RURAL BROADBAND AVAILABILITY AND ADOPTION:

Evidence, Policy Challenges, and Options

By Brian Whitacre (Oklahoma State University), Roberto Gallardo (Mississippi State University), and Sharon Strover (University of Texas)

NARDeP
National Agricultural & Rural Development Policy Center
A Regional Rural Development Centers Initiative

Funding

This project was funded through a contract with the National Agricultural and Rural Development Policy Center.

Cover Photo: istockphoto.com

This is a publication of the National Agricultural & Rural Development Policy Center (NARDeP). NARDeP was formed by the Regional Rural Development Centers in response to the increasingly contentious and complex agricultural and rural development policy issues facing the U.S. NARDeP is funded by USDA National Institute of Food and Agriculture (NIFA) under a competitive grant (Number 2012-70002-19385), and works with the land-grant college and university system and other national organizations, agencies, and experts to develop and deliver timely policy-relevant information. NARDeP is an affirmative action/equal opportunity employer. For information about NARDeP, visit the website: nardep.info.

TABLE OF CONTENTS

Executive Summary

Broadband, or "high-speed" Internet access, has become an integral part of the everyday life of many Americans. Household broadband adoption rates are above 60% as of 2011, providing opportunities for communication, information, income, and entertainment. However, the persistence of a rural – urban "digital divide" in both broadband *availability* (including basic and higher speed broadband connectivity) and *adoption* has prompted concerns that rural areas might be left behind in terms of the benefits of this technology.

Many federal programs have been designed to increase the availability and adoption of broadband into areas with limited or no access to broadband, including over $7 billion as part of the 2009 American Recovery and Reinvestment Act (ARRA). This funding included a component to map, at a low level of detail, the availability of broadband infrastructure across the nation. The resulting National Broadband Map (NBM) represents an unprecedented amount of data that, when combined with other sources of broadband data, can be used to assess the state of rural broadband and provide the basis for policy suggestions. For the first time, information is available on *both* broadband components mentioned above (availability and adoption). This report meshes the NBM availability data with household-level adoption information from the Current Population Survey (CPS) and county-level adoption data from the Federal Communication Commission's (FCC) Form 477, data which are supplied by providers.

We focus on four specific questions, each of which comprises a chapter in this report:

1) *What is the nature and extent of the broadband digital divide across geographic space?*
   Household-level (CPS) surveys document a persistent 13-percentage point gap between metropolitan and non-metropolitan areas between 2003 and 2010. Notably, households with characteristics predicting low levels of broadband adoption (low income, low education, and elderly) have seen the metro – non-metro gap *increase* over time. A somewhat brighter picture is painted by the FCC county-level data, which focuses on categories of residential broadband adoption. The most rural counties have made impressive strides in increasing levels of broadband adoption between 2008 and 2011; however, a gap still exists. Further, a significant broadband availability gap is evident as of 2011, not only in terms of the number of providers but also with respect to service quality as indicated by averages of the maximum advertised upload and download speeds.

2) *What factors strengthen or impede broadband adoption by rural households and communities?*
   Logistic regressions at the household level reveal that the traditional factors (income, education, age, race, region, and non-metro location) all play a role in the broadband adoption decision in both 2003 and 2010. When various broadband availability measures

for 2010 are included, low levels of providers (<3 in a county) and high levels of availability (>85% of county population with access) are shown to negatively and positively impact the adoption decision, respectively. Further, decomposition techniques demonstrate that differences in metro – non-metro broadband availability are large contributors to the adoption gap between the two areas.

Ordered logit modeling results using county-level data suggest that in addition to the expected results for income, education, age, and race, employment in specific industries (namely the real estate and information sectors) also affects broadband adoption in non-metropolitan areas. Low (<3) and high (>6) numbers of broadband providers had statistically significant impacts on non-metro adoption rates in 2010; however, by 2011 the more influential variable was broadband speed (specifically download speeds at the low (<3-6 mbps) and high (>10 mbps) levels). Increases in the number of residential broadband providers in non-metro counties between 2008 and 2010 were shown to relate to increases in county-level adoption rates, even after controlling for changes in income, education, and employment rates. Additional analysis on the presence of the 'Connected Nation' program in 2 states demonstrates a dramatic influence on the number of residential broadband providers in non-metro counties; however, the Connected Nation county participants did not show higher increases in broadband adoption compared to otherwise similar non-participating counties.

3) *Does broadband availability / adoption contribute to the economic health of rural areas?*
Three different modeling techniques demonstrate that various levels of broadband availability or adoption do, in fact, contribute to different measures of economic health in rural areas. Cross-section spatial models in 2010 find that areas with low levels of adoption, low numbers of broadband providers, or low levels of broadband availability have significantly lower median household incomes, higher levels of poverty, and decreased numbers of both firms and total employees. Further, first-differenced regressions show that changes in non-metro median household income and total employment between 2008 and 2010 are positively influenced by increases in broadband adoption over that time. Finally, propensity score matching results are used to estimate causal impacts of broadband on economic growth measures in non-metropolitan counties between 2001 and 2010.The results suggest that broadband *adoption* thresholds have more impact on economic health in rural areas than do broadband *availability* thresholds.

4) *What policy options are most relevant for increasing economic development opportunities related to broadband in rural America?*
Policies addressing the digital divide have spanned many governmental and administrative jurisdictions. Programs have been launched and operated within municipalities, states, regions, and nationally, and many have been initiated with the

promise that improved broadband facilities or adoption or utilization will prompt improved economic opportunities, alongside additional or improved educational and health options. The tools of such programs have included investments in transit infrastructure, grants and loans to commercial providers, discounted connection rates to community anchor institutions such as school or libraries, training programs, subsidy programs for end-user equipment acquisition, options for communities to provision their own broadband services, and other initiatives.

The policy options that grow out of our findings include actions to address (1) broadband availability, and especially competitive availability, and (2) rurally-based populations with low education or low income, or who are elderly, or members of racial or ethnic minorities. Given that availability gaps alone do not explain the digital divides illustrated by the data, programs addressing adoption and utilization would be the next logical steps in a comprehensive effort to improve our national statistics.

Tables

Figures

1. An Introduction to Rural Broadband

1.1 Rationale for Research Performed in this Report

Scholars of economic development have been interested in broadband's potential since the early 2000s, when adoption rates of this "always on" type of Internet access began to rise.[1] As the literature review in the following section notes, immediate attention was given to the "digital divide" between rural and urban areas, following in the footsteps of research examining similar divides in terms of first computer use, and later, Internet use. Researchers began to explore why broadband adoption rates were lower in rural areas, and to suggest what the sources and the implications of these gaps might be (Malecki, 2001; Mills and Whitacre, 2003; Parker, 2000; Strover, 2001). Related work began to assess the relationship between broadband and economic growth, with some evidence linking higher levels of broadband infrastructure and adoption to improvements in economic outcomes (Czernich et al, 2011; Kolko, 2010; Holt and Jamison, 2009). These results led many rural advocates to highlight the importance of broadband as a tool for economic development. However, until recently, very little reliable and useable broadband infrastructure data has been available, and assessments of programs designed to improve broadband access and adoption are quite limited. Contemporary empirical evaluations of the economic impacts of broadband in rural areas are generally lacking.

In light of the importance of this topic for rural America and this dearth of empirical analysis, the recently formed National Agricultural & Rural Development Policy Center (NARDeP) issued a call for proposals in July 2012 to "examine policy and program options that can spur the growth of broadband access and use by rural people."

This report responds to that request by focusing on four distinct questions that make up the remaining chapters:

1) *What is the nature and extent of the broadband digital divide across geographic space?*
2) *What factors strengthen or impede broadband adoption by rural households and communities?*
3) *Does broadband availability / adoption contribute to the economic health of rural areas?*
4) *What policy options are most relevant for increasing economic development opportunities related to broadband in rural America?*

We use household and county-level broadband adoption data, meshed at the appropriate level with newly available detailed broadband infrastructure availability data, to answer these

[1] The FCC's definition of broadband has changed over time. Historically, the definition has been 200 kilobits of data transfer per second (kbps) in at least 1 direction. The most recent (2010) definition is 4 megabits (mbps) download and 1 mbps upload. This report incorporates various thresholds, depending on the data used for analysis.

questions. The inclusion of both availability and adoption measures allows for previously unavailable insight into the rural – urban broadband gap, including an assessment of how each component may contribute to different economic growth measures.

1.2 Literature Review

1.2.1 History of the Digital Divide and Digital Inclusion Efforts

Changing definitions of the digital divide illustrate how scholars and policymakers have responded both to alterations of technological opportunities as well as deeper research that has unpacked the social dynamics around lags in certain population groups' use of computers and the Internet.

The notion of a digital divide goes back at least to the 1990s when several people noted inequalities in access to computers. With the proliferation of personal computers, and a nascent Internet network and culture, the federal government joined efforts of independent scholars and various agencies to begin to track computer ownership and use.

The National Telecommunications and Information Administration (NTIA) issued the first of many surveys beginning with its *Falling through the Net* studies in 1995, documenting the growing acquisition of computers and their use in home, work and school settings, and characterizing the demographic factors that predicted ownership and use. These reports cultivated the notion that the digital divide was predominantly a divide in terms of *physical access* to the technology. For example, NTIA's 1995 report Falling Through the Net: A Survey of Have-Nots in Rural and Urban America (NTIA, 1995) amply documented the relationship between computer ownership and use relative to sex, income, race and ethnicity, age, location (rural/metro), age and other demographic variables. From a policy standpoint, the notion also was linked to universal service, the language found in telecommunications regulation that advocates rural and urban parity – comparable telephone service and comparable rates – in an affirmation of a social contract that Schement (2009) called "the trinity of opportunity, participation and prosperity."

Falling through the Net II (1998) continued in the same terms, with the added nuance of an admonition that all Americans should be connected to "the Information Superhighway," deemed essential to commerce and the services of the future. The 1999 version, Falling through the Net: Defining the Digital Divide (NTIA, 1999) added to the documentation task, raising concerns about a widening divide in which minorities, low-income persons, the less educated, children of single-parent households, and people in rural areas or central cities, were among the groups that lacked access to the information resources conveyed through the Internet and computers. Falling through the Net: Toward Digital Inclusion (NTIA, 2000) added new emphasis on how people were accessing "digital tools," and for what purposes they were using them.

Growing concerns about gaps accompanied a broader awareness that the Internet, and especially its potential, could be revolutionary for the economy. The dot.com boom of the late 1990s was in full swing, and the great deal of technology-based optimism centered in Silicon Valley and Washington, D.C. was quietly accompanied by community-based efforts to insure that both access to technology and the abilities to use it were not limited to those with the money to purchase their own computers. Community technology centers, operating under various names, were already underway and exploring different models to remediate gaps in computer availability. Oden and Strover (2002) highlighted the lags characterizing rural regions, and demonstrated the contributions of computer-based Information and Communications Technologies (ICTs) to economic growth.

The 2002 version of the national assessment studies, titled A Nation Online (NTIA, 2002), focused on the gains of the past decade, and espoused the position that the growing market for technologies and services was adequately providing for the diffusion of these technologies and the Internet itself. The idea of a gap or a deficit was downplayed in favor of highlighting the rapid acquisition of computers and growing Internet subscriptions. This report, and growing acceptance of the notion that both computers and Internet connectivity were somehow important even if data demonstrating this point were elusive, crystallized alternative positions on appropriate policies to address gaps in technology acquisition and use: would normal market forces solve the problem, or were special subsidies and government programs necessary to close gaps in certain social groups' opportunity to use technologies?

Physical access to computers and to Internet connections played a key role in these early conceptualizations of the digital divide, and the thornier question of why one would acquire a computer or pay for Internet access was sidelined in favor of presumed or obvious benefits. The access definition of the digital divide led to what one might call a "drive by" approach to remediating the digital divide: simply insure that computers and connections are available, and the rest will take care of itself. As Warschauer (2002) pointed out, "issues of content, language, education, literacy, or community and social resources" were not part of the discourse. Rather, it was the access definition that figured in several programs at local, state and federal levels seeking to get technology into the hands of the demographic groups identified in the surveys as on "the wrong side" of the divide. The Department of Commerce's Technology Opportunities Program, active from 1994-2004, made over $200 million (plus another $3 million in matching funds) available for computer and Internet technology used for various purposes; Texas' Telecommunications Infrastructure Fund, a $1.5 billion fund, awarded grants to schools and libraries for equipment purchases and discounted connectivity from 1996 through 2002; the 1996 Telecommunications Act created the e-rate program that provided discounted connections to schools and libraries; various states and even municipalities initiated programs supporting similar efforts. Subsidized spread of computers and Internet connectivity joined market-based diffusion to broaden the overall technology based in the U.S.

By the 21st century, two perspectives dominated the general understanding of the digital divide. One, typified by Ben Compaine (2001) advocated two points: first, that since the costs of information technologies continually decrease, market forces will eliminate the divide; and second, that gaps across populations' acquisition and use are typical of many commodities in capitalist society, and the gap in using computers and the Internet is no different from these other sorts of lags. In other words, the gap was in access to technologies, and the normal forces of private enterprise would determine the appropriate distribution of access. Michael Powell, FCC Commissioner from 2001-2005, characterized this in memorable fashion: when asked about the "so-called digital divide," Powell responded, "You know, I think there's a Mercedes divide. I'd like to have one. I can't afford one" (C-Span, 2001). While best remembered for that line, Powell expanded on his point by stating the essential conundrum that faces government when questions about its role in early-stage innovation processes come up. When can one justify government intervention? How do we know when a technology and a market require a nudge?

On the other hand, Servon (2002) argued that technology access gaps are one of many causal factors that keep certain population groups at a disadvantage. Persistent poverty and inequality are at the root of such divides, and while technology cannot solve such problems, it can "help to show the way out" (Servon, p. 2). In this Servon anticipated much of the research of the past decade that seeks to more carefully examine the resources, skills, and literacies that enable people to put computer and Internet access to work. This view of the divide acknowledges the importance of access but goes beyond it: access alone may not be enough to eliminate differential advantages associated with opportunities to utilize technology. Moreover, even with access to technologies, divides may be inevitable.

Broadening our understand of the digital divide, in the past ten years the research community embarked upon work exploring digital literacy, defined as the complement of skills and knowledge enabling one to use computers and the Internet. Prensky (2001) was among the first to use the terms 'digital immigrants' and 'digital natives' to denote differences between a population base that taught themselves about the Internet versus those who were immersed in the Internet culture from birth. As Internet usability and relevance emerged as significant factors associated with non-adoption in the 2000's, explaining how to frame usability and how to improve it has become a focus, domestically as well as internationally (Hargittai, 2008; Van Dijk, 2003; van Deursen and van Dijk, 2011; Mossberger et al. 2003; Mansell, 2002; Gangadharan and Byrum, 2012). The original access divide, while still relevant (albeit in fewer geographic regions), has "evolved" for some researchers into one defined by skills and "meaningful use."[2] The series of surveys published by the Pew Internet and American Life

[2] This is a very deliberate reference to the development of this concept in the health field in the U.S.

project during the 2000s amply documents the evolution of user skills and ways in which the Internet has become a relevant and powerful tool in everyday life (Pew, 2012).

For rural areas, however, access issues remain even as better understanding of the Internet's relevance and usability take center stage in recent work.

Overall, then, the early history of the digital divide literature shifted from simply documenting the gaps, to focusing on the rapid growth in Internet adoption among most demographics, to an emphasis on the provision of computers and access, and finally to assessing the role of digital literacy in the adoption decision.

1.2.2 Economic Outcomes and Broadband

Alongside these attempts to document Internet and computer availability and use, researchers also have inquired into the economic outcomes associated with access to and use of computers and the Internet. The growing significance of the Internet for economic transactions, for e-government, and for business vitality has been scrutinized. Several researchers have sought to document Internet adoption's or broadband's influence on productivity or economic gains. As Kolko (2012) highlights, there are several vulnerabilities to such studies. The problem of endogeneity is common: does broadband cause economic growth, or is the reverse true? Population growth may prompt broadband expansion, or broadband providers may choose to locate in regions more economically attractive. Sorting out the causal issues involved requires careful research design. A second problem concerns possible specification effects: it may be that certain industries – especially information-intensive industries – have unique impacts on broadband availability and adoption. Workers in such industries may be disproportionately dependent on network connectivity and hence their adoption would be higher than that of workers in other industries. Addressing this calls for analyses capable of attending to local employment patterns. As well, the nature of economic outcomes typically does not identify whether existing populations are gaining jobs or whether new workers are moving to regions where broadband might create jobs.

One of the most widely cited studies by Lehr et al. (2005) concluded that between 1998 and 2002 communities with consumer broadband experienced growth in employment, numbers of businesses, and businesses in IT-intensive sectors. However, their study also pointed out that the data available at that time were primarily supply-side, and that better data on demand were sorely needed. Gillett et al. (2006) found similar results: broadband availability produces employment growth and business growth – especially growth in IT-related businesses. They found no relationship on wage levels.

Kolko's studies on broadband's contribution to local economic development (2010; 2012) examined broadband's causal relationship to employment, and specific industries likely to be affected by the presence of faster networks. Reasoning that broadband could have the effect of lowering communication costs, Kolko hypothesized that effects on employment could be either positive in terms of the need to hire more workers, or negative in terms of using technology to replace labor. His studies also examined specific locational effects, singling out the so-called "footloose" industries and rural places. Kolko's work integrated broadband supply data from the FCC with employment data from the National Establishment Time-Series database, Census information on employment and household income, and Forrester surveys in household technology adoption. Kolko's work focused on the U.S. during the time frame 1999 through 2006. He reported that broadband expansion is positively related to economic growth, with more strength in ICT-intensive industries and in rural regions. However, this study found only limited influence on household income.

Stenberg et al. (2009) produced a thorough review of the value of broadband Internet for rural America, focusing on consumers, communities, and businesses. One finding, again using FCC data, is particularly noteworthy. Comparing rural counties with relatively high levels of broadband in 2000 with otherwise similar rural counties, they found higher levels of growth in wage and salary jobs, non-farm proprietors, and private earnings between 2002 and 2006 for those counties with early access to broadband. They did caution, however, that their research does not necessarily imply causality. This report also summarized ways that rural communities and businesses can benefit from broadband, including research on distance education, telehealth, and telework. Along these same lines, Kuttner (2012) discussed the opportunity costs of *not* having broadband in rural areas for households, communities, and specific industry sectors.

Calling attention to the significance of place-based analyses as opposed to sectoral analyses, Dickes, Lamie and Whitacre (2010) affirmed the need to examine both supply-side and demand-side policies in addressing the rural digital divide. A similar point is reinforced by economists Glasmeier and Greenstein in Strover (2011) when they state that while the most economic rural regions already have broadband connectivity, the remaining areas still could benefit in highly local ways; more granular approaches to the outcomes of broadband will be necessary to understand impacts. One such granular study is LaRose et al. (2011), who did not find strong evidence that local broadband availability produced greater community satisfaction or local individual economic development activities. They did find, however, that local community efforts to publicize and demonstrate broadband applications increased adoption. This finding reinforces some of Hauge and Prieger's (2009) suggestions regarding ways in which local organizations may be effective in stimulating adoption.

Several scholars have wondered whether estimating the link between broadband and economic gains might be similar to the dilemma facing economists as they sought to measure the early relationship between investments in IT and productivity in the 1980s and 1990s, the so-called productivity paradox. It was not until studies examined the changes *within* firms that people understood how computerization was affecting productivity, and those studies emerged much later than the initial investment in IT. So too, it may be that one cannot expect a technology such as broadband to create singular, direct effects. Rather, we might expect that it would interact with specific contexts, certain businesses, and certain applications or services. An alternative approach is to calculate the cost of digital exclusion, which Econsult Corporation (2010) attempts to estimate for various industry sectors and sums to over $55B per year lost. Suffice it to say, that with the presence of improved data, examining potential economic outcomes associated with broadband availability and use is a critical research subject.

1.2.3 Government Investment and Goals

New technological opportunities associated with the Internet intersect social and economic policy in several ways. The government's interest in cultivating advanced and competitive infrastructure has been focused decidedly on matters of economic productivity, employment, and growth. This is not to say that other sorts of outcomes associated with broadband might be unimportant; certainly there is discursive attention to broadband's positive role in delivering distance education, in contributing to remote delivery of health services, and to enhancing recreational activities (listening to music, watching videos, accessing news). However, development issues, and especially development issues within rural regions and during times of economic duress, garner most of the federal attention. We briefly note four components important in considering how the public sector interest has addressed broadband's influence on rural regions: improving data gathering; institutionalizing a broadband-focused universal service program; implementing federal policies intent on insuring continued federal oversight of broadband network development; and using the American Recovery and Reinvestment Act (ARRA) to invest in physical and social capital helpful to broaden broadband's reach to unserved and underserved populations.

First, in the wake of the 1996 Telecommunications Act, the FCC began to gather data on the deployment of "advanced networks" (which came to be called broadband networks). Their original efforts using Form 477 produced large datasets based on network availability data as submitted by the provider community. Many scholars have meticulously analyzed these datasets and called for improved data. The FCC responded to the need for better data (FCC, 2012a) and now collects information on both supply and demand. New federal efforts under ARRA to support broadband infrastructure created even better opportunities for data on both the supply and the demand side of broadband. A key impetus for improving data gathering was the desire to insure that technological capabilities were being offered equitably to all regions of the country.

A second major response occurred with the universal service provisions within the 1996 Telecommunications Act. The Schools and Libraries Program or E-rate, which provides discounted broadband connectivity to schools and libraries and rural health facilities, constitutes an annual investment of about $2.3 billion and has become an essential ingredient in maintaining broadband services to community anchor institutions. The High Cost Fund, currently in transition to a newly articulated program called the Connect America Fund, invests approximately $4.5 billion per year in telecommunications company infrastructure serving regions that incur higher costs (such as rural areas). Other universal service programs also target low income households with subsidizes for both equipment acquisition and recurring costs for services.

Third, control over the Internet has emerged in several legal cases over the past several years. They represent a range of efforts that epitomize the struggle between private companies that want to maintain control over their investments and infrastructure and government interests that want to assure the best and fairest possible network development process. While a detailed review of these struggles is out of the scope of this report, some of these control issues are associated with net neutrality, with the national effort by cable companies to push for statewide video franchising, and with several state initiatives to prohibit or limit municipal networks dedicated to providing broadband services. These endeavors are related to the digital divide more generally because they cut to the core matter of where networks are built, how they function, and how markets are defined. In other countries, there is ready recognition of broadband's relationship to social equality; for example, the concept of "social inclusion" is directly associated with Internet connectivity in the UK (BIS, 2010). However, in the U.S., a privately owned and operated telecommunications system is bound to conflict with public sector institutions that historically have had a role in how those systems operate and that espouse social goals such as comparable quality and rates in urban and rural regions (a longstanding commitment of universal service). It is worth bearing in mind, however, that the FCC's universal service program disbursing funds under the High Cost program[3] - which directly benefits carriers serving all regions that incur greater expenses - has explicitly collected funds from the consumer rate base and allocated them back to telecommunications companies, effectively blending public money with private operations.

Finally, ARRA's attention to improving economic circumstances throughout the country brought broadband services under its umbrella. Approximately $7.2 billion was allocated to the National Telecommunications and Information Administration and the Department of Agriculture so that they could implement programs that would invest in broadband infrastructure to serve people in unserved and underserved regions.[4] By building out last mile networks, creating additional middle mile facilities, establishing public computing facilities or so-called "third places" for access, and by erecting programs to help with training, both the Broadband Technology Opportunities Program (BTOP, under NTIA) and the Broadband Initiatives Program (BIP, under Agriculture) have contributed to improved broadband access and adoption. BTOP also awarded grants to each of the 50 states under its State Broadband Initiatives program that would map each

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[3] This program is being recast by the FCC as the Connect America Fund.
[4] Over $6 billion of these funds was actually awarded between 2009 and late 2010, when the last broadband grant was awarded (Salway, 2011).

state's broadband assets and also engage in planning and coordination among local stakeholders. Other federal policies have attempted to address the rural – urban digital divide over the past decade. Notably, the United States Department of Agriculture (USDA) broadband grant and loan program for unserved and underserved areas began around 2001. Kandilov and Renkow (2010) find that although the pilot loan program had positive impacts on employment, payroll, and number of business establishments, these outcomes are driven by communities very close to urban areas – and no impact is found for the current (as opposed to the pilot) loan program. Regardless, the ARRA efforts represent a major resource infusion, although other smaller state and regional efforts (such as Connected Nation) also have occurred over the years.

The stimulus program investment crystallizes the policy question hovering over digital divide research: when is government intervention needed? How do we evaluate conditions of market failure as opposed to the "normal" course of technological diffusion? How effective are government interventions in broadband infrastructure provision, i.e., what outcomes are associated with such investment? The next generation of research on the digital divide doubtless will take up such questions.[5]

1.3 Data Used in this Report

The "value-added" of this report lies in the meshing and use of *both* availability and adoption data related to broadband. Three primary sources of data are used to accomplish this:

- Current Population Survey data – Internet use supplement (household broadband decision)
    - Data used: 2003, 2010 (most current)
- FCC County-level broadband adoption data (county broadband adoption rates)
    - Data used: 2008, 2010, 2011 (most current)
- National Broadband Map infrastructure availability data
    - Data used: 2010, 2011 (most current)

Each of these sources is detailed below.

1.3.1 Current Population Survey (CPS)

The Current Population Survey is a monthly survey of roughly 50,000 households conducted by the U.S. Census Bureau. Supplementary surveys dealing with the topic of Internet use (including type of connection) have been included for a single month in 2001, 2003, 2007, 2009, and 2010. We focus on the years 2003 and 2010 (the latest available for this analysis) to answer the

[5] NTIA's programs are being evaluated by ASR Analytics. At this writing, they have released preliminary reports (NTIA, 2012).

questions in this report, primarily because broadband adoption was still in its infancy in 2001.[6] The downside of these data is that the lowest level of geographic detail is the state of residence and whether the household resides in a non-metropolitan area. No county or community identifier is provided. Thus, the CPS data can be used to document national and state level gaps between rural (defined as non-metro) and urban (defined as metro) areas over time, but cannot assess any lower level of rurality.[7] We are aware that definitions of broadband vary across this time period.

After dropping households with missing or incomplete data, there are 40,172 observations in 2003 (10,357 non-metro) and 46,082 observations in 2010 (10,244 non-metro). This large sample size is very useful for statistical testing, and the application of survey weights developed by the Census Bureau ensures that the sample is nationally representative.

1.3.2 Federal Communications Commission Form 477

Since 2008, in response to the Broadband Data Improvement Act, the FCC has provided data on county-level household broadband adoption rates, along with measures of the number of broadband providers in each county and better data on speeds. One of the most useful features of these data is that they can be easily meshed with other county-level sources, such as demographic data provided by the Census or economic measures provided by the Bureau of Economic Analysis (BEA) or elsewhere. Counties are also readily classified as non-metro, micro, and non-core, allowing for a lower level of analysis for more rural parts of the country. Counties are considered metropolitan if they have a core community of at least 50,000 people or 25% of their workforce commutes to a neighboring core; micropolitan if they have an urban core of at least 10,000 up to 49,999 people or 25% of their workforce commute to a neighboring core; and noncore if they do not have a core of at least 10,000 people. There are 3,072 counties in each year of the FCC data, of which 2,037 are non-metropolitan (671 micropolitan and 1,366 non-core).[8] The FCC data also include information on two distinct speed thresholds for "broadband" – one defined under the traditional measure of at least one direction with 200kbps, and another under the faster definition of 768kbps download, 200kbps upload.[9] The spatial nature of the data allows for informative maps to be drawn as well as for spatial modeling techniques.

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[6] A reviewer notes that caution should be used when citing historical broadband experiences, since the associated costs and mindsets from the early 2000s changed rapidly.
[7] Throughout the remainder of this report, we use the terms rural and non-metro (and urban and metro) interchangeably, though our focus is on non-metro areas since we primarily use county-oriented datasets.
[8] We mesh Virginia independent cities with the counties where they reside.
[9] This speed (768 kbps down, 200 kbps up) was adopted by the FCC at one point as a definition for broadband, and BTOP likewise used it for reporting purposes. The most current broadband speed definition the FCC uses is 4 mbps for download and 1 mbps upload.

The FCC broadband adoption data are split into 5 categories based on the proportion of households that connect to the Internet with a high-speed connection: 0-19.9% adoption, 20-39.9% adoption, 40-59.9% adoption, 60-79.9% adoption, and 80-100% adoption. While this results in a loss of fidelity regarding the actual percentage of households that adopt, it does provide useful data in assessing the extent of the digital divide. It is worth noting that this primary variable of interest deals with residential *fixed* (wireline) broadband connections – therefore, wireless or phone connections are not included. We use data from 2008, 2010, and 2011 (the latest available for this analysis) to assess broadband gaps over time and also to model broadband's impacts on economic growth measures that can be captured at the county level.

1.3.3 National Broadband Map

Fall 2010 data[10] and June 2011 data from the National Broadband Map (NBM) were utilized to obtain average values for the maximum advertised download/upload speeds and unique number of providers at the county level. The National Broadband Map is an online database that allows users to access broadband availability at the neighborhood level. This dataset also includes holding company unique numbers, maximum advertised upload/download speeds, typical upload/download speeds, and technology utilized, among other variables. This project was a response to mandates under ARRA and the Broadband Data Improvement Act. As such, the National Telecommunications and Information Administration (NTIA), in partnership with the Federal Communications Commission, the 50 states, and District of Columbia, instituted the State Broadband Data and Development Grant Program in order to gather data for these maps. The NBM data has been critiqued on several points; namely that it is provided by infrastructure carriers who have an incentive to overstate their service areas, and that a census block is considered served if even one customer in that area has access to broadband. This may inflate the availability rates for some rural areas since a small portion of those areas may receive the same level of broadband service as a neighboring urban community. Nevertheless, this data represents a marked improvement from previous data collection efforts related to broadband infrastructure provision.

This study focuses on several variables from the NBM: maximum advertised[11] upload/download speeds and number of providers. However, since data are available at the block group level, aggregation to the county-level was necessary. In order to achieve this, Microsoft Access and Excel software were utilized. First, due to the size of the datasets, Microsoft Access was utilized to "break up" the dataset into smaller sub-datasets so these in turn could be analyzed in Excel. Second, a unique identifier was assigned after combining the holding company unique number

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[10] This dataset does not include census tracts larger than 2 square miles.

[11] Advertised maximum speeds were utilized rather than typical speeds for two main reasons. First, data availability is higher when using advertised maximum speeds and second, according to the FCC's "Eighth Broadband Progress Report", there is no significant difference between advertised maximum speeds and typical speeds. The report finds that, "most of the broadband providers studied deliver actual speeds that are generally 80 to 90 percent of advertised speeds or better." (FCC, 2012a, P. 56)

and the county-level FIPS code. Third, pivot tables in Microsoft Excel were used to obtain the unique number of providers as well as the average maximum advertised upload/download speeds at the county level.

Data provided for the NBM resulted in another useful measure: the percentage of the population for which no wired broadband infrastructure was available. These data, referred to in the text that follows as "no broadband," are only available for 2010 and are based on an alternative definition of broadband (3 mbps download, 768 kbps upload) than is typically used elsewhere. However, this measure is quite useful in providing information about broadband availability; such a measure cannot be gleaned from county-level numbers of providers. Again, for the purposes of this report, these data were aggregated to the county level for use with FCC data and to the metro / non-metro portion of the state when meshed with CPS data. Only wireline technologies were used for this measure due to concerns about the accuracy of the mobile wireless broadband data (FCC, 2012a).[12] Finally, NBM data for wireless providers were also included, but is only available for 2011 due to these accuracy concerns.[13]

[12] According to the FCC report, "…we have concerns that providers are reporting services as meeting the broadband speed benchmark when they likely do not. … although mobile networks deployed as of June 30, 2010 may be capable of delivering peak speeds of 3 Mbps / 768 kpbs or more in some circumstances, the conditions under which these peak speeds could actually occur are rare." (FCC, 2012a, P. 25-26)

[13] The 2011 NBM dataset uses another data source (Mosaik Data) for mobile broadband deployment which distinguishes between network technologies.

2. Nature and Extent of the Metro – Non-metro Broadband Divide

This chapter places broadband adoption across metro and non-metro areas in both a current and historical context. CPS household data are used to describe how the metro – non-metro broadband gap has changed over time, and also denotes trends related to the commonly accepted determinants of broadband adoption (education, income, etc.). FCC data are similarly used to display county-level broadband adoption rates among metro, micro, and non-core counties. Both datasets are meshed with National Broadband Map data to paint a picture of the broadband availability situation across geographies.

2.1 CPS Household Data (2003 & 2010): Is the Metro – Non-metro Broadband Divide Changing Over Time?

Current Population Survey data from 2003 and 2010 demonstrate a persistent 13 percentage point broadband adoption gap between metropolitan and non-metropolitan households (***Figure 1***). Rates of broadband adoption in non-metropolitan households increased from 10% to 57% over this time, but were matched by similar increases among metropolitan households.

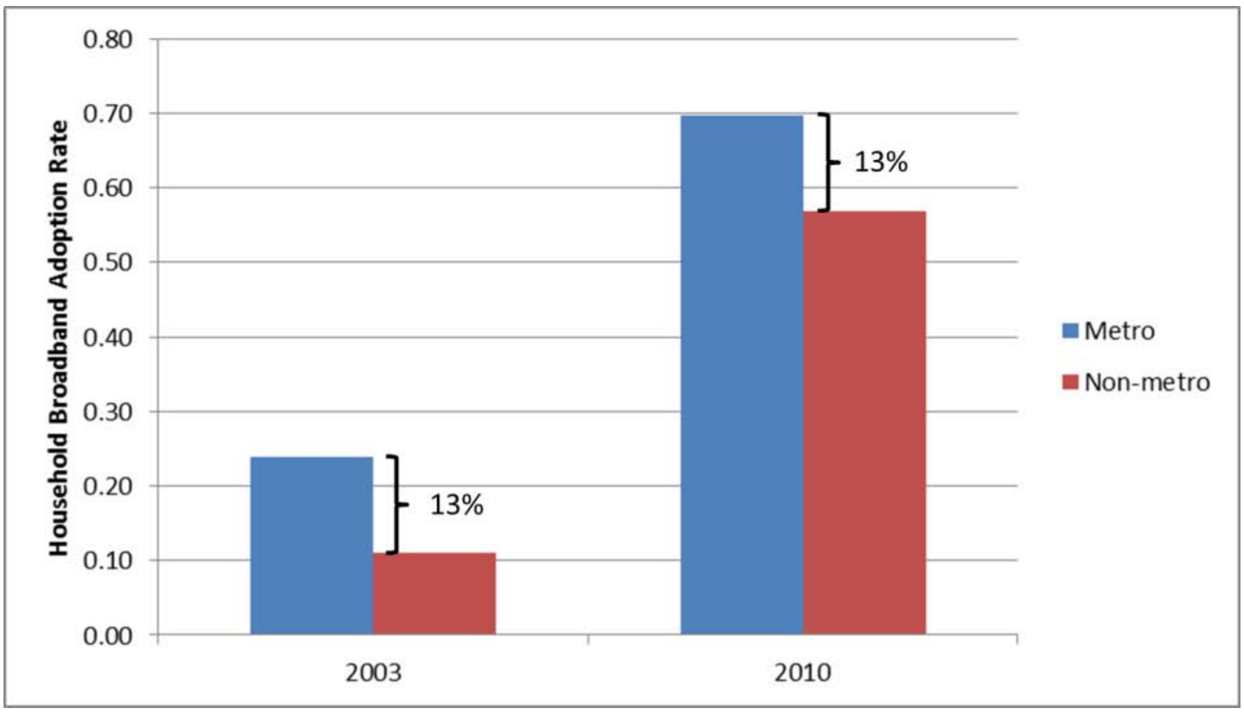

Figure 1. Household Broadband Adoption Rates by Metro / NM Status, 2003 and 2010.
Note. From "Current Population Survey Internet Use Supplement," 2003 & 2010.

While this lack of progress in closing the broadband digital divide is noteworthy, perhaps more interesting are the changes in the broadband gap over time among particular demographic groups. In particular, as discussed below, the metro – non-metro gap has actually *increased* over time for households with characteristics that typically predict low levels of broadband adoption (low income, low education, and elderly). We now turn to a more in-depth analysis of these trends.

Two household characteristics that historically have been highly predictive of broadband adoption are income and education levels. Figures 2 and 3 demonstrate that, as expected, adoption rates of all households increased with income and education levels in both 2003 and 2010. More striking, however, is the shifting metro – non-metro gap at different income and education levels over time. For example, households with lower income levels (<$40,000) actually had larger metro – non-metro adoption gaps in 2010 than in 2003, suggesting that non-metro areas in this income range fell further behind over time (***Figure 2***). Similarly, the metro – non-metro gap for households headed by an individual with a less than a high school degree were larger in 2010 than they were in 2003 (***Figure 3***). Overall, these trends suggest that non-metropolitan households with higher levels of education and income are catching up to their metropolitan counterparts in terms of broadband adoption – but lower socioeconomic groups in non-metro areas have seen the gap widen.

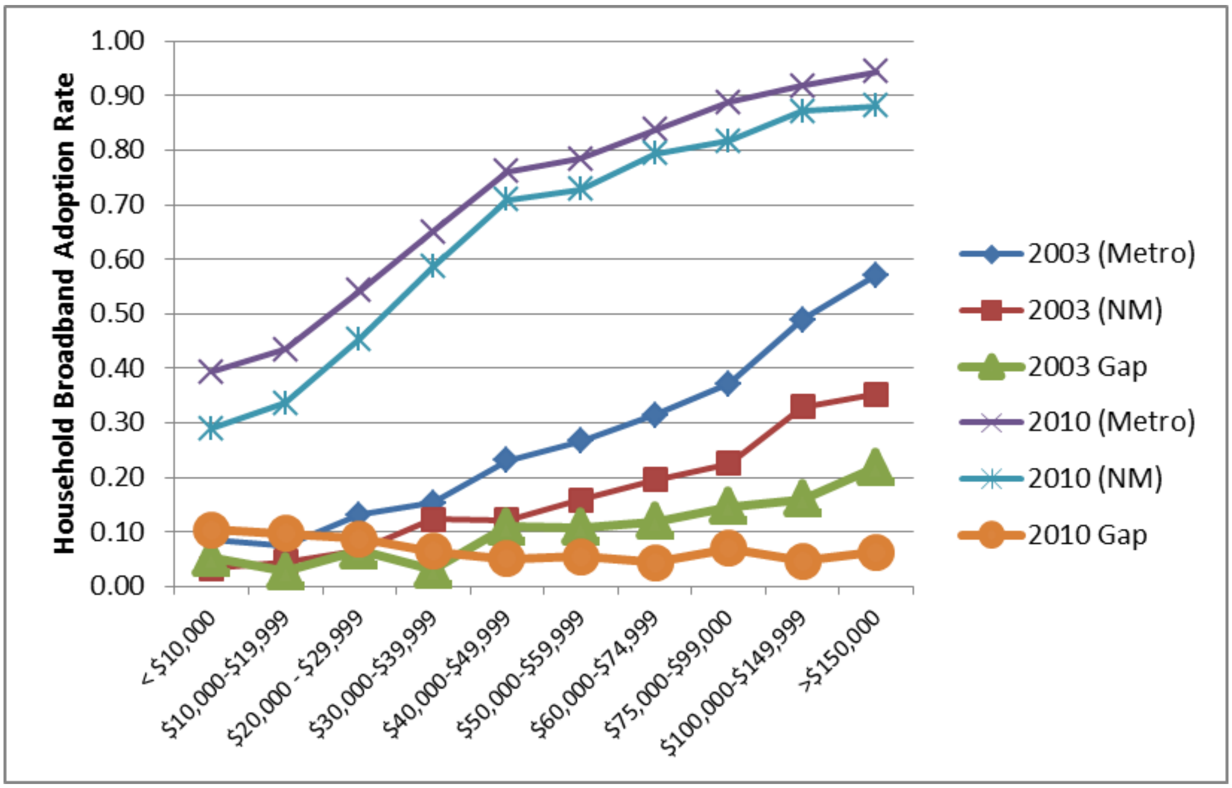

Figure 2. Household Broadband Adoption Rates by Income, 2003 and 2010.
Note. From "Current Population Survey Internet Use Supplement," 2003 & 2010.

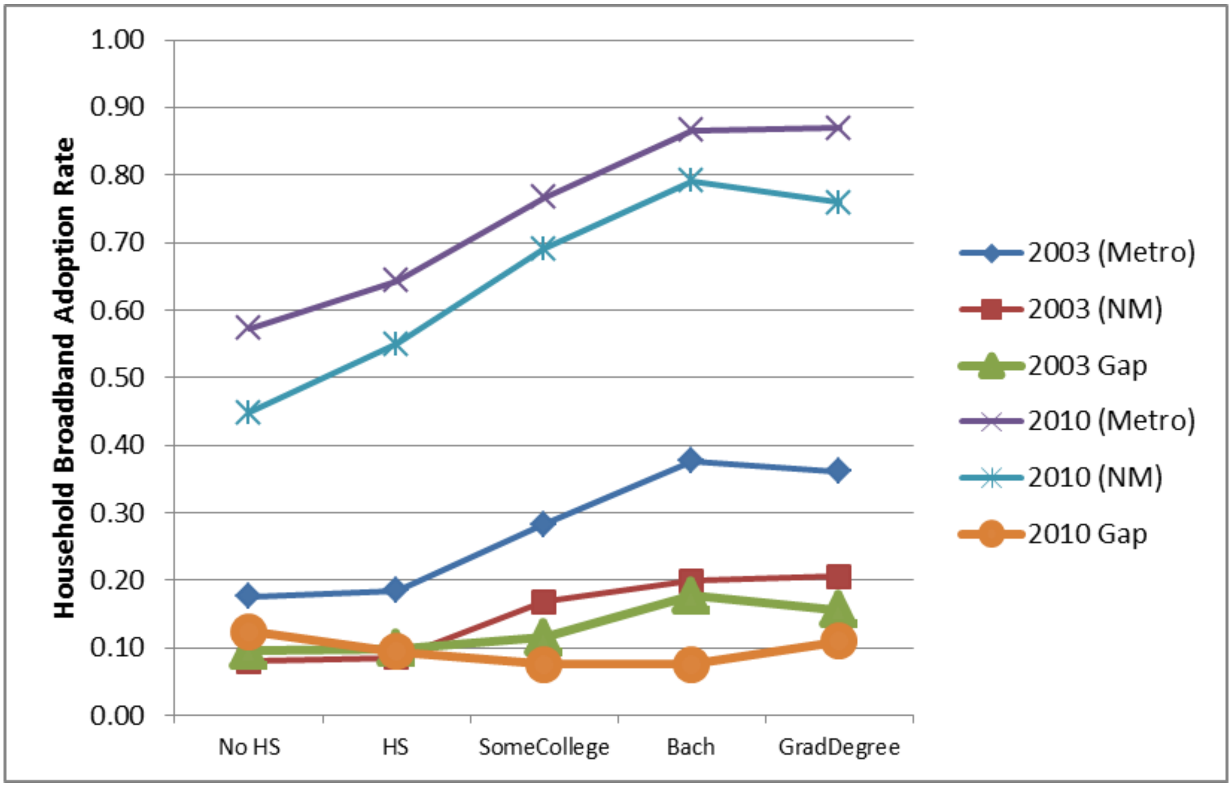

Figure 3. Household Broadband Adoption Rates by Education, 2003 and 2010.
Note. From "Current Population Survey Internet Use Supplement," 2003 & 2010.

A similar story can be told about another important predictor of Internet adoption – household head age. ***Figure 4*** demonstrates that older household heads (ages 60+) in metropolitan areas increased their broadband adoption rates between 2003 and 2010 at a faster rate than their non-metropolitan counterparts. This means that another group of historically slow adopters – the elderly – are seeing the metro – non-metro broadband gap increase rather than decrease.

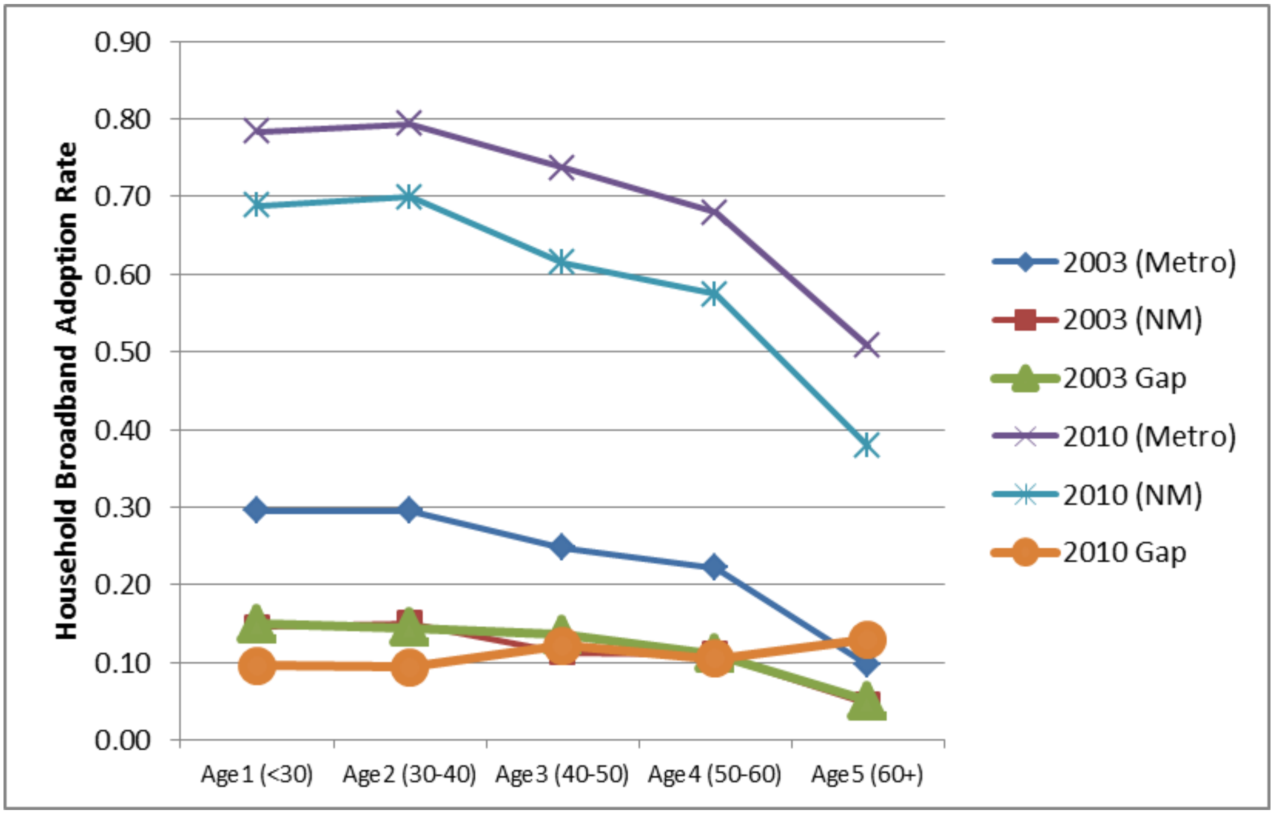

Figure 4. Household Broadband Adoption Rates by Age, 2003 and 2010.
Note. From "Current Population Survey Internet Use Supplement," 2003 & 2010.

This trend of increasing metro-non-metro broadband gaps over time for specific demographic groups continues along racial and ethnic lines. ***Figure 5*** demonstrates that although minority categories such as Black, Hispanic, and other race increased their broadband adoption rates in non-metropolitan areas, the gaps are larger in 2010 than they were in 2003. The metro – non-metro gap for Whites was consistent in both years, while Asian households actually had higher broadband adoption rates in non-metro areas in 2010.

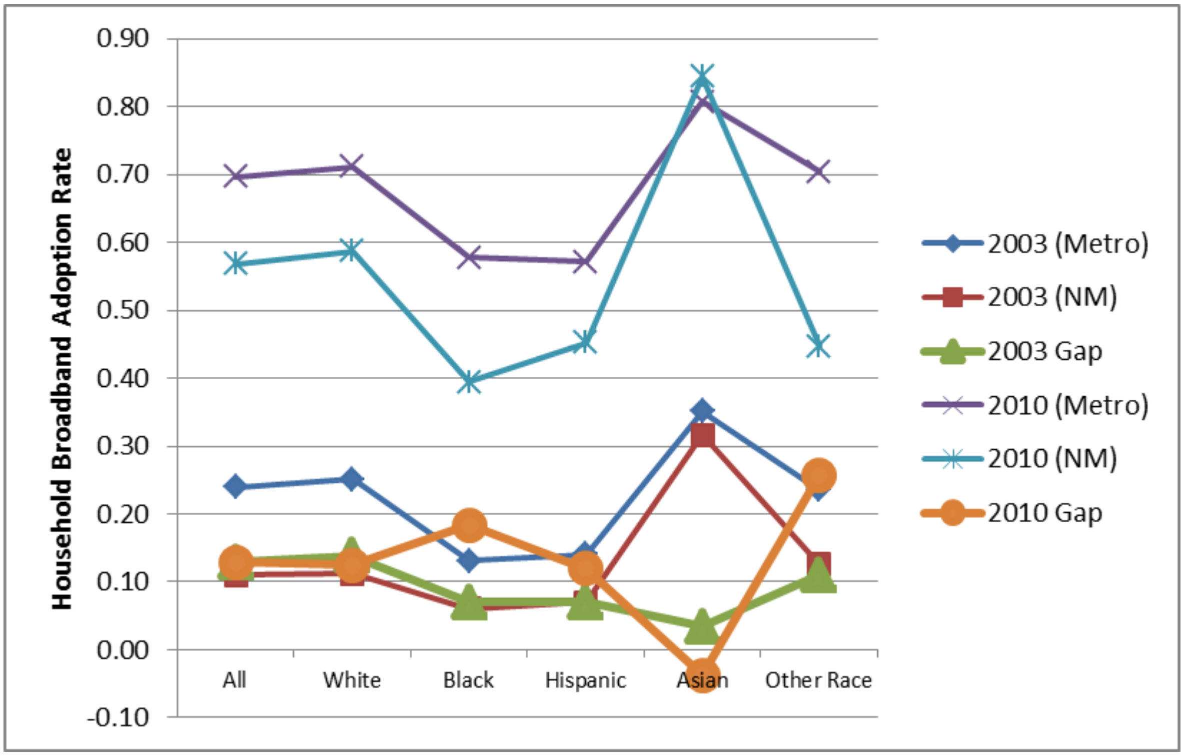

Figure 5. Household Broadband Adoption Rates by Race, 2003 and 2010.
Note. From "Current Population Survey Internet Use Supplement," 2003 & 2010.

In terms of broadband availability, it is no surprise that non-metropolitan areas lag behind their urban counterparts. After meshing the National Broadband Map data to a county level and then aggregating to state metro and non-metro totals, ***Table 1*** indicates that 18.3% of non-metropolitan households do not have any type of broadband available to them. Compared with only 3.1% in metropolitan areas, the resulting gap in broadband availability is striking. Chapter 3 explores the role of this availability difference in explaining the 13 percentage point gap between household-level metro and non-metro broadband adoption rates documented above.

Table 1. Broadband Availability Measures in 2010 (Metro vs. Non-metro).

Broadband Availability (2010)	Metro	Nonmetro	Gap	
Pct with No BB	3.1%	18.3%	-15.2%	***
Avg. Number Providers	8.4	5.2	3.2	***
Avg. Max. Ad. Download (Cat)	5.6	5.7	-0.1	***
Avg. Max. Ad. Upload (Cat)	3.9	3.8	0.1	***

*** Indicates means are statistically significantly different from each other at the p = .01 level.

Table 1 also demonstrates that metropolitan areas have higher numbers of broadband providers; however, the average maximum advertised download and upload categories are similar between metro and non-metro areas (although the differences are statistically significant given the large

CPS sample size). Note that the advertised speed data displayed is categorical, thus a mean of 5.6 represents speeds somewhere between category 5 (3-6 mbps) and 6 (6-10 mbps).[14]

The CPS also asks questions about why households without broadband did not adopt. These are summarized in ***Figure 6*** (for non-metropolitan households only). The primary reason for non-adoption in both 2003 and 2010 was a lack of perceived need. It also may be the case that nonadopters are unaware of availability simply because they are not interested in the service. It is interesting to note that the likelihood of the "no need" reason being given increased as a percentage of nonadopters over time. Thus, as more households adopted broadband, the remaining non-adopters increasingly consisted of those who had a hard time seeing its value. Horrigan (2012a) has suggested that as the U.S. reaches a broadband saturation point, those without broadband may constitute a "hard core" group that is simply not interested in the Internet.

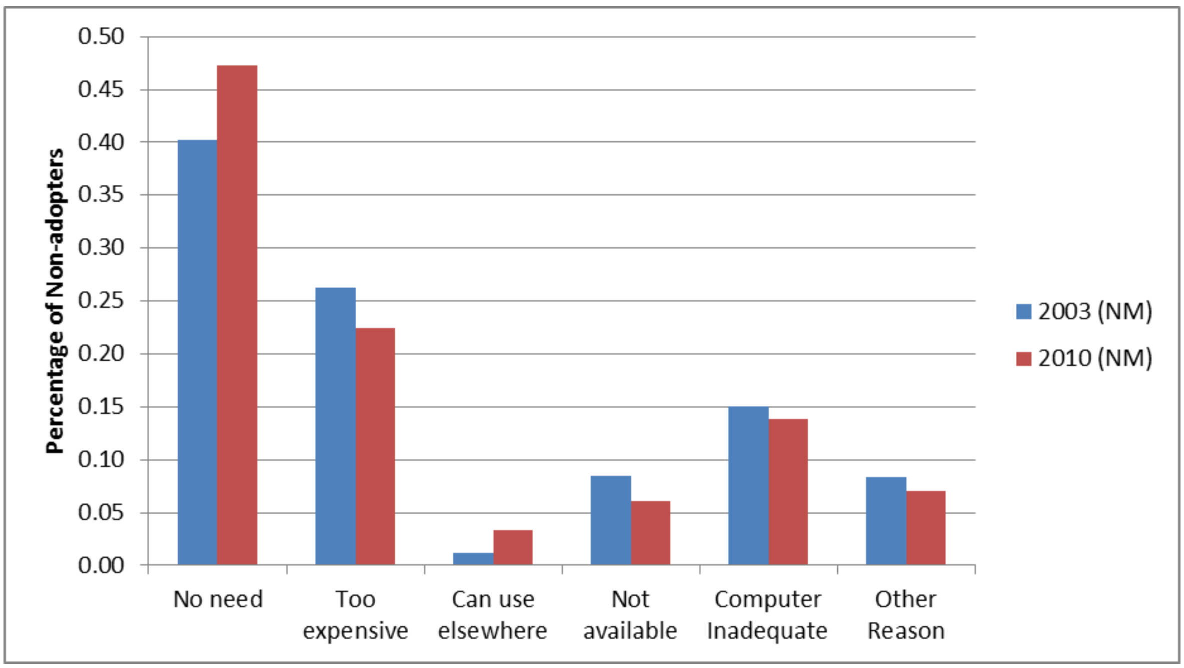

Figure 6. Primary Reason for Non-adoption of Broadband in Non-metropolitan Households, 2003 and 2010.
Note. From "Current Population Survey Internet Use Supplement," 2003 & 2010.

It is worth noting that "not available" is listed as the primary reason for non-adoption by less than 10% of non-metropolitan households in both years, despite the lower levels of broadband availability noted in ***Table 1*** above. This supports the premise, shared by many economists, that

[14] The 11 categories for maximum advertised download / upload speed are: (1) < 200 kbps, (2) ≥ 200 kbps and < 768kbps, (3) ≥768kbps and < 1.5 Mbps, (4) ≥ 1.5 Mbps and < 3 Mbps, (5) ≥ 3 Mbps and < 6 Mbps, (6) ≥ 6Mbps and < 10 Mbps, (7) ≥ 10 Mbps and < 25 Mbps, (8) ≥ 25 Mbps and < 50 Mbps, (9) ≥ 50 Mbps and < 100 Mbps, (10) ≥ 100 Mbps and < 1 Gbps, and (11) ≥ 1 Gbps.

the main barrier to increasing rural broadband adoption rates is on the demand side as opposed to the supply side (Whitacre, 2010; Hauge and Prieger, 2009).

Finally, the CPS dataset allows for observation of the types of technologies that households use to connect to the Internet. ***Table 2*** summarizes these for metro and non-metropolitan households in both 2003 and 2010. Note that the percentages shown in ***Table 2*** are relevant to all households (including non-adopters), so that the connection types sum to the overall adoption rate. *Figure 7* also uses these data, but focuses only on the subset of households with broadband access (so that non-adopters are left out, and the percentages total to 100). This allows for visualization of how the types of household connections changed as overall adoption rates increased.

Table 2. Rates of Residential Broadband Connection Types, by Metro / Non-metro, 2003 & 2010.

	2003			2010		
	Metro	Non-metro	Gap	Metro	Non-metro	Gap
Broadband at Home (any)	23.9%	11.0%	12.9%	69.7%	56.8%	12.9%
DSL	9.9%	3.7%	6.2%	23.5%	28.0%	-4.5%
Cable	13.3%	6.3%	7.0%	36.4%	19.6%	16.7%
Fiber	0.2%	0.4%	-0.1%	3.9%	1.1%	2.8%
Cell	0.1%	0.1%	0.1%	6.6%	5.9%	0.8%
Satellite	0.2%	0.3%	-0.1%	1.5%	3.3%	-1.8%
Other	0.3%	0.3%	0.0%	1.1%	0.9%	0.1%

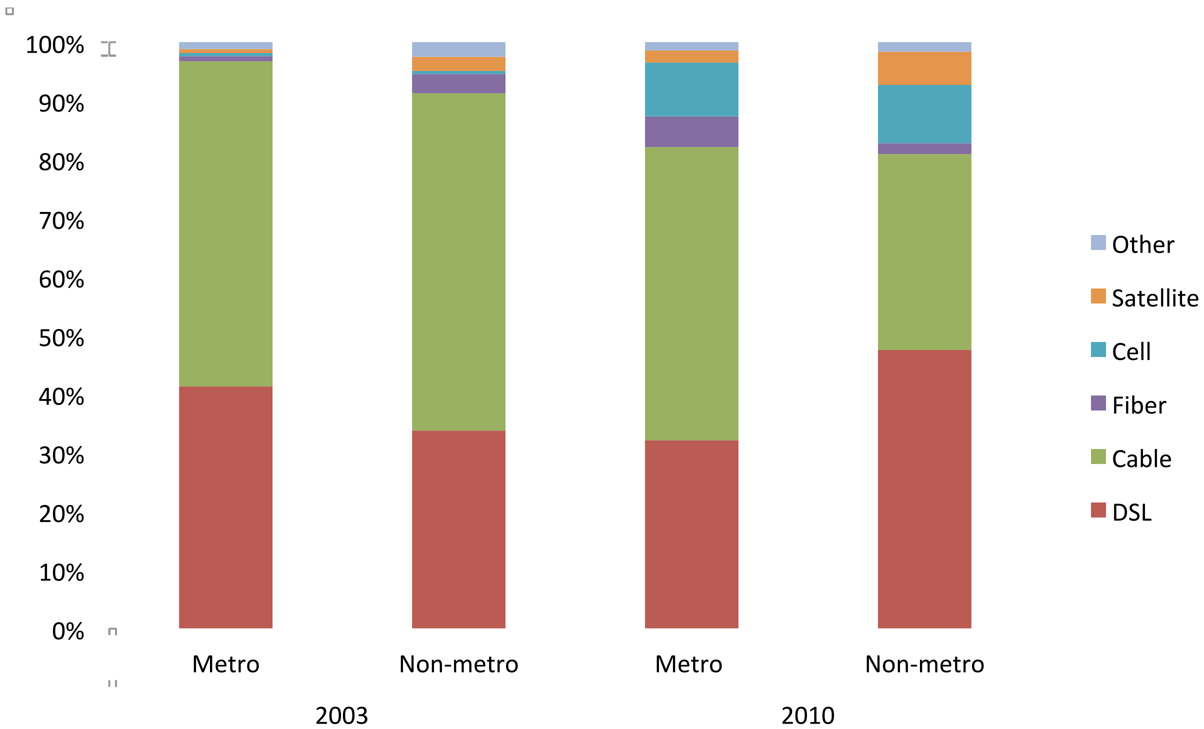

Figure 7. Composition of Residential Broadband Connections, by Metro / Non-metro, 2003 & 2010.

These statistics suggest that while the broadband gap has remained consistent between 2003 and 2010, the types of technologies used have changed across geographies. Notably, rates of Digital Subscriber Line (DSL) access are now higher in non-metro areas compared to their metro counterparts for 2010, diminishing the early advantage of cable-based access in non-metro regions. We also point out that DSL speeds are generally lower than cable-provided broadband, a possible disadvantage in non-metro areas. Cellular broadband access (which is mostly cell phones) increased dramatically over this time period, but differences are minimal between metro and non-metro areas. It is worth noting, however, that more recent data has shown a surge in use of Smartphone for connecting to the Internet between 2011 and 2012 (Horrigan, 2012b). These more recent data also indicates that households that have a Smartphone as their only type of broadband connection are more likely to be found in rural areas, and that mobile phones are used for broadband access more frequently than are satellite connections. Even so, the data show that the proportion of satellite connections increased in non-metro areas (and in metro areas as well), suggesting that availability of wired infrastructure may still be an issue for some rural residents or that bundled services (TV plus Internet access) typical of satellite plans is a draw. Finally, fiber access has increased, though mostly in metropolitan areas, but is still not a dominant type of connection. Interestingly, several fiber projects were supported in non-metro areas after 2010 by BTOP funding, and economic developers are debating whether the provision of this type of very high speed access will impact business attraction or other development measures. Similarly, case studies of Chattanooga and Kansas City (both offering speeds of 1 Gbps, or 1,000 Mbps as of late 2012) will be useful in assessing whether "out of the ordinary" broadband access impacts economic development.

2.2 FCC County Data (2008 – 2011): County-level Adoption Rates Show Improvement in Non-metro Areas

The CPS household data used in the previous section showed a consistent 13 percentage point gap in broadband adoption rates between metro and non-metro areas over the 2003 – 2010 time period. The FCC county-level data paints a more attractive picture for non-metro areas, with rates of broadband adoption increasing significantly over the 2008 – 2011 time period. Noncore counties, in particular, saw large improvements in the percentage of households adopting broadband over this time (***Figure 8***).

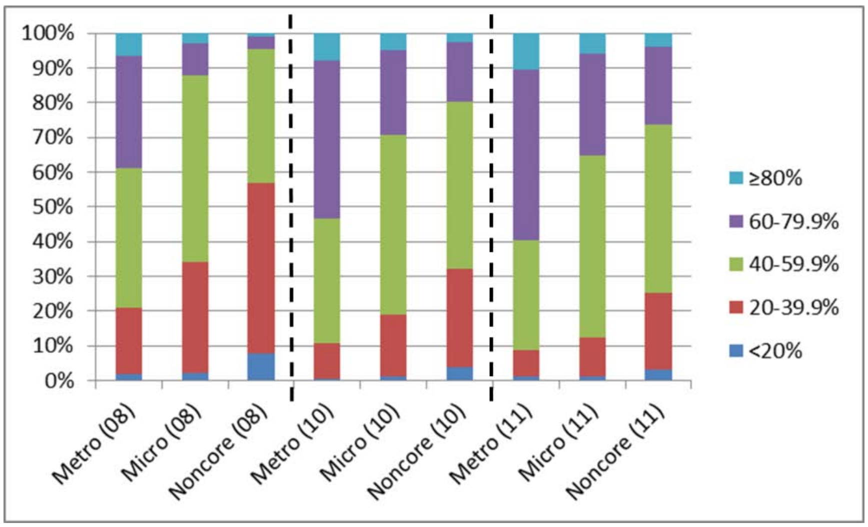

Figure 8. County-level Broadband Adoption by Metropolitan Status, 2008-2011.
Note: From FCC Form 477 Data, 2008, 2010, 2011.

While over 50% of non-core counties had broadband adoption rates lower than 40% in 2008, only 25% met this criterion in 2011. Additionally, the proportion of non-core counties with relatively high levels of broadband adoption (>60%) grew from only 4% in 2008 to over 26% in 2011.

To assess county-level broadband adoption gaps between metro / micro and metro / non-core areas, ***Figure 9*** presents means of the 5 adoption categories (1 = <20%, 2 = 20-39.9%, 3 = 40-59.9%, 4 = 60-79.9%, 5 = >80%) for 2008 and 2011. Thus, a mean broadband adoption rate of 3.2 would suggest adoption rates in the 40-59.9% range for the included counties. The results show a decline in both the metro – micro adoption gap (from 0.44 to 0.33) and the metro – non-core adoption gap (from 0.82 to 0.58) over this 3-year period. Thus, while broadband adoption rates continue to climb in metropolitan counties (nearly 60% had county-level adoption rates of over 60% in 2011), increases among micro and non-core counties with very low levels of adoption have reduced the gaps over time.

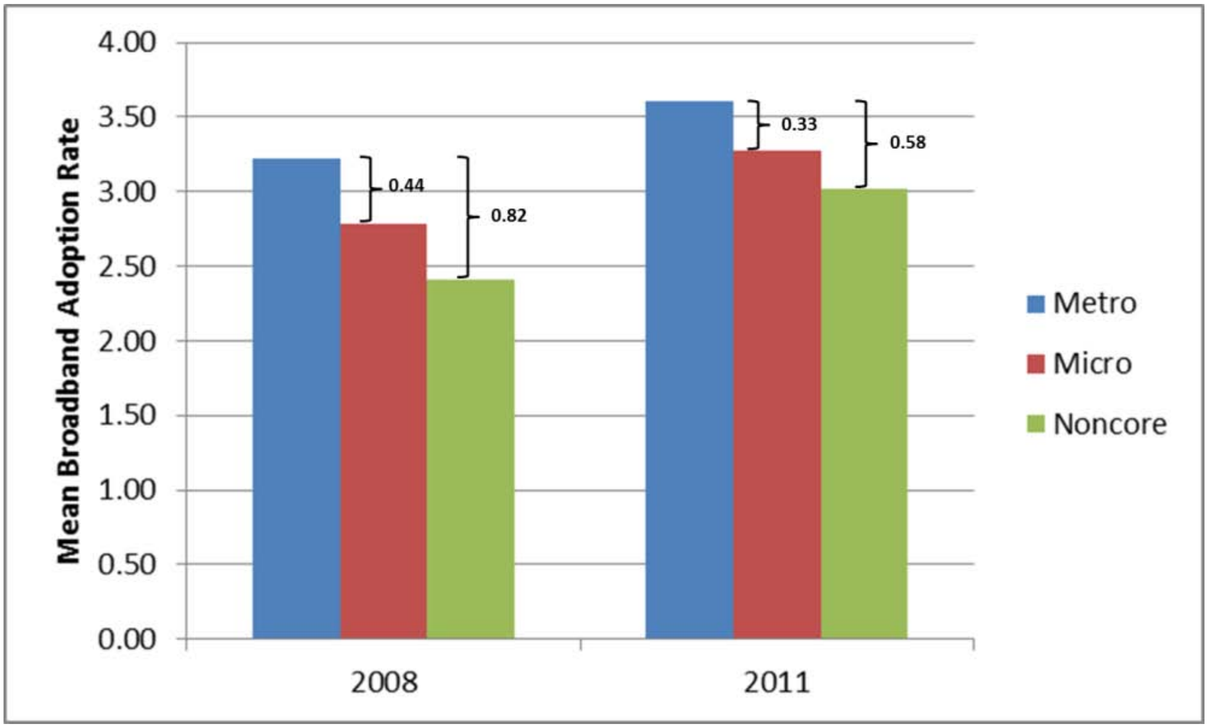

Figure 9. County-level Broadband Adoption Gaps, 2008 and 2011.
Note: From FCC Form 477 Data, 2008, 2011.

2.2.1 Adoption by Geographic Location

Figure 10 looks at the 2011 FCC data from a geographic perspective. Several states exhibit low levels of broadband adoption, notably those in the South (Georgia, Mississippi, and parts of Louisiana, Texas, and Oklahoma). Very high levels of broadband adoption exist in the Northeast, and near Denver in Colorado. Interestingly, most states have pockets of counties with high levels of adoption, but there does appear to be a general spatial trend among the data. Many of the counties with low levels of adoption are lightly populated and have lower income levels. In fact, the average county population in 2011 for counties with the lowest adoption levels is 12,640 (compared to the national average of 25,055 for all non-metro counties). Similarly, the average income level in these counties is $35,700 compared to $39,500 for all non-metro counties.

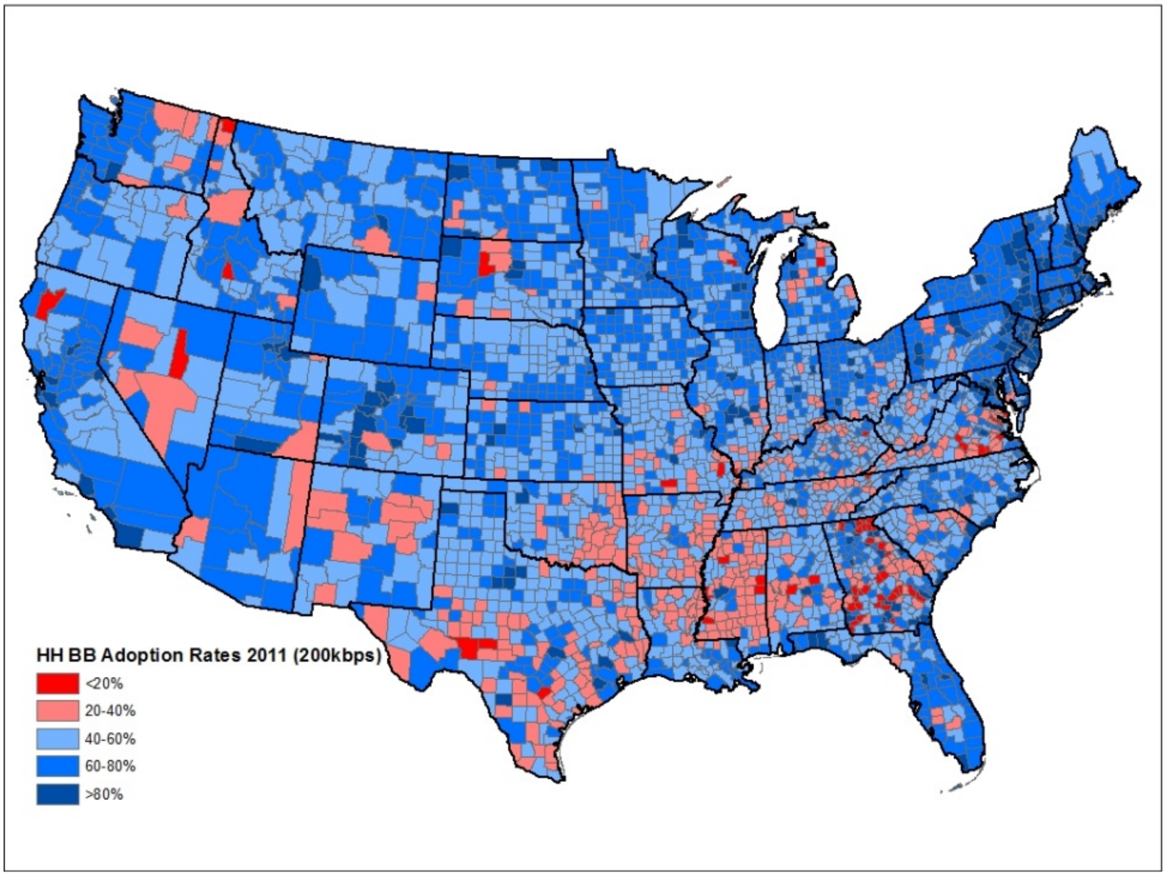

Figure 10. County-level Household Broadband Adoption Rates, 2011.
Note: From FCC Form 477 Data, 2011.

2.2.2 Differences in Broadband Availability by Metropolitan Status

This report also seeks to document differences in broadband availability (including measures of upload / download speeds) between metropolitan and micropolitan, and metropolitan and non-core areas. The county-level FCC data can also be meshed with the lower-level National Broadband Map data to report on different measures of broadband infrastructure availability. We look at the number of residential wired and wireless providers, average maximum advertised upload / download speeds, and the percentage of population without any type of broadband access below.

As expected, micro and non-core counties lag behind in terms of both wired and wireless providers. Nearly 20% of all non-core counties have 2 or fewer landline providers as of 2011, compared with only 4% of metropolitan counties (***Figure 11***). Further, a full 17% of metropolitan counties have over 10 landline providers in 2011, while only 5% and 2% of micro and non-core counties, respectively, can boast that many. A similar story holds for wireless infrastructure, with over 37% of non-core counties but only 5% of metropolitan counties having 3 or fewer providers (***Figure 12***).

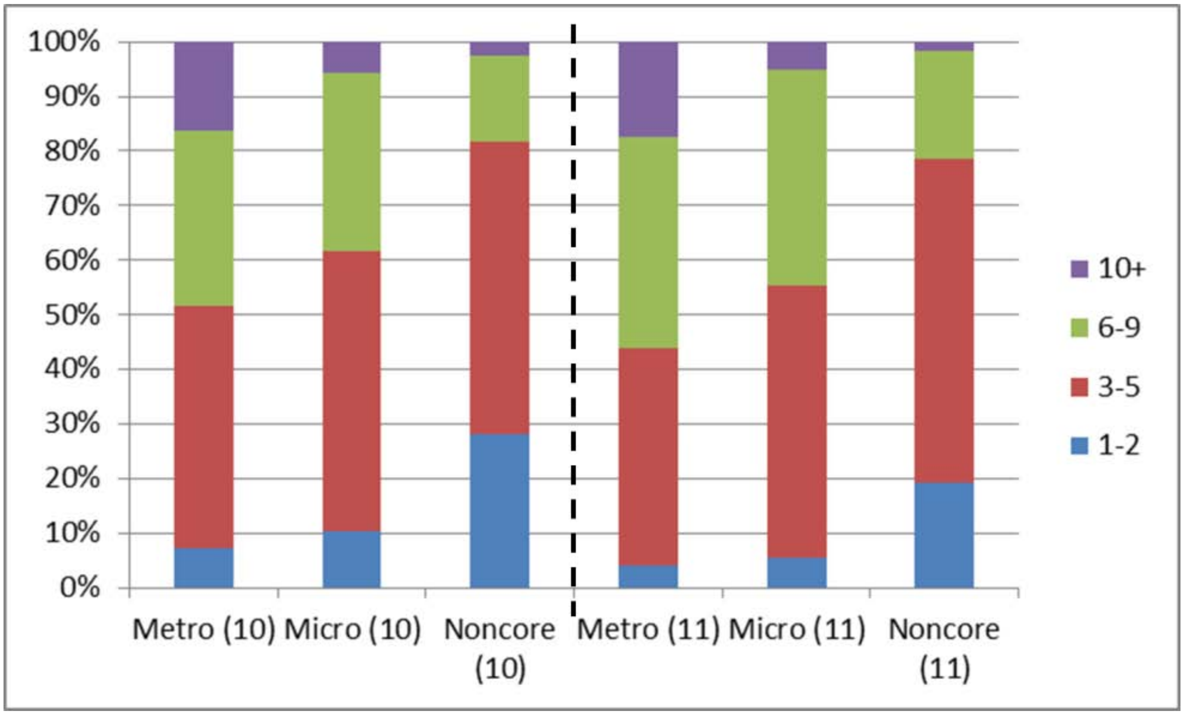

Figure 11. Number of Landline (Wired) Broadband Providers by Metropolitan Status, 2010-2011.
Note: From National Broadband Map Data aggregated to County Level, 2010 & 2011.

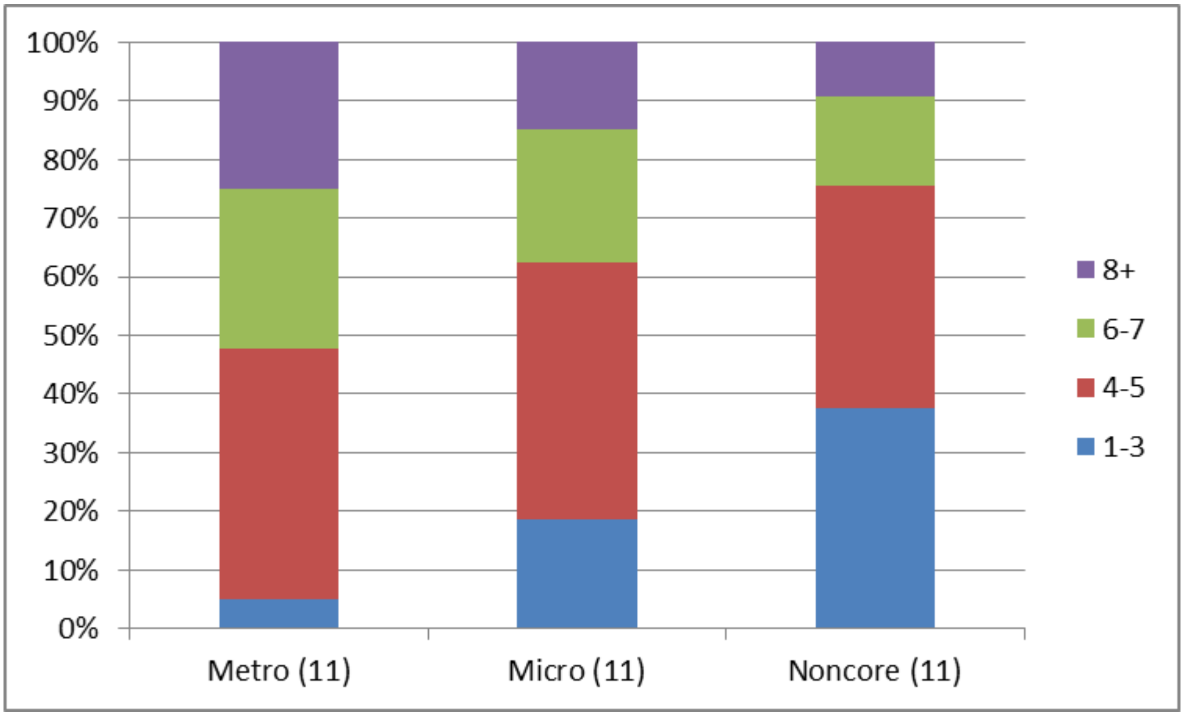

Figure 12. Number of Wireless Broadband Providers by Metropolitan Status, 2011.
Note: From National Broadband Map Data aggregated to County Level, 2011.

When the number of residential landline providers per county is overlaid with county-level adoption rates, however, there is not a clear correlation between them (***Figure 13***).

Some counties with high adoption levels have only a few residential providers, while some with large numbers of providers have poor adoption rates. In fact, the correlation between the number of residential broadband providers and the mean broadband adoption rate is only 0.32 (and only 0.09 in non-core counties) in 2011. This number is even lower for wireless providers; the correlation coefficient is only 0.18 for all counties, and 0.07 in non-core areas. One pattern that does emerge, however, is that areas with the lowest levels of adoption seem to have the lowest number of providers.

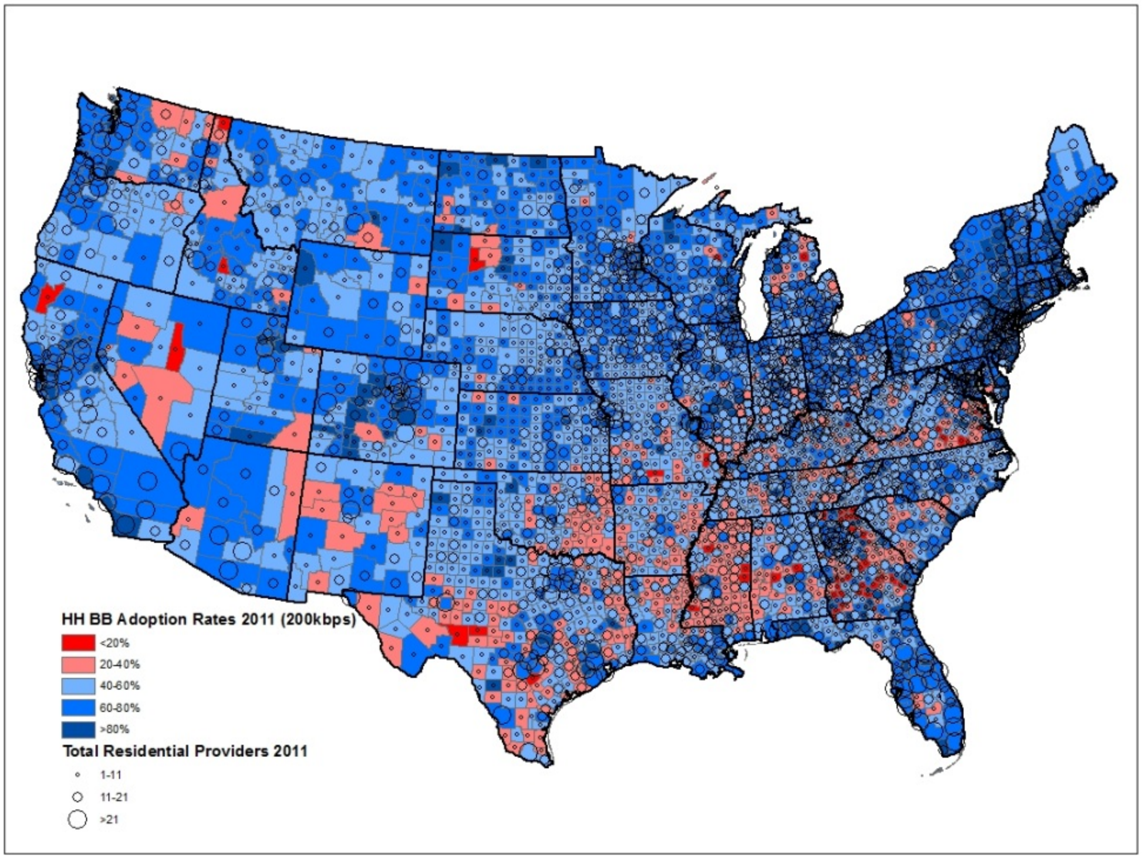

Figure 13. County-level Household Broadband Adoption Rates and Number of Residential Providers, 2011.

Figure 14 depicts the percentage of county population without any type of broadband available to them in 2010, again using data from the National Broadband Map. Here, broadband is defined as 3 mbps down and 768 kbps upload. As expected, most metropolitan counties have very high levels of broadband availability (only about 3% of the metropolitan population lack it), while the non-core areas have the worst (26% of the non-core population lack availability). There are large pockets of micro and non-core counties with very poor levels of broadband availability in the south, perhaps contributing to the lower adoption rates seen in ***Figure 8***.

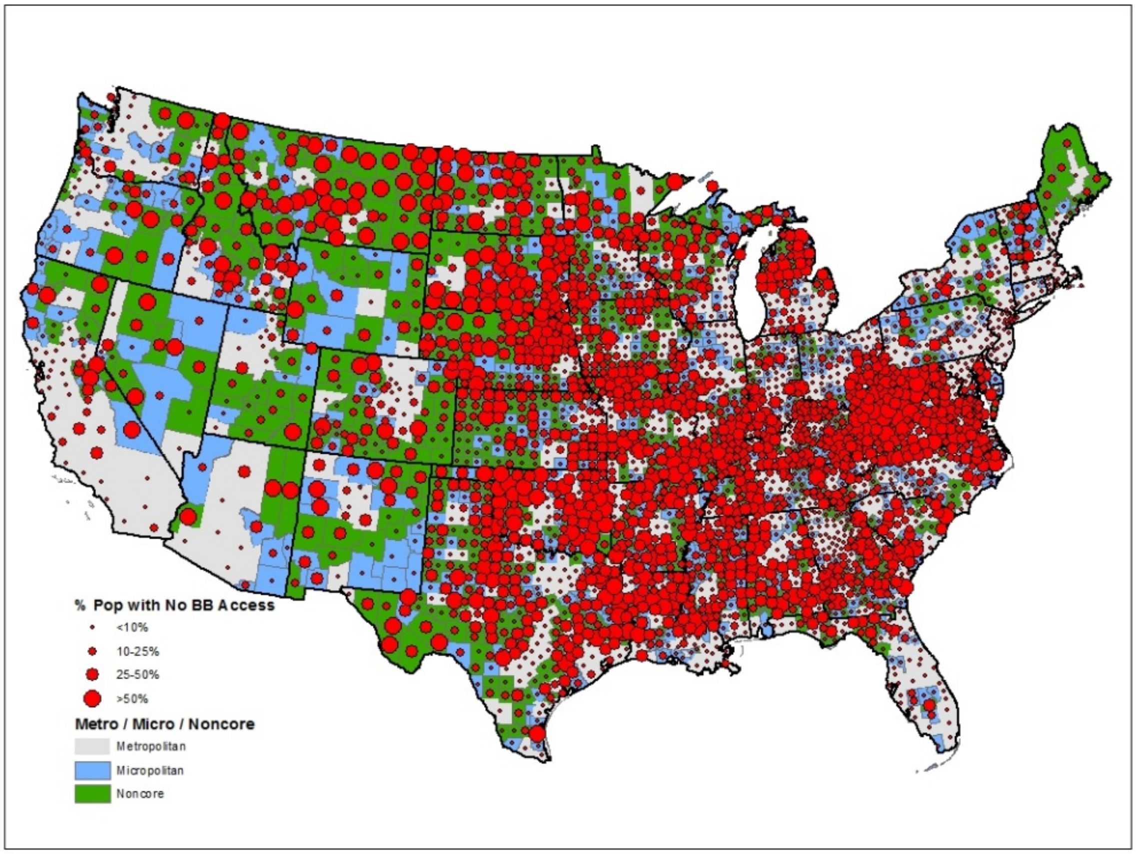

Figure 14. Percent of Population with No Broadband Availability by Metropolitan Status, 2010.

Additionally, ***Figure 15*** displays a spectrum of broadband availability categories for metro, micro, and non-core counties. It clearly demonstrates that the more rural areas are significantly worse off in terms of the availability of broadband infrastructure. In fact, nearly 30% of all non-core counties have more than 40% of their population lacking access to wired broadband infrastructure. Alternatively, only 5% of non-core counties have the highest category of availability, compared to nearly 40% of metro counties.[15] The extent of the relationship between availability and adoption is explored in greater detail in Chapter 3.

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[15] The highest level of broadband availability is where < 2% of the county's population lacks access to wired broadband.

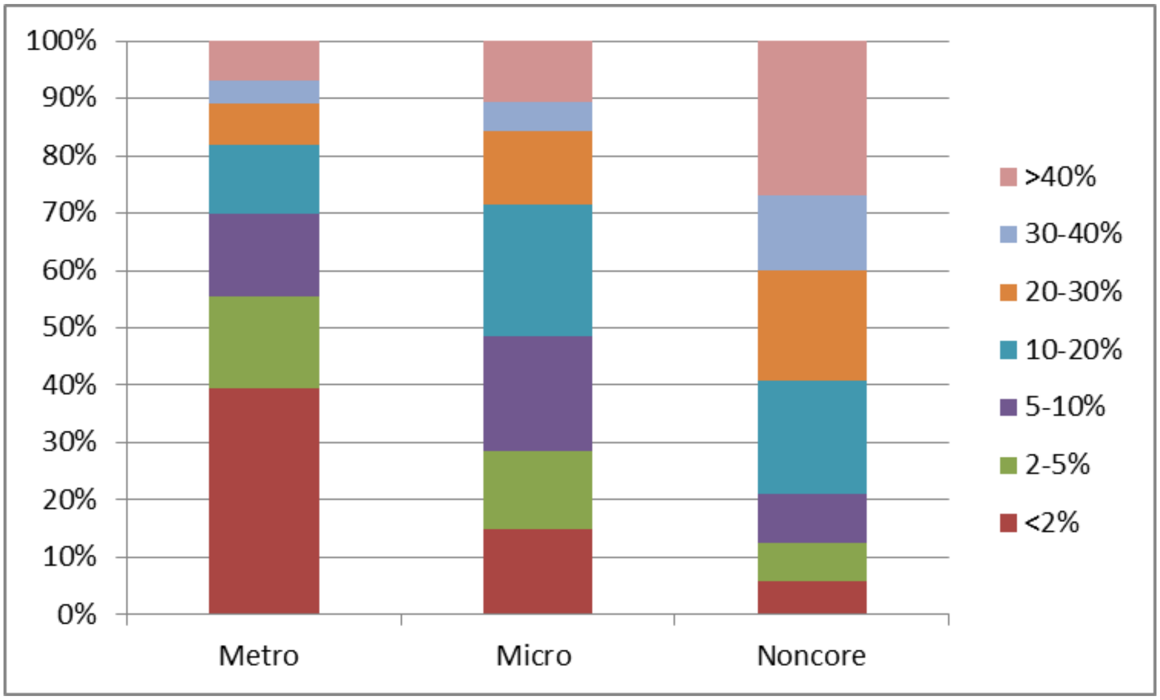

Figure 15. No Broadband Availability by Metropolitan Status, 2010.
Note: From National Broadband Map Data aggregated to County Level, 2010.

2.2.3 Differences in Broadband Download / Upload Speeds by Metropolitan Status

The National Broadband Map also provides information regarding the maximum advertised upload and download speeds by provider. A similar story unfolds, as over 60% of metropolitan counties were served by providers advertising more than 10 mbps *download* speeds in 2011 (***Figure 16***). Only 31% of non-core counties could boast similar download speeds. The same general trend holds for maximum advertised *upload* speeds (

), with approximately 60% of non-metro counties reporting an average maximum speed of 768 kbps or less. This compares to about 25% of metropolitan counties. The difference in very high-speed infrastructure was not quite as dramatic for micropolitan areas in terms of download speeds, but still holds for upload speeds. It should be noted that the number of counties reporting these data increased significantly between 2010 and 2011, perhaps explaining why the percentage of noncore counties with the highest levels of download and upload speeds shows a decrease over this time period.

Some issues with the National Broadband Map data between 2010 and 2011 are worth discussing. The 2010 data were the first dataset published by the NBM and thus some glitches did surface. First, data for census blocks over 2 square miles were not included. Second, some entire states – Arkansas for example – were missing all upload and download speed data. Third, wireless information was absent. However, the data gathering improved in 2011, addressing each of the three issues mentioned. Data were included for all census blocks including those larger than 2 square miles; wireless information were included; and the amount of missing data for some geographies was reduced. In conclusion, important differences exist between the 2010 and 2011 datasets that may not necessarily reflect an improvement in broadband availability/adoption per se; rather, these changes are the result of data gathering improvements.

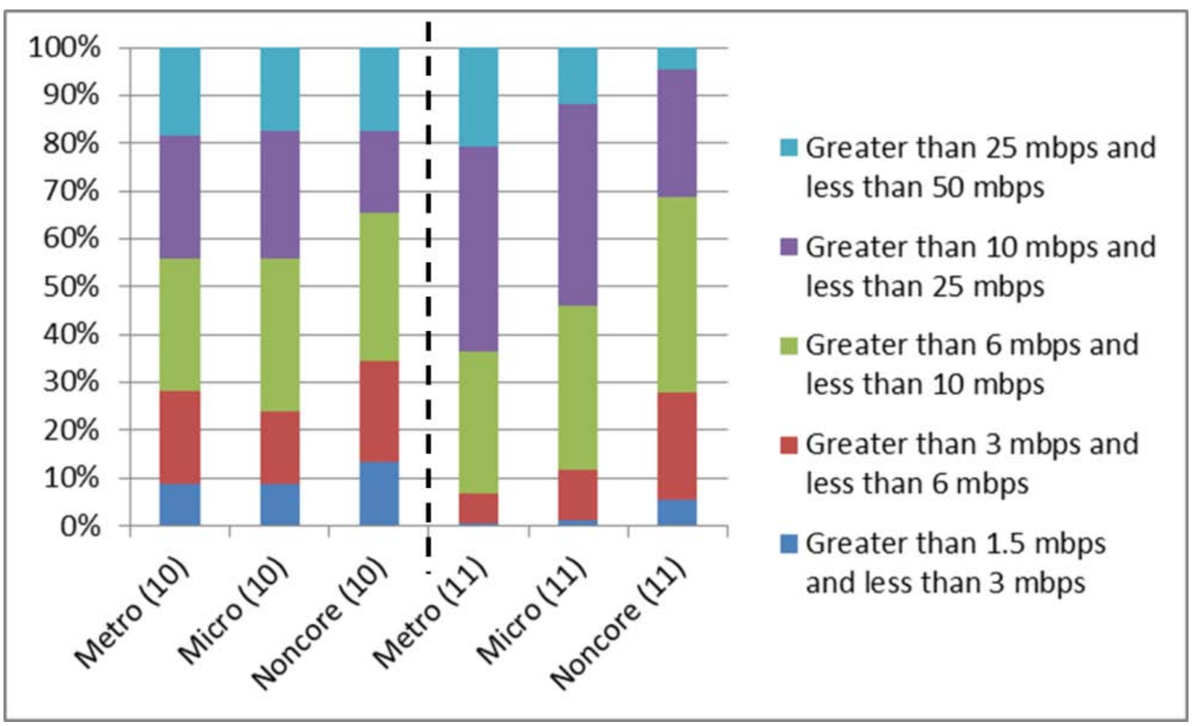

Figure 16. Average Maximum Advertised Download Speed by Metropolitan Status, 2010 & 2011.
Note: From National Broadband Map Data aggregated to County Level, 2010 & 2011.

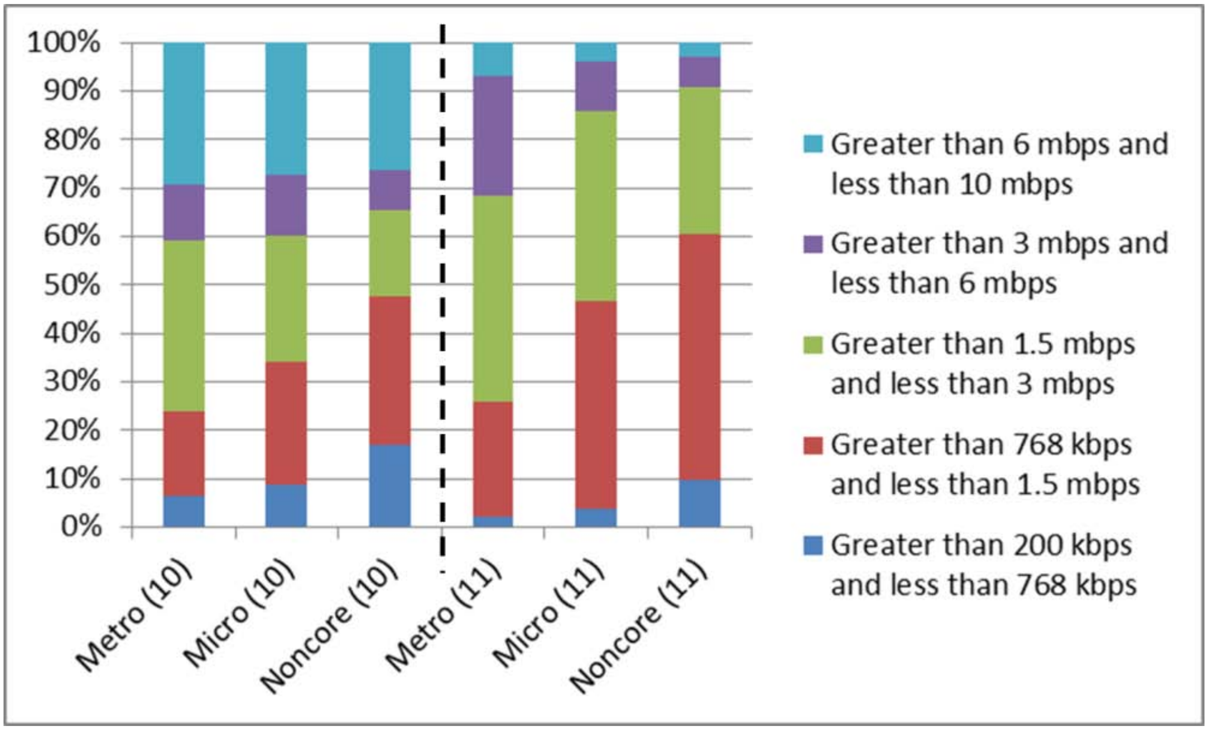

Figure 17. Average Maximum Advertised Upload Speed by Metropolitan Status, 2010 & 2011.
Note: From National Broadband Map Data aggregated to County Level, 2010 & 2011.

In conclusion, while the general county-level trends show a reduction in the broadband adoption gap between metropolitan and non-metropolitan areas, a definite gap still exists. Further, a significant broadband availability gap is evident not only in terms of the number of providers but also in terms of maximum advertised upload and download speeds.[16]

The next chapter explores the factors underlying broadband adoption rates in non-metropolitan areas, including whether or not the availability gaps documented above play a role in explaining the lower adoption rates across rural areas.

[16] Note that the speed differences shown in ***Figure 16*** and 17 contrast with the findings displayed in ***Table 1***. This is due to the aggregation from county to metro / non-metro portion of a state for the CPS data (***Table 1***), and also with potential inaccuracies / missing info from the 2010 data as discussed above.

3. Factors that Strengthen or Impede Broadband Adoption in Rural Areas

The previous chapter provided summary statistics on both household and county-level broadband adoption rates. In essence, we found that the gap in broadband adoption rates between metropolitan and non-metropolitan *households* remained at 13 percentage points between 2003 and 2010. However, the *county-level* (FCC) data shows a slightly shrinking gap between metro and micro (and metro and non-core) areas between 2008 and 2011. Although this seems contradictory, the county-level results are mostly influenced by increases in the percentage of non-metro counties moving from a very low adoption category (<20% in 2008) to higher categories in 2011. Metropolitan counties already had relatively high levels of adoption, and moving from 60% adoption to 70% or even 79.9% would not show up as an increase in the categorical county-level data. Thus, aggregate household rates between metro and non-metro areas may have increased at a similar pace, but because non-metro counties started from a lower base in 2008, the county-level adoption gap shows a reduction.

Data from the National Broadband Map suggests that more rural parts of the nation lag behind in terms of number of broadband providers and available upload / download speeds. This chapter changes the focus from simple descriptive statistics towards modeling the factors that drive broadband adoption. The sub-sections under each dataset provide additional analyses, such as decomposing the rural-urban and inter-temporal gaps using variations on the Oaxaca-Blinder technique, and also assessing whether counties participating in the Connected Nation program immediately after 2008 saw larger increases in the number of providers or county-level adoption rates.[17]

3.1 CPS Household Data

Previous studies have uncovered a number of household characteristics associated with Internet (and broadband) adoption. We build off of these findings to lead our own modeling efforts on household-level broadband adoption in both 2003 and 2010. Section 3.1.1 uses CPS data to model the adoption decision, with a focus on whether non-metropolitan status has an impact after controlling for other factors such as education, income, and age. We are also interested in whether the impact of non-metropolitan status has shifted over time. This section also explores the role of broadband availability by including a number of measures from the National Broadband Map, and also models the adoption decision specific to non-metro counties by eliminating metropolitan counties from the dataset. The remaining sections (3.1.2 and 3.1.3) use

[17] The Connected Nation program was selected for analysis due to the high number of participating states (16) and its relatively unique 'grassroots' approach to improving broadband availability and adoption.

a decomposition technique to further examine the 13 percentage point household broadband adoption gap documented above.

The existing literature on broadband adoption has largely focused on the impacts of various demographic characteristics. Most studies have found that education and income levels have a positive effect on the probability of broadband adoption (NTIA, 1999; NTIA, 2002; Hitt and Tambe, 2007; Whitacre, 2010). More educated households likely have more exposure to digital technologies, and households with greater disposable income are likely more willing to purchase broadband connections at home. Age is also likely to influence the propensity to adopt, with younger household heads typically more comfortable with the associated technologies. Several studies have found that a quadratic age term is useful since the influence of age may not be linear (Rose, 2003; Whitacre and Mills, 2007). Surveys have also shown that adoption rates vary greatly by racial characteristics, such as Hispanic or African-American status, and as such a host of racial and ethnic variables are included here (Horrigan, 2007; Horrigan, 2009). Other demographic characteristics may also influence the adoption decision, such as employment / retired status, the presence of an Internet connection at work, the existence of a business in the household, and the number of children in the household. Retirement status may positively impact the propensity to adopt as broadband technology has diffused, given the increase in time available to spend online. Mills and Whitacre (2003) found a positive relationship between the presence of an Internet connection at work (denoted 'netatwork' in the analysis below) and having one at home, suggesting complementarity between the two. Having a business in the household may increase the likelihood of broadband adoption given the wide variety of ways that small businesses are using this technology (SBA, 2010; SBA, 2005). Popular online tasks such as gaming and music downloading (which require a broadband connection) have been shown to be very popular among children (Horrigan, 2006). Some early studies found positive impacts on the presence of children (Mills and Whitacre, 2003), while more recent studies found no such affect (Whitacre, 2010). Finally, significant geographic variation in broadband adoption has already been documented in this report (***Figure 10***). We include four geographic regions in our analysis to capture some of these trends.[18]

One variable notably missing from our analysis is the cost of broadband access. Accurate data reflecting broadband prices across the country is simply not available, although at least one study has suggested that the own-price demand for this service is inelastic (Flamm and Chaudhuri, 2007). We recognize that cost is an important contributor to the adoption decision (it is the 2nd largest reason for non-adoption according to ***Figure 6***); but follow tradition of most studies modeling broadband adoption and omit the cost variable due to lack of data.

[18] The four regions are those defined by the U.S. Census Bureau: Northeast: ME, NH, VT, MA, RI, CT, NY, PA, NJ. Midwest: WI, MI, IL, IN, OH, MO, ND, SD, NE, KS, MN, IO. South: DE, MD, DC, VA, WV, NC, SC, GA, FL, KY, TN, MS, AL, OK, TX, AR, LA. West: ID, MT, WY, NE, UT, CO, AZ, NM, AK, WA, OR, CA, HA.

Summary statistics for these characteristics are broken out by metropolitan and non-metropolitan households in the CPS and displayed in ***Table 3***. Survey weights are applied to both the summary statistics and the regressions in the sections that follow, which make the CPS data nationally representative.

Table 3. CPS Data Household Characteristic Means, by Metro / Non-metro status - 2003 & 2010.

	2003		2010	
	Metro	Non-metro	Metro	Non-metro
Broadband at Home	0.239	0.110	0.697	0.568
Dial-up at Home	0.354	0.362	0.026	0.050
Income				
< $10,000	0.094	0.134	0.085	0.115
$10,000-$19,999	0.122	0.189	0.126	0.177
$20,000 - $29,999	0.136	0.175	0.131	0.160
$30,000-$39,999	0.130	0.141	0.120	0.131
$40,000-$49,999	0.096	0.089	0.086	0.093
$50,000-$59,999	0.086	0.086	0.085	0.082
$60,000-$74,999	0.097	0.081	0.094	0.085
$75,000-$99,000	0.110	0.067	0.108	0.076
$100,000-$149,999	0.080	0.027	0.097	0.056
>$150,000	0.051	0.011	0.067	0.024
Education				
No HS	0.285	0.344	0.262	0.309
HS	0.309	0.376	0.314	0.400
SomeCollege	0.219	0.189	0.228	0.198
Bach	0.139	0.068	0.143	0.065
GradDegree	0.047	0.022	0.053	0.029
Racial / Ethnic				
white	0.811	0.881	0.792	0.874
black	0.126	0.080	0.139	0.085
othrace	0.023	0.033	0.023	0.033
hispanic	0.129	0.064	0.137	0.058
Other Demographics				
age	42.230	45.650	44.290	47.120
retired	0.161	0.216	0.182	0.223
employed	0.522	0.562	0.511	0.477
selfemployed	0.058	0.069	0.054	0.068
businessinhh	0.120	0.148	0.104	0.143
netatwork	0.237	0.147	0.377	0.281
numberkids	0.442	0.423	0.385	0.348
Geography				
northeast	0.194	0.101	0.191	0.120
midwest	0.214	0.304	0.207	0.331
south	0.357	0.433	0.372	0.433
west	0.234	0.159	0.229	0.116
# Observations	29,814	10,357	35,837	10,244

The descriptive statistics demonstrate the roughly 13 percentage point gap in metro – non-metro broadband adoption in both 2003 and 2010. They also show the dramatic decline in dial-up access over that time, from over 35% in 2003 to less than 5% in 2010. Non-metropolitan households had lower levels of income, with over 45% earning less than $30,000 in 2010 compared to only 34% of metropolitan households. They also had lower levels of education, with over 70% having only a high school degree or less in 2010. This compares to 58% in metropolitan counties. Non-metropolitan households were less diverse in terms of racial and ethnic composition, with only 13% of households that are non-white (compared to over 20% in metropolitan areas) in 2010. Hispanic households, in particular, were much more prevalent in metropolitan areas. Non-metro household heads were also older, with an average age of 47 years in 2010 versus 44 for heads in metropolitan counties – a factor that might tip the potential user balance toward digital immigrants as opposed to natives. Interestingly, non-metropolitan household heads were more likely than metropolitan heads to be employed in 2003, but less likely in 2010, perhaps due to the impacts of the recession. Non-metropolitan households were more likely to be self-employed or to have a business in the home, but also more likely to be retired. They were less likely to have Internet access at work, with only 28% having such access in 2010 compared to 38% of their metropolitan counterparts. Most of these trends are consistent over time, with the only exception being the employment shift noted earlier. Given the large number of observations, all of the metro – non-metro differences shown in the table are statistically significant.

This data is used to model the factors associated with broadband adoption in the sections below. Further, the contribution of differences in metro – non-metro characteristics to the digital divide is explored using non-linear versions of the Oaxaca-Blinder decomposition technique (which is explained in section 3.1.2).

3.1.1 Logit Model Results

Logistic regression was used to uncover factors that are related to household-level broadband adoption in both 2003 and 2010. In each case, the dependent variable is whether or not the household has a broadband Internet connection. This comes from the initial question, "At home, does this household access the Internet?" and follow up questions categorizing the Internet service as DSL, cable, fiber optic, mobile broadband, or satellite. Each of these categories is considered "broadband" in the analysis that follows. The explanatory variables are largely taken from the existing literature and include education, income, age, racial, and employment categories (as discussed above).

A traditional logit model of the form:

$$y_i^* = X_i\beta + \varepsilon_i,$$
$$y_i = 1 \text{ if } y_i^* \geq 0,$$
$$y_i = 0 \text{ if } y_i^* < 0$$

is used, where y_i^* is a latent (unobserved) measure of the relative costs and benefits associated with broadband access for household *i* and y_i is the observed level of household broadband access. X_i is a vector of demographic variables noted above and summarized in ***Table 3***, and β is the associated parameter vector. In some specifications, X_i will include a dummy variable for the non-metro status of household *i*; in others it will also include a measure of broadband availability for that household. Other specifications will be limited to the subset of non-metropolitan households to explore the characteristics affecting the adoption decision of that particular demographic. ε_i is the error term of the model.

Table 4 presents the results of 5 distinct logit specifications:

- Model (1) is for 2003 – all observations
- Model (2) is for 2010 – all observations
- Model (3) is for 2010 – also includes a measure of broadband availability
- Model (4) is for 2003 – only non-metro households
- Model (5) is for 2010 – only non-metro households

Multicollinearity was assessed using correlation coefficients for all included covariates. Most (90+%) correlation coefficients were under ±0.20, with only the relationship between retired and age^2 being over 0.70. Thus, none of the logistic models were deemed to have multicollinearity issues.

***Table 4*. CPS Household Logit Results.**

	(1) 2003		(2) 2010		(3) 2010		NM Only 2003	(4)	NM Only 2010	(5)
Income										
$10,000-$19,999	0.028		0.316	***	0.315	***	0.443	*	0.368	***
$20,000 - $29,999	0.458	***	0.662	***	0.660	***	0.613	***	0.680	***
$30,000-$39,999	0.636	***	0.974	***	0.972	***	1.264	***	1.063	***
$40,000-$49,999	0.992	***	1.389	***	1.388	***	1.154	***	1.469	***
$50,000-$59,999	1.158	***	1.424	***	1.422	***	1.470	***	1.512	***
$60,000-$74,999	1.326	***	1.702	***	1.700	***	1.624	***	1.733	***
$75,000-$99,000	1.513	***	1.925	***	1.923	***	1.755	***	1.804	***
$100,000-$149,999	1.932	***	2.146	***	2.144	***	2.286	***	2.196	***
>$150,000	2.218	***	2.365	***	2.363	***	2.368	***	2.202	***
Education										
hs	0.163	***	0.305	***	0.305	***	0.082		0.324	***
somecollege	0.566	***	0.706	***	0.705	***	0.662	***	0.771	***
bach	0.604	***	0.977	***	0.976	***	0.613	***	1.061	***
graddegree	0.525	***	0.993	***	0.991	***	0.711	***	0.934	***
Racial / Ethnic										
black	-0.459	***	-0.464	***	-0.471	***	-0.160		-0.327	***
asian	0.277	***	0.248	***	0.240	***	1.034	***	1.026	***
othrace	0.070		-0.245	***	-0.237	***	0.269		-0.625	***
hispanic	-0.365	***	-0.467	***	-0.472	***	-0.234		-0.350	***
Other Demographics										
age	-0.024	***	0.000		0.000		-0.022		0.000	
age2	0.000		0.000	***	0.000	***	0.000		0.000	***
retired	-0.053		0.173	***	0.173	***	0.111		0.259	**
employed	-0.273	***	-0.179	***	-0.180	***	-0.273	**	-0.036	
selfemployed	0.103		0.059		0.058		0.268		0.214	
businessinhh	0.249	***	0.355	***	0.357	***	-0.005		0.261	**
netatwork	0.383	***	0.820	***	0.821	***	0.484	***	0.666	***
numberkids	-0.059	***	0.029		0.029		-0.040		0.053	
Geography										
midwest	-0.278	***	-0.168	***	-0.142	***	-0.424	***	-0.322	***
south	-0.238	***	-0.133	***	-0.077	*	-0.400	***	-0.373	***
west	-0.089	*	0.093	**	0.132	***	-0.381	***	-0.066	
nonmetro	-0.590	***	-0.329	***	-0.163	***	--		--	
Infrastructure										
nobbpct	--		--		-1.148	***	--		--	
constant	-1.247	***	0.114		0.115		-2.083	***	-0.150	
# Obs	40,172		46,082		46,082		10,357		10,244	
F-stat	138		251		243		17		51	

*, **, and *** represent statistically significant differences from 0 at the *p*=0.10, 0.05, and 0.01 levels, respectively.

Most of the significant results from models (1) and (2) are as expected. In particular, higher levels of income and education lead to higher likelihoods of broadband adoption. Several racial and ethnic categories (Black, Hispanic) show lower propensities to adopt home broadband, while Asian household heads demonstrate higher propensities. Having a business in the household and having Internet access at work both increase the likelihood of broadband adoption. The Northeast has typically had the highest broadband adoption rates over this time period, so the negative impacts of the other regional location dummies is predicted. Even after accounting for all of these other characteristics, non-metropolitan location exhibits a significantly negative impact on the likelihood of broadband adoption in both years.

Notable changes that occurred between 2003 and 2010 include the quadratic age term becoming significant (and positive – although the near-zero value is not economically meaningful) over time. Additionally, retired status became positive. Both of these shifts reflect the increasing inclinations of the elderly to have a broadband connection at home (also demonstrated in ***Figure 4***). The number of children in a household had a negative impact in 2003, but was not significant in 2010, perhaps reflecting an increased acceptance of the role of broadband access for school-aged children. Indeed, other studies have found that children in the household typically have a positive influence on broadband adoption (Clements and Abramowitz, 2006).

Also noteworthy is the highly significant impact of the broadband availability measure in model (3). Given the lack of geographic detail in the CPS data, this variable is an aggregate measure of the percentage of the metro (or non-metro) population within the state that lacks broadband access. This was computed by initially aggregating the availability data to the county level, and then population-weighting each county to construct a state measure for their metro and non-metro regions. The mean state-level measure for metropolitan areas was 3.1%, while the mean for non-metropolitan areas was 18.3% (***Table 1***) - reflecting the large availability gap documented both in this report and others (FCC, 2012). In the regression results above, a higher percentage of population without any access to broadband was associated with a significant decline in the propensity to adopt. This is an expected result, and it demonstrates the importance of availability in the adoption decision. Interestingly, however, the impact of being in a non-metropolitan area does not disappear after this variable is included. Thus, even after controlling for high-level differences in broadband availability, location in a non-metropolitan area still has a negative impact on the likelihood of adoption. The role of these differing propensities to adopt between metro and non-metro areas is further explored in section 3.1.2 below.

Models (4) and (5) deal explicitly with non-metropolitan households. Generally, the results for these specifications are similar to those for all households, particularly with respect to income education, and age. However, several interesting changes occurred between 2003 and 2010. First, household heads with only a high school education showed a positive result in 2010 relative to the default of no high school. This suggests that households at this education level became more aware of the benefits of broadband during this time. Second, Blacks, Hispanics, and other racial/ethnic categories were not significant in 2003, but each demonstrated a negative association with adoption in 2010. This gives additional credence to ***Figure 5*** that demonstrated how racial broadband gaps were increasing in non-metropolitan areas over this period. Finally, the Western non-metro region no longer lags the Northeast, suggesting that at least some convergence across rural parts of the country is occurring, although the South and Midwest maintain significant, negative coefficients.

A large contribution of this report is an assessment of the impact that broadband *availability* has on *adoption* in nonmetropolitan areas. To conduct this analysis, various measures of broadband availability were added to the dependent variable list for model (5). This included numbers of broadband providers, upload / download speeds, and the percentage of the population without broadband available to them. The results for these variables are shown below.

Table 5. Non-metro Broadband Availability Measures - Impact on Adoption (CPS Data).

NM Only - Availability Measures	2010	
lowprov (<3)	-0.372	*
lonobbpct (<.15)	0.123	*
No statistical impact:		
No Broadband Availability (%)		
Low Download speeds		
Low Upload speeds		
Hi Number of Providers		
Hi Download speeds		
Hi Upload speeds		
Hi NoBBPct		

* Represents statistically significant difference from 0 at the p=0.10 level

Only two specific availability measures showed any impact on adoption rates in non-metropolitan areas. First, having a low number of broadband providers (<3) had a negative impact on the likelihood of adoption. This suggests that provider competition is important in rural areas, and that the threshold for an appropriate number of providers is 3. Results from a 2009 PEW Internet study on prices paid for broadband access lend further credence to this finding. While the CPS data do not include any information regarding price paid for broadband, the PEW study found that the average monthly bill for broadband subscribers with four or more providers in their area was $32.10, significantly lower than the $38.10 or $42.80 for subscribers with three providers and two providers, respectively (Horrigan, 2009). This result could be of particular interest to grant / loan broadband infrastructure programs that have steered away from regions that already have a provider. The second finding relates to a dummy variable for having a low percentage of the population without broadband available to them. While various thresholds were modeled, a positive impact was found when this number was less than 15% for all non-metropolitan areas in the state (the mean across all states was 18%). Thus, the number of providers and the percentage of the population they cover both have an impact on broadband adoption rates for non-metropolitan households. If more people in one's community have broadband, they may function as models for potential adopters.

Other measures of broadband availability did not show statistically significant results. Surprisingly, the continuous measure for no broadband availability was not significant when isolated to only non-metropolitan areas. This may be influenced by the aggregation of county-level availability data to non-metropolitan area within a state – the 10,000+ observations only have a total of 48 data points for non-metro broadband availability, limiting the amount of variation.[19] Further, measures of upload / download speeds were never significant, regardless of the threshold used. Similarly, no impact was found for high numbers of providers, or if a high percentage of the population lacked broadband availability.

3.1.2 Nonlinear Oaxaca-Blinder Decompositions – Rural vs. Urban

One popular method for examining gaps in mean outcomes (such as broadband adoption rates) between two groups is to examine how much of the gap can be explained by differences in observable characteristics. A typical approach is to conduct separate regressions on each of the groups, and then create a hypothetical outcome where characteristics from one group are meshed with parameters from the other. This technique is known as an Oaxaca-Blinder decomposition based on the seminal work of Oaxaca (1973) and Blinder (1973). While the original technique was applicable only to linear models, others have modified it to include non-linear specifications (Nielsen 1998). In the context of a logistic regression, the difference in probabilities between the two groups can be expressed as:

$$\left(\hat{P}_M - \hat{P}_{NM}\right) = \sum_{i=1}^{N_M} F\left[X_{Mi}\hat{\beta}\right]/N_M - \sum_{i=1}^{N_{NM}} F\left[X_{NMi}\left(\hat{\beta} + \hat{\delta}\right)\right]/N_{NM}$$

where $\hat{P}_M$ and $\hat{P}_{NM}$ are the average probabilities of broadband use among metropolitan and non-metropolitan households, respectively. N_M and N_{NM} are the sample sizes for metro and non-metropolitan households, while X_M and X_{NM} are vectors of characteristics for the respective households. $\hat{\beta}$ is the estimated parameter vector for metro households and $\hat{\delta}$ is the estimated shift for non-metropolitan households. The key component, however, is a calculation that hypothetically meshes non-metropolitan characteristics (X_{NM}) with metropolitan parameters ($\hat{\beta}$):

[19] Neither New Jersey nor Rhode Island have any non-metropolitan counties.

$$\hat{P}_{NM}^{0} = \sum_{i=1}^{N_{NM}} F[X_{NMi}\hat{\beta}]/N_{NM}$$

$\hat{P}_{NM}^{0}$ is then calculated for each non-metropolitan household and is interpreted as the probability of broadband adoption for non-metro households if metropolitan parameters were applied. The metro – non-metro gap can then be written as:

$$(\hat{P}_M - \hat{P}_{NM}) = (\hat{P}_M - \hat{P}_{NM}^{0}) + (\hat{P}_{NM}^{0} - \hat{P}_{NM})$$

This allows the metro – non-metro gap to be broken into one component associated with differences in underlying characteristics of those households $(\hat{P}_M - \hat{P}_{NM}^{0})$ and another component which is due to differences in the underlying parameters, or behavioral differences $(\hat{P}_{NM}^{0} - \hat{P}_{NM})$. Mills and Whitacre (2003) used this technique to decompose the metro – non-metro gap in dial-up Internet adoption, and concluded that two-thirds of the 2001 gap was due to differences in characteristics.

The results of the metro – non-metro decomposition are shown in ***Table 6*** below. Decompositions are performed in both 2003 and 2010. Further, two distinct decompositions are performed in 2010 – one for a logit specification without any broadband availability data (similar to Model (2) in *Table 4*) and one from the logit specification that does include a measure of broadband availability (Model (3) in *Table 4*). The metro – non-metro difference in broadband availability is then included as a characteristic difference when the decomposition technique is applied.

Table 6. CPS Logit Decomposition Results - Metro / Non-metro Broadband Adoption Gap.

Year	Model	Rate	Share of Gap	
2003	BB Adoption			
	P_M	0.239		
	P_{NM}^0	0.178	47.3%	% Due to M-NM Characteristic Differences
	P_{NM}	0.110	52.7%	% Due to M-NM Parameter Differences
2010	BB Adoption			
	P_M	0.697		
	P_{NM}^0	0.627	54.3%	% Due to M-NM Characteristic Differences
	P_{NM}	0.568	45.7%	% Due to M-NM Parameter Differences
2010	BB Adoption with BB Availability Included			
	P_M	0.697		
	P_{NM}^0	0.581	89.9%	% Due to M-NM Characteristic Differences
	P_{NM}	0.568	10.1%	% Due to M-NM Parameter Differences

The results in ***Table 6*** suggest that roughly 50% of the 13 percentage point broadband adoption gap between metro and non-metro households in was due to characteristic differences in both 2003 and 2010. Particularly, higher levels of education and income in metropolitan areas are responsible for a significant portion of the underlying gap. Characteristic differences have comprised a slightly larger proportion of the gap over this time period. This implies that place-based differences in adoption behavior (i.e. parameter differences) have become somewhat less important. However, this change is small, and as of 2010 there is still a sizable portion of the gap that is due to these underlying differences in preferences – or, characteristics that have not been accounted for.

The most interesting finding, however, is the dramatic jump in explanatory power of characteristic differences once the measure of broadband availability is included. Nearly 90 percent of the metro – non-metro adoption gap is explained once this variable is included. This is an additional 35 percentage points on top of the original specification – suggesting that broadband availability is an important cause of the metro - non-metro adoption gap. Put another way, if non-metro households were to automatically be given the same characteristics as metro households (except for availability), 54 percent of the broadband adoption gap would disappear. If they were also given the same levels of broadband availability, 90 percent of the gap would disappear!

As noted above, this measure of broadband availability is rather terse since it aggregates neighborhood-level data to metro and non-metro measures within a state. The variable itself is the percentage of the population without broadband access for an entire non-metro area within a state. This can clearly vary by neighborhood, as one non-metro region in a state can have dramatically different broadband availability than another. The decomposition technique, however, treats all non-metropolitan neighborhoods in a state as equal. The situation is not ideal, but is a result of CPS data limitations. Even with this caveat, the increase in explanatory power with the broadband availability measure is striking.

3.1.3 Nonlinear Oaxaca-Blinder Decompositions – Inter-temporal

While the results discussed above suggest that roughly half of the metro – non-metro household broadband adoption gap is due to differences in characteristics such as education and income, the same technique can be applied over time to see what has been driving temporal increases in broadband adoption rates. Focusing specifically on non-metropolitan households, the broadband adoption rate increased from 11.0% in 2003 to 56.8% in 2010. Was this due primarily to changes in characteristics of those rural areas – perhaps because they became more educated, or earned more income over that time? Or, was the change primarily driven by shifting parameters – meaning that the likelihood of adopting for any given income / education level shifted over time? Diffusion theory (Rogers, 2003) would suggest that the latter explanation is correct – as an innovation becomes more popular and more visible, larger proportions of all households see the potential value and become more likely to adopt. This represents shifting parameters, since the underlying characteristics of the household did not change over that time. Figures 2, 3, 4, and 5 suggest that this is indeed the case, with all levels of income, education, age, and race demonstrating higher levels of adoption in 2010. To fully answer the question, an inter-temporal decomposition technique similar to that used in section 3.1.2 is constructed by estimating the following probabilities:

$$\hat{P}_{03} = \sum_{i=1}^{N_{03}} F\big[X_{03i}\hat{\beta}\big]/N_{03}$$

$$\hat{P}_{10} = \sum_{i=1}^{N_{10}} F\big[X_{10i}(\hat{\beta} + \hat{\delta})\big]/N_{10}$$

$$\hat{P}_{10}^{03} = \sum_{i=1}^{N_{10}} F\big[X_{10i}\hat{\beta}\big]/N_{10}$$

Here $\hat{P}_{03}$ and $\hat{P}_{10}$ represent the probabilities of broadband access for non-metropolitan households in 2003 and 2010, respectively. The hypothetical rate $\hat{P}_{10}^{03}$ applies 2003 parameters to 2010 characteristics for these non-metropolitan households. The difference over time can then be expressed as:

$$\left(\hat{P}_{10} - \hat{P}_{03}\right) = \left(\hat{P}_{10} - \hat{P}_{10}^{03}\right) + \left(\hat{P}_{10}^{03} - \hat{P}_{03}\right)$$

The results of this technique are shown in ***Table 7***.

Table 7. Inter-temporal CPS Logit Model Decomposition – Non-metro Broadband Adoption between 2003 & 2010.

	Model	Rate	Share of Gap	
2003-10	BB Adoption Decomp (NM Only)			
	P_{03}	0.110		
	P_{10}^{03}	0.131	4.5%	% Due to Differences in '03-'10 Characteristics
	P_{10}	0.568	95.5%	% Due to Differences in '03-'10 Parameters

These results clearly demonstrate that nearly all of the increase in the non-metropolitan broadband adoption rate was due to changing *parameters* (as Rogers' diffusion theory would suggest). In essence, the general perception of broadband experienced dramatic shifts between 2003 and 2010 as all types of households increased their adoption rates. Households that previously had not adopted now did so, driven by increasing recognition of the benefits of the technology. The minor shifts in non-metropolitan household *characteristics* (***Table 3***) accounted for less than 5% of the higher broadband rates. This agrees with the descriptive analysis shown in ***Figure 2*** through 5 that depicted higher adoption rates across a wide variety of non-metropolitan household characteristics between 2003 and 2010. It further demonstrates that 2003 was a very different time for broadband adoption in terms of overall attitudes towards and access to the technology.

3.2 FCC County Data

While the above section focused on household-level broadband adoption, the FCC data allows for assessment of the factors that influence *county*-level adoption rates. The dependent variable for this dataset is what category the county falls into, based on the percentage of households that adopt broadband. Recall that this dataset includes a total of 5 categories, which were summarized for metro, micro, and noncore counties in ***Figure 8*** in Chapter 2:

1. <20% household broadband adoption
2. 20 – 39.9% household broadband adoption
3. 40 – 59.9% household broadband adoption
4. 60 – 79.9% household broadband adoption
5. >80% household broadband adoption

As discussed in section 1.3.3, data from the National Broadband Map were aggregated to the county level so that they could be included in analysis of the FCC adoption data. Thus, in addition to the categorical adoption data broken out above, our dataset contains information on the number of wired and wireless broadband providers, the percentage of population in the county without any type of broadband provider available to them, and the average maximum advertised download and upload speeds by the providers in that county. Descriptive statistics on these variables were provided in section 2.2.

In addition to county-level versions of the variables used in the CPS household analysis (education, income, race / ethnicity, age), several supplementary variables are appended to the FCC dataset. Each of the variables included is hypothesized either to impact levels of broadband adoption or to be influenced by levels of broadband adoption. County population, for example, has been shown to influence broadband provision – namely, the number of broadband providers in an area (Horrigan, 2009; Grubesic, 2008). Other measures of income and employment of interest include the percentage of non-farm proprietors (self-employed) and the percentage of creative class employees, since broadband may have a particularly notable impact on these categories. Goetz and Rupasingha (2009) noted the dramatic increase in non-farm proprietors since the 1970s and found that the self-employed respond rationally to the risk of self-employment, and particularly noted the potential influence of broadband for this cohort. Stenberg et al. (2009) used a quasi-experimental design to demonstrate that non-farm proprietor jobs grew faster in rural counties with greater broadband access by 2000. McGranahan et al. (2011) found that rural employment in the creative class is strongly associated with outdoor amenities, but left open the question of whether broadband access also plays a role. We also include measures of poverty and unemployment since several studies demonstrated a negative relationship between these variables and broadband adoption (Blake, 2011; Kaylor and Fenton, 2012; Holt and Jamison, 2009; Van Gaasbeck, 2008).

Initially, a host of location quotients was also included for each of the 20 two-digit North American Industrial Classification Sectors (NAICS) codes since some research has suggested that specific industries might be particularly suited to broadband access (Shideler et al., 2007; Kandilov and Renkow 2010; Kolko, 2012). Additional variables are also included to proxy for economic dependencies or conditions across counties. Dummy variables denoting county dependencies on farming and manufacturing, and county classifications for recreation and retirement will allow for assessment of how these dependencies relate to broadband. Other demographic variables, such as the USDAs natural amenity ranking, the number of farms per county, and whether or not the county is a high out-migration will be important control variables when our attention turns to modeling the economic impacts of broadband in Chapter 4.

Mean values of the variables used for analysis of the FCC Data are displayed for metro, micro, and non-core areas in ***Table 8*** below. Data for the last year available are shown, but generally, the dataset contains information from 2008, 2010, and 2011. Note that the "no broadband access" variable is an average of county values, and thus does not reflect the population-weighted estimates reported in ***Table 1***.

Table 8. FCC Data Mean Values and Descriptions.

Variable name	Description	All	Metro	Micro	Noncore
Adoption / Infrastructure Data					
rfcper1k_11	Residential Fixed BB Connections per 1,000 HH (1-5)	3.14	3.60	3.28	3.02
prov_11	# Wired BB Providers, 2011	5.28	6.63	5.49	4.13
wprov_11	# Wireless BB Providers, 2011	5.21	6.23	5.30	4.35
nobbnd_10	% of population with no BB access, 2010	20.86	10.78	16.54	30.81
avgdn_11	Avg advertised download speed in county (1-11)	6.39	6.78	6.53	6.00
avgup_11	Avg advertised upload speed in county (1-11)	3.72	4.12	3.68	3.41
pop_11	Population, 2011	100,384	244,812	45,929	14,824
Education					
lths_11	% age 25+ with less than H.S. Education	0.17	0.15	0.17	0.18
hs_11	% age25+ with only H.S. Education	0.35	0.32	0.35	0.37
sc_11	% age25+ with some college	0.29	0.29	0.29	0.28
bach_11	% age25+ with bach. Degree or more	0.19	0.23	0.18	0.16
Income and Employment					
mhhi_10	median household income, 2010	43,078	49,872	41,209	38,715
nfpinc_10	Income for non-farm proprietors, 2010	18,293	20,554	18,532	16,417
nfp_10	% of employment - non-farm proprietors	0.24	0.23	0.21	0.26
cre_11	% creative class employment	0.33	0.32	0.30	0.35
ur_11	unemployment rate, 2011	0.09	0.09	0.09	0.08
pov_10	poverty rate, 2010	0.16	0.14	0.17	0.17
Race/Ethnicity					
black_11	% black	0.09	0.11	0.09	0.07
asian_11	% asian	0.01	0.02	0.01	0.00
hisp_11	% hispanic	0.09	0.09	0.09	0.08
othrace_11	% other race	0.03	0.02	0.03	0.05
Age					
age15-25pct	% age 15-25	0.13	0.14	0.14	0.12
age25-44pct	% age 25-44	0.24	0.25	0.24	0.22
age45-64pct	% age 45-64	0.28	0.28	0.27	0.29
age65+pct	% age 65+	0.16	0.14	0.16	0.18
Location Quotients					
info_11	Location Quotient for information sector	0.51	0.64	0.51	0.41
re_11	Location Quotient for real estate sector	0.77	0.91	0.75	0.66
County Dependencies					
fade_00	farming dependency (1 if yes), 2000	0.14	0.03	0.07	0.26
made_00	manufacturing dependency (1 if yes), 2000	0.29	0.29	0.37	0.24
recde_00	recreation classification (1 if yes), 2000	0.11	0.03	0.12	0.16
retde_00	retirement classification (1 if yes), 2000	0.14	0.15	0.12	0.14
Other Demographics					
natam_04	Natural Amenities ranking (1-7)	3.49	3.58	3.47	3.44
farms_07	# farms in county, 2007	710.30	841.51	778.93	574.67
homig	high out-migration status (1 if yes), 1990-2010	0.03	0.00	0.01	0.07
Metropolitan Status					
micro	micropolitan	0.22	-	1	-
noncore	noncore	0.44	-	-	1

Given the categorical and ordinal data for the variable of interest (rfcper1k), ordered logistic regression is used. This modeling technique requires the assumption that the relationship between any two categories is the same – which results in only one set of coefficients. Given that each category consists of a 20 percentage point range, this is a reasonable assumption. Additionally, because the FCC data is available for 2011, more recent National Broadband Map data can be meshed with this dataset. Notably, the number of wireless providers is available only in 2011, and this allows for an assessment of how wired and wireless providers might impact county-level adoption. Further, the wired upload / download speed data is reported for nearly every county in 2011, which was not the case in 2010. The models discussed below look at the role that basic demographic characteristics play in influencing adoption levels, along with the role of broadband speed and availability. As noted above, a host of location quotients was initially included for each of the 20 two-digit NAICS codes based on research that suggested some industries might influence broadband adoption more than others (Shideler et al., 2007; Kandilov and Renkow 2010; Kolko, 2012). Later, all non-significant sectors were removed due to multicollinearity with several of the dependency categories.

The FCC data has two distinct definitions of broadband: one based on 200kbps in at least one direction (rfcper1k), and the other based on the BTOP definition of 768kbps download, 200kbps upload. Models for both definitions were run; however, the results were very similar. The results reported below focus on the 200 kbps definition.

3.2.1 Ordered Logit Model Results

The independent variables for modeling the county-level adoption rate include most of those shown in ***Table 8***: county-level population, education, income, unemployment and poverty rates, the percentage of non-farm proprietors, a dummy variable that equals one if the county is a high out-migration county, dummy variables for dependency categories such as farming or manufacturing, age categories, racial and ethnic dummy variables, and micro / non-core status. Note that state-level fixed effects are included in each regression to control for any legislative, economic, or social factors that are common to the state.[20] Results are displayed in ***Table 9*** below.

[20] Examples of state-level fixed effects would be states with high levels of tribal lands, large regions of poverty, or those with specific legislation focused on funding for broadband infrastructure.

Table 9. FCC Ordered Logit Results - 2008, 2010, 2011.

	(1) 2008		(2) 2010		(3) 2010 - with NOBBND		(4) 2011		(5) 2011 - with NOBBND	
Infrastructure										
prov_YY					0.034	*			0.023	
wprov_YY									-0.070	***
nobbnd_10					-0.017	***			-0.018	***
lnpop_YY	0.550	***	0.430	***	0.316	***	0.332	***	0.240	***
Education										
hs_YY	0.016		0.023	*	0.023	*	0.033	***	0.031	**
sc_YY	0.066	***	0.081	***	0.081	***	0.088	***	0.088	***
bach_YY	0.107	***	0.091	***	0.088	***	0.100	***	0.098	***
Income and Employment										
lnmhhi_YY	1.255	*	1.655	***	1.608	**	1.914	***	1.981	***
lnnfpinc_YY	-0.406	***	-0.278	***	-0.253	***	-0.319	***	-0.310	***
nfp_YY	-0.061	***	-0.036	***	-0.034	***	-0.039	***	-0.037	***
cre_YY	-0.009		-0.020	**	-0.016		-0.017	*	-0.013	
ur_YY	-0.091	**	-0.052	**	-0.048	**	-0.048	**	-0.038	
pov_YY	-0.090	***	-0.046	**	-0.041	**	-0.026		-0.022	
Race/Ethnicity										
black_YY	-0.015	***	-0.028	***	-0.028	***	-0.022	***	-0.020	***
asian_YY	-0.025		-0.063	**	-0.062	**	-0.011		-0.009	
hisp_YY	-0.001		-0.008		-0.010	*	-0.007		-0.010	*
othrace_YY	-0.025	***	-0.035	***	-0.029	***	-0.038	***	-0.031	***
Age										
age15-25pct	0.001		0.001		0.000		-0.029		-0.030	
age25-44pct	-0.095	***	-0.043		-0.036		-0.039		-0.029	
age45-64pct	-0.105	***	-0.067	**	-0.057	*	-0.085	***	-0.072	**
age65+pct	-0.044		-0.011		-0.014		-0.015		-0.018	
Location Quotients										
info_YY	0.529	***	0.547	***	0.540	***	0.577	***	0.554	***
re_YY	1.614	***	1.162	***	1.104	***	1.193	***	1.159	***
County Dependencies										
fade_00	0.018		0.362	**	0.429	***	-0.108		-0.043	
made_00	-0.162		-0.144		-0.162		-0.208	**	-0.227	**
recde_00	-0.245		0.270		0.351	**	0.328	**	0.385	**
retde_00	-0.068		0.012		0.017		0.039		0.069	
Other Demographics										
natam_04	-0.073		-0.047		-0.006		-0.096		-0.071	
lnfarms_07	-0.433	***	-0.288	***	-0.275	***	-0.211	***	-0.162	**
homig	0.639	**	0.913	***	0.875	***	1.402	***	1.405	***
Metropolitan Status										
micro	-0.042		-0.037		-0.049		0.039		0.016	
noncore	0.088		0.131		0.157		0.253	*	0.235	*
State FE?	Y		Y		Y		Y		Y	
# Obs	3,072		3,072		3,069		3,071		3,066	
Pseudo R2	0.3865		0.3115		0.3186		0.3053		0.3149	

*, **, and *** represent statistically significant differences from 0 at the p = 0.10, 0.05, and 0.01 levels, respectively.

Overall, some similar and expected patterns emerge for 2008, 2010, and 2011: the log of population has the expected positive sign, the percentage of the population with higher levels of education is positive and significant, and the log of median household income is positive and significant. The unemployment rate holds its negative sign across all models, and the poverty rate has the predictable negative influence on adoption rates in 2008 and 2010. Higher levels of Blacks and other racial categories also have a negative relationship with broadband adoption, while Hispanic is initially not significant but becomes negative over time. Older age groups also decrease the categorical adoption variable, as expected. Only the age group from 45-64 has a consistently negative impact on adoption over 2008 – 2011.

While these results are expected, a number of other interesting results emerge from these models. First, both the percentage of the population that are non-farm proprietors and the log of the non-farm proprietors' income are negatively associated with county-level adoption rates – a result that is consistent over time. Goetz (2003) demonstrates the dramatic increase in the percentage of non-farm proprietor employment in non-metro areas between 1980 and 2000, while noting that these individuals tend to earn significantly less than their wage-and-salary counterparts. Anecdotal evidence suggests that while some of these individuals are heavy users of broadband, many are not. Thus, the negative relationship is not overly surprising. Second, the variable for the percentage of the population with no access to broadband is, as expected, negative and highly significant once it is introduced (Models (3) and (5)).[21] This implies that as the percentage of the population without access to broadband infrastructure increases, county-level adoption rates decline. After controlling for this availability measure, higher numbers of broadband providers positively influenced adoption in 2010; however, this impact disappears in 2011.[22] Even more striking, once the number of wireless providers is included in 2011, its impact on adoption is *negative*. Therefore, after controlling for a lack of broadband access (which is defined as where *wired* broadband providers are lacking), adding wireless providers does not positively influence broadband adoption. Further, breaking the models out by metro / micro / noncore counties in 2011, this result is driven by noncore areas (***Table 10***). This suggests that focusing on increasing the number of wireless broadband providers in rural areas may not help bridge the adoption gap of wired broadband.[23] In particular, it may imply that some rural households are substituting wireless phone access for wired broadband. The financial constraints associated with monthly payments for both wireless and wired access gives this hypothesis even more credence. In turn, it raises questions about what communities do – and do differently – with wired and wireless access. Their substitutability requires additional research.

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[21] Note that the measure of broadband availability (nobbnd_10) is only available for 2010. We assume that 2011 does not significantly vary from 2010 in this regard, and also include this measure for the 2011 specification.
[22] The number of wired providers can also serve as a proxy for cost, since Horrigan (2009) found that monthly costs were lowered as the number of providers increases.
[23] A reviewer also notes that selling wireless providers as the solution to rural broadband often overlooks the fact that a robust wireless network requires a robust wired network running to the towers.

Rural status (micro or non-core) is only significant in one year in these results – 2011 (Models (4) and (5)). Here, non-core status is actually positive, reflecting the shrinking county-level gap between metro and non-core counties noted in Section 2.2. This is in stark contrast to the results seen using the CPS data, where non-metro status had a significantly negative impact in the logit models specified in both 2003 and 2010. Thus, while rural location seemed to reduce the likelihood of household-level adoption in 2010, there is some evidence that the most rural counties are slowly increasing their overall adoption rates relative to their urban counterparts in 2011.

Only two location quotients exhibit significance across this time period: those for the information and real estate sectors. This implies that counties with high concentrations of jobs in these industries will have higher broadband adoption rates. The information sector result is driven by noncore areas in 2011 (***Table 10***) while the real estate parameter is positively significant across all metro and non-metro categories. Rural areas focusing heavily on the information and real estate sectors will therefore tend to have higher broadband adoption rates.

Several results are unexpected and warrant closer inspection. Being a high out-migration county (where over 20% of population was lost between 1990 and 2010) has a positive relationship with the broadband adoption rate across all models. This result contradicts the findings of Mahasuweerachai et al. (2010) who demonstrated that nonmetro counties with early access to high levels of broadband had slight *increases* in net migration. The finding here might be interpreted as a signal that this is a population base that is inclined toward geographic mobility and is also more interested in technologies such as broadband that can deliver additional awareness of new options and new places. Additionally, being in a farming dependent county positively impacts broadband adoption in 2010, although the actual number of farms itself is negatively related across all years. This may be due to different patterns of Internet use by farms across metropolitan status – note that there are generally more farms located in metropolitan counties than in non-core ones, although farming dependency is much more common in non-metro counties (***Table 8***). Thus, smaller (but more numerous) farms in metro areas may not be likely to use broadband, while the larger farms that are drivers of the economy in non-metro areas may be more likely to adopt. However, when the analysis is restricted to metro, micro, or non-core counties only (***Table 10***), these farm-related results disappear. Perhaps more intuitive are the results for manufacturing dependence (negative) and recreation dependence (positive) in 2011.

Table 10 displays the ordered logit results in 2011 when the models are restricted to metro, micro, and non-core areas. Focusing on the non-core areas (model (8)), it is interesting to see that simply having higher population does not translate to higher rates of broadband adoption. Similarly, higher levels of income in non-core counties do not have a significant impact on adoption rates, although they do for metro and micro areas. This may suggest that rates of non-adoption in the most rural counties are more related to relevancy issues than cost – a finding backed up by the high number of non-metro residents citing “no need” as their primary reason for not having broadband (***Figure 6***).

Table 10. FCC Ordered Logits for 2011: Metro, Micro, Noncore Counties.

	(6) 2011 Metro		(7) 2011 Micro		(8) 2011 Noncore	
Infrastructure						
prov_YY	-0.006		-0.013		0.056	
wprov_YY	-0.056		-0.010		-0.082	**
nobbnd_10	-0.017	***	-0.032	***	-0.015	***
lnpop_YY	0.460	***	0.557	**	-0.265	
Education						
highschool_YY	0.078	**	0.027		0.017	
somecoll_YY	0.139	***	0.097	***	0.060	***
bach_YY	0.143	***	0.106	***	0.075	***
Income and Employment						
lnmhhi_YY	2.510	*	3.264	**	0.614	
lnnfpinc_YY	-0.278		-0.285		-0.189	
nfp_YY	-0.051	***	-0.029		-0.039	***
creative_YY	0.002		0.002		-0.039	**
ur_YY	0.089	*	-0.102		-0.068	*
pov_YY	-0.095	**	0.010		-0.019	
Race / Ethnicity						
black_YY	-0.014		0.005		-0.036	***
asian_YY	-0.025		0.130		0.001	
hisp_YY	-0.018		-0.003		-0.018	**
othrace_YY	-0.013		-0.033		-0.028	**
Age						
age15-25pct	-0.064		-0.002		-0.014	
age25-44pct	-0.127	*	0.162	*	-0.035	
age45-64pct	-0.181	***	-0.075		-0.007	
age65+pct	-0.132	**	0.128	*	-0.022	
Location Quotients						
info_YY	0.267		0.211		0.814	***
re_YY	1.582	***	1.533	***	0.793	***
County Dependencies						
fade_00	0.062		-0.251		-0.126	
made_00	-0.301		-0.229		-0.130	
recde_00	1.015	**	0.413		0.435	**
retde_00	0.326		0.272		-0.058	
Other Demographics						
natam_04	0.116		-0.137		-0.125	
lnfarms_07	-0.091		-0.227		0.007	
homig	0.985		1.070		0.927	***
State FE?	Y		Y		Y	
# Obs	1,059		664		1,343	
Pseudo R2	0.422		0.354		0.2475	

*, **, and *** represent statistically significant differences from 0 at the p = 0.10, 0.05, and 0.01 levels, respectively.

Several other distinctions from ***Table 10*** are noteworthy, in particular the finding that both the percentage of non-farm proprietors and the percentage of employment in the creative class have significantly negative impacts on adoption only in non-core areas. These findings are perplexing; they may be evidence that many non-farm proprietors or creative class workers are simply not utilizing broadband, or they may be related to the industry codes being used to define the creative class. In particular, McGranahan and Wojan (2007) suggested that some occupations included in the creative class definition require relatively little creativity – which can be particularly problematic for analysis in rural areas. As noted above, high outmigration counties in non-core areas tend to have higher adoption rates. This may be an indication that individuals with more human capital (and thus the knowledge to effectively use the Internet) are also more mobile. Further, levels of Hispanic, Black, and other non-White residents only show up as negative in non-core areas.

Data from the national broadband map also allows for testing whether or not specific numbers of broadband providers or download / upload speeds have any significant impact on county-level adoption rates in rural areas. To conduct this analysis, a series of broadband availability measures (typically in dummy format) were added to the dependent variable list for model (4) in ***Table 9*** **–** but restricted to non-metro (and micro / non-core) areas. The results of these regressions are displayed in ***Table 11***.

Table 11. Non-metro Broadband Availability Measures - Impact on Adoption (FCC Data), 2010 & 2011.

2011	NM		Micro		Noncore	
Low # Providers (<3)	NS		NS		NS	
Low Download Speed (<3-6 mbps)	-0.288	**	NS		-0.347	**
Low Upload Speed (200k - 768k mbps)	NS		NS		NS	
High # Providers (>6)	NS		-0.672	***	NS	
High Download Speed (>10 mbps)	0.267	**	NS		0.389	***
High Upload Speed (>6mbps)	NS		NS		NS	

2010	NM		Micro		Noncore	
Low # Providers (<3)	-0.231	**	-0.501	**	NS	
Low Download Speed (<3-6 mbps)	-0.245	**	-0.403	*	-0.297	**
Low Upload Speed (200k - 768k mbps)	NS		NS		-0.279	*
High # Providers (>6)	0.275	**	0.476	**	NS	
High Download Speed (>10 mbps)	NS		NS		NS	
High Upload Speed (>6mbps)	NS		NS		NS	

*, **, and *** represent statistically significant differences from 0 at the p = 0.10, 0.05, and 0.01 levels, respectively
NS = Not statistically significant.

The results suggest that some measures of broadband availability did in fact play a role in increasing or decreasing broadband adoption levels in non-metro counties. Notably, the trend seems to have changed from a focus on *numbers* of broadband providers in 2010 to their *average download speeds* in 2011. In 2010, low (<3) and high (>6) numbers of broadband providers had negative and positive impacts, respectively, on the category of broadband adoption for non-metro counties. This relationship held when the analysis was restricted to only micropolitan counties, although it did not hold for non-core counties – perhaps because the norm in these counties is a much lower number of providers in general. It seems that non-metro residents were also affected by low download speeds in 2010, as counties with relatively low average download speeds saw lower adoption rates across all non-metro categories. By 2011, however, the impacts of low or high numbers of providers had mostly disappeared, except for an unexpected negative relationship for micro counties with high levels of providers. Instead, the most influential availability measures are low and high download speeds. Low download speeds continued their negative association with adoption rates observed in 2010, but it appears that non-metro residents were also affected by providers offering high download speeds. For non-core counties in particular, offering an average maximum advertised download speed of more than 10 mbps had a positive impact on broadband adoption in the county. An interesting observation from ***Table 11*** is that upload speeds (high or low) are rarely significant – which is perhaps not overly surprising given that most Internet users are primarily interested in gathering, rather than providing, information. In terms of facilitating network upgrades, these results suggest that policymakers should consider how to create incentives for providers to offer higher speeds and invest in their infrastructure; whether or how local rural telecommunications monopolies can be service- and price- competitive is a crucial question.

3.2.2 First-differenced Regressions: Explaining increases in Adoption Rates

The FCC data is essentially a panel data set: the same counties report information over the period 2008 to 2011. This allows for observation of increases or decreases in county-level broadband adoption rates over that time. A first-differenced regression can then be used to model these changes over time, including whether increases in the number of broadband providers has any impact. This model takes the form:

$$\Delta BB_i = \beta_0 + \beta_1 \Delta X_i + \varepsilon_i$$

where ΔBB_i is the change in broadband adoption rate for county i, ΔX_i is the change in a vector of county-level characteristics such as education, income, or number of broadband providers, and ε_i is the associated error term. This technique is essentially a form of fixed effects modeling, and benefits from eliminating the bias of time-invariant unobserved factors. It is quite popular for policy evaluation, and also allows for some preliminary claims regarding causality (although endogeneity is still a concern) (Imai and Kim, 2012; Gangl, 2010; Antonakis et al. 2010).

It is worth noting that since the time frame being explored is relatively short, many counties in the data set do not report any increases in broadband adoption. Recall that the broadband adoption rates in this dataset are reported in intervals of 20 percentage points (20-40%, 40-60%, etc.); thus a 1-unit increase translates roughly to an increase in adoption rates of 20 percentage points over this three year period. The table below shows the percentage of metro, micro, and non-core counties that experienced increases (or decreases) in broadband adoption categories over that time.

Table 12. Changes in Broadband Adoption Categories, 2008-2011 (Metro, Micro, and Non-core).

	Metro	Micro	Non-core
Increase	0.40	0.48	0.58
Increase of > 1 category	0.02	0.03	0.06
No Change	0.56	0.50	0.40
Decrease	0.04	0.02	0.02
# Obs	1,064	671	1,369

As ***Table 12*** demonstrates, non-metro counties (both micro and non-core) were more likely to experience increases in broadband adoption categories over this time, reflecting the improvements seen in ***Figure 8***. Several counties (about 4% overall) saw jumps of 2 categories or more; these were again predominantly located in non-metro areas. Further, some counties, both metro and non-metro, actually saw reductions in their broadband adoption levels over this time. The regression results in ***Table 13*** show how various county-level characteristic changes affected these shifting broadband adoption rates.

Table 13. First-differenced regressions: Changes in Broadband Adoption, 2008-2011 (All, Micro, Noncore).

	ALL OBS		MICRO ONLY		NONCORE ONLY	
Δresprov	0.048	***	0.043	**	0.075	***
Δlnpop	0.498	*	-1.023		0.912	**
Education						
Δhighschool	-0.003		-0.028		0.008	
Δsomecoll	-0.006		-0.021		0.026	
Δbach	0.016		0.009		0.024	
Income / Employment						
Δlnmhhi	0.641	***	1.178	**	0.654	*
Δunemprate	-0.028	**	-0.002		-0.045	***
Δpov	0.010		0.021		0.017	
Δlnnfpinc	-0.034		-0.045		0.014	
Δnfp	0.018		-0.014		0.034	**
Age						
Δage0-15	-0.059		-0.103		0.186	
Δage15-24	-0.054		-0.113		0.207	
Δage25-44	-0.068		-0.138		0.177	
Δage45-64	-0.076		-0.145		0.186	
Δage65+	-0.033		-0.078		0.208	
Race / Ethnicity						
Δblack	-0.012		0.032		0.005	
Δasian	-0.044		-0.075		0.036	
Δhisp	-0.015		-0.021		0.000	
Δothrace	-0.030		-0.045		-0.024	
Metropolitan Status						
micro	0.079	**				
noncore	0.148	***				
State FE	Y		Y		Y	
No. Obs	3101		671		1366	
Adj R2	0.0903		0.0843		0.0835	

*, **, and *** represent statistically significant differences from 0 at the p = 0.10, 0.05, and 0.01 levels, respectively.

The results demonstrate that not many characteristic shifts impact the changing adoption rates. Increases in population, income, and employment rate changes are all significant and have the expected signs, but no age or racial shifts play any role. Micro and non-core status are positively related to increases in adoption categories (which was expected given the fact that the county-level adoption gap has shrunk over this time (***Figure 9***)). Further, and perhaps most conspicuously, increases in the number of residential broadband providers has a positive impact on increasing adoption rates – a finding that persists in both micro and non-core counties. This suggests that increasing the number of broadband providers does have an impact on broadband adoption rates in rural areas. The adjusted R^2 values of 0.08 – 0.09 are reasonable for regressions utilizing a difference-oriented methodology, especially considering the dependent variable shows only limited variation.

The FCC data also includes another measure of broadband: the BTOP definition of 768 kbps download (versus the 200 kbps used here). A first-differenced regression was also run using this more restrictive definition; the results were very similar to those reported in ***Table 13***. In particular, non-core status was again highly positively significant, as were increases to the number of residential broadband providers across all locations.

3.2.3 Connected Nation: Impacting Adoption Rates or Number of Providers?

One of the most well-known ‘grassroots’ programs focusing on broadband availability and adoption is Connected Nation. Originally started in Kentucky, the program is known for working with various broadband providers and community stakeholders and residents to generate detailed maps of unserved areas within a state. A large portion of their work, however, focuses on increasing broadband adoption in various communities. Their programs include “Get Connected,” which gathers technology champions in an area to evaluate the current state of broadband adoption and use; digital training efforts that help people lacking basic computer training and web-browsing skills; and Computers 4 Kids, which not only provides computers to vulnerable children but also partners with community anchor organizations such as YMCAs or community centers that help provide technology support to vulnerable populations. Currently, 13 states are participating in the Connected Nation effort, with 3 others having already completed the process. The states that participate in the program typically work on a county-by-county basis, with each county reviewing its own broadband infrastructure. Each county also focuses heavily on broadband awareness and technology training (typically through hands-on teaching) in an effort to promote broadband adoption. The efforts related to increasing broadband infrastructure and adoption are the focus on this section.

The Connected Nation program provided data on eight of the states they have worked with in the past, including the dates when each county in those states began the process. Given the FCC’s county-level adoption data from 2008-2011, a natural experiment opportunity arises: we can assess whether counties that went through the program during those years experienced higher levels of broadband adoption than those that did not. Thus, only counties that began the program after 2008 and before 2011 can be included in the analysis, so that relevant pre- and post-adoption data can be gathered. This restricts the analysis to 2 states: Ohio and Tennessee. Both states began the program in 2008 / 2009, with the start dates in nearly all counties running from mid-2008 until mid-2009. This implies that the 2008 FCC data were collected prior to beginning the program, and that the 2011 FCC data would allow for a reasonable amount of time to pass after the program was initiated.

Summary statistics for counties that participated in the Connected Nation program in these states are displayed in ***Table 14*** below. The two measures of interest are the percent increase in the broadband adoption category between 2008 and 2011, and the percent increase in the number of residential broadband providers over that time.

Table 14. Percent Increase in BB Adoption and # of BB Providers by Connected Nation participation, 2008-2011.

	All		Metro	Micro		Noncore
% Increase in BB Adoption Category (2008-2011)						
CN Participants	0.19		0.12	0.16		0.31
All Other	0.24		0.16	0.22		0.31
Difference	-0.05	**	-0.04	-0.07	*	0.00
% Increase in # of Residential BB Providers (2008 - 2011)						
CN Participants	0.10		0.02	0.04		0.25
All Other	0.07		0.00	0.05		0.14
Difference	0.02		0.02	-0.01		0.11

* and ** represent statistically significant different means at the $p = 0.10$ and 0.05 levels, respectively.

The statistics displayed above suggest that while Connected Nation participants saw larger increases to the number of broadband providers in their counties, they tended to lag non-participants in terms of broadband adoption increases (though none of the differences in non-core counties are statistically significant).

However, simple descriptive statistics of program participant categories do not give a fair comparison. It is highly possible (and even likely) that counties participating in the program had drastically different socio-economic characteristics than their non-participating counterparts. These characteristics clearly impact broadband adoption rates, as demonstrated from the logit and ordered logit results in sections 3.1.1 and 3.2.1. To accurately control for this and assess the impact of the Connected Nation program in Ohio and Tennessee, a quasi-experimental design technique was used. The technique is known as Mahalanobis matching, and involves creating a distance based on correlations between variables (in this case, between variables known to influence broadband adoption)[24]. The idea is to generate a list of non-participating counties with characteristics similar to those that went through the Connected Nation program. Comparing changes between these two groups is much more revealing than looking at summary statistics for all non-participating counties.

The Stata command 'mahapick' was used to create matching counties for each Connected Nation participant based on Mahalanobis distances associated with 2008 levels of factors influencing broadband adoption taken from the ordered logit analysis (***Table 9***): population sizes, education

[24] For more information on this technique, see Appendix E in Stenberg et. al (2009).

levels, unemployment and poverty rates, median household income levels, and age and racial composition. The average percentage change in the variables of interest (broadband adoption category and number of residential providers) was then calculated for the 5 closest counties matching each Connected Nation participant.[25] ***Table 15*** below displays the resulting statistics for the matched counties, and t-tests for whether the differences between Connected Nation and matched counties are statistically significant.

Table 15. Matched Counties: Percent Increase in BB Adoption and # of BB Providers by Connected Nation Participation, 2008-2011.

	All		Metro		Micro		Noncore	
% Increase in BB Adoption Category (2008-2011)								
CN Participants	0.19		0.18		0.16		0.31	
Non-CN Participants (Matched)	0.24		0.12		0.23		0.32	
Difference	-0.04	**	0.06	**	-0.07	*	-0.01	
% Increase in # of Residential BB Providers (2008 - 2011)								
CN Participants	0.10		0.02		0.04		0.25	
Non-CN Participants (Matched)	0.03		0.02		0.06		0.00	
Difference	0.07	*	0.00		-0.02		0.25	**

* and ** represent statistically significant different means at the $p = 0.10$ and 0.05 levels, respectively.

Once the analysis has been restricted to 'similar' counties as of the 2008 time period, several results emerge. First, Connected Nation participating counties still exhibit lower rates of increased broadband adoption than their matched counterparts. In metro areas, however, this trend is reversed, with CN participants demonstrating a higher propensity to increase their broadband adoption category. The negative result is mostly seen in micropolitan counties, with similar adoption increases in non-core counties regardless of program participation. In terms of the number of residential broadband providers, however, taking part in the Connected Nation program seems to have a dramatic impact in the most rural counties. Non-core counties participating in the program saw a 25 percentage point increase in the number of residential broadband providers over the 2008-2011 timeframe, while matched non-participating counties saw *no* additional providers over that time. These results suggest that the Connected Nation program has been particularly effective at helping with infrastructure provision in rural areas. However, in terms of broadband adoption, Connected Nation seems to be having more impact in metropolitan counties.

These findings – that Connected Nation helped increase the number of providers in noncore counties but did not influence adoption rates – seem at odds with the results of the first-differenced regressions from section 3.2.2 suggesting that more providers lead to higher adoption rates. This may reflect state-level differences, since the Connected Nation data are limited to

[25] Larger numbers of matched counties (10, 20) were also used with no meaningful changes in the results.

two states. More generally, these inconsistent findings may be a result of inaccuracies that arise when aggregating the National Broadband Map infrastructure data to the county level.

4. Broadband's Contribution to Economic Health in Rural Areas

One of the most intriguing questions this proposal seeks to answer is whether broadband availability and / or adoption contribute to the economic health in rural areas. Recent studies (Stephens and Partridge, 2011; McGranahan, Wojan, and Lambert, 2011; Goetz, Fleming, and Rupasingha, 2012) point to the percentage of self-employed (i.e. nonfarm proprietors), the percentage of employees classified as creative class, income levels, and employment levels as measures of rural economic health. Therefore, we use these indicators as well as standard ones (such as poverty rates and number of firms) to better understand the relationship between economic health in rural areas and broadband adoption/availability.

The sections below use the FCC data combined with National Broadband Map data to assess the impact of various broadband measures on the wide range of economic indicators noted above. The analytic techniques are discussed below, and are included in order of increasing statements that can be made about causality:

- Cross-section spatial models
- First-differenced regression
- Propensity score matching

For instance, cross-section spatial models assess the correlation between broadband and economic variables at one specific point in time, but have limited input regarding causality. First-differenced regressions look at changes over time, and as a form of fixed-effects modeling, can make some preliminary claims about causality. The propensity score matching technique used in the last section, also known as average treatment effects, compares economic growth in counties that meet a specific threshold of broadband availability / adoption versus otherwise similar counties that do not meet this threshold. This technique makes the strongest case for a causal relationship (Rosenbaum and Rubin, 1983; Dehejia and Wahba, 2002).

4.1 Cross-Section Spatial Models

A series of OLS regressions with spatial dependency were conducted, again using the FCC data. Spatial analyses are important because not accounting for spatial effects – spatial autocorrelation and spatial heterogeneity – can cause inaccurate interpretations of the associations between predictor and dependent variables (Voss, Long, Hammer, and Friedman, 2006). The most frequently cited forms of spatial dependency include spatial lag and spatial error (Chi, 2010). Spatial lag refers to changes in the dependent variable of a particular geography as being affected by its neighbors while spatial error refers to spatially correlated model residuals (Chi, 2010).

The models were run using GeoDa software and a first order queen contiguity spatial weights matrix[26] to define the neighborhood structure. Queen contiguity considers neighbors of a particular county or polygon to be any other county that shares a common boundary or single point of contact in any direction (Voss et al, 2006). For this reason, only counties within the continental U.S. were utilized. The spatial dependency analysis results after running a standard OLS showed the majority of the models had both spatial lag and spatial error. Therefore, a spatial error model with lag dependency[27] or SEMLD was employed (Chi, 2010). This model is more robust in that it controls both for spatial error and lag in the same model.

The following variables were used as dependent variables regarding economic health in rural areas: percent creative[28] occupations of total occupations, percent nonfarm proprietors of total employed (includes part-time), average nonfarm proprietors' income, median household income, percent individuals in poverty, number of firms with paid employees, and total employed. See ***Table 16*** below for a summary of the dependent variables utilized.

Table 16. Summary of Dependent Variables for Spatial Regression.

Name	Description	Mean	Observations	Year	Source
CRE	% Creative	32.6	3,073	2010	ERS; EMSI
NFP	% Nonfarm proprietors	23.8	3,073	2010	BEA
POV	% Poverty (Ind.)	16.1	3,073	2010	SAIPE
NFPINC	Avg. Nonfarm Prop. Income	$18,285	3,073	2010	BEA
MHHI	Median Household Income	$42,973	3,073	2010	SAIPE
ESTPE	No. estab. w/paid employees	2,387	3,073	2010	CBP
CBPTOT	Total Employed	35,883	3,033	2010	CBP

On the other hand, a total of sixteen (16) variables plus a broadband adoption/availability variable were used as control variables including population, educational attainment, age groups, race breakdown, natural amenities, unemployment rate, and micropolitan or noncore typology. ***Table 17*** provides a summary of these control variables.

[26] Multiple spatial weights matrix were tested before settling for the queen first order including queen second order as well as rook first and second order.
[27] The lag dependency variable was calculated by multiplying the dependent variable times the spatial weight matrix utilized, in this case first order queen contiguity.
[28] Creative occupations include the following 2-digit SOC codes: management (11), business & financial operations (13), computer and mathematical science (15), architecture and engineering (17), life, physical, and social science (19), legal (23), education, training, and library (25), arts, design, entertainment, sports, and media (27), healthcare practitioners and technical (29).

Table 17. Summary of Control Variables for Spatial Regression.

Name	Description	Mean	Observations	Year	Source
POP_LN	Log of population	10.28	3,073	2010	Census
HS	% Pop 25+ with High School	35.47	3,073	2010	EMSI
SC	% Pop 25+ with Some College	28.48	3,073	2010	EMSI
BACH	% Pop 25+ with Bachelor's or more	18.90	3,073	2010	EMSI
AGE15-24	% Ages 15-24 years	12.92	3,073	2010	Census
AGE25-44	% Ages 25-44 years	23.68	3,073	2010	Census
AGE45-64	% Ages 45-64 years	28.18	3,073	2010	Census
AGE65+	% Ages 65 or more	15.97	3,073	2010	Census
BLACK	% Black non-Hispanic	8.72	3,073	2010	Census
ASIAN	% Asian non-Hispanic	1.06	3,073	2010	Census
HISP	% Hispanic	8.34	3,073	2010	Census
OTHRACE	% Other	3.02	3,073	2010	Census
NATAM	Natural Amenities Scale	3.49	3,072	2004	ERS
UR	Unemployment Rate	9.19	3,073	2010	BLS-LAU
Micro	Micropolitan County (1=Yes)	0.22	3,073	2003	OMB
Noncore	Noncore County (1=Yes)	0.44	3,073	2003	OMB

As discussed earlier, in addition to the sixteen control variables summarized in ***Table 17***, multiple variables were used for broadband adoption/availability measures including: percent of total population without access to broadband, average high download speeds (greater than 10 mbps), high adoption rate (at least 600 residential fixed connections over 200 kbps in at least one direction per 1,000 households), high number of unique providers (6 or more), high broadband availability (less than 15% of population does not have access to broadband), low average download speeds (less than 3mbps), low adoption rate (less than 400 residential fixed connections over 200 kbps in at least one direction per 1,000 households), low number of unique providers (3 or less), and low broadband availability (35% or more of population does not have access to broadband). ***Table 18*** includes a summary of the broadband adoption/availability used in the spatial specifications that follow.

On average, 20.6% of county residents do not have access to broadband – though this number varies greatly, specifically by geography (see ***Table 1*** and ***Figure 14***). The lower numbers of observations indicate that not all counties report maximum advertised download speeds, but of those that do, 29% and 36% can be classified as having high and low download speeds available to them, respectively. About 33% of counties can be classified as high adoption according to the definition above, while 22% are low adoption. Further, about 33% can be classified as having high and low numbers of providers. Finally, using the definitions above, 53% have high levels of broadband availability, and 20% have low levels of availability.

Table 18. Summary of Broadband Adoption / Availability Measures included in Spatial Regression.

Name	Description	Mean	Observations	Year	Source
NOBBND	% Pop. without broadband[29]	20.57	3,073	2010	FCC
HIDN	Hi download speeds (1=Yes)	0.29	2,594	2010	NBM
HIADPT	Hi adoption (1=Yes)	0.33	3,073	2010	FCC
HIPROV	Hi providers (1=Yes)	0.33	3,069	2010	NBM
HIAVAIL	Hi availability (1=Yes)	0.53	3,073	2010	FCC
LODN	Low download speeds (1=Yes)	0.36	2,594	2010	NBM
LOADPT	Low adoption (1=Yes)	0.22	3,073	2010	FCC
LOPROV	Low providers (1=Yes)	0.33	3,069	2010	NBM
LOAVAIL	Low availability (1=Yes)	0.20	3,073	2010	FCC

A total of more than one-hundred twenty standard OLS and SEMLD models were run using the sixteen criterion variables plus a single broadband adoption/availability variable. Because the objective of this section is to better understand the contribution of broadband-related indicators to economic health, the results shown in ***Table 19*** indicate only if the broadband-related indicators had a statistically significant impact on the specified economic health-related dependent variables and the direction of this relationship after controlling for all other variables included in ***Table 17***.

[29] Includes only fixed connections of at least 3mbps down and 768kbps up.

Table 19. Broadband Adoption/Availability Impact on Economic Health Indicators (Spatial Regression Results).

	%Creative		**%NFP**		**NFPINC**		**MHHI**		**%Poverty**		**#Firms**		**#TotEmp**	
	OLS	SEMLD	OLS	SEMLD	OLS	SEMLD	OLS	SEMLD	OLS	SEMLD	OLS	SEMLD	OLS	SEMLD
NOBBND	+**	+**	+**	+**	-**	-**	-**	-**	+**	+**	-**	-**	-**	-**
HIDN	-**	-**									+**	+**	+**	+**
HIADPT	-**	-**	-**	-*			+**	+**	-**	-**	+**	+**	+**	+**
HIPROV	-**	-**	-**	-**	+**	+**	+**		-**		+**	+**	+**	+**
HIAVAIL	-**	-**	-**	-**		+**	+**				+**	+**	+**	+**
LODN	+**	+**	+**		-*						-**		-**	
LOADPT	+**	+**	+**	+**			-**	-**	+**	+**	-**	-**	-**	-**
LOPROV	+**	+**	+**	+**	-**	-**	-**	-**	+**	+**	-**	-**	-**	-**
LOAVAIL	+**	+**	+**	+**		-*	-**	-**	+**	+**	-**	-**	-**	-**

** and * indicate statistical significance at the $p<0.01$ and $p<0.05$ levels, respectively

Several points can be made based on ***Table 19***. First, only two broadband adoption/availability indicators are significantly related to all economic health indicators: the percentage of the population without broadband (NOBBND) and a low number of unique providers (LOPROV). As the lack of broadband increases, so does the percent employed in creative occupations (%Creative) and the percent of nonfarm proprietors (%NFP). These counterintuitive correlations were also documented in the ordered logit results (***Table 9***), and may reflect a lack of technical expertise among many non-farm proprietors, or poor measurements related to actual "creative" occupations in rural areas (McGranahan and Wojan, 2007). The results also suggest that increases in the percentage lacking broadband is associated with a higher percent in poverty (%Poverty), and decreases in nonfarm proprietor average income (NFP), median household income (MHHI), total firms with paid employees (#Firms), and total employed (#TotEmp). Identical relationships are seen with the low number of providers and indicators of economic health. The results for median household income, poverty, number of firms, and total employment demonstrate that low levels of broadband availability do impact these variables, even after controlling for spatial effects.

Second, all "high" broadband adoption/availability variables have a positive impact on the number of firms with paid employees and total employed while all "lows" have a negative impact. Interestingly, only high levels of adoption (and not high levels of availability) display a significant relationship with median household income once spatial effects are included. Low levels of adoption and availability, however, are all negatively related to median household income. Thus, in 2010, the hypothesized relationships clearly existed between broadband adoption / availability and several measures of economic health.

It is interesting to point out that the effects of the broadband adoption/availability indicators are reversed between the percent of nonfarm proprietors and the average nonfarm proprietor income. For example, as the lack of broadband increases so does the percentage of nonfarm proprietors; however the average nonfarm proprietor income decreases. The same pattern is seen with the "high" and "low" provider variables. The findings suggest that while high levels of broadband may not be positively related to the proportion of non-farm proprietors, they do have a positive association with the income levels earned by those proprietors. This supports the notion that while not all non-farm proprietors will take advantage of broadband access, it is likely high important for a subset of these self-employed individuals.

An example of a spatial model output is shown in ***Table 20*** below. All sixteen variables plus a broadband adoption/availability variable – the percent of population without access to broadband – were utilized as control variables. The dependent variable was the log of total employed obtained from the Census Bureau (County Business Patterns).

Table 20. Example of Spatial Regression Result - Total Employed as Dependent Variable.

CBTOT_LN (Total Employed)	Models	
	OLS	SEMLD
Constant	+3.67**	+6.85**
POP10_LN	+0.03*	+0.01
Education		
HS_10	+0.01	-0.00
SC_10	+0.01**	+0.02**
BACH_10	+0.06**	+0.05**
Age		
AGE15-24_10	+0.02*	-0.01
AGE25-44_10	+0.14**	+0.11**
AGE45-64_10	-0.08**	-0.13**
AGE65+_10	+0.07**	+0.05**
Race / Ethnicity		
BLACK_10	-0.00	+0.00**
ASIAN_10	+0.13**	+0.11**
HISP_10	-0.00	+0.00
OTHRACE_10	-0.00	-0.00*
Other Demographics		
NATAM_04	-0.03	+0.06
UR_10	+0.11**	+0.08**
Metropolitan Status		
MICRO	-0.42**	-0.23**
NONCORE	-1.24**	-0.86**
Broadband Infrastructure		
NOBBND_10	-0.01**	-0.01**
Lagged DV		
CBPTOT_LAG	---	+0.02
R^2	0.56	0.62
F-Score	231.87	---
Lambda	---	0.48**
Lagrange Multiplier (lag) – p value	0.12	---
Lagrange Multiplier (error) – p value	0.00	---
n	3,073	3,073

As shown, 56% of the variance of the log of total employed was explained with the standard OLS model compared to 62% for the spatial error model with lag dependence. Notice that the lag Lagrange multiplier is not significant when testing for spatial dependency while the error

Lagrange multiplier is significant. Once the lag dependent variable is added to the spatial error model, its impact continues to be insignificant. Overall, the lag dependent variable added to the SEMLD models was significant in 57 out of the 63 models run.

The results suggest that the number of total employed residents will be less in micropolitan and noncore counties (even after controlling for population), and increases to the percentage of residents with some college or a bachelor's degree will increase the number of total employed. Regarding the broadband adoption/availability variable, the percent of population without access to broadband is significant and negative in both models. This implies that as broadband availability increases (and nobbnd_10 decreases), the number of total employed residents also increases. As noted previously, however, this type of cross-section model can make only very limited claims about causality. We turn to first-differenced and propensity score matching techniques to make more robust claims regarding the causal direction.

4.2 First-differenced Regressions

This section focuses primarily on the impact of changing levels of broadband adoption (as opposed to availability) on shifts in various economic indicators. While section 3.2.2 used first-differenced regressions to explain the changes in county-level broadband adoption over the 2008-2011 time period, this section uses those changes as right-hand side (explanatory) variables. The dependent variables shift to different measures of economic health, and thus the primary model can be written as:

$$\Delta Y_i = \beta_0 + \beta_1 \Delta X_i + \beta_2 \Delta BB_i + \varepsilon_i$$

where ΔY_i is the change to a specific economic measure such as median household income, ΔX_i is a vector of other county-level characteristics such as population, education, and age groupings, ΔBB_i is the right-hand side variable of interest denoting changes in broadband adoption category; β_0, β_1, and $\beta_2$are parameter vectors, and ε_i is the associated error term. The resulting models explore the role of increasing broadband adoption rates on the economic measures, after controlling for other influential variables. As previously noted, the first-differenced technique is essentially a form of fixed effects modeling, with its primary benefit being the elimination of bias from time-invariant unobserved factors. It also allows for some preliminary claims regarding causality, although endogeneity is still a concern. Most of the models that follow use only the 2008 – 2010 time period since the majority of the dependent variables have 2010 as their latest available data. Each of the models is restricted to non-metropolitan counties (which includes both micro and non-core), and some are run solely on non-core counties.

Table 21 provides the results for six measures of economic health: change in the log of median household income, changes in the percentage of non-farm proprietors, changes to the logs of income of those proprietors, changes in the log of the total number of firms, changes in the log of total employment, and changes in the percentage of creative class workers. Only the last model uses data from 2008-2011; the rest are run on changes over the 2008-2010 time period.

Table 21. First-difference Regressions: BB Adoption Impacts on Economic Health Measures.

	Δln(MHHI) (2010 - 2008)		ΔNFP (2010 - 2008)	Δln(# Firms) (2010 - 2008)		Δln(Total Empl) (2010 - 2008)
	NM	Noncore	NM	NM	Noncore	NM
ΔBBadop	0.004 **	0.004 *	-0.003	-0.002	-0.002	0.006 *
Δln(pop)	-0.085 ***	-0.126 ***	-0.942 *	0.052 *	-0.011	0.087 *
Education						
ΔLTHS	-0.016	-0.015	0.130	-0.007	-0.001	-0.017
ΔHS	-0.015	-0.016	0.205	-0.007	-0.002	-0.027
ΔSC	-0.014	-0.015	0.213	0.006	-0.001	-0.019
ΔBACH	-0.014	-0.015	0.105	-0.015	-0.002	-0.023
Income and Employment						
Δunemp	-0.004 ***	-0.003 ***	0.219 ***	-0.009 ***	-0.008 ***	-0.016 ***
Δpov	-0.012 ***	-0.012 ***	0.019 *	-0.002 ***	-0.002 **	-0.003 ***
ΔNFP	-0.005 ***	-0.005 ***		-0.002 *	-0.003 **	-0.029 ***
Age						
Δage<15	0.025 *	0.020	0.247	-0.017	-0.024	-0.025
ΔAge15-24	0.026 **	0.018	0.086	-0.013	-0.024	-0.031
ΔAge25-44	0.028 **	0.022	0.175	-0.013	-0.022	-0.024
ΔAge45-64	0.026 **	0.019	0.183	-0.013	-0.024	-0.022
ΔAge65+	0.023 *	0.018	0.202	-0.012	-0.023	-0.026
Race / Ethnicity						
Δblack	-0.001	0.000	0.012	0.002	0.000	0.007 ***
Δasian	-0.003	-0.011 **	0.071	-0.004	-0.006	0.003
Δhisp	0.000	0.001	0.049 **	0.000	-0.002	-0.001
Δothrace	-0.001	0.001	-0.093 ***	-0.002	-0.002	-0.001
constant	0.024 ***	0.024 ***	0.231 ***	0.005	0.001	0.011 *
No. Obs	2037	1366	2037	2037	1366	1978
Adj R2	0.2293	0.2	0.1358	0.1381	0.0867	0.2377

	Δln(NFP Income) (2010
	NM
ΔBBadop	-0.011
Δln(pop)	-0.581 ***
Education	
ΔLTHS	-0.037
ΔHS	-0.033
ΔSC	-0.065
ΔBACH	-0.064
Income and Employment	
Δln(MHHI)	-0.090
Δunemp	-0.007
Δpov	0.002
ΔNFP	-0.016 **
Age	
Δage<15	-0.019
ΔAge15-24	-0.017
ΔAge25-44	-0.007
ΔAge45-64	-0.024
ΔAge65+	-0.017
Race / Ethnicity	
Δblack	-0.027 ***
Δasian	0.002
Δhisp	-0.016 ***
Δothrace	-0.017 **
constant	0.020
No. Obs	2037
Adj R2	0.027

	Δcreative Class (2011 - 2008)
	NM
ΔBBadop	-0.006
Δln(pop)	-0.064
Education	
ΔLTHS	0.290
ΔHS	0.252
ΔSC	0.304
ΔBACH	0.343 ***
Income and Employment	
Δunemp	0.190
Age	
Δage<15	-0.104
ΔAge15-24	-0.051
ΔAge25-44	-0.154
ΔAge45-64	-0.083
ΔAge65+	-0.047 **
Race / Ethnicity	
Δblack	0.061
Δasian	0.002 ***
Δhisp	0.060 ***
Δothrace	0.150
constant	0.049 ***
No. Obs	2037
Adj R2	0.1063

*, **, and *** represent statistically significant differences from 0 at the p = 0.10, 0.05, and 0.01 levels, respectively.

The results indicate that increasing levels of broadband adoption do impact several observed shifts in economic indicators for non-metro counties over the 2008-2010 time period. Namely, changes in median household income and total employment are positively influenced by increases in broadband adoption over this time. Further, the increase in median household income is still seen when the analysis is restricted to non-core counties. Changes to the other economic measures considered (percentage of non-farm proprietors, total number of firms, level of non-farm proprietor income, and percentage of creative class employees) do not show any impact from changing levels of broadband adoption. Most of these are not surprising, given some of the relationships between non-farm proprietors / creative class and broadband that have been noted previously (***Table 10***). Overall, however, the results do suggest that changing adoption levels do positively impact income and employment in non-metropolitan areas. This finding is particularly impressive since it focuses on relatively recent increases in broadband adoption (since 2008) and looks over only a very short time period (2 years).

When similar regressions are run using changes in residential providers over the 2008 – 2010 period as the independent variable of interest (replacing changes in broadband adoption category), no statistical impacts are found for any measure. This suggests that broadband adoption, rather than availability, is the more important factor for improving economic health in rural areas.

4.3 Propensity Score Matching (FCC County-level data)

The final technique used to estimate broadband's contribution to economic health is known as propensity score matching, used in the context of estimating average treatment effects (ATE). The ATE measures the average causal difference in outcomes between a treated group and a control group (Rosenbaum and Rubin, 1982). In this case, various measures of broadband availability or adoption serve as "treatment" indicators – for instance, having a high level of broadband adoption (>60%) or having a high level of average download speed available in your county. The "controls" would be otherwise similar counties that do not meet this criterion. In general, if ΔY_1 and ΔY_0 represent the changes to economic indicators to areas that have and have not met the broadband criterion, respectively, then the ATE is written as

$$ATE = E(\Delta Y_{t1} | \, BB_t = 1) - \, E(\Delta Y_{t0} | \, BB_t = 1)$$

where BB_t equals 1 for areas that meet the broadband availability criteria (treated) and 0 for areas that do not (non-treated). However, we can observe either ΔY_{t1} or ΔY_{t0} for a particular place, but not both, since each county will have either met or not met the broadband threshold of interest. This implies that there is self-selection into the treatment group, which would typically cause unbiased estimates of the treatment's impact (Wooldridge, 2002).[30] To obtain unbiased estimates, an assumption of conditional independence is applied (Imbens, 2004), which means that there are no unobservable differences between areas that meet the broadband threshold and those that do not. Thus, each 'treated' county needs a comparable, nontreated counterpart. To accomplish this, the ATE technique seeks to "match" counties that met the broadband criterion with otherwise similar communities that did not. The first step in doing so is to estimate the propensity score – that is, the likelihood of meeting the broadband adoption / availability criteria.

Most applications in the statistics literature use a logit model to estimate this propensity score, where the conditional probability of meeting the broadband threshold is modeled on observable predictors such as the socioeconomic variables included in the regressions from section 3.2.1. The propensity score is then used to match treated and non-treated counties by creating blocks of counties with similar propensity scores. A test developed by Becker and Ichino (2002) is used to determine whether the treated and non-treated counties in each block have the same distribution of covariates – essentially ensuring that the matches are in fact 'good.' The literature suggests various methods for matching, the simplest of which is nearest-neighbor. This technique matches treated and non-treated units by searching for the closest propensity score between the two groups, and can be altered to include nearest 'groups' of neighbors to prevent outliers from skewing the results. The results presented in this section use the five closest neighbors from the comparison group.

To ensure that the logit model capturing the likelihood of meeting a particular broadband threshold is not influenced by broadband investments already made, relatively deep lags are used in this specification. In particular, the probability of meeting each of the broadband thresholds is modeled on 2001 county characteristics, which is before most private cable or phone companies began aggressively investing in broadband – particularly in non-metro areas (Bright, 2001).[31] For each model run, the logit specification included 2001 levels of variables that could potentially influence future broadband availability and adoption: population, income, and education; unemployment and poverty rates, total employment, and percent of the population residing in an urban area. The logit models are restricted to non-metro counties, and the resulting probabilities of meeting the chosen broadband threshold are used to develop the propensity scores. The ATE technique then tests whether the growth rates for different economic measures (in this case, between 2001 and 2010) are statistically different for the treated and non-treated groups.

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[30] Another way of interpreting the self-selection issue is that there is some unmeasured variable (including the presence of a broadband 'champion' in the community) that influences whether two otherwise similar counties end up in different treated vs. non-treated groups.

[31] Note that additionally, the USDA's Rural Utilities Service pilot broadband loan program focused on providing infrastructure to rural areas did not begin until FY2001 (Kruger, 2012).

The results of the propensity score matching technique are displayed in ***Table 22*** below. A multitude of different broadband adoption / availability thresholds were tested; only those displayed below demonstrated statistically significant differences between treated and non-treated groups of economic measures. All economic outcomes used are changes over the 2001 to 2010 time period. The pseudo R^2 of the logit model specification is also displayed.

Table 22. Propensity Score Matching Results.

			Treated	Control	Diff	T-stat	
Propensity Scores with Significant Results:							
1	High levels of BB adoption in 2010 (>=4 RFC) - NM Only						
			Treated	Control	Diff	T-stat	
	(+)	%Δ MHHI (2001 - 2010)	0.235	0.219	0.016	2.19	***
	(-)	%Δ NFP Income (2001 - 2010)	-0.082	-0.010	-0.071	-2.08	***
	(-)	%Δ Poverty (2001 - 2010)	0.198	0.234	-0.037	-2.31	***
	(-)	%Δ Unemp (2001 - 2010)	0.706	0.782	-0.076	-2.17	***
		Fit of Logit Model: (Pseudo R2)	0.236				
2	Low levels of BB Adoption in 2010(<=2 RFC) - NM Only						
			Treated	Control	Diff	T-stat	
	(-)	%Δ Number Firms (2001 - 2010)	-0.038	0.000	-0.038	-2.02	***
	(-)	%Δ Total Employment (2001 - 2010)	-0.097	-0.053	-0.044	-2.34	***
	(+)	%Δ Unemp (2001 - 2010)	0.808	0.749	0.059	1.84	*
		Fit of Logit Model: (Pseudo R2)	0.245				
3	Low Levels of BB Availability (<50%) - NM Only						
	(+)	%Δ MHHI (2001 - 2010)	0.259	0.243	0.016	1.89	*
	(-)	%Δ NFP (2001 - 2010)	0.228	0.270	-0.042	-2.23	***
		Fit of Logit Model: (Pseudo R2)	0.182				
Propensity Scores with no significant results:							
	Hi Levels of 2010 Avg D/L speeds (>10MB)						
	Hi Levels of 2010 BB availability (>85%)						
	Hi Levels of 2010 BB Providers (>=5)						
	Low levels of 2010 BB Providers (<=2)						
	Low levels of 2010 Avg D/L speeds (<3MB)						

*, **, and *** represent statistically significant differences at the p = 0.10, 0.05, and 0.01 levels, respectively.

The results suggest that, generally, broadband *adoption* thresholds have more impact on economic health in rural areas than do broadband *availability* thresholds. In particular, high /

low levels of average download speeds never show any impact; neither do high / low levels of broadband providers. On the other hand, results (1) and (2) above suggest that high and low levels of broadband adoption *do* influence economic growth. In particular, non-metro counties that demonstrated high levels of broadband adoption (defined as county-level adoption rates >60%) had significantly higher levels of growth in median household income, and significantly reduced levels of poverty and unemployment. On the negative side, the change to non-farm proprietors income declined in these areas with high broadband adoption, which reinforces the negative correlation between these two variables that has been present throughout this analysis. Similarly, the results suggest that non-metro counties with low levels of broadband adoption have had lower rates of growth than otherwise similar counties without such low adoption levels. In particular, growth in the number of firms and in total employment is significantly lower in counties with low broadband adoption, and growth in unemployment rates is significantly higher.

The only availability measure that influences economic growth rates in rural areas is a dummy variable for very high levels (>50%) with no broadband availability. In this case, the percentage of non-farm proprietor's employment is significantly lower; however, growth rates of median household income are marginally higher. Although this result is counterintuitive, recall that the treated and non-treated groups are matched based on their probabilities of reaching the broadband threshold – in this case, having very poor broadband availability. Counties with high likelihoods of having such poor levels of infrastructure likely have low population densities, and relatively low income and education levels. Changes to these levels over a 10-year period can be driven by any number of factors, including returns to those residents that *do* have access to broadband.

It is important to note that because the only difference between the treated and control group is meeting the broadband criterion, use of the ATE technique allows for statements about causality (Rubin, 2006). In general, then, the results of the propensity score specifications suggest that broadband does contribute to the economic health of non-metro counties, and that this contribution is associated mostly with high levels of broadband *adoption* (as opposed to levels of infrastructure). Similarly, low levels of broadband adoption can negatively impact non-metro counties, in the form of lower numbers of firms and employment. From a policy standpoint, this suggests a need to focus on increasing adoption rates in order to spur economic growth, and that simply improving levels of infrastructure availability will not necessarily achieve that goal.

5. Policy Options for Increasing Broadband-Related Development Opportunities

These varied and exhaustive results based on the best data available present striking confirmation of a persistent divide that disadvantages populations in rural locations. Over the past decade, the characteristics that have historically figured in predicting a digital divide – income, education, race and ethnicity, and age – interact with non-metro locations to produce environments increasingly lagging behind metropolitan locations. Macro-level assessments such as those offered by Susan Crawford (2012) or Tim Wu (2010) focus on large scale supply, investment and pricing behaviors attributed to unchecked corporate power, while counter arguments such as those from the Information Technology and Innovation Foundation (Bennett, Stewart, and Atkinson, 2013) offer what they call a more balanced assessment of U.S. broadband that basically endorses the private sector-led efforts that have brought us to the current situation. In all these cases however, both pessimistic and optimistic, the difficulties and circumstances of rural regions are given short shrift. With roughly 20 percent of the American population in rural regions, issues of equity and economic productivity are paramount. These results further suggest that broadband (even at the modest level of 200 kbps) is positively and causally associated with improved household income and employment, and that not all broadband is created equal: slower speeds are disincentives for adoption in the most recent years. Service availability and quality are factors in rural development.

Some policy options seem clear: to the extent that broadband capabilities are simply not present, the policies that can draw infrastructure to less economically robust regions lacking broadband must be supported. Our data do not comment on the results of the infrastructure investments associated with BTOP and BIP since they were under development from 2010 onward, but nevertheless it seems clear that the better data now available should be used to target the locations without services and infrastructure so that investment can do the most good. As a testament to this, the Government Accountability Office (2012) highlighted the need for better data to be able to fully evaluate the BTOP and BIP projects.[32]

The FCC's Connect America Fund appears to be committed to an approach that targets areas that lack availability. In moving from a definition of universal service that focused on telephone service to one predicated on broadband access, and access specifically in regions that are underserved, the FCC's policies are moving in the right direction.[33] The service speeds espoused by the FCC, four Mbps download and one Mbps upload, also are important: our results show that higher speeds are increasingly significant in predicting adoption. However, even these speeds may not be sufficient for institutional users.

[32] News outlets have highlighted the inefficiencies associated with several BTOP projects (Wyatt, 2013).
[33] We are aware that the specifics of the universal service funding formula are hotly disputed at this writing.

Even though availability logically is the *sine qua non* of any attempt to quantify the impacts associated with broadband, our results also emphasize the significance of adoption: simple availability does not necessarily mean that divides are remedied. Solving broadband availability represents one infrastructure-centric policy approach; tackling adoption entails different approaches. Our data suggest that the demand side of the broadband equation must receive attention. The results of the Oaxaca-Blinder analysis are especially striking: if non-metro households had the same characteristics as metro households (except for broadband availability), 54 percent of the broadband adoption gap would disappear. With comparable levels of broadband availability, 90 percent of the gap disappears. Hence broadband availability in rural regions is important, but so are parameters that may reflect the increasing importance of familiarity with broadband use and functionalities.

In terms of policy options that mobilize local providers and communities to map and become more aware of local telecommunications infrastructure, the comparisons presented in the analyses of two states in the Connected Nation program illustrate that even with an increase in numbers of providers – an outcome of the Connected Nation program – adoption may not (and did not in these data) necessarily increase. More generally, our results on the effect of increasing the number of broadband providers are inconsistent, possibly a reflection of inaccuracies that result when aggregating to the county level. Inasmuch as adopting (and using) broadband must be a focus of digital divide policy, our options must consider the means to encourage people to subscribe to broadband services once they are present. The FCC's attempt to experiment with the Lifeline programs through the Broadband Adoption Pilot Program, in which providers are expected to help address "other challenges" to broadband adoption such as the cost of devices and digital literacy, represents an interesting behavioral economics approach to this issue (FCC, 2012b). As well, the endeavors of municipalities and other groups to provide broadband services, particularly when local privately-owned options are deemed insufficient, should be carefully examined and supported when community needs warrant this option.

Efforts to increase the awareness of broadband advantages and uses should target rural populations with lower levels of income and education as well as racial and ethnic minorities, the population groups that continue to show up as non-adopters. Strong relationships related to age and broadband adoption were also present in many analyses, especially populations over 45 years of age. Policies might specifically target these groups for special attention to encourage adoption; arguably the interests and abilities of an older population may differ from those of a younger one. Some programs doing exactly this are now underway through BTOP's Sustainable Broadband Adoption program, as well as its Public Computer Center program (which often includes training efforts). Systematic evaluation of these efforts would help to calibrate policy endeavors (Hauge and Prieger, 2009). More fine grained analysis that recognizes the multidimensionality of adopters would benefit the sponsored efforts to encourage people to use Internet resources to their advantage.

Some results (notably the CPS logit model decomposition findings) support the conclusion that placed-based differences have become less important over time. When broadband simply is not a strong presence within one's community, the limited opportunity to see its utilities can depress peoples' interest in the technology and their ability to consider how it could be useful. Information campaigns invoking classic diffusion factors such as trialability, observability, compatibility, simplicity, and relative advantage accruing to broadband could be useful in enhancing the opportunities for people to encounter and understand broadband (LaRose et al., 2011). Programs specifically focusing on the economic development potentials of broadband applications in highly public ways – through town meetings, public demonstrations, and through mobilizing local community change agents – may contribute to improved adoption levels. In particular, use of community anchor sites for broadband during these programs may help encourage Internet use among historically low adopters, which may in turn lead to future adoption at the household level.

We are cautious about suggesting that increased use of mobile smartphones for broadband access "solves" the digital divide even though data show that more people are using these devices for that purpose. Many of the productivity gains and economic advantages of broadband access are more difficult to realize on the cellphone, even if that technology is highly valued for social, informational and recreational purposes. For example, it remains difficult to complete online job applications, or applications for services, using a cell phone. Our results hint that mobile phones may be pragmatic tradeoffs with wireline broadband within the rural population, possibly a reflection of financial constraints that limit the ability to pay both a mobile phone bill as well as a wireline Internet access bill. We report that cell phone access for broadband is growing, and also that the presence of additional wireless providers does not increase adoption of wired broadband access (FCC data). Additional research should seek to clarify the relationship between these two systems (wireless and wireline access) for rural populations. Current data illustrating the higher percentages in mobile smartphone-based Internet access among minorities and people in lower income groups (compared to White, non-Hispanic groups and households with incomes over $30,000) gives us pause (Pew, 2012). To the extent that cell phone access is not equivalent in capabilities to other types of access, policies espousing it as a substitute for wireline broadband should proceed cautiously.

Federal and state policies subsidizing equipment and services speak directly to the matter of broadband affordability. Our results demonstrate that over time the significance of Internet affordability diminishes, while the importance of "not being interested in" or "needing the Internet" increases as a proportion of people who remain nonsubscribers. Further, while the costs of end user equipment have decreased over time, the cost of broadband subscription appears to be relatively constant; Flamm and Chaudhuri (2007) found that demand for broadband is relatively inelastic, i.e., not especially sensitive to price. Additional data on affordability and the price of subscriptions in metro and non-metro regions would enhance our understanding of how these elements figure into adoption decisions. The role and costs of bundled services in particular would be helpful: positioning broadband alongside cable television service, for example, may alter the price-utility equation for would-be subscribers, even as it influences how policymakers should think about universal service subsidies. Hence, Lifeline and equivalent policies at the state level might reexamine what exactly is subsidized and whether their investments target the most meaningful aspects of the broadband subscription decision process. It might be the case that obtaining equipment is a trivial component of the decision, while access to training and expertise is more significant to users.

The development-related implications of our findings also prompt certain comments on the data themselves. First, the data are much better now than in earlier years: it is more granular, the collection methods are superior, and the abilities to mesh different types of datasets are improved. We note that the 2011 data from the National Broadband Map efforts are much improved over the first year's offering (satisfying many of Ford's critiques (2011)). Our work begins to explore the links between economic outcomes and broadband in ways that are more robust. That said, given our findings on the significance of download speeds, better data on service speeds would be useful, as would be the price data mentioned above. Some fine tuning of the measures on service quality would enable us to better understand the affordability trade-offs for consumers and businesses.

This research yields important findings on the effect of broadband on economic gains, namely on household income and employment levels. The ability to do matched county comparisons demonstrates the influence of adoption (as opposed to availability) in producing these positive outcomes, and constitutes another indication that development efforts should focus on mobilizing populations to subscribe to and use broadband capabilities. Again, cultivating local leadership, mobilizing the services of our cooperative extension educators nationwide, and working more closely with each State Broadband Initiative could be fruitful avenues for targeting adoption.[34] However, there are still some puzzles in the economic outcomes domain. We cannot explain why broadband is associated with out-migration, for example. We might speculate that this has to do with the idea that populations prone to moving may already be interested in the Internet and in examining opportunities and information from elsewhere – they are more "cosmopolitan" in diffusion terms. We also cannot explain entirely the counterintuitive findings with respect to creative class occupations and the negative relationship with broadband. Whereas most literature suggests there would be a strong association between the needs of creative class/information workers and broadband, our data show the opposite. We speculate that since this occupational category is rather broad, it may be that the specific occupations in rural regions are less dependent on Internet access. However, this is a topic for future research – perhaps occupational

[34] Under NTIA, the State Broadband Initiative launched in 2009 awarded funds to an entity in each state to undertake mapping, data gathering, and planning for broadband.

categories based on Science, Technology, Engineering, and Math (STEM) jobs might have a different result. Case studies on very high speed networks such as those in Chattanooga and Kansas City may also be warranted given that most (76%) of economic development professionals in a recent survey felt that speeds of 100 Mbps or greater were needed to effectively attract new businesses (Settles, 2012).

Finally, is high speed broadband enough to solve the problems of rural America? These results suggest that broadband may not be sufficient to entirely rescue depressed rural areas; regions with low income, extreme poverty, and high out-migration may not realize economic turnarounds when such infrastructure is introduced. However, *without* broadband such rural communities may suffer even more in simply not being able to keep up with regions that do offer high speed connectivity and the attendant gains in income and employment.

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