(2016) 46, 171–190

The Review of Regional Studies

The Official Journal of the Southern Regional Science Association

Does Broadband Matter for Rural Entrepreneurs and Creative Class Employees?*

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Abstract: Efforts to attract entrepreneurs and "creative class" workers have become important components of economic development strategies for rural communities. One commonly held perception is that broadband access is important for these types of employees; however, empirical research on the relationship between the two is generally lacking. This study uses county-level data from the continental U.S. to estimate spatial and first-differenced regression models on the association between broadband and measures of entrepreneurship/creative-class employees in rural areas. The results suggest that high levels of broadband adoption may in fact serve to *reduce* the numbers of entrepreneurs and creative class employees in rural America. These findings serve as a reminder that broadband is not a panacea for all issues of importance to rural communities and provide evidence that there may be negative implications associated with efforts to increase levels of rural broadband access and adoption.

Keywords: broadband, rural entrepreneurs, rural creative class, spatial error, first-differenced

JEL Codes: O33, R15, L26

1. INTRODUCTION

Broadband access[1] has long been hailed as a savior for rural communities. Its distance-negating nature led researchers to be optimistic about the new opportunities presented to many rural communities in terms of education, health, and work (Stenberg et al., 2009; Kuttner, 2012). In particular, policy-oriented research and Congressional testimony have emphasized the importance of broadband access for rural entrepreneurs and small businesses (Drabenstott, Novack, and Abraham, 2003; Greene, 2010). At the same time, there has been a significant push among rural economic developers to focus on attracting entrepreneurs and other "creative class" employees (Henderson, 2002; Klemz, 2013).[2] Indeed, innovation and "thinking creatively" have been shown to be driving forces for economic growth in both rural and urban contexts (McGranahan and Wojan, 2007a, 2007b; McGranahan, Wojan, and Lambert, 2010). Despite dramatic increases in broadband access and adoption across rural America (including over $7 billion invested as part of the American Reinvestment and Recovery Act), however, there has

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[1]According to the Federal Communications Commission (FCC), broadband is defined as data transmission with at least 25 megabits (mbps) download and 3 mbps upload speeds as of 2015. The definition has varied over time but generally reflects speeds significantly greater than those available via a dial-up modem (56 kilobits of data transfer per second (kbps)).

[2] USDA-ERS (2014) defines the creative class as those employed in 'creative' occupations, specifically occupations "developing, designing, or creating new applications, ideas, relationships, systems, or products, including artistic contributions."

ISSN 1553-0892, 0048-749X (online)

www.srsa.org/rrs

been surprisingly little empirical research on whether broadband is in fact associated with more entrepreneurship or creative-class jobs in relatively sparsely populated portions of the country.

As research cited above has argued, a case can be made that broadband is a necessity for many entrepreneurs and creative-class employees. In rural areas, then, high levels of broadband access (or adoption) could both attract entrepreneurs looking to relocate as well as induce current residents to consider starting a business venture. The alternative (and much less publicized) viewpoint is that broadband allows individuals to see other options that might be available to them—particularly employment/entrepreneurial opportunities in other locations. Under this view, the relationship between rural broadband and measures of entrepreneurship would be negative, as individuals use the technology either to help them relocate elsewhere (LaRose et al., 2008) or discontinue current entrepreneurial activities as other employment opportunities arise. The ultimate direction of this impact is an open question that has implications for future broadband and rural development policies.

This paper explores the relationship between broadband availability/adoption and entrepreneurship/creative-class employment in rural areas of the U.S. using county-level data from publicly available sources. The overall objective is to assess whether broadband availability/adoption has a meaningful relationship with these important categories of jobs in rural America and, if so, to demonstrate broadband's role both currently and over time. Employing both spatial and first-differenced regression models, we find evidence that high (or increasing) levels of broadband *adoption* in rural areas are associated with *lower* propensities of creative class employment. The results suggest that broadband may not be a panacea for creative jobs in rural areas of the country, and that high levels of broadband adoption in these areas may in fact be leading to losses among those likely to be employed in the creative class. Other results are more positive, with high levels of broadband *availability* in rural areas associated with *higher* entrepreneurial activity as of 2012.

2. BACKGROUND

Although the U.S. broadband grid is expanding, there are still many rural areas throughout the U.S. that continue to lack access to high-speed internet. In 2010, the Federal Communications Commission (FCC) estimated that seven million housing units had no available broadband connection. At the time broadband was defined as speeds exceeding 3 Mbps for downloads and 768 kbps for uploads. Using the new (2015) FCC threshold of a 25 Mbps download, roughly 45 percent of the rural population lacks broadband access, compared to only 6 percent of the urban population (FCC, 2015). This gap in digital communications technology, known as the "digital divide," has been, and continues to be, a problem for rural America (Dickes, Lamie, and Whitacre, 2010; NTIA, 2013). Most federal policies aimed at the rural-urban digital divide have historically focused on increasing broadband infrastructure in rural areas. Such efforts have included USDA Rural Utility Service broadband loan programs and over $7 billion in grants and loans as part of the American Reinvestment and Recovery Act (ARRA) legislation enacted in 2009 (Kruger, 2013). More recently, the Connect America Fund (CAF) was launched by the FCC and combined public and private investment in an attempt to expand broadband infrastructure in rural communities (FCC, 2014a; 2014b). Recent empirical evidence, however, has suggested that more effort should be made to increase broadband demand as opposed to focusing solely on supply (Hauge and Prieger, 2010; Whitacre, Strover, and Gallardo, 2015). At least two federal efforts have responded to this call: the FCC's Low-income

Broadband Pilot Program, which subsidizes access for low-income households, and the Obama Administration's recent "ConnectHome" initiative, which attempts to make the adoption of broadband more sustainable by collaborating with nonprofits for digital literacy training (White House Fact Sheet, 2015).

The focus on increasing broadband adoption rates is supported by recent studies that show rural areas with high levels of broadband adoption benefit in terms of economic growth. This is true both for jobs and income at a specific point in time (Whitacre, Gallardo, and Strover, 2014a) and in terms of income and employment levels over a longer term (Whitacre, Gallardo, and Strover, 2014b). Additionally, one study documented that nonmetropolitan counties with competitive broadband providers by the year 2000 experienced significant in-migration between 2000 and 2006 (Mahasuweerachai, Whitacre, and Shideler, 2010). Still, that study focused on very early providers of broadband, and the potential also exists for broadband to encourage rural out-migration over time by providing easy access to information on employment opportunities in other areas.

While broadband may be an important building block for the rural economy, other policies have also been discussed as ways to improve rural areas. These include attracting both creative-class workers and entrepreneurs to rural areas. McGranahan and Wojan (2007a) argued that specific rural areas (notably those with a reasonable level of services, and those with natural amenities) can benefit significantly from strategies to attract creative workers. Likewise, McGranahan, Wojan and Lambert (2010) argued that creative-class employees are part of a trifecta (along with outdoor amenities and entrepreneurial context) that is clearly associated with rural economic growth. Their research found that the share of creative-class employees is strongly associated with growth in new business establishments and overall employment in rural counties.

Similarly, encouraging and attracting entrepreneurs has been emphasized as a method of economic development for rural areas. Some studies have shown that the returns to self-employment have a notable impact on the larger economy (Deller and McConnon, 2009) and that the number of self-employed workers in rural areas has doubled since the 1970s (Goetz, 2008). Rupasingha and Goetz (2011) used county-level panel data to examine the relationship between self-employment and income growth, employment growth, and the change in poverty in both metro and nonmetropolitan counties. Using nonfarm proprietorships (NFP) as a proxy for self-employment/entrepreneurship, they find a significant, positive relationship between NFPs and new economic development opportunities. They also found a reduction in family poverty rates in counties with high levels of NFP's, especially in rural areas. Similarly, Fleming and Goetz (2011) found a robust, positive relationship between locally owned firms and growth of per capita income. Goetz et al. (2010) evaluated U.S. rural entrepreneurship policy and concluded that, while the benefits of promoting rural entrepreneurs may be high, the costs are high as well. To that end, several studies have questioned whether self-employment is in fact a desired outcome (Wong, Ho, and Autio, 2005; Acs, 2006; Mandelman and Montes-Rojas, 2009).

Other recent work has examined the link between broadband and the location of knowledge intensive firm clusters (Mack, Anselin, and Grubesic, 2011; Mack, 2014). Mack (2014) evaluated the relationship between the spatial distribution of broadband providers and the presence of knowledge intensive firm clusters in U.S. counties. Results of this study indicated that both broadband and knowledge clusters are located predominantly within core counties of large metropolitan areas (Mack, 2014). These findings have implications for rural communities, although the studies did not focus on these areas.

Very few studies to date have actively explored the role of broadband in encouraging entrepreneurship. Gallardo (2014) and Low (2004) emphasized that broadband access and the effective use of broadband applications may have on leveling the playing field between metropolitan and rural businesses. They noted that broadband can save money and increase productivity for the self-employed, thus fostering higher-value entrepreneurship. However, both of these studies only hypothesized this relationship; there is no accompanying empirical evidence that broadband attracts entrepreneurs to rural areas. One notable exception is Gallardo and Scammahorn (2012) who used a spatial regression model to find that the number of broadband providers in an area is positively associated with the presence of self-employed individuals, but only those defined as "non-innovative." Their analysis, however, was limited to three states and did not focus explicitly on rural areas.

Documenting a relationship between the provision/adoption of broadband and entrepreneurial activity in rural areas could beneficially inform policy and aid in the distribution and allocation of scarce taxpayer dollars. Many rural communities have invested in broadband with the hope of lowering unemployment or attracting entrepreneurs or those in creative industries. Some artists, who are classified as creative-class employees, prefer the amenities in rural areas over those in large cities, and broadband availability in those locations could potentially increase their sales (Markusen and Schrock, 2006). For example, areas in rural Minnesota emphasize coupling their abundant natural amenities with improvements in broadband infrastructure when trying to dampen the effect of rural "brain drain" and to attract creative-class employees and entrepreneurs (Klemz, 2013). However, empirical evidence regarding broadband's link with these measures is lacking.

3. DATA AND METHODS

The research reported here explores the relationship between entrepreneurs/creative-class workers and broadband availability/adoption in rural America. Two distinct methods are used: cross-sectional spatial models and first-differenced regressions. The data are at the county level, obtained from a variety of sources, and are gathered over at least two periods (to accommodate the first-differenced model). The data sources include the Bureau of Economic Analysis [percentage of nonfarm proprietors as a measure of entrepreneurship (Goetz and Rupasingha, 2010; Rupasingha and Goetz, 2011)], the Economic Research Service [percentage employed in the creative class as used by McGranahan and Wojan (2007a, b)], the National Broadband Map (broadband availability[3]), the Federal Communications Commission (broadband adoption[4]), and

[3] The NBM's "Analyze Table" measures the percentage of households having any access and no access to specific technologies. Here, broadband is defined as technologies that provide 768 kbps download and 200 kbps upload speeds. Separate measures are given for wired versus wireless connections. The NBM data have been criticized because they originate from providers, who have an incentive to overstate their service areas (Grubesic, 2012) and due to potential bias and inefficiencies in the data (Ford, 2011). Further, the method used to calculate availability in rural areas is especially problematic (Grubesic and Mack, 2015). Still, NBM data collection has been improved notably since their original release (GAO, 2009; FCC, 2012), and these data are quite superior to others used to measure broadband infrastructure nationwide.

[4] The FCC broadband adoption data is categorical: six categories (0-5) are defined based on the number of connections per 1,000 households: 0: zero; 1: zero$<x\leq$200; 2: 200 $< x \leq$400; 3: 400 $< x \leq$600; 4: 600 $< x \leq$800; 5: 800 $< x$. Broadband is defined as at least 200 kbps of data throughput in at least one direction, and only represents fixed (wireline) residential connections such as cable Internet, fiber, or Digital Subscriber Lines.

Table 1: Summary of Data Sources, 2012 Descriptive Statistics by Metro/Nonmetropolitan Counties

Type of Variable	Description	Source	Year	Overall	Metro	Non-metro	
DEPENDENT VARIABLES							
Creative Class	percent Employed in creative class	ERS	2000, 2007-11	0.18	0.22	0.16	***
Entrepreneurship	percent Nonfarm proprietors	BEA	2000, 2012	0.26	0.24	0.26	***
INDEPENDENT VARIABLES							
POP	Population	ERS	2000, 2011, 2012	98,232	224,894	23,427	***
MHI	Median Household Income	Census	2000, 2011, 2012	45,644	52,447	41,626	***
WHITE	percent White non-Hispanic	Census	2000, 2011, 2012	0.84	0.81	0.85	***
BLACK	percent Black non-Hispanic	Census	2000, 2011, 2012	0.08	0.10	0.07	***
HISP	percent Hispanic	Census	2000, 2011, 2012	0.08	0.09	0.08	**
ASIAN	percent Asian non-Hispanic	Census	2000, 2011, 2012	0.01	0.02	0.00	***
HSEDU	percent People w/ High School diploma	Census	2000, 2011, 2012	0.06	0.05	0.06	**
BACH	percent People w/ Bachelor's or higher	Census	2000, 2011, 2012	0.35	0.32	0.37	***
AGE_5_19	percent People ages 5-19 years	NBM	2000, 2011, 2012	0.19	0.24	0.17	***
AGE_20_34	percent People ages 20-34 years	NBM	2000, 2011, 2012	0.21	0.21	0.22	***
AGE_35_60	percent People ages 35-60 years	NBM	2000, 2011, 2012	0.19	0.20	0.19	***
AGE_60+	percent People ages 60 or more	NBM	2000, 2011, 2012	0.23	0.33	0.30	***
UR	Unemployment Rate	ERS	2000, 2011, 2012	0.08	0.22	0.24	***
PCTEMPAGRI	percent Employed in Agriculture	BEA	2000, 2011, 2012	0.07	0.03	0.09	***
PCTMANUF	percent Employed in Manufacturing	BEA	2000, 2011, 2012	0.12	0.12	0.12	*
NATAM	Natural Amenities Scale (1-7)	ERS	2004	3.49	3.58	3.44	***
AVAIL	percent Pop w/ wired technology avail	NBM	2011, 2012	0.87	0.93	0.84	***
ADOPT	# Connections per 1,000 HH (0-5)	FCC	2011, 2012	3.43	3.77	3.23	***
Number Observations				3,109	1,161	1,948	

*,**, and *** represent statistically different means at the p = 0.10, 0.05, and 0.01 levels, respectively

ERS: Economic Research Service, BEA: Bureau of Economic Analysis, NBM: National Broadband Map, FCC: Federal Communications Commission the U.S. Census (other demographic measures such as county population, race/ethnicity, and household income). Data are gathered for 2000, 2011, and 2012 to accommodate for first-differenced models and creative-class[5] measures that are only available when measured across the entire 2007-2011 period. The data are summarized in Table 1, including statistical tests for the differences in the means of metropolitan and nonmetropolitan counties.

The most recent statistics indicate that, while nonmetropolitan counties have fewer creative-class employees, they typically have more nonfarm proprietors. In terms of broadband access, nonmetropolitan counties have lower levels of both availability and the categorical adoption measure (as expected). The control variables include elements that the literature identifies as having an impact on entrepreneurial and creative-class employment. These include race/ethnicity, educational attainment, age, local unemployment rates, employment percentages in industries such as agriculture and manufacturing, and a natural amenity measure (McGranahan, Wojan, and Lambert 2010; Fleming and Goetz, 2011; Gallardo and Scammahorn, 2012). To help visualize the dependent variables, Figure 1 shows the nonmetropolitan counties that rank in the top quartile overall in terms of creative-class employment and in the percentage of nonfarm proprietors. Note that many nonmetropolitan counties are included in both categories.

3.1 Cross-sectional Spatial Models

Studies using traditional ordinary least squares (OLS) procedures with data that are inherently location-based are rife with spatial autocorrelation and spatial heterogeneity problems. These problems violate OLS assumptions and, thus, can lead to misinterpretations of the model parameters. Hence, one cannot trust tests of whether or not the parameters are statistically different from zero, let alone make assumptions of about the relative magnitude of the parameters themselves. Previous research has pointed out the need for the use of spatial econometric methods when examining the effect of broadband (Mack and Faggian, 2013; Dinterman and Renkow, 2014). Several of the variables used in this study (measures of creative class/entrepreneurship and broadband) are clearly spatial in nature (McGranahan and Wojan, 2010; Whitacre, Gallardo, and Strover, 2014b). Moreover, in relation to creative class and entrepreneurship, spatial heterogeneity (as opposed to spatial dependence) seems to be more appropriate. For example, the culture or "feel" of an area likely leads to pockets of innovation or entrepreneurship. This emphasis on spatial heterogeneity is a characteristic of the spatial error model, and can be contrasted with the idea of an active process, which is associated with the spatial lag model. Therefore, a spatial error model is used to determine the relationship between broadband availability/adoption and entrepreneurs/creative-class workers in rural America.[6]

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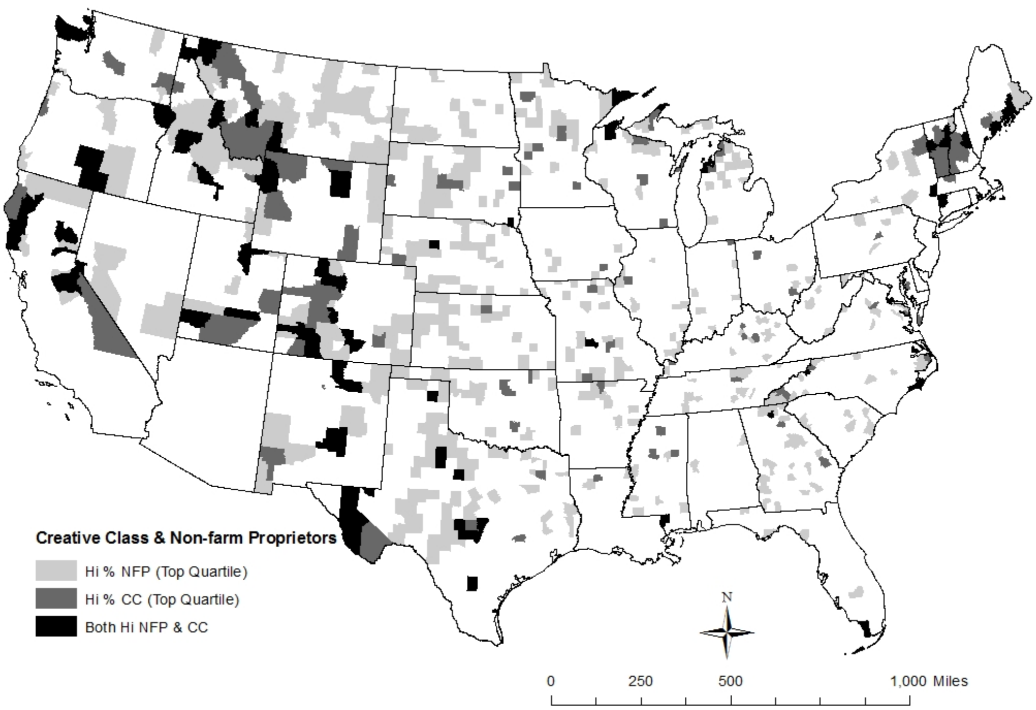
[5] We acknowledge some limitations to the creative-class data outlined by the ERS, including a difference in data collection from 2000 to the 2007-2011 pooled data. Significant aggregation issues exist, since the detail in occupational categories was greatly reduced over this period. Nonetheless, the ERS has attempted a "crosswalk" over time using unpublished Census data, and the measures used here represent the best available data on the topic. More information can be found on how the data was calculated at http://www.ers.usda.gov/data-products/creative-class-county-codes/documentation.aspx.

[6] The appropriate spatial specification (OLS, error, or lag model) is first tested via Lagrange Multiplier tests in GeoDa. Log-likelihood, Akaiki Information Criteria (AIC), and the Schwarz Criterion (SC) measures are also used to determine the most appropriate model (Anselin, 2004).

Figure 1: Non-Metropolitan Counties with High Levels of Creative Class Employees (2007-11) and Non-farm Proprietors (2012)



Source: ERS (Creative Class), BEA (Nonfarm Proprietors)

Formally, the spatial error model is specified as:

$$y_i = \mathbf{X}_i\boldsymbol{\beta} + \boldsymbol{\varepsilon}_i \tag{1}$$

$$\boldsymbol{\varepsilon}_i = \lambda\mathbf{W}\boldsymbol{\varepsilon}_i + \boldsymbol{\epsilon}_i$$

where $\boldsymbol{y}_i$ is the dependent variable of interest (measures of entrepreneurship or creative-class workers), $\mathbf{X}_i$ is a vector of demographic and socioeconomic variables (including measures of broadband availability/adoption), $\boldsymbol{\beta}$ is the associated parameter vector, $\boldsymbol{\varepsilon}_i$ is the error term that incorporates a spatial term, $\boldsymbol{\lambda}$ is a spatial parameter, $\mathbf{W}$ is a spatial weight matrix,[7] and $\boldsymbol{\epsilon}_i \sim N(0, \sigma_\epsilon)$ is the random error term, all for county i.

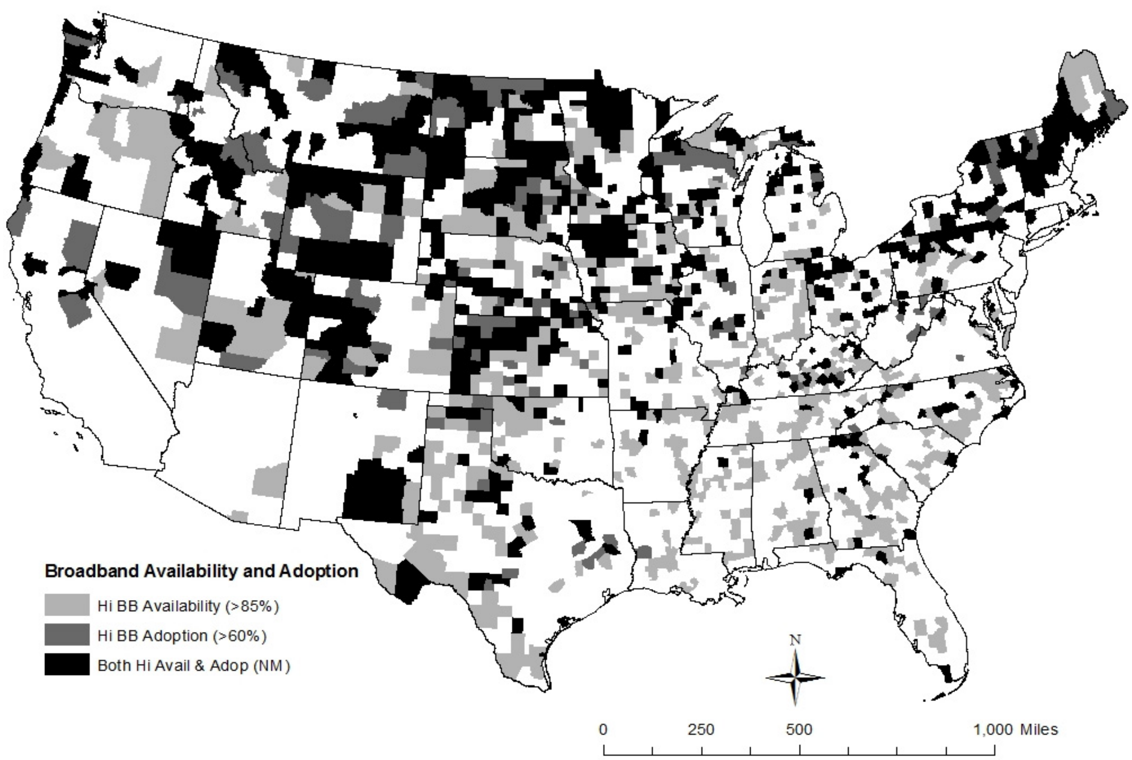
Since we are mainly interested in whether high levels of broadband availability/adoption are related to entrepreneurship or creative-class employment, we construct dummy variables for these high levels. High adoption ($HIADOPT_i$) is defined as residential broadband adoption rates of greater than 60 percent, and high availability ($HIAVAIL_i$) is defined as greater than 85 percent of households with wired broadband availability. These definitions of "high" were selected based on the overall broadband availability/adoption statistics for 2012 – essentially to allow for

[7] A queen contiguity weights matrix is used in the main analysis. A robustness check was done to compare the Moran's *I* (error) using the rook and queen matrices from spatial error models ran in GeoDa. The following Moran's *I* values of the residuals were obtained; for NFP: rook (-0.012916) and queen (-0.012847); for CC: rook (-0.005953) and queen (-0.006997). A value closer to zero indicates that the model controls for more spatial processes. Therefore, rook contiguity is best for NFP and queen for CC. But none of the values was statistically different from zero.

enough variation both between (in terms of number of observations) and within (in terms of other socioeconomic variables) the high and low categories.

To specifically determine the impact of *rural* broadband availability and adoption on creative class employment and entrepreneurship, interaction terms are created. Following the technique laid out by Mack and Faggian (2013) and used in a rural context by Whitacre, Gallardo, and Strover (2014b), the broadband variables are interacted with a nonmetropolitan dummy variable. This creates a $NMHIADOPT_i$ dummy variable along with a $NMHIAVAIL_i$ dummy. The coefficient associated with these interaction terms is designed to reveal the impact that *nonmetropolitan* levels of broadband have on the economic variables of interest (essentially acting as a shift on the stand-alone (urban) broadband measure). A map of the nonmetropolitan counties fitting these definitions is provided in Figure 2. The figure shows that while some nonmetropolitan counties are classified as both high adoption and high availability, the correlation is not great (as documented below).

Figure 2: Nonmetropolitan Counties with High Levels of Broadband Availability and Adoption (2012)



Source: FCC (Adoption), National Broadband Map (Availability)

As Table 2 displays, 68 percent of all counties were classified as being high-availability under this definition in 2012, and 38 percent were classified as being high-adoption. For nonmetropolitan counties, the numbers were 58 percent and 34 percent, respectively. Interestingly, the correlation between high adoption counties and high availability counties is not large (correlation coefficient of .41) and is only slightly bigger for non-metropolitan counties (correlation coefficient of .47). Thus, both types of variables can be used in a single model without significant multicollinearity concerns.

To test if a positive relationship exists between wired broadband adoption/availability and measures of entrepreneurship/creative class employment in rural America, the primary model in (1) can be extended as:

$$(2)\quad \boldsymbol{y_i = \beta_0 + \beta_1 \mathbf{HIADOPT_i} + \beta_2 \mathbf{NMHIADOPT_i} + \beta_3 \mathbf{HIAVAIL_i} + \beta_4 \mathbf{NMIAVAIL_i} + \beta_5 \mathbf{X}_i + \varepsilon_i}$$

$$\boldsymbol{\varepsilon_i = \lambda \mathbf{W} \varepsilon_i + \epsilon_i}$$

Table 2: Broadband Adoption/Availability Summary Statistics

Name	Description	2011 Mean	2012 Mean	Observations	Source
HiAvail	=1 if ≥ 85 percent of county population has access to at least one wireline provider	0.66	0.68	3,109	NBM
NMHiAvail	=1 ≥ 85 percent of county population has access to at least one wireline provider if AND county is non-metro	0.57	0.58	1,948	NBM
HiAdopt	=1 if household wired adoption is ≥ 60 percent	0.38	0.46	3,109	FCC
NMHiAdopt	=1 if household wired adoption is ≥ 60 percent AND county is nonmetropolitan	0.25	0.34	1,948	FCC

NBM: National Broadband Map, FCC: Federal Communications Commission

Here, y_i is the employment measure of interest, $HIADOPT_i$ is the overall broadband adoption dummy variable, $NMHIADOPT_i$ is the nonmetropolitan broadband adoption interaction term, $HIAVAIL_i$ and $NMHIAVAIL_i$ are similar measures for broadband availability, and X_i includes various other socio-economic controls. A positive and statistically significant β_2 suggests that high broadband *adoption* levels are associated with larger shares of creative-class employees or entrepreneurs in rural areas and that this relationship is different than that in urban areas. Similarly, a statistically significant β_4 implies that a high level of broadband *availability* in rural areas meaningfully influences the employment measure being scrutinized. Comparing the statistical significance and magnitudes of β_2 and β_4 will shed light on whether broadband availability or adoption drives the results for the specific types of employment in nonmetropolitan counties.

3.2 First-differenced Regression

Another technique that can be used to evaluate the relationship between broadband availability/adoption and measures of creative-class employment and entrepreneurship is first-differenced regression. This technique focuses on the impact of *changing* levels of broadband availability/adoption on shifts in the percentage of creative-class employees or nonfarm proprietors over the same time frame (Whitacre, Gallardo, and Strover, 2014b). As such, they address a critique of the cross-sectional models, i.e., that the relationships only hold for a specific point in time. The first-differenced specifications use changes between 2000 and the latest data available (2011 for creative-class employment, 2012 for nonfarm proprietors) as the dependent variables of interest. The right-hand side (explanatory) variables include the changes in all relevant socioeconomic variables between 2000 and the appropriate ending year. Because broadband access was not widely available in 2000, this analysis assumes it was negligible, and zero will be used both for broadband availability and adoption in this year (Pew Research Center 2015).[8] The primary model can be written as:

$$(3) \qquad \Delta \boldsymbol{Y_i} = \boldsymbol{\beta_0} + \boldsymbol{\beta_1}\Delta \mathbf{X}_i + \boldsymbol{\beta_2}\Delta \mathbf{BBADOPT_i} + \boldsymbol{\beta_3}\Delta \mathbf{BBAVAIL_i} + \boldsymbol{\varepsilon_i}$$

where ΔY_i is the change in the percent employed (either in creative-class jobs or nonfarm proprietors) in county i, ΔX_i is a vector of changes to other county-level characteristics such as population, education, and age groupings, $\Delta BBADOPT_i$ and $\Delta BBAVAIL_i$ are the right-hand side variables of interest denoting changes in broadband availability or adoption between 2000 and 2011 (or 2012); β_0, β_1, β_2, and β_3, are parameters, and ε_i is the associated error term. If β_2 is positive and statistically significant, it provides evidence that increasing levels of broadband adoption are associated with a rising shares of creative-class or entrepreneurial workers during the period in question.

Note that unlike cross-sectional spatial models, which require the use of all contiguous U.S. counties to estimate the spatial error parameter, these models can be restricted to non-metropolitan counties. First-differenced models allow for some preliminary claims regarding causality since time-invariant unobserved factors are essentially eliminated (Winship and Morgan, 1999). Still, endogeneity remains a concern since the direction of the relationship is undetermined a priori.

4. RESULTS

4.1 Cross-section Spatial Model

Table 3 shows the results from the spatial error models testing the relationship between wired broadband availability/adoption and entrepreneurship/creative-class measures. Since this research is focused on rural America, the primary variables of interest are NMHIADOPT_12 and NMHIAVAIL_12 (for Nonfarm Proprietors), and NMHIADOPT_ 11 and NMHIAVAIL_11 (for Creative Class).

For entrepreneurs (NFP), both dummy variables related to broadband *adoption* (overall and for nonmetropolitan counties) were not statistically significant. Alternatively, while the dummy variable measuring overall high broadband *availability* is statistically significant and negative, the nonmetropolitan specific dummy variable is positive and significant. This indicates that nonmetropolitan areas with high levels of broadband availability (but not adoption) are associated with higher shares of entrepreneurs. One interpretation of this is that some rural entrepreneurs need broadband to do their jobs, so the availability of it is important to them. However these entrepreneurs may not care as much about the broadband adoption tendencies of

[8] The correlation between broadband availability and adoption in the first-differenced model is .40 in 2011 and .43 in 2012. These are different from the correlations reported for the spatial models because the variables used are either continuous (availability) or categorical (adoption) compared to the "hi" dummy variables in the spatial model.

Table 3: Spatial Error Regression Results: Nonfarm Proprietors (NFP) and Creative Class (CC)

Percent NonFarm Proprietors (2012)				Percent Creative Class (2011)			
Variables	Coefficient		Standard Error	Variables	Coefficie nt		Standard Error
CONSTANT	0.6309	***	0.1243	CONSTANT	-0.3528	***	0.0374
UR_12	0.6228	***	0.0849	*UR_11*	0.0498	**	0.0236
LNMHI_12	0.0099		0.0118	*LNMHI_11*	0.0398	***	0.0036
LNPOP_12	-0.0361	***	0.0020	*LNPOP_11*	0.0028	***	0.0006
NATAM	0.0107	***	0.0021	*NATAM*	0.0038	***	0.0006
BLACK_12	-0.0395	**	0.0158	*BLACK_11*	-0.0119	***	0.0045
HISP_12	0.0146		0.0182	*HISP_11*	-0.0086	*	0.0053
ASIAN_12	0.0857		0.1043	*ASIAN_11*	0.0501		0.0310
OTHER_12	-0.1161	***	0.0240	*OTHER_11*	-0.0016		0.0072
HSEDU_12	0.1857	***	0.0449	*HSEDU_11*	-0.0161		0.0130
BACH__12	0.1539	***	0.0411	*BACH__11*	0.4193	***	0.0125
AGE_5_19_12	-0.0615		0.0689	*AGE_5_19_1*	0.0026		0.0259
AGE_20_34_12	-0.8263	***	0.0810	*AGE_20_34_11*	-0.1575	***	0.0270
AGE_35_60_12	-0.1684	**	0.0688	*AGE_35_60_11*	0.1159	***	0.0251
NONMETROPOLITAN	-0.0472	***	0.0068	*NONMETROPOLITAN*	-0.0009		0.0019
PCTEMPAGRI	0.0578		0.0364	*PCTEMPAGRI*	-0.1399	***	0.0105
PCTMANUF	-0.1784	***	0.0328	*PCTMANUF*	-0.0542	***	0.0097
HIADOPT_12	0.0016		0.0063	*HIADOPT_11*	0.0041	**	0.0018
NMHIADOPT_12	-0.0080		0.0072	*NMHIADOPT_ 11*	-0.0044	**	0.0022
HIAVAIL_12	-0.0267	***	0.0074	*HIAVAIL_11*	0.0014		0.0021
NMHIAVAIL_12	0.0176	**	0.0082	*NMHIAVAIL_11*	-0.0019		0.0023
LAMBDA	0.3613	***	0.0251	*LAMBDA*	0.3066	***	0.0262
Observations	3,109				3,109		
R^2	.3966				.8442		

*,**, and *** represent statistically significant differences at the p = .10, .05, and .01 levels, respectively

others living near them (which is why the adoption parameter is not significant). It is also interesting to note that the nonmetropolitan availability shift is from a negative overall broadband parameter (-0.0267), suggesting that high levels of availability in more urban areas are associated with lower entrepreneur shares. As a further testament of this result, the bivariate Moran's *I* value between high broadband availability and the percentage of nonfarm proprietors switches from -0.036 (p-value<0.001) for all counties to 0.061 (p-value<0.001) for only nonmetropolitan counties.

It is worthwhile to note that the nonmetropolitan dummy variable itself is still negative (-0.0472) and so this positive result for availability does not completely offset the nonmetropolitan disadvantage. Other positive, significant relationships with the proportion of entrepreneurs include education variables (*HSEDU_12* and *BACH_12*), natural amenities, and the unemployment rate, all of which are expected. Factors that have a negative relationship with the prevalence of entrepreneurs include counties with high percentages of African-Americans (*BLACK_12*), those with high proportions aged 20-34 (*AGE_20_34*), and those with high percentages in manufacturing (*PCTEMPMANUF*).

Shifting our focus to the relationship between broadband adoption and creative class (CC), the findings are almost exactly reversed. Broadband availability is not a statistically significant factor (either overall or for the nonmetropolitan shift) while it is broadband adoption that presents a meaningful statistical relationship. Interestingly, though, the overall broadband adoption variable is now positive (0.0041), while the nonmetropolitan shift is negative (-0.0044). This is exactly the opposite of the findings for broadband availability/adoption in the entrepreneurship (NFP) model. As a robustness check on this result, the bivariate Moran's *I* value for broadband adoption/creative class employment is 0.282 (p-value<0.001) for all counties but -0.019 (p-value = 0.072) for nonmetropolitan counties only, confirming the switch in sign. This indicates that those employed in the creative class in rural America are *negatively* influenced by broadband adoption, giving credence to the idea that rural areas with high levels of adoption may in fact lose some of their creative workers to other locations. Alternatively, this may reflect the types of creative-class jobs often found in rural areas, for example, farm labor contractors, butchers, and pipe layers.

Other positive and significant relationships with creative-class employees include median household income, natural amenities, population, bachelor's degree or greater, and those aged 35-60. Factors exhibiting a negative relationship include the percentage African-American, the percentage aged 20-34, and the percentage employed in both agriculture and manufacturing. In both models, the spatial parameter (lambda) is highly significant (0.361, p-value<0.01 for NFP, 0.3066, p-value < 0.01 for CC) indicating that the inclusion of a spatial error term is appropriate. The R^2 values are also reasonable, with the model explaining nearly 40 percent of the variation in the percentage of nonfarm proprietors and over 84 percent of the variation in creative-class employees.

4.2 First-differenced Regression Results

The cross-section spatial results above provide evidence that broadband does in fact matter for rural entrepreneurs and creative-class employees for a specific snapshot in time, namely 2011 and 2012. Still, some may argue that a more important question is whether *changes* in measures of rural entrepreneurs and creative-class workers over time are associated with observed increases in broadband availability/adoption. In particular, this type of model identifies the level of entrepreneurship or creative-class employment before broadband was typically even available. In doing so, it removes some of the bias that may exist when areas with already high (or low) levels of entrepreneurs or creative-class employees experience broadband growth. Both models were tested for both homoscedasticity and multicollinearity.[9] Results from first-differenced regressions are displayed in Table 4.

Table 4: First-differenced Regression Results: Δ NFP (2012-2000) and Δ Creative Class (2011-2000), Nonmetropolitan Counties Only

	Δ Non-farm Proprietors			Δ Creative Class		
	Coefficient		Standard Error	Coefficient		Standard Error
Broadband						
Δ BBADOPT	-0.0090	***	0.0028	-0.0018	*	0.0010
Δ BBAVAIL	-0.0421	***	0.0152	-0.0039		0.0046
Population / Income						
Δ LNMHI	0.0153	**	0.0071	0.0086	***	0.0028
Δ LNPOP	-0.1748	***	0.0267	0.0121		0.0088
Race / Ethnicity						
Δ BLACK	-0.2141		0.1430	-0.1337	**	0.0524
Δ HISP	0.1564	**	0.0752	-0.0381		0.0293
Δ ASIAN	0.1289		0.3935	-0.1563		0.1986
Education						
Δ HSEDU	0.1639	***	0.0591	-0.0605	***	0.0217
Δ BACH +	0.1161		0.1068	0.1070	**	0.0459
Age						
Δ AGE 5-19	-0.0969		0.0590	-0.0054		0.0237
Δ AGE 20-34	-0.2379	***	0.0417	-0.0304	*	0.0178
Δ AGE 35-59	-0.4027	***	0.0546	-0.0299		0.0227
Employment						
Δ Unemp. Rate	0.5111	***	0.0976	-0.0245		0.0327
Δ % Ag Emp	-0.3152	***	0.0910	-0.1279	***	0.0260
Δ % Manuf Emp	-0.0263		0.0459	-0.0518	***	0.0185
Constant	0.0927	***	0.0138	0.0164	***	0.0047
Observations	1,931			1,947		
R^2	.1965			.0645		

*,**, and *** represent statistically significant differences at the p = .10, .05, and .01 levels, respectively

When examining the change in the percentage of nonmetropolitan entrepreneurs (NFP) from 2000 to 2012, changes in both broadband adoption and availability are negative and statistically significant. This implies that nonmetropolitan counties that experienced the largest

[9] Robust standard errors are reported after White's Test initially indicated the presence of heteroscedasticity; variable influence factors (VIFs) are minimal in both models (average VIF score across 15 variables was 1.28 for the Creative Class model and 1.33 for the Non-Farm Proprietor model).

increases in broadband availability and adoption rates also had the largest drops in shares of entrepreneurs. This finding is contrary to the cross-sectional result from 2012 alone (Table 3), which suggested a positive relationship between nonmetropolitan broadband availability and entrepreneurship. However, the negative time-related relationship is consistent with the hypothesis that as more individuals obtain and use broadband, they will be better able to become more aware of alternative employment opportunities in non-entrepreneurial environments. In essence, the rise of broadband Internet may be reducing the "necessity entrepreneurs" often found in rural areas by providing them with information about other employment possibilities.

The change in the percentage of creative class employees from 2000 to 2007-2011 is also found to have a negative and statistically significant (though only at the p=.10 level) correlation with the change in broadband adoption in nonmetropolitan counties. This suggests that a situation similar to the one for entrepreneurs is unfolding for nonmetropolitan creative-class workers. Namely, the rise in broadband adoption is associated with a decrease in these types of workers. This may be due to an increased awareness of other types of (non-creative-class) work opportunities, or perhaps due to more awareness of more attractive creative-class jobs in nearby metropolitan areas (thus leading to out-migration). These first-differenced results support the findings in the spatial models when only ones nap-shot in time (2011) is examined. Note, however, that the R^2 is significantly lower for the creative-class model, due mostly to the low variation in changes to the share of creative-class employees over this time.[10]

The remaining control variables in the first-differenced regressions have the expected relationships and are generally consistent with those observed in the previously spatial models. For example, increases to the unemployment rate over time are related in a positive and statistically significant manner to the percentage of entrepreneurs, as are increases in the share of the population with a high-school education or less. Additionally, rises in the share of employment in agriculture lowers the share of local entrepreneurs. Each of these results lends credence to the "necessity entrepreneur" hypothesis, which suggests that individuals become engaged with entrepreneurship when other employment opportunities are lowered. For creative-class employment, increases over time are positively associated with rises in the percentage with a bachelor's degree or higher and also with increases in median household income. These results reinforce the general notion that creative-class employment is associated with workers who possess higher incomes and education levels. Even after controlling for these factors, the influence of increasing broadband adoption over time is negative for both entrepreneurs and creative-class employees.

5. CONCLUSION

This research has focused on improving the understanding of the relationship between broadband and levels of creative-class employment and entrepreneurship across rural America. Table 5 summarizes the overall findings, specific to nonmetropolitan counties, from both the spatial error model and the first-differenced specification.

The aggregate results suggest that generally, the relationship in question is a negative one. In particular, high levels of broadband adoption in nonmetropolitan counties are associated

[10] The average nonmetropolitan county experienced rises in their shares of creative class employees by only 1.2 percent over the 2000 and the 2007-2011 periods. As a comparison, the percentage of nonfarm proprietors increased by an average of 6.8 percent in nonmetropolitan counties between 2000 and 2012.

with lower levels of creative-class employees both at a specific point in time (2011) and when changes over time are considered (2000-2011). The only positive relationship that exists in these nonmetropolitan counties is between the percentage of nonfarm proprietors and broadband

Table 5: Nonmetropolitan Summary Results

	Percent NFP	Percent CC
Spatial Error Models		
Hi BB Adoption	-0.0079	-0.0044**
Hi Wired BB Availability	0.0176**	-0.0019
First-differenced Regressions		
Δ BB Adoption (2000-2011/12)	-0.0090***	-0.0018*
Δ BB Availability (2000-2011/12)	-0.0421***	-0.0039

availability in 2012. When the analysis shifts to changes over time (2000-2012), however, increases in broadband adoption and availability were negatively correlated with this measure of rural entrepreneurship. As previously noted, the negative correlation could be spurred by increases in broadband adoption leading to discoveries of job opportunities in non-entrepreneurial sectors.

In a recent article, Low and Isserman (2015) challenged the traditional measures of entrepreneurship, suggesting an expansion to encompass a combination of innovative start-ups and self-employed in innovative industries. This new, non-employer based "innovative entrepreneurship" was observed to have a positive relationship with growth, where conventional definitions did not. Therefore, this new and potentially better definition could prove useful in capturing the importance of the relationship between broadband and entrepreneurship, especially when it comes to spurring growth in rural areas. We also note the problematic nature of several datasets (NBM and ERS creative class). Refining the analysis in this paper to focus explicitly on these innovative entrepreneurs, or to use updated/improved data would be useful topics for future research, and could potentially lead to different conclusions. Along these lines, the broadband availability data used in this study have been shown to have significant reliability issues in rural areas (Grubesic and Mack, 2015). Although the NBM data remain the best available source of information, conclusions drawn from its use should be tempered.

The analysis also finds that broadband adoption (but not necessarily availability) seems to be negatively associated with creative-class employment in rural America. By definition, creative-class employees develop, design, or create new applications, ideas, relationships, systems, or products, including artistic contributions (USDA-ERS 2014). Building off the same premise, the negative association documented here could be attributed to rural residents becoming aware of creative-class jobs in metropolitan areas (leading to out-migration), or other (non-creative class) employment opportunities within rural areas.

From an economic development standpoint, it is important to keep in mind that the overall "high" broadband adoption variable has a significant and positive relationship with the percentage of creative class employees in the spatial error model. This suggests that for the overall economy, local broadband adoption rates do matter to creative class employees, but these results are only positive in more urban areas. There is no evidence that improving local broadband infrastructure (or adoption rates) could help rural communities attract and increase their "creative" presence by luring in creative-class employees from metropolitan areas.

Many previous broadband-oriented policies have focused heavily on increasing the infrastructure (availability) of rural broadband as opposed to increasing broadband adoption (Kruger, 2013). When it comes to entrepreneurs in rural areas, this research suggests these policies are a step in the right direction. Results from the most recent (2012) spatial model imply that high levels of wired availability in nonmetropolitan counties are associated with higher levels of entrepreneurs. However, the first-differenced findings indicate that increases in wired availability over time may in fact lead to fewer entrepreneurs. This discrepancy could be viewed as evidence that as rural broadband availability improved between 2000-2012, rates of "necessity entrepreneurs" declined in these areas, and that those entrepreneurs who remain (as of 2012) now perceive broadband access as a positive factor. Focusing more explicitly on the definitions of innovative entrepreneurs as provided by Low and Isserman (2015) could help resolve this issue.

Moreover, federal broadband policy has recently begun to focus more explicitly on broadband adoption in response to an array of academic work suggesting that this may be the best way to solve various "digital divides" (Atkinson, 2009; Whitacre, Strover, and Gallardo, 2015). Recent initiatives such as ConnectHome and the inclusion of monthly broadband subsidies into the federal Lifeline program are clearly adoption-oriented. But our findings suggest that, even if successful, these programs do not necessarily benefit rural areas hoping to enhance entrepreneurship or creative-class employment. Across the board, higher levels of rural broadband adoption has negative associations with these types of workers, at least in our models.

None of this is to say that pursuing improved broadband availability or adoption rates is something that rural areas should avoid. There is mounting evidence that achieving higher broadband adoption rates can lead to improved economic outcomes in rural areas (Whitacre, Gallardo, and Strover, 2014a; 2014b). Instead, our results should remind us that not all implications of this type of policy are positive and that there may in fact be negative consequences.

While the first-differenced regressions used in this analysis are a first step towards establishing a causal relationship, the direction of the relationship remains undetermined, even from an empirical perspective. It could very well be the case that the lack of an increase in creative-class employees or entrepreneurs was actually responsible for higher growth in broadband availability, perhaps because broadband providers did not perceive these workers as heavy users of their services. Establishing strict causality requires alternative approaches such as structural equations modeling or propensity score matching. It also likely requires detailed surveys specifically focused on creative-class employees and entrepreneurs in rural areas.

While many fruitful avenues for future research remain, this analysis is a first step in determining the relationship between rural broadband and creative-class employees/entrepreneurs. The results suggest that the direction of influence is not necessarily positive, which is of itself an interesting finding that should be accounted for as rural development policies are conceived.

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