Residential Broadband Availability: Evidence from Kentucky and North Carolina

Mitch Renkow

I analyze the determinants of county-level broadband availability to gauge the extent to which the rural-urban broadband gap has narrowed and the factors that underlie that narrowing. Using data that have been collected by organizations tracking and promoting broadband in Kentucky and North Carolina, I find that in both states the rural-urban availability gap has indeed narrowed substantially, although there appears to be a limit on the extent to which broadband service will extend into the least densely populated counties. Among rural counties, availability rates increase systematically with the size of the county's urbanized population.

Key Words: broadband availability, digital divide, rural development

Broadband connectivity is widely promoted as a potentially significant contributor to local economic development in relatively isolated rural places. Broadband facilitates high-speed data transmission, thereby reducing the effective cost of distance to businesses and to consumers. This in turn eases key constraints related to economic and geographic remoteness that characterize what Parker (1990) dubbed the "rural penalty"—small markets, high transport costs, and geographic isolation. Thus, broadband deployment is projected to increase the productivity and profitability of newly served firms (Crandall, Lehr, and Litan 2007); increase the probability of attracting new firms into an area (Heath 1999); and facilitate innovations in healthcare delivery, distance education, and e-commerce that bring significant welfare improvements for rural residents.

Ironically, precisely the same physical remoteness and low population densities that make broadband particularly desirable in rural areas also render its deployment expensive.[1] A 2005 Office of Management and Budget (OMB) study found that investment per subscriber in rural systems averaged $2,921 compared to $1,920 in urban locations (OMB 2005, p. 262). Broadband technologies require very large up-front financial outlays by service providers. For this reason, rural small businesses generally pay more than do their urban counterparts for high-speed Internet access (Pociask 2005). In addition, demand side factors have been found to limit deployment of broadband in rural areas, insofar as broadband carriers generally require a minimum number of customers before they will offer service in an area (Malecki 2003).

For all these reasons, broadband penetration into rural areas—and particularly into more remote areas—has lagged behind its deployment in

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[1] Both DSL and cable require investments in delivery infrastructure, especially in establishing or upgrading transmission lines. The existing cable network does not extend into many rural areas; remedying this requires very costly network expansion. Although telephone lines do extend to virtually all rural places, provision of DSL to more remote locations still requires significant upgrades to insure adequate network quality. Fixed wireless transmission does not suffer from these problems; however, it is constrained by sightline issues, topography, and even weather (Staihr 2000, Stenberg 2002). Finally, rural counties are especially unlikely to contain a national Internet Service Provider; this also lessens the speed and extent of broadband off-takes from the national fiber optics backbone (Malecki 2003) and makes access, where available, more costly.

more densely populated and less remote locations, even while rural-urban differences in computer and Internet usage[2] have narrowed dramatically in the recent past [U.S. General Accountability Office (GAO) 2006]. In an attempt to narrow this rural-urban "digital divide," and to promote the projected positive economic impacts of broadband in rural places, the Rural Utilities Service of the U.S. Department of Agriculture (USDA) has, since 2000, made $1.8 billion in loans at subsidized rates to telecommunications providers, primarily for broadband deployment (Kandilov and Renkow 2010). Additionally, many states provide grants to Internet service providers for purposes of extending broadband into hitherto unserved (or underserved) locations. Most recently, the American Recovery and Reinvestment Act (ARRA) of 2009 authorized $2.5 billion in new federal spending for these same purposes (Kruger 2009).

The extent to which public policies promoting broadband deployment and broadband adoption have had the desired positive economic impacts has not been well chronicled. In part, this reflects a deficiency in time-series data suited to tracking broadband availability across geographical units. In particular, much of the research on availability has relied on ZIP code-level information reported to the Federal Communications Commission (FCC) by broadband suppliers (Aron and Burnstein 2003, Flamm and Chaudhuri 2005, Grubesic 2004, Wallstein 2005). The drawbacks of this data are well known: a ZIP code is reported as being served even if there is only one subscriber (Prieger 2003). This tends to overstate availability, particularly in large and sparsely populated rural areas (U.S. GAO 2006).[3] Other work on broadband availability and adoption has sought to work around this problem by using data from the National Exchange Carriers Association (NECA) and *Television and Cable Factbooks* (Mills and Whitacre 2003, Whitacre and Mills 2007, Whitacre 2008). These data provide a more accurate spatial delineation of which ZIP codes actually possess DSL or cable service. However, the analyses using these data still assume that *all* residents of a ZIP code that possesses broadband connectivity have access to broadband and hence overstate rural broadband availability (Whitacre 2008, p. 677).

In this paper I analyze the determinants of county-level broadband availability and changes in availability. I use data that have been collected by organizations tracking and promoting broadband in Kentucky and North Carolina (Connect Kentucky 2008, e-NC Authority 2004) to gauge the extent to which the rural-urban broadband gap has narrowed and the factors that underlie that narrowing. At the current time, these are the only two sources of data on availability at the county level for multiple points in time.

I find that in both states the rural-urban availability gap has narrowed substantially: the data reveal a general convergence in the share of residents having access to broadband across all counties, although there appears to be a limit on the extent to which broadband service will extend into the least densely populated counties. Among rural counties, availability rates increase systematically with the size of the county's urbanized population. Other drivers of broadband availability appear to differ across states, with income being more important in North Carolina and county population size and density being more important in Kentucky. Finally, I find evidence that USDA grant programs are having the desired impact of boosting residential broadband availability in Kentucky, but that state grant programs in North Carolina have had no statistically significant impact on availability.

Questions about the Spread of Residential Broadband Availability

The analyses below are oriented toward providing insight into three questions regarding the spread of broadband over time and across different types of communities.

(a) To what extent do various exogenous factors discussed in the literature—the income, size, and density of the potential customer base—constrain or facilitate deployment of broadband, particularly as regards relatively remote rural communities?

It is possible that deployment of broadband into rural areas is proceeding relatively efficiently, in that the market opportunities confronting broad-

[2] Note that while reported rural-urban differences in Internet usage have almost disappeared, a significant fraction of rural households—particularly households located in remote areas—only use the Internet via much slower dial-up connections that effectively preclude many highly data-intensive uses vis-à-vis broadband (U.S. GAO 2006).

[3] In addition, the FCC data on broadband availability is permeated by a number of sizable discrepancies from one year to the next, as well as by unexplained "revisions" of earlier data. For example, a recent analysis of FCC data on availability in North Carolina points to unexplained—and unrealistic—retroactive increases in reported numbers of broadband lines from one year to the next (Baller and Lide 2008).

band suppliers reflect with reasonable accuracy the relevant social costs and benefits. The rate of expansion of broadband services into rural communities might be tracking the expansion of the geographic extent of urban labor markets (via exurbanization), as an increasing number of workers employed in urban areas take up residence in rural communities within a commutershed (Renkow and Hoover 2000, Partridge, Ali, and Olfert 2010). Or expansion of broadband availability in rural places might be more related to local earnings and other factors internal to communities. Gaining some knowledge of the magnitude and direction of these impacts should help explain observed geographic patterns of broadband deployment and perhaps improve our ability to project likely patterns of future deployment.

(b) Is there a threshold level of density and/or distance beyond which we should not expect market-based provision of broadband services?

This is a question that speaks to a possible role for targeted public investments—to the extent that universal or near-universal broadband access is regarded as socially desirable—as well as to the efficacy of past, current, and planned spending by state and federal governments to promote broadband deployment. Considerable debate exists regarding the merits of establishing universal broadband service for rural areas in much the same way that universal telephone was accomplished in the last century [Milgrom 1997, Congressional Budget Office (CBO) 2005].

Two points are relevant in this regard. First, as Malecki (2003) notes, universal telephone service was established when infrastructure investment decisions were made by public service providers or regulated monopolies. Similar coordination of large numbers of (unregulated) private firms today would be extremely difficult, if not impossible.

Second, particularly with regard to communications infrastructure, there is a long tradition of the federal government underwriting the costs of universal service provision, dating back to the implementation of Rural Free Delivery of mail in the late 1800s (Kernell 2001) and continuing on through Rural Electrification Administration subsidization of extending electrical service and telephone service into rural areas (Cooke 1948). To a large extent, the impetus for government involvement in these sorts of activities has been non-economic, in the sense that access to these infrastructures was determined to be a "citizenship" benefit that should be made available to all, regardless of where they dwelt (Renkow 2007). Moreover, some evidence suggests that extending telecommunications services into highly remote areas has in many instances led to sufficiently large and sustained demands for those services over time, to have justified the initial public investments on cost benefit grounds (Parker 1990).[4]

(c) Do observed patterns of expansion of broadband into the rural space represent integration of (less remote) rural places into expanding urban economic zones?

Here the issue is the relative importance of local clustering of population versus some sort of spatial gradient based on proximity to an urban "growth pole" (Rodell 1975). For rural communities, this can be tested by examining econometrically the impact of proximity to large urban centers. A strong positive relationship here is consistent with broadband expanding into rural areas as part of the larger process of exurbanization noted earlier. Conversely, lack of a positive relationship between availability and proximity is consistent with a more decentralized pattern of broadband deployment, driven by more localized demand forces and perhaps characterized by a "leapfrogging" of observed availability across space.

Data

ConnectKentucky and e-NC are state-mandated organizations whose mission is to facilitate the spread of high-speed Internet access into underserved portions of their respective states. This mission is pursued by providing public education programs on the beneficial aspects of the adoption of computer-based technologies; by facilitating public-private partnerships for extending broadband service into previously unserved areas; by serving as a clearinghouse for public funds available for extending broadband service; and by

[4] For example, in discussing the REA's rural telephone loan program, Parker writes: "In rural Alaska where distances and costs are enormous and the population density particularly low, rural telecommunications were provided because of political pressures and State government intervention, rather than because the telephone company saw greater economic opportunity. Nevertheless, the investment turned out to be economically sound, because use greatly exceeded the most optimistic projections" (Parker 1990, p. 55).

Table 1. Residential Broadband Availability in Kentucky, 2005 and 2007

	2005		2007		
Type of County	Mean	Minimum	Mean	Minimum	No.
Rural, not adjacent to a metro county	74.1%	26.4%	89.9%	42.1%	63
Rural, adjacent to a metro county	68.6%	32.7%	85.1%	66.6%	35
Metro	84.9%	45.5%	96.0%	90.5%	22
Rural w/ urban population < 2,500	68.5%	26.4%	86.6%	42.1%	43
Rural w/ urban population of 2,500 to 20,000	73.6%	41.4%	88.8%	50.7%	51
Rural w/ urban population > 20,000	93.0%	88.3%	97.3%	95.7%	4

monitoring trends in computer usage and broadband penetration. While many states currently possess organizations with similar mandates and activities, ConnectKentucky and e-NC (and its predecessor, the NC Rural Internet Access Authority) were among the earliest to come into existence (in 2002 and 2001, respectively).

ConnectKentucky and e-NC have collected county-level data on residential broadband availability annually since 2005 and 2002, respectively, via surveys of the states' broadband service providers. Broadband providers operating within these states submit data on which census blocks or street segments they serve; these data are then aggregated up to the county level.[5] The analyses below use data from 2005 and 2007 for Kentucky, and 2002 and 2007 for North Carolina. These were the earliest and latest available years for which both availability data and complementary socioeconomic data were available. I supplement the availability data with socioeconomic data drawn from the U.S. Census and from the Bureau of Economic Analysis.

Table 1 summarizes residential broadband availability in 2005 and 2007 for different geographical categorizations of Kentucky counties. By the end of 2007[6] the great majority of households in all locations had access to broadband—more than 85 percent of households, on average, in even in the most remote (i.e., rural nonadjacent) and least urbanized counties. Growth in average availability in rural counties was substantial as well, although there remained a handful of counties in which less than half of all residents had access to broadband. Meanwhile, metro counties were nearly totally "wired" for high-speed data transmission by 2007.

Table 2 presents broadband availability for the same geographical categories for North Carolina in 2002 and 2007. Compared with Kentucky, availability in North Carolina has been generally lower across all county types; but, as with Kentucky, availability increased substantially over the period, and in some counties the increases were

[5] e-NC collects information on DSL and cable availability separately and as a composite figure, indicating the fraction of households having either type of broadband. ConnectKentucky only reports the composite availability, so in the analyses that follow I employ the composite numbers for both states. Neither state reports data on the availability of wireless broadband.

[6] Kentucky availability data were collected in January of each year from 2004 through 2008. Thus, throughout this paper, availability reported in January 2008 is denoted as 2007 availability.

Table 2. Residential Broadband Availability in North Carolina, 2002 and 2007

	2002		2007		
Type of County	Mean	Minimum	Mean	Minimum	No.
Rural, not adjacent to a metro county	64.7%	0.0%	79.1%	51.3%	26
Rural, adjacent to a metro county	61.0%	17.1%	78.8%	41.8%	39
Metro	80.9%	48.8%	84.9%	61.3%	35
Rural w/ urban population < 2,500	45.7%	0.0%	70.7%	41.8%	22
Rural w/ urban population of 2,500 to 20,000	60.5%	17.1%	80.7%	51.3%	35
Rural w/ urban population > 20,000	72.7%	48.2%	78.7%	59.5%	8

quite large. Nonetheless, in 2007 in North Carolina there were rural counties of all size classifications for which residential broadband service was unavailable to 40 percent of households, and broadband availability was below 75 percent in 27 of North Carolina's 65 rural counties. In a similar vein, for seven of North Carolina's 35 metro counties, residential broadband availability remained below 75 percent in 2007.

Determinants of Availability

To assess the determinants of residential broadband availability, I regressed availability on a set of covariates generally thought to affect the supply of broadband services by telecommunications firms: income, population, area, and population density. Tables 3 and 4 present the regression results for Kentucky and North Carolina, respectively. In each table, the first regression (Model 1) includes both population and geographic area, while the second regression (Model 2) replaces these with population density. Both of these models also contain logged per capita income and dummies for metro and rural adjacent counties (rural nonadjacent counties are the omitted category). Model 3 additionally includes categorical variables indicating differing levels of urbanized population in rural counties [as delineated by the USDA's Rural-Urban Continuum Codes (RUCCs)].[7]

Kentucky

In all Kentucky regressions (Table 3), per capita income had no statistically significant influence on availability. Rather, the key determinants appear to have to do with the size and concentration of the population. Model 3 suggests that there exists a gradient of availability based on urban population. All else being equal, broadband availability in rural counties possessing urban populations between 2,500 and 20,000 was, on average, 4 percentage points greater than the least urbanized counties (i.e., those having no population center greater than 2,500 in size). And broadband availability in rural counties possessing larger urban populations (greater than 20,000) was more than 17 percentage points greater than the least urbanized counties.

At the same time, however, the dummy variable for rural adjacent counties is consistently negative

[7] The RUCCs were defined on the basis of 2004 population distributions. As such, it is possible that they may not fully account for endogenous changes in population that may be correlated with other covariates of broadband availability.

Table 3. Residential Broadband Availability Regressions: Kentucky

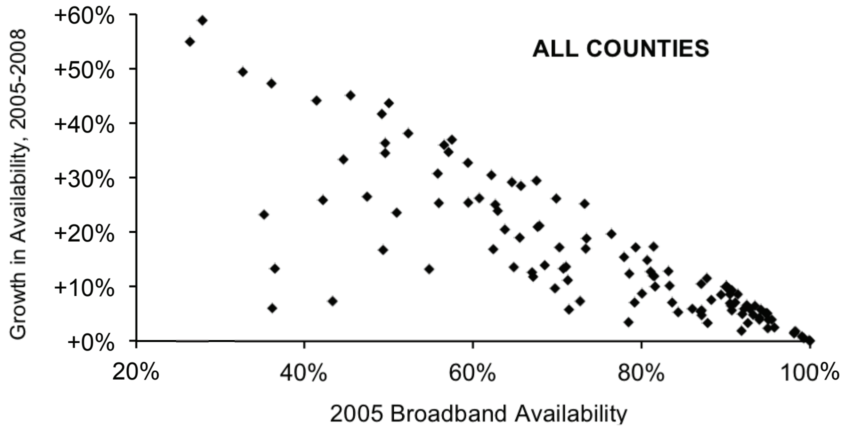
Variable	Model 1	Model 2	Model 3
Log per capita income	0.076	0.064	–0.017
	(1.28)	(1.16)	(0.26)
Population (× 10^{-6})	0.380**		
	(2.31)		
Area (× 10^{-3})	–0.109		
	(1.37)		
Population density (× 10^{-3})		0.151**	0.152**
		(2.55)	(2.49)
Year	0.064***	0.064***	0.064***
	(3.25)	(3.26)	(3.32)
Rural adjacent	–0.083***	–0.078***	–0.077***
	(3.55)	(3.41)	(3.39)
Metro	0.024	0.021	0.072*
	(0.76)	(0.66)	(1.96)
Rural w/ urban population > 20,000			0.178***
			(2.98)
Rural w/ urban population of 2,500 to 20,000			0.044*
			(1.94)
Intercept	0.001	0.067	0.861
	(0.00)	(0.11)	(1.35)
R^2	0.172	0.173	0.207
N	240	240	240

t-values in parentheses. ***, **, and * denote significance at the 0.01, 0.05, and 0.10 levels.
Dependent variable is the percentage of households for which broadband was available 2005 and 2007.

Table 4. Residential Broadband Availability Regressions: North Carolina

Variable	Model 1	Model 2	Model 3
Log per capita income	0.460***	0.438***	0.393***
	(4.54)	(4.25)	(3.99)
Population (× 10^{-6})	0.003		
	(0.22)		
Area (× 10^{-3})	0.016		
	(0.34)		
Population density (× 10^{-3})		0.050	0.025
		(0.66)	(0.34)
Year	0.080***	0.084***	0.091***
	(2.87)	(2.98)	(3.40)
Rural adjacent	0.016	0.016	–0.025
	(0.55)	(0.54)	(0.87)
Metro	0.064*	0.059*	0.136***
	(1.83)	(1.68)	(3.61)
Rural w/ urban population > 20K			0.197***
			(4.17)
Rural w/ urban population of 2.5K to 20K			0.119***
			(3.89)
Intercept	–4.13***	–3.90***	–3.53***
	(4.14)	(3.86)	(3.64)
R^2	0.357	0.358	0.425
N	200	200	200

t-values in parentheses. ***, **, and * denote significance at the 0.01, 0.05, and 0.10 levels.
Dependent variable is the percentage of households for which broadband was available 2002 and 2007.



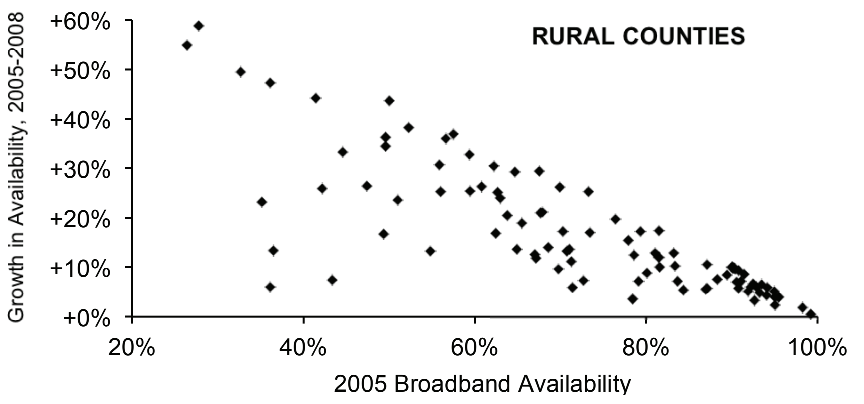


Figure 1. Convergence of Residential Broadband Availability in Kentucky, 2005-2008

and significant, indicating that broadband availability is in fact greater in rural counties located further away from metro counties. This, presumably, reflects the fact that, in Kentucky, a substantial number of relatively populous nonmetro counties are not contiguous with metro counties, while a good number of less densely populated rural counties *are* contiguous with metro counties.

North Carolina

In contrast to Kentucky, the regression results for North Carolina suggest that broadband availability is positively (and significantly) related to average per capita income, while population or population density does not exert a significant influence. As with Kentucky, the results point to a gradient of broadband availability based on urban populations within counties. All else being equal, broadband availability in rural counties possessing urban populations between 2,500 and 20,000 was on average just under 12 percentage points greater than the least urbanized counties (i.e., those having no population center greater than 2,500 in size), and broadband availability in rural counties possessing urban populations greater than 20,000 was nearly 20 percentage points greater than the least urbanized counties.

Among rural counties, adjacency to a metro county had no significant impact on availability. Coupled with the significant positive coefficients on the urban population size dummies, this suggests that the pattern of broadband deployment in rural counties is relatively decentralized, driven

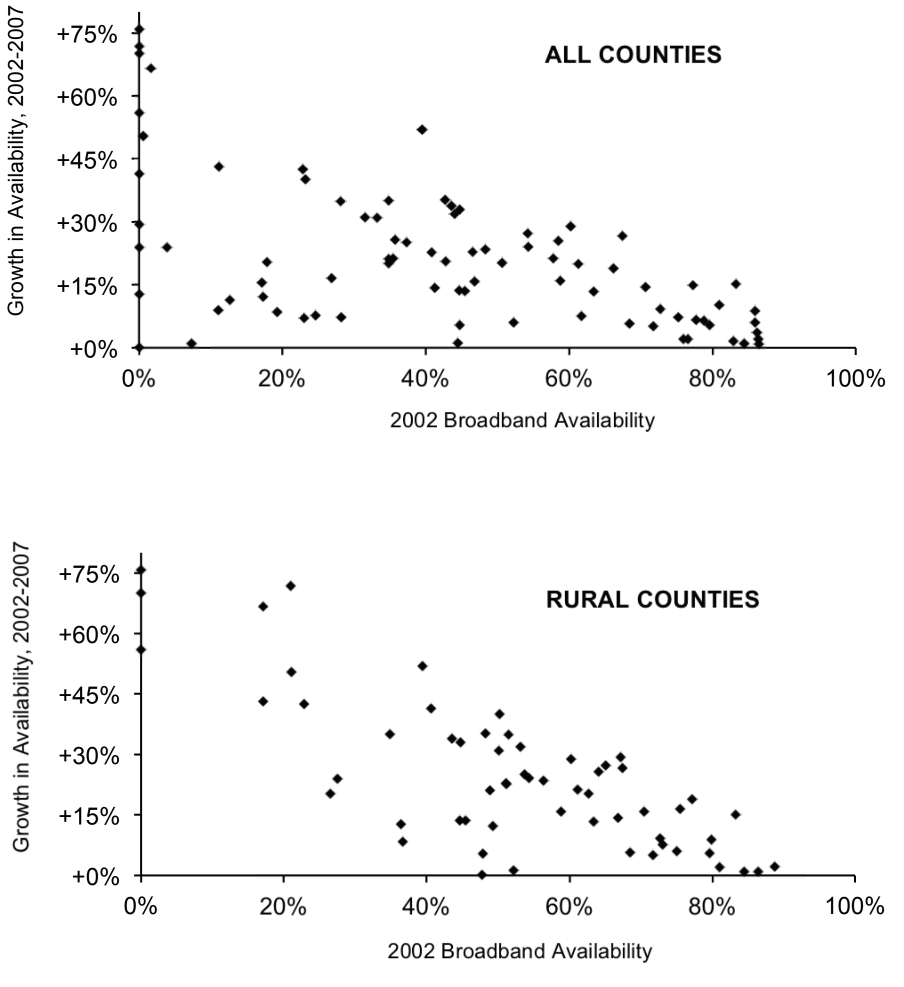


Figure 2. Convergence of Residential Broadband Availability in North Carolina, 2002-2007

by localized demand patterns rather than being driven by exurbanization related to expanding metropolitan labor market areas.

Growth of Availability and Convergence across Counties

An overall convergence of residential broadband availability across Kentucky's and North Carolina's counties is apparent in the data. This can be seen in Figures 1 and 2, which plot the growth rate of residential broadband availability—measured as the number of percentage points differences over the period for which data were available (January 2005 to January 2008 for Kentucky; 2002 to 2007 for North Carolina)—against the initial level of availability for individual counties over the period for which data were available.

In both states, availability has generally grown the most in counties that were the least well served initially. This is particularly the case for rural counties. In Kentucky in 2005, 34 of the 37 least well-served counties were rural; between 2005 and 2008 the average broadband availability in these counties grew from about 50 percent to nearly 74 percent. In North Carolina, in 2002, broadband was available to less than 50 percent of households in 25 of the state's 100 counties.

Table 5. Changes in Broadband Availability, Kentucky and North Carolina

Variable	Kentucky	North Carolina
Initial availability[a]	–0.537***	–0.772***
	(13.29)	(10.96)
2006 per capita income (× 10^{-3})	–0.002	0.008**
	(1.28)	(2.15)
Δ Population[b] (× 10^{-5})	–0.291	–0.004
	(0.48)	(0.41)
Grant amount[c] (× 10^{-6})	0.158*	-0.009
	(1.86)	(0.92)
Rural adjacent	–0.020	0.001
	(1.27)	(0.32)
Metro	0.036	0.031
	(1.42)	(0.73)
Rural w/ urban population > 20K	0.028	0.027
	(0.67)	(0.48)
Rural w/ urban population of 2.5K to 20K	0.007	0.087**
	(0.43)	(2.47)
Intercept	0.601***	0.317***
	(13.07)	(3.26)
R^2	0.692	0.661
N	120	100

t-values in parentheses. ***, **, and * denote significance at the 0.01, 0.05, and 0.10 levels.
Dependent variable is difference in the percentage of households for whom broadband was available (2005-2007 for Kentucky, 2002-2007 for North Carolina).
a. Initial availability date is 2005 for Kentucky and 2002 for North Carolina.
b. Population change over the period 2005-2007 for Kentucky and 2002-2007 for North Carolina.
c. For Kentucky, these are the amount of USDA Community Connect grants. For North Carolina, these are the amount of state-funded grants.

All but one of these counties were rural. Between 2002 and 2007, the fraction of households for whom broadband was available more than doubled in those counties (from 32 percent to 65 percent on average). In comparison, average availability in the other 75 counties grew by 9.2 percentage points (from 73 percent to 82 percent).

To better understand the sources of convergence in broadband availability, I regressed the growth in availability against initial availability (in 2005 and 2002 for Kentucky and North Carolina, respectively); 2006 per capita income (the latest year for which per capita income estimates are available); population growth over the relevant period; and location and urban population dummies.

Also included in these regressions was a variable for the size of grants awarded to counties for purposes of promoting broadband deployment. In Kentucky, I used Rural Utilities Service Community Connect Grant awards received by counties. Since 2003, nine of these awards—ranging in size from $95,000 to $426,000—have been received by Kentucky counties. Community Connect grants are designed to stimulate broadband deployment (Kruger 2007). No North Carolina county has received any Community Connect grants. However, between 2002 and 2006 the state government authorized $9.5 million in Connectivity and Infrastructure grants to nonprofits and for-profit broadband service providers for purposes of promoting broadband deployment to the least-wired counties (Baller and Lide 2008).[8]

The regression results are presented in Table 5. For both states, the negative (and strongly significant) sign on the initial availability variable reflects the convergence relationship graphically depicted in Figures 1 and 2. For Kentucky, the only other significant explanatory factor was the Community Connect Grant variable. The significant positive relationship between public investment and changes in broadband availability suggests that these grants did indeed have the desired effect of promoting measurable increases in broadband deployment. The small magnitude and nonsignificance of the urban population dummies suggest no particular pattern in the growth of availability in the various size categories. The income or population variables were not significant either.

In North Carolina, per capita income was significantly and positively related to growth in broadband availability. Coefficients of urban size variables were generally insignificant except for that on the dummy for rural counties with medium-sized urban populations—indicating that availability grew by roughly 9 percentage points more than in counties with the smallest urban populations.

Most importantly, the broadband deployment grants variable had no significant impact on the growth of broadband availability. This was a surprising, and potentially troubling, result—albeit one that mimics the findings of other research (Whitacre and Mahasuweerachai 2008, Feser 2007, Kandilov and Renkow 2010). On the surface it suggests that state grants made for purposes of promoting the deployment of broadband lines have not had the desired impact of increased availability. Alternatively, given that these grants are explicitly targeted to the "least-wired" counties, it may be that other unobservables, negatively correlated with availability, swamp any positive impacts that the grants might have in these particular counties.[9] A useful extension would be to replace the simple regression analysis employed here with a matching estimator that controlled for these unobservables—such as more closely pairing counties with similar (i.e., similarly unfavorable) conditions with regard to demand for broadband services.

Discussion

The preceding empirical results shed some light on the three questions posed at the beginning of this section:

(a) To what extent do income, size, and density of a potential customer base constrain deployment of broadband into remote rural communities?

In Kentucky, population and population density appear to dominate income in driving broadband deployment. The insensitivity of broadband availability to local income suggests that Internet service providers may well perceive the demand for broadband as being income inelastic, in which case the costs of the physical infrastructure required for extending broadband service capacity into unserved areas would be the primary consideration of service providers.

The reverse is true in North Carolina, where per capita income has a positive, significant impact on availability but population and density do not. Given that income tends to be positively related to broadband adoption (Whitacre 2008), this suggests that broadband service provision is demandled to a greater extent than in Kentucky.

(b) Is there a threshold level of density and/or distance beyond which we should not expect market-based provision of broadband services?

Growth in the availability of broadband in both states is consistent with the well-known S-shaped pattern of technology diffusion [see Hall and Khan (2002) for a recent review]. In Kentucky,

[8] The USDA has, since 2002, operated a Broadband loan program that extends low interest loans to small broadband providers operating in small rural communities. Over the time period covered in this analysis, no Broadband loans were extended to any community in North Carolina, and only one county in Kentucky (Wayne County) received a Broadband loan (approved in September 2006). The econometric results were virtually the same, whether or not this particular loan was included in the analysis.

[9] Additionally, the fact that these grants were explicitly targeted to counties with low availability calls into question whether the grant amount variable is statistically endogenous. To test for this, I reestimated the model by Two Stage Least Squares, using as an instrument for Grant Amount a dummy variable equal to 1 if a county was included in a group of "Connectivity Challenged" counties delineated in 2000 by the North Carolina Rural Center. The resulting Wu-Hausman statistic (of 1.39) indicated that the statistical exogeneity of the Grant Amount variable could not be rejected.

the growth of availability in even the most sparsely populated counties is striking: by 2007, broadband was available to more than 75 percent of households in all but eight of Kentucky's 120 counties. Seven of those eight least-served counties were in the group of least urbanized counties (i.e., those with urban populations less than 2,500). But even in those counties, more than 40 percent of households had broadband available.

In North Carolina, the fraction of rural households without broadband access is greater than in Kentucky—availability in 2007 was less than 60 percent in 11 of the state's 100 counties. As in Kentucky, most of these (7 of 11) had urban populations below 2,500; but, also like Kentucky, the rate of increase in availability in these counties exceeded the average for other, more "wired" counties in the state. Thus, for both states it appears that while there is a limit to the extent to which broadband service will extend into the least densely populated and most remote counties, the overall number of unserved households statewide is relatively small (and shrinking).

Pinpointing the ultimate extent of broadband availability—what Griliches (1957) termed the "ceiling" for aggregate adoption—is, of course, not possible. But the econometric results shed a bit of light on the roles that economic geography and public policy might play in that regard. In both states, county-level availability is clearly (and systematically) related to the size of the county's urbanized population. Beyond that, however, there is substantial heterogeneity between the two states in terms of the economic forces underpinning county-level broadband availability: Demand forces (related to income elastic demand for broadband services) appear to be more important in North Carolina, while supply side forces (related to the cost of extending broadband service capacity into unserved areas) appears to be dominant in Kentucky.

Similarly, the econometric results present a mixed picture of the effectiveness of public policy initiatives (via grants provided to broadband service providers). In Kentucky these initiatives appear to be working, whereas in North Carolina there is no statistically significant evidence that they are. Thus, to the extent that universal service provision is a compelling public policy goal, the results suggest that achieving that goal might be more difficult in some states than in others.

(c) Do observed patterns of expansion of broadband into the rural space represent integration of (less remote) rural places into expanding urban economic zones?

In both Kentucky and North Carolina, the key determinants of broadband availability appear not to be related to proximity to large urban centers (i.e., metro counties). Indeed, in Kentucky the significant negative relationship between availability and a rural county being adjacent to a metro county suggests that a sort of "leap-frogging" of service may have occurred. More generally, it seems that in both states local clustering of population dominates broadband service provision, as opposed to some sort of spatial gradient based on proximity to an urban "growth pole."

This suggests a decentralized pattern of broadband deployment driven by localized demand and /or supply forces, as opposed to some sort of spatial gradient of availability related to exurbanization trends. From a policy perspective, this would seem to indicate that efforts to promote broadband deployment will require interactions with—and perhaps provision of incentives to—smaller Internet service providers that tend to operate in less populated locales (Wood 2008).

Concluding Remarks

In this paper I have analyzed the determinants of county-level broadband availability and changes in availability, using data that have been collected by organizations that track and promote broadband in Kentucky and North Carolina. The empirical results reported above indicate that, in both states, rural-urban "digital divides" have narrowed substantially in recent years. In both states there has been a substantial convergence in the share of residents having access to broadband across all counties—even the most remote and least populous—although there appears to be a limit on the extent to which broadband service will extend into the least populous counties.

Among rural counties in both states, availability rates increase systematically with the size of the county's urbanized population. Other drivers of broadband availability appear to differ across states, with income being more important in North Carolina, and population size and density being more important in Kentucky. In addition, I have found evidence that USDA grant programs have had the desired stimulative effect on availability in Kentucky, but that grant funding by the state of North Carolina for purposes of promoting broadband deployment have not had a statistically significant impact on availability. This latter result is a fruitful avenue for future research efforts.

Finally, it is worth noting that Connect Kentucky and e-NC have been in existence for nearly a decade and would appear to have very successfully pursued their mandates to promote and monitor broadband penetration into underserved portions of their respective states. The focus on Kentucky and North Carolina in this article is attributable to the fact that, at the time the research was being conducted, these were the only states for which comprehensive county-level data on broadband availability existed for multiple points in time. Currently, a growing number of states have commissioned programs similar to those of Kentucky and North Carolina (many patterned after ConnectKentucky), and most of these are collecting county-level data on availability. Thus, in the future it will be feasible to expand the geographical coverage of the analysis that has been conducted here to include more states. In particular, it will be very useful to monitor the extent to which the very large amount of money recently disbursed via the American Recovery and Reinvestment Act translates into broadband penetration into previously underserved rural communities.

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