profit private organizations in less than ten years. While the general public is starting to gain a better understanding of the technology and its use, broadband is still at the beginning stages of development, and deployment is still hindered by the kinks in the infrastructure. Over time, I expect to see technology to find ways to fix some problems of deployment, and this may stimulate more competition and growth in these markets.

Section 3 Literature Review

1-3.1 Falling through the net

Limited research on broadband usage and access is available. The U.S. Department of Commerce published a study *Falling Through the Net* which looks at modem ownership, e-mail use, and Internet use as measures of general access among households.[83] It concludes that only one-quarter of all households were actually connected to the Internet by the end of 1998, and that those segments of the society least

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[83] Internet use data is only available from 1997. Prior to 1997, modem ownership is used as a measured of Internet access. While modems provide a means to access the Internet, they do not necessarily mean that a household actually has Internet access. This measurement therefore does not provide an exact proxy for Internet access. The availability of modem ownership data discontinued in 1998 because nearly all computers contain modems today and because modems, n practice, are not always used to connect to the Internet. Source: National Telecommunications and Information Administration. Falling through the net: - defining the digital divide. Washington, DC: US Department of Commerce, July 1999 , p.85 <http://www.ntia.doc.gov/ntiahome/fttn99/FTTN.pdf>.

likely to be connected to the Internet are "low-income, Black, Hispanic, or Native American, senior in age, not employed, single-parent (especially female-headed) households, those with little education, and those residing in central cities or especially rural areas."[84] While this study provides us with information about who is less likely to be using the Internet, it does not tells us whether this outcome is affected by the availability of service. "Usage" is the embodiment of both demand and supply factors. On the demand side, households choose whether or not to buy a computer, and then choose whether to subscribe to Internet service. Households with computers may or may not want to subscribe to Internet services due to their preference and ability to pay, but Internet access is in their choice set only if Internet service is available to them. The *Falling Through the Net* study provides insights as to the demand characteristics that may be associated with usage, but no supply side or availability information is included.

1-3.2 Geographic coverage of ISPs

In their study on the geographic coverage of ISPs, Downes and Greenstein (1998) characterize the location of 54,000 points of presence (POPs), local phone numbers offered by commercial ISPs in the spring of 1998. By mapping these POPs and reflecting the density of ISPs coverage areas across the U.S., they illustrate the uneven geographic coverage of the ISP industry. ISPs tend to locate in all the major population centers. As further evidence that low entry is predominantly a rural phenomenon, their study suggests that more that 95% of the counties with ten or fewer providers are rural. Another finding

[84] *Id.*, p. 85.

suggests that "over ninety-two percent of the U.S. population has easy access to a competitive Internet access market"[85] in the spring of 1998. While this finding may suggest close to universal access for traditional narrowband Internet access, it does not provide any insight into the availability of broadband Internet access such as that via Digital Subscriber Line (DSL) and cable modem. Because broadband is superior service compared to narrowband both in terms of speed and capabilities, and the fact that broadband is limited by inadequate infrastructure, more research is warranted to investigate the availability of broadband services.

1-3.3 Geographic coverage of Internet backbones

A paper by Olbeter and Robison (1999) identifies twelve states – the disconnected dozen – that are falling behind in the deployment of Internet backbone hubs. They cautioned that these states are at serious risk of being denied the end-to-end broadband Internet. The authors used the analogy of a train station to illustrate the benefits of being close to an Internet hub. The greater the distance from a town to an Internet hub, the more expensive the service, the more constrained the speed of the service, and the more limited the service offerings. These towns can get on the slower, narrowband Internet, but cannot acquire broadband connectivity at a reasonable price, if at all.

Using standard regression analysis, they show that two economic factors have a statistically significant and positive impact on the number of backbone hubs constructed in a state: per-capita income per state, and the number of cities with populations over

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[85] Olbeter, Eric R., and Matt Robison. "Breaking the Backbone: The Impact of Regulation on Internet Infrastructure Deployment." *Iadvance Internet Facts* 27 Jul. 1999, p.1-3

100,000. According to the authors, this is not a surprising finding. It makes sense that backbone network builders would target customers in densely populated areas with dollars to spend. This deployment strategy allows network providers to spread their costs over a large number of people who have the income to buy numerous services.

Regulation is also found to be a statistically significant determinant of backbone hub deployment. When independent local exchange companies – those not under backbone deployment prohibitions –own a significant number of access lines in a state, more backbone hubs are built. What this suggests is that the presence of this regulation has slowed down the construction of backbone hubs. It also suggests that removing interLATA restrictions on the Regional Holding Companies- those ILECs which are under broadband deployment prohibitions – will have a significant and measurable impact on the diffusion of internet backbone hubs.

This study assumes that the proximity to a backbone hub is a major factor in determining broadband service availability, and by analyzing factors that affect the deployment of backbone hubs, the authors try to draw the conclusion that due to certain factors, broadband services will be less or more likely to be available in a particular state. This analysis brings out an important point – that distance to a backbone hub is a significant factor in determining availability of broadband services, but the study does not look at availability directly.[86]

A recently released FCC report on advanced services finds that that there has been ample national deployment of backbone and other fiber facilities that provide backbone

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<http://www.iadvance.org/background/index.html>.
[86] *Id.*, p.6.

functionality.[87] The report states that there is "no indication that specific types of areas have inadequate access to backbone or functionally equivalent facilities". Another finding of the study is that "extensive middle mile facilities exist, that innovative compression and modulation techniques continue to expand the capability of existing fiber links, and that the broad geographic distribution of subscribers to high-speed services demonstrates the wide availability of middle mile facilities". Nonetheless, there remains the potential that a bottleneck exists in certain areas and that a lack of competition in that market could lead to high prices.[88]

1-3.4 FCC study on advanced services[89]

In August 2000, the FCC released its second report on the deployment of advanced telecommunications capabilities in the United States. In general, the Commission finds that "advanced telecommunications capability is being deployed in a reasonable and timely fashion". The study looks at trends in the investment in the facilities needed to provide advanced telecommunications capability, subscription rates for advanced services, and provider competition in the marketplace. The Commission is encouraged that these factors will lead to widespread deployment, but pointed out that the deployment of advanced telecommunications capability is still not uniform across the nation. While the Commission expects that economic forces will drive deployment as the

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Federal Communications Commission. "Deployment of Advanced Telecommunications Capability: Second Report," *CC Docket No. 98-146* Washington, DC: Federal Communications Commission, August 2000, p.6. <http://www.fcc.gov/Bureaus/Common_Carrier/News_Releases/2000/nrcc0040.html>.

[88] *Id.*, p.6.

[89] *Id.*, p.6.

market develops, it appears that consumers in certain areas of the country may be particularly vulnerable to not receiving timely access to advanced telecommunications capability.

As Congress directed in section 706, the focus of the study is the *availability* of advanced telecommunications capability. Accordingly, the report concentrates largely on addressing the deployment of the infrastructure necessary to bring advanced telecommunications capability to consumers. However, the Commission also recognizes that deployment of infrastructure alone does not guarantee that the benefits of advanced telecommunications capability will flow to all consumers as Congress intended. Factors such as household income, computer ownership, education, and technical skill, to name a few, all affect whether consumers are able to access the advanced services available through advanced telecommunications capability. The Commission also pointed out that the speed and ubiquity of advanced telecommunications capability deployment will depend in large measure on consumers' demand for content and services that require this capability.

The study concludes that, as of December 31, 1999, there were approximately 1.8 million residential subscribers of high-speed services. And of these people, approximately 1.0 million subscribed to services that meet the FCC's definition of advanced telecommunications services. This is a three-fold increase in residential advanced from the previous year.

The Commission identified five groups as being particularly vulnerable of not having access to advanced services if deployment is left to market forces alone:

1. rural Americans, particularly those outside of population centers;
2. inner city consumers;
3. low-income consumers;
4. minority consumers;
5. tribal areas; and
6. consumers in U.S. territories[90]

1-3.5 Conclusion

This dissertation attempts to complement the existing research by investigating the availability of broadband services to residential subscribers, focusing on the choice of providers to deploy cable modem and DSL technology. I focus on these two technologies because, as recently reported by the FCC, only these two technologies are rapidly being deployed to provide two-way, high-speed access to the Internet.[91] Both cost and socio-economic factors are taken into account as determinants of availability. This not only allows us to look at cost issues that may affect a provider's decision to deploy advanced technology, it also helps to identify segments of society that are disenfranchised from *advanced* communication services.

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[90]Federal Communications Commission. "FCC Issues Report on the Availability of High-Speed and Advanced Telecommunications Services." *CC Docket No. 98-146* Washington, DC: Federal Communications Commission, 3 August 2000
<http://www.fcc.gov/Bureaus/Common_Carrier/News_Releases/2000/nrcc0040.html>.
[91] Federal Communications Commission. "Deployment of Advanced Telecommunications Capability: Second Report," *CC Docket No. 98-146* Washington, DC: Federal Communications Commission, August 2000, p.ii..
<http://www.fcc.gov/Bureaus/Common_Carrier/News_Releases/2000/nrcc0040.html>.
High-speed access is also available to residential customers through satellites but this technology only provides one-way broadband service. For example DirectPC upstream communications is via standard telephone lines and therefore should not be characterized as

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two-way broadband service.

CHAPTER 2 THEORY AND ECONOMETRIC MODEL

Section 1 Theoretical Consideration

In this section, I provide a discussion of the demand and supply considerations in the decision of a firm to provide broadband Internet services. These considerations were translated into a logistic availability model, and the data to be applied this model is described.

2-1.1 Demand for residential broadband Internet services

The demand for residential broadband Internet service depends on several factors. First of all, underlying the demand for residential Internet service is the demand for PCs. Having a computer at home is a pre-requisite for accessing the Internet from home. As discussed in sections 1-1.1 and 1-1.2, computer ownership and general online penetration are both expected to be in the mid-50 percent by year-end 2000. In order for residential online penetration to grow, PC ownership has to grow just as fast. So, we need to look at the factors that drive the demand for PCs. As with any other consumer products, price is a key determinant of demand. It has been reported by the Department of Commerce that since the mid-1990s, the price decline for IT products has accelerated, and one of the steepest price declines occurred in the computer industries, where prices fell at average annual rates of 24 percent for the years 1995 to 1998 (see Figure 2-1).[92] The same data is not yet available for 1999 and 2000, but given the trend reported, I expect computer prices to drop as the technology matures. Another report shows that year-over-year growth rate in worldwide PC unit shipments grew 17 percent in the last quarter of 1999[93]. This is indication that PC growth is still strong.

Assuming that PC ownership is growing, we need to consider whether people's preference for the Internet is growing. As Internet content providers create a larger variety of content on the Internet, and as e-commerce develops, it is likely that the Internet will attract more people. Another factor that is likely to increase demand in a positive way is the fact that the Internet exhibits the property of positive externality. There is a general consensus that the more people online, the more benefits people online will derived from the Internet. As online penetration increases, the value of the Internet to its users increases exponentially with it, hence driving demand higher.

So far this discussion is around general Internet demand. More needs to be considered when we shift the focus to the demand for broadband Internet services. As content becomes more sophisticated – with video on demand, real-time video conferencing, etc., I expect the demand for higher speed and capacity to increase. Indeed, even without the new ways of using the Internet, speed is being cited as the number one problem with the Internet (see Table 2-1).[94]

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[92] Economics And Statistics Administration, Office of Policy Development. Digital Economy 2000. Washington, DC: U.S. Department of Commerce, June 2000, p.25 <http://www.esa.doc.gov/de2000.pdf>.
[93] Kane, Margaret. "IDC predicts 17% PC growth." ZDNet News. 7 Dec. 1999 <http://www.zdnet.com/zdnn/stories/bursts/0,7407,2405465,00.html>.
[94] Morgan Stanley Dean Witter . The Internet Data Services Report 11 Aug. 1999, p.16

Another key factor affecting demand is the cost of subscribing to high-speed Internet service. Price is related to people's ability to pay. The more income one has, the more goods one can include in his/her choice set. Cable modem service and DSL subscription rates are around $40/month for an average broadband connection. This is still at least double that of the subscription rate for traditional dial-up narrowband service. Moreover, for these broadband technologies to work, the consumer must either spend money on a new modem or on the installation of it. Price has been a definite deterrent for consumers to buy these new services, but the monthly subscription fees for both technologies have declined since they emerged, and one can expect them to decline further as the technology matures.

To summarize, the demand for residential broadband Internet service depends on computer ownership, the growth and creation of value of the Internet, preferences including the benefits of broadband compared to narrowband, ability to pay, and the price of subscription to these services.

2-1.2 Supply for Internet services

Different factors determine whether a provider decides to provide broadband service in a particular area. Potential demand for the service is important. The more demand we expect in a service area, the easier it is for the provider to recover the fixed investment costs associated with providing the service. Potential demand is an even more significant factor if providing the service requires large up-front fixed costs. A straight-forward measure of potential demand is the size of the market the provider is entering. In

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<http://www.msdw.com/techresearch/inetdata/index.html>.

the case of DSL, the provider deciding to invest in co-location and switching equipment at a wire center would try to find out the coverage area of the wire center and the number of lines served by the wire center. In Section 2-1.1, I pointed out that preference and ability to pay enters the demand function. Preference varies by demographics such as age, race, and education level. Using these characteristics to control for preference is generally acceptable. Income should be a factor that a provider looks at when deciding where to provide service. An area with a large number of potential customers with money to spend would be ideal. Once potential demand is assured, the provider needs to consider the costs involved in providing service in a given area.

In the case of a LEC trying to provide DSL service, access costs represent a huge portion – 55% - of the over-all service cost.[95] Generally, access costs (the cost of a DS1/T1 connection) depend on the distance from the Internet backbone. The longer the distance, the higher the cost will be. Also, quality of service is affected by distance. The longer the distance the more routers the traffic has to go through. Each time the traffic goes through a router there can be degradation in the quality of service. In order that customers get good service, providers would try to minimize the number of routers that the connection goes through.

There are large fixed up-front costs involved in setting up the delivery of DSL and cable modem service. In the case of DSL, for example, a provider needs to put DSL concentration equipment in an ILEC central office (CO). This is a significant investment, an up-front costs of as much as 50K per CO.[96] There are other costs involved such as

[95] AccessLan Communications, Inc. "Blueprint for Building a Facilities-based Local Loop Infrastructure Using DSL Overview." *AccessLan Website* accessed on 15 Sept. 2000 <http://www.accesslan.com/case/>.
[96] *Id.*

switching and transmission costs and other administrative costs, but these should not vary as much in different markets.

There is other information that the provider can use in determining whether the market will be profitable. They can go into a community and talk to people to see whether their potential customers really need this higher-speed, higher capacity service, they can find out whether there is competition from other providers of the same service or comparable service.

The decision to deploy advanced technologies depends on both demand- and supply-side factors. This dissertation attempts to quantify their effect on availability of advanced services through the modeling of suppliers' decision to make available these services. The following section outlines the objectives of this dissertation and the factors to be included in my regression analysis.

2-1.3 Determinants of the availability of DSL and cable modem services-Objectives

In this dissertation I examine providers' choice to deploy advanced technology, hence the choice to make broadband services available to different segments of the population. The question of access is analyzed in the context of federal policy favoring reasonable and timely access for all Americans. I look at residential broadband services offered by telephone and cable television operators, with a focus on high-speed Internet access via xDSL and cable modems. Although cable television operators have not been traditionally viewed as competitors in the telecommunications market, there is an increasing trend towards cable operators offering the same services as local exchange carriers—telephony and high-speed Internet access. There were an estimated 2.3 million cable modem subscribers in the U.S. by June 30, 2000. Cable modem service was commercially available to 48 million homes in the U.S. and Canada, equal to 44 percent of all cable homes passed.[97]

Based on my understanding of the telecommunications network, there are a few crucial factors that impact the decision to offer service, as laid out in Sections 2-1.1. and 2-1.2. First, there is the cost of supplying the service. Whereas there are sizeable fixed costs associated with establishing service, a firm needs to estimate the potential size of the market. I use two types of data to control for the size of the market, the number of customers that can be reached, and the economic and demographic characteristics of the population. We would expect that all else equal, the older and poorer the customer base, the lower the forecasted interest in the service and therefore there is a reduced likelihood that service will be introduced.[98] Furthermore, the more telecommunications users per square mile of service territory, the greater the likelihood that advanced telecommunications services will be made available.

The decision to rollout high-speed access is also influenced by the cost of reaching the Internet backbone. The cost of a link to the Internet backbone increases with distance. The mileage transport rate to the Internet backbone is also a function of

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[97] Kinetic Strategies. "Cable Modem Customer Count Reaches 2.7 Million in U.S. and Canada" *Kinetic Strategies Website* accessed on 15 Sept. 2000 <http://www.kineticstrategies.com/cable_count.html>.

At this point in time, there are fewer in-service xDSL modems. According to TeleChoice, there were 754,770 DSL lines were in service at the end of the first quarter of 2000. Source : XDSL.com. "TeleChoice DSL Deployment Summary." *XDSL.com* accessed on 9 August 2000 <http://www.xdsl.com/content/resources/deployment_info.asp>.

[98] Whereas we are modeling the decision to enter a market, it is appropriate to include economic and demographic data as variables that influence the decision to rollout the service in a community. Based on our conversation with network providers, the supplier is unable to observe the level of demand and instead relies on census information to estimate the interest in

population density. For a given distance, fiber transport rates are lower in urban areas because of the greater degree of rivalry between telecommunications suppliers. Therefore there is a need to control for the cost of connecting customers to the Internet backbone. Based on my research on industry suppliers, as well as other published research, I have estimated the cost of transport from the local market to the Internet backbone by estimating the cost of connecting to the nearest inter-exchange carrier's point of presence.[99]

I also test if the regulations imposed on Regional Bell Operating Companies impedes the roll-out of advanced telecommunications services to residential customers. Under the Telecommunications Act of 1996, the Regional Bell Operating Companies are prohibited from providing interLATA (long-distance) services until they have satisfied a competitive list of conditions established by Congress and monitored by the Federal Communications Commission. I test to see if residential customers in areas served by Regional Bell Operating Companies, all else equal, are less likely to have high-speed access to the Internet.

Utilizing a statistically valid sample of customer locations,[100] logistic regression techniques are used to estimate the following relationship:

Availability = f (economic & demographic variables, teledensity, area served by incumbent RBOC).

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the service.

[99] National Telecommunications and Information Administration, and Rural Utilities Service. Advanced Telecommunications in Rural America: The Challenge of Bringing Broadband Service to All Americans Washington, DC: National Telecommunications and Information Administration and Rural Utilities Service, Apr. 2000, p. 9 <http://www.usda.gov/rus/unisrv/ntia-rusbroad.pdf>..

The modal specification outlined above addresses the availability of high-speed access. The dependent variable is binary—service is or is not available to a household.

2-1.4 Summary of Hypothesis

Given the basic model and the data I have available (to be discussed in Section 2-3.1), the parameter estimates from the regression will afford us the opportunity to test the following hypothesis:

A) Number of Access Lines or Average Fixed Costs – The coefficient estimate will allow me to test the significance of economies of scale in influencing availability.

B) Line Density – defined as number of access lines per square mile. The coefficient estimate will allow me to test the significance of the potential size of customer pool per square mile.

C) Bell Operating Company - The coefficient estimate will allow me to test if the line-of-business restrictions established by the 1996 Telecommunications Act is promoting or hindering the development of broadband services.[101]

D) Percentage of households without telephones - The coefficient estimate will allow me to test whether or not having a telephone decreases the likelihood that DSL service is available to a household.

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[100] In appendix A we describe the method used to establish the sample size.

[101] In subsequent research we will test to see if unregulated cable companies, relative to the regulated telecommunications industry, are more or less likely to provide broadband services.

E) Median year housing structure built – This variable can be considered a proxy for the age of the communications infrastructure. The coefficient estimate will allow me to test whether it is more costly to provide advanced services where infrastructures are relatively old, hence decreasing the likelihood of these services being available.

F) Percentage of households/residents in Rural or metropolitan area- The coefficient estimate will permit me to test if rural and urban areas of the United States have equal access to broadband services.

G) Percentage of Black/Hispanic/American Indian/Asian households- This will allow me to test if broadband access is less available to minority groups.

H) Age of residents- This will allow me to test if availability is significantly different between different age groups.

I) Median Household income- This will allow me to test if broadband access is less available to lower income groups.

J) Educational attainment- This will allow me to test if availability is significantly different between groups with different educational attainment.

K) Percentage of foreign-born residents - This will allow me to test if broadband access is less or more available to foreign-born residents.

L) T1 charges for connecting to an Internet backbone - This will allow me to test if higher access charges have a negative impact on the probability that the new technologies are deployed.

Section 2 Econometric specifications

In this section, I lay out the basic regression model for the data analysis. A simple logistic regression is specified, where the dependent variable is the availability of advanced services.

2-2.1 Basic Estimation Model- The logistic model

I am modeling the rollout of advanced telecommunications services. The decision to deploy advanced telecommunications services is effectively binary—either advanced services are or are not available. There are a few econometric techniques that were developed to deal with experiments in which there are just two possible outcomes. I have employed one of these specifications, logit. If I had used a different specification, say probit, our qualitative results would not have changed.

In this section I outline the logit specification. Let D_i = line density; R_i = Dummy equals 1 if RBOC; U_i = percentage of households in urbanized area; M_i = median year housing structure was built; H_i = household income; and T_i = percentage of households without telephone, for the i^{th} wire center, where i = 1,2,...286. Further, let π_i = the conditional probability that DSL or cable modem service is available at wire center i^{th}, and $(1-\pi_i)$ the conditional probability that they are not available, given D_i, R_i, U_i, M_i, H_i, and T_i. Then the logistic regression model for the log-odds of service being available is

$$\log\left(\frac{\pi_i}{1-\pi_i}\right) = \log Y_i = \alpha + \beta_1(D_i) + \beta_2(R_i) + \beta_3(U_i) + \beta_4(M_i) + \beta_5(H_i) + \beta_6(T_i),$$

where Y_i is simply the conditional odds of DSL or cable modem service being available, given the explanatory variables.

Results of different specifications of this model, including the addition of demographic and other variables, are presented in the "Results" section.

Section 3 Data

In this section, I summarize the sources of the data to be used in the regression analysis, defining the variables to be included. A discussion of the descriptive statistics by availability are provided, as well as an analysis of the correlation between the explanatory variables.

2-3.1 Summary of data used

I examine the availability of broadband services at the wire center level of observation.[102] For my estimation, I used data from three different sources. First I obtained data on the number of access lines at a wire center, as well as the size of its service territory, and the type and name of the company that owns the wire center. This data is from the HAI proxy cost model, which is a cost model developed by AT&T and MCI for the purpose of estimating the cost of providing telephone service throughout the United States. DSL and cable modem service availability data were collected from

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[102] A wire center is the building in which one or more local switching systems are installed and where the outside lines leading to customer premises are connected to the switching equipment.

various company and technology websites such as getspeed.com and dslprime.com, which I was able to map to wire center locations. For a few locations, additional data was obtained by calling service providers. I use the 1990 census data for the economic and demographic characteristic of various areas of the country. Census block group data were aggregated to the wire-center level and merged with the availability data. Data on access charges (T1) are taken from StratSoft, Inc.[103]. The database allows us to find the monthly charge of obtaining a T1 connection to the nearest IXC point of presence, which is a good proxy for an Internet backbone access point. For a list of the variables and their description, see Table 2-2.

2-3.2 Descriptive Statistics

Given the nature of my data and my research objectives, the best way to get an overview of the data sample is to create frequency tables for the different explanatory variables against the dependent variable –AVAIL. (Again, AVAIL is a dummy equal to 1 if DSL or cable modem service is available in the wire center area.) Table 2-3 is the frequency table for line density. Notice that in our sample, 63 percent of the wire centers has DSL or cable modem service available. For our stratified sample selection, see Appendix A. Of the wire centers with AVAIL=1, the 65 percent belong to the 10,000 lines per square mile category. In contrast, the majority of the wire centers with AVAIL=0 belong to the 50 lines per square mile, 100 lines per square mile, and 1,000 lines per square mile categories. Another way to look at this is to compare the "column

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[103] I would like to thank StratSoft Inc for providing in-kind research support for this research project.

percent". It shows that 95 percent of wire centers with 10,000 lines per square mile has DSL or cable modem service available in their area, whereas 98 percent of the wire centers with less than 50 lines per square mile are without these services. So, this table indicates that higher line density at a wire center is associated with availability. Table 2-4 is the frequency table for telephone lines served by wire centers. This table tells the same story as that for line density, that is, the more lines served by a wire center, the more likely that the service area will have DSL and cable modem service available.

Table 2-5 is the frequency table for median household income. Looking at "column percent" for AVAIL=1, we can see that for the $55,000 median income category and the $75,000 median income category the percentage of wire center with service availability is over 80 percent. Comparing this with the 64 percent and 54 percent for median income categories of $15,000 and $35,000, we can see that the higher the median household income for a wire center area, the more likely services are available. This table suggests that wire centers with median household income higher than $55,000 are more likely to have service availability than wire centers with lower median income. This is consistent with the statistics reported by the FCC in its second report on Advanced Services. It concludes that high speed service availability rises with median household income. [104]

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[104] Federal Communications Commission. "Deployment of Advanced Telecommunications Capability: Second Report," *CC Docket No. 98-146* Washington, DC: Federal Communications Commission, August 2000, p.41 <http://www.fcc.gov/Bureaus/Common_Carrier/News_Releases/2000/nrcc0040.html>.

Table 2-6 is the frequency table for the percent of white householders in a wire center area. The table shows that in our sample, 76 percent of the wire centers belong to the "25 percent white householder" category. This means that more wire centers in our sample are in areas with a low percentage of white population, or a high percentage of minority population. Looking at the row and column percents, I do not see any significant pattern in the association between availability and this race variable.

Table 2-7 is the frequency table for percent of persons with less than high school education in a wire center area. Looking at the "column percent" for AVAIL=1, we can see that the lower the percent less than high school, the higher the probability of service availability. Of all the wire centers with percent less than high school lower than 10 percent, 88 percent of these wire centers have service availability. Of all the wire centers with percent less than high school at or over 30 percent, only 55 percent of these wire centers have service availability. This suggests that availability is positively related to the level of education.

Table 2-8 is the frequency table for percent of persons with age greater than 65 years. Looking at the row and column percents, I do not see any significant pattern in the association between availability and this age variable.

Table 2-9 is the frequency table for percent of households in urbanized area. Looking at the "row column", we can see that of all the wire centers without service availability (AVAIL=0), 43 percent are in the least urban category (0-25% urban). Of all the wire centers with service availability (AVAIL=1), 87% are in the most urban category (75-100% urban). This shows that availability is positively related to percent of households in urbanized area. In fact, this observation is consistent with the statistics reported by the FCC in its second report on Advanced Services. The FCC report looks at the relationship between population density and availability at the zip code level. It concludes that "high speed service availability rises with population density".[105]

These simple statistics show that without considering all factors involved, I see some possible association between availability and the selected explanatory variables. Line density, income, education level, and percent urban are all showing a positive association with availability. Race and age does not seem to be associated with availability in any uniform way.

2-3.3 Correlation

Having explanatory variables that are very correlated in the same statistical model can sometimes skew the effects of important variables and give misleading results. Calculating simple correlation coefficients for the explanatory variables is one way to check for correlation between variables. Table 2-9 shows the correlation coefficients for variables used in the basic regression model. Overall, I do not see very high correlation between the explanatory variables – the highest correlation is under 0.6. DSLFIN, which one of the dependent variable that I will use in the regression analysis, is showing a 0.69 correlation coefficient with percent urban. The variable for "T1 charges" (TOT_CHG) is

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105 Federal Communications Commission. "Deployment of Advanced Telecommunications Capability: Second Report," *CC Docket No. 98-146* Washington, DC: Federal Communications Commission, August 2000, p.40

also showing a higher correlation coefficient than other variables, -0.55. This gives us an idea of the possible association we will see in my regression results when all variables are used to explain availability in the same model. "Percent urban" and "median household income" are showing positive correlation with DSL availability, whereas the "charges" variable is showing a negative correlation. Absolute correlation between explanatory variables is higher at around 0.5 between percent urban and charges, percent urban and percent white householders, and percent without phone and income. The rest of the variables are showing absolute correlation of less than 0.4. Correlation between these variables is greater 0.5 but under 0.6.

Table 2-10 is the correlation table for percent urban and selected demographics variables. The absolute correlation between these variables are all less than 0.5. Percent urban is positively correlated with percent of foreign-born population and percent of persons in managerial occupation. Percent is negatively correlated with percent urban, implying that the percent of population belonging to minority groups tend to be higher in urbanized area.

To summarize, the variables I plan to include in the regressions are not highly correlated and I should be able to include them in the same regression model.

<http://www.fcc.gov/Bureaus/Common_Carrier/News_Releases/2000/nrcc0040.html>.

CHAPTER 3 RESULTS AND SUMMARY

Section 1 Logistic regression results

In this section, I provide a discussion of the regression results, presenting the different specifications. An explanation of how I arrive at the preferred model is given and conclusions from the data analysis are summarized.

3-1.1 Basic Availability Model

Table 3-1 shows the results of our basic availability model (Model 1). The dependent variable is AVAIL, which equals 1 if DSL or cable modem service is available in the wire center area. The explanatory included are line density[106], percent of households in urbanized area, age of housing stock (median year housing unit was built), and median household income. The logic for including these variables in our first model is that these are the basic factors that a firm considers when deciding whether to provide service in a wire center area. As discussed in section 2-1.2, potential demand and ability to pay are key factors affecting profitability of the investment by a provider. The age of housing stock is used here as a proxy for the "kinks" that the provider has to iron out before services can be provided. The older the housing stock, the more costly this process is expected to be.

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106 Line density is included instead of number of lines because the two variables are highly correlated and line density is less correlated with other explanatory variables.

The logit regression results suggest that the availability of DSL or cable modem services in a wire center area increases in those areas with increasing line density, percent of population in an urbanized area, and median income. The age of the housing stock has a positive and barely significant coefficient. The positive sign is consistent with expectations that the newer the housing stock (the higher the median year built), the more likely that these services will be available.

The chi-square test shows that the model as a whole is statistically significant. The pseudo R-square is 0.623, which is considered high for a cross-section data analysis. The marginal effects of each explanatory variable evaluated at the mean are presented at the bottom of the table. It shows that for the average wire center, if percent urban increased by one percent, the probability of DSL or cable modem service being available (on a 100% scale) increases by 0.2 percentage point. The marginal effect for MEDYRBLT is 0.4, implying that for the average wire center, if the age of the housing stock decreases by one year, the probability of availability increases by 0.4 percentage point. The marginal effects for line density are positive and statistically significant, but are not really significant in terms of the magnitude of their effects on availability.

Table 3-2 shows the results for the basic availability model with the RBOC dummy added (Model 2). The RBOC dummy is equal to one if the wire center belongs to a Regional Bell Operating Company, and hence is subject to the "line-of-business" restriction. The coefficient on RBOC is positive but insignificant. The coefficients on the other variables remain similar to those in our basic model, although to coefficient on MEDYRBLT becomes insignificant. The results of this model indicate that wire centers belonging to RBOCs are just as likely to provide DSL or cable modem services as non-RBOC wire centers. This suggests that the "271 restriction" does not discourage an RBOC-owned wire center from providing high-speed services.

The third model presented in Table 3-3 includes the same explanatory variables as the second model, but the dependent variable is now DSLFIN, which equals one if DSL service is available at a wire center area (Model 3)[107]. I want to see if this model with RBOC included has a different effect on DSL availability alone. Surprisingly, the RBOC dummy has a positive and significant coefficient in this model, suggesting that RBOC-owned wire centers are *more* likely than non-RBOC wire centers to provide DSL service. This again is evidence suggesting that the line-of-business restriction does not deter wire centers from providing high-speed services. The results indicate that if a wire center is owned by an RBOC, it is expected to be 3.4 percentage points more likely than non-RBOC wire centers to provide DSL services (on a 100% likelihood scale). The pseudo R-square for this model is 0.718.

Seeing the significance of the RBOC dummy in the DSL model, I ran a similar regression but with individual RBOC dummies instead of one RBOC dummy (Model 4). In other words, I put in a dummy for SBC (composed of Ameritech, Southwest, and Pacific Bell), one for NYNEX-Bell Atlantic (this is pre-Verizon merger), one for Bell

[107] For the DSL models, I tried a different specification to include the average fixed cost variable. Because the AVG_FC variable is defined as $50,000/square mile in a wire center area, we would not be able to include both line density and this variable due to correlation. However, the effects of AVG_FC and DENLINE1 could be estimated by algebraically manipulating the regression equation. The equation we estimate in the end looks as follows:

$$\ln(\text{AVAIL}) = \text{constant} + \beta \ln(\text{LINES}) + \gamma \ln(\text{square miles}), \text{ where}$$

$-\gamma$ is an estimate of the effect of line density, and $-(\gamma+\beta)$ is an estimate of the effect of average fixed costs. This did not work well in that the coefficient on the "percent urban" variable becomes negative and significant. Also, because I have another measure of production costs, e.g., T-1 charges, and because the AVG_FC variable only applies to the DSL model, I decided to exclude it from the models.

South, and one for US West. By including these separate dummies for the individual RBOCs, I am able to see whether there is a significant difference between the RBOCs in terms of affecting DSL availability. Table 3-4 contains the regression results. All four RBOC dummies have a positive coefficient, consistent with our results for the last model, but only NYNEX-Bell Atlantic and US West have a significant coefficient. All else equal, the results indicate that if a wire center is owned by NYNEX-Bell Atlantic or US West, it is expected to be about 4 percentage points more likely than non-RBOC wire centers to provide DSL services (on a 100% likelihood scale).

The next explanatory variable I look at is T1 charges for connecting to the nearest Internet backbone. Going back to the "availability" model (both cable modem and DSL), I take the basic model and add the "charges" variable (Model 5). The RBOC variable is excluded from this model because RBOC was insignificant in Model 2. The coefficient on TOT_CHG is negative and significant, implying that T1 charges are negatively related to availability. This is not contrary to expectations because access charge is a significant portion of the provider's costs. Increasing the charges for connecting to an Internet backbone would significantly decrease the profitability of the provider's investment in high-speed services, all else equal. The marginal effect of a $1 increase in the monthly T1 charges would decrease the likelihood of service availability by 0.03 percentage points (on a 100% scale). Similarly, a $10 increase in the charges would decrease this likelihood by 0.3 percentage point. The results on the other variables are similar to what we saw in Model 1, showing that my results are satisfactorily robust.

Table 3-6 contains the results for Model 4 with the "charges" variable added (Model 6). I obtained a significant effect of RBOC from Model 4 (DSL model with

RBOC), but once the "charges" variable is added, the RBOC coefficient becomes insignificant. A likelihood ratio test was done to test whether the RBOC variable belongs in the model. Results of the test suggest that I should leave it out. Therefore, I arrive at Model 7, which is the basic DSL model with Charges (Table 3-7). The results are similar to Model 5 with the same explanatory variables but with AVAIL as the dependent variable. Comparing marginal effects, the absolute negative effect of charges is higher for Model 5 (with AVAIL) than with Model 7 (with DSLFIN).

Lastly, in Table 3-8 and Table 3-9, I present the results of my preferred availability and DSL only models. I arrived at these preferred models by conducting likelihood ratios tests on all the demographics variables. As a result, I included a set of age variables, each representing the percentage of persons belonging to the age group. Only two age variables have significant coefficients: P_A3034 is positive but P_A3539 is negative. This suggests that the higher the percentage of persons in a wire center area belonging to the age group 30-34 years, the more likely DSL and cable modem services are available; the higher the percentage of persons belonging to the age group 35-39 years, the *less* likely services are available. I cannot offer any explanatory for the opposite effects of these two age groups. But these specifications once again prove that our results are robust in a satisfactory way.

To summarize, our regression data analysis indicate that availability is positively affected by line density, percent of households in urbanized area, and median household income, and is negatively affected by increase in T1 charges for connecting to an Internet backbone. The result on line density and percent urban confirmed our expectation that the higher the potential size of the market, the more likely provider will deploy high-speed technologies. The result on income also confirmed our expectation that ability to pay of potential customers can motivate a provider to deploy technologies. Lastly, the result on T1 charges confirmed our expectation that the higher the cost of providing service, the less likely services will be provided.

Section 2 Policy implications and direction of further research

The objective of Section 706 of the Telecommunications Act of 1996 is to encourage deployment of advanced telecommunications capabilities (ATCs) [108] "on a reasonable and timely basis . . . to all Americans." Specifically, Section 706(a) states:

> "The Commission and each [s]tate commission with regulatory jurisdiction . . . shall encourage the deployment on a reasonable and timely basis of advanced telecommunications capability to all Americans (including, in particular, elementary and secondary schools and classrooms) by utilizing, in a manner consistent with the public interest, convenience, and necessity, price cap regulation, regulatory forbearance, measures that promote competition . . . [or] . . . that remove barriers to infrastructure investment.[109]

The Section encourages the participation of both the Federal Communications Commission (FCC) and state public utility commissions (PUCs) to ensure that its pro-competitive and deregulatory strategy is appropriately implemented. Removing barriers to infrastructure investment is emphasized as a way to accelerate private sector deployment of advanced telecommunications capabilities. Underlying this deregulatory

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[108] Telecommunications Act of 1996, Pub. L. No. 104-104, section 706(c), 110 Stat. 153.
ADVANCED TELECOMMUNICATIONS CAPABILITY.—The term "advanced telecommunications capability" is defined, without regard to any transmission media or technology, as high-speed, switched, broadband telecommunications capability that enables users to originate and receive high-quality voice, data, graphics, and video telecommunications using any technology.
[109] Telecommunications Act of 1996, Pub. L. No. 104-104, section 706(a), 110 Stat. 153.

strategy is the basic assumption that competitive market forces will produce the most efficient economic outcome. However, as is common in most markets, the government still plays a role in correcting for market failures. In the case of advanced telecommunications services, our research suggests that at this early stage of the industry, we are far from achieving the goal of ubiquitous access for all Americans. Specifically, I found evidence that advanced telecommunications service is not being deployed in low-income and rural areas. Hence, government intervention may be necessary in order to achieve the goal of Section 706. If indeed the market has failed, and government intervention is necessary, there are different approaches that have been proposed to address the problem.

Tax incentives

To promote advanced capabilities, tax incentives could be used to encourage technology deployment. Implementing such a program would require that the size of the tax incentive be appropriately estimated and assigned, that is, the tax incentive should be sufficient to encourage firms to serve underserved markets but not sufficiently large that more funding is provided than is needed. In order to determine this, a government agency would need to create a model that estimates the cost of providing advanced services, and proceedings similar to those held for the implementation of the universal service program will have to be initiated. The process of establishing the support mechanism for the universal service program took the FCC over three years to complete, and there needs to be improvements on what was adopted in November 1999.[110] Creating a cost model suitable for advanced services will prove to be even more complicated than that for universal service. There are at least four ways by which advanced services are provided: xDSL, cable modems, satellite, and fixed wireless. It would be a - more time-consuming process to create a model that captures all four technologies, which is necessary to ensure that only minimum amount of support would be required in the future. Taking a long period of time is however not acceptable in an industry where technology is changing so rapidly. By the time the model is completed, the industry would likely be introducing new variations of the four types of technologies, or using completely new types of technology.

Auctions

An alternative to the provision of tax incentives is an the auction, whereby firms state the minimum amount of money that they would require in order to provide high-speed access to the Internet in low-income and rural areas. The auction winner would obtain the rights to provide services in a given geographic area and also receive support for providing those services. Although this approach ensures that the lowest-cost firm will get the contract, there are a few concerns about an auction when applied to the market for advanced telecommunications services.

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[110] Federal Communications Commission. "Federal-State Joint Board On Universal Service To Convene An Open Meeting On Wednesday." *CC Docket No. 96-45* Washington, DC: Federal Communications Commission, Released 29 Jul. 1998.

The government may want to award the right to serve an area to only one supplier. If this were the case, less of a subsidy would be required because a monopoly can more easily recover its investments in the technology over time. This brings up the question of how long the monopoly is to be granted. The monopoly cannot be a permanent one, because it would be contrary to Congress' goal in promoting competition. But, putting a time limit on the monopoly contract would discourage firms from even participating in the auction because there is less assurance that their investments could be completely recovered.

It would be difficult to establish the geographical unit for the auction contract because the different technologies have different potential levels of coverage. For the satellite companies, it makes sense to hold one auction for the forty-eight contiguous states because their reach is nation-wide. But the companies that use the other technologies have smaller footprints that are scattered across the country. Hence, a single auction for all forty-eight states would not work. This approach could be made feasible for the competitors of the satellite technologies if grand coalitions are allowed to be formed in order to have ubiquitous coverage. But the government would not want to encourage the industry players to form such horizontal coalitions, for they would be contrary to the pro-competitive goal of Congress. Therefore, it is unlikely that one auction could be held for the entire forty-eight states.

If a smaller geographical unit were to be used, then the cost to the satellite companies of participating in the auction could be raised significantly. Because their market is the entire country, they would incur the administrative costs of participating in auctions for multiple geographical areas. Even if the satellite companies are willing to bear these costs, there is still the question of how the service geographical areas should be defined. Should they be defined as the service territories of the wireless, cable, or the incumbent telephone companies? Choosing one of these would provide some advantage to one of the technologies. This violates the regulatory objective that the support mechanism should be technologically neutral.

Federal policy-makers may find the auction approach unattractive for another reason. With auctions, regulators have no control over the outcome. The government officials do not determine the level of support that needs to be provided; rather, the bidding determines the value. The policy-makers will likely be uncomfortable with a process where the auction determines the level of support but the policy-makers have to create a tax that raises the revenues associated with the outcome of the auction. Also, with the FCC universal service fund, the federal government has more of an opportunity to pass on most of the taxation to the States. The federal government only provides support for 25% of the fund for voice services. For high-speed access to the Internet, a service that the FCC has deemed to be exclusively interstate, arguably the federal government would have to provide 100% of the support. The federal policy makers will likely be unwilling to take on the financial burden associated with the auctions.

Apart from these two proposed regulatory approaches, whether state or federal government is in a better position to address the needs of the country is an important issue. Arguably, the states know their needs for infrastructure investment better than the federal government. If this proposition is true, it is the States that should be determining the need for support, rather than the federal government. On the other hand, the federal government needs to be involved as a mediator that balances the interest of rural states and those states that have no or little need for the creation of such a fund.

Discussion of different regulatory approaches may seem contradictory to the pro-competitive, deregulatory strategy of the Telecommunications Act of 1996. Section 706 states that the government agencies should remove barriers to infrastructure investment in order to speed the deployment of advanced services. But it does not require the agencies to provide any kind of support for these services. There is, however, another Section in the 1996 Act that does mention a support requirement. Section 254 states that the government should provide support for those services that are subscribed to by a majority of telecommunications users. Reading these two Sections in conjunction provide a more complete and more consistent picture of the 1996 Act.

At the current state of the development of these technologies, I recommend that the government continue to monitor the issue of "ubiquitous access for all Americans" and not offer any prescriptive remedy. There is a lot of innovation taking place in this industry that may provide a quick solution to the problem. Given the complications and costs associated with the proposed regulatory approaches, government should hold off providing tax incentives or any other type of support until there is clear evidence of market failure. At this early stage of the industry, it is not clear that there will be a market failure. It is possible that the market is in the process of achieving the goal of Section 706 on its own, with little government intervention, as new technologies become available to make deployment less costly.

Although our research suggests that in the first quarter of 2000, rural and low-income households are less likely to have access to Cable Modem and xDSL service, this only shows that the technology is being deployed faster in urbanized, high-income areas. It, however, does not provide evidence that technology will not be deployed in other areas in the near future. To address this question, I will have to continue to collect data and create a database that will allow us to look at changes in technology deployment over time.

Table 1-1 Backbone Market Share — Number of ISP Backbone Connections[111]

MCI	31.3%
Sprint	22.4%
UNNET/ANS/CIS	20.4%
AGIS	4.4%
GTE	4.1%
DIGEX	2.4%
Other	2.4%
CRL	2.0%
PSINet/iSTAR	1.8%
GoodNet	1.5%
DataXchange	1.0%
SAVVIS	0.9%
Verio	0.9%
Nap.Net	0.9%
CWIX	0.9%
GridNet	0.7%
AT&T	0.6%
IBM	0.6%
TCG/CERFnet	0.5%
CAIS	0.5%

Source: Boardwatch Magazine

[111]Morgan Stanley Dean Witter . The Internet Data Services Report 11 Aug. 1999, p.34 <http://www.msdw.com/techresearch/inetdata/index.html>.

Table 1-2 MSO Cable Modem Customer Rankings as of June 30, 2000 for North America (US/Canada)[112]

Source: Kinetic Strategies, Inc.

MSO	Cable Modem Customers	Cable Modem Market Share
AT&T/MediaOne	689,030	23%
Time Warner	573,000	19%
Cox	320,349	11%
Rogers	265,900	9%
Shaw	253,000	8%
Comcast	237,200	8%
Charter	149,300	5%
Cablevision	93,350	3%
Videotron	85,000	3%
Adelphia	71,157	2%
Cogeco	64,000	2%
RCN	40,292	1%
Other	196,000	6%
TOTAL	3,037,578	100%

[112] Cable Datacom News. "Cable Modem Market Stats & Projections." *Cable Datacom News* 16 August 2000 <http://www.cabledatacomnews.com/cmic/cmic16.html >.

Table 1-3 Road Runner (Time Warner Cable) Availability [113]

USA Markets	
California	Bakersfield, Fresno , Los Angeles (Media One), Los Angeles (Time Warner), San Diego,
Florida	Central Florida (Brevard, Seminole and Orange Counties), Fort Myers, Jacksonville, Miami, Naples, Pompano Beach , Tampa Bay (Hillsborough and Pinellas Counties),
Georgia	Atlanta
Hawaii	Oahu
Kansas	Wichita
Maine	Portland, South Maine
Massachusetts	Boston, Cape Cod, Fall River,New Bedford, Pittsfield, Springfield
Michigan	Ann Arbor, Detroit, Plymouth
Minnesota	Twin Cities (Media One),Twin Cities (Time Warner)
Mississippi	Jackson
Missouri	Kansas City
New Hampshire	Concord, Portsmouth, Salem,
New York	Albany, Binghamton, Corning,Elmira, Ithaca, New York City,Norwich, Oneida,Oswego, Rochester, Troy,Saratoga, Syracuse
North Carolina	Charlotte, Greensboro, Raleigh, Wilmington
Ohio	Akron, Canton, Cincinnati , Cleveland suburbs, Columbus, Lima/North Area, Youngstown,Central Ohio
Oklahoma	Oklahoma City (suburbs)
Oregon	Bend, Sisters, and Black Butte
Pennsylvania	Johnstown
Tennessee	Bartlett,Collierville, Cordova, Memphis, East Memphis, Germantown, Southeast Memphis
South Carolina	Columbia
Texas	Austin, El Paso, Houston, San Antonio, Waco
Virginia	Fairfax County, Richmond
Upcoming launches in 2000	
Nebraska	Lincoln
Wisconsin	Green Bay, Milwaukee

[113] Time-Warner Cable. "In your Neighborhood." *Time-Warner Cable Website* accessed on 15 Sept. 2000 < http://www.roadrunner.com/rdrun/>.

Table 1-4 DSL Market (include both Consumer and Business Customers) – December 1999[114]

Note: Customers "passed" have a DSLAM in the nearest telco central office. Homes too far away (more than 18,000 feet from central office), served through a digital loop carrier, etc must be subtracted to determine "serve-ability".

Company	12/99 (K) Customers	Market Share	Serveable (M)	Passed (M)	Future projections
SBC	155	31%	10	13	1M in 2000, 7-10M in 2005 Universal broadband available
US West	110	22%	4	6	
Covad	60	12%	22	27	290K in 2000
GTE	55	11%	6.1	10	
Bell South	35	7%	5.5	9	Deployment doubling in 2000
Bell Atlantic	30	6%	10	13	500K in 2000, 7M in 2004,80% + territory coverage
Northpoint	23	5%	22	27	
Broadwing	17	3%	0.7	1	
Rhythms	12	2%	22	27	
Sprint	< 10	< 2%	2.5	3.4	
@Link	< 5	< 1%			1000 COs 2000
Allegiance	< 5	< 1%	1.2	1.5	
Bluestar	< 5	< 1%			500 COs 2000
Choice One	< 5	< 1%	1.8	2.4	
DSL.net	< 5	< 1%	1.3	1.8	
Harvardnet	< 5	< 1%	1.8	2.4	
JATO	< 5	< 1%	1.7	2.4	875 COs by end 2000
NAS	< 5	< 1%	8	11	
New Edge Networks	< 5	< 1%	-	-	just starting, going for 50 states
Prism/Comdisco	< 5	< 1%	1.4	2	33 cities, 800 COs in 2000
Vitts	< 5	< 1%	1	1.5	planning 1500 COs for 2001
Others	<15	< 3%			
US Total	**500**		**780**	**780**	

Bell Atlantic and GTE have since merged to become Verizon.

Qwest and USWest have since merged- became Qwest. Qwest's DSL offering called Megabits is primarily a business offering.

[114] DSL Prime. "US DSL Deployment and Subscribers." *DSL Prime Website.* Updated 4 Feb. 2000 <http://www.dslprime.com/News_Articles/Availability/availability.html>.

Table 2-1 Problems with the Web [115]
Oct.1998

Speed	61.40%
Broken Links	57.10%
Find New Info.	45.40%
Find Known Info.	30.00%
Organize Info.	27.60%
Revisit Found Sites	16.60%
Cost	7.90%
Other	10.60%

Source: GVU Research

[115] Problems with the Web p.16
The Internet Data Services Report August 11, 1999 MORGAN STANLEY DEAN WITTER
Morgan Stanley Dean Witter . The Internet Data Services Report 11 Aug. 1999 , p.16
<http://www.msdw.com/techresearch/inetdata/index.html>.

Table 2-2 Variable Description

AVAIL	AVAIL=1 if DSL or cable modem service is available in a wire center area.
DSLFIN	DSLFIN=1 if DSL service is available in a wire center area.
DENLINE1	Line Density (total telephone lines per square mile)
RBOC	RBOC=1 if Telephone service provided by a Regional Bell Operating Companies
AM_SW_PB	RBOC dummy for Ameritech, Southwest, PacBell
NX_BA	RBOC dummy for NYNEX or Bell Atlantic
BS	RBOC dummy for Bell South
US	RBOC dummy for US West
PCTNPHOH	Percent households without telephone service
PCTURBHU	Percent housing units – in urbanized area
MEDYRBLT	Median year housing structure built
MEDHHINC	Median Household Income
PCTBLKH	Percent Householders - Black
PCTAMIH	Percent Householders - Amer Ind, Esk, Aleut
PCTASIH	Percent Householders - Asian, Pacific Island
PCTWHTH	Percent householders –White
P_A13	Percent persons age 13 or younger
P_A1418	Percent persons age 14-18
P_A1924	Percent persons age 19-24
P_A2529	Percent persons age 25-29
P_A3034	Percent persons age 30-34
P_A3539	Percent persons age 35-39
P_A4049	Percent persons age 40-49
P_A5064	Percent persons age 50-64
P_A65	Percent persons age 65+
AVG_FC	Fixed costs divided by number of access lines
TOT_CHG	Estimated monthly charge for connection to the nearest Internet backbone
MISSTOT	Equals 1 for the 25 wire centers without information on connection charges
PCTLHSP	Percent of persons with less than high school education
PCTHSP	Percent of persons with high school education
PCTSCOLP	Percent of persons with some college education
PCTCOLP	Percent of persons with four year college education
PCTCOLMP	Percent of persons with graduate level education
PCTMGRP	Percent of persons in managerial occupation
PCTFORBP	Percent of persons who are foreign-born

Table 2-3 Descriptive Statistics: Line Density and Availability

Telephone Lines Per Square Mile

avail		50	100	1,000	10,000	140,000	Total
0	wire center frequency	41	19	39	6	0	105
	row percent	39%	18%	37%	6%	0%	100%
	column percent	98%	90%	46%	5%	0%	37%
1	wire center frequency	1	2	45	119	15	182
	row percent	1%	1%	25%	65%	8%	100%
	column percent	2%	10%	54%	95%	100%	63%
Total	wire center frequency	42	21	84	125	15	287
	row percent	15%	7%	29%	44%	5%	100%
	column percent	100%	100%	100%	100%	100%	100%

Telephone Lines Per Square Mile
50 = denline>0 & denline<51
100 = denline>50 & denline<101
1,000 = denline>100 & denline<1,001
10,000 = denline>1,000 & denline<10,001
140,000 = denline>10,000 & denline<140,001

There are no wire center in our sample with more than 140,000 lines per square mile.

Table 2-4 Descriptive Statistics: Number of Lines and Availability

Telephone Lines in Wire Center Area

avail		100	1,000	10,000	140,000	>140,000	Total
0	wire center frequency	2	21	38	44	0	105
	row percent	2%	20%	36%	42%	0%	100%
	column percent	100%	100%	86%	20%	0%	37%
1	wire center frequency	0	0	6	175	1	182
	row percent	0%	0%	3%	96%	1%	100%
	column percent	0%	0%	14%	80%	100%	63%
Total	wire center frequency	2	21	44	219	1	287
	row percent	1%	7%	15%	76%	0%	100%
	column percent	100%	100%	100%	100%	100%	100%

Telephone Line
100 = lines>50 & lines<101
1,000 = lines>100 & lines<1,001
10,000 = lines>1,000 & lines<10,001
140,000 = lines>10,000 & lines<140,001
>140,000 = lines>140,000

There are no wire center in our sample with fewer than 50 lines.

Table 2-5 Descriptive Statistics: Median Household Income and Availability

Median Household Income of Wire Center Area

avail		$15,000	$35,000	$ 55,000	$75,000	$ 105,000	Total
0	wire center frequency	5	90	8	2	0	105
	row percent	5%	86%	8%	2%	0%	100%
	column percent	36%	46%	12%	18%	0%	37%
1	wire center frequency	9	104	59	9	1	182
	row percent	5%	57%	32%	5%	1%	100%
	column percent	64%	54%	88%	82%	100%	63%
Total	wire center frequency	14	194	67	11	1	287
	row percent	5%	68%	23%	4%	0%	100%
	column percent	100%	100%	100%	100%	100%	100%

Median Household Income
$ 15,000 = medhhinc<$15,001
$ 35,000 = medhhinc>$15,000 & medhhinc<$35,001
$ 55,000 = medhhinc>$35,000 & medhhinc<$55,001
$ 75,000 = medhhinc>$55,000 & medhhinc<$75,001
$105,000 = medhhinc>$75,000 & medhhinc<$105,001

There are no wire center in our sample with median household income greater than $105,000.

Table 2-6 Descriptive Statistics: Percent White Householders and

Percent White Householders in Wire Center Area

avail		25%	50%	75%	100%	Total
0	wire center frequency	88	15	1	1	105
	row percent	84%	14%	1%	1%	100%
	column percent	40%	29%	8%	17%	37%
1	wire center frequency	130	36	11	5	182
	row percent	71%	20%	6%	3%	100%
	column percent	60%	71%	92%	83%	63%
Total	wire center frequency	218	51	12	6	287
	row percent	76%	18%	4%	2%	100%
	column percent	100%	100%	100%	100%	100%

Percent White Householders
25% = less than or equal to 25%
50% = greater than 25% and less than or equal to 50%
75% = greater than 50% and less than or equal to 75%
100% = greater than 75% and less than or equal to 100%

Availability

Table 2-7 Descriptive Statistics: Percent Persons with Less Than High School Education and Availability

Percent Persons with Less Than High School Education in Wire Center Area

avail		10%	20%	30%	40%	> 40%	Total
0	wire center frequency	4	24	35	27	15	105
	row percent	4%	23%	33%	26%	14%	100%
	column percent	13%	29%	45%	44%	45%	37%
1	wire center frequency	28	59	43	34	18	182
	row percent	15%	32%	24%	19%	10%	100%
	column percent	88%	71%	55%	56%	55%	63%
Total	wire center frequency	32	83	78	61	33	287
	row percent	11%	29%	27%	21%	11%	100%
	column percent	100%	100%	100%	100%	100%	100%

Percent Persons with Less Than High School Education
10% = less than or equal to 10%
20% = greater than 10% and less than or equal to 20%
30% = greater than 20% and less than or equal to 30%
40% = greater than 30% and less than or equal to 40%
> 40% = greater than 40%

There are no wire center in our sample with greater than 75% of persons with less than high school . education

Table 2-8 Descriptive Statistics: Percent Persons with Age > 65 Years and Availability

Percent Persons Age>65 in Wire Center Area

avail		5%	10%	15%	20%	25%	> 25%	Total
0	wire center frequency	3	14	47	33	0	8	105
	row percent	3%	13%	45%	31%	0%	8%	100%
	column percent	33%	22%	37%	50%	0%	53%	37%
1	wire center frequency	6	50	81	33	5	7	182
	row percent	3%	27%	45%	18%	3%	4%	100%
	column percent	67%	78%	63%	50%	100%	47%	63%
Total	wire center frequency	9	64	128	66	5	15	287
	row percent	3%	22%	45%	23%	2%	5%	100%
	column percent	100%	100%	100%	100%	100%	100%	100%

Percent Persons Age>65
5% = less than or equal to 5%
10% = greater than 5% and less than or equal to 10%
15% = greater than 10% and less than or equal to 15%
20% = greater than 15% and less than or equal to 20%
25% = greater than 20% and less than or equal to 25%
> 25% = greater than 25%

There are no wire center in our sample with greater than 50% of persons age>65.

Table 2-9 Descriptive Statistics: Percent households in urbanized area and Availability

Percent Households in Urbanized Area in Wire Center Area

avail		25%	50%	75%	100%	Total
0	wire center frequency	45	13	22	25	105
	row percent	43%	12%	21%	24%	100%
	column percent	92%	93%	79%	13%	37%
1	wire center frequency	4	1	6	171	182
	row percent	2%	1%	3%	94%	100%
	column percent	8%	7%	21%	87%	63%
Total	wire center frequency	49	14	28	196	287
	row percent	17%	5%	10%	68%	100%
	column percent	100%	100%	100%	100%	100%

Percent Households in Urbanized Area in Wire Center Area

25% = less than or equal to 25%

50% = greater than 25% and less than or equal to 50%

75% = greater than 50% and less than or equal to 75%

100% = greater than 75% and less than or equal to 100%

Table 2-10 Descriptive Statistics: Correlation

Correlation Table - DSLFIN and Explanatory Variables

	DSLFIN	PCTNPHOH	PCTURBHU	MEDYRBLT	MEDHHINC	TOT_CHG	PCTWHTH
DSLFIN	1.000						
PCTNPHOH	-0.259	1.000					
PCTURBHU	0.691	-0.211	1.000				
MEDYRBLT	-0.027	-0.132	-0.024	1.000			
MEDHHINC	0.331	-0.575	0.241	0.311	1.000		
TOT_CHG	-0.551	0.228	-0.546	-0.029	-0.276	1.000	
PCTWHTH	-0.233	-0.345	-0.348	0.278	0.294	0.232	1.000

Table 2-11 Descriptive Statistics: Correlation

Correlation Table - Percent Urban and Selected Demographic Variables

	PCTURBHU	PCTWHTH	PCTLHSP	PCTFORP	PCTMGRP	P_A65
PCTURBHU	1.000					
PCTWHTH	-0.348	1.000				
PCTLHSP	-0.166	-0.490	1.000			
PCTFORP	0.391	-0.326	0.206	1.000		
PCTMGRP	0.398	0.157	-0.715	0.111	1.000	
P_A65	-0.085	0.214	0.159	-0.033	-0.146	1.000

Table 3-1 Econometric Results: Basic Availability Model

Logit Estimates			Number of obs =	287
			chi2(4) =	169.660
			Prob > chi2 =	0.000
Log Likelihood =	-51.304		Pseudo R2 =	0.623
AVAIL	**Coef.**	**Std. Err.**	**z**	**P>|z|**
DENLINE1	0.002	0.001	2.517	0.012
PCTURBHU	0.022	0.009	2.535	0.011
MEDYRBLT	0.054	0.032	1.676	0.094
MEDHHINC	0.000	0.000	4.428	0.000
Constant	-112.023	62.585	-1.790	0.073
Variable	**Marginal Effect**	**Marginal Effect on 100% Scale**	**Mean of X**	
DENLINE1	0.000	0.012	516.196	
PCTURBHU	0.002	0.172	23.517	
MEDYRBLT	0.004	0.418	1959.493	
MEDHHINC	0.000	0.001	26031.356	
Constant	-8.741			

Table 3-2 Econometric Results: Basic Availability Model with RBOC

Logit Estimates			Number of obs =	287
			chi2(5) =	169.780
			Prob > chi2 =	0.000
Log Likelihood =	-51.247		Pseudo R2 =	0.624
AVAIL	**Coef.**	**Std. Err.**	**z**	**P>|z|**
DENLINE1	0.002	0.001	2.501	0.012
RBOC	0.222	0.650	0.341	0.733
PCTURBHU	0.021	0.009	2.215	0.027
MEDYRBLT	0.052	0.032	1.615	0.106
MEDHHINC	0.000	0.000	4.057	0.000
Constant	-108.904	63.059	-1.727	0.084

Variable	**Marginal Effect**	**Marginal Effect on 100% Scale**	**Mean of X**
DENLINE1	0.000	0.012	516.196
RBOC	0.017	1.717	0.307
PCTURBHU	0.002	0.161	23.517
MEDYRBLT	0.004	0.403	1959.493
MEDHHINC	0.000	0.001	26031.356
Constant	-8.431		

Table 3-3 Econometric Results: Basic DSL Model with RBOC

Logit Estimates			Number of obs =	287
			chi2(5) =	177.700
			Prob > chi2 =	0.000
Log Likelihood =	-34.975		Pseudo R2 =	0.718
DSLFIN	**Coef.**	**Std. Err.**	**z**	**P>|z|**
DENLINE1	0.001	0.000	2.155	0.031
RBOC	1.874	0.828	2.264	0.024
PCTURBHU	0.032	0.011	2.754	0.006
MEDYRBLT	0.031	0.037	0.838	0.402
MEDHHINC	0.000	0.000	4.212	0.000
Constant	-69.960	72.392	-0.966	0.334
Variable	**arginal Effect**	**Marginal Effect on 100% Scale**	**Mean of X**	
DENLINE1	0.000	0.002	516.196	
RBOC	0.034	3.371	0.307	
PCTURBHU	0.001	0.057	23.517	
MEDYRBLT	0.001	0.056	1959.493	
MEDHHINC	0.000	0.000	26031.356	
Constant	-1.258			

Table 3-4 Econometric P .sults: Basic DSL Model with Individual RBOC Dummies

Logit Estimates			Number of obs =	287
			chi2(8) =	178.970
			Prob > chi2 =	0.000
Log Likelihood =	-34.341		Pseudo R2 =	0.723
DSLFIN	**Coef.**	**Std. Err**	**. z**	**P>|z|**
DENLINE1	0.001	0.000	2.245	0.025
PCTURBHU	0.033	0.012	2.792	0.005
MEDYRBLT	0.056	0.044	1.267	0.205
MEDHHINC	0.000	0.000	3.130	0.002
AM_SW_PB	1.291	0.953	1.355	0.175
NX_BA	2.480	1.065	2.329	0.020
BS	1.197	0.998	1.200	0.230
US	2.399	1.366	1.756	0.079
Constant	-118.344	86.347	-1.371	0.171
Variable	**Marginal Effect**	**Marginal Effect on 100% Scale**	**Mean of X**	
DENLINE1	0.000	0.002	516.196	
PCTURBHU	0.001	0.060	23.517	
MEDYRBLT	0.001	0.102	1959.493	
MEDHHINC	0.000	0.000	26031.356	
AM_SW_PB	0.023	2.347	0.089	
NX_BA	0.045	4.507	0.083	
BS	0.022	2.176	0.095	
US	0.044	4.360	0.036	
Constant	-2.151			

Table 3-5 Econometric Results: Basic Availability Model with Charges

Logit Estimates			Number of obs =	287
			chi2(6) =	178.840
			Prob > chi2 =	0.000
Log Likelihood =	-46.717		Pseudo R2 =	0.657
AVAIL	**Coef.**	**Std. Err.**	**z**	**P>|z|**
DENLINE1	0.001	0.001	2.083	0.037
PCTURBHU	0.025	0.010	2.381	0.017
MEDYRBLT	0.056	0.032	1.751	0.080
MEDHHINC	0.000	0.000	3.656	0.000
TOT_CHG	-0.007	0.003	-2.306	0.021
MISSTOT	0.007	0.003	2.398	0.016
Constant	-115.818	62.948	-1.840	0.066
Variable	**Marginal Effect**	**Marginal Effect on 100% Scale**	**Mean of X**	
DENLINE1	0.000	0.005	516.196	
PCTURBHU	0.001	0.096	23.517	
MEDYRBLT	0.002	0.218	1959.493	
MEDHHINC	0.000	0.000	26031.356	
TOT_CHG	0.000	-0.028	514.403	
MISSTOT	0.000	0.026	295.913	
Constant	-4.486			

Table 3-6 Econometric Results: Basic DSL Model with RBOC and Charges

Logit Estimates			Number of obs =	287
			chi2(7) =	184.700
			Prob > chi2 =	0.000
Log Likelihood =	-31.475		Pseudo R2 =	0.746
DSLFIN	**Coef.**	**Std. Err**	**. z**	**P>|z|**
DENLINE1	0.001	0.000	1.650	0.099
RBOC	1.258	0.937	1.342	0.180
PCTURBHU	0.026	0.012	2.211	0.027
MEDYRBLT	0.025	0.038	0.655	0.513
MEDHHINC	0.000	0.000	3.697	0.000
TOT_CHG	-0.007	0.004	-1.991	0.047
MISSTOT	-0.001	0.007	-0.207	0.836
Constant	-55.333	74.349	-0.744	0.457
Variable	**Marginal Effect**	**Marginal Effect on 100% Scale**	**Mean of X**	
DENLINE1	0.000	0.000	516.196	
RBOC	0.002	0.230	0.307	
PCTURBHU	0.000	0.005	23.517	
MEDYRBLT	0.000	0.005	1959.493	
MEDHHINC	0.000	0.000	26031.356	
TOT_CHG	0.000	-0.001	514.403	
MISSTOT	0.000	0.000	295.913	
Constant	-0.101			

Table 3-7 Econometric Results: Basic DSL Model with Charges

Logit Estimates			Number of obs =	287
			chi2(6) =	182.860
			Prob > chi2 =	0.000
Log Likelihood =	-32.392		Pseudo R2 =	0.738
DSLFIN	**Coef.**	**Std. Err**	**z**	**P>|z|**
DENLINE1	0.001	0.000	1.694	0.090
PCTURBHU	0.027	0.012	2.323	0.020
MEDYRBLT	0.030	0.036	0.825	0.409
MEDHHINC	0.000	0.000	3.811	0.000
TOT_CHG	-0.008	0.004	-2.261	0.024
MISSTOT	-0.004	0.006	-0.626	0.531
Constant	-64.593	71.301	-0.906	0.365
Variable	**Marginal Effect**	**Marginal Effect on 100% Scale**	**Mean of X**	
DENLINE1	0.000	0.000	516.196	
PCTURBHU	0.000	0.003	23.517	
MEDYRBLT	0.000	0.003	1959.493	
MEDHHINC	0.000	0.000	26031.356	
TOT_CHG	0.000	-0.001	514.403	
MISSTOT	0.000	0.000	295.913	
Constant	-0.074			

Table 3-8 Econometric Results: Basic Availability Model with Age and Charges

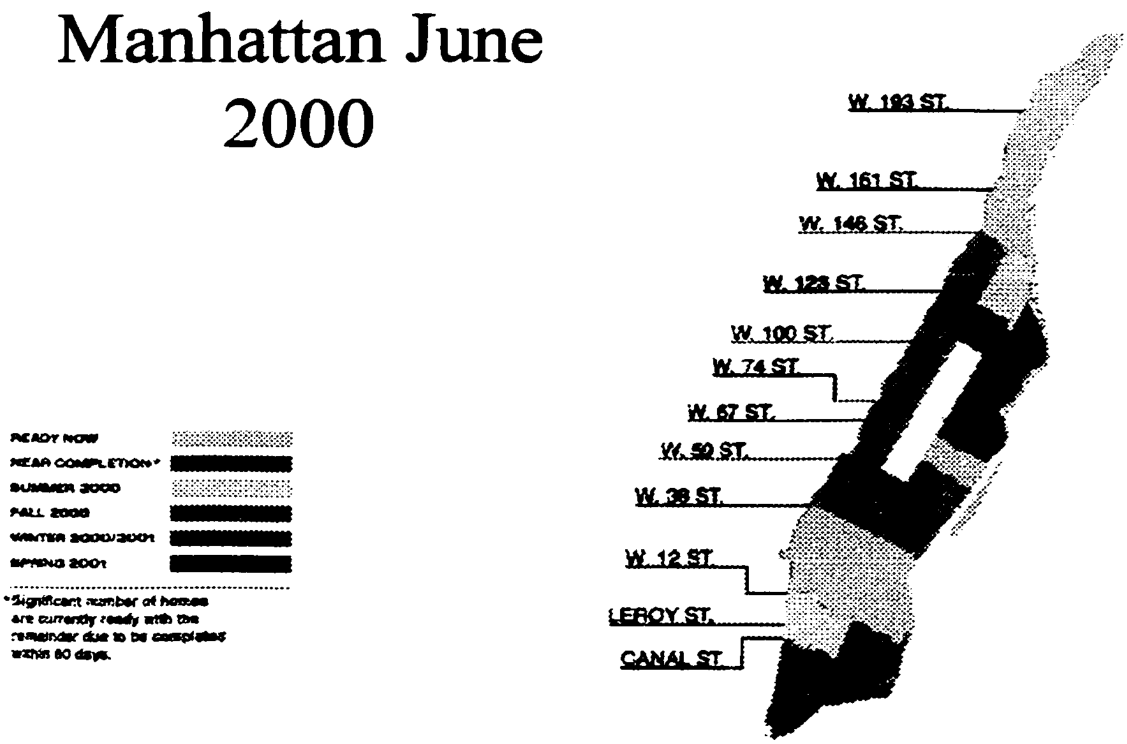
Logit Estimates			Number of obs =	287
			chi2(13) =	193.840
			Prob > chi2 =	0.000
Log Likelihood =	-39.215		Pseudo R2 =	0.712
AVAIL	**Coef.**	**Std. Err.**	**z**	**P>|z|**
DENLINE1	0.001	0.001	1.780	0.075
PCTURBHU	0.019	0.013	1.478	0.139
MEDYRBLT	0.060	0.038	1.575	0.115
MEDHHINC	0.000	0.000	2.002	0.045
TOT_CHG	-0.012	0.004	-3.105	0.002
MISSTOT	0.010	0.003	3.155	0.002
P_A13	-0.339	0.177	-1.917	0.055
P_A1418	0.233	0.409	0.569	0.569
P_A1924	0.069	0.121	0.573	0.567
P_A2529	0.225	0.273	0.824	0.410
P_A3034	0.692	0.272	2.541	0.011
P_A3539	-0.620	0.375	-1.654	0.098
P_A4049	0.250	0.257	0.972	0.331
Constant	-122.515	74.381	-1.647	0.100

Variable	**Marginal Effect**	**Marginal Effect on 100% Scale**	**Mean of X**
DENLINE1	0.000	0.001	516.196
PCTURBHU	0.000	0.019	23.517
MEDYRBLT	0.001	0.059	1959.493
MEDHHINC	0.000	0.000	26031.356
TOT_CHG	0.000	-0.012	514.403
MISSTOT	0.000	0.010	295.913
P_A13	-0.003	-0.333	20.978
P_A1418	0.002	0.229	6.899
P_A1924	0.001	0.068	6.815
P_A2529	0.002	0.221	7.446
P_A3034	0.007	0.679	8.186
P_A3539	-0.006	-0.609	7.978
P_A4049	0.002	0.245	12.399
Constant	-1.203		

Table 3-9 Econometric Results: Basic DSL Model with Age and Charges

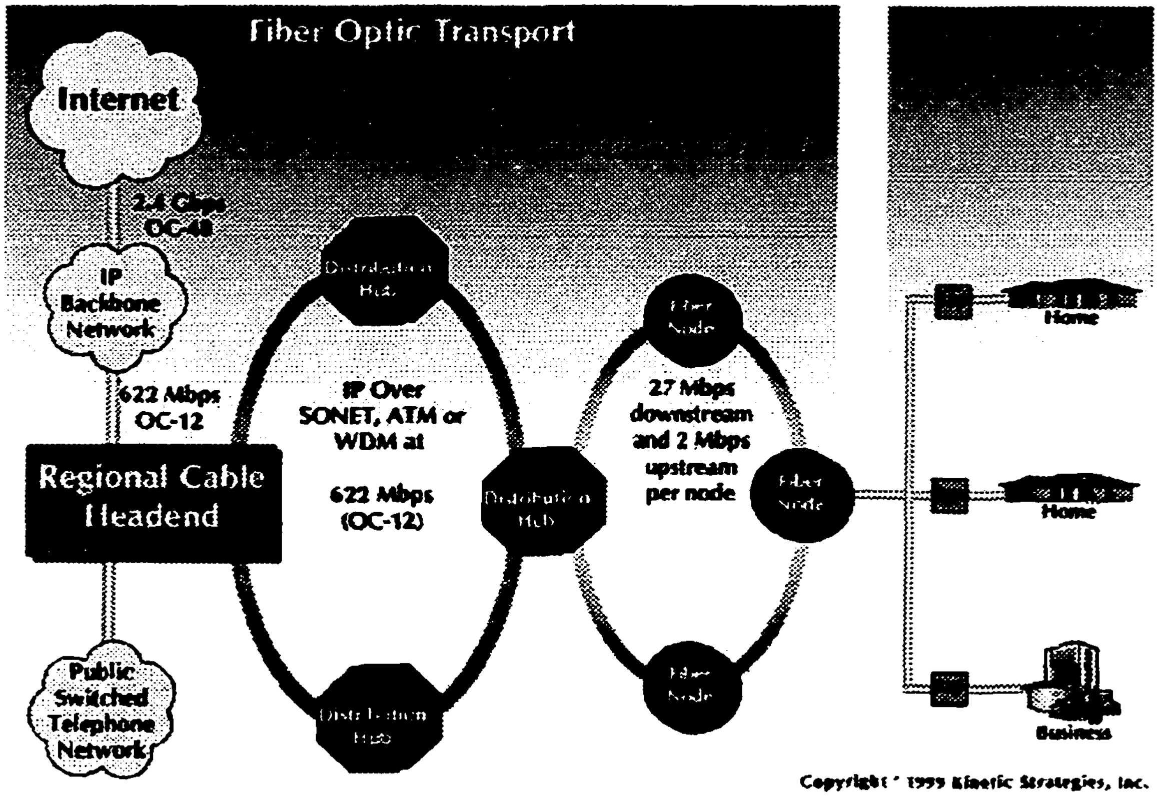
Logit Estimates			Number of obs =	287
			chi2(13) =	188.030
			Prob > chi2 =	0.000
Log Likelihood =	-29.811		Pseudo R2 =	0.759
DSLFIN	**Coef.**	**Std. Err.**	**z**	**P>|z|**
DENLINE1	0.001	0.000	1.728	0.084
PCTURBHU	0.029	0.015	1.856	0.063
MEDYRBLT	0.035	0.041	0.856	0.392
MEDHHINC	0.000	0.000	1.220	0.223
TOT_CHG	-0.009	0.004	-2.231	0.026
MISSTOT	-0.006	0.008	-0.688	0.491
P_A13	-0.021	0.179	-0.117	0.906
P_A1418	-0.455	0.540	-0.842	0.400
P_A1924	0.043	0.134	0.321	0.749
P_A2529	-0.233	0.312	-0.746	0.456
P_A3034	0.647	0.371	1.744	0.081
P_A3539	-0.284	0.423	-0.673	0.501
P_A4049	0.334	0.340	0.983	0.325
Constant	-76.256	81.364	-0.937	0.349
Variable	**Marginal Effect**	**Marginal Effect on 100% Scale**	**Mean of X**	
DENLINE1	0.000	0.000	516.196	
PCTURBHU	0.000	0.001	23.517	
MEDYRBLT	0.000	0.001	1959.493	
MEDHHINC	0.000	0.000	26031.356	
TOT_CHG	0.000	0.000	514.403	
MISSTOT	0.000	0.000	295.913	
P_A13	0.000	-0.001	20.978	
P_A1418	0.000	-0.015	6.899	
P_A1924	0.000	0.001	6.815	
P_A2529	0.000	-0.007	7.446	
P_A3034	0.000	0.021	8.186	
P_A3539	0.000	-0.009	7.978	
P_A4049	0.000	0.011	12.399	
Constant	-0.024			

Figure 1-1 Availability of Cable Modem Service in Manhattan from Time Warner Cable[116]



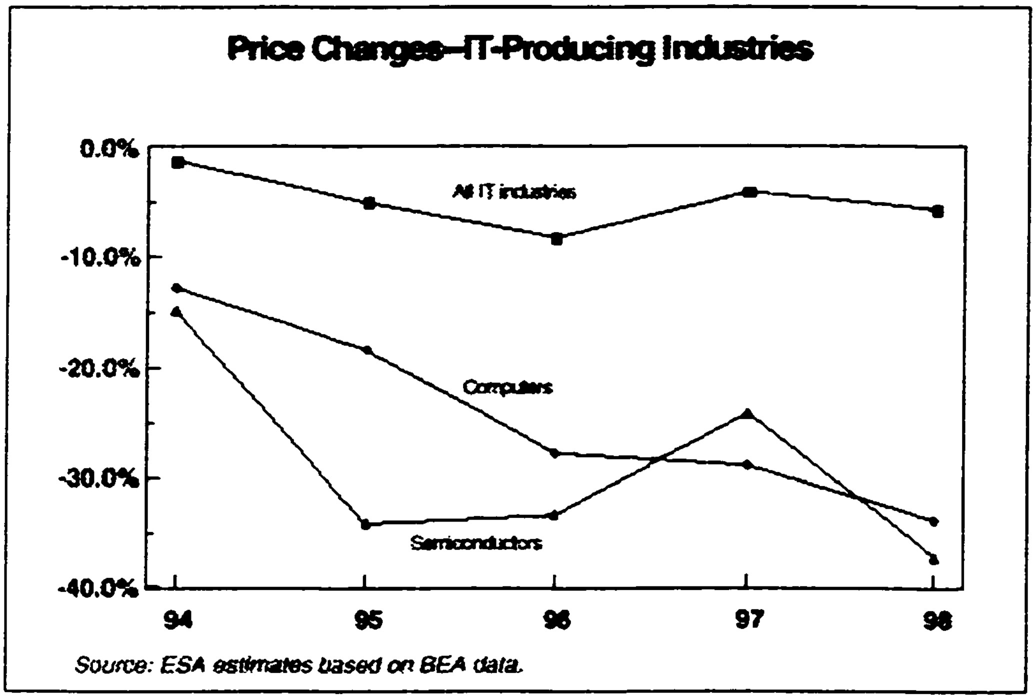
[116] Time-Warner Cable. "In your Neighborhood." *Time-Warner Cable Website* accessed on 15 Sept. 2000 < http://www.roadrunner.com/rdrun/>.

Figure 1-2 Cable Data Network Architecture[117]



[117] Cable Datacom News. "Cable Data Network Architecture." *Cable Datacom News Website* accessed on 15 Sept. 2000 <http://www.cabledatacomnews.com/cmic/diagram.html>.

Figure 2-1 Price Changes – IT-Producing Industries[118]



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[118] Economics And Statistics Administration, Office of Policy Development. Digital Economy 2000. Washington, DC: U.S. Department of Commerce, June 2000, p.25 <http://www.esa.doc.gov/de2000.pdf>.

Appendix A: Sample Selection - Stratified Sampling

There are 19,928 wire centers in the United States. I determined a statistically valid sample size of 287 using the formula:

$$n = \left(\frac{z\sqrt{p(1-p)}}{e} \right)^2$$

where n = sample size

z = z-value for 95% level of confidence

p = probability that DSL service is available at a central office

e = acceptable level of error (3%).

Dslreports.com posts a list containing the number of central offices by state and the number of those central offices with DSL. From this, I calculated p, the probability that DSL service is available at a central office in the United States. Based on our objectives of having a sample size where our margin of error was within three percentage points of the population mean ninety-five percent of the time, I determined that I needed a sample size of 286 addresses.

I then needed to select a random sample of this size from the wire centers. I decided that a stratified random sampling method is appropriate because about 75% of all wire centers have fewer than 7,500 access lines. In these small wire centers the fixed cost of providing xDSL service makes it less economical to provide service than in larger central offices. In these small wire centers, there is less of a likelihood that service will be available. Therefore, I divided wire centers into three strata: fewer than 7,500 lines, 7,501-45,000 lines, and more than 45,001 lines.

For the three strata, I selected random samples of 43, 122, and 122 wire centers respectively. These are 15.0%, 42.5%, and 42.5% of the total sample size. Whereas this sampling produces a sample that is not representative of the characteristics of the population of wire centers,[119] I make adjustments in our regression analysis by assigning appropriate weights to wire center in each strata.

[119] The unit of the observation is the wire center because we are modeling the investment decisions of firms. Providers of xDSL service install the technology in wire centers and therefore this is the correct unit of observation for the modeling of xDSL technology. For cable modems, the unit used for investment decisions is not observable. As shown by the map of Manhattan, the geographical unit considered for investments is clearly not the city nor the borough. To the best of our knowledge, there is no publicly available data that identifies at a finer level of detail the geographic area which cable companies consider when they decide if to offer cable modem service. Nevertheless the economic and demographic characteristics of a wire center should not be radically different than the similar characteristics of a cable company's service territory.

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