Metropolitan Policy Program
at BROOKINGS

# Broadband Adoption Rates and Gaps in U.S. Metropolitan Areas

**Adie Tomer and Joseph Kane**

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**For many Americans, daily life orbits around a high-speed Internet connection. Workers and students go online to communicate and learn. Families stay in touch through live video feeds. Job seekers often need an electronic resume and an email address for applications. Smartphones put maps, social networks, and video streams in people's pockets. The American economy has gone digital.**

Yet, the rapid transition to online content and services comes at a price. Buying cheaper goods directly from wholesalers, immediately accessing government services, and finding employment opportunities are increasingly only available to those who have an online connection. As a result, individuals without a private Internet subscription or digital skills are at a disadvantage when it comes to accessing economic opportunity.[1] Individuals with digital skills but no private broadband subscription –likely due to the United States' relatively expensive broadband service—must spend extra time getting to public connection points, such as libraries.[2] And since everyone cannot regularly access the Internet, government agencies must operate both digital and analog systems, and private businesses miss out on an expanded customer base.[3]

There is no question that the Internet is a huge boon to the economy and society, but maximizing its potential is only possible if all individuals are online. As a result, it is critical that policymakers closely track broadband adoption rates: the share of house-

**1.** The term "digital skills" is used throughout this report, but is sometimes referred to as digital literacy or digital readiness. For more background the subject and statistical assessments for middle skill jobs, see: "Crunched by the Numbers: The Digital Skills Gap in the Workforce," Burning Glass, March 2015.

**2.** The National Telecommunications and Information Administration (NTIA) analysis found that 28 percent of non-subscribers list price as their primary reason for not subscribing to in-home internet. This may relate to the United States' expensive broadband service when compared to other OECD countries. Sources: National Telecommunications and Information Administration, "Exploring the Digital Nation: America's Emerging Online Experience," June 2013; the OECD broadband data portal is online at http://www.oecd.org/internet/broadband/oecdbroadbandportal.htm [accessed October 2015].

**3.** Julia Greenberg, "Why Helping the Poor Pay for Broadband Is Good for Us All," Wired, May 31, 2015. Available online at http://www.wired.com/2015/05/helping-poor-pay-broadband-good-us/ [accessed October 2015].

holds with a DSL, cable, fiber optic, mobile broadband, satellite, or fixed wireless subscription.[4]

Until now, public, private, and civic leaders have frequently concentrated on broadband adoption at a national or international scale, looking at how rates vary across large segments of the population.[5] However, new survey questions from the U.S. Census Bureau enable analysis at the metropolitan scale, creating new ways to measure and understand where America falls short in getting people online. This subnational approach is especially important because local and state governments play a lead role in guiding Internet policy, including infrastructure deployment, public outreach, skills development, and affordability programs.[6]

This brief uses 2013 and 2014 American Community Survey data to track current and changing broadband adoption rates at the metropolitan scale, while using a combination of other Census and Internet speed data to model what factors affect metropolitan adoption rates. In turn, the results of this analysis have clear implications for efforts to address the significant gaps in American Internet adoption.

Further information on the analytical approach and methods is available in the appendix.

## While 75.1 percent of American households had a broadband Internet subscription in 2014, there is enormous variation in U.S. digital connectivity across demographic groups and between metropolitan areas.

In 2014, more than 87 million households—or three-quarters of all households nationally—had a broadband Internet subscription, speaking to the importance of having a

**4.** This brief uses the Census definition of a broadband subscriber. However, there are competing definitions based on the speed of service and fixed versus wireless access. In addition, this definition was informed by requirements in the Broadband Data Improvement Act, passed by the U.S. Congress in 2008.

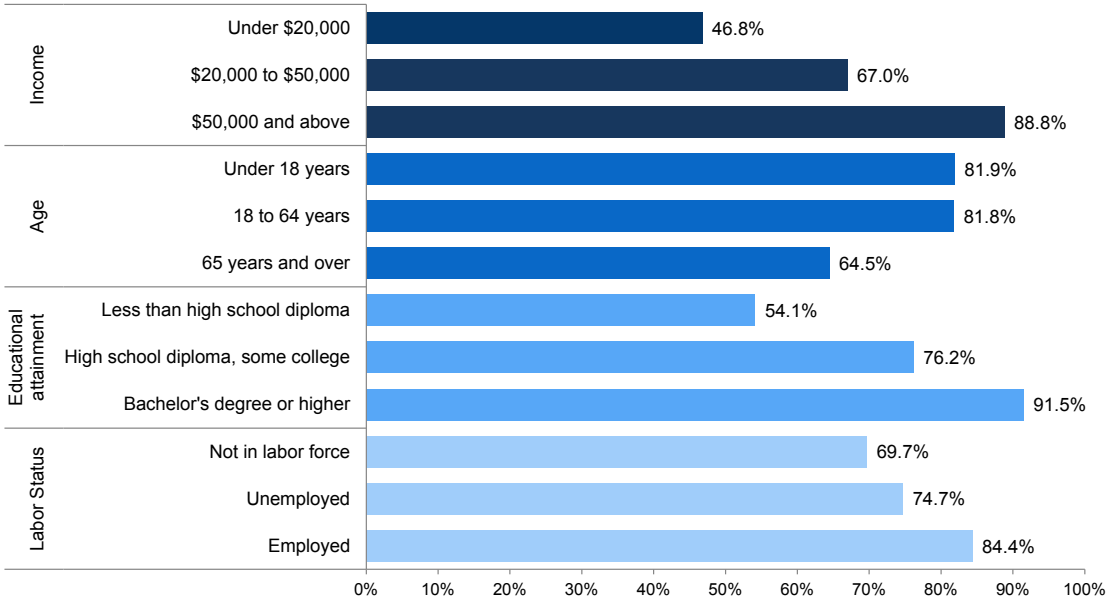
**5.** For more information on how the Census defines broadband adoption and collects data, see: Thom File and Camille Ryan, "Computer and Internet Use in the United States: 2013," United States Census Bureau, November 2014.

**6.** See Table 1 and pages 13 -16 in: Government Accountability Office, "Broadband: Intended Outcomes and Effectiveness of Efforts to Address Adoption Barriers Are Unclear," GAO-15-473 (Washington, 2015).

reliable, efficient connection to digital information networks across the United States.[7] There's little question broadband has evolved into the defining infrastructure of the 21st century.[8]

Yet despite its central role in promoting economic prosperity, broadband adoption remains highly uneven among specific groups, limiting opportunity for many people. For example, only 46.8 percent of households with incomes under $20,000 annually had a broadband subscription in 2014, compared to 88.8 percent of households earning $50,000 or more. Likewise, while 54.1 percent of individuals with less than a high school diploma had a broadband subscription, 91.5 percent with a bachelor's degree or higher did. Relatively low adoption rates also appear among older age groups—64.5 percent of individuals 65 years and older—while those not in the labor force (69.7 percent) subscribe to broadband at marginally lower rates relative to the national average.

**Figure 1. Broadband adoption rates by different demographic and economic indicators, United States, 2014**



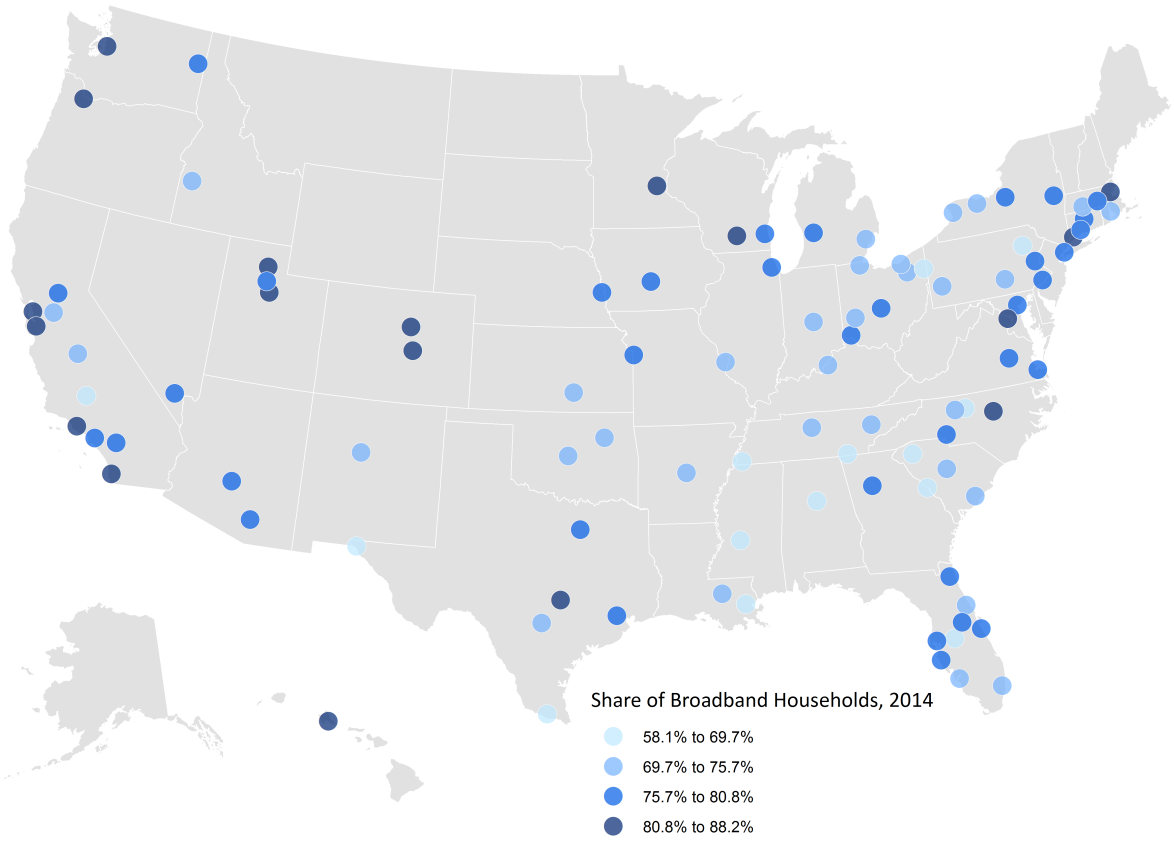

Source: Brookings analysis of American Community Survey data
Note: Rates of broadband adoption are reported for households in terms of income, and for individuals in terms of age, educational attainment, and labor status

**7.** This references the ACS definition, which includes households with a DSL, cable, fiber optic, mobile broadband, satellite, or fixed wireless subscription.

**8.** Tom Wheeler, chairman of the Federal Communications Commission, "Maximizing the benefits of broadband." Public speech. Brookings Institution Falk Auditorium, Washington, D.C. June 26, 2015.

Broadband adoption also varies substantially across different U.S. markets, including the country's 100 largest metropolitan areas. Although these areas tend to have higher adoption rates (77.8 percent) than the country as a whole (75.1 percent), these rates can still differ by up to 30 percentage points or more in some cases. Tech centers like San Jose (88.2 percent), Seattle (84.8 percent), and Boston (82.7 percent), for instance, far exceed the shares seen in Lakeland (64.1 percent), Greensboro (64 percent), and McAllen (58.1 percent). Table 1 includes the top and bottom performers across all metro areas, demonstrating the enormous range seen across the country. However, as revealed in Figure 2, the level of variation among broader geographical regions in the West, South, and East is less clear, suggesting local dynamics may be a more important indicator of broadband adoption.

**Figure 2. Share of households with a broadband internet subscription in the 100 largest metropolitan areas, 2014**




Source: Brookings analysis of American Community Survey data

## Table 1. Metropolitan areas with the greatest and lowest share of households with a broadband internet subscription, 2014

| Metro area | Total households | Broadband households | Adoption rate |
|---|---|---|---|
| **Top 10** | | | |
| San Jose-Sunnyvale-Santa Clara, CA | 639,301 | 563,863 | 88.2% |
| Anchorage, AK | 135,449 | 117,299 | 86.6% |
| Bremerton-Silverdale, WA | 95,249 | 82,390 | 86.5% |
| Boulder, CO | 123,690 | 106,497 | 86.1% |
| Iowa City, IA | 64,409 | 55,392 | 86.0% |
| Colorado Springs, CO | 255,330 | 219,073 | 85.8% |
| San Diego-Carlsbad, CA | 1,100,858 | 944,536 | 85.8% |
| Provo-Orem, UT | 154,567 | 132,000 | 85.4% |
| Seattle-Tacoma-Bellevue, WA | 1,406,259 | 1,192,508 | 84.8% |
| Washington-Arlington-Alexandria, DC-VA-MD-WV | 2,154,147 | 1,824,563 | 84.7% |
| **Bottom 10** | | | |
| Yakima, WA | 79,700 | 51,407 | 64.5% |
| El Paso, TX | 256,548 | 165,217 | 64.4% |
| Lynchburg, VA | 98,399 | 63,271 | 64.3% |
| Lakeland-Winter Haven, FL | 218,286 | 139,921 | 64.1% |
| Greensboro-High Point, NC | 289,450 | 185,248 | 64.0% |
| Beaumont-Port Arthur, TX | 152,806 | 96,421 | 63.1% |
| Dothan, AL | 55,998 | 35,111 | 62.7% |
| Visalia-Porterville, CA | 132,742 | 82,433 | 62.1% |
| McAllen-Edinburg-Mission, TX | 226,000 | 131,306 | 58.1% |
| Laredo, TX | 70,418 | 39,575 | 56.2% |

Source: Brookings analysis of American Community Survey data

Note: Broadband households are estimated based on the metro area's total broadband adoption rates

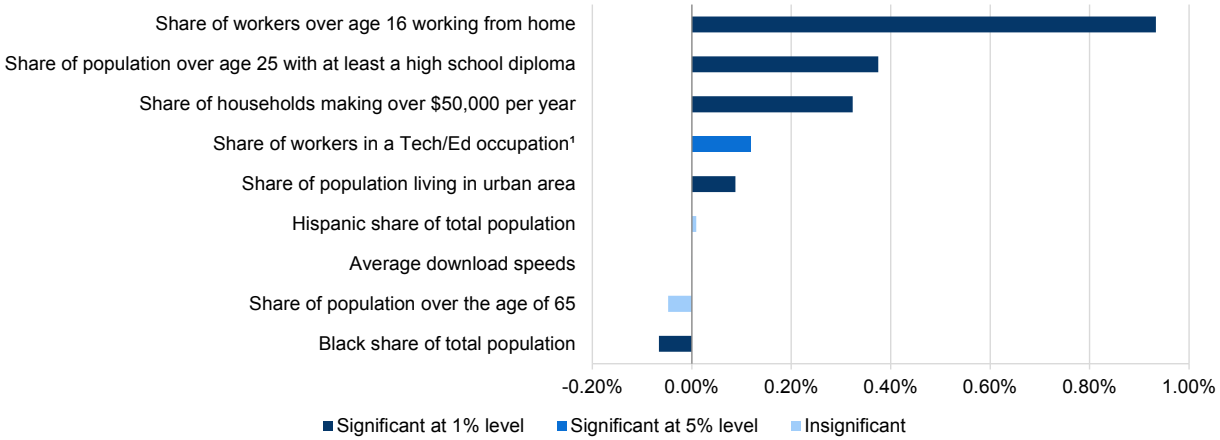
## Multiple factors—including higher levels of income, educational attainment, and telecommuting—all have a positive and significant effect on broadband adoption rates in metropolitan America.

National surveys—conducted by the Census Bureau, the Pew Research Center, and other organizations—have consistently found large variation in household broadband adoption across many demographic characteristics, including age, income, race, and

education.[9] While such cross-tabulations provide valuable context, they do not reflect the simultaneous influence of other relevant factors. This brief aims to addresses this shortcoming by developing a regression model to assess those variables of interest while controlling for other factors.[10]

Consistent with findings from national surveys, the model provides further evidence that income, education, and telecommuting had the largest effects on metropolitan broadband adoption in 2014 (Figure 3). Wealthier and more educated metro areas tend to have higher broadband adoption rates. Specifically, the model estimates a 1 percent increase in either the share of households making over $50,000 annually or individuals with at least a high school diploma is associated with a 0.3 percentage-point increase in metro adoption rates. Telecommuting has an even larger estimated effect, where a 1 percent rise in the share of all commuters working from home is associated with a 1 percentage-point increase in broadband adoption.

**Figure 3. Estimated change in metropolitan broadband adoption per 1 percentage point increase in the variable, 2014 Single Year ***




* adjusted $R^2$ = 0.750; n = 237; F = 79.51

¹: Any occupation classified under 2-digit SOC Codes 11, 13, 15, 17, 19, 23, 25, 27

Source: Brookings analysis of Census, Bureau of Labor Statistics, and Ookla NetIndex data

**9.** To find the most current Pew Research Center survey statistics on broadband adoption, visit http://www.pewinternet.org/fact-sheets/broadband-technology-fact-sheet/ [accessed October 2015].

**10.** In more technical terms, the model allows an examination of the effect of any given characteristic of interest while simultaneously controlling for others.

On the other hand, the model failed to find statistically significant evidence of an association between broadband adoption and two traditional demographic indicators of interest. Neither the share of population 65 and older nor the Hispanic share of total population registered a significant effect. In no way do these results contradict the demographic splits found in the ACS and previous surveys. Instead, they suggest top-line findings of earlier surveys may reflect a combination of other underlying factors. Older individuals tend to have lower broadband adoption, for instance, but these modeled results suggest that could be due to lower incomes or less education.[11] Yet not all traditional demographic splits were insignificant: The share of black population had a significant and small negative effect on broadband adoption. Overall, these results invite deeper investigation of demographic factors at a more local level.

The model also helps clarify the extent to which local broadband quality, development patterns, and industries can affect adoption rates. While media narratives often suggest deployment of higher-speed networks will boost local subscribership—and current data does show a wide range in average speed across the country—the model finds that faster download speeds are not yet associated with higher subscription rates.[12] Instead, the share of a metro's population living in urban areas is positively associated with adoption rates. This association may speak to a combination of different factors, including greater infrastructure deployment in denser areas, lower costs of service relative to rural areas, and potential network effects from neighbors using computers and the Internet.[13] In addition, with broadband connectivity of growing importance to many service-related industries, the share of workers in technology-, management-, and education-focused occupations registered a moderately significant (at the 5 percent level) effect.[14] The relative importance of industry was sensitive to model specification,

**11.** According to the Census, the country's over-65 population has the highest share of non-high school graduates and the lowest median household income among all over-25 age groups. Source: Brookings analysis of American Community Survey 2014 1-Year and 2012 3-Year data.
**12.** For an example of this narrative and the concept of Solow's paradox, see: Edward Wyatt, "Fast Internet Is Chattanooga's New Locomotive," New York Times, February 3, 2014.
**13.** For a thorough analysis of the urban/rural divide at the sub-metropolitan scale, see: David Beede and Anne Neville, "Broadband Availability: Beyond the Rural/Urban Divide," (Washington: National Telecommunications and Information Administration, Broadband Brief Number 2, 2013). For research on network effects in adoption, see: Austan Goolsbee and Peter Klenow, "Evidence on Learning and Network Externalities in the Diffusion of Home Computers," Journal of Law and Economics, Vol. 45(2), October 2002.
**14.** "Measuring the Digital Economy: A New Perspective," (Paris: Organisation for Economic Co-Operation and Development, 2014).

though, suggesting the need for further research into the relationship between occupations and broadband.[15] Still, the kinds of jobs people hold and where they live are important indicators of projected subscribership at the metro level.

Collectively, the model points to many different factors influencing broadband adoption rates in metro areas in 2014. Markets boasting higher levels of income, educational attainment, and urban density with many tech workers—like Seattle or university towns like Iowa City—tend to have the greatest rates of broadband adoption. On the other hand, markets with lower levels of income, educational attainment, and density with fewer tech workers tend to lag behind in adoption, including places like Memphis and Laredo, Tex. In turn, viewing broadband adoption at a metro scale is often tightly linked to several variables, many of which will need to be examined in greater depth and over longer timeframes to gauge their relative importance.

## From 2013 to 2014, the share of households with a broadband Internet subscription rose by 1.7 percentage points nationally, including a statistically significant increase among 58 of the country's 100 largest metropolitan areas.

Over the two years the American Community Survey has collected data on broadband adoption, approximately 2.6 million more households gained a broadband Internet subscription in 2014 compared to 2013, driving up the national share from 73.4 percent to 75.1 percent. At the same time, the share of households without a computer dropped from 16.2 percent to 14.9 percent. Collectively, these year-to-year changes point to a growing a reliance on high-speed Internet access—and digital hardware in general—that has resulted in an increased demand for broadband, in line with previous studies.[16]

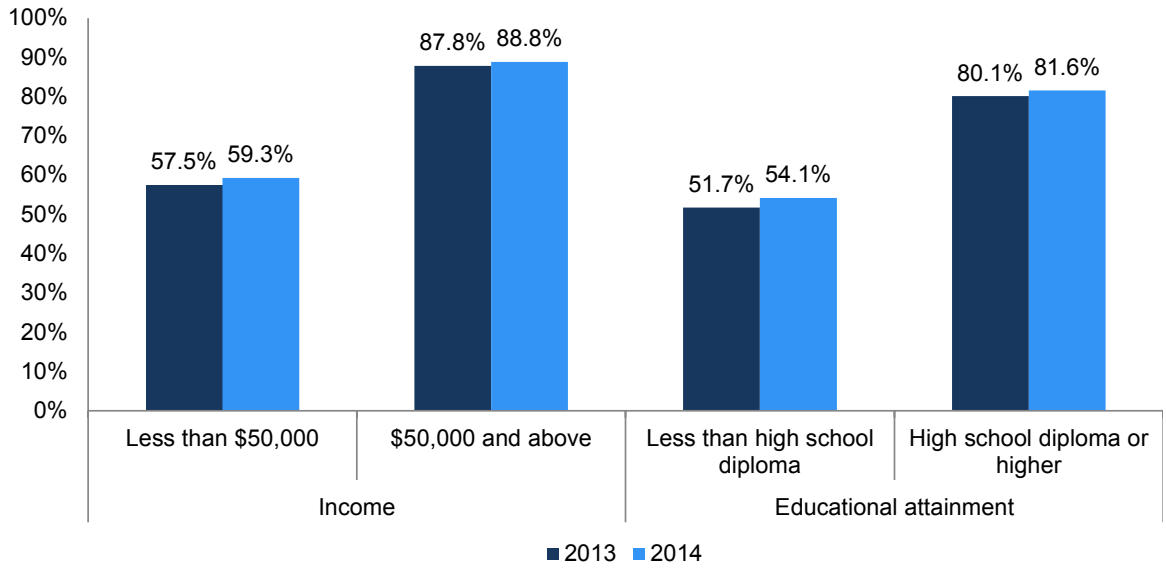
However, broadband adoption rates have continued to differ markedly among certain households and individuals, confirming two indicators of significance from the previous finding: income and educational attainment. For instance, while households with annual incomes under $50,000 tended to see their adoption rates increase the most from 2013 (1.8 percentage points), their overall shares remained considerably below households

**15.** See Appendix A for results of different regression models.

**16.** John Horrigan, "Adoption of Information and Communications Technologies in the United States: Narrowing Gaps, New Challenges" (Miami: Knight Foundation, August 2013).

earning more than $50,000 (59.3 percent compared to 88.8 percent). Individuals with less than a high school diploma made similarly high gains—jumping from 51.7 percent to 54.1 percent, or 2.4 percentage points— but they still lagged far behind individuals with a high school diploma or higher (81.6 percent). Although it's promising to see lower-income and less-educated groups increase their subscribership, these growth rates will need to accelerate even more to achieve adoption across the entire population.

**Figure 4. Change in Broadband Adoption By Levels of Income and Educational Attainment United States, 2013 to 2014**




Source: Brookings analysis of American Community Survey data

Note: Rates of broadband adoption are reported for households in terms of income, and for individuals in terms of educational attainment

The country's 100 largest metropolitan areas followed many of these national trends, with most markets seeing a statistically significant increase in broadband adoption. Almost 1.8 million more households in these metro areas had a broadband Internet subscription in 2014 versus 2013, accounting for 68 percent of the entire U.S. gain. While widespread, the largest increases overall were concentrated in the most populated metro areas, including 426,000 more households with a broadband subscription in New York, Los Angeles, Houston, Seattle, and Chicago.

### Table 2. 10 metro areas with the greatest increase in the share of households with a broadband internet subscription, 2013 to 2014

| Rank | Metro area | 2013 adoption rate | 2014 adoption rate | 2013 to 2014 change |
|---|---|---|---|---|
| 1 | Fresno, CA | 66.1% | 71.5% | 5.4% |
| 2 | Youngstown-Warren-Boardman, OH-PA | 63.6% | 68.9% | 5.3% |
| 3 | McAllen-Edinburg-Mission, TX | 53.7% | 58.1% | 4.4% |
| 4 | Tulsa, OK | 70.0% | 74.2% | 4.2% |
| 5 | Albany-Schenectady-Troy, NY | 76.9% | 80.8% | 3.9% |
| 6 | Hartford-West Hartford-East Hartford, CT | 76.9% | 80.7% | 3.8% |
| 6 | New Haven-Milford, CT | 72.7% | 76.5% | 3.8% |
| 8 | Charlotte-Concord-Gastonia, NC-SC | 74.7% | 78.1% | 3.4% |
| 8 | Richmond, VA | 74.0% | 77.4% | 3.4% |
| 10 | Dayton, OH | 71.7% | 74.9% | 3.2% |
| | **100 Largest Metro Areas** | **76.3%** | **77.8%** | **1.5%** |
| | **United States** | **73.4%** | **75.1%** | **1.7%** |

Source: Brookings analysis of American Community Survey data

### Table 3. 10 metro areas with the greatest increase in households with a broadband internet subscription, 2013 to 2014

| Rank | Metro area | 2013 broadband households | 2014 broadband households | 2013 to 2014 change |
|---|---|---|---|---|
| 1 | New York-Newark-Jersey City, NY-NJ-PA | 5,501,697 | 5,643,528 | 141,831 |
| 2 | Los Angeles-Long Beach-Anaheim, CA Metro Area | 3,294,909 | 3,404,651 | 109,742 |
| 3 | Houston-The Woodlands-Sugar Land, TX | 1,625,079 | 1,700,758 | 75,679 |
| 4 | Seattle-Tacoma-Bellevue, WA | 1,143,109 | 1,192,508 | 49,399 |
| 5 | Chicago-Naperville-Elgin, IL-IN-WI | 2,618,801 | 2,667,685 | 48,884 |
| 6 | Phoenix-Mesa-Scottsdale, AZ | 1,177,499 | 1,226,075 | 48,576 |
| 7 | Miami-Fort Lauderdale-West Palm Beach, FL | 1,499,939 | 1,547,778 | 47,839 |
| 8 | Charlotte-Concord-Gastonia, NC-SC | 642,203 | 689,842 | 47,639 |
| 9 | Atlanta-Sandy Springs-Roswell, GA | 1,536,118 | 1,577,232 | 41,114 |
| 10 | San Diego-Carlsbad, CA | 905,324 | 944,536 | 39,212 |
| | **100 Largest Metro Areas** | **58,097,773** | **59,862,980** | **1,765,207** |
| | **United States** | **84,783,856** | **87,398,926** | **2,615,070** |

Source: Brookings analysis of American Community Survey data

Note: Broadband households are estimated based on the metro area's total broadband adoption rates for 2013 and 2014

In total, 58 of the 100 largest metro areas saw a statistically significant increase in their broadband adoption rates compared to 2013, including 39 metro areas that exceeded the U.S. increase over this span (1.7 percentage points). The biggest gains—of 3 percentage points or more—tended to occur in metro areas with relatively low adoption rates to begin with, such as Fresno (66.1 percent to 71.5 percent), Youngstown (63.6 percent to 68.9 percent), and Tulsa (70 percent to 74.2 percent), which are building off a

number of initiatives.[17] Nonetheless, significant gains have also taken place in markets with higher adoption rates—those that were above 80 percent or more in 2013—like San Diego, Honolulu, and Ogden, Utah.

The 42 remaining metro areas saw little to no change. Many of these markets registered increases under 1 percentage point or less, with 11 other markets seeing a slight and insignificant decline. The largest drops were concentrated in the south, led by Greensboro (4.8 percentage points), Augusta (1.3 percentage points), and Lakeland (1 percentage point). In this way, while many metro areas are recording significant gains in broadband adoption, several others are declining or remain stuck in place, reinforcing the continued need to get more Americans online.

# Implications

National and local broadband adoption rates confirm the country's transition to a digital economy is well underway. Private subscribership rates at the national level continue to grow each year, connecting millions of more Americans to digital information networks. Meanwhile, leading metro areas like San Jose and Washington, D.C. demonstrate how rates have the potential to get even higher around the country.

However, completing the transition to an all-digital economy will be impossible until broadband adoption looks ubiquitous like water and electricity infrastructure.[18] And much like electricity development in the 20th century, ensuring every American has reliable online access is a clear 21st century mandate to maintain the country's global economic preeminence.

The results of this brief begin to sketch a roadmap to get there.

Targeted income assistance programs are a clear priority. Some of these policies will be set at the federal level, including efforts already underway; a reformed Lifeline program and the newly-announced ConnectHome will both improve broadband availability

**17.** For example, the Fresno Housing Authority and the City of Fresno are working with a variety of regional partners to accelerate broadband adoption, as noted in the following July 15, 2015 press release: http://www.fresnohousing.org/wp-content/uploads/2015/07/ConnectHome-Press-Release-7.15.15.pdf [accessed October 2015].
**18.** Source: Brookings analysis of World Bank data.

and affordability for low-income households.[19] However, regional programs must also address local needs. In addition, there will need to be greater coordination across all government levels with private Internet service providers, most of whom already have a demonstrated commitment to community investment, despite lingering questions over civic transparency.[20]

Expanding digital skills curricula and training are equally important—and they should extend across entire metro areas.[21] Digital literacy classes and training programs, for instance, can help prepare young students for their digital future and offer opportunities for adults to improve their digital skills today. Community assets like libraries are especially important in this respect, by providing public Internet access and representing centers for training.[22] Fortunately, the recently-expanded federal eRate program will help communities build capacity at their schools and libraries, in particular.[23]

Public and private sector employers should also continue to incentivize telecommuting for both broadband and transportation benefits.[24] Many of the largest metro areas with the highest broadband adoption rates also have some of the country's worst roadway congestion—places like Washington, D.C. and San Jose. Telecommuting could both help get more households online and better maximize the transportation capacity already built

**19.** Lifeline 2015 reform proposal can be found online at https://www.fcc.gov/document/fcc-releases-lifeline-reform-and-modernization-item [accessed October 2015]. The ConnectHome announcement can be found online at https://www.whitehouse.gov/the-press-office/2015/07/15/fact-sheet-connecthome-coming-together-ensure-digital-opportunity-all [accessed October 2015].
**20.** For one example of a private program, see: Mike Snider, "Comcast upgrades its Internet essentials plan," USA Today, August 4, 2015.. For one example regarding transparency, see: Emily Hong, Laura Moy, and Isabelle Styslinger, "Broadband Truth-in-Labeling: Empowering Consumer Choice through Standardized Disclosure," (Washington, DC: New America Foundation, July 2015).
**21.** Jessica A. Lee and Adie Tomer, "Building and advancing digital skills to support Seattle's economic future" (Washington: Brookings Institution, October 2015).
**22.** Amy Garner, "Rising to the Challenge: Re-Envisioning Public Libraries" (Washington, DC: Aspen Institute, October 2014).
**23.** For coverage of the eRate expansion, see: Edward Wyatt, "F.C.C. Increases Money for E-Rate Program for Internet in Schools and Libraries," New York Times, December 11, 2014.
**24.** For a thorough discussion of telecommuting's benefits and costs, see: Tammy D. Allen, Timothy D. Golden, and Kristen M. Shockley, "How Effective Is Telecommuting? Assessing the Status of Our Scientific Findings," Psychological Science in the Public Interest, Vol. 16, no. 2, October 2015.

in these regions.

Finally, continuing development of those federal and local policy roadmaps will also require continued research into broadband adoption. As demonstrated by the wide range in metropolitan adoption rates, it's especially important to understand the local neighborhoods that drive high or low metropolitan performance, and how other variables may impact neighborhood-scale adoption. Considering the macro importance of getting the entire country online, the results of this study are really just a start. ■

# Appendix A. Statistical Methodology

## Data Sources

This brief uses data from the United States Census Bureau (Census), Bureau of Labor Statistics (BLS), and Ookla to measure national and metropolitan broadband adoption between 2013 and 2014. Metropolitan areas use the 2013 delineations created by Census and the Office of Management and Budget.

The primary dataset for broadband adoption—both at the national and metropolitan scale—comes from Census' American Community Survey (ACS). The ACS introduced a series of broadband-related questions in 2013, making that year's 1-year estimates the first time ACS published related broadband statistics. To assess adoption rates and related cross tabulations for both 2013 and 2014, we use national data from Tables B28001 through B28009 and metropolitan data from Table GCT2801.[25]

The other datasets were used as independent variables to better understand what affects metropolitan broadband adoption (see the next section for more information on the model). The majority of the indicators are also from the ACS 2014 1-year estimate tables, including: Share of Households Making over $50,000 per Year; Share of Workers over Age 16 Working from Home; Share of Population over Age 25 with at least a High School Diploma; and Share of Population over the Age of 65. Due to the need for larger sample sizes, the most recent estimates of a metro area's black (non-Hispanic) population or Hispanic (any race) are from the 2013 3-Year ACS estimates. Estimating the urban share of a metro area's population is only provided every 10 years, meaning

**25.** Table B28009 actually includes nine separate tables for nine different race and ethnicity categories.

this report uses the 2010 estimates.[26] To estimate the share of workers in occupations that rely heavily on computers—termed "Tech/Ed" occupations in our analysis—we use BLS data from 2014 for eight major groups.[27] Finally, the download speeds data is from Ookla's NetIndex. Since NetIndex reports data for multiple jurisdictions within metro areas, we used a weighted average based on the population of the reporting jurisdiction.

The only dataset included in the brief not reported directly by Census or Ookla is the number of broadband households in a metropolitan area. To impute that estimate, we multiply the share of metropolitan households reported to be broadband subscribers (ACS Table GCT2801) by the total number of households in the metro area (ACS Table DP02). As a result, the quantity of broadband households within this brief should be cited as "Brookings Institution estimates of American Community Survey data."

## Regression Model and Results

The brief uses an Ordinary Least Squares (OLS) multiple regression to investigate the association between demographic, economic, and infrastructure variables and metropolitan broadband adoption rates. The model is based on single year of data from 2014, with three exceptions: urban share of a metro area's population, black share of population, and Hispanic share of population. The model did not include female or male share of metropolitan population because past research work did not find rates varying by gender. [28]

We predict broadband adoption rates based on the following formula:

$$Y_m = \beta_0 + \beta_1 X_{1,m} + \cdots + \beta_p X_{p,m}$$

Where m designates metropolitan area and p designates the nine independent variables.

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**26.** While the urban/rural population estimates are from 2010, we use a county-to-metropolitan area crosswalk to match the estimates to 2013 metropolitan area definitions.
**27.** The eight Standard Occupational Classification (SOC) major groups are: Management Occupations (11); Business and Financial Operations Occupations (13); Computer and Mathematical Occupations (15); Architecture and Engineering Occupations (17); Life, Physical, and Social Science Occupations (19); Legal Occupations (23); Education, Training, and Library Occupations (25); and Arts, Design, Entertainment, Sports, and Media Occupations (27).
**28.** Andrew Perrin and Maeve Duggan, "Americans' Internet Access: 2000-2015" (Washington, DC: Pew Research Center, 2015).

The nine independent variables are: Share of Households Making over $50,000 per Year; Share of Workers over Age 16 Working from Home; Share of Population over Age 25 with at least a High School Diploma; Share of Population over the Age of 65; Share of Workers in a Tech/Ed Occupation; Average Download Speeds; Share of Population Living in Urban Area; Black Share of Total Population; and Hispanic Share of Total Population.

### Table A1: Regression of Variables on Metropolitan Broadband Adoption Rates, 2014 Single Year+

| Variables | Model 1 | Model 2 | Model 3 | Model 4 |
|---|---|---|---|---|
| Share of households making over $50,000 per year | 0.437*** | 0.355*** | 0.323*** | 0.353*** |
| | (0.0318) | (0.0387) | (0.0397) | (0.0421) |
| Share of workers over age 16 working from home | 1.165*** | 1.062*** | 0.934*** | |
| | (0.152) | (0.148) | (0.160) | |
| Share of population over age 25 with at least a high school diploma | 0.282*** | 0.331*** | 0.375*** | 0.469*** |
| | (0.0400) | (0.0409) | (0.0763) | (0.0798) |
| Share of population over the age of 65 | | | -0.0477 | 0.065 |
| | | | (0.0740) | (0.0765) |
| Share of workers in a Tech/Ed occupation | | 0.0993* | 0.118** | 0.187*** |
| | | (0.0523) | (0.0558) | (0.0583) |
| Average download speeds | | -0.000242 | -0.000109 | 0.000057 |
| | | (0.000356) | (0.000353) | (0.000377) |
| Share of population living in urban area | | 0.0833*** | 0.0877*** | 0.0838*** |
| | | (0.0192) | (0.0218) | (0.0233) |
| Black share of total population | | | -0.0662*** | -0.0796*** |
| | | | (0.0240) | (0.0256) |
| Hispanic Share of Total Population | | | 0.00888 | 0.0431 |
| | | | (0.0267) | (0.0279) |
| Constant | 0.225*** | 0.146*** | 0.130** | 0.0382 |
| | (0.0327) | (0.0374) | (0.0658) | (0.0683) |
| Observations | 238 | 238 | 237 | 237 |
| R-squared | 0.718 | 0.745 | 0.759 | 0.723 |

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

+: All data from 2014 except Share of Population Living in Urban Area (2010) and Black and Hispanic Share of Total Population (2013 3-Year Estimates)

Source: Brookings analysis of Census, Bureau of Labor Statistics, and Ookla data

The results of this regression, plus three alternative models, are shown in Table A1. All told in Model 3—the preferred model—five variables were found to have significance at the 1 percent level, and a sixth variable was significant at the 5 percent level. Overall, this model explains about three-quarters of the variation in broadband adoption for the 237 metro areas that had data for all fields.

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## For More Information

**Adie Tomer**
Fellow
Brookings Metropolitan Policy Program
atomer@brookings.edu

**Joseph Kane**
Senior Research Assistant
Brookings Metropolitan Policy Program
jkane@brookings.edu


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1775 Massachusetts Avenue, NW
Washington D.C. 20036-2188
telephone 202.797.6000
fax 202.797.6004
**www.brookings.edu**

**Metropolitan Policy Program**
telephone 202.797.6139
fax 202.797.2965
**www.brookings.edu/metro**

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