Broadband's Contribution to Economic Health in Rural Areas: A Causal Analysis and an Assessment of the 'Connected Nation' Program

Brian Whitacre
Oklahoma State University

Roberto Gallardo
Mississippi State University

Sharon Strover
University of Texas

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Abstract:

This paper uses the latest data on both broadband availability and adoption to empirically gauge the contribution of broadband to the economic health of rural areas. We utilize availability data from the National Broadband Map aggregated to county level, and county-level adoption data from Federal Communication Commission's Form 477. Economic health variables of interest include median household income, number of firms with paid employees, total employed, percentage in poverty, and the percentage of employees classified as either creative class or non-farm proprietors. A propensity score matching technique (between a "treated" group and a control group) is used to make causal statements regarding broadband and economic health. We measure whether the growth rates between 2001 and 2010 for different economic measures are statistically different for the treated and non-treated groups, restricting the analysis to non-metropolitan counties. Results suggest that high levels of broadband adoption in rural areas do causally (and positively) impact income growth between 2001 and 2010 as well as (negatively) influence unemployment growth. Similarly, low levels of broadband adoption in rural areas lead to declines in the number of firms and total employment numbers in the county. Broadband availability measures (as opposed to adoption) demonstrate only limited impact in the results.

We also use the FCC data to assess whether 'Connected Nation' participants in two states achieved higher increases in broadband providers or adoption rates when compared to similar counties that did not participate in the program. We find that the program has a dramatic influence on the number of residential broadband providers in non-metropolitan counties but no impact on increases in broadband adoption rates compared to otherwise similar non-participating counties. Consequently, there is no particular effect on economic growth.

Keywords: *Broadband, Rural, Average Treatment Effects, Economic Health*

JEL Classification: R11, O18

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Introduction

The diffusion of broadband Internet access across America during the 2000s brought with it a significant amount of concern that rural areas might be left behind in terms of the availability, adoption, and benefits of this technology (Malecki, 2003; Parker, 2000; Strover, 2001)[1]. The presence of a rural – urban broadband "digital divide" is well documented in the economic literature (Whitacre and Mills, 2007; Dickes, Lamie, and Whitacre, 2010; Strover, 2011). Several studies have suggested that broadband access positively impacts employment as well as other quality of life issues (health care, education, social linkages) in rural areas (Katz and Suter, 2009; LaRose et al., 2008; Stenberg et al., 2009); however, many analyses were based on hypothetical assumptions or case studies. 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.

State and federal policies related to broadband investment and deployment remain contested. As the funds flowing to additional advanced broadband infrastructure under the American Reinvestment and Recovery Act end and as the FCC initiates changes to universal service, questions regarding where American broadband infrastructure stands and how high speed capability contributes to economic development are receiving new attention. Better data from the NTIA/Census Current Population Supplements and the more detailed data that NTIA's

[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.

investments in statewide mapping efforts provide can be used to provide better responses to questions regarding broadband's contributions to economic health.

This study uses recent data from the National Broadband Map (NBM) and the Federal Communications Commission (FCC) to assess the causal relationship between broadband availability / adoption and measures of economic health, specifically focusing on rural areas. Propensity score matching techniques are used to match non-metropolitan counties with high / low levels of broadband availability and adoption as of 2010 with otherwise similar communities. The growth rates of a variety of economic development variables between 2001 and 2010 are then compared across groups.

Literature Review

Many recent studies in the economics literature have attempted to demonstrate broadband's influence on productivity or economic gains, although most have been focused on aggregate or urban economies. In one of the earliest (and most widely cited) studies, Lehr et al. (2005) concluded that relative to communities without broadband, communities with consumer broadband between 1998 and 2002 experienced larger levels of growth in employment, numbers of businesses, and businesses in IT-intensive sectors. Gillett et al. (2006) similarly demonstrated a positive relationship between broadband availability and employment / business growth – especially growth in IT-related businesses. They did not, however, find any relationship with wage levels. Each of these studies noted that the data available at that time were primarily supply-side, and that better data on demand (i.e. adoption) were sorely needed.

The organization Connected Nation (2012) reports the results of several surveys on business uses of broadband, concluding that improved infrastructure contributes to economic outcomes such as more retail sales and additional job opportunities associated with building wireless (and wireline) networks. As a supply-side organization that facilitates infrastructure development and statewide broadband mapping – and consequently has access to important data - Connected Nation's analyses could make crucial contributions to our understanding of broadband's outcomes. However, their 2012 business analysis is based on self reported data from 7004 firms and lacks the controls and design features that allow causal determinations; they also do not focus on rural regions.[2] Nevertheless, this organization's advocacy has been a loud voice in the discourse around how broadband serves rural regions.

Several current studies have attempted to rigorously assess the causal relationship between broadband and economic development. Koutroumpis (2009) incorporates a simultaneous equations model to disentangle the relationship between broadband infrastructure and GDP (country-level) growth. Using data from 22 OECD countries over the period from 2002-2007, Koutroumpis found a significant causal positive link between broadband infrastructure and growth. This link became stronger as thresholds for broadband penetration increased. However, OECD data are notoriously weak, and country-level relationships are prone to measurement problems. Kolko (2012) focused instead on broadband's causal relationship with *local* economic growth, including its effect on employment and wage levels. Recognizing that broadband could have heterogeneous impacts on employment (due to the degree an industry is reliant on information technology), Kolko meshes FCC broadband provider data with North American Industrial Classification System (NAICS) employment data at the zip-code tabulation area level from 1999 through 2006. Nearly all industries demonstrated a positive relationship between increasing broadband providers and employment growth over this time; the strongest

[2] Connected Nation has received both federal and state funds for infrastructure planning activities and statewide mapping. The non-profit Public Knowledge (2009) has written that Connected Nation's status as an advocacy organization jeopardizes its ability to contribute impartial and complete data and analyses.

relationships were found in IT-intensive industries such as information and finance. However, this study found no evidence that areas with faster broadband expansion had higher household incomes or better employment *rates*. Similarly, Jayakar and Park (2013) found no evidence that broadband deployment significantly impacted changes in unemployment rates between 2008 and 2011. None of the Lehr et al., Gillett et al., Koutroumpis, Kolko, or Jayakar and Park studies focused explicitly on rural parts of the country.

The most thorough examination of broadband's role in rural America is likely Stenberg et al. (2009), who focused on broadband use by consumers, communities, and businesses. One finding, using FCC data, is particularly noteworthy. Comparing rural counties with relatively high levels of broadband by the year 2000 with otherwise similar rural counties, they found that the counties with early access to broadband had higher levels of growth in wage and salary jobs, non-farm proprietors, and private earnings between 2002 and 2006. They were careful to caution, however, that their research does not necessarily imply causality. Stenberg et al. also summarized ways that rural communities and businesses can potentially benefit from broadband, including research on distance education, telehealth, and telework. Kuttner (2012) concurs with the notion that broadband is important for rural areas, but focuses instead on attempting to quantify the opportunity costs of *not* having broadband in these communities by using hypothetical examples. Similarly, Whitacre (2011) demonstrates the economic importance of telemedicine in rural areas (which requires broadband), but his analysis is based on simple case studies. However, while most of the literature suggests that broadband is important for sustaining and improving rural economies, some work has questioned its relative value. In particular, Galloway (2007) implies that rural businesses do not tend to seek growth opportunities, which is more important for job growth than broadband availability.

In general, the studies related to broadband and *rural* economic development are limited. Most analysis related to broadband and economic outcomes are focused on aggregate or urban measures, with investigations specific to rural typically being more anecdotal or hypothetical. This paper seeks to address this shortfall and provide empirical evidence of a causal relationship between broadband availability / adoption and economic growth in rural areas.

Data

This paper meshes recent broadband *availability* data with recent *adoption* data. The specific data sources used are 2010 versions of:

- FCC County-level broadband adoption data (county-level broadband adoption rates)
- National Broadband Map infrastructure availability data (aggregated to county level)

Each of these sources is detailed below.

FCC County level data (Form 477)

Since 2008, the FCC has provided categorical data on county-level household broadband adoption rates, along with measures of the number of broadband providers for residential fixed (wired) connections. 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.[3] 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

[3] We recognize the difference between rural / urban (defined at the community level) and metro / non-metro (defined at the county level). Our data is county-oriented, so we generally speak in terms of metro / micro / non-core; however we still use the term "rural" to connote a lack of population density.

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 3,073 counties in each year of the FCC data, of which 2,037 are non-metropolitan (671 micropolitan and 1,366 non-core).[4] 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 a faster definition of 768kbps download, 200kbps upload.[5] The spatial nature of the data allows for informative maps to be drawn.

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. Although the FCC does provide data on the number of residential fixed providers, for confidentiality reasons counties with between 1 and 3 providers all have the same designation. Since the National Broadband Map data discussed below do not have this limitation, we defer to their provider counts. We use adoption data from 2010 to model broadband's impacts on economic growth measures that can be captured at the county level.

National Broadband Map (NBM) Data

[4] We mesh Virginia independent cities with the counties where they reside.
[5] 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.

Fall 2010 data[6] from the National Broadband Map were utilized to obtain average values for the maximum advertised download/upload speeds and unique number of providers at the county level. The NBM is an online database that allows users to access broadband availability at the neighborhood (census block) level. 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, that a census block is considered served if even one customer in that area has access to broadband, and the manner in which empty census blocks are handled (Grubesic, 2012). These caveats 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[7] 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 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.

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

[7] 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, 2012, P. 56)

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, 2012).[8]

Demographic and Economic Data

This paper seeks to answer whether broadband availability and / or adoption contribute to (and in particular, cause) economic health outcomes 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. We also include a wide array of demographic data that may be related to broadband adoption such as age category, race, natural

[8] 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, 2012, P. 25-26)

amenity ranking, and county dependencies such as farming or manufacturing. These data come mostly from the Census and the Bureau of Economic Analysis.

Maps and Descriptive Statistics

Figure 1 displays the 2010 FCC adoption data from a geographic perspective. Several states exhibit low levels of 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 also near Denver in Colorado. Interestingly, most states have pockets of counties with high levels of adoption, and 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 2010 for counties with the lowest adoption levels is 11,760 (compared to the national average of 25,020 for all non-metro counties). Similarly, the average median household income level in these counties is $34,500 compared to $39,500 for all non-metro counties.

[Figure 1 about here]

Figure 2 displays the NBM availability data related to the number of unique fixed residential providers per county. Again, some states demonstrate relatively low numbers of providers (West Virginia, Kentucky, North and South Dakota, Wyoming) while others generally have high numbers (Ohio, Indiana, California, Michigan). Overall, there is not an overly strong correlation between household adoption rates and the number of residential providers (correlation coefficient = 0.308) and the relationship is even weaker for non-metropolitan counties (0.17).

[Figure 2 about here]

We also look at the percentage of the population in each county without access to broadband capability, and how these trends differ by metro / micro / noncore status (Figure 3). Here, broadband is defined as 3 Mbps download speed and 768 kbps upload, a higher threshold than used in the previous maps. As expected, most metropolitan counties have high levels of broadband availability (only about 3% of the metropolitan population lacks it), while the non-core areas have the worst (26% of the non-core population lacks availability). There are large pockets of micro and non-core counties with very poor levels of broadband availability in several states, notably the mountainous terrain of West Virginia and portions of many Midwest states.

[Figure 3 about here]

As another way of looking at this data, Figure 4 displays the spectrum of broadband availability categories across metro, micro, and non-core counties. This figure shows that there are wide discrepancies in broadband availability across these designations. While more than 40% of metropolitan counties have the highest level of availability (with less than 2% of the population lacking access), only 5% of non-core counties are in this category. And perhaps more strikingly, nearly 30% of all non-core counties have more than 40% of their population lacking access to wired broadband infrastructure.

[Figure 4 about here]

In order to assess the relationship between broadband and economic health, we develop several thresholds related to broadband adoption and availability. Our hypothesis is that high or low levels of broadband adoption / availability may promote or deter economic activity within the county. In particular, we define high and low thresholds for: (1) broadband adoption, (2) broadband availability (% of population with access), (3) number of broadband providers, (4) average advertised download speed. Table 1 below summarizes these thresholds and demonstrates the percentage of non-metropolitan counties that can be placed in each. 23% of non-metro counties achieve the "high-adoption" threshold (household adoption rates of over 60%), while 27.8% are classified as "low-adopting" (household rates of less than 40%). In terms of availability, 41% of non-metro counties have more than 85% of their population with broadband available to them, and are classified as "high-availability." 14.5% have more than 50% of their population without access to wired broadband, and are classified as "low-availability." Similar cutoff points are applied to the number of residential broadband providers (high threshold: 5) and average advertised download speeds (high threshold: 10 Mbps).

[Table 1 about here]

As a preliminary way of investigating how achieving these thresholds has affected economic prosperity, Table 2 summarizes how the percentage change between 2001 and 2010 in 8 economic measures has varied across the high and low categories. These statistics demonstrate that while higher levels of economic improvement are often found in counties meeting the "high" broadband thresholds, this is not always the case. For example, non-metro counties meeting the high threshold for broadband adoption experienced higher growth in median household income levels, number of firms, and total employment when compared to non-metro counties that did not meet either the high or low threshold. However, these same counties also experienced lower growth rates in the percentage of non-farm proprietors. Similarly, under the broadband availability category, non-metro counties with high levels of availability experienced more growth in the percentage of employees in the creative class and in the overall number of firms. However, they also had lower growth rates in median household income levels and the percentage of non-farm proprietors, and had higher growth rates of poverty and unemployment. Comparable trends can be found with the high threshold for the number of residential providers (higher growth in the creative class, but lower levels of income and higher rates of poverty / unemployment). Non-metro counties with high levels of average advertised download speeds demonstrate mostly positive comparisons, with higher levels of creative class employees, lower losses in the number of total employees, and lower increases in poverty rates. Similar stories can be told regarding the "low" broadband thresholds: low adoption is associated with lower growth in the number of firms and the number employed, but higher rates of non-farm proprietors. Counties with lower levels of broadband availability surprisingly demonstrate higher growth in income levels and the number of firms, but also show higher growth in poverty.

[Table 2 about here]

The statistics provided in Table 2 represent a first step in assessing whether achieving specific broadband thresholds might influence the economy of a non-metropolitan county. There is, however, a significant amount of self-selection occurring: counties with high levels of income or employment growth may see their broadband adoption rates rise. To begin discussing causal relationships, however, more rigorous statistical techniques are required. The following section discusses the use of a propensity score matching technique, which, along with the FCC and National Broadband Map data, is used to assess the impact of various broadband thresholds on the eight economic indicators discussed above.

Propensity Score Matching (Average Treatment Effects)

The technique implemented to estimate broadband's causal 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). The previously defined thresholds 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 (>10 Mbps) 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 (or more precisely, the ATE on the Treated or ATET) is written as

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

where BB_t equals 1 for areas that meet the broadband availability criteria (treated) and 0 for areas that do not (non-treated). The second term is this expression is non-observable: it is the expected value of the economic indicator for the treated group had they not achieved the broadband threshold of interest. Our modeling strategy seeks to produce a control group that is measurably similar to the treated group, but did not achieve the broadband threshold. Put another way, 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).[9] 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.

[9] 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.

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 that might influence adoption or availability. A wide array of literature has already assessed this topic; we draw from many of these studies to develop the socio-economic characteristics to be included in our propensity score model. These characteristics include income and education levels, age, race / ethnicity, and level of urbanization. (Whitacre and Mills, 2007; Hitt and Tambe 2007; Whitacre, 2010; Horrigan, 2007, 2009; Aron and Burnstein, 2003; Flamm and Chaudhuri 2007). The propensity score results are then used to match treated and non-treated counties by creating blocks of counties with similar propensity scores. That is, we are looking for groups of non-metro counties with similar likelihoods of achieving the broadband threshold as predicted by 2001 values of income, education, number of firms, levels of non-farm proprietors, and other variables (including growth rates during the 1990s). The primary difference between the two groups is that one actually achieved the threshold while the other did not. 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. As a robustness check, we also include kernel matching estimators. These estimators offer a solution in the case of potentially large discrepancies between neighbors by calculating the distance between a treatment case and various control cases, and giving higher weight to the control cases that are closer.

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).[10] 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; age group composition, race / ethnicity, and percent of the population residing in an urban area.[11] In some models, growth rates over the 1990s for specific variables (population, income, percent with bachelor's degree) are also included to control for historical trends in those variables. 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.

In an ideal situation, we would have data available post-control period (i.e. after 2010) so that we could assess the impact of meeting the broadband threshold in 2010. However, our broadband availability data are limited (2010 is the only time we have specific measures such as the percentage with no access) and as such we are limited to assessing growth over the 2001 – 2010 time period, based on meeting a threshold in 2010. This is not ideal; however, the

[10] 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).

[11] The final specification for each propensity score logit model will vary based on whether or not the covariates selected satisfy the balancing property developed by Becker and Ichino (2002).

implication is that movement towards these thresholds began to occur after 2001 and before 2010. Our modeling approach, then, looks at the likelihood of obtaining a threshold based on 2001 demographics (including accounting for growth rates during the 1990s) and then suggests that growth rates between 2001 and 2010 may be influenced by the progress made towards those thresholds. Some non-metro counties achieved the threshold (and are placed in the treatment group); others with similar 2001 characteristics did not (and are placed in the control group). The ATET methodology allows for a comparison between the groups.

Results

The results of the propensity score matching / ATET technique are displayed in Table 3 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. The results displayed are those for the nearest neighbor matching method; however all significant outcomes were verified with the kernel matching technique. All outcomes reported in Table 3 demonstrated significant results under both methods.

[Insert Table 3 about here]

The results suggest that, generally, broadband *adoption, availability,* and *download speed* do have meaningful impacts on growth rates of economic health measures in non-metropolitan counties. 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 unemployment when compared with otherwise similar counties that did not meet this threshold. Alternatively, low levels of broadband adoption (<40%) imply detrimental impacts for rural businesses, with low-adoption counties having firm and employment growth rates approximately 3 percentage points lower when compared to their matched counterparts. The logit models underlying these two results had relatively high goodness of fit measures, with pseudo R^2 values of around 0.25.

Broadband *availability* thresholds also demonstrate some (potentially causal) relationships with economic health, although the results are somewhat counterintuitive. Non-metro counties with high levels of broadband availability (>85%) had growth rates of non-farm proprietors income that were over 5 percentage points *lower* than comparable counties with lower levels of availability. This suggests that high levels of availability are actually causing non-farm proprietor income to decline – perhaps suggesting that non-farm proprietors in these areas are not taking advantage of higher levels of availability. If residents have high levels of availability, they may expect most businesses they deal with (including the self-employed) to offer online payment options or have a viable web presence. Entrepreneurs who do not offer these elements might find their incomes declining. Table 4 also demonstrates that non-metro counties with low levels of broadband availability (<50%) had growth rates of median household income that were marginally higher than otherwise similar counties. 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 median household income over a 10-year period can be driven by any number of factors, including returns to those residents that *do* have access to (and productively use) broadband.

In terms of broadband *download speeds*, attaining a high threshold (> 10 Mpbs) appears to be causally linked to higher increases in the percentage of employees classified as creative class workers. Although the difference between treated and control groups was less than 1 percentage point in this case, many rural communities are actively seeking to attract creative class workers, and these results indicate that having high download speeds available plays a role. Poverty levels were also roughly 2.6 percentage points lower in non-metro counties with high download speeds compared to otherwise similar counties, suggesting that broadband speed can be an important contributor to general community well-being. Finally, having only low levels of average download speeds (< 3Mbps) is associated with marginally higher growth rates in median household income. This counterintuitive result may suggest that many productive uses of broadband can still be accomplished at lower speeds. Note, however, that the fit of these models is significantly lower than previous efforts (pseudo R^2 of only 0.04 to 0.07). Finally, having a high or low number of broadband providers does not provide any significant results for the economic health measures in question.

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; Dehejia and Wahba, 2002). 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 meaningful relationships are found for broadband adoption, availability, and download speeds. In particular, high levels of broadband *adoption* are causally linked to increases in median household income and lower unemployment growth; low levels of broadband adoption negatively impact non-metro counties in the form of lower numbers of firms and employment. The relationships with *availability* and *download speeds* are less intuitive –

the impacts of achieving some “high” or “low” thresholds are not always in the hypothesized direction. 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.

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 of this analysis.

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 availability of 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 4 below. The two measures of interest are the percent of counties that demonstrated an increase in the broadband adoption category between 2008 and 2011, and the percent that demonstrated an increase in the number of residential broadband providers over that time.

[Insert Table 4 about here]

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 a review of the relevant literature (Horrigan, 2009; Hitt and Tambe, 2007; Whitacre, 2010). 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). 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, and has been shown to reduce bias in random samples (Rubin, 1980). Further, the Mahalanobis distance has been shown to work quite well when there are relatively few (less than 8) covariates (Zhao, 2004).

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 relevant literature on this topic: population sizes, education 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. Table 5 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.

[Insert Table 5 about here]

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, this difference is statistically significant, with non-participating counties that have characteristics similar to CN participants being less likely to increase adoption categories. The negative result is also seen in micropolitan counties. In non-core counties, similar adoption increases are observed 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 very rural areas. However, in terms of broadband adoption, Connected Nation does not seem to be having the desired impact, at least in the 2 states that comprise this analysis.

Conclusion and Policy Implications

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, specifically in non-metro counties, 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 cooperative extension educators nationwide, and working more closely with each State Broadband Initiative could be fruitful avenues for targeting adoption.[12] Our matching results do produce some puzzling results, including a positive relationship between low levels of both availability / download speeds and median household income growth. We can hypothesize that median income can grow on the basis of those that do have access to at least some level of broadband, but these results still warrant further investigation. A particularly interesting result is that achieving high levels of download speed in non-metropolitan counties does seem to have the desired result of attracting creative class workers and lowering poverty levels. This suggests that

[12] 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.

while promoting adoption should be the first and foremost goal, achieving higher levels of speed in rural areas is also a worthy policy premise. In the future, 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). The recent growth of fiber networks in rural portions of the country (many funded by the American Recovery and Reinvestment Act) will also provide an opportunity for studies related to economic growth.

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. 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. Hauge and Prieger (2010) provide an excellent overview of issues associated with encouraging broadband adoption, including the need for systematic evaluation of programs focused on demand. 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, 2012). 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.

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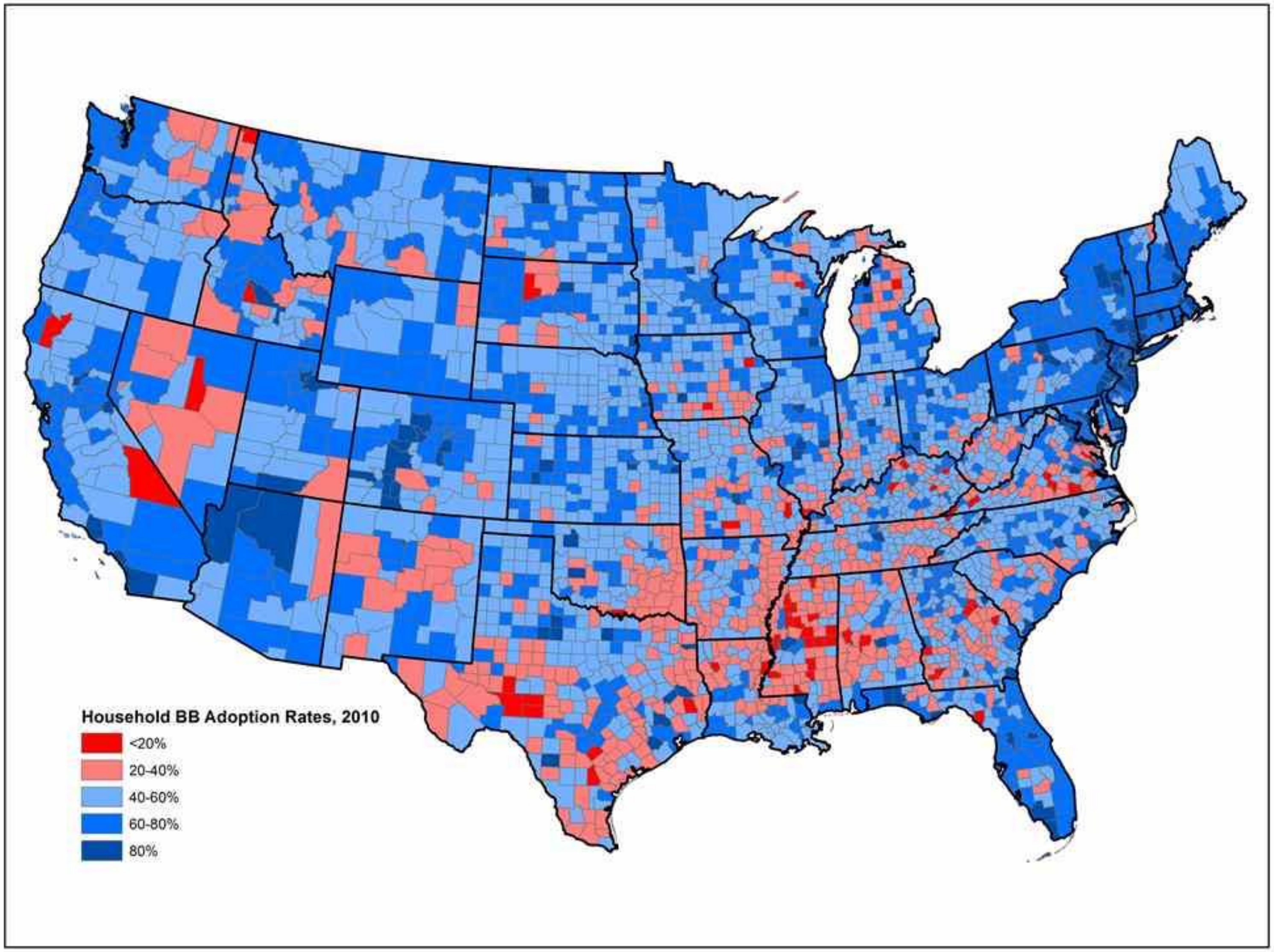
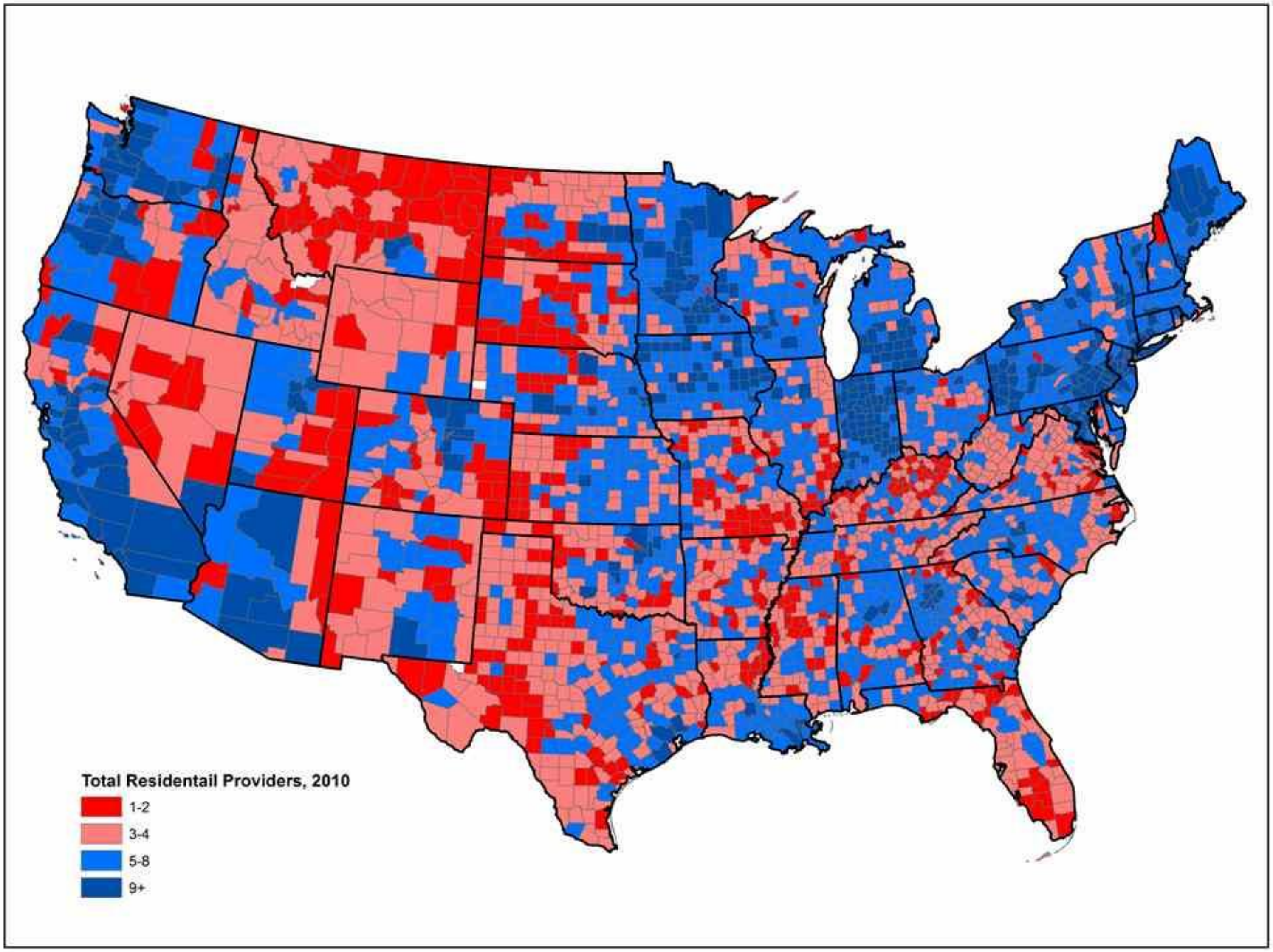
Figure 1. County-level Household Broadband Adoption Rates, 2010



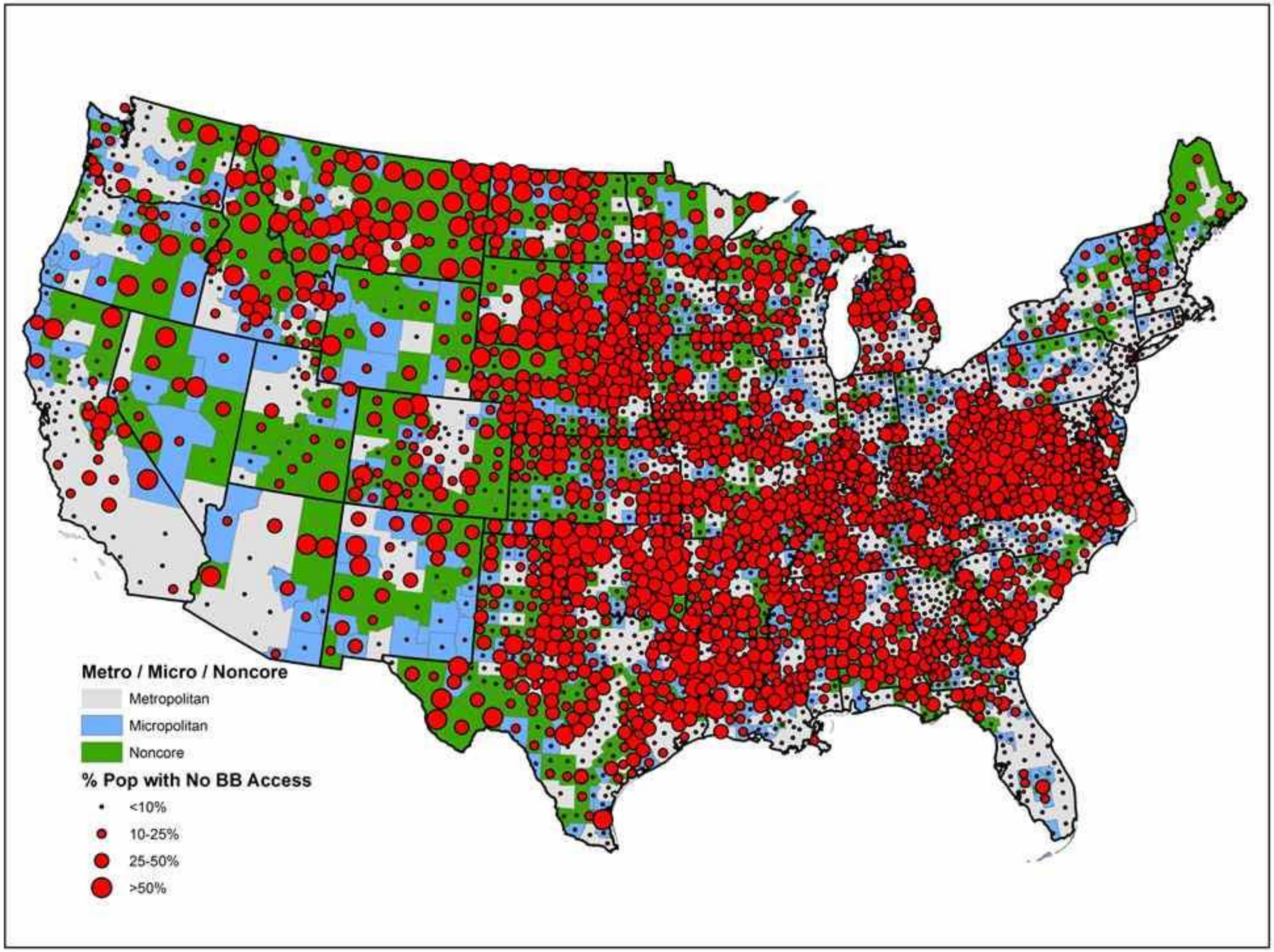
Source: FCC Form 477 Data, 2010

Figure 2. Number of Residential Broadband (Wired) Providers, 2010



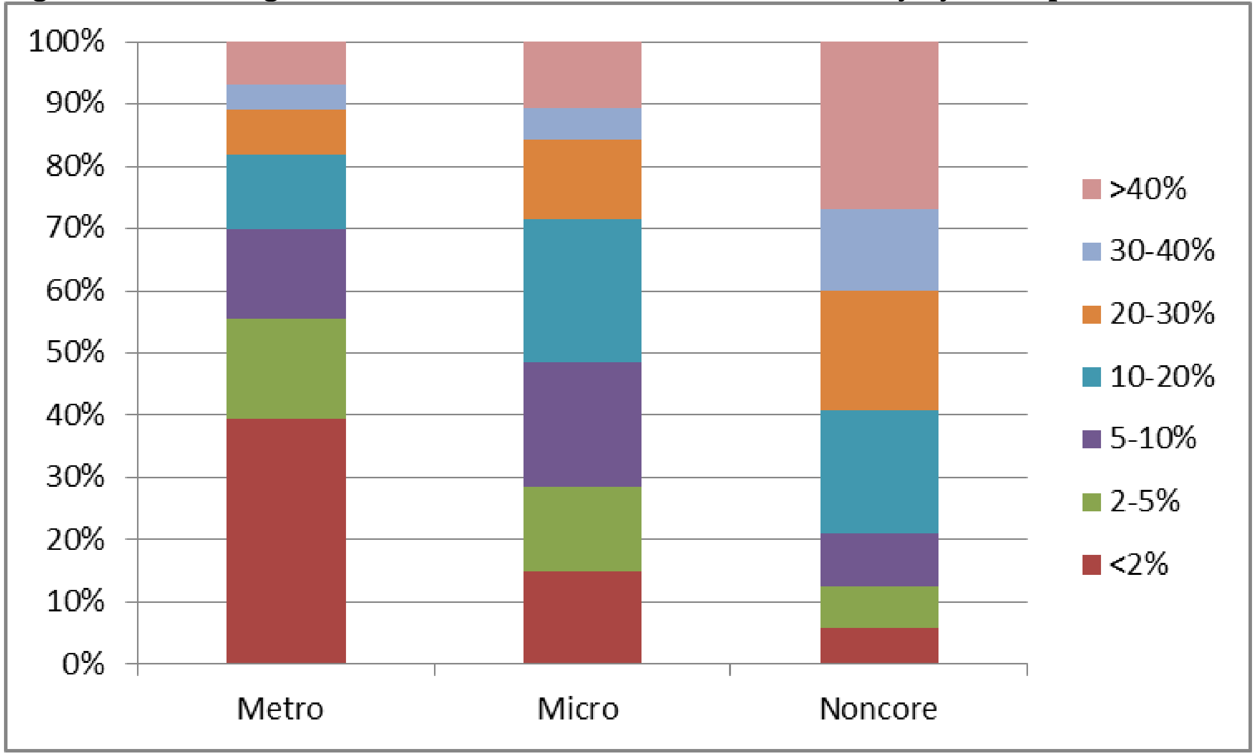
Source: NBM, 2010

Figure 3. Percent of Population with No Broadband Availability by Metropolitan Status, 2010



Source: NBM, 2010

Figure 4. Percentage of Residents with No Broadband Availability by Metropolitan Status, 2010



Source: NBM Data, 2010

Table 1. Broadband Threshold Definitions and Percentage of Non-metro Counties in Each

Threshold	Non-metro average	% of Non-metro Counties in category
Broadband Adoption Category (1-5 category)	2.95	
High (Category 4,5: >60% adoption)		0.230
Low (Category 1,2: <40% adoption)		0.278
Broadband Availablity (% with access)	0.739	
High (>85% with access)		0.410
Low (<50% with access)		0.145
Number of Residential Broadband Providers	4.30	
High (5+)		0.402
Low (1-2)		0.223
Average Advertised Download Speed (1-11 Category)	5.72	
High (Category 7+: >10 Mbps)		0.376
Low (Categories 2 - 5: <3 Mbps)		0.310

Table 2. Summary Statistics on Changes in Economic Growth (2001-2010) across Broadband Threshold Categories

Non-metropolitan Categories	High		Neither	Low	
Broadband Adoption	(>60%)			(<40%)	
%Δ Median HH Income	0.231	*	0.221	0.226	
%Δ Non-farm proprietors	0.207	**	0.234	0.300	***
%Δ Non-farm proprietor income	-0.090		-0.069	-0.066	
%Δ Creative Class	0.041		0.040	0.035	
%Δ Number firms	0.027	***	-0.013	-0.036	**
%Δ Total Employed	-0.001	***	-0.048	-0.081	**
%Δ Poverty	0.221		0.216	0.176	***
%Δ Unemployment rate	0.763		0.784	0.772	
Broadband Availability (% of Pop with access)	(>85%)			(<50%)	
%Δ Median HH Income	0.209	***	0.226	0.264	***
%Δ Non-farm proprietors	0.231	***	0.262	0.244	
%Δ Non-farm proprietor income	-0.089	*	-0.056	-0.080	
%Δ Creative Class	0.048	***	0.036	0.015	***
%Δ Number firms	0.002	**	-0.026	0.001	**
%Δ Total Employed	-0.040		-0.052	-0.047	
%Δ Poverty	0.256	***	0.125	0.185	***
%Δ Unemployment rate	0.855	***	0.746	0.641	***
Number of Residential Providers	(5+)			(1-2)	
%Δ Median HH Income	0.202	***	0.231	0.254	***
%Δ Non-farm proprietors	0.221	***	0.254	0.280	**
%Δ Non-farm proprietor income	-0.050		-0.057	-0.142	***
%Δ Creative Class	0.050	***	0.037	0.016	***
%Δ Number firms	-0.016		-0.002	-0.015	
%Δ Total Employed	-0.056		-0.041	-0.038	
%Δ Poverty	0.284	***	0.172	0.121	***
%Δ Unemployment rate	0.853	***	0.759	0.666	***
Average Advertised Download Speed	(>10Mbps)			(<3Mbps)	
%Δ Median HH Income	0.219		0.212	0.244	***
%Δ Non-farm proprietors	0.243		0.237	0.260	**
%Δ Non-farm proprietor income	-0.075		-0.079	-0.065	
%Δ Creative Class	0.052	**	0.041	0.018	***
%Δ Number firms	-0.012		-0.001	-0.017	
%Δ Total Employed	-0.037	*	-0.061	-0.043	
%Δ Poverty	0.202	***	0.244	0.171	***
%Δ Unemployment rate	0.814		0.794	0.711	***

*, **, and *** indicate differences from the "Neither" category at p = 0.01, 0.05, and 0.10, respectively

Table 3. Propensity Score Matching Results

Propensity Scores with Significant Results:		Treated	Control	Diff	T-stat		Psuedo R2
Adoption							
1	High levels of BB adoption in 2010 (>60%) - NM Only						0.254
(+)	%Δ MHHI (2001 - 2010)	0.234	0.221	0.013	1.84	*	
(-)	%Δ Unemp (2001 - 2010)	0.751	0.847	-0.096	-2.74	***	
2	Low levels of BB Adoption in 2010(<40%) - NM Only						0.244
(-)	%Δ Number Firms (2001 - 2010)	-0.033	-0.005	-0.028	-2.42	***	
(-)	%Δ Total Employment (2001 - 2010)	-0.078	-0.044	-0.034	-1.88	*	
Availability							
3	Hi Levels of 2010 BB availability (>85%) - NM Only						0.166
(-)	%Δ NFP Income (2001 - 2010)	-0.087	-0.034	-0.054	-2.33	**	
4	Low Levels of BB Availability (<50%) - NM Only						0.222
(+)	%Δ MHHI (2001 - 2010)	0.265	0.248	0.017	1.94	*	
Download Speed							
5	High Levels of 2010 Avg D/L Speeds (>10Mbps) - NM Only						0.041
(+)	%Δ Creative Class (2001 - 2010)	0.051	0.043	0.008	1.83	*	
(-)	%Δ Poverty (2001 - 2010)	0.201	0.227	-0.026	-2.41	***	
6	Low Levels of 2010 Avg D/L Speeds (<3Mbps) - NM Only						0.075
(+)	%Δ MHHI (2001 - 2010)	0.245	0.235	0.010	1.84	*	
Propensity Scores with no significant results:							
	Hi Levels of 2010 BB Providers (>=5)						0.229
	Low levels of 2010 BB Providers (<=2)						0.218

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

Table 4. Percentage of Counties Demonstrating Increases in Broadband Adoption Category and Number of Broadband Providers by Connected Nation Participation, 2008-2011

	All		Metro	Micro		Noncore
% Counties Demonstrating an 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
% Counties Demonstrating an 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		0.15
Difference	0.02		0.02	-0.01		0.11

* and ** represent statistically significant different means between participants and non-participants at the *p* = 0.10 and 0.05 levels, respectively

Table 5. Matched Counties: Percentage Increase in Broadband Adoption Category and Number of Broadband 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	
Non-CN Participants (Matched)	0.24		0.18		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 between participants and non-participants at the *p* = 0.10 and 0.05 levels, respectively