# Accessibility of Broadband Telecommunication Services by Various Segments of the American Population

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## Abstract

Technology such as the Internet is becoming an important ingredient for economic and social advancement. There is a growing national concern about the ability of all segments of the American society to be able to access and benefit from advanced telecommunications services. In this research we estimate the impact that supply costs, demographic and economic variables have on the decision to offer residential broadband services. By controlling for the various factors that influence a firm's decision to enter a market, we model the factors that explain the variation in the availability of broadband data services. The results from this analysis provide insights into a number of interesting academic and policy questions. Consistent with previous research done on general Internet access, our results suggest that high-speed access to the Internet is more likely to be available in urbanized area. As expected, the higher the line density, the more likely services are available. Also, we found that the higher the average fixed cost, the less likely advanced technology will be deployed. Our statistical analysis also suggests that residential customers in areas served by Regional Bell Operating Companies, all else equal, are equally likely to have high-speed access to the Internet as customers served by Independent telephone companies.

**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 services 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 segments of American

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1 We would like to thank StratSoft Inc for providing in-kind research support for this research project. We would also like to thank Steven Burns and Zeng Yu Chen for their able research assistance.

2 National Telecommunications and Information Administration. US Department of Commerce. Falling Through the Net: Defining the Digital Divide., July 1999

3 In our 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: *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, Adopted March 18, 1999, Released March 31, 1999, ¶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, 10/25/99, http://www.nwfusion.com/archive/1999/78877_10-25-1999.html.) While AT&T, through its MediaOne acquisition, is busy rolling out cable modem hookup options to consumers throughout the country.

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.[8] In a related proceeding,[9] 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[10] (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 its recent *First Report and Order and Further Notice of Proposed Rulemaking; In the Matters of Deployment of Wireline Services Offering Advanced*

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[6] William E. Kennard, *Consumer Choice Through Competition*, Remarks Before the National Association of Telecommunications Officers and Advisors 19th Annual Conference (September 17, 1999). 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, 06/21/00, http://www.nwfusion.com/news/2000/0621eleven.html.

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

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

[9] *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*, Released July 7, 1999 (FCC 99-141) ("Further Notice of Proposed Rulemaking").

[10] 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).

*Telecommunications Capability*, where it has adopted "…measures that we consider critical steps in encouraging the competitive provision of advanced services."[11]

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."[12] 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. The study presented here is offered as a step in the development of that understanding.

In designing this study we were interested in examining where advanced service is and is not available. In addressing this matter we recognized that we needed to look at what is happening in different markets. We 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.[13] We have used a level of granularity that is finer than the city. This is necessary because, as the map from Time-Warner's web site illustrates, there can be a lot of variation with a city.[14]

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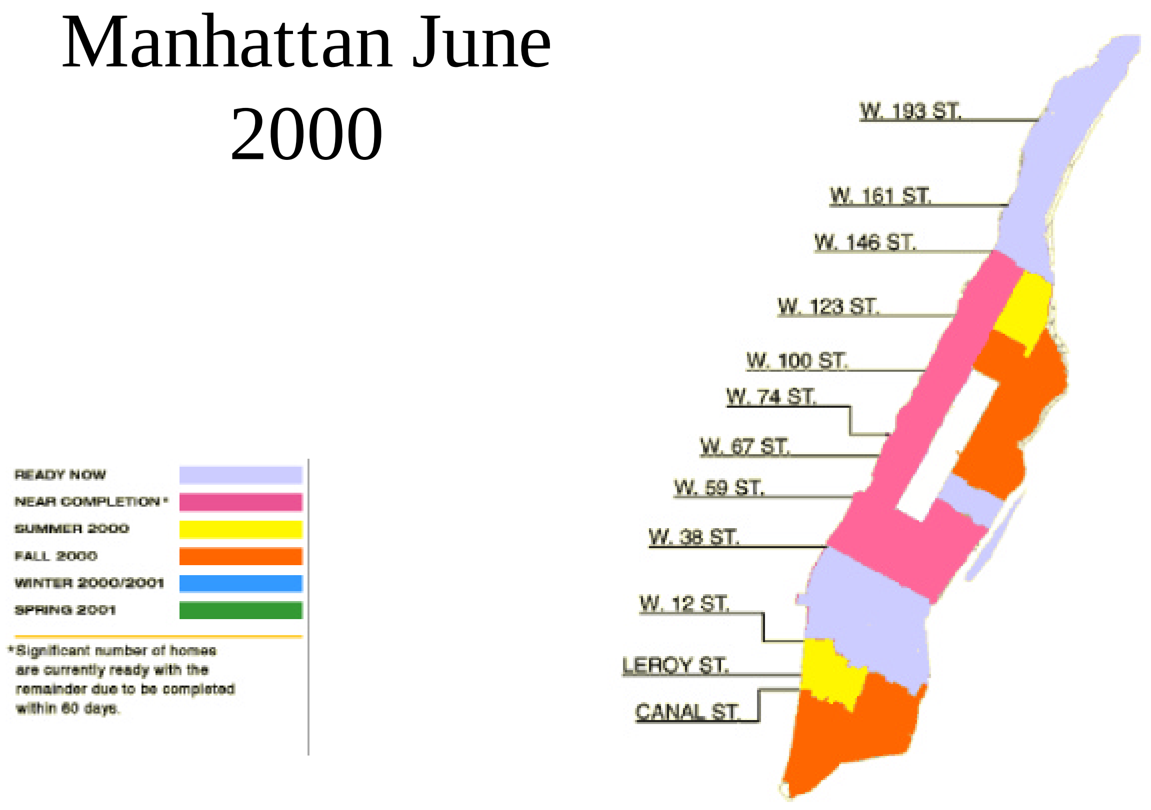
[11] FCC 99-48, Adopted March 18, 1999, Released March 31, 1999, ¶21.
[12] *Id.*, at 17.
[13] See, for example, Eric R. Olbeter and Matt Robison, *Breaking the Backbone: The Impact of Regulation on Internet Infrastructure Deployment*, iAdvance, July 27, 1999; National Telecommunications and Information Administration and Rural Utilities Service, Advanced Telecommunications in Rural America: The Challenge of Bringing Broadband Service to All Americans (Washington: April 2000),, appendix A and B.
[14] Map is from the Time-Warner Website and can be seen at Http://www.twcnyc.com/rr/maps/man_base.html.




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. We have undertaken this analysis to see what influence such factors as income, race, and regulation may have on the availability of high-speed access to the Internet for residential customers.

**Prior Studies that Addressed Access to the Internet**

Limited research on broadband usage and access is available. The U.S. Department of Commerce recently 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.[15] 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 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.”[16] 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.

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[15] National Telecommunications and Information Administration. US Department of Commerce. Falling Through the Net: Defining the Digital Divide., July 1999, 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.

[16] *Id.*, at 85.

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”.[17] While this finding may suggest close to universal access for traditional narrowband Internet access, the same cannot be suggested for broadband access such as that via Digital Subscriber Line (DSL) and cable modem. Narrowband Internet access (traditional dial-up) 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[18]. 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 infrastructure rollout is still in its nascent stage, the availability of Internet service via these technologies is growing but is far from universal[19]. Due to the fact that consumers are limited by inadequate infrastructure, we believe that it is important to understand the factors that affect the availability of these services.

The Federal Communications Commission has announced the completion of a study of the availability of high-speed and advanced telecommunications services. The Commission found “that advanced telecommunications capability is being deployed in a reasonable and timely fashion overall, although the Commission identified certain groups of consumers that are particularly vulnerable to not receiving service in a timely fashion.” The Commission identified five groups as being particularly vulnerable of not having access to advanced services if deployment is left to market forces alone:

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[17] Thomas A. Downes and Shane M. Greenstein. “Do Commercial ISPs Provide Universal Access?” Working Paper, December 2, 1998

[18] U.S. household telephone penetration rate as of December 1998 is estimated at 94.1%. (Falling Through the Net, Department of Commerce. July 1999)

[19] Approximately one-third of U.S. homes currently have access to at least one high-speed Internet access service. (IDC, “Broadband to the Home: A Revolution in Internet Access”, January 2000)

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[20]

Our study 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. We have focused on these two technologies because, as recently reported by the federal government, only these two technologies are rapidly being deployed to provide two-way, high-speed access to the Internet.[21] 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.

**Objectives**

In this paper we 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. We look at residential broadband services offered by telephone and cable television operators, with a focus on high-speed Internet access via xDSL and cable

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[20] Federal Communications Commission, "FCC Issues Report on the Availability of High-Speed and Advanced Telecommunications Services," August 3, 2000. As of August 13, 2000 only the press release had been issued.

Our data set does not include any information from U.S. territories.

[21] NTIA and RUS, Advanced Telecommunications in Rural America, p. ii.

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 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.[22]

Based on our understanding of the telecommunications network, there are a few crucial factors that impact the decision to offer service. 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. We 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.[23] 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 population density. For a

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standard telephone lines and therefore should not be characterized as two-way broadband service.

[22] Kinetic Strategies Inc., Cable Datacom News, web site accessed July 17, 2000 at http://cabledatacomnews.com.

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. http://www.xdsl.com/content/resources/deployment_info.asp

[23] 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

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 our conversations with industry suppliers, as well as other published research, we have estimated the cost of transport from the local market to the Internet backbone by estimating the cost of connecting to the nearest interexchange carrier's point of presence.[24]

We 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.[25] We 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,[26] 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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instead relies on census information to estimate the interest in the service.

[24] See, for example, NTIA and RUS, Advanced Telecommunications in Rural America, p. 9.

[25] Pub. L. No. 104-104, 110 Stat. 56 (1996) (codified at scattered sections of 47 U.S.C.). See, especially, §276.

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

**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.Data**

We examine the availability of broadband services at the wire center level of observation.[27] For our estimation, we used data from three different sources. First we 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. DSL and cable modem service availability data were collected from various company and technology websites, which we were able to map to wire center locations. For a few locations, additional data was obtained by calling service providers. We 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. The resulting database contains the following variables:

- Switch Identity - to determine the geographic boundaries and demographics of a wire center service area. For the purpose of this study the switch identity will be the Common Language Location Identifier (CLLI code);
- Company Type - the type of company supplying telecommunications services: Regional Bell Operating Company and name of RBOC;
- Average Fixed Costs – Proxy measure for the average fixed costs of a xDSL provider is calculated as fixed costs divided by the number of access lines at wire center. Average fixed

[27] 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.

cost is the fixed cost divided by the number of DSL subscribers. Since we do not have data for the latter value, we use lines to represent the potential market for the service.

- Line Density – the number of access lines per square mile.
- Demographics such as race, age, education, income, and residence in urbanized area.
- Availability – dummy equals one if residential DSL or cable modem service is available.

**Basic Estimation Model**

We are 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. We have employed one of these specifications, logit. If we had used a different specification, say probit, our qualitative results would not have changed.

In this section we outline the logit specification. For readers that are most interested in the results of the analysis, they may want to jump ahead to the sections on results (page 15~~14~~) or policy implications of the study (page 24~~22~~).

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 $p_i$ = the conditional probability that DSL or cable modem service is available at wire center $i^{th}$, and (1-$p_i$ ) 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

$$\log\left(\frac{p_i}{1-p_i}\right) = \log Y_i = a + b_1(D_i) + b_2(R_i) + b_3(U_i) + b_4(M_i) + b_5(H_i) + b_6(T_i),$$

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.

**Testable Hypothesis**

Given the basic model and the data we have available, 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 us 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 us to test the significance of the potential size of customer pool per square mile.
C) Bell Operating Company - The coefficient estimate will allow us to test if the line-of-business restrictions established by the 1996 Telecommunications Act is promoting or hindering the development of broadband services.[28]
D) Percentage of households without telephones - The coefficient estimate will allow us to test whether or not having a telephone decreases the likelihood that DSL service is available to a household.
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 us 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.

[28] 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.

F) Percentage of households/residents in Rural or metropolitan area- The coefficient estimate will permit us 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 us to test if broadband access is less available to minority groups.

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

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

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

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

## Results

In this section we present the results from our model. First we look at the availability of either cable modem or DSL service. We then focus on just the DSL market.

The logit regression results suggest that the availability of DSL or cable modem services in a wire center area increases in those areas with decreasing monthly costs of connecting to the Internet backbone and increasing line density, percent of population in an urbanized area, and median income. Model A (Table 2) shows the results for the preferred model specification. The dependent variable is AVAIL, which takes on the value of one if either DSL or cable modem service is available in the wire center area. Notice that variables such as race, education, and foreign-born population do not appear as explanatory variables in the regression. In determining whether certain variables should be included, we conducted likelihood ratio (LR) tests for each set of these variables. The LR test evaluates whether the maximized log-likelihood for the restricted model ($LnL_R$) is significantly less than that from the unrestricted model ($LnL_{max}$), the restriction being the exclusion of the variables tested.[29] That is, if ($LnL_R$ - $LnL_{max}$) is significantly different from zero, it means that by including the variables being tested, the overall significance of the model increases, and those variables should be included in the model. The results of separate LR tests on education, race, and foreign-born population suggest that these variables should not be included in our regression. Stated differently, the statistical test suggests that after controlling for other factors, such as income and if a household is located in an urban area, there is no discrimination in the provision of advanced services to minority households.

One demographic factor that we included in the model is age. The coefficients suggest that the higher the percentage of persons in the 30-34 age group, the more likely that advanced services are available.

When the RBOC dummy is added to the regression, the coefficient is positive but insignificant. We also tried a specification with the set of dummies representing the individual RBOCs, the coefficients have different signs for the different RBOCs, but all are insignificant. As a last check, a LR test is done testing the joint significance of these dummies, and the results suggest that we should leave them out of the regression. These statistical tests suggest that residential customers in areas served by Regional Bell Operating Companies, all else equal, are equally likely to have high-speed access to the Internet as customers served by Independent telephone companies.

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[29] Kennedy, Peter, A Guide to Econometrics, Third Edition, Cambridge, MA: The MIT Press,, 1993 , p.61-62.

The percent of households without telephone service is not significant in any of our models. This is expected because there is not a lot of variation in this variable. For our sample of 287 wire centers, the mean value for this variable is 93%, suggesting that very few households are actually without telephone service. We did not include this variable in our preferred model. Line density is included instead of “number of access lines” because the two variables are highly correlated, and line density seems to be less correlated with other explanatory variables. For our preferred model, the Pseudo $R^2$ is 0.712, a high value for cross-section analysis. This statistic suggests that approximately 71% of the variation in the dependent variable is being explained by our model specification. The model chi-square is 193.84, suggesting that our model is highly statistically significant.

Marginal effects evaluated at the mean are shown at the bottom of table two. The age variables seem to have the largest effect on availability, but it is important to note that the value that the age variables can take on is within the range 0.00 to 1.00. If P_A3034=0.08, it means that 8% of the population in the wire center belong to the age group. Taking this into account by re-scaling, the age coefficient on P_A3034 really suggests that, at the mean, a one point increase in the percent of persons belonging to the 30-34 age range would increase the AVAIL by 0.0067, which means that on a 100% scale, it increases the likelihood of service availability by 0.67 percentage point.

Similar re-scaling needs to be done for the effect of “percent urban”, which also ranges from 0.00 to 1.00. After re-scaling, a one-point increase in the percent of persons in urbanized area would increase AVAIL by 0.00019, and on a 100% scale, it increases the likelihood of service availability by 0.019 percentage point. The interpretation of the marginal effects of the other variables is more straight-forward. A one unit increase in the line density of the wire center increases the likelihood of service availability by 0.001 percentage point on a 100% scale. On a 100% scale, the marginal effect of a $1 increase in median household income on service availability seems insignificantly small. But if we change the scale and look at the effect of a $1,000 increase in median income on service availability, then the marginal effect needs to be multiplied by 1000. The result is that, at the mean, a $1,000 increase in median income increases the likelihood of service availability by 0.11 percentage point on a 100% scale. Similarly, a $10,000 increase in median income would increase the likelihood of service availability by 1.1 percentage points.

A $1 increase in the monthly cost of transport, the cost of connecting to an Internet backbone, would decrease the likelihood of service availability by 0.012 percentage point on a 100% scale. A $10 increase in this cost will decrease the likelihood of service availability by 0.12 percentage point on a 100% scale, and a $100 increase in this cost will decrease the likelihood of service availability by 1.2 percentage points on a 100% scale.

Table 3 shows the results for Model B, where the dependent variable is DSL, which takes on the value of one if DSL service is available in the wire center area, and zero otherwise. This contrasts with Model A whose dependent variable is AVAIL. AVAIL includes both DSL and cable modem service availability. Results for Model B are not much different from Model A, except for the coefficients on income and the age variables. Notice that the coefficient on median income is positive but *not* significant. Also, the marginal effects on the age variables are much smaller than those in Model A. A LR test is done for the age variables and the results suggest that for this model, we should exclude the age variables. In Table 4, the results of Model C are shown. The age variables are excluded, and the income coefficient becomes significant again. Comparing Model C to Model A, the results are similar, but the marginal effects for all the variables are smaller in Model C than in Model A.  In other words, at the mean, the effects of these factors on DSL availability is less than on DSL and cable modem availability.

Table 1. Variable Description

| | |
|---|---|
| **DENLINE1** | Line Density (total telephone lines per square mile) |
| **RBOC** | 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 |
| **PCTNWHTH** | Percent householders – Non-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 |
| **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 |
| **PCTFORBP** | Percent of persons who are foreign-born |

## Econometric Results

Table 2: Model A

| Logit Estimates | | | Number of obs = | 287 |
|---|---|---|---|---|
| | | | chi2(7) = | 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[**] | 1.941 | 1.313 | 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 | -33.932 | 17.704 | -1.917 | 0.055 |
| P_A1418 | 23.300 | 40.915 | 0.569 | 0.569 |
| P_A1924 | 6.930 | 12.104 | 0.573 | 0.567 |
| P_A2529 | 22.508 | 27.305 | 0.824 | 0.410 |
| P_A3034 | 69.154 | 27.213 | 2.541 | 0.011 |
| P_A3539 | -62.002 | 37.476 | -1.654 | 0.098 |
| P_A4049 | 24.986 | 25.717 | 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 | 0.019 | 1.906 | 0.235 | |
| 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[*] | -0.333 | -33.328 | 0.210 | |
| P_A1418 | 0.229 | 22.885 | 0.069 | |
| P_A1924 | 0.068 | 6.807 | 0.068 | |
| P_A2529 | 0.221 | 22.107 | 0.074 | |
| P_A3034 | 0.679 | 67.923 | 0.082 | |
| P_A3539 | -0.609 | -60.899 | 0.080 | |
| P_A4049 | 0.245 | 24.541 | 0.124 | |
| Constant | -1.203 | -120.334 | | |

[**] The value that the “percent urban” can take on is within the range of 0.00 to 1.00. If PCTURBHU=0.23, it means that 23% of the households in the wire center area live in an urbanized area.

[*] The value that the age variables can take on is within the range of 0.00 to 1.00. If P_A3034=0.08, it means that 8% of the population in the wire center area belong to the age group.

Table 3: Model B

| Logit Estimates | | | Number of obs = | 287 |
|---|---|---|---|---|
| | | | chi2(7) = | 188.030 |
| | | | Prob > chi2 = | 0.000 |
| Log Likelihood = | -29.811 | | Pseudo R2 = | 0.759 |
| **DSL** | **Coef.** | **Std. Err.** | **z** | **P>\|z\|** |
| DENLINE1 | 0.001 | 0.000 | 1.728 | 0.084 |
| PCTURBHU** | 2.872 | 1.548 | 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* | -2.097 | 17.854 | -0.117 | 0.906 |
| P_A1418 | -45.476 | 54.010 | -0.842 | 0.400 |
| P_A1924 | 4.309 | 13.444 | 0.321 | 0.749 |
| P_A2529 | -23.272 | 31.198 | -0.746 | 0.456 |
| P_A3034 | 64.676 | 37.081 | 1.744 | 0.081 |
| P_A3539 | -28.439 | 42.284 | -0.673 | 0.501 |
| P_A4049 | 33.419 | 33.982 | 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 | 0.001 | 0.092 | 0.235 | |
| 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 | -0.001 | -0.067 | 0.210 | |
| P_A1418 | -0.015 | -1.459 | 0.069 | |
| P_A1924 | 0.001 | 0.138 | 0.068 | |
| P_A2529 | -0.007 | -0.746 | 0.074 | |
| P_A3034 | 0.021 | 2.074 | 0.082 | |
| P_A3539 | -0.009 | -0.912 | 0.080 | |
| P_A4049 | 0.011 | 1.072 | 0.124 | |
| Constant | -0.024 | -2.446 | | |

Table 4: Model C

** The value that the "percent urban" can take on is within the range of 0.00 to 1.00. If PCTURBHU=0.23, it means that 23% of the households in the wire center area live in an urbanized area.

* The value that the age variables can take on is within the range of 0.00 to 1.00. If P_A3034=0.08, it means that 8%

| Logit Estimates | | | Number of obs = | 287 |
|---|---|---|---|---|
| | | | chi2(7) = | 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** | 2.683 | 1.155 | 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 | 0.003 | 0.307 | 0.235 | |
| 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 | -7.382 | | |

of the population in the wire center area belong to the age group.

** The value that the "percent urban" can take on is within the range of 0.00 to 1.00. If PCTURBHU=0.23, it means that 23% of the households in the wire center area live in an urbanized area.

**Policy Implications**

The objective of Section 706 of the Telecommunications Act of 1996 is to encourage deployment of advanced telecommunications capabilities (ATCs) [30] "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.[31]

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 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, we found evidence that advanced telecommunications service is not

[30] 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.

[31] Telecommunications Act of 1996, Pub. L. No. 104-104, section 706(a), 110 Stat. 153.

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.[32] 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

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[32] *In the Matter of Federal-Joint Board on Universal Service,* CC Docket No. 96-45.

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.

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, we 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, we will have to continue to collect data and create a database that will allow us to look at changes in technology deployment over time.

## Appendix A: Sample Selection - Stratified Sampling

There are 19,928 wire centers in the United States. We 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, we 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, we determined that we needed a sample size of 286 addresses.

We then needed to select a random sample of this size from the wire centers. We 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, we 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, we 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,[33] we make adjustments in our regression analysis by assigning appropriate weights to wire center in each strata.

The data was collected in February 2000.

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[33] 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.