The Timing of Broadband Provision: The Role of Competition and Demographics

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Abstract:

This chapter examines the supply of DSL broadband by the incumbent local exchange company (LEC) in five Midwestern states in the earlier years of deployment in the U.S. Income, other demographics, and cost factors are important determinants of entry and availability. After controlling for other factors, the racial characteristics of the area do not affect DSL provision. Active competition in broadband from competitive LECs reduces the likelihood the incumbent deploys DSL, but potential competition from competitive LECs increases the likelihood of incumbent deployment. Competition from cable companies also negatively influences the DSL supply decision, in accord with the carrying capacity hypothesis for entry decisions.

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I. Introduction

The worldwide explosion in the growth of broadband infrastructure is allowing countries to enjoy productivity gains in industries that heavily use communications. Consumers also are deriving increased benefits from the availability of broadband connection to the Internet, as the technology lowers the time cost of some applications (e.g., downloading music) and creates entirely new possibilities (e.g., telemedicine).[1] Households typically connect to the Internet through digital subscriber line (DSL) service provided on their telephone line or through cable modem service. Although broadband technology of these and other types is diffusing rapidly, some policy makers in the U.S. and abroad are concerned that not all regions within countries are receiving broadband access at the same time. The phenomenon of unequally diffusing information and communications technology is known as the "digital divide." The digital divide in the U.S. takes the form of a well-documented gap in computer and Internet usage between richer and poorer households, majority and minority groups, and urban and rural areas (Newberger, 2001; NTIA, 2002; Mills and Whitacre, 2003; Fairlie, 2004). Broadband Internet access has become one of the latest aspects of the digital divide to be discussed, examined, and lamented in arenas of public policy.

In the early years of broadband Internet adoption, the U.S. Department of Commerce (NTIA, 2000) issued an influential report showing that black and Hispanic households had less access to broadband Internet access than did white households. The report also found that households in rural areas were less likely than urban households to

[1] Crandall and Jackson (2003) estimate that the value of the benefits to consumers in the U.S. from broadband Internet access (net of subscription cost) reaches the hundreds of billions of dollars yearly.

subscribe to broadband access, and that lower-income households lagged the subscription rates of more affluent households. The U.S. Federal Communications Commission (FCC) opined that low subscription to broadband services in rural, low-income, and minority areas was due at least in part to a lack of availability (FCC, 2000a). Since availability—the supply of broadband infrastructure by communications providers—is necessary for the household to subscribe to broadband service, fundamental analysis of the broadband digital divide must begin on the supply side.

What are the determinants of the supply side of the digital divide? Both the demographic characteristics of the territory and competition among broadband service providers play a role in entry in the broadband market. The racial composition and income of a market may influence broadband supply directly through overt discrimination (sometimes called “redlining” in the U.S.) on the part of the providers, or (more likely, according to the profit maximization hypothesis and Prieger (2003)), through reducing the demand in an area (and therefore the profit) perceived by a potential supplier. Competition in local communications also affects broadband access. For example, incumbent telephone and cable companies may be more likely to provide broadband access to “meet the competition” when they face broadband competitors (the competitive stimulus hypothesis). On the other hand, if potential entrants deem a market large enough to support one broadband provider but not two, then the availability of cable modem service (for example) will discourage deployment of DSL (the carrying capacity, or market size, hypothesis modeled by Bresnahan and Reiss (1987)). If competition is an important driver of broadband availability, then policy efforts to close the digital divide should encourage competition. Although the data we examine are from the U.S., the public policy concerns of the digital divide and the issue of the role of competition in broadband rollout are universal.

In this chapter, we examine the supply of DSL broadband by the incumbent local exchange company (LEC) in five Midwestern states in the U.S. Our objective is to gauge the importance in the DSL entry decision of the various market and competitive factors discussed above. The preliminary findings in this study show that there is no evidence that race *per se* matters in the supply of DSL once the impact of the income of the area is removed. However, household income does matter, with lower-income areas receiving less access. We also find that the education levels, average length of commute, size of firms in the area, and costs affect the deployment of DSL. The effect of competition in the area is in accord with the carrying capacity hypothesis.

II. Literature Review

A growing body of literature exists on the determinants of broadband availability in an area. Our study has the advantage of examining a precise geographical market for DSL deployment, the wire center serving area. This allows us to gather exact demographic characteristics of the markets, as would be considered by the decision makers at the potential broadband providers. Previous studies in the economics literature looking at deployment throughout the U.S. typically examine postal service code areas[2] (Flamm, 2005; Xiao and Orazem, 2005; Grubesic and Murray, 2004; Prieger 2003) or counties (Gillett and Lehr, 1999), neither of which conform to telecommunications geography. Gabel and Kwan (2001) also use the wire center serving area as the unit of observation. Studies considering broadband diffusion within a state or metropolitan area

[2] Postal codes are known as “ZIP codes” in the U.S.

have used other geographical units. For example, Grubesic (2003) uses the finest level of geography available for each type of provider (townships for cable modem providers and wire centers for DSL providers) in his study of broadband availability in Ohio.

The studies on the determinants of broadband availability generally confirm that rural and low-income areas are less likely to have broadband available, but the set of variables included in the estimations can greatly influence the conclusions. For example, Prieger (2003) uses a nationally comprehensive broadband survey by the FCC to examine the income and racial aspects of the supply side of the digital divide. The author shows that if the only area characteristics included in an estimation for the availability of broadband are the racial composition, urban density, and the identity of the incumbent telephone company, then areas with more minorities appear to be less likely to have broadband. However, one cannot draw a causal link between race and supply-side overt discrimination, because once Prieger (2003) controls for income, the statistical significance of the racial composition of the area disappears. Furthermore, when Prieger (2003) introduces additional demographic and business characteristics of the area to the estimation, the author found that there is no evidence of unequal availability based on race *or* income, except for Native Americans. Rural location and demand characteristics such as age, education, commuting time, gender, and size of businesses in the area were determinants of broadband availability that were more important.

There are many more studies on household-level demand for broadband Internet access than there are on supply (see other chapters of this book for citations). A few studies (Burnstein and Aron, 2003; Wallsten, 2005) commingle supply and demand and examine the factors determining the state-level penetration rate (the ratio of subscribers to total households in a state). These studies consider the impact of competition (among other factors) on the penetration rate. Burnstein and Aron (2003) find that intermodal competition between cable companies and telecommunications firms is positively correlated with broadband penetration. In a similar vein, Wallsten (2005) finds that states with more competition in local telephony (as proxied by the number of telephone lines sold by competitive local exchange carriers) have higher broadband penetration rates. One disadvantage of using state-level penetration rates is that the relatively small number of observations makes identifying driving factors problematic.

The most ambitious of the broadband entry studies, those mentioned above using the FCC data from postal service code areas, are subject to criticism because broadband access is not necessarily ubiquitous in an area.[3] Thus, using characteristics of the postal code areas subjects the broadband deployment estimations to measurement error bias, since the characteristics of the actual geographical market may be different.[4] One contribution of our study is that by examining the unit of actual deployment of DSL, the central office area, we are able to test conclusions from earlier studies in a setting free from the measurement error bias that stems from geographical imprecision. For example, we find that there is no evidence that race matters in the supply of DSL, which confirms the finding of Prieger (2003). We thus lend credence to the methods used in the previous studies.

[3] The FCC data list a ZIP code if there is at least one broadband subscriber whose premises are in the ZIP code area. Researchers then treat the listed codes as having broadband available, and all ZIP codes not on the list as not having broadband available. In large ZIP code areas, not all parts of a ZIP code on the FCC's list may be in the actual broadband service areas, however. Prieger (2003) and Flamm (2005) discuss the issue at length.

[4] Measurement error bias is also known as error-in-variables bias. See Cameron and Trivedi (2005, ch. 26) for a textbook treatment of the issue.

III.The Decision to Deploy Broadband Infrastructure

There are several steps involved when a household connects to the Internet via broadband access. Consider the case of DSL first, the mode of access examined in this chapter. Data moves across various networks from the Internet backbone until it reaches the local exchange carrier's central office. The central office is the carrier's point of presence in the local exchanges, and contains the telecommunications switching and DSL multiplexing equipment. From the central office, data is transmitted over a DSL connection residing on the telephone line between the central office and the subscriber's premises. In cable data networks, data flows from the Internet through the cable company's headend (a cable service provider's version of the local exchange carrier's central office), and on to regional high-capacity data networks. To reach the cable modem subscriber's premises, data travels through local fiber optic networks and finally over coaxial cable. Wireless and satellite carriers also offer broadband capability, although such firms typically focus on the business market and have small market shares.[5] Thus, for residential subscribers, cable modem service and DSL are the broadband options of choice in the U.S. (see Figure 1), with cable modems enjoying about a three to one advantage around 2000, the vintage of the data analyzed here. The FCC found as early as 2000 that the Internet backbone and the networks between the backbone and the telephone central offices and the cable company headends were generally adequate to provide broadband access (FCC, 2000a). The so-called "last mile" to the subscribers' premises is the limiting factor on the supply side of the market.

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[5] Local telephone companies also lease high-speed dedicated circuit access lines to residences and businesses, but their high prices generally restrict them to high-volume business use. More recently, some telephone companies have also begun to deploy fiber optic cable in the last mile network, but most of such investment occurred after the period of the data examined here.

A broadband carrier's decision to enter a market depends on the expected demand, costs, and entry by other firms. The entry decision depends on the expected profits $E(\pi(t,w,z(t),\varepsilon))$, where π is the profit flow at time t, w is a vector of demographics of the area and other observed variables, z is the competitors' entry decisions (itself a function of time), and ε is a random variable reflecting uncertainty about future profitability. Flow profits depend explicitly on time because, for example, the cost of telecommunications equipment falls over time. Entry also depends on the fixed cost incurred at time of deployment, $C(t)$. Given a discount rate r, *a* risk-neutral firm has an optimal adoption time t^* for a particular market defined by:

$$t^* = \arg\max_t \int_t^{\infty} e^{-rs} E[\pi(s,w,z(s),\varepsilon)]ds - e^{-rt}C(t)$$

Entry time t^* may be treated as a random variable from the standpoint of the econometrician, who will not be able to observe all the relevant elements of the decision (including the firm's subjective probability distribution for ε) that the firm takes into account. Then the probability that DSL has been deployed in area i as of the time T of our data is

$$\Pr(t_i^* < T|x) \tag{1}$$

where x is the subset of (w,z) observed in the data. We model (1) as a probit on the binary variable for DSL availability in the market. Using the probit model is tantamount to assuming that the distribution of random variable T, conditional on x, is standard normal.[6]

[6] See Cameron and Trivedi (2005, ch. 14) for a textbook treatment of the probit model.

IV.Data

In October 1999, SBC and Ameritech merged. Both companies were dominant telecommunications service providers,[7] albeit in different locations, and as such, their merger required FCC approval in addition to the usual scrutiny by the Department of Justice. The FCC approved the transaction subject to certain conditions, including promoting advanced services such as broadband Internet access. Failure to meet the conditions was to trigger penalty payments of more than $2 billion in payments. In particular, SBC was required to locate at least 10% of their advanced service facilities in low-income areas in the Ameritech region.[8] State regulators in Ameritech's operating region (Illinois, Indiana, Michigan, Ohio, and Wisconsin) also pushed the merged firm to accelerate broadband deployment. The regulators' concern was that Ameritech had made slow progress deploying DSL compared to other major telephone companies in other areas of the U.S. Precise statistics at the company level on DSL deployment are closely held data, and so comparisons must rely on estimates, but one industry source (see Table 1) calculated that at the end of 1999, Ameritech had only 2% as many DSL lines in service as the next smallest dominant telephone company in the U.S.

To allow regulators to gauge Ameritech's progress in implementing DSL, as part of the regulatory contract the company made available a list of their DSL subscribers by nine-digit postal code (known as ZIP+4 codes) as of March 2000. The data are a snapshot of DSL deployment as of shortly after the merger, and established a baseline to which regulators could compare future deployment. ZIP+4 areas are typically very small

[7] SBC and Ameritech were both Regional Bell Operating Companies (RBOCs), formerly known as the Baby Bells after the breakup of AT&T. The merged entity kept the name SBC, and later adopted the moniker AT&T after merging with that firm in 2005.
[8] SBC's SEC filings from the time discuss these conditions.

geographic areas, comprising a few blocks worth of addresses at most. The list contains every ZIP+4 code in Ameritech's subscriber database and the deployment date, and allows us to see which central offices had DSL deployed.

In addition to the DSL deployment list, the other data for the study come from five other sources: a GIS database of ZIP+4 codes and locations, a GIS telecommunications wire center database, the FCC local competition database, and two Census data sources for household demographic and business information. A complete list of variables and summary statistics for the data are in Table 2.

Given the nascent state of the market in the area in 2000, the data are from the early years of broadband roll out in the area. The advantage to examining data from the early years is that there was still much geographic variation in the availability of broadband, which allows identification of the impact of explanatory variables on deployment. Today's nearly ubiquitous coverage in U.S. urban and suburban areas does not allow researchers to apply fruitfully similar methodology to current data.

1. DSL Availability Data

There are over 170,000 entries in the Ameritech DSL ZIP+4 list. Note that this implies that there are at least that many DSL subscribers, which means that either the external industry source in Table 1, grossly undercounted DSL lines, or Ameritech enjoyed a phenomenal growth rate over the three months between the two data collection dates. The pattern of deployment can be seen be plotting the centroids of the ZIP+4 areas with DSL. Figure 2 shows all the ZIP deployments in the five-state region.[9] The striking picture shows that DSL is available in only a small fraction of the total

[9] The state abbreviations in the figure are Illinois (IL), Indiana (IN), Ohio (OH), Michigan (MI), and Wisconsin (WI).

geography. However, it is important to remember that we do not observe DSL deployed by incumbent phone companies other than Ameritech, and that Ameritech is not the incumbent carrier in many rural areas in these states. In Illinois, all deployment is in the extended Chicago area. In Indiana, there is no DSL. In Michigan, most deployment is in the Detroit area. In Ohio all DSL is around Cleveland. In Wisconsin, the few DSL customers live in the Milwaukee area. These are the most populous areas in the region.

DSL, as deployed by Ameritech at least, clearly lags other forms of broadband infrastructure in the region (as suggested by the data in Figure 1). Figure 3 compares the Ameritech DSL locations with the comprehensive FCC data on five digit ZIP codes with broadband access for Illinois. Many parts of the state have broadband access from non-Ameritech sources. Only in the Chicago area does the Ameritech DSL deployment come close to matching deployment from all sources.

The local exchange carrier implements DSL in the central office, and so the relevant decision unit is a central office serving area. Although it is theoretically possible that Ameritech could choose which neighborhoods within the area to offer DSL to, as a marketing decision, the company offers it to all neighborhoods in area.[10] We determined which central offices were DSL capable by matching the ZIP+4 centroids on the DSL list to the central office areas.[11] Our dependent variable in the estimations is an observation on a central office area, equal to one if DSL is deployed or zero if not. The sample

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[10] Due to technological restrictions at the time, transmission speeds degrade beyond 2.2 miles. Therefore, homes in the area may not have access if they are too far from the central office. The distance limitation can be seen in figure 3 from the circular clusters of DSL points, each of which surrounds a central office.

[11] We matched the ZIP+4 centroids to central offices using ArcMap GIS software and GDT's WireCenter Premium telecommunications geography product.

includes all Ameritech central offices in the five-state region, which yields 1,120 observations.[12]

2. Market Characteristics Data

We model the deployment decision as a function of demand variables, cost factors, and the competitive environment.

Demand Variables. Socioeconomic statistics at the block or block group level from the U.S. Bureau of the Census 2000 decennial census capture factors influencing carriers' expected subscriber demand for broadband. We aggregate the variables to the central office area for the entry estimations.[13] These variables proxy the expected post-entry price and profit in the DSL deployment estimations. The variables include racial breakdown of the area, Hispanic ethnicity, income, market size and composition, rural, age and education profile, gender ratio, commute time, and telephone penetration. An additional set of business-market related variables (the average number of workers per firm and the percentage of firms that have fewer than 20 employees) are taken from Census sources for establishment and employment counts at the postal code level.[14]

Costs. Various studies and industry sources suggest that relevant cost considerations for broadband deployment are fixed costs, subscriber density, and the vintage of the telecommunications infrastructure.[15] Controls for these costs include

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[12] When there were only between one and nine DSL ZIP+4's in the central office area (18 out of over 1,100 central offices), we removed the central office from the estimation to be conservative, because these might be "stray" ZIP+4's that do not actually belong in the DSL list. The average number of ZIP+4's in a DSL-capable central office is 800.

[13] Blocks are the smallest unit of U.S. Census geography, and typically contain about 10-30 households. Some statistics, such as household income, are available at the block group level but not at the block level. Block groups typically contain about 600 households. We aggregated the statistics at the Census block or block group level to the central office serving area using the GIS software.

[14] The business data are from U.S. Bureau of the Census, *ZIP Code Business Patterns* CD-ROM, 2000 data. The ZIP code areas were matched to the central office areas using GIS software.

[15] See Faulhaber and Hogendorn (2000) and Gabel and Kwan (2001), for example.

subscriber density and a proxy for the vintage of the local telecommunications networks (median age of the housing structures) in the area. For a more complete explanation of broadband costs and these variables, refer to Prieger (2003).

Local telecommunications and broadband competition. Local telecommunications competition has started to spring up since the passage of the Telecommunications Act of 1996. Anecdotal evidence from the industry suggests that incumbent local exchange carriers are more likely to offer advanced services in areas in which they face competition, although the endogeneity of entry prevents any statement of causality. Some facilities-based competitive local exchange carriers (CLECs) offer DSL. CLECs can offer DSL in Ameritech's serving area even if Ameritech does not itself deploy DSL in the central office, by collocating their own equipment in the incumbent's central office and renting the subscriber line to the customer's premises.

The FCC makes available a list of postal codes in which there is local competition. In some specifications, we include an indicator variable, *CLEC presence*, for the presence of at least one competing local exchange company (CLEC) in the area. The FCC data do not indicate whether the competitor offers DSL, however, and so *CLEC presence* indicates only the potential for competition. We collected information on actual competition in DSL from CLECs from New Paradigm Resources Group (2001). The data from NPRG lists which CLECs operate in which cities, and whether they offer DSL.[16] For a subset of ZIP codes, we also have data on deployment of cable modem service, which we matched to our central office serving areas. The cable modem data

[16] The data from NPRG are not as geographically precise as our other data, because the CLEC locations are listed by city or suburb name. We matched the city names to the central office areas by hand.

cover a random sample of ZIP codes across the five states[17] except for Ohio, where coverage is complete.[18]

V. Empirical Findings

The results for the DSL entry estimations begin in Table 3. Table 3 contains two estimations that show an apparent supply-side digital divide based on race and income. Recall that the unit of observation is an Ameritech central office area. In all tables, we report the probit coefficients, the marginal effects of the variables, and the *p*-value for the hypothesis that the coefficient is zero. The marginal effect of a variable expresses the change in the estimated probability that broadband is deployed from a unit change in the variable (evaluated at sample averages of the data).

In Estimation 1, we control for nothing except race and market size. Areas with high concentrations of blacks, Native Americans, and "other" races (as defined by the Census categories) are significantly less likely to have DSL available. Areas with many Asians and (surprisingly) Hispanics are significantly more likely to have access to DSL. This simple portrait of the digital divide is incomplete, however. An obvious question is whether race is a causal factor or merely correlated with other demographic characteristics upon which firms base their entry decision, such as income, education, and the business market. In estimation 2, we add income variables. Access to DSL is correlated with higher income and fewer households in poverty, although the latter coefficient is not significant. Important to note is that the significant negative effects for blacks, Native Americans, and other races disappear. The coefficient for blacks switches

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[17] These data were collected by Kevin Duffy-Deno and are described more fully in Duffy-Deno (2000) and Rappoport *et al.* (2003). We gratefully acknowledge permission to use these data.
[18] The cable modem data for Ohio are from Grubesic (2003). We gratefully acknowledge permission to use these data.

sign, and is now significantly positive. Thus, income appears to be a more important factor contributing to the digital divide on the supply side than race *per se*.

In estimations 3 and 4, we add a host of other demographic and economic variables. The distinction between the two is the addition of state fixed effects in estimation 4. The addition of state fixed effects removes the impact of any factor, observed or unobserved, that varies among states but not within a state. Examples of such factors include the state regulatory environment, unique or historical reasons why costs of provision differ among states, and average demand and supply conditions. Adding state effects necessitates dropping observations from Indiana, where no DSL was in place. Except for some of the education variables, there are no statistically significant large differences between the coefficients in the two estimations.[19]

The education level of the area has a curious correlation with DSL access. The excluded educational category in the estimation is high school education, and all coefficients are positive relative to this category. The largest positive effect is for "less than high school" education. Perhaps inner urban areas with low average educational attainment but other desirable characteristics (from the firm's point of view), such as business demand, are driving this result. More expected is that the fraction of people with some college education or higher positively affects the probability of DSL.[20]

Commuting has the expected impact. There are large positive effects for the "work at home" variable, perhaps due to demand for telecommuting. For those who commute, entry rises with the length of the commute up to one hour, which may reflect a

[19] The apparently large differences in some of the coefficients do not translate into significant differences in the marginal effects.
[20] The unexpected result for the less than high school coefficient is not an artifact of collinearity; the variable is not highly correlated with any variables expected to increase the likelihood of deployment.

combination of urban area effects (urban areas have more demand for DSL) and stronger demand for telecommuting. The industry press has noted the link between longer commuting times and demand for broadband access (NPRG, 2006). The longest commuting category, over an hour, causes the probability of access to fall, which is probably a reflection of low rural demand for broadband (perceived or real on the part of the firm). An interesting finding is that areas with more women are less likely to have access to DSL. Median age of the area has an inverted U relationship to access, with the maximum occurring around age 40 to 45. The impact of age might reflect lower demand for Internet access among the elderly and the very young.[21]

Regarding business demand, access rises with the average number of workers per firm, but also with the fraction of firms that have fewer than 20 employees. The latter probably reflects that DSL is an especially attractive broadband access option for small businesses, given its low price in comparison to high-speed dedicated telecommunications lines (so-called "special access" lines) and the relative lack of availability of cable modem service to business addresses.[22] In a separate estimation (results not reported), we added variables for the percent of the businesses in the area in various industrial categories. While some of the categories had significant effects, they did not change the main results of interest.[23]

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[21] Fox (2004) documents low demand among the elderly, and finds that in 2000, only 15% of Americans age 65 or older reported having access to the Internet. Low demand for household broadband subscription among younger adults may reflect both lack of income and the availability of broadband at school or work as a substitute for access at home.

[22] Cable companies built their networks to offer primarily residential service.

[23] The main changes were that the statistical significance of the Asian and income variables declined, compared to estimation 3. The industry category of "finance and insurance" and of "real estate" had significant negative effects and the category of "professional, scientific and technical services" had positive effects on deployment. The former results are probably indicative of the other broadband options taken by firms in these communications-intensive industries. The incumbent marketed DSL at the time toward

The cost variables mostly have the expected signs. Denser areas, measured by population or telephone penetration, have higher probability of access to DSL. Rural areas, defined in accord with the Census definition of a density less than 500 persons per square mile, have lower access. The marginal effects indicate that Ameritech was 4 to 10 percentage points (depending on which estimation is used) less likely to deploy DSL in its rural central offices than in its urban ones. Older infrastructure, as proxied by structure age, has a negative impact—at least for levels of the variable above the median. Younger structure ages show the opposite sign, but neither coefficient is significant in estimation 4.

The carrying capacity, or market size, hypothesis states that competition from CLECs and cable modem providers should make the provision of DSL less attractive to the phone company, other things equal. Some markets may only be large enough to support one entrant, and if the cable company or a CLEC already offer broadband, then the phone company may delay DSL provision until the market grows. An alternative hypothesis is that competition provides competitive stimulus to telecommunications investment (Willig, 2003; Aghion *et al.* 2001).[24] To test which of these hypotheses better fits the data, we examine how competition affects the probability of DSL deployment. Since our cable modem data are not available for the full sample, in estimations 3 and 4 we include only the CLEC variables for potential and actual competition.

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home and small-business users, since the phone company had little incentive to cannibalize demand for the high-speed (and high-cost) dedicated circuits it leased to businesses.

[24] Willig (2003) characterizes the competitive stimulus hypothesis as follows: "[u]nder this view, the previous lack of competition in monopoly local telephone markets may have dissuaded the I[ncumbent]LECs from making certain investments, and the competitive stimulus from CLEC entry under the 1996 Act may have encouraged greater investment by both the ILECs and the CLECs." The author is not referring the DSL investment in particular, but the same notion applies to investment generally (Aghion *et al.* 2001).

The coefficient for CLEC presence is not significant, but when the CLEC actually offers DSL, the impact is negative and significant. The marginal effect of -0.001 for *CLEC DSL presence* from estimation 3 implies that when a CLEC is actively offering DSL service in the central office area, Ameritech is 0.1 percentage points less likely to deploy DSL itself. When the state fixed effects are included in estimation 4, the marginal effect of DSL competition rises in magnitude to -0.26 percentage points. Thus while the potential broadband competition that a CLEC represents neither spurs not hinders deployment, actual competition in DSL is associated with less deployment by the incumbent.

To explore the impact of the availability of cable modem service on DSL deployment, we turn to our subset of central offices for which we have both CLEC and cable modem data. The carrying capacity hypothesis, which predicts a negative sign on coefficients for CLEC and cable modem presence in the central office area, depends crucially on other things in the market being equal. If one fails to control adequately for the potential profitability of a market (through cost and demand variables), then the unobserved differences among markets may make it look like the presence of competitors is associated with greater DSL entry. If areas expected to be more profitable *a priori* attract both DSL and cable modem entry, then not controlling adequately for expected profitability would lead to a false rejection of the carrying capacity hypothesis in favor of the competitive stimulus hypothesis. The correlation between DSL and cable modem entry would not be causal in nature.

To illustrate this point, we estimate a model controlling only for state fixed effects and the competition variables (estimation 5 in Table 5). The presence of both cable modem and competitive DSL options for subscribers in the central office area is associated with a higher likelihood of deployment by the incumbent DSL provider. Before taking this as evidence for the competitive stimulus hypothesis, however, we control for other market factors affecting expected profitability in estimation 6 (Table 5). The results show that negative coefficients for competitive DSL and cable modem service appear—results in accord with the evidence for the carrying capacity hypothesis found in estimations 3 and 4. We cannot include as many controls for market factors as in estimations 3 and 4, due to the smaller sample size in estimation 6. The coefficients on the variables *Cable modem presence* and *CLEC DSL presence* are negative (but not statistically significant, however, due to the small sample size). The marginal effect for *CLEC DSL presence*, 0.52 percentage points, is even higher than that estimated in the full sample. Given these results, together with those from the larger estimations, it appears that support is greater for the carrying capacity hypothesis than the competitive stimulus hypothesis.

The variable measuring potential competition, *CLEC presence*, is positive but not statistically significant. Prieger (2003) found a positive correlation between CLEC presence and broadband provision, but could not separate provision from the incumbent local exchange company from other sources. A positive association with DSL deployment by the incumbent may reflect a desire by Ameritech to beat the competition to market (and perhaps prevent the CLEC from entering the DSL market at all).[25]

[25] Note that when the competition is potential but not actual, it is difficult to distinguish the competitive stimulus hypothesis from predatory conduct (i.e., investment undertaken specifically to deter entry (Dixit, 1980)).

VI.Future Trends and Conclusion

The empirical results indicate that race and ethnicity do not matter independently of other related factors such as income and education in the entry of DSL broadband Internet connection. Thus, to the extent that society desires to close what remains of the broadband digital divide in the U.S., attention must be given to the demand side of the equation.

The experience in the U.S. with the diffusion of broadband since the early years examined here shows that for most areas of the country, the question of broadband deployment is not "if" but "when". At the time of the data we examine, the FCC (2000b) found in its first comprehensive survey that there was at least one customer for high-speed service in 59% of all the postal code areas in the United States. By the end of 2005, the same statistic rose to 99% of postal code areas (FCC, 2006).[26] The speed at which the U.S. attained nearly ubiquitous broadband access is all the more remarkable given that (unlike some other countries) there are no general federal subsidy programs for either broadband infrastructure or household subscription.[27]

Even though some form of broadband access is available in most areas of the U.S. today, the lessons learned from looking at the early years of adoption are still important. While broadband availability is a precondition necessary for closing the digital divide, Cooper (2004) emphasizes that bringing down the price of service is essential if lower income households are to be brought online. Competition among providers holds the greatest promise for bringing down prices in the U.S., given the reluctance of the FCC to

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[26] Cable modem or DSL service was available in 87% of the ZIP codes. Most of the remaining ZIP codes were covered by satellite.

[27] There are a few relatively small *targeted* federal infrastructure subsidy programs. Two of these are the eRate program subsidizing broadband infrastructure for schools (Flamm, 2005) and the USDA Rural Development broadband program for rural LECs (Wallsten, 2005).

add broadband explicitly to the list of services supported under federal universal service programs. As the market grows, it is reasonable to expect that the factors influencing future entrants in an area will follow similar patterns to that of the incumbent DSL entrant uncovered in this chapter. Thus, understanding what drives initial DSL deployment lends insight into what drives increasing competition.

Furthermore, many countries around the world are in situations today similar to where the U.S. was five years ago. In 2001, the U.S. had about a 4.5% subscription rate to broadband, which is higher than in Turkey, the Slovak Republic, Mexico, or Greece in 2006, just to mention OECD countries.[28] If the profitability of geographical markets relative to each other in the U.S. is similar to that in other countries, then we should expect broadband to be available first in denser, urban areas with longer commutes, a more educated populace, and wealthier households. Furthermore, intermodal competition (and thus lower prices) may be slower in coming than initial diffusion, as areas with an existing broadband provider look less attractive to enter (other things equal) than do virgin territories.

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[28] Source of statistics: OECD data for June 2006, released 13 October 2006, available at www.oecd.org/sti/ict/broadband.

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Terms and Definitions

Central office: see wire center.

digital divide: The gap in computer and Internet usage between richer and poorer households, majority and minority groups, and households in urban and rural areas.

Last mile: the part of the local telecommunications network that connects the central office to the subscriber premises. The last mile typically consists of copper telephone wire.

Redlining: The practice of deliberately avoiding selling products or services (in context here, broadband Internet service) in particular neighborhoods. The term comes from the credit industry, and originally meant the refusal of a bank or other lender to extend credit to customers located in a high-risk geographical area, usually a declining inner-city neighborhood. These institutions supposedly drew red lines on maps marking off the high-risk areas.

Telephony: a system of telecommunications employing telephonic equipment to transmit sound between points. In common parlance, the "telephone system."

Wire center: the location where a central office switch connects to the loop facilities that cover part or all of a local exchange. It is also the physical location where the loop distribution plant in the local telecommunications system can be accessed, and where the equipment enabling DSL service for subscribers is deployed. Used synonymously with "central office" in this chapter, although elsewhere sometimes the wire center refers to the physical building and the central office refers to the switches within the wire center.

Local exchange company (LEC): a public telephone company in the U.S. that provides local telecommunications service.

CLEC: Competitive Local Exchange Carrier. A CLEC is a public telephone company that provides local telecommunications service in competition with the incumbent local exchange company.

Table 1
DSL Deployment by the Bell Operating Companies at the Time of the Data

Bell Operating Company	**Monthly price (transport and ISP service from the BOC), $**	**Number of DSL lines provisioned, millions (12/99)**
Ameritech	59.95	0.045
Bell Atlantic	49.95-189.95	17.0
Bell South	59.95	5.0
SBC/Pacific Bell	49.95-339.00	9.8
US West	49.95-859.95	2.2

Source: *CED*, "DSL technology looms ever larger," December 1999, p.100.
Notes: when a range of prices is listed, higher prices are for higher data transmission rates.

Table 2: Summary Statistics for the Central Office Level Data

Variable	Mean	Std. Dev.	Min	Max
DSL	0.051	0.220	0.000	1.000
Race and Ethnicity				
% Black	0.033	0.109	0.000	0.984
% Native American	0.006	0.033	0.000	0.962
% Asian	0.007	0.017	0.000	0.315
% Other	0.023	0.070	0.000	1.000
% Hispanic	0.021	0.042	0.000	0.695
Income and Poverty				
Income (log)	10.652	0.245	9.613	11.911
% in poverty	-2.628	0.615	-5.778	-0.724
Size of Market				
Households (log)	7.369	1.507	-0.693	11.562
Number of firms (log)	4.537	1.638	0.000	8.661
Education profile				
% Less than H.S.	0.172	0.070	0.000	0.704
% Some College	0.269	0.052	0.000	0.465
% College Degree	0.104	0.061	0.000	0.447
% Graduate Degree	0.053	0.044	0.000	0.429
Commuting Profile				
% Work at home	0.046	0.033	0.000	0.356
% Commute 20-40 mins	0.348	0.109	0.020	0.713
% Commute 40-60 mins	0.104	0.059	0.000	0.556
% Commute > 60 mins	0.069	0.045	0.000	0.499
Other Demographics				
% Female	0.500	0.028	0.062	0.728
Median Age	38.022	3.783	19.943	73.752
Business Market				
Ave. workers/firm	2.253	0.671	-0.847	5.676
% Small Firms	0.900	0.072	0.000	1.000
Cost variables				
Pop. density (log)	4.479	1.680	-2.857	10.215
Rural	0.846	0.361	0.000	1.000
Phone density†	4.059	1.114	0.525	6.908
Structure Age (log)	3.571	0.297	1.747	4.126
Competition				
Cable Modem Presence	0.338	0.474	0.000	1.000
CLEC DSL Presence	0.083	0.275	0.000	1.000
CLEC Presence	0.871	0.335	0.000	1.000
States				
Illinois	0.266	0.442	0.000	1.000
Indiana	0.147	0.354	0.000	1.000
Michigan	0.188	0.391	0.000	1.000
Ohio	0.226	0.418	0.000	1.000
Wisconsin	0.173	0.379	0.000	1.000

†Phone density is transformed with a reverse log transformation: $-\ln(1-x)$.

Table 3
Probit Estimations for the Availability of Broadband Service within a Central Office Area: Race and Income

	Estimation 1 Race			Estimation 2 Race and Income		
Variable	**Coefficient**	**Marginal Effect**	**P-Value of Coef.**	**Coefficie nt**	**Marginal Effect**	**P-Value of Coef.**
Race and Ethnicity						
% Asian	13.030***	0.621	0.000	7.408**	0.155	0.013
% Black	-0.701**	-0.033	0.034	1.199***	0.025	0.008
% Native American	-127.046***	-6.057	0.002	-19.546	-0.410	0.510
% Other	-13.682**	-0.652	0.017	2.192	0.046	0.725
% Hispanic	8.591***	0.410	0.008	-0.219	-0.005	0.951
Income and Poverty						
Income (log)				2.227***	0.047	0.000
% in poverty				-0.269	-0.006	0.253
Size of Market						
Households (log)	0.216**	0.010	0.018	0.157	0.003	0.174
Pop. density (log)	0.692***	0.033	0.000	0.852***	0.018	0.000
Intercept	-7.364***		0.000	-33.406***		0.000
Log Likelihood		-264.793			-220.818	
N		1,120			1,119	
Pseudo R^2		0.490			0.575	

** significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level.*

Notes: Dependent variable is 1 if there is at least one broadband customer in the Central Office serving area, 0 if not. The sample includes all Ameritech central office areas. *Marginal effect* is the marginal effect on the mean evaluated at the sample mean of *x*. Asterisks and *P*-values are for the coefficient, not the marginal effect.

Table 4: Probit Estimations for the Availability of Broadband Service within a Central Office Area: All Variables

	Estimation 3 All Variables			Estimation 4: All Variables & State Fixed Effects		
Variable	Coefficient	Marginal Effect	P-Value of Coef.	Coefficient	Marginal Effect	P-Value of Coef.
Race and Ethnicity						
% Asian	12.345**	0.036	0.016	7.145	0.050	0.193
% Black	0.143	0.000	0.866	0.172	0.001	0.859
% Native American	3.515	0.010	0.943	-92.174	-0.639	0.255
% Other	-1.875	-0.005	0.833	-8.318	-0.058	0.401
% Hispanic	-3.316	-0.010	0.518	2.115	0.015	0.723
Income and Poverty						
Income (log)	1.893**	0.006	0.039	0.887	0.006	0.367
% in Poverty	0.056	0.000	0.892	0.304	0.002	0.485
Size of Market						
Households (log)	0.296	0.001	0.116	0.275	0.002	0.172
Number of Firms (log)	0.268*	0.001	0.086	0.357**	0.002	0.026
Education profile						
% Less than H.S.	22.491***	0.066	0.000	13.795**	0.096	0.019
% Some College	12.621***	0.037	0.006	1.346	0.009	0.805
% College Degree	3.314	0.010	0.355	1.455	0.010	0.705
% Graduate Degree	8.004*	0.023	0.056	2.654	0.018	0.567
Commuting Profile						
% Work at home	17.864	0.052	0.11	27.176**	0.188	0.018
% Commute 20-40 mins	2.670*	0.008	0.095	3.918**	0.027	0.019
% Commute 40-60 mins	17.069***	0.050	0.000	16.393***	0.114	0.000
% Commute > 60 mins	-9.176***	-0.027	0.006	-7.704**	-0.053	0.043
Other Demographics						
% Female	-6.211	-0.018	0.198	-10.517**	-0.073	0.038
Median Age	0.538*	0.002	0.070	0.401	0.003	0.208
Median Age squared	-0.007*	0.000	0.096	-0.004	0.000	0.296
Business Market						
Ave. Workers/Firm	1.135***	0.003	0.002	1.189***	0.008	0.002
% Small Firms	7.399*	0.022	0.051	7.194*	0.050	0.06
Cost variables						
Pop. Density (log)	0.708***	0.002	0.001	0.784***	0.005	0.001
Rural	-0.804*	-0.004	0.063	-0.939**	-0.010	0.041
Phone Density†	0.611***	0.002	0.002	0.681***	0.005	0.001
Structure Age < median (log)	0.965**	0.003	0.035	0.353	0.002	0.482
Structure Age > median (log)	-1.762	-0.005	0.105	-1.813	-0.013	0.123
States						
Michigan				0.792**	0.009	0.035
Ohio				-0.613	-0.003	0.151
Wisconsin				-0.001	0.000	0.999
Competition						
CLEC Presence	-0.021	0.000	0.963	0.086	0.001	0.862
CLEC DSL Presence	-0.517**	-0.001	0.025	-0.544**	-0.003	0.035
Intercept	-64.317***	0.036	0.000	-42.590***	0.050	0.003
Log Likelihood		-152.242			-133.255	
N		1,119			957	
Pseudo R^2		0.707			0.725	

** significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level.*

†Phone density has a long left tail, and is transformed with a reverse log transformation: –ln(1–x). Omitted racial variable is White. Omitted education variable is High School Degree. Omitted commute variable is 1-20 minutes. Marginal effects for dummy variables are for a zero to one change in *x*. Observations from Indiana are dropped from estimation 4 because no DSL is deployed in the state. See notes to previous table.

Table 5
Probit Estimations for the Availability of Broadband Service within a Central Office Area: Competition Variables

	Estimation 5			Estimation 6		
Variable	**Coefficient**	**Marginal Effect**	**P-Value of Coef.**	**Coefficient**	**Marginal Effect**	**P-Value of Coef.**
Competition						
Cable Modem Presence	0.898***	0.270	0.000	-0.204	-0.003	0.442
CLEC Presence	0.719**	0.151	0.027	0.813	0.007	0.551
CLEC DSL Presence	-0.029	-0.008	0.867	-0.440	-0.005	0.187
Income and Poverty						
Income (log)				1.491	0.023	0.108
% in Poverty				-0.145	-0.002	0.775
Size of Market						
Households (log)				-0.380	-0.006	0.168
Number of Firms (log)				0.530***	0.008	0.009
Other Demographics						
Median Age				-0.998**	-0.015	0.028
Median Age squared				0.014**	0.000	0.028
Business Market						
Ave. Workers/Firm				0.448	0.007	0.464
% Small Firms				4.469	0.069	0.385
Cost variables						
Pop. Density (log)				1.264***	0.019	0.000
Rural				-0.624	-0.009	0.537
Phone Density†				0.226	0.003	0.444
Structure Age				0.454	0.007	0.471
Intercept	-1.800***		0.000	-15.522		0.212
State Fixed Effects		No			Yes	
Log Likelihood		-175.104			-71.056	
N		374			360	
Pseudo R^2		0.116			0.634	

** significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level.*

†Phone density is transformed with a reverse log transformation: $-\ln(1-x)$.

See notes to previous table.

Figure 1:
Choice of Broadband Technology by Residences and Small Businesses

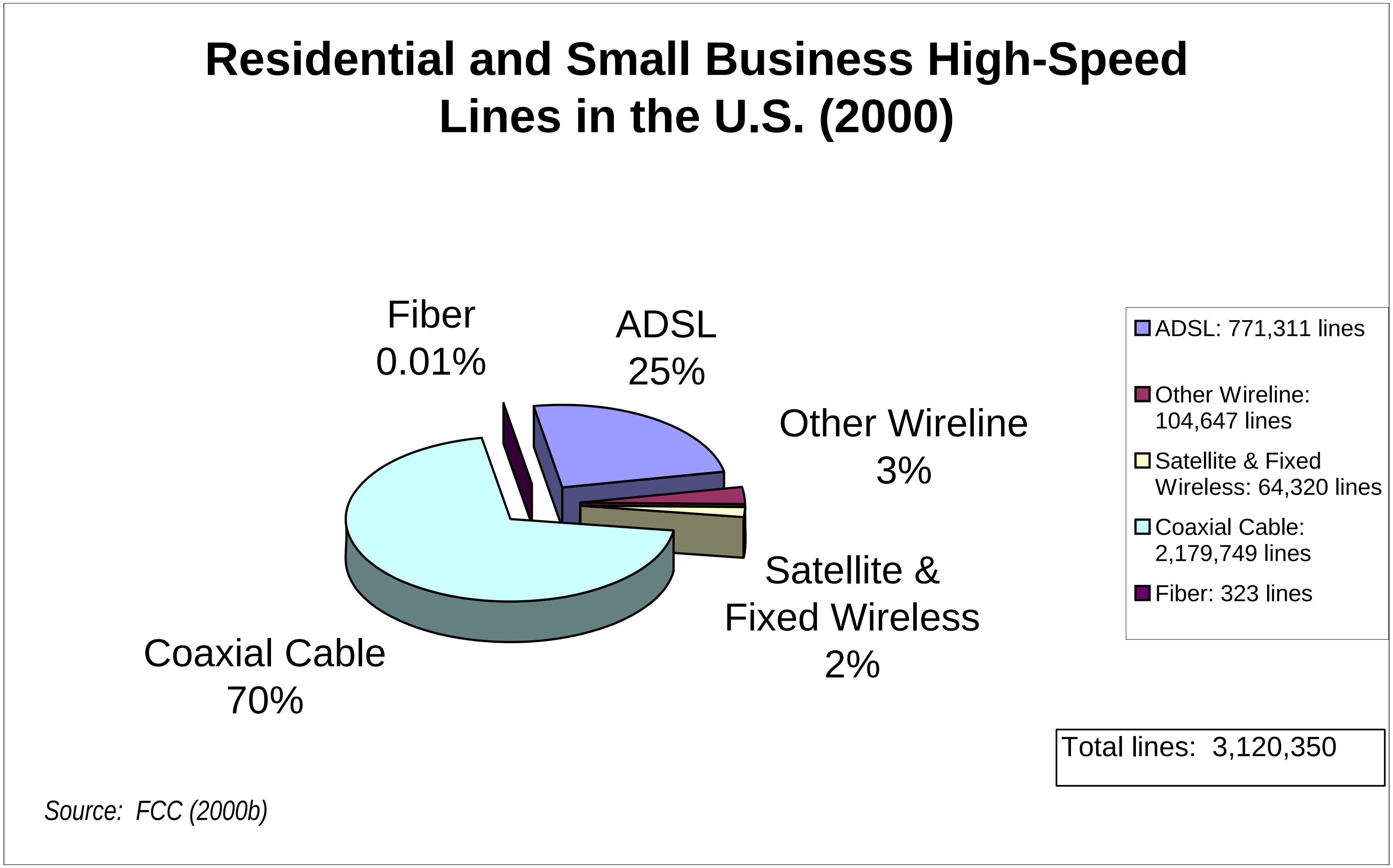

Figure 2: DSL Subscribers in the Ameritech Region

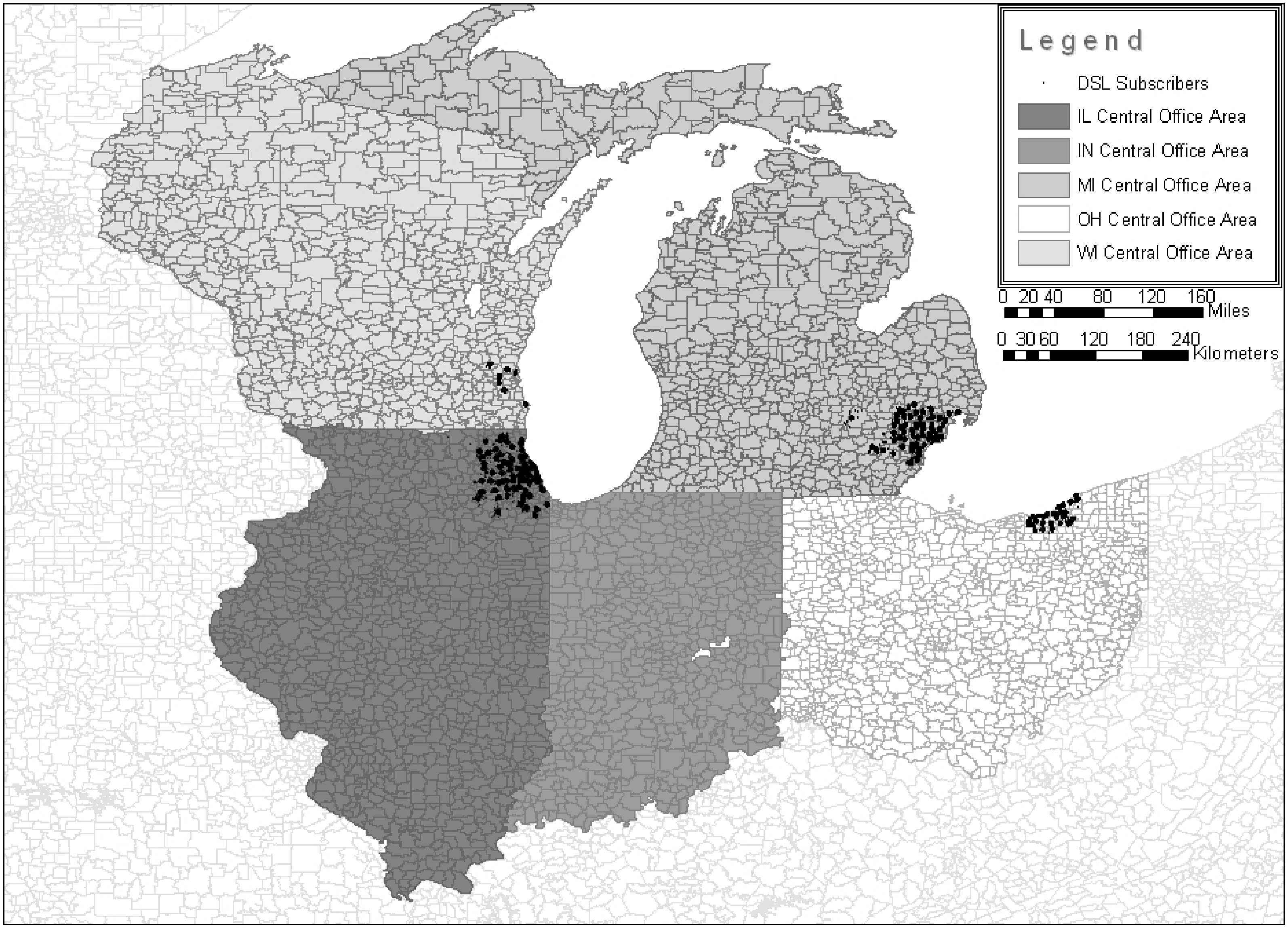

Figure 3: Comparison with FCC Data for Illinois