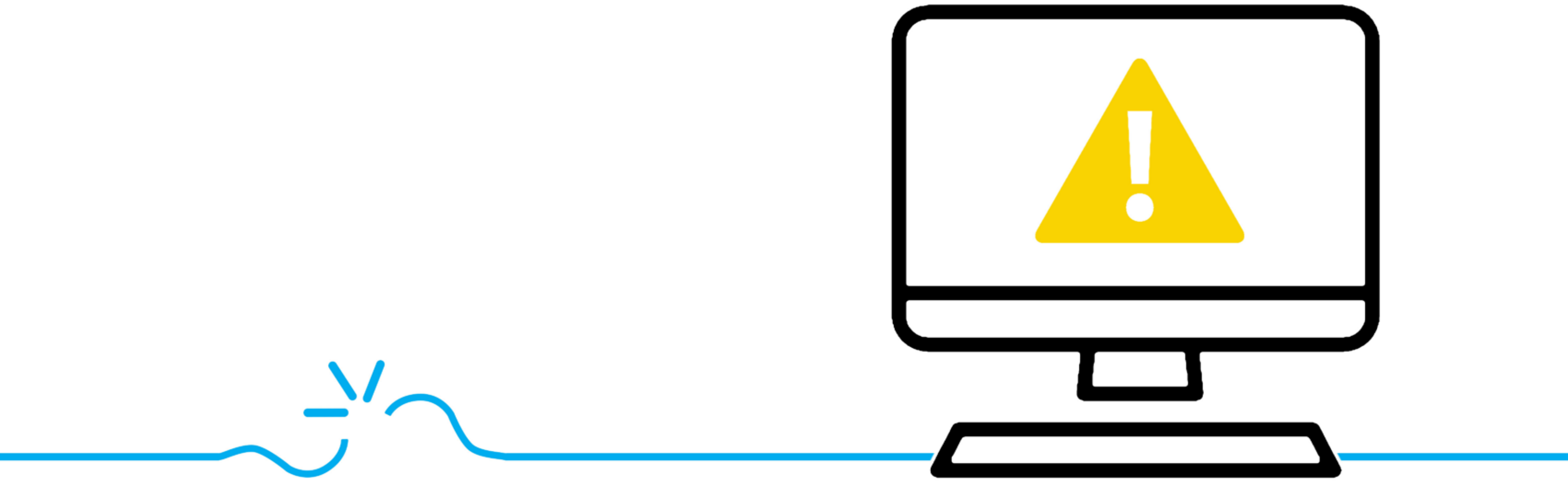

SIGNS OF DIGITAL DISTRESS

Mapping broadband availability and subscription in American neighborhoods

Adie Tomer, Elizabeth Kneebone & Ranjitha Shivaram

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EXECUTIVE SUMMARY

The internet is now a fundamental component of the American economy, creating new ways to educate, employ, bring services to, and entertain every person. Broadband, especially wireline broadband in American homes, is the essential infrastructure for unlocking the internet's economic benefits. However, broadband infrastructure is far from ubiquitous, both in terms of where it operates and who subscribes to it, and those deficits are not shared evenly across the country. As such, policymakers have a responsibility to understand a national digital divide that has different contours depending on the place.

Using data from the Federal Communications Commission and the American Community Survey, this paper assesses broadband's deployment and consumer subscriptions at the census tract level. It finds:

As of 2015, broadband services were available to 93 percent of the nation's population, but large availability gaps existed in lower-density areas. In December 2015 the vast majority of residents in the United States lived in communities served by wireline broadband that offered download speeds of at least 25 Mbps. However, more than 22 million people lacked such services in their neighborhoods. Geography, rather than demographic characteristics, is the predominant factor determining broadband services available to them: more than half of residents who lack access to broadband live in rural America.

Most major metro areas offer near complete broadband coverage to their residents, but lower-density, more agriculturally focused regions in the South and West lag behind. Among the 100 largest metro areas, five in Florida and five others—ranging from Akron, Ohio to Salt Lake City—have achieved 100 percent broadband coverage for their residents. Yet even among metro areas with near universal broadband availability, deployment gaps can leave tens of thousands of residents without the option of broadband.

Over 73 million people (23 percent of the nation's population) live in neighborhoods where in-home broadband subscription rates fall below 40 percent. In contrast, just 18 percent of the nation live in neighborhoods where subscription rates exceed 80 percent. Neighborhoods most likely to lag behind are those with lower incomes, lower educational attainment levels, and an aging population.

Nearly every large metro area includes neighborhoods with subscription rates below 40 percent, but the gaps are largest in less dense regions. Over half of the population in metropolitan

McAllen, Texas, Albuquerque, N.M., and Boise City, Idaho live in neighborhoods where subscription rates fall below 40 percent. Conversely, in metropolitan Washington, Honolulu, and four other metro areas, over half the population lived in neighborhoods with subscription rates over 80 percent.

Eighteen of the 20 metro areas that rank highest on a combined index of broadband availability and subscription are in Florida, the Northeast, and the Pacific Coast. Top performers include some of the nation's largest metro areas like New York and San Francisco, but also relatively smaller places like Palm Bay, Fla. and Oxnard, Calif. Conversely, 15 of the 20 lowest-ranking metro areas lie largely in the Southeast and Great Plains.

While the nation still falls short of complete broadband coverage—especially in rural America—geographic and demographic disparities in who subscribes to wireline broadband subscription drive today's digital divide. Addressing the availability and subscription gaps that limit economic opportunity in specific neighborhoods requires a balanced policy framework and collaborative partnerships between the private, public, and civic sectors. Considering that broadband is essential infrastructure in today's digital economy, the status quo limits American competitiveness and equitable access to economic opportunity. Less than two decades into the new century, the internet is already an unquestioned foundation of the modern American economy and the American home.

01 INTRODUCTION

Less than two decades into the new century, the internet is already an unquestioned foundation of the modern American economy and the American home.

Much as with the introduction of electricity in the 20th century—an innovation that changed how people lit their rooms, cooked their food, washed their clothes and dishes, and entertained themselves—the internet is redefining how the 21st century household operates. Job seekers can scan online job boards and socially network with colleagues. Internet-connected applications allow families to control their lights and thermostats from anywhere in the world. Internet-based companies can ship fresh dinner ingredients straight to front doors, or households can order carryout via internet-connected devices. Each year, more people use the internet to stream videos and play games.

Like electricity, the internet can also substitute for entire tasks that used to require a trip outside the home. Streaming video and digital blackboards create virtual classrooms in any room with a computer. Video conferencing and remote file access redefine what a home office can be. Telemedicine even brings health care into the home.

A high-speed internet connection—what's known as broadband—is the newest essential infrastructure. But to maximize its economic potential, broadband must be both physically available to and adopted by every home. These twin objectives stand at the center of national policy via the National Broadband Plan.[1]

Based on the transformative power of the internet, researchers inside and outside government have long understood the importance of mapping

broadband availability and adoption. The existence of significant shares of households without a connection or subscription came to be known as the digital divide, and regular studies of the national digital divide since the late 1990s created a benchmark for U.S. broadband penetration.[2] But because broadband deployments and subscription patterns can vary significantly from one neighborhood to the next, these national studies say little about local conditions and needs.

This report generates new measures of the digital divide by using neighborhood-level indicators to assess national and local measures of in-home broadband availability and adoption. In the process, the findings create a more granular view of broadband needs across the country.

The report begins by outlining broadband's importance to the American economy and current perceptions of the digital divide. After a brief review of methodology, the first two findings compare broadband availability at both the national and local levels. The following two findings assess what is driving broadband subscription and where gaps exist at the neighborhood and metropolitan scale. The fifth finding offers a composite ranking—combining availability and subscription—of the largest metro areas. The report concludes with a set of policy implications for all governmental levels.

Definitions

Availability **—** The Federal Communications Commission (FCC) considers fixed broadband connections to be available in a specific geography if the service provider can provide two-way data transmission to end users at or above the specified speed that is typical for that type of connection.[3] In this report, availability of fixed, wireline broadband connections is used to denote whether the majority of a census tract's residents can access fixed, wireline broadband service at or above the specified speed. Availability is sometimes also referred to as coverage and used in conjunction with the phrase "broadband deployment." For instance, the FCC uses a metric called the deployment rate, which is "the ratio of the population with access to fixed broadband service at or above the specified speed to the total population."[4]

Subscription **—** In this report, the rate of subscription is the share of a census tract's population with a fixed subscription of a specific speed. Subscription is a major component of the broader concept of broadband adoption, which also considers whether an individual uses broadband.

02 BACKGROUND

Broadband is an inherently flexible term. Intrinsically, it refers to a high-speed connection to the internet that is always available. Yet as digital telecommunications continue to evolve, so too do definitions of what qualifies as broadband-level speeds. Moreover, the term is not limited to only one transmission technology. Any of the multiple technologies that deliver digital telecommunications to end users—including digital subscriber lines (DSL), cable, fiber, or satellite—can qualify as broadband.

This paper specifically focuses on wireline broadband.[5] While wireless data plans have exploded in popularity since 2011, wireline broadband continues to offer multiple benefits to household users.[6] Specifically, it delivers higher connection speeds, permits greater cross-platform security, typically includes unlimited data, and maximizes a mobile device's utility via high-speed WiFi.[7] As such, wireline broadband is a critical, in-home gateway to the content, applications, and services that enable households to participate in a digital economy.[8] Additionally, there is a concern that individuals who rely exclusively on wireless plans—and who tend to be lower income, younger, and more racially diverse—are limited in their capacities to tap the internet's potential.[9]

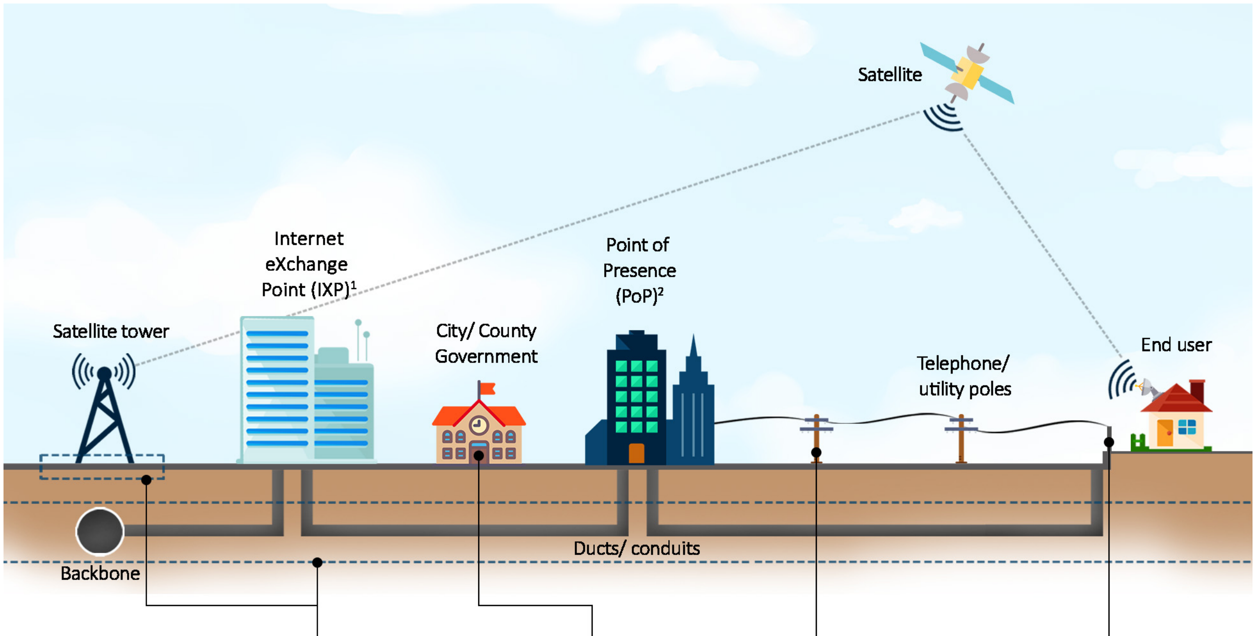
How does wireline broadband work?

Most households see broadband only as the cable or telephone line running from a socket in their wall to a modem and, increasingly, to a WiFi router sending signals across their home. But delivering wireline broadband to homes relies on an expansive collection of fixed telecommunications infrastructure (Figure 1).

The process begins with internet backbone

FIGURE 1

America's privately built, publicly regulated broadband infrastructure



Level of regulation

	Right-of-Way Permits	Franchise Agreement	Pole Permits	Last-mile Access
Federal	Permits to access federal lands, buildings, highways and roadways to build and operate broadband infrastructure	Contract between service provider and local government required by Cable Communications Act of 1984	Access to poles owned by investor-owned utilities in states that had no pole regulation prior to Pole Attachment Act	
State	Permits to access state lands, buildings, highways and roadways to build and operate broadband infrastructure	State-wide cable/ video franchise agreements issued by the Department of State or Public Utilities Commisions	Access to poles owned by investor-owned utilities in states that pre-empted federal pole regulation, and to poles owned by public electric cooperatives and municipalities	
Local	Franchise agreements typically subsume right-of-way permits to access local public and private land, buildings and roadways to build and operate broadband infrastructure. Franchise agreements can also include franchise fees, programming requirements and customer service standards.		Access to poles owned by public electric cooperatives and municipalities in states that have no specific pole regulation	Access to customers in individual/ multiple dwelling units often determined by exclusive contracts between owners/ homeowners' associations and provider

[1]Internet eXchange Point (IXP)- Typically, a location that facilitates the costless/ low-cost exchange of internet traffic between the networks of different Internet Service Providers through mutual peering agreements.
[2]Point of Presence (POP)- Typically, a location where a long-distance carrier's cables end and connect into a local network, such as a regional or city network. From the point of presence, internet traffic is routed to the end user.

Source: The Brookings Institution

infrastructure, internet exchange points (IXP), and points of presence (PoP)—the privately held cables and exchanges that connect in-home devices to servers across the world. While private internet service providers (ISPs) and other telecommunications firms are responsible for constructing such long-distance infrastructure and ensuring its stable operation, any access to and construction along public rights-of-way—typically streets—requires permission of the relevant government authority. Whether the cables cover long distances or sit within local broadband infrastructure, and whether cables run under streets or from telecommunications poles, connecting private homes and larger buildings to global broadband infrastructure requires rights-of-way access. All along the way, different levels of government carry different responsibilities to regulate the physical delivery of internet data to the end user. Figure 1 details some of the major responsibilities, and Appendix A describes them in more detail.

While complex in nature, the system of privately managed infrastructure and public regulation depicted in Figure 1 created a platform that allowed most of America to go online. As of June 2016, there were 104 million fixed internet subscriptions in the United States.[10] Although this figure does not discern by speed, it does reflect the roughly 73 percent of adults who subscribe to wireline broadband service.[11]

Why does wireline broadband matter?

As wireline broadband deployment grows, both in terms of physical reach and speed thresholds, macro- and microeconomic outcomes are increasingly intertwined with the digital innovation enabled by reliable, fast, and secure internet connections in American homes.

The internet is now an indispensable resource for workers, both actively employed and seeking employment. As of 2015, 79 percent of Americans who looked for work in the last two years used online resources and information in their job searches.[12] At the same time, telecommuting has become a tangible alternative to onsite work: in 2016, 24 percent of Americans did some or all of their work at home on the days that they worked, with the percentage rising to 34 percent for management workers.[13] Creating materials for job applications, searching for employment, and working from home are all made possible by wireline broadband. Of course, the modern workplace—including service, manufacturing, and government industries—all rely on dependable broadband to execute their work.

Regional broadband also helps grow the United States' advanced industries. Relying on a combination of workers trained in science, technology, engineering, and math (STEM) and relatively large R&D investment, the country's 50 advanced industries employ about 9 percent of all workers, and the average pay is nearly twice that of jobs outside the supersector.[14] These knowledge-intensive firms often choose their locations based on broadband availability.[15] An in-home broadband connection enables workers to develop their digital skills and become valuable assets to these digitally connected industries—and then telecommute once on the job.

Beyond the workplace, wireline broadband provides access to many activities that are integral to the well-being of American households. Commerce has gone digital, with around eight in 10 Americans now shopping online, 15 percent of them on a weekly basis.[16] The same transition is underway with in-home entertainment, where roughly 75 percent of non-Baby Boomers subscribed to a video streaming service in 2017.[17] Similarly, 70 percent of Americans use social media to connect with one another, read news content, share information, and entertain themselves.[18] Wireline broadband also carries the majority of cellular data, showing how the more communication-driven functions of smartphones tend to rely on WiFi and other connections to fixed infrastructure.[19]

These direct benefits to households combine to create significant aggregate economic benefits, too. Broadband helps metropolitan areas attract top talent from around the world and thus boosts their long-term competitiveness.[20] Within a community, broadband can raise home values and, in the process, increase local tax revenues.[21] Research also consistently finds that broadband—including in-home connectivity—helps add jobs, business establishments, and a more diverse industry mix.[22] Greater broadband adoption can even raise per capita incomes across entire countries.[23] Getting more people online within a community can address issues of data poverty and create cost savings for government operations.[24] Based on this research, plus more featured by the White House Council of Economic Advisors, broadband is a powerful and necessary economic engine for the digital age.[25] But the question remains: will it be an inclusive force, or will it only deepen disparities between socioeconomic groups?

Why is it important to understand broadband deployment and subscription at the neighborhood scale?

Neighborhood-level analyses of broadband infrastructure and uptake are essential for better identifying and addressing deployment gaps within regions, municipalities, and rural counties. At the same time, disaggregating metrics on the digital divide down to the neighborhood level also allows policymakers and practitioners to more effectively target their limited resources to boost adoption among the lagging populations and neighborhoods that stand to benefit most from those efforts.

Neighborhood-level broadband conditions can indicate which neighborhoods are most likely to be left behind in a digital era. Chicago's multiyear Smart Communities program—which offered digital literacy and other training in targeted, low-income neighborhoods—proved that more residents will access job and health care services when they receive a neighborhood-wide intervention to promote broadband use.[26] These promising results suggest that getting entire neighborhoods online can lead to greater economic outcomes, but they also confirm that neighborhoods struggling with broadband subscription are important focus areas for inclusive economic development planning.

There may also be a case for further study to understand the "neighborhood effects" of broadband deployment and subscription, much like work around neighborhood concentrated poverty.[27] For instance, neighborhood broadband conditions—the presence of broadband connectivity and total subscription levels within a small geography—could create spillovers that impact the entire population in those neighborhoods and even the broader region. Much like the broader phenomenon of network effects within the infrastructure sector, the more (or less) people who can access and subscribe to broadband the better (or worse) a neighborhood will be situated across multiple critical policy dimensions.

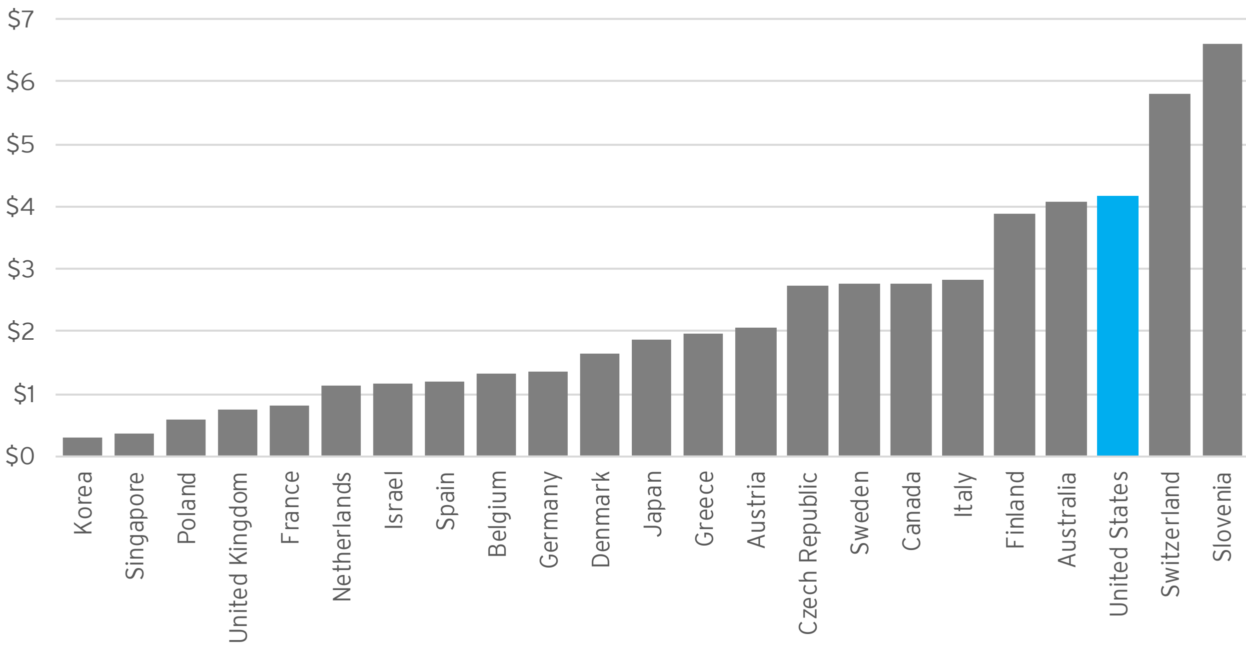
Consider education. Since school catchment areas tend to match neighborhoods in size, schools serving neighborhoods with either poor broadband availability or lower broadband subscription rates will face distinct challenges in executing a digital curriculum. This is especially the case for one-to-one device programs, which provide every student with a mobile computing device.[28] While the devices' broadband capabilities likely can be used within school facilities, many students will not be able to tap their device's full potential once they go home. The opposite is then true for schools (or entire school districts) where every child lives with an in-home broadband connection. Those schools will more easily execute digital curricula, to the long-term benefit of all students.

Limited broadband service and subscription rates can increase costs for government service

FIGURE 2

Broadband service in the United States is more expensive compared to similar service in other countries

Average price of fixed broadband plans per Mbps of download speed, by country, 2014 ($US)



Source: Federal Communications Commission, Fifth International Broadband Data Report, 2016

programs that rely on targeted delivery. Consider food assistance programs that may want to streamline food deliveries and attract the most at-risk populations, or job training programs that could be delivered remotely to interested individuals. Clusters of non-broadband subscribing individuals will slow local governments' transition to such digital programs, resulting in higher costs and limited effectiveness. Such higher costs impact entire communities that must pay more for public programs that offer the same level of service (or less) as those in more digitally connected places.

Such questions merit additional research. Not only does the following analysis provide a baseline understanding of neighborhood conditions that could help inform those inquiries, but it also offers immediately informative and actionable metrics for policymakers and practitioners looking to close deployment and subscription gaps in their communities.

The persistent digital divide

Even with the immense benefits in-home broadband brings to people and their neighborhoods, broadband access and adoption are not ubiquitous. Since at least the late 1990s, researchers have used the digital divide framework to study these dual challenges.[29]

From the supply side, market dynamics impact private-sector deployments.[30] Since telecommunications firms need revenues to justify infrastructure construction and operation, population density and average income affect availability in critical ways.[31] In particular, far-flung and sparsely populated rural areas are often underserved relative to their metropolitan peers.[32] Competition can also significantly influence the quality of service offered, especially for minority groups.[33] Even up against these equity hurdles, broadband deployment has seen a significant uptick, and the quality of service continually improves.[34]

Broadband adoption is a more persistent challenge. Across a wide range of applied research, a consistent set of socioeconomic factors have been found to drive disparities in subscription rates.[35]

As the Pew Research Center's long-running survey series regularly finds, price is a major adoption barrier.[36] Confirming this work, other research found that a 10 percent increase in subscribership could require a price reduction of as much as 15 percent.[37] These findings are especially concerning for those living in poverty, who may need targeted subsidies to connect to the digital economy within their homes.[38] One important consideration is the clear price gap between comparable broadband service in the United States and its developed peers (Figure 2).[39] Though the figure doesn't take into account the fact that some domestic ISPs offer cheaper pricing plans at lower speeds, the general finding holds that U.S. broadband is relatively expensive. And while broadband pricing involves multiple, complex factors—including how firms must balance revenues and investment needs, and how countries approach regulation differently—boosting adoption will require balancing variable willingness and ability to pay among different populations.[40]

Digital readiness and access to equipment are other consistent adoption barriers. In this instance, digital readiness includes both digital skills—such as the ability to use digital hardware and software to manage information, communicate, navigate the internet, solve problems, and create content—and trust in digital platforms.[41] A lack of digital readiness is especially prevalent among older, non-Asian minority, less-educated, and lower-income individuals.[42] A lack of in-home computing equipment also functions as a major barrier, although community centers like libraries can function as substitutes.[43] Indeed, 97 percent of public libraries now offer free Wi-Fi access.[44] However, community internet access points may not lead to greater in-home adoption.[45] More troubling, a lack of in-home equipment can have a negative impact on school enrollment for youth.[46]

To develop effective and equitable policies that address the digital divide, governments at all levels must clearly understand where gaps exist, both in terms of availability and subscriptions. The following research provides just such a roadmap.

03 DATA AND METHODS

To assess the availability of wireline broadband service across places and population groups in the United States, and the extent to which people subscribe to broadband where it is available, we compiled fixed broadband deployment and subscription data from the FCC's Form 477 and demographic data from the U.S. Census Bureau's American Community Survey (ACS) for every census tract in the nation. Census tracts—often used as proxies for neighborhoods—represent the lowest level of geography for which the full complement of relevant FCC variables is available. To ensure that the data align temporally, we use Form 477's December 31, 2015 dataset and the ACS 2015 five-year estimates.[47]

Together, these data allow us to analyze two key metrics:

Availability. We determine whether broadband internet is available to (or has been "deployed" to) a neighborhood based on FCC data that identify the number of service providers offering fixed, wireline broadband services (i.e., high-speed internet service not delivered through mobile technologies) in each census block as of December 2015. We aggregate census block data up to census tracts to be consistent with the level at which the FCC reports subscription data (described in more detail below). We consider a census tract "covered" by broadband if at least half of its census block residents have the option to purchase fixed, wireline broadband-speed internet service from at least one provider. This method produces aggregate results extremely close to other national studies. In addition, it allows us to join tract-level demographic data from the ACS to the FCC data to assess population and

neighborhood characteristics (e.g., education and income levels) not available at the block level. However, this approach does introduce a modest level of assignment error when looking at specific tracts.[48] Appendix B expands on this point.

We focus in particular on the 25 Mbps download speed threshold, as it is the current standard in the United States for determining what constitutes broadband.[49] In particular, this is the advanced speed to originate and receive high-quality voice, data, graphics, and video telecommunications. However, because the definition of broadband has evolved and continues to do so, we also consider patterns of availability according to alternative speed thresholds (e.g., 10 Mbps download speed, which is one prevailing international standard).

Subscription. The FCC provides tract-level information on the share of residents that had subscribed to a fixed connection internet access service at download speeds of at least 10 Mbps and upload speeds of at least 1 Mbps as of December 2015.[50] Rather than reporting the actual proportion of households subscribing to a fixed service that meets those speed thresholds, the FCC assigns each tract to one of six subscription categories: 0 percent, 0 to 20 percent, 20 to 40 percent, 40 to 60 percent, 60 to 80 percent, or 80 to 100 percent.[51]

For the purposes of this analysis, we collapse these demarcations into three tiers of subscription. By our definition, a *low subscription neighborhood* is one where fewer than 40 percent of households subscribed to broadband as of December 2015 (or, put differently, a neighborhood where most households did not subscribe to broadband). A *moderate subscription* neighborhood had adoption rates between 40 and 80 percent, and a *high subscription* neighborhood had more than 80 percent of its households connected to high-speed, fixed service by the end of 2015. Recognizing that subscription levels are undoubtedly influenced by the extent to which broadband service is available in a neighborhood in the first place, the analysis in the paper's final finding combines both availability and subscription metrics.

Using these tract-level availability and subscription designations in combination with tract-level ACS data, we assess the size of the population (both numbers and shares of people) living in neighborhoods with and without broadband service and in neighborhoods with low, moderate, and high subscription rates, as well as the characteristics of those residents (e.g., age, race, poverty status, educational attainment).

In addition to neighborhood measures of broadband availability and subscriptions, we also aggregate tracts to assess geographic patterns in the nation's 100 most populous metropolitan areas, including in their major cities and surrounding suburbs. By our definition, cities include the first city in the official metropolitan statistical area title and any other city in the title with a population over 100,000, while suburbs account for the remainder of the metro area. We also report findings for the nation's smaller metropolitan regions and rural communities (or tracts that fall outside of metropolitan statistical areas).[52]

Finally, all mentions of broadband speeds reference download speeds unless otherwise noted.

04 FINDINGS

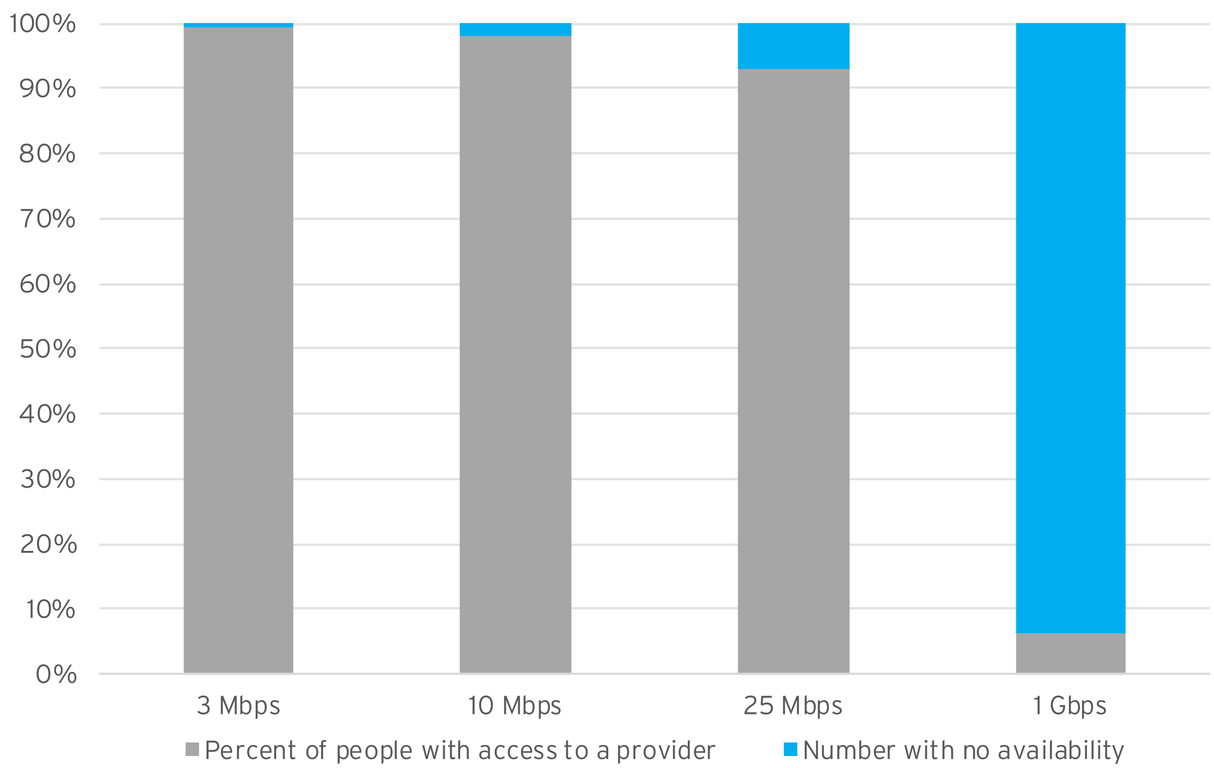
Finding 1: As of 2015, broadband services were available to 93 percent of the nation's population, but large availability gaps existed in lower-density areas.

After multiple decades of build-out, broadband connections are now available to most of the population, but the variation in deployment at higher speed thresholds reveals growing gaps in availability (Figure 3). Nearly the entire population has the option to connect to the internet at slower speed tiers like 3 Mbps, but those speeds can restrict the ease of even basic web browsing.[53] Availability is nearly as high for 10 Mbps service, a level that could still limit certain multi-user and/or high-use web activity. The 25 Mbps threshold represents the official definition of "advanced telecommunications capability" in the FCC's Broadband Progress Report. Here, availability drops again, but still exceeds 90

FIGURE 3

The gap in broadband availability grows considerably as download speeds increase

Broadband availability in the United States by advertised download speeds



Source: Brookings Institution analysis of 2011-2015 American Community Survey (ACS) and FCC data

percent. Not until reaching gigabit-level speeds (see Box 1) does availability drop precipitously.

High coverage rates notwithstanding, small gaps in availability mean that millions of people across the country lack the option of subscribing to high-speed wireline service. Even at the 3 Mbps threshold, service failed to reach 2.2 million people in 2015. If the bar is raised to 10 Mbps, the number of residents without coverage triples, and it more than triples yet again using the 25 Mbps standard. Under that definition, 22.1 million people lived in neighborhoods that lacked broadband service in 2015.

Those residents are not distributed evenly across the nation. As might be expected, denser parts of the country offer greater deployment of broadband service than less populous places. In the cities that anchor the nation's 100 largest metro areas, more than 99 percent of the population lived in neighborhoods where at least one provider offered broadband at speeds of 25 Mbps or higher in 2015, leaving a gap of just 363,000 unserved residents (Figure 4). The suburbs of those regions followed closely behind, with a coverage rate of 97 percent, or a service shortfall of 4.2 million people. Small metro areas registered a coverage gap slightly above the national average at 8 percent, leaving 4.8 million residents without the option of broadband service.

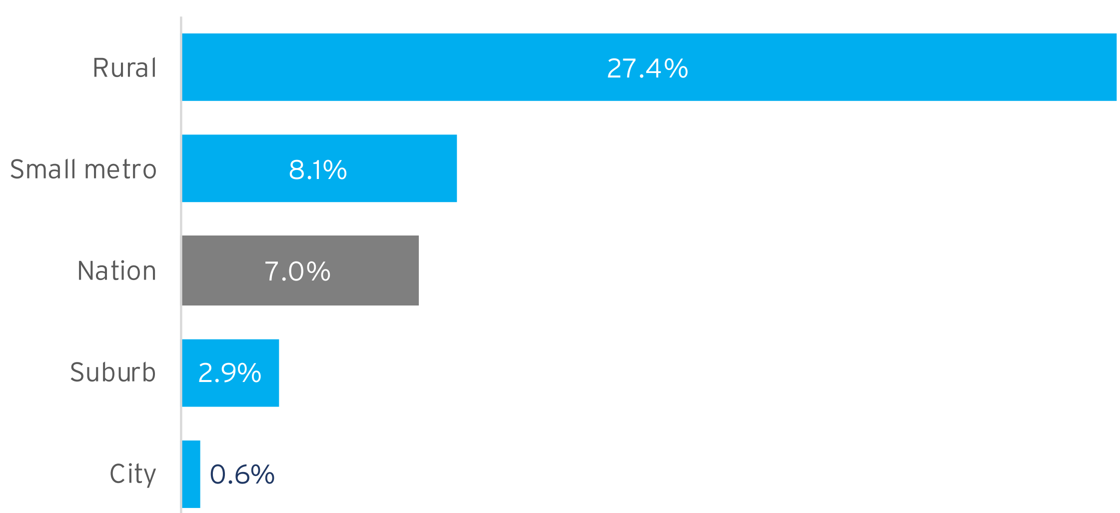
By far, the largest broadband deployment gap exists in rural communities, where more than one in four residents (12.7 million people) lacked 25 Mbps broadband service in 2015. As Figure 5 illustrates, while rural communities are home to just 15 percent of the nation's total population, they accounted for 57 percent of the nation's residents in neighborhoods where broadband has yet to be deployed—a ratio that remains roughly the same at lower speed thresholds.

The heavily rural tilt to the broadband service gap makes sense given the challenges inherent in bringing wireline service to diffuse or sparsely populated communities. The average population

FIGURE 4

The largest gaps in broadband service are found in rural America

Share of residents without 25 Mbps service in their neighborhoods

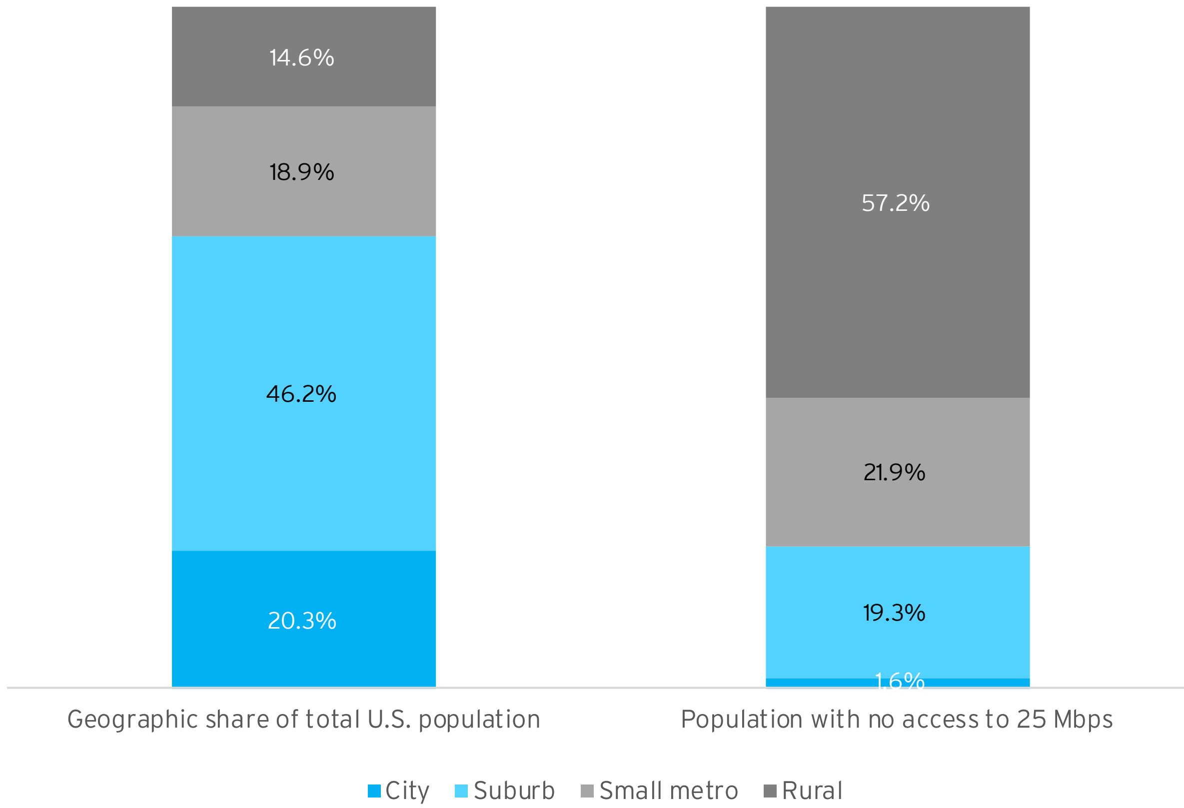


Source: Brookings Institution analysis of 2011-2015 American Community Survey (ACS) and FCC data

FIGURE 5

Rural residents account for over half the population in neighborhoods without broadband service

Geographic distribution of residents without 25 Mbps service in their neighborhoods



Source: Brookings Institution analysis of 2011-2015 American Community Survey (ACS) and FCC data

density of neighborhoods in the nation's cities was 14,639 people per square mile in 2010-2015, compared to just 467 people per square mile in the average rural neighborhood. (Suburban and smaller metro area neighborhoods fall in between the two, with respective averages of 3,858 and 2,054 people per square mile.[54])

Indeed, any disparities in broadband deployment across different segments of the population appear to stem more from geography than demography (Table 1). It is true that, compared to the population as a whole, residents living in neighborhoods where broadband was not available were more likely to be born in the United States, to be white, and less likely to have completed college; they were also more likely to own their homes and to have a member of the household with a disability.

But those differences do not reflect a broadband service map that systematically disadvantages or advantages a particular demographic or socioeconomic group so much as they underscore demographic differences in the makeup of rural and urban America. Given the rural bent of the broadband availability gap, it is not surprising to see that the demographic and economic profile of the unserved population closely mirrors the composition of the rural population overall.

TABLE 1

Differences in the makeup of neighborhoods with and without broadband service stem more from geography than demography

Characteristics of the population with no 25 Mbps service in their neighborhood

Demographic Characteristic	Total population	Population with no 25 Mbps service in their neighborhood	Rural population
Share of population that is:			
Foreign born	13%	**4%**	4%
White	62%	**76%**	79%
Black	12%	**9%**	8%
American Indian, Alaskan Native, Native Hawaiian, and Pacific Islander	1%	**3%**	2%
Asian	5%	**1%**	1%
Hispanic	17%	**10%**	8%
Under 18 years old	23%	**22%**	23%
18 to 64 years	61%	**60%**	59%
65 years or older	14%	**16%**	17%
A non-native English speaker with limited proficiency	9%	**4%**	3%
At least a college graduate	30%	**17%**	18%
Unemployed	5%	**5%**	5%
Poor	15%	**17%**	18%
Share of households that are:			
Owner occupied	64%	**77%**	71%
Family households	66%	**70%**	67%
Include a member with a disability	25%	**32%**	32%
Receive public assistance	3%	**2%**	3%

Source: Brookings Institution analysis of 2011-2015 American Community Survey (ACS) and FCC data

When it comes to deploying broadband, it seems to be density, rather than demographics, that proves the strongest determining factor of the nation's remaining availability gaps. That challenge holds even within the major metropolitan markets that are home to the majority of the nation's population and economic activity.

Finding 2: Most major metro areas offer near complete broadband coverage to their residents, but lower-density, more agriculturally focused regions in the South and West lag behind.

While residents of the nation's 100 largest metro areas enjoy the highest broadband availability rates in the country—more than 97 percent had at least one provider offering 25 Mbps (or faster) service in their neighborhoods in 2015—that collective statistic masks considerable variation across and within these regions.

Box 1. Residential gigabit is still under construction

Each year, data exchange becomes a more important process within the broader economy. Falling computer processing and data storage prices, cloud computing, connected video surveillance, and media streaming all combined to produce over 1 zetabyte of global internet traffic in 2016.[55] And with new features like the Internet of Things coming online, that number is expected to continue its exponential rise.

Gigabit broadband technology, which correlates with 1 Gbps (or 1,000 Mbps) download and upload speeds to residential users, is an integral component to support those massive data exchange volumes, both for power users today and more typical users in coming years. However, the build-out of such infrastructure is only just beginning.

At the end of 2015, only 6.3 percent of the nation's population lived in neighborhoods with gigabit-speed service available. The largest availability gap was in the suburbs, where only 3.8 percent of residents had the option of connecting. Overall, availability was slightly better in cities (10.1 percent), smaller metro areas (8.4 percent), and rural areas (6.3 percent).

Even with such large gaps in the aggregate, many individual places achieved much higher levels of gigabit service in 2015. Those included seven of the 100 largest metro areas, where gigabit speeds reached at least one-third of the population. Rates in Allentown, Pa. and Chattanooga, Tenn. topped 70 percent. Many smaller metro areas with prominent universities, like Columbia, Mo. and College Station, Texas, offered service to over 80 percent of their population.[56]

Boosting the availability of gigabit service will require more places to leverage the telecommunications infrastructure already built but not yet connected directly to many homes. Increasing market demand, new market entrants, and emerging backbone requirements via new technologies like 5G are all likely to incentivize and spur expanded build-out of gigabit-capable technologies. As those expansions occur, policymakers should ensure they happen in ways that do not exacerbate the digital divide but instead enable all types of communities to access the broadband connectivity needed to support inclusive economic growth in the coming decades.

By 2015, 10 of the nation's largest metro areas had reached complete coverage in terms of broadband availability at speeds of at least 25 Mbps (Map 1). Five of those regions fall in Florida, while the remaining five are spread across the country—Akron, Ohio; Allentown, Pa.; Greensboro-High Point, N.C.; New Haven, Conn.; and Salt Lake City, Utah. Another 66 metro areas registered broadband availability gaps below 5 percent—and as little as 0.05 percent. (For detailed metropolitan area statistics, see Appendix C.)

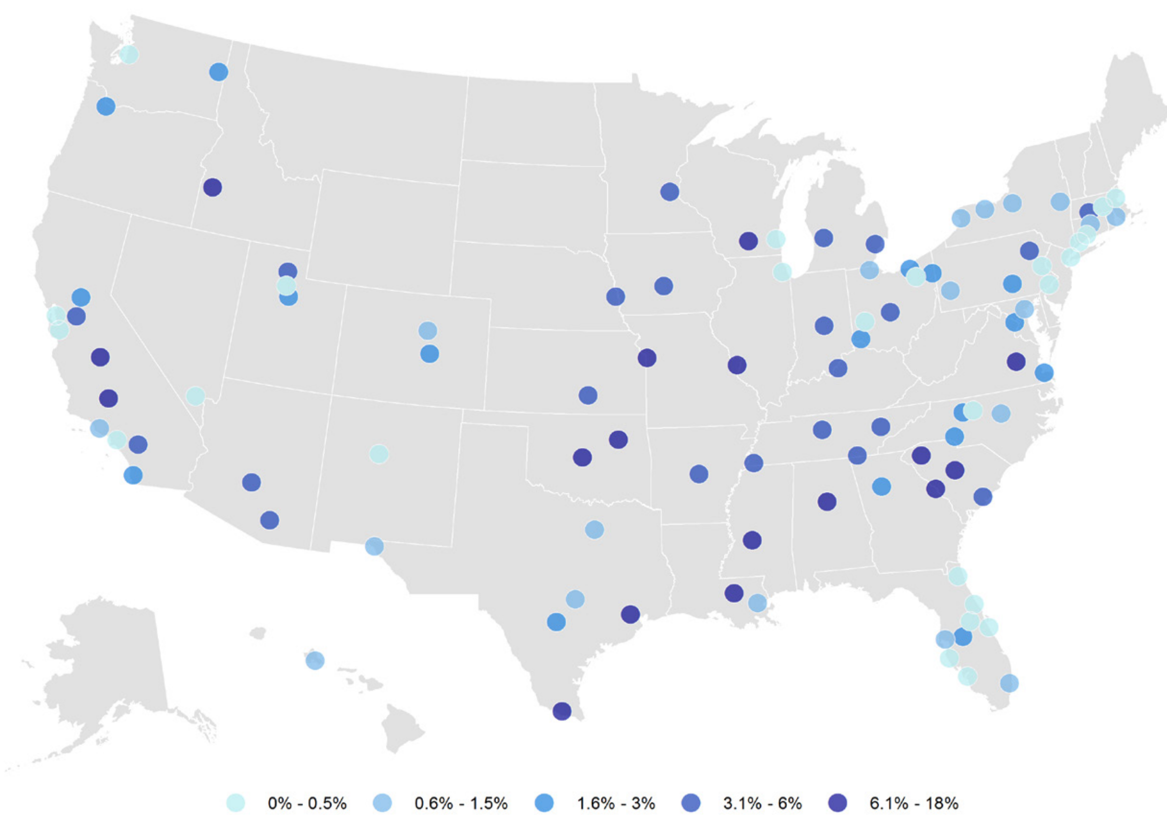
At the other end of the spectrum, more than a dozen regions experienced gaps in coverage that outstripped the national average. The availability gap reached 18 percent in the Tulsa, Okla. region and hit double digits in another six metro areas (Table 2). By and large, the metro areas with the biggest shortfalls in broadband availability are located in the South, including Tulsa and Oklahoma City; Jackson, Miss.; and Augusta-Richmond County, Ga., and in agriculturally oriented regions in the West, like Fresno and Bakersfield in California.

For these regions, gaps in broadband availability translate into tens of thousands, and in some cases hundreds of thousands, of residents lacking high-speed wireline service in their neighborhoods. By far, Houston was home to the largest population with no broadband coverage in 2015, with almost half a million metro area

MAP 1

The largest gaps in broadband availability tend to be found in the South and West

Share of the population in neighborhoods without 25 Mbps broadband service, 100 largest metro areas



Source: Brookings Institution analysis of 2011-2015 American Community Survey (ACS) and FCC data

TABLE 2

In regions where broadband service gaps are largest, most residents without a broadband option in their neighborhood live in the suburbs

Major metro areas that have the largest share of residents without 25 Mbps broadband service in their neighborhoods

Metro area	Residents without 25 Mbps service in their neighborhoods		Average population density of unserved tracts	Percent of unserved neighborhoods located in suburbs
	Share	Number	Pop./sq mi.	
Tulsa, Okla.	18%	169,510	104	100%
Jackson, Miss.	16%	92,864	134	100%
Oklahoma City, Okla.	12%	156,399	546	76%
Augusta-Richmond County, Ga.	12%	67,966	213	86%
Fresno, Calif.	11%	101,999	392	100%
Birmingham-Hoover, Ala.	11%	119,557	240	96%
Columbia, S.C.	10%	76,823	45	100%
Greenville-Anderson-Mauldin, S.C.	9%	80,760	428	100%
Kansas City, Mo.-Kan.	8%	161,466	48	93%
Baton Rouge, La.	8%	64,221	467	92%
Madison, Wis.	8%	47,682	36	100%
Boise City, ID	8%	49,443	51	100%
Houston-The Woodlands-Sugar Land, TX	8%	478,781	5,091	60%
Richmond, Va.	7%	89,242	321	100%
Bakersfield, Calif.	7%	57,034	895	100%

Source: Brookings Institution analysis of 2011-2015 American Community Survey (ACS) and FCC data

residents living in neighborhoods without 25 Mbps broadband service.

As with coverage disparities between rural and urban America, gaps in broadband availability across and within metro areas often reflect differences in density. In the nation's 100 largest metro areas, the average population density for neighborhoods with 25 Mbps service was 7,731 residents per square mile. For tracts without broadband availability, the average population density was six times lower (1,339). Unserved neighborhoods tend to be even more sparsely populated than average in the metro areas posting the largest overall coverage gaps, with as few as 36 people per square mile in the unserved neighborhoods of Madison, Wis.

Table 2 also shows, perhaps not surprisingly, that neighborhoods without broadband service in the nation's largest metro areas are overwhelmingly suburban. Among the 90 metro areas that have a gap in 25 Mbps broadband service coverage, in all but five of those regions that gap was driven mostly (in 24 regions) or entirely (in 61 metro areas) by suburban neighborhoods.

Houston proves a bit of an exception among the metro areas listed in Table 2. Its availability gap is distributed more evenly between urban and suburban neighborhoods, and, in turn, the region's unserved neighborhoods are much more densely populated than might be expected. However, if the bar for high-speed service is lowered from 25 Mbps to 10 Mbps, the picture improves dramatically for Houston: the region's coverage gap shrinks to 1 percent and its rank drops from 13th to 16th among the nation's 100 largest metro areas. However, because Houston is such a populous region, even a coverage gap of just 1 percent means that a significant number of residents – 94,000 of them – lacked high-speed wireline service as of December 2015.

Indeed, every major metro with a coverage gap sees that gap shrink to some degree using the 10 Mbps benchmark, and no major metro area registers a shortfall of more than 6 percent under that measure (Table 3).

These service patterns within and across the nation's largest metro areas show that, while broadband is not yet ubiquitous, providers of wireline infrastructure have succeeded in deploying it to the vast majority of residents in major metro areas. At the same time, the larger coverage gaps at 25 Mbps compared to 10 Mbps suggest that less dense, agriculturally oriented regions and farther-flung suburban neighborhoods may experience a lag in gaining service at faster speeds.

That is not to say that metropolitan America has entirely bridged the digital divide. "Laying the

TABLE 3

Broadband availability gaps shrink considerably for 10 Mbps service

Major metro areas that have the largest share of residents without 10 Mbps broadband service in their neighborhood

	Residents without 10 Mbps service in their neighborhoods		Rank among top 100 metro areas	
	Number	Share	10 Mbps	25 Mbps
Richmond, Va.	71,454	6%	1	14
Augusta-Richmond County, Ga-S.C.	32,553	6%	2	4
Bakersfield, Calif.	43,282	5%	3	15
Baton Rouge, LA	40,453	5%	4	10
Fresno, Calif.	44,968	5%	5	5
Tulsa, Okla.	42,477	4%	6	1
Jackson, Miss.	22,150	4%	7	2
Oklahoma City, Okla.	41,767	3%	8	3
Wichita, Kan.	19,020	3%	9	22
Boise City, ID	16,297	3%	10	12
Memphis, Tenn.-Miss.-Ariz.	32,564	2%	11	23
Greenville-Anderson-Mauldin, S.C.	19,564	2%	12	8
Little Rock-North Little Rock-Conway, Ariz.	14,019	2%	13	19
Riverside-San Bernardino-Ontario, Calif.	75,491	2%	14	38
Columbia, S.C.	12,624	2%	15	7

Source: Brookings Institution analysis of 2011-2015 American Community Survey (ACS) and FCC data

pipes" is a necessary step to ensuring residents can physically access the benefits of broadband service, but availability alone does not equal adoption—broadband subscriptions are equally important. Otherwise, a broadband connection with no subscription is simply an underused asset. The next two findings assess subscription patterns in neighborhoods across the country.

Finding 3: Over 73 million people (23 percent of the nation's population) live in neighborhoods where in-home broadband subscription rates fall below 40 percent.

National statistics on the extent to which households are subscribing to broadband reveal a country undergoing an uneven transition to the digitally connected economy, and they illuminate a digital divide that splits along both geographic and economic lines.

Due to the structure of FCC subscription data, broadband speeds within this section are defined as 10 Mbps download and 1 Mbps upload.

In 2015, almost one in four people (a total of 73.5 million) in the United States lived in low subscription neighborhoods, where fewer than 40 percent of households subscribed to broadband. Such neighborhoods concentrate the digitally disconnected portions of the American population, leaving their residents at risk of missing the economic benefits of a high-speed internet connection. Especially concerning are the 17.7 million children under the age of 18 dwelling in these neighborhoods. Living without an in-home broadband connection is a challenge for children, as they may not be able to benefit from digital curricula or develop digital skills for the future workplace. But it is especially challenging for schools and school districts that serve clusters of non-subscribing households.

Most Americans—185.7 million people or 59 percent of the nation—experienced somewhat better connectivity in moderate subscription

Box 2. Digital distress among youth

Broadband connectivity is important for the entire economy but especially so for the under-18 population. Digital curricula, including requirements to complete and submit homework online, are already a central component of primary and secondary schools' educational strategy. Once students complete school, they'll find a job market that increasingly requires digital skills to qualify for employment and to succeed on the job. Wireline broadband in the home fundamentally prepares youth for the digital present and future.

However, U.S. broadband performance leaves many youth digitally disconnected in their homes (Figure 6). It starts with a lack of availability: nearly 5 million children under the age of 18 live in neighborhoods where 25 Mbps broadband service is not available. The largest gaps are in rural America, where 2.8 million youth lack broadband in their neighborhoods, but 1 million suburban youth spread across metro areas like Atlanta, St. Louis, and Riverside, Calif. also live without broadband options.

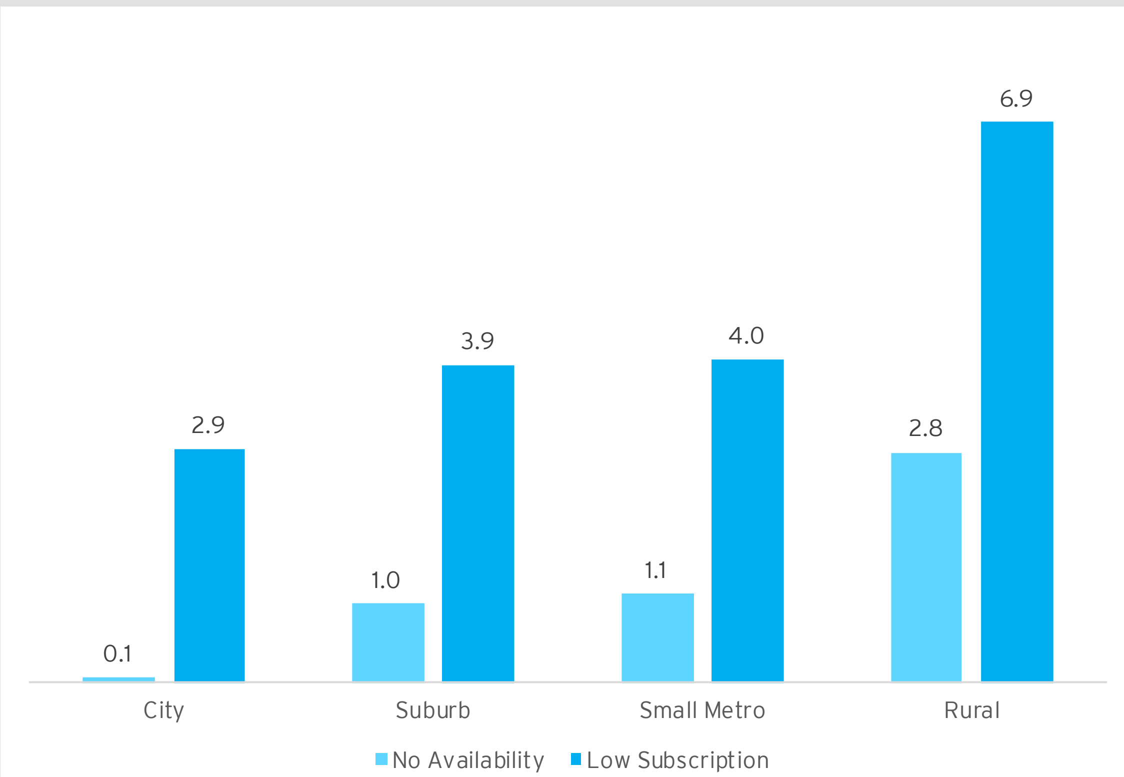
Equally troubling are the 17.7 million children living in neighborhoods with low subscription rates, meaning that fewer than 40 percent of all households in those neighborhoods subscribe to a wired connection. In rural areas, two-thirds of all children live in low subscription neighborhoods, demonstrating just how pervasive the broadband disconnect is in these corners of the country. There are also over 7,000 neighborhoods between large metro cities and suburbs that fall into the low subscription category, housing almost 7 million children. These neighborhoods include 1,800 where subscription rates fall below 20 percent.

Such broadband disconnection among the country's youth is a significant social equity and economic competitiveness challenge. A child cannot choose whether to live in a house with a wired broadband subscription—nor one with a wireless data plan—but it will shape his or her economic future. Likewise, in school districts where many households do not have broadband, educational capabilities may be limited for all students. Leaving children unprepared for the jobs of today and tomorrow stands not only to weaken their access to economic opportunity, but it also could limit the next generation of entrepreneurs and skilled workers necessary to power future industry.

FIGURE 6

A significant number of children, particularly in rural America, live in neighborhoods with low uptake of wireline broadband

Population (in millions) under 18 with no broadband availability or living in low-subscription neighborhoods



Source: Brookings Institution analysis of 2011-2015 American Community Survey (ACS) and FCC data

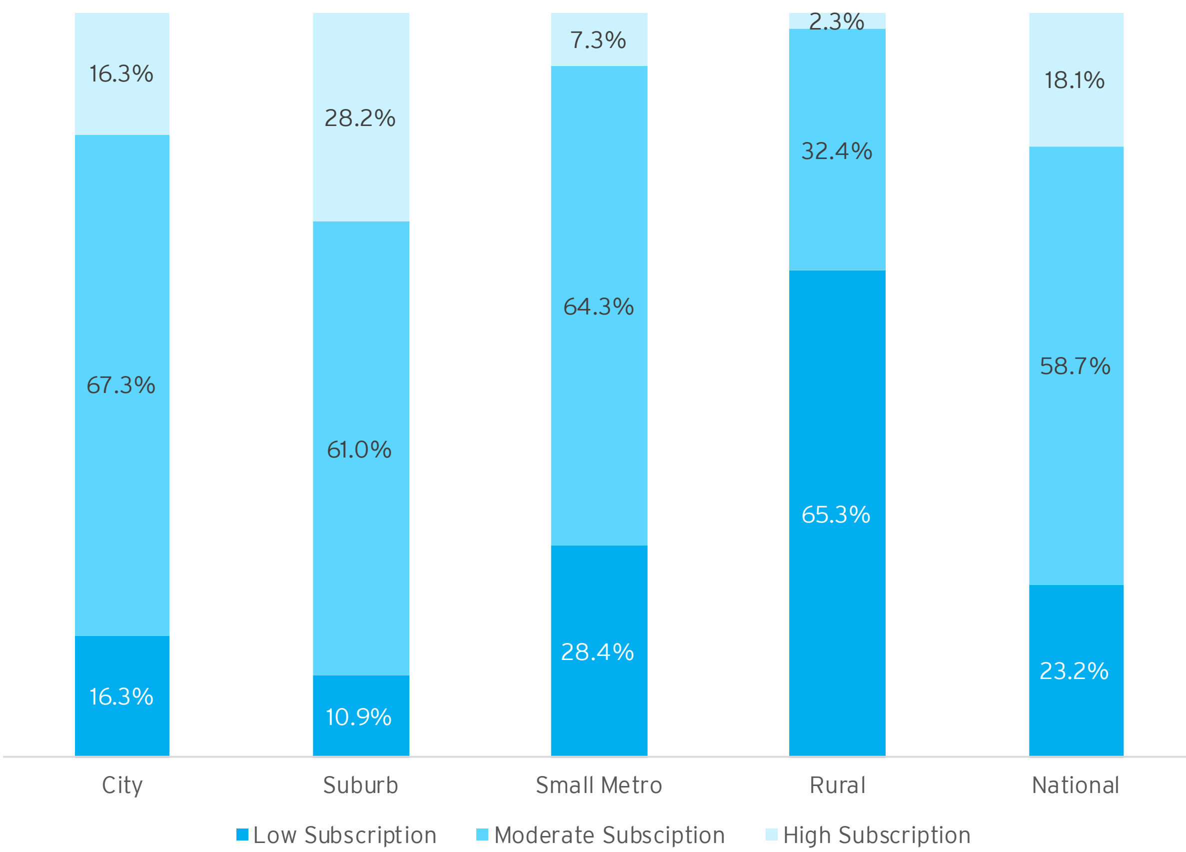
neighborhoods, i.e., census tracts with subscription rates between 40 and 80 percent. However, these neighborhoods still fall short of a national goal of nearing 100 percent subscription. In practice, only a modest share of the population lives in neighborhoods that either come close to or have already achieved that goal. **High subscription** neighborhoods, where at least 80 percent of households subscribe to high-speed broadband, were home to just 18 percent of the nation—or 57.1 million people—in 2015.

Looking at these three neighborhood-level subscription categories across different kinds of communities brings to light clear geographic differences (Figure 7), and those differences are distinct from availability performance. Suburban neighborhoods in the 100 largest metro areas achieve the country's highest broadband subscription rates, with only 11 percent of suburban residents living in low subscription neighborhoods and over a quarter of residents living in high subscription neighborhoods. While large city neighborhoods have fewer availability gaps than suburban neighborhoods, they are home to higher shares of residents living in low subscription neighborhoods and lower shares in high subscription tracts compared to the suburbs. Finally, small metro and rural neighborhoods adopt broadband at much lower rates than large

FIGURE 7

Almost two-thirds of rural residents live in low subscription neighborhoods

Share of the population by neigborhood broadband subscription category and geographic type



Source: Brookings Institution analysis of 2011-2015 American Community Survey (ACS) and FCC data

metro neighborhoods. The 65 percent of rural residents living in low subscription neighborhoods is especially troubling since it far exceeds the availability gap in those places.

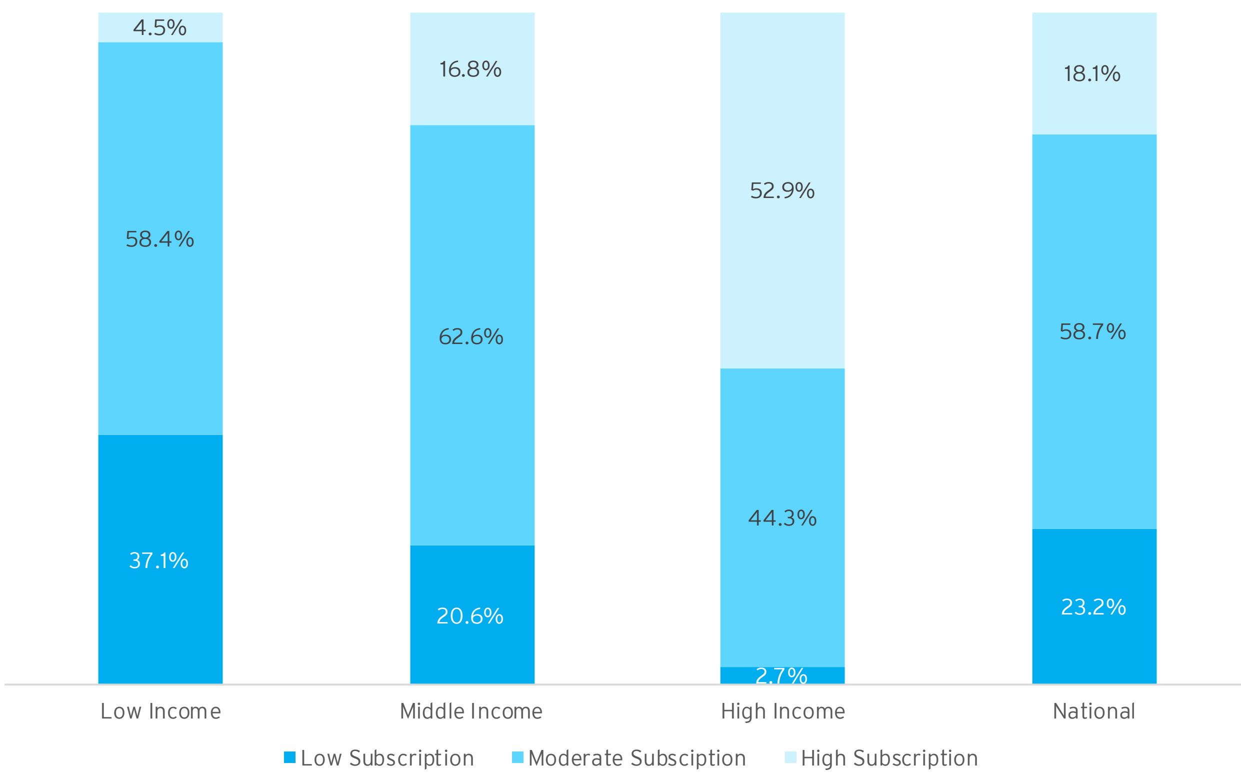
Parsing subscription levels by income reveals similar discrepancies (Figure 8). Low-income neighborhoods (i.e., census tracts with median incomes below 80 percent of the area median income, or AMI) register the weakest subscription rates, both in terms of how many people live in low subscription neighborhoods (37 percent) and how few live in high subscription neighborhoods (4 percent). It is the opposite for high-income neighborhoods (i.e., census tracts with median incomes at least 150 percent above the AMI), where just 3 percent of residents live in low subscription neighborhoods and more than half live in high subscription places (53 percent). Perhaps not surprisingly, subscription levels in middle-income neighborhoods, where most Americans live (56 percent), align closely with national averages. Taken as a whole, the discrepancies in neighborhood broadband subscription levels across income categories suggest that those being left behind by the transition to the digitally connected economy are also those who were already struggling economically.

Yet, geography and income are just two components that might affect broadband subscription. Using national census data at the neighborhood scale, it is possible to control for an even wider range of demographic and economic characteristics to test which have the strongest relationships with neighborhood subscription

FIGURE 8

Low-income neighborhoods are far more likely to exhibit low broadband subscribership than higher-income neighborhoods

Share of the population by neigborhood broadband subscription category and income



Source: Brookings Institution analysis of 2011-2015 American Community Survey (ACS) and FCC data

levels. (To see a detailed explanation and analysis of the regression model, see Appendix B.)

The results in many ways confirm past academic research but also raise important questions. Neighborhoods with less-educated, lower-income, and older residents all are associated with lower subscription rates—a clear confirmation of past research and an important signal for policymakers. Race tended to have much smaller and sometimes insignificant effects, however, a finding that deviates from survey results and individual-level models that find significant subscription gaps by race. In this case, further research should investigate racial components and how neighborhood effects may impact broadband subscription. Interestingly, larger shares of foreign-born residents were associated with higher subscription levels. This is another area ideally suited for more research.

Overall, these aggregate and modeled results suggest that the digital divide is now primarily one of subscription, not availability. The next finding investigates how those subscription gaps deviate between and within specific metropolitan areas.

Finding 4: Nearly every large metro area includes neighborhoods with subscription rates below 40 percent, but the gaps are largest in less dense regions.

While residents in large metropolitan areas subscribe to wireline broadband at higher rates than their small metropolitan and rural peers, there is considerable variation between and within these places. Addressing subscription gaps within the 100 largest metro areas, which represent 67 percent of the national population and 74 percent of GDP, is a critical step to get more Americans online and engaged in the digital economy.

Policymakers' chief concern should be addressing gaps in low subscription neighborhoods where fewer than 40 percent of households have an in-home subscription. As Map 2 shows, there are 23 metro areas where the share of residents living in such neighborhoods exceeded the national average of 23.2 percent in 2015. Most of these low-performing metro areas are in the South and West, stretching from the Carolinas to California, and are home to fewer than 1 million residents.[57] McAllen, Texas stands out in this regard, with 75 percent of its residents living in low subscription neighborhoods. In Albuquerque, N.M. and Boise, Idaho, over half the population lives in such neighborhoods.

Metro areas that register the largest absolute number of residents in low subscription neighborhoods tend to be regions that are more populous overall, including the four largest metro areas in the nation: Los Angeles, Houston, Dallas, and Chicago. While each metro area in Table 4 is below average in terms of the share of people living in low subscription neighborhoods, collectively this group comprises 5.7 million people. To put that number in perspective, it is more than the entire population of metropolitan Atlanta. For these large metro areas, getting more people online within low subscription neighborhoods is vital to boosting metropolitan-wide subscription rates.

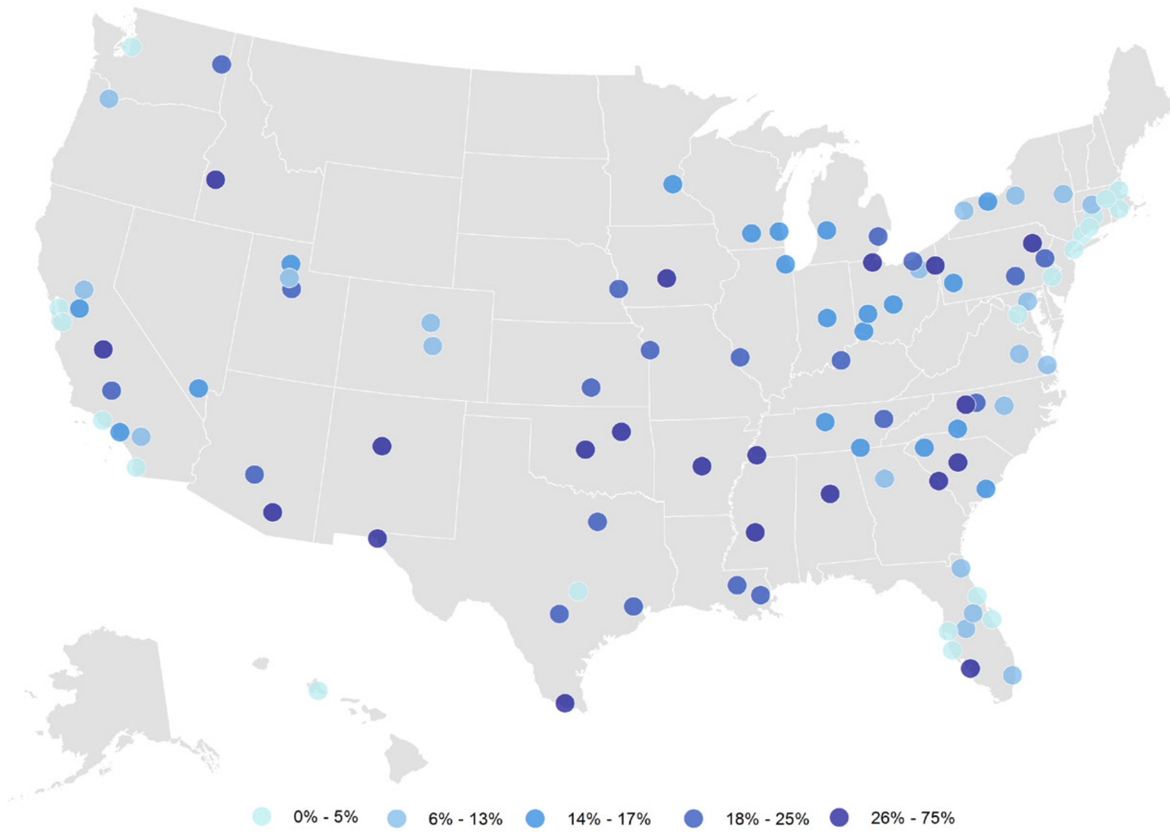
At the same time, there are many metro areas with very few residents living in low subscription neighborhoods. In six, fewer than 1 percent of residents lived in low subscription neighborhoods in 2015. In Bridgeport, Conn.; Providence, R.I.; Boston; and Palm Bay, Deltona, and North Port, Fla., fewer than 10 percent did. The higher rates of subscription in these regions may reflect market dynamics (e.g., resident preferences or competitive pricing) or targeted policies that encourage or enable greater broadband uptake. These are topics beyond the scope of this paper, but worthy of additional and perhaps local research.

At the other end of the spectrum, 41 of the nation's 100 largest metro areas had a higher-than-average

MAP 2

Almost 1 in 4 major metro areas have an above-average share of residents living in low-subscription neighborhoods

Share of population in low subscription neighborhoods, 100 largest metro areas



Source: Brookings Institution analysis of 2011-2015 American Community Survey (ACS) and FCC data

TABLE 4

Some of the nation's more populous metro areas have more than half a million residents-and as many as 1.8 million-living in low-subscription neighborhoods

Top 10 metro areas by total population living in low subscription neighborhoods

Rank	Metropolitan Area	Low Subscription Tract Population	Share
1	Los Angeles-Long Beach-Anaheim, Calif.	1,805,928	13.7%
2	Houston-The Woodlands-Sugar Land, TX	1,312,198	20.7%
3	Dallas-Fort Worth-Arlington, TX	1,312,032	19.2%
4	Chicago-Naperville-Elgin, Ill.-Ind.-Wis.	1,248,573	13.1%
5	Phoenix-Mesa-Scottsdale, Ariz.	753,609	17.1%
6	Detroit-Warren-Dearborn, Mich.	739,865	17.2%
7	McAllen-Edinburg-Mission, TX	613,797	74.9%
8	Minneapolis-St. Paul-Bloomington, Minn.-Wis.	567,459	16.4%
9	San Antonio-New Braunfels, TX	565,239	24.7%
10	St. Louis, Mo.-Ill.	512,259	18.3%

Source: Brookings Institution analysis of 2011-2015 American Community Survey (ACS) and FCC data

share of residents living in high subscription neighborhoods. Washington performed the best by this measure, with over 61 percent of people living in high subscription neighborhoods and just 2.5 percent living in low subscription tracts. In New York, Philadelphia, San Diego, and Tampa, Fla.—each large population centers with more than 2 million residents—the share of residents in high subscription neighborhoods outstrips the proportion in low subscription tracts.

Several other metro areas, including Minneapolis, Salt Lake City, and Portland, Ore., lagged behind the national average for the share of residents living in high subscription neighborhoods; for each, fewer than 5 percent of residents did in 2015. But these low shares were not the result of having high shares of residents in low subscription places. Instead, over three-quarters of the population in these regions lived in moderate subscription neighborhoods.

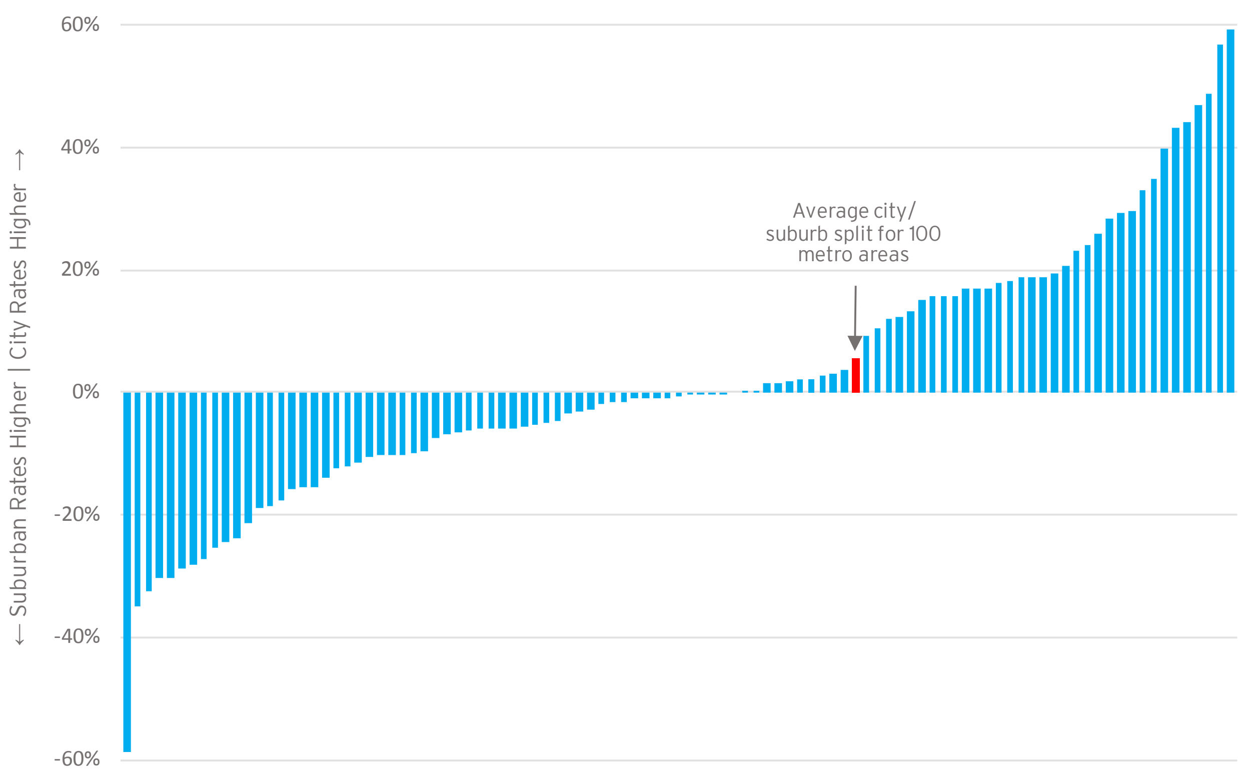
In addition to each metro area's baseline, it is also possible to compare broadband subscription between cities and suburbs. At the aggregate level, greater shares of the suburban population live in high subscription tracts and smaller shares live in low subscription tracts than their city peers. But, disaggregating that data shows extreme differences between metro areas.

Figure 9 charts the difference between the

FIGURE 9

Neighborhood subscription patterns differ between cities and suburbs within the same metro areas

City versus suburban population share living in low subscription neighborhoods, 100 largest metro areas

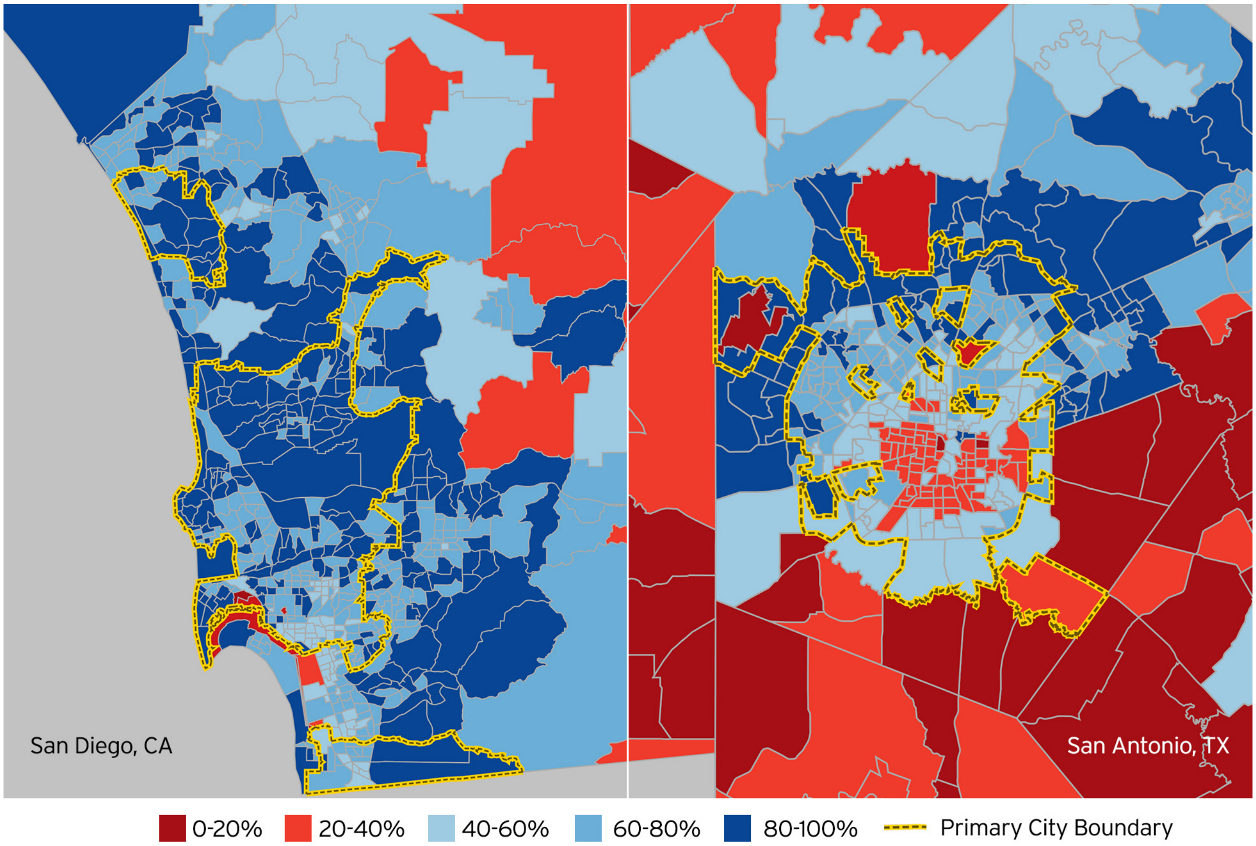


Note: Red bar indicates average city/ suburb split for the 100 metropolitan areas
Source: Brookings Institution analysis of 2011-2015 American Community Survey (ACS) and FCC data

MAP 3

While San Diego and San Antonio have similar broadband availability and total population, subscription patters vary widely between the two metro areas

25 Mbps broadband subscription patterns by neighborhood, San Diego and San Antonio



Source: Brookings Institution analysis of 2011-2015 American Community Survey (ACS) and FCC data

share of city and suburban residents living in low subscription tracts. The bars' overall curvature confirms how much neighborhood-level subscription patterns differ between metro areas. Furthest to the left, in suburbs in McAllen, Texas; Boise, Idaho; Albuquerque, N.M.; and Cape Coral-Fort Myers, Fla., significantly higher shares of the population live in low subscription tracts relative to the central cities. Conversely, much higher rates of city residents in metropolitan Cleveland, Detroit, Baltimore, and Provo, Utah live in low subscription tracts. Overall, 59 of the 100 metro areas show absolute differences of at least 10 percentage points between their cities and suburbs, whether positive or negative on this scale. And while not charted here, the variation is similar when comparing city and suburban populations living in high subscription tracts.

Diving into two specific markets helps one visualize different local subscription patterns (Map 3). San Antonio and San Diego are both Sunbelt metro areas with over 2 million total residents and a heavy military presence. The two regions also have comparable levels of availability: broadband serves 98 percent of the total population in both metro areas, with only minor gaps in their suburbs and full coverage in their core city. Yet their neighborhood subscription patterns vary significantly. San Diego has only small pockets of low subscription, mostly located in the sparsely populated east. High subscription tracts are much more prevalent, with 43 percent of people living in such neighborhoods. Conversely, a quarter of San Antonio's population lives in low subscription tracts in large swaths of the city and suburbs. High subscription tracts appear almost exclusively in the northern suburbs and in isolated places within the central city.

While a great amount of variation in subscription levels exists both within and across the 100 largest metro areas, the pattern uniting each metro area is the presence of digital disconnect. In fact, low subscription tracts exist in the surrounding suburbs of all 100 metro areas and in the cities of all but six metro areas: Allentown, Pa.; Deltona, North Port, and Palm Bay, Fla.; Providence, R.I.; and San Jose, Calif. In other words, the digital divide is pervasive.

Finding 5: A combined index of broadband availability and subscription demonstrates the overall strength of metro areas in Florida, the Northeast, and the Pacific Coast and lagging performance in the Southeast and Great Plains.

Broadband availability and subscription both are integral to unlocking the economic benefits of a high-speed internet connection. While limited deployments are a pressing challenge in some metropolitan areas, other places struggle with getting residents subscribed. This section introduces a combined index to simultaneously assess both broadband availability and subscription in the country's largest metropolitan areas. The index uses percentile standard scores to measure the share of all residents where broadband is available and the distribution of broadband subscription across the FCC's categorical data.[58] These two standard scores are then added to rank the best and worst overall metropolitan performers (Appendix C includes all rankings).

Perhaps not surprisingly given the strong performance of many Florida metro areas throughout this analysis, those areas dominate the highest rankings produced by this combined measure (Map 4 and Table 5). In places like Palm Bay and Deltona, not only is complete service coverage available to residents, but higher-than-average shares of the populations live in high subscription neighborhoods and virtually none live in low subscription areas. In addition to the four Florida metro areas that rank in the top 10, Orlando ranks 12th out of 100 and Miami and Jacksonville are just outside the top 20. Just as importantly, none of the state's large metro areas rank in the bottom half.

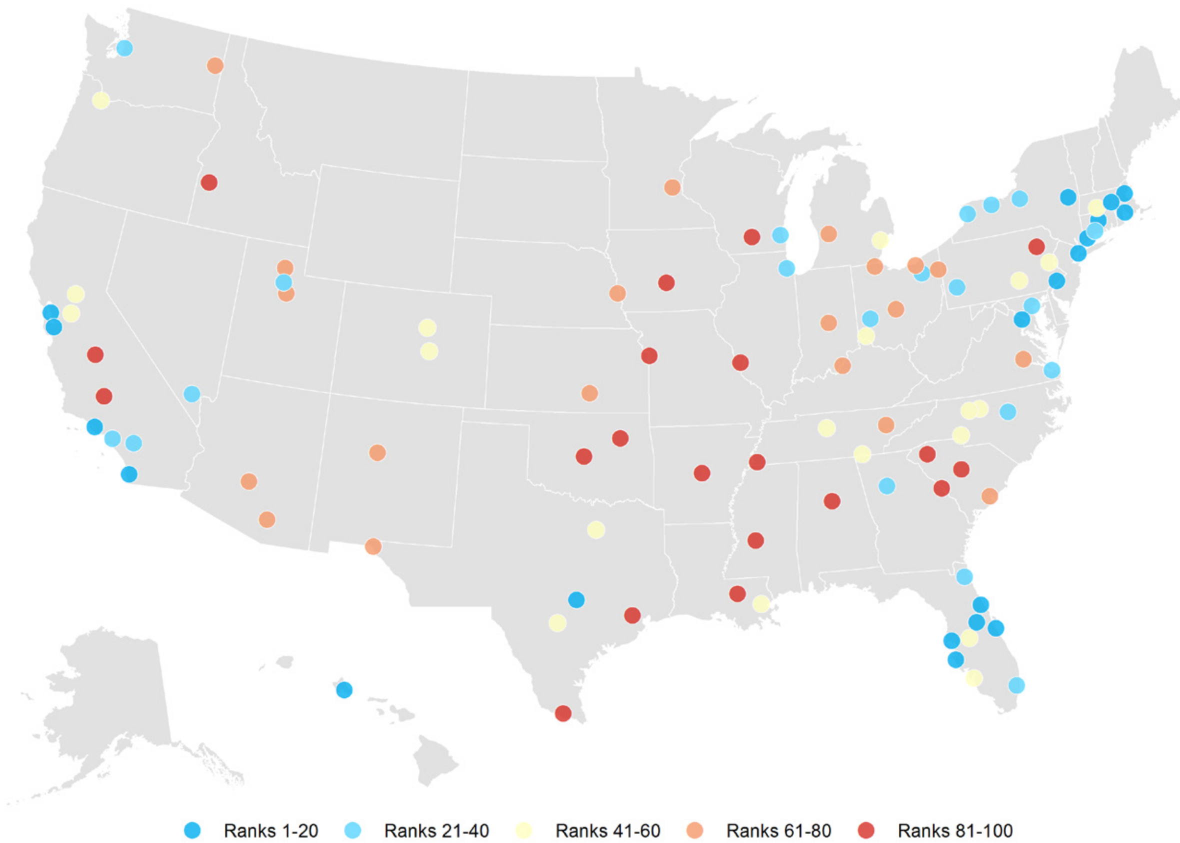
The Northeast exhibits similar patterns, with regions like New York and Boston offering 25 Mbps service availability to practically all of their millions of residents, the majority of whom live in high subscription neighborhoods. Philadelphia and Washington generate nearly the same high scores. Many Pacific Coast large metro areas—including San Jose, San Francisco, and San Diego—also rank in the top 20. Austin, Texas is the only top 20 metro area not on either coast.

In contrast, Southeastern metro areas outside Florida and many Great Plains metro areas exhibit lagging performance on both availability and subscription metrics relative to their peers. The large metro areas in states running from Texas to South Carolina and north along the Mississippi River represent two discernible bands of bottom-20 places. Many of these metro areas—including Tulsa, Okla.; Jackson, Miss.; and Columbia, S.C.—rank among the lowest for availability rates and register some of the highest shares of residents living in low subscription neighborhoods. But a number of the metro areas in this bottom quintile struggle more with availability than subscription, including Houston, St. Louis, and Madison, Wis.

MAP 4

Among the nation's largest metro areas, the strongest overall performers on broadband availability and subscription fall in Florida and the Northeast

Combined broadband availability/ subscription standard score, 100 largest metro areas



Source: Brookings Institution analysis of 2011-2015 American Community Survey (ACS) and FCC data

It is important to note these rankings will continue to change over time as broadband deployment and consumer choices evolve, both of which can change quickly. For instance, new broadband deployments would improve statistics in some markets. Also, people may have subscribed to high-speed service after the time period our data capture, which would shift neighborhoods to higher subscription categories.

Regardless of change over time, these rankings amplify the need to assess where strengths and challenges exist within metropolitan areas. Based on the first two findings, metro areas scoring lower on broadband availability likely need to look to their lower-density neighborhoods to boost deployment and service quality. Metro areas with lower scores based on their broadband subscription rates will likely need to focus on lower-income, less-educated neighborhoods where residents tend to subscribe at lower rates. While these rankings provide metropolitan benchmarks, effectively targeting solutions will require neighborhood-level maps.

TABLE 5

The metro areas with the lowest combined scores on broadband availability and subscription largely span the south, from Columbia, S.C. in the East to Fresno, Calif. in the West

Top and bottom ten metro areas by combined availability/ subscription standard score

Rank	Metropolitan Area	Broadband Available @ 25 Mbps	Low Subscription Share	High Subscription Share	Combined Standard Score
1	Palm Bay-Melbourne-Titusville, Fla.	100.0%	0.6%	58.3%	1.79
2	Urban Honolulu, HI	100.0%	2.8%	59.6%	1.78
3	Bridgeport-Stamford-Norwalk, Conn.	99.9%	0.0%	47.3%	1.78
4	New York-Newark-Jersey City, N.Y.-NJ..-Pa.	99.9%	2.1%	51.8%	1.77
5	Boston-Cambridge-Newton, Mass.-N.H.	99.7%	0.4%	55.3%	1.76
6	North Port-Sarasota-Bradenton, Fla.	100.0%	1.0%	42.5%	1.75
7	Deltona-Daytona Beach-Ormond Beach, Fla.	100.0%	1.0%	36.1%	1.74
8	Philadelphia-Camden-Wilmington, Pa.-N.J.-Del.-Md.	99.8%	4.2%	47.0%	1.72
9	Tampa-St. Petersburg-Clearwater, Fla.	99.0%	1.6%	51.3%	1.70
10	Providence-Warwick, R.I.-Mass.	99.1%	0.1%	41.0%	1.70
91	Little Rock-North Little Rock-Conway, Ariz.	94.1%	36.3%	2.5%	0.31
92	Oklahoma City, Okla.	88.1%	25.7%	21.7%	0.22
93	McAllen-Edinburg-Mission, TX	93.9%	74.9%	1.2%	0.20
94	Columbia, S.C.	90.3%	25.5%	5.5%	0.20
95	Boise City, ID	92.4%	51.2%	0.0%	0.15
96	Fresno, Calif.	89.3%	36.2%	6.6%	0.14
97	Tulsa, Okla.	82.4%	34.0%	14.0%	0.13
98	Birmingham-Hoover, Ala.	89.5%	38.1%	10.0%	0.11
99	Augusta-Richmond County, Ga.-S.C.	88.3%	39.4%	16.0%	0.11
100	Jackson, Miss.	83.9%	43.8%	2.8%	0.07

Source: Brookings Institution analysis of 2011-2015 American Community Survey (ACS) and FCC data

Box 3. Historical role of the government in addressing the digital divide

While the digital divide persists across both the availability and adoption dimensions, governments and private firms continue to evolve in how they address these inequities. When discussing ways in which policymakers and practitioners can act to help close deployment and subscription gaps, it is important to understand what efforts are already underway.

Federally, there is a long tradition of direct policy interventions regarding broadband availability and adoption (Figure 10). With the passage of the Telecommunications

Act in 1996, Congress built the foundation for modern broadband law, and in the 2000s it acted to improve data policies, tax approaches, and to authorize targeted investments. However, Congress has so far focused almost exclusively on deployment. The Department of Agriculture also focuses on availability (versus adoption) by financing rural broadband infrastructure through its longstanding Broadband Loan and Community Connect programs.[59] The Department of Housing and Urban Development recently began to build out deployment and adoption programs such as ConnectHome, although the future of those programs is uncertain. Similar funding concerns apply to the Department of Commerce's National Telecommunications and Information Administration, which runs the nearly complete Broadband Technology Opportunities Program and did run the now-closed State Broadband Initiative. Together, those programs represent the largest federal broadband adoption programs to date.

The FCC has the largest sustained presence on these issues among federal agencies, owing to the sizable and secure funding streams for its availability and adoption programs. Using fees collected from telecommunications providers, the Universal Service Fund directs billions each year to rural deployments (through the Connect America Fund), connections for schools and libraries (E-rate), rural health care facilities, and low-income broadband adoption support (Lifeline).

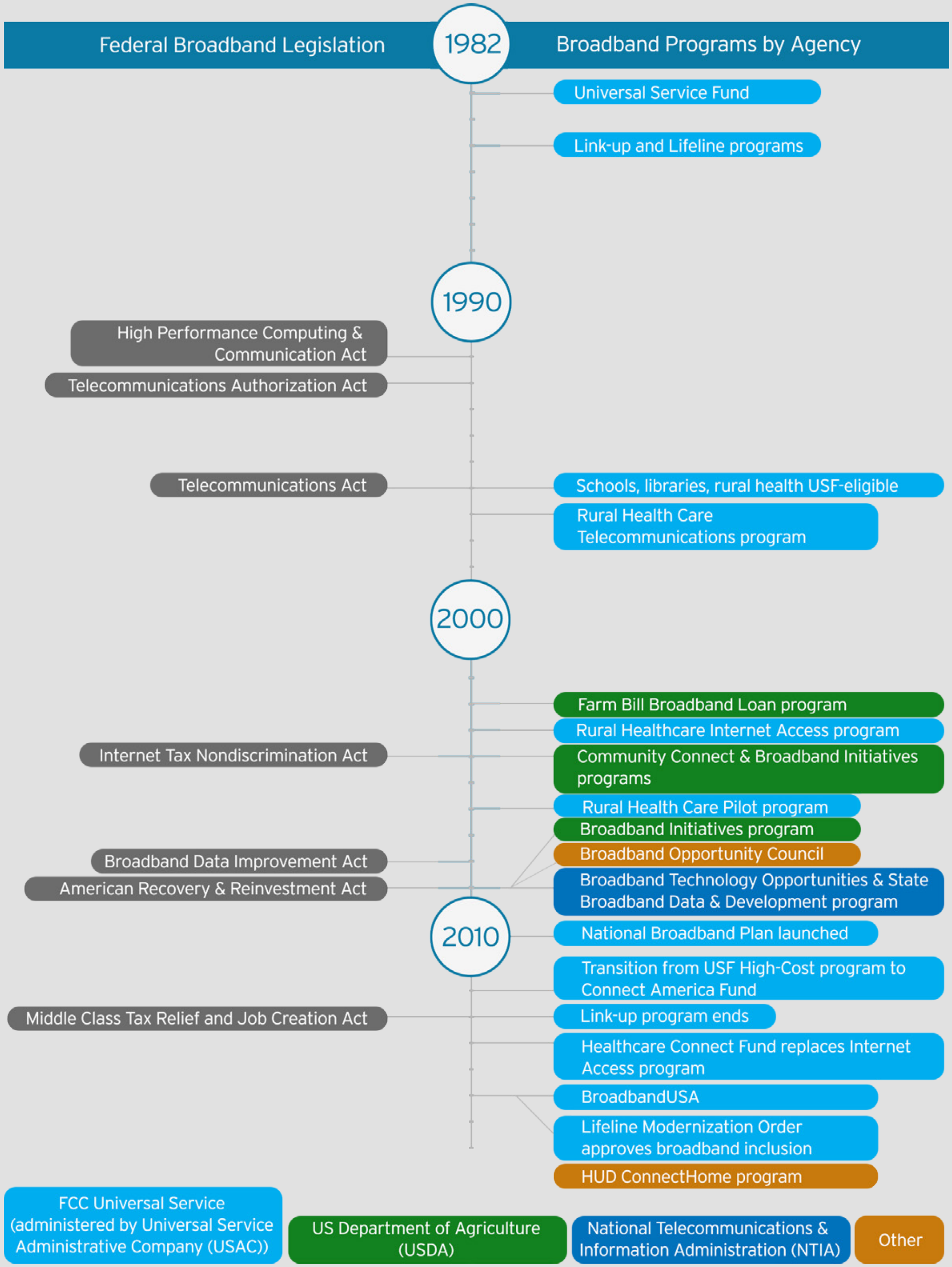
Flexibilities in federal law give states and localities latitude in how they approach broadband deployment and adoption. In some states, such as Kentucky, public construction efforts are underway.[60] In others, like Tennessee, laws explicitly forbid local governments from building their own public networks—and those laws were reinforced by a federal judicial decision.[61] There is a similar disparity between how localities approach cable franchise agreements, right-of-way access, and pole attachment policies.[62]

Internet service providers (ISPs) also play an important role. As the primary investor in and operator of the country's telecommunications networks, these private firms will continue to be the primary driver of where broadband is available, at what speeds, and for what price. But many of the largest providers also offer—independent of the federal Lifeline program—discounted rates to low-income households. Many also engage in civic philanthropy through such initiatives as equipment donations to local school districts. While there are certainly adversarial components to ISPs' relationships with governments, there are also many areas where goals and objectives align.

Moving forward, governments will need to ensure that broadband deployment and adoption policies continue to evolve. One step would be the promotion of higher bandwidths to match greater hardware-processing capacity. New innovations like immersive online courses, virtual reality gaming, and real-time property management will all require gigabit-level speeds in the home.[63] And as more daily activity shifts to digital platforms, promoting greater broadband adoption will only grow in importance.

FIGURE 10

Federal broadband law and agency programs, 1982 to present



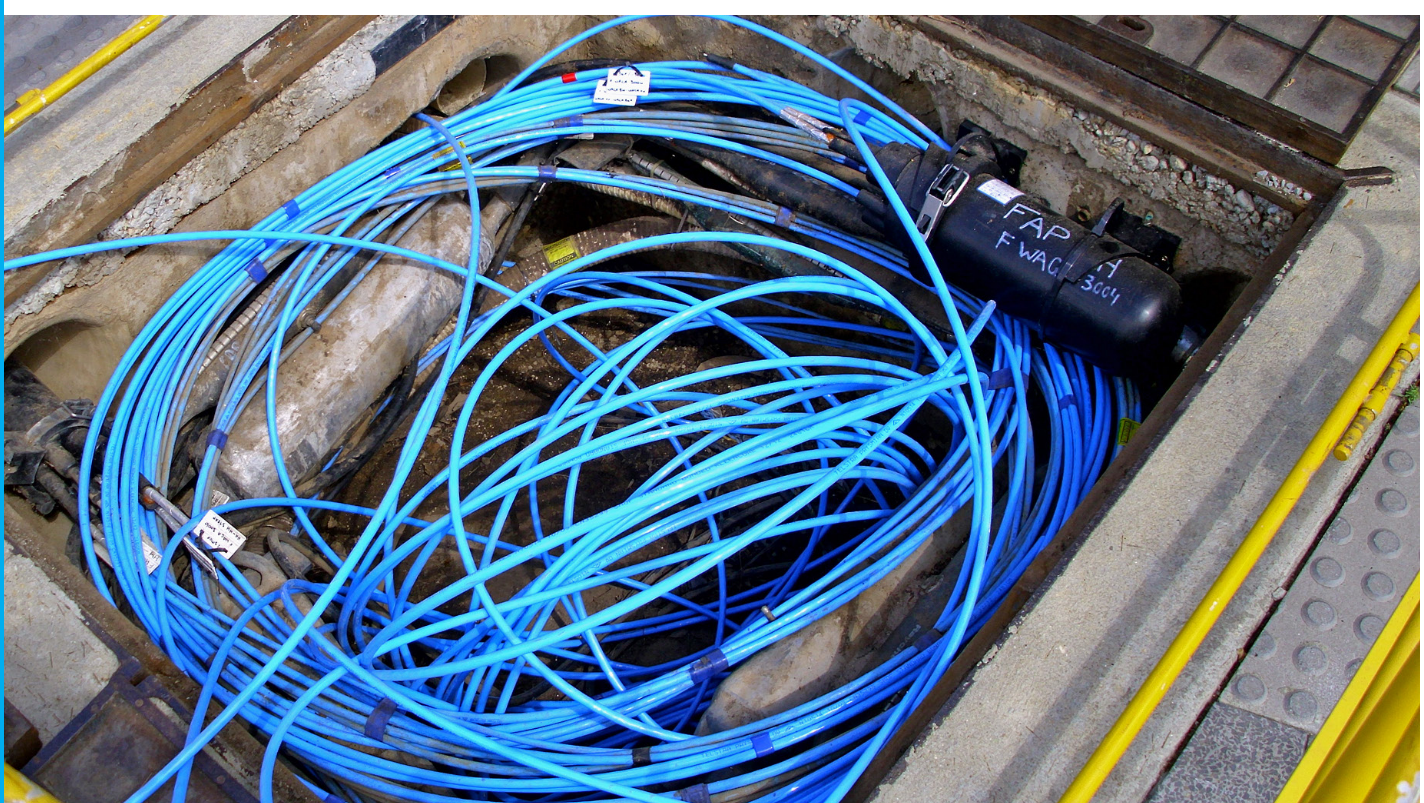
Source: The Brookings Institution

05 IMPLICATIONS

Internet use is a fundamental component of the modern American economy, and that is especially true inside people's homes. Students of all ages complete their homework online and stream videos to sharpen their skills. Jobseekers scan for new openings and network with colleagues. People of all ages use the internet to shop, watch television, play games, and talk face-to-face with family and friends. The internet also allows governments at all levels to find efficiencies and cost savings in their service provision, and these improvements stand to be particularly important for low-income residents. As dozens of mayors and city leaders recently wrote to the FCC, "Getting more low-income households online will help modernize delivery of public services—facilitating more responsive and effective governance while lowering overheads for local governments. E-government delivery also saves the public the expense of visiting government offices in person—a particular concern for low-income households."[64]

In-home broadband makes all this possible. Unfortunately, many of the nation's residents do not yet fully participate in the broadband economy.

In some parts of the country, availability is the chief issue. Over 22 million people live in neighborhoods that lack in-home broadband service at speeds of 25 Mbps or greater. Rural America represents over half of this group, confirming the difficulties of delivering high-speed service in low-density settings. Yet many large metro area neighborhoods also fail to connect a significant number of their residents to broadband service, including over 100,000 in Houston; Tulsa, Okla.; and Fresno, Calif. Even in the nation's largest regional economies where 25



Mbps is widely available, few communities now offer a broadband platform built for the digital future: current gigabit-speed connections—which will be instrumental to growing, attracting, and sustaining data-hungry industries and occupations—reach only 5.7 percent of residents in the 100 largest metro areas.[65]

> As long as the twin gaps in availability and adoption exist, the digital divide will hold back the national economy and limit economic opportunity in specific neighborhoods.

As formidable a hurdle as those availability gaps are for enhancing digital inclusion, particularly in rural America, for the 93 percent of the nation's population where high-speed wireline service is available, it is broadband adoption that represents the primary hurdle to achieving full participation in the digital economy. The residents most likely to be left out—like the 73 million people living in low subscription neighborhoods—tend to be older, have lower incomes, and lower levels of education. These residents can be found in urban, suburban, and small metropolitan communities alike. But by far, subscription rates remain lowest in rural America, where adoption challenges (almost two-thirds of residents live in low subscription neighborhoods) are compounded by the high costs of addressing gaps across far-flung, low-density communities.

While gaps in availability have traditionally dominated the debate about digital equity, this analysis reveals the extent to which adoption, or lack thereof, has come to define America's digital divide. As long as these twin gaps exist, the digital divide will hold back the national economy and limit economic opportunity in specific neighborhoods.

Assembling the right array of policy and programmatic interventions to address these availability and adoption challenges will require both an understanding of the diversity of starting points across different kinds of neighborhoods and communities—as evidenced by this analysis—and a forward-looking perspective on the role of evolving technology. It will also require the alignment of multiple efforts, bringing together a balanced framework of federalist public policies and collaborative partnerships between the private, public, and civic sectors.

As broadband's presence within the American economy continues to mature, now is an opportune time to reconsider both national and local policy frameworks. The following section considers the role that federal actors do and should play in advancing both availability and adoption goals, and the next section turns to the role of local and regional stakeholders.

The federal role: Balancing availability and adoption goals to bridge the digital divide

Recognizing the fragmented landscape that governs broadband deployment, federal policy has long focused overwhelmingly on solving the collective action challenges inherent in increasing availability. Yet federal policy continues to largely overlook adoption. How the FCC handles Section 706 of the 1996 Telecommunications Act is emblematic of this tension: the law mandates that the FCC review advanced telecommunications deployment based on population, but it is on a voluntary basis that the agency monitors adoption.[66]

To some extent this arms-length approach stems from the complex array of factors—from pricing and marketing down to consumer choice and digital literacy—that shapes subscription levels. At the same time, the sheer scale of non-subscribed broadband households is difficult to ignore, and the fact that every community is affected—from New York City to rural Wyoming—generates political resonance and suggests the need for more targeted federal policy attention. There are clear opportunities to move adoption issues to the forefront of national policy, but current and past efforts have been patchwork.[67] Simply put, formal policy must move beyond volunteerism.

Moving forward, there are a number of ways—through funding, regulation, research, and technical assistance—that federal actors can continue to advance gains in availability while at the same time elevating their focus and commitment to reducing adoption barriers.

Adopt policies to reduce deployment costs. Today, high-speed wireline service remains the most dependable way to get people connected to the digital economy. For the foreseeable future, then, it will still be vital to get more Americans subscribed to in-home broadband connections. To do so in an era of limited resources, Congress and executive agencies should give immediate attention to reducing deployment costs. One promising way to do so—if politics and industry can align on implementation—is through "dig once" policies, which allow for installing conduit or fiber optic cables during any right-of-way construction project (e.g., road construction).[68] Similar debates and alignment will need to take place regarding pole attachments and the potential for "one touch make ready" policies, which simplify the steps needed to create a new attachment on poles that may already be in use by other telecommunications or cable providers. For example, a one touch make ready policy might direct pole users to come together and select a common contractor for adjusting attachments as needed, rather than sending separate crews for each provider.[69]

Consider the role of evolving wireless technology and business practices. Congress and the FCC must continue to craft policy and market interventions for the 12.7 million rural residents without broadband service, including many residents on tribal lands. The Connect America Fund will continue to make vital investments to advance availability for these households, but leaders should both consider the potential for future satellite technology to reduce public investment needs and actively review whether the quality of current Connect America Fund wireline investments will meet rural recipients' long-term needs.

At the same time, policy leaders should consider how the build-out of new wireless networks—including proposed fifth-generation standards (5G)—and unlimited data plans within current networks will impact unserved populations in both rural and metropolitan communities.

Through small cell technology, 5G promises to offer wireless service to large geographic areas at speeds significantly faster than current networks. 5G will still require a wired backbone to connect the small cell transmission points, but it could eliminate the need for wired connections to each home.[70] However, questions remain whether in-home consumers would make the switch, and dependability relative to current wired offerings will be a major sticking point. Given that state and local decisions will determine how such policies are rolled out and where small cell transmission points will be located, local political dynamics and competing agendas could conceivably stymie efforts to close the digital divide through 5G deployment. There is a real opportunity for federal policy to create consistent guidelines for local governments and private firms, but those must both protect digital equality and local governments' independence.

Likewise, unlimited data plans using current 4G

LTE networks already enable many individuals to access broadband speeds in neighborhoods underserved by wireline. However, these services will only unlock broad-based economic benefits if all individuals can afford the service and if they connect to more productive devices, specifically desktops and laptops. Since lower-income individuals own computing devices and subscribe to wireless data plans at lower rates, these service improvements will not necessarily reach the entire population. Congressional and agency officials should debate whether other complementary programs, including device or service vouchers, are worthwhile complements to service changes by private wireless service providers.

Move beyond stopgaps and pilots to more sustained adoption-focused funding streams and programming. Broadband Technology Opportunities Program (BTOP) grants from the National Telecommunications and Information Administration (NTIA) enabled recipients to support adoption via outreach and training, but that program was funded only temporarily under the American Recovery and Reinvestment Act of 2010.[71] The Obama administration's ConnectHome initiative targeted adoption among low-income families with school-age children living in public housing, but the effort was only an unfunded pilot.[72] And, as noted above, the FCC and NTIA do not formalize adoption objectives within their strategic plans.[73] The only sustained direct support to individuals is the Lifeline program, which the FCC recently expanded to offer direct broadband pricing support.[74]

Moving forward, Congress must work with the FCC, the NTIA, and other relevant agencies to establish sustained adoption-focused programs. That should include targeted pricing support where possible, both for monthly service like the FCC Lifeline program and potential purchase credits for equipment. Ideally, targeting support to low-income families with school-age children could ensure those families bring the digital classroom home. Similarly important are sustained support for training programs and capacity support in low-adoption communities. While the Broadband Opportunity Council has ended, the Broadband Interagency Working Group now meets in its place, with the goal of improving coordination among federal partners and programs, reducing regulatory hurdles that impede deployment, and raising awareness of available federal resources at the community-level.[75] In addition, NTIA's BroadbandUSA Connectivity Assessment Tool provides a set of tools, resources, and technical assistance to support communities as they work to advance local broadband availability and adoption policies. The evolution and sustainability of this resource is contingent on continued funding from the current administration.[76] The federal government can also help scale successful interventions by assembling and distributing local best practices, a recommendation echoed by the Information Technology and Innovation Foundation.[77] Regularly updating NTIA's Adoption Toolkit, first published in 2013, is one possible approach, and one that would also require sustained funding.[78]

Forge metropolitan/rural alliances on Capitol Hill. Considering geographic differences and aggregate funding needs, Congress will likely need to strike a grand bargain between those representing more metropolitan constituents and those representing primarily rural areas. Since each group has clear needs, there is room for a balanced approach. In particular, there is an opportunity for legislators to reform current public revenue streams to simultaneously fund availability and adoption programs and remove those programs from annual appropriations' fights.

Leverage public data more effectively. The federal government can do more around data. The geographic granularity of the FCC's availability and adoption data is excellent. However, the use of quintiles to report wireline adoption levels limits accuracy of analysis. The FCC should have an open debate about publicly releasing granular wireline neighborhood-level adoption rates, allowing researchers controlled access, and producing companion adoption statistics within the "Measuring Broadband America" report series.[79] Adding pricing and speed information within the availability data would help researchers and consumers alike, although this step introduces complexities due to internet-service bundling.[80] In both cases, however, it is clear that local leaders could use more accurate broadband data to better target their policy interventions. Likewise, the continued emergence of wireless data subscriptions demands improved data releases and followup research. If wireless becomes a more preferred option for in-home data, the FCC and independent researchers will have performance data to understand why.[81]

Support further research efforts, including around technology, competition, and ownership. Broadband is an essential service, but a relatively new technology. There are many opportunities for research to expand the public's understanding of how the broadband marketplace works and what the federal role could and should be. Fully funding research efforts like the National Science Foundation's Advanced Wireless Initiative will be key to ensuring the United States stays at the digital telecommunications forefront.[82]

Another debate that looms large in this arena is what role competition does or should play in the provision of in-home broadband, both in terms of investment needed for deployment and in reaching optimal price points. Likewise, the emergence of state laws to block public ownership of broadband networks merits further national research, especially if such state laws are found to block ownership schemes that could improve economic opportunity.

The role of local stakeholders: Align data and programs to reflect local needs

Neighborhood-level broadband indicators reveal clear performance differences within and between communities of all sizes. As such, no one community will require the same interventions to address its availability and adoption gaps. However, local stakeholders from the public, private, and civic sectors can use common approaches to geographically target and design interventions that leverage federal, state, and local resources and programs and reflect local conditions and needs.

Communities should use the levers they control to influence broadband availability. Franchise agreements are a traditional way to influence a cable company's broadband deployments in a given jurisdiction, but there are many more options to improve infrastructure extent and quality. In states where the law does not preempt local authority, competitiveness levers include establishing public or cooperative broadband providers, streamlining permitting for new entrants, and constructing public conduit that is available to all providers (or incentivizing private operators to do the same). Urban communities big and small could use targeted subsidies to incentivize deployments in specific neighborhoods, with one idea being Gigabit Opportunity Zones introduced by FCC then-Commissioner Ajit Pai.[83] The major challenge around deployment will continue to be the natural tensions between the public sector, whose mission is to maximize public utility for all, and private broadband providers, who are responsible for delivering profit to their shareholders.

Collect and reflect on data to inform local priorities. National surveys of broadband availability and adoption do an excellent job conveying the full extent of broadband challenges, but they're often too aggregated to help design specific policy reforms. Given that broadband adoption is ultimately a household-by-household decision, blanket policies may not maximize impact. Effectively addressing the digital divide requires that policymakers, service providers, and advocates understand how policies and resources "go to ground" at the local level, and align federal, state, and local interventions accordingly.

For instance, a number of issues, such as pricing, can influence in-home adoption rates. The Pew Research Center's most recent home broadband report finds that cost—both in terms of a subscription and computing equipment—is the primary reason 43 percent of survey respondents did not adopt in-home broadband.[84] Stakeholder interviews by the Government Accountability Office (GAO) confirmed similar issues with affordability.[85] At an even more fundamental level, GAO interviews and NTIA research finds that many Americans continue to question the relevance of the internet or perceive it as unsafe.[86] Even for those with the financial means and understanding of broadband's benefits, a lack of digital literacy may impede adoption.[87]

While neighborhood-level performance indicators like those in this paper are a first-order requirement to benchmark local need, to fully understand the factors underlying the outcomes presented here, public officials should go a step further and survey their neighborhoods on local conditions and attitudes related to broadband. For example, the city of Seattle runs a technology access and adoption survey every four years under its Digital Equity Initiative; the survey includes both demographic details and specific broadband performance measures.[88] The Minnesota Office of Broadband Development puts out annual reports on the state's availability and adoption progress.[89] Such surveys are especially important in rural communities, where bridging availability gaps may be expensive and should require clear articulation of bandwidth needs based on local economic activity.

Collaborate to drive adoption improvements. Addressing multiple adoption barriers at the same time is vital, but it will not be cheap. Educators in community centers of all kinds will need to teach skeptical households and those struggling with digital literacy. Equipment will need to be bought, both to outfit community centers and to directly support individuals. Likewise, fully funded marketing campaigns (described in more detail below) are critical to reach the right people in the right neighborhoods. Orchestrating these complementary but separate efforts will require management staff inside and outside government, who must be paid. Government can certainly play a role in all this, but efforts at this scale will also require coordination with the private sector and civic institutions that have much to gain. One successful model is DigitalC, a Cleveland civic organization that collaborates directly with public agencies and private firms to close the digital divide. For example, DigitalC worked alongside the Cuyahoga Metropolitan Housing Authority to bring broadband service, computing equipment, and training to public housing units and their residents.[90]

Develop campaigns tailored to local needs. Governmental, nonprofit, and academic research consistently finds public outreach and training programs to be an important strategy to boost broadband adoption. Doing so effectively will require a layered approach, including digital curricula in primary schools, classes and free internet access at community institutions like libraries, and branded marketing campaigns to expand reach to target populations.[91] In some places, effective outreach may require equipment subsidies and discounts. Especially promising is a compelling case made by staff at the Federal Reserve Bank of Dallas: engaging financial institutions to support broadband investments in low- and moderate-income communities via the Community Reinvestment Act.[92]

Marketing campaigns are especially important as it relates to attitudes around wireless broadband subscriptions relative to wireline. Many tech-savvy Pacific markets demonstrate lower wireline subscription rates when compared to broader subscription statistics from other sources, like those from the American Community Survey that simultaneously measure wireless and wireline.

Tailored campaigns in markets like those may seek to understand why wireless rates may be higher and what other factors—such as ease of use, pricing, or even widespread availability of free WiFi—may impact wireless versus wireline subscription rates.

Think locally, act regionally. Finally, how communities navigate jurisdictional boundaries will determine how effectively and efficiently they are able to close their availability and adoption gaps. Subpar broadband adoption in a handful of neighborhoods can limit an entire region's ability to grow its economy or switch to digital government platforms. As such, digital skills campaigns cannot just be core city programming—they should have extensive regional reach. NTIA's Adoption Toolkit touches on many of these approaches and includes applied examples from across the country.[93]

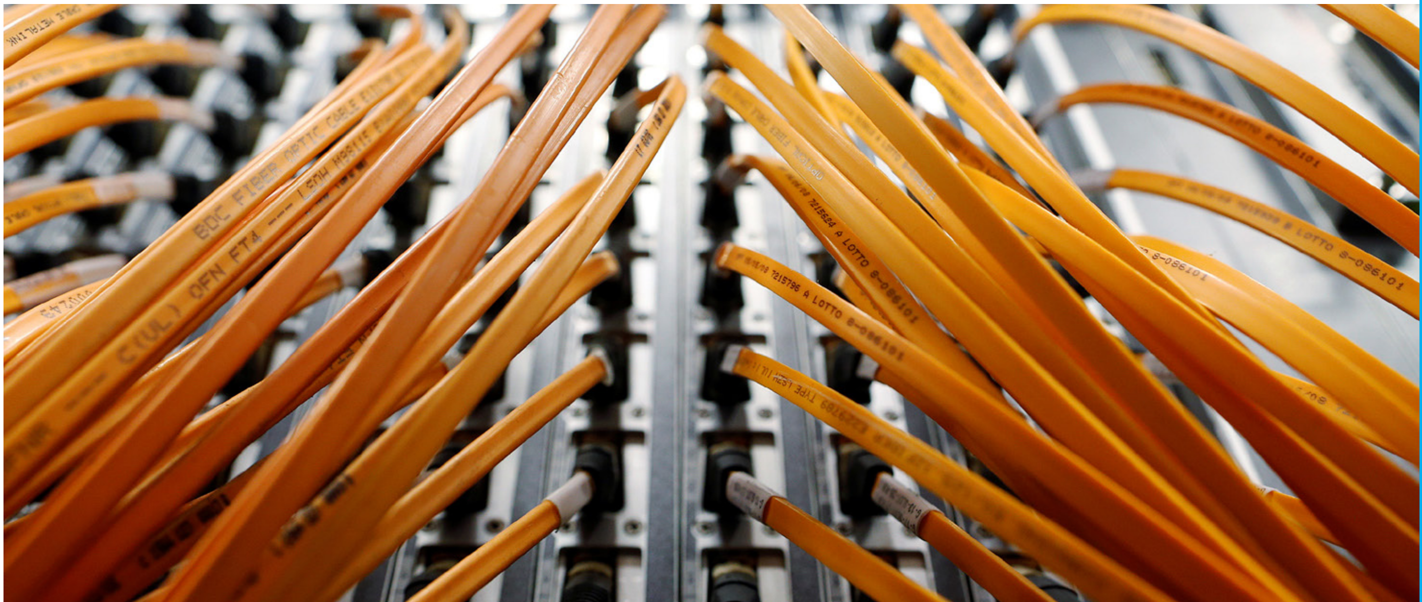
06 CONCLUSION

Broadband may be the country's newest essential infrastructure, but it is still not everywhere. Over 22 million people live in neighborhoods where high-speed internet service is not available, including an outsized share of rural residents. For the neighborhoods where broadband is available, over 73 million people live in areas of low adoption, and many economically at-risk groups like the school-age population, low-income households, and the less-educated are most affected. There is not one metropolitan area that does not face some form of broadband constraint, whether it is missing service or pockets of low subscribership. Two-plus decades into the digital revolution, the country's digital divide is both persistent and pervasive.

The consequences of these inequities are sizable. Homes without in-home broadband subscriptions will struggle to connect their children to digital curricula, to enjoy cost-effective media, and to find and be prepared for job opportunities. Unconnected households also limit business growth, from media subscriptions to e-commerce. And as long as residents cannot access parallel digital services, governments have little choice but to run analog systems like brick-and-mortar service centers.

Fortunately, there is progress. Broadband deployments, including expanded gigabit-speed systems and experiments around next-generation technology, continue to evolve. Government programs at all levels, ranging from targeted pricing support to publicly accessible training programs, aim to boost broadband adoption. Just as importantly, vigorous debate continues among public officials, civic organizations, technology providers, major industries, and researchers about how to best address the gaps highlighted in this report.

Market demand for broadband connectivity will only continue to grow as more and more economic, social, and government activity moves to the digital, connected world. As that growth occurs, it is paramount that no one gets left behind by the deployment of this generation's essential infrastructure.



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51 The FCC first began using the 10/1 speed threshold for subscription data in June 2015. As such, it is the fastest speed threshold for which subscription data are currently available.

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58 Standard scores, or z-scores, in this analysis, are a relative ranking of how better or worse a specific value is than the average from a given population. Converting those scores to percentages reflects the proportion of scores the given value exceeds, meaning higher percentages are better. To create a standard score for the broadband adoption distribution, a Gini coefficient was created (where higher inequality reflects more people living in higher-adopting neighborhoods).

59 The Broadband Loan Program was formerly known as the Rural Broadband Access Loan and Loan Guarantee Program.

60 Official information about the Kentucky Wired Program can be found on the program website at http://kentuckywired.ky.gov/Pages/index.aspx.

61 For more information on preemption and the judicial decision, see Jon Brodkin, "States Win the Right to Limit Municipal Broadband, Beating FCC in Court," Ars Technica, August 10, 2016, https://arstechnica.com/tech-policy/2016/08/in-blow-to-muni-broadband-fcc-loses-bid-to-overturn-state-laws/.

62 Pole access represents a complicated regulatory responsibility. For example, federal rules apply unless states elect to exercise their authority to access poles; the FCC's rules do not apply to an electric co-op's poles.

63 Lee Raine, Janna Anderson, and Jennifer Connolly, "Killer Apps in the Gigabit Age" (Washington: Pew Research Center, 2014).

64 See the New Century Cities letter to the FCC, http://nextcenturycities.org/wp-content/uploads/2015/11/NCC-Lifeline-Letter1.pdf.

65 Nicolaus Henke et al., "The Age of Analytics: Competing in a Data-Driven World," McKinsey Global Institute, 2016.

66 FCC, "2016 Broadband Progress Report," GN Docket No. 15-191.

67 At the time of publication, the Broadband Opportunity Council maintains the clearest collection of broadband-related federal programs. See United States Departments of Agriculture and Commerce, "Broadband Opportunity Council Agencies' Progress Report," January 2017.

68 For a primer on the "dig once" congressional state of play at time of publication, see Jon Brodkin, "'Dig Once' Bill Could Bring Fiber Internet to Much of the US," Ars Technica, March 22, 2017, https://arstechnica.com/information-technology/2017/03/nationwide-fiber-proposed-law-could-add-broadband-to-road-projects/.

69 For a supportive description of "one touch make ready" policy, see Next Century Cities, "One Touch Make Ready Fact Sheet," 2017, http://nextcenturycities.org/2017/02/01/one-touch-make-ready-fact-sheet/; or Jon Brodkin, "Verizon Supports Controversial Rule That Could Help Google Fiber Expand," Ars Technica, June 16, 2017. However, some established internet service providers have sued over initial ordinances in Louisville, Ky. and Nashville, Tenn. See, e.g., Blair Levin, "Next Battlefield in the Game of Gigs: Cities and Polls" (Washington: Brookings Institution, 2016).

70 At the time of publication, there is still no current established standard for fifth-generation wireless networks.

71 For the most recent information regarding the BTOP program, see the quarterly progress reports at https://www.ntia.doc.gov/category/broadband-technology-opportunities-program.

72 The White House's ConnectHome fact sheet can be found at https://obamawhitehouse.archives.gov/the-press-

office/2015/07/15/fact-sheet-connecthome-coming-together-ensure-digital-opportunity-all.

73 Government Accountability Office (GAO), "Intended Outcomes and Effectiveness of Efforts to Address Adoption Barriers Are Unclear," GAO-15-473, 2015.. Note that NTIA's position in response to the GAO report is that, because its technical assistance role to communities is purely advisory, an outcome-based adoption metric would not be appropriate.

74 For the full library of Lifeline-related information, see https://www.fcc.gov/general/lifeline-program-low-income-consumers.

75 The Broadband Opportunity Council's website is https://www.ntia.doc.gov/category/broadband-opportunity-council; the Broadband Interagency Working Group's website is https://www.ntia.doc.gov/category/broadband-interagency-working-group.

76 The BroadbandUSA Connectivity Assessment Tool can be found at http://www2.ntia.doc.gov/CCI.

77 Doug Brake and Robert D. Atkinson, "Comments of the Information Technology and Innovation Foundation in the Matter of Broadband Opportunity Council Request for Comment" (Washington: Information Technology and Innovation Foundation, 2015).

78 National Telecommunications and Information Administration (NTIA), "NTIA Broadband Adoption Toolkit," 2013.

79 FCC, "2016 Measuring Broadband America Fixed Broadband Report," 2016.

80 For more information about broadband performance and consumer-facing transparency, see Emily Hong and Sarah Morris, "Getting Up to Speed: Best Practices for Measuring Broadband Performance" (Washington: New America Foundation, 2016).

81 For current research on in-home use of wireless broadband subscriptions, see Giulia McHenry, "Evolving Technologies Change the Nature of Internet Use" (Washington: NTIA, 2016), https://www.ntia.doc.gov/blog/2016/evolving-technologies-change-nature-internet-use.

82 For more information on the Advanced Wireless Initiative, visit the National Science Foundation website at https://nsf.gov/cise/advancedwireless/.

83 FCC, "Summary of FCC Commissioner Ajit Pai's Digital Empowerment Agenda," 2016, https://apps.fcc.gov/edocs_public/attachmatch/DOC-341210A2.pdf.

84 Horrigan and Duggan 2015.

85 GAO, 2015.

86 GAO 2015; NTIA, 2013.

87 NTIA defines digital literacy as "the ability to use information and communication technologies to find, evaluate, create, and communicate information; it requires both technical and cognitive skills"; NTIA 2013, or see https://www2.ntia.doc.gov/resources.

88 City of Seattle, "Information Technology Access and Adoption in Seattle: Progress Towards Digital Opportunity and Equity," 2014.

89 Minnesota Office of Broadband Development, "Governor's Task Force on Broadband – 2016 Annual Report," 2016.

90 Marcia Pledger, "First High-Speed Broadband in Cleveland's Public Housing Celebrated Today," Cleveland Plain Dealer, May 11, 2017.

91 Jessica A. Lee and Adie Tomer, "Building and Advancing Digital Skills to Support Seattle's Economic Future" (Washington: Brookings Institution, 2015).

92 Jordana Barton, "Closing the Digital Divide: A Framework for Meeting CRA Obligations" (Federal Reserve Bank of Dallas, 2016).

93 NTIA 2013.

APPENDIX A
BROADBAND REGULATORY FRAMEWORK

The United States primarily deploys a private model of broadband service provision.[1] Broadband service is generally provided by telephone and cable companies, both of which upgraded their traditional voice and video networks, respectively, to offer data services. These broadband service providers (BSPs) invest significant capital in constructing, operating, and maintaining a large network of cables and facilities that house data centers, servers, and routers. Since these key components of broadband infrastructure must be integrated into the existing built environment, the providers need access to poles, ducts, and conduits, as well as the rights-of-way (both public and private) within which their broadband infrastructure can be housed. Once the physical infrastructure is in place, BSPs also must adhere to policies regulating the provision of services. This process of accessing and obtaining permission to use existing facilities, construct new infrastructure, and provide internet services is governed by a multitude of federal, state, and local policies.

This appendix summarizes the major features of broadband regulation policy at the federal level.

Wireline broadband infrastructure: Who regulates what?

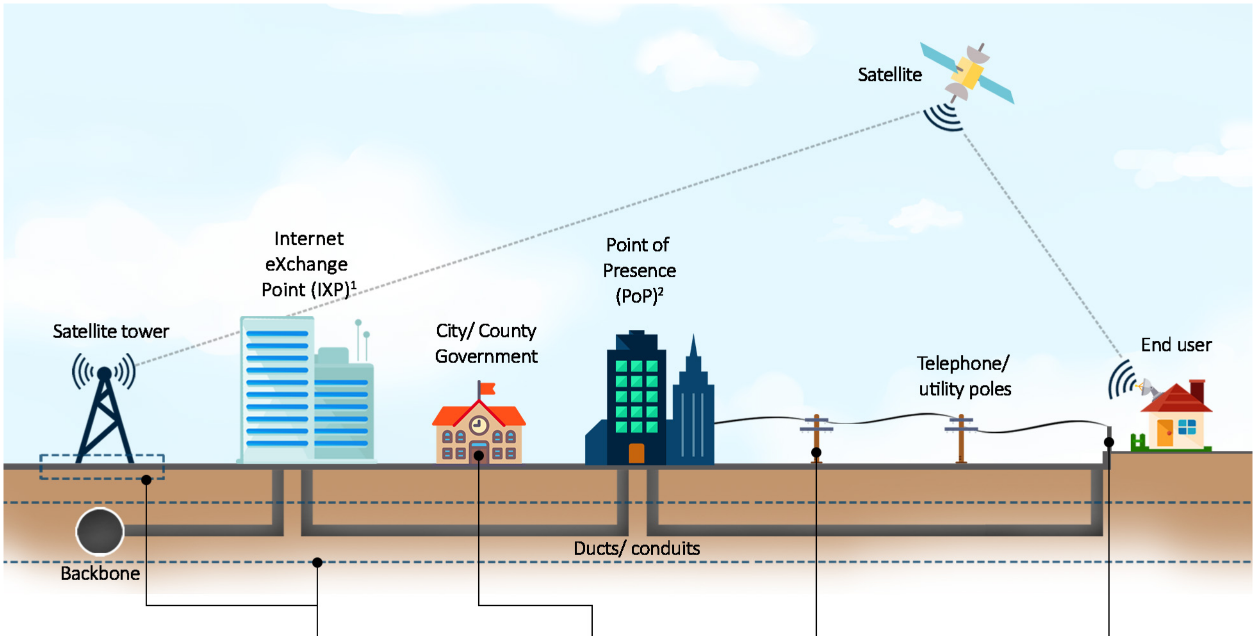
There are three primary modes of wireline broadband provision today: digital subscriber line (DSL), cable, and fiber optic cable. All these modes require the construction, operation, and maintenance of a physical cable network. DSL uses phone lines to provide broadband service, while cable companies transmit digital data over cable television lines. Fiber optic cable, a newer and faster technology, contains strands of glass fibers inside an insulated casing. The deployment of fiber optic cable is still in its infancy in the United States, making DSL and cable broadband the dominant modes of internet service provision. [2] It is important to note that cable broadband companies can update their infrastructure capabilities without retrenching their networks, while DSL providers would need to do so.

The network for these three modes can be constructed in three primary ways: underground installation, where cables are placed in conduits that are then buried; buried installation, where cables (with or without protective ducts) are directly buried in the ground; and aerial installation, where cables are attached to existing utility poles. Trenches for underground or buried cable are most commonly dug alongside existing infrastructure networks, such as highways and roadways. Cables may also require supporting infrastructure such as pedestals, manholes, and controlled-environment vaults. The installation of the network and its associated components thus requires permission (most often from city or local governments) to access and modify the existing built environment.

The top half of Figure A1 depicts the typical pathway for broadband service provision, while the bottom half points to key regulatory policies at the federal, state and local levels that govern

FIGURE A1

America's privately built, publicly regulated broadband infrastructure



Level of regulation

	Right-of-Way Permits	Franchise Agreement	Pole Permits	Last-mile Access
Federal	Permits to access federal lands, buildings, highways and roadways to build and operate broadband infrastructure	Contract between service provider and local government required by Cable Communications Act of 1984	Access to poles owned by investor-owned utilities in states that had no pole regulation prior to Pole Attachment Act	
State	Permits to access state lands, buildings, highways and roadways to build and operate broadband infrastructure	State-wide cable/ video franchise agreements issued by the Department of State or Public Utilities Commisions	Access to poles owned by investor-owned utilities in states that pre-empted federal pole regulation, and to poles owned by public electric cooperatives and municipalities	
Local	Franchise agreements typically subsume right-of-way permits to access local public and private land, buildings and roadways to build and operate broadband infrastructure. Franchise agreements can also include franchise fees, programming requirements and customer service standards.		Access to poles owned by public electric cooperatives and municipalities in states that have no specific pole regulation	Access to customers in individual/ multiple dwelling units often determined by exclusive contracts between owners/ homeowners' associations and provider

[1]Internet eXchange Point (IXP)- Typically, a location that facilitates the costless/ low-cost exchange of internet traffic between the networks of different Internet Service Providers through mutual peering agreements.
[2]Point of Presence (POP)- Typically, a location where a long-distance carrier's cables end and connect into a local network, such as a regional or city network. From the point of presence, internet traffic is routed to the end user.

Source: The Brookings Institution

important points along the pathway. The top half of the figure illustrates the key components of physical infrastructure for wireline broadband provision, from the backbone to the end user. The Internet relies on a backbone to carry data over long distances. The backbone consists of several ultra-high bandwidth connections that link together at key network nodes all over the world. Next, an Internet Exchange Point (IXP) facilitates the costless/low-cost exchange of internet traffic between different provider networks through mutual peering agreements. Finally, at a point of presence (PoP), a long-distance carrier's cables typically end and connect into a local regional or city network. From the point of presence, internet traffic is routed to the end user.

Rights-of-way

Rights-of-way permits determine access to the public transportation and utility corridors as well as the private land required to build a broadband network. These permits are typically part of franchise agreements with local governments. However, governments at all levels may exhibit regulatory authority, including federal, state, local, and even tribal governments.[3] For instance, the United States Department of Transportation (DOT) governs access to federally assisted highways. Below the federal level, rights-of-way policy is often inconsistent between different states and cities. To add to the complexity, rights-of-way are also used by other utilities, including electricity, water, and gas.

In 2012, President Obama signed an executive order to facilitate broadband deployment on federal lands, buildings, rights-of-way, federally assisted highways, and tribal lands.[4] The order created an interagency working group composed of a number of federal agencies, including DOT, with a goal to reduce barriers to the expansion of broadband services in underserved communities. The order directed the Federal Highway Administration to review "dig once" requirements in existing programs, in order to coordinate the placement of underground fiber optic cable along highway and roadway rights-of-way. The order also includes provisions such as imposing a moratorium on street excavation to preserve new roadways, installation of empty conduit in the right-of-way during new construction, and the use of trenchless technologies, such as horizontal directional drilling or micro-trenching.[5]

Franchise agreements

The Cable Communications Act of 1984 requires city, county, and state governments and cable television providers who offer internet service to sign a contract known as a franchise agreement. Before any service provider can install infrastructure, governments typically request bids from companies that wish to provide service. The bid process is followed by a franchise negotiation and the signing of a contract between the government and the provider that is typically renewed every 10 years. Note that local franchise requirements legally apply only to cable television companies, but today, internet, television, and voice (telephone) provision are often bundled into a single package. This can bring internet service providers under the purview of these agreements.

A franchise agreement is a contract that typically covers rights to access public and private rights-of-way, to construct and operate infrastructure, and to provide customer service. It can also include service standards, franchise fees of up to 5 percent of the provider's gross revenue, and provision of public, educational, and government programming. Critically, those standards can mandate ubiquitous service to all neighborhoods within a service territory. However, the agreements cannot determine the price of services.[6]

The questions of how easy it is to negotiate with governments and how willing governments are to make concessions often play a key role in broadband deployment. According to the Government Accountability Office, providers can be sensitive to how receptive state and local government officials are to new market entrants.[7] They specifically consider the degree to which state and local government officials make efforts to reduce administrative requirements that pose significant barriers to entry. More recently, when telecommunications companies started providing video services, a large number of states changed the law to allow for statewide franchising.[8]

Poles, ducts, and conduit access

There are roughly 134 million poles in the United States owned by various entities, including private investors and public agencies such as electric utilities and municipalities.[9] Access to poles, ducts, and conduits is often crucial for attaching cables/wires to existing poles or future small cell facilities. Under the federal Pole Attachment Act, as amended by the Telecommunications Act of 1996,[10] the procedure for applying for the right to access poles varies by whether the utilities are investor-owned or owned by public electric cooperatives or municipalities. When poles are owned by investor-owned utilities, there can be one of two situations:

- States whose investor-owned utilities are regulated by the Federal Communications Commission (FCC) for pole attachment purposes; or

- States whose investor-owned utilities are regulated by the states themselves as the states have preempted federal regulation of pole attachments.

The 1996 act exempts public electric cooperatives and municipalities from any federal pole regulation, and it is therefore left to the states to decide how to regulate them. Some states have state-level regulation in place, while some don't, in which case the BSPs have to negotiate with individual cooperatives and municipalities. This can be an expensive and time-consuming process.

In recognition of the barrier posed to timely and cost-efficient broadband provision by the lack of access to poles at reasonable rates and conditions, the FCC has tried to simplify and hasten the process. In 2010, the FCC's National Broadband Plan recommended the establishment of rental rates for pole attachments that are as low and uniform as possible to promote broadband deployment. In 2011, the FCC issued the Pole Attachments Order to streamline access to utility poles across the country.[11] State legislatures, too, have been under pressure to create consistent and favorable rules for pole attachments.

Pole access and related policies will only continue to gain interest from BSPs and governments in the coming years as emerging technologies like 5G require new pole infrastructure.

Last-mile access

Homeowner associations and managers of buildings, especially apartments classified as multiple tenant environments, often have exclusive contracts with incumbent cable operators to provide broadband to their residents. These agreements can pose a problem to new BSPs trying to use the existing infrastructure within the buildings to provide service, as well as a problem to new or existing BSPs seeking to install new technologies such as fiber. In response to this issue, the FCC released a Notice of Inquiry in June 2017 seeking comment on the need to reduce barriers faced by broadband providers that are serving or want to serve multiple tenant environments.[12]

Broadband service provider limitations

While the vast majority of BSPs are privately owned, there are publicly owned broadband service providers in many communities. Laws in some states prevent local governments from building public broadband networks, also called municipal broadband. These limitations can extend to entire networks, or might stop publicly built networks from connecting to end users. This highly contentious and important topic is beyond the scope of this paper.

Endnotes

1 There are important exceptions, including community-owned broadband networks in places like Chattanooga, Tenn. and Wilson, N.C.

2 One significant difference between telecom and cable companies is that telecom companies have to re-trench in order to upgrade from DSL to fiber optic, whereas cable companies can upgrade their existing network without re-trenching.

3 Scott Walsten, "Broadband Penetration: An Empirical Analysis of State and Federal Policies" (Washington: American Enterprise Institute-Brookings Joint Center for Policy Studies, Working Paper 05-12, 2005.

4 "Accelerating Broadband Infrastructure Deployment," https://obamawhitehouse.archives.gov/the-press-office/2012/06/14/executive-order-accelerating-broadband-infrastructure-deployment.

5 "Minimizing Excavation Through Coordination," Federal Highway Administration, Office of Transportation Policy Studies, October 2013, https://www.fhwa.dot.gov/policy/otps/policy_brief_dig_once.pdf.

6 Historically, local communications infrastructure depended on telephone networks that were owned and operated by large companies that serviced areas that were larger than any one single neighborhood or community. This meant that the telephone companies were regulated as "common carriers" by state public utility commissions and the FCC, and not by local governments. Federal law thus prohibits local governments from regulating cable rates, except for the lowest-cost tier of service.

7 "Broadband Deployment Is Extensive Throughout the United States, But It Is Difficult to Assess the Extent of Deployment Gaps in Rural Areas," U.S. Government Accountability Office, GAO-06-426, 2006.

8 "Statewide Video Franchising Status," National Conference of State Legislatures, 2014, http://www.ncsl.org/research/telecommunications-and-information-technology/statewide-video-franchising-statutes.aspx.

9 FCC.

10 Jill M. Valenstein, "Communications Attacher Efforts Lead to Laws Governing Pole Owning Electric Cooperatives and Municipalities," Broadband Deployment Law Advisor, 2013, http://www.broadbandlawadvisor.com/2013/05/articles/infrastructure-poles-conduit-and-rights-of-way/communications-attacher-efforts-lead-to-laws-governing-pole-owning-electric-cooperatives-and-municipalities/.

11 FCC Order 11-50, 2011.

12 "Improving Competitive Broadband Access to Multiple Tenant Environments," FCC Fact Sheet, 2017, http://transition.fcc.gov/Daily_Releases/Daily_Business/2017/db0601/DOC-345161A1.pdf.

APPENDIX B
TECHNICAL METHODOLOGY

Data sources

This study combines detailed data on broadband deployment and fixed connections from the Federal Communications Commission (FCC) and demographics from the U.S. Census Bureau's American Community Survey (ACS) to determine the variation in accessibility and subscription of broadband across the United States.

FCC Form 477 broadband data

The two primary datasets for broadband availability and subscription come from the FCC's Internet Access Service Reports as of December 2015.[1] The FCC compiles these reports from Form 477 data that all facilities-based broadband providers are required to file twice a year.[2]

Fixed broadband deployment data

For the analysis on broadband availability, the fixed broadband deployment data from Form 477 were used. These data are available at the census block level, which is the smallest geographic entity for which the U.S. Census Bureau tabulates decennial census data.[3] Each broadband provider submits lists of census blocks where it offers internet access service to at least one location at speeds exceeding 200 kbps in at least one direction, with additional information about the technology and bandwidth provided. Each row in the dataset compiled from these data corresponds to a provider within a census block. In the raw data, there can thus be multiple rows for any given census block, based on the number of providers offering broadband service in that block. Note that a provider that reports deployment of a particular technology and bandwidth in a census block may not necessarily offer that particular service everywhere in the census block. This dataset thus provides details on whether or not each census block has any service provision and the number of providers for each speed category in a block.

Residential fixed connections data

For the analysis on broadband subscription, the FCC's residential fixed connections dataset was used. This dataset provides the number of residential fixed internet access service connections of at least 10 Mbps downstream and 1 Mbps upstream per 1,000 households by census tract based on Form 477 fixed broadband subscribership data.[4] In other words, these data tell us the proportion of the population within any given census tract that has "adopted" broadband by subscribing to a fixed connection with at least 10Mbps downstream speeds. The FCC reports these data in quintiles, plus a sixth "zero percent" category.

American Community Survey demographics data
To assign demographic data to all census tracts, we used the 2011-2015 five-year ACS estimates, the most recent as of publication.[5] Primary variables in this dataset include population, poverty, race, age, education, income, nationality, and housing characteristics of residential tracts. All data are downloaded through the National Historical Geographic Information System (NHGIS).[6] The ACS five-year estimates represent data collected between January 1, 2011 and December 31, 2015. It is the most geographically-precise dataset

offered by the ACS, but the data represent a five-year average in all of the reported categories.

Decennial census data

The 2010 decennial census was the source for aggregate population data within census blocks. This is the only public data source providing universal population counts at this geographic level. The data were used in the aggregation process described below.

Constructing a merged broadband-demographics dataset

Aggregation of availability data from block to tract level

Broadband availability data are at a more detailed census block level, while subscription and demographic data are at the census tract level. This distinction necessitates the aggregation of availability data from block to tract level in order to make the data compatible with the other datasets and create a merged model-ready dataset. To achieve this aggregation, the availability data were first aggregated by census block, wherein each row specifies whether or not there is service provision by different speed categories for a specific census block based on the number of providers in the raw FCC data. The speed categories are chosen based on the characteristics in Table B1.

In aggregating from block to tract, we first calculate the total population in all blocks within the tract that has no service provision. If a majority (greater than 50 percent) of the population in all blocks in a given tract has no provider in a certain speed category, we qualify the tract as having no service provision. If exactly 50 percent of the population in the tract has no provider, then that tract is given the benefit of the doubt and categorized as having service provision at the highest-qualifying speed tier. If a majority (greater than 50 percent) of the population in all blocks in a given tract has one or more providers in a certain speed category, then the tract is categorized as having service provision.

It is critical to qualify the potential assignment errors inherent to these techniques. First, the FCC Form 477 data qualify an entire census block as being serviced by a given provider if any address is serviced. This inference naturally leads to potential overestimation of coverage within a given census block. Second, because the demographic and income data we use in this analysis are not available at the block level, we aggregate blocks to census tracts, a step that required us to either qualify an entire tract as served or not served by broadband. However, since broadband may serve only some of the census blocks within a tract, this method will miscategorize a certain share of the population. Our methodology causes these mischaracterizations to skew in a positive direction—on net we overestimate the number of people served by broadband. This margin of error does not meaningfully change the overall

TABLE B1

Speed category	Justification
3 Mbps and above	Broadband speed permitting high-quality, non-video internet browsing and some video streaming
10 Mbps and above	Broadband speed standard in some developed countries
25 Mbps and above	Formal FCC definition of broadband speed
1,000 Mbps (or 1 Gbps) and above	A prominent speed tier that is advertised and sold, often in the context of fiber optic cable

Source: The Brookings Institution

TABLE B2

Regression of variables on metropolitan broadband subscription rates, 2014 single year*

VARIABLES	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Poverty Rate	-0.368***	-0.419***	-0.396***	-0.427***	-0.395***	-0.423***	-0.399***	-0.376***
	-0.00626	(0.00637)	(0.00620)	(0.00661)	(0.00620)	(0.00667)	(0.00652)	(0.00741)
Population Density per Mile	3.07e-06***	2.86e-06***	1.08e-06***	1.01e-06***	1.04e-06***	9.97e-07***	8.98e-07***	9.61e-07***
	(5.50e-08)	(5.48e-08)	(5.97e-08)	(5.98e-08)	(5.99e-08)	(6.00e-08)	(5.85e-08)	(5.93e-08)
Broadband Availability at 25 Mbps (Boolean)	0.315***	0.309***	0.286***	0.283***	0.287***	0.284***	0.247***	0.248***
	(0.00242)	(0.00241)	(0.00236)	(0.00237)	(0.00236)	(0.00238)	(0.00240)	(0.00241)
Share of Population over Age 25 with No More than a High School Diploma	-0.539***	-0.530***	-0.560***	-0.561***	-0.547***	-0.554***	-0.490***	-0.498***
	(0.00448)	(0.00445)	(0.00434)	(0.00434)	(0.00461)	(0.00464)	(0.00465)	(0.00484)
Share of Population Aged 65 or Older		-0.301***	-0.207***	-0.198***	-0.220***	-0.206***	-0.166***	-0.154***
		(0.00863)	(0.00850)	(0.00852)	(0.00864)	(0.00871)	(0.00853)	(0.00871)
Foreign Born Share of Total Population			0.355***	0.366***	0.389***	0.384***	0.340***	0.339***
			(0.00539)	(0.00545)	(0.00684)	(0.00685)	(0.00672)	(0.00672)
Black Share of Total Population				0.0426***		0.0384***	0.000467	-0.000265
				(0.00324)		(0.00339)	(0.00336)	(0.00337)
Hispanic Share of Total Population					-0.0345***	-0.0195***	-0.0533***	-0.0577***
					(0.00434)	(0.00453)	(0.00446)	(0.00451)
Rural Neighborhood (Boolean)							-0.114***	-0.114***
							(0.00190)	(0.00190)
Families Share of Total Population								0.0342***
								(0.00523)
Constant	0.531***	0.585***	0.568***	0.568***	0.565***	0.567***	0.599***	0.575***
	(0.00298)	(0.00334)	(0.00325)	(0.00325)	(0.00327)	(0.00327)	(0.00324)	(0.00494)
Observations	72,222	72,222	72,222	72,222	72,222	72,222	72,222	72,222
R-squared	0.485	0.494	0.522	0.524	0.523	0.524	0.546	0.547

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

Source: Brookings Institution analysis of 2011-2015 American Community Survey (ACS) and FCC data

findings, but it does mean that individual tract data, in particular, should be read with caution.

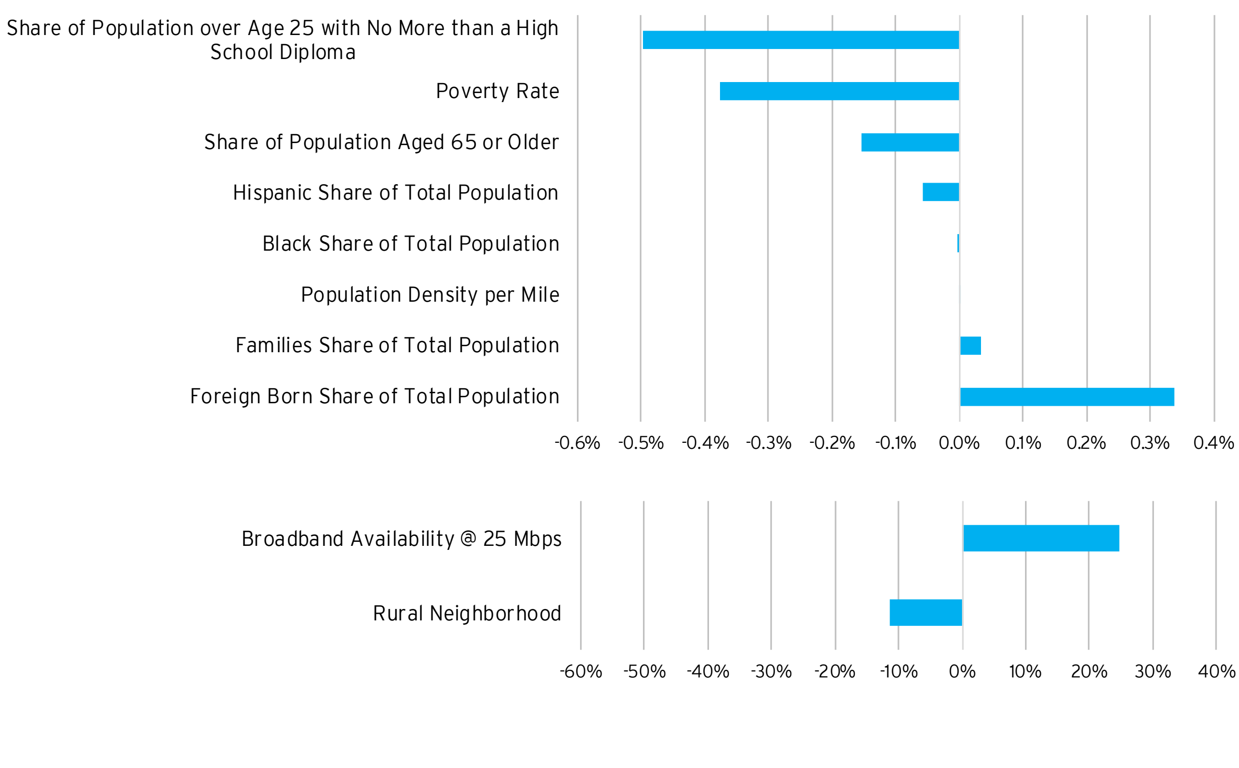
Finally, note that there are two types of speed data in the Form 477 dataset, advertised speed and typical speed. Based on comments from an expert roundtable held by Brookings in the summer of 2016, advertised speed was chosen as the speed variable used in the analysis.

Geographic typologies

We assign all census tracts to one of the following mutually exclusive categories: large metro, small metro, and nonmetropolitan areas. Of the 381 metropolitan statistical areas (MSAs) defined by the Office of Management and Budget in 2013, the 100 with the largest total population—per the 2010 decennial census—are considered large metro areas. Tracts falling within any MSA not among the 100 largest are considered to be in a small metro area. All others are considered rural. For tracts that fall within the 100 largest metropolitan areas, we further categorize them as either cities or suburbs. City tracts are those that fall within the first named city in the MSA's official title, as well as all other cities in the MSA title with population totals greater than 100,000 (also per the 2010 decennial census). Tracts that fall within the 100 largest metropolitan areas but outside of these primary cities are considered suburban.

FIGURE B1

Estimated change in neighborhood broadband subscription rate per 1 percentage point increase in the variable, 2015*



* Adjusted R^2 = 0.547; n = 72,222; F = 8,705.26.

Source: Brookings Institution analysis of 2011-2015 American Community Survey (ACS) and FCC data

Model for estimating relationship between demographic variables and subscription rates

The brief uses an ordinary least squares (OLS) multiple regression to investigate the association between demographic variables and broadband subscription rates at the census tract level. The model is based on the same FCC and ACS data vintages described in this appendix. The model did not include female or male share of tract population because past research work did not find rates to vary by gender.[7]

We predict broadband subscription rates based on the following formula:

$$Y_t = \beta_0 + \beta_1 X_{1,t} + \cdots + \beta_p X_{p,t}$$

Where t designates tract and p designates the 10 independent variables.

The 10 independent variables are: poverty rate; population density per mile; broadband availability at 25 Mbps (Boolean); share of population over age 25 with no more than a high school diploma; share of population age 65 or older; foreign-born share of total population; black share of total population; Hispanic share of total population; rural neighborhood (Boolean); and families share of total population.

Because the FCC reports tract-level subscription data in categorical quintiles, we converted each quintile into the median value of the given quintile to create a continuous dependent variable. For example, the "0 to 20 percent" category became a value of 10 percent. To check for validity, we also tested the categorical data as the upper bound of the quintile and the model reported the exact same results.

The results of this regression, plus seven alternative models, are shown in Table B2. All told in Model 8—the preferred model—nine variables were found to have significance at the 1 percent level. Overall, this model explains about 55 percent of the variation in broadband subscription for the 72,222 tracts that had data for all fields.

Model analysis

Overall, the model demonstrates the strong, significant relationships that exist between a number of neighborhood characteristics and broadband subscription levels. The preferred model includes 10 variables, nine of which were significant (Figure B1). It is worth emphasizing that these results are not suggesting causality or directionality to the results; rather, they present relationships between subscription rates and the given independent variables. Similarly, it is important to recognize that the model cannot specify many variables likely to impact subscription demand, including digital skills.

Education levels and poverty are associated with the largest effects, and both relate to broadband subscription in ways one would expect.[8] For education, every 1 percent increase in the share of residents with no more than a high school diploma suggests broadband subscription rates will drop by 0.49 percent. This may seem like a small effect, but it is not. While adults with no more than a high school diploma represent 41 percent of the median neighborhood's population, there are over 1,700 neighborhoods where this population share jumps above 75 percent. Based on the model's findings, it is not surprising that 71 percent of these low-educated neighborhoods fall into the low-subscription category.

Poverty rates function in a similar way: every 1 percent increase in the share of residents living in poverty suggests broadband subscription rates will drop by 0.38 percent. Here again, the median neighborhood poverty rate of 13 percent says little about the 4,379 neighborhoods where over 40 percent of people live below the poverty line. For a neighborhood of concentrated poverty, a lack of broadband subscriptions is yet another barrier to opportunity for its residents. These risks only grow when neighborhoods house people with both lower education levels and higher poverty rates.

Age also has a negative relationship with subscription rates, although the effects are smaller than education and income. As expected, neighborhoods with larger shares of retirement-age individuals demonstrate lower subscription levels. Specifically, every 1 percent increase in the share of residents over the age of 65 suggests broadband subscription rates will drop by 0.15 percent. These impacts will be especially acute in the hundreds of neighborhoods where retirees represent over half of the population.

In contrast, the share of foreign-born residents carries the largest positive effect among the demographic variables. The model finds that every 1 percent increase in the foreign-born population leads to a 0.34 percent increase in broadband subscription. One possible explanation is that foreign-born populations' enhanced global connectivity—such as family, social, and even business connections outside the country—could increase their interest in broadband subscriptions. However, the level of relationship warrants further study.

The model also found racial groups' share of neighborhood population to have relatively small effects on broadband subscription. Larger Hispanic populations are significant but their negative impacts on subscription are relatively small, while larger black populations do not significantly impact subscription rates. These findings do not suggest these groups are unimportant to track for broadband policy purposes, especially since surveys regularly confirm major gaps by race, and individual-level regression models have found race to be a significant factor for subscription.[9] Instead, this neighborhood-level model suggests that further research should investigate racial gaps in broadband subscription and how they relate to other features such as age, income, and education.

Finally, the model reported some critical results from the two dummy variables. When controlling for broadband availability at 25 Mbps—the same measure used in the first two findings and a faster benchmark than the 10 Mbps qualification used in the subscription data—the model found that the presence of neighborhood broadband connections increases likely subscription rates by a striking 25 percent. This result suggests that deploying even higher-speed networks can promote greater subscription rates among local populations. The rural flag also was significant and led to an 11 percent drop in subscription rates. Considering the model controls for other factors like availability, income, and education, it is possible that other barriers to subscription exist specifically for rural residents.

In the future, this model's explanatory ability should improve with more specific subscription data provided by the FCC. Due to the quintile nature of reported broadband subscription rates, there are unknown limitations to the model's accuracy.

Endnotes

1 FCC Internet Access Service Reports can be found online at https://www.fcc.gov/reports-research/reports/internet-access-services-reports/internet-access-services-reports.

2 Four types of entities must file Form 477s with the FCC: facilities-based providers of broadband connections to end users, providers of wired or fixed wireless local exchange telephone service, providers of interconnected voice over internet protocol (VoIP) service, and facilities-based providers of mobile telephony (mobile voice) service. For more information, see the FCC description online at https://transition.fcc.gov/form477/WhoMustFileForm477.pdf.

3 Blocks are statistical areas bounded by visible features such as streets and railroad tracks and by nonvisible boundaries such as selected property lines and city and county limits. Generally, census blocks are small in area; for example, a block in a city bounded on all sides by streets. Census blocks in suburban and rural areas may be large, irregular, and bounded by a variety of features, such as roads, streams, and

transmission lines. Census blocks cover the entire territory of the United States, Puerto Rico, and the Island Areas. As of 2010, there were 11,078,297 census blocks in the 50 states and the District of Columbia, 77,189 blocks in Puerto Rico, and 10,850 blocks in the Island Areas.

4 Census tracts are small, relatively permanent statistical subdivisions of a county or equivalent entity that are updated by local participants prior to each decennial census as part of the Census Bureau's Participant Statistical Areas Program. The primary purpose of census tracts is to provide a stable set of geographic units for the presentation of statistical data. Census tracts generally have a population size between 1,200 and 8,000 people, with an optimum size of 4,000 people. As of 2010, there were 73,056 census tracts in the 50 states and the District of Columbia, 945 tracts in Puerto Rico, and 132 tracts in the Island Areas.

5 Full details on the American Community Survey can be found online at https://www.census.gov/programs-surveys/acs/.

6 The National Historical Geographic Information System's website is https://www.nhgis.org/.

7 Andrew Perrin and Maeve Duggan, "Americans' Internet Access: 2000-2015" (Washington: Pew Research Center, 2015).

8 While prior research findings have found correlations between poverty and education, the model's variance inflation factors did not find multicollinearity among any of the variables.

9 For an example of wireline broadband subscription research with an individual-level model, see S. Derek Turner, "Digital Denied: The Impact of Systemic Racial Discrimination on Home-Internet Adoption" (Washington: Free Press, 2016).

APPENDIX C

METROPOLITAN BROADBAND DATA

Metro	Metro Availability @ 25 Mbps	Availability Z-Score* %	Subscr-iption GINI**	Subscr-iption Z-Score* %	Com-bined Score	Com-bined Rank
Palm Bay-Melbourne-Titusville, Fla.	100.0%	81.3%	0.64	98.2%	1.79	1
Urban Honolulu, HI	100.0%	80.9%	0.63	97.5%	1.78	2
Bridgeport-Stamford-Norwalk, Conn.	99.9%	80.4%	0.63	97.6%	1.78	3
New York-Newark-Jersey City, N.Y.-N.J.-Pa.	99.9%	80.8%	0.61	96.3%	1.77	4
Boston-Cambridge-Newton, Mass.-N.H.	99.7%	79.3%	0.62	97.1%	1.76	5
North Port-Sarasota-Bradenton, Fla.	100.0%	81.3%	0.58	93.4%	1.75	6
Deltona-Daytona Beach-Ormond Beach, Fla.	100.0%	81.3%	0.58	93.2%	1.74	7
Philadelphia-Camden-Wilmington, Pa.-N.J.-Del.-Md.	99.8%	79.4%	0.57	92.5%	1.72	8
Tampa-St. Petersburg-Clearwater, Fla.	99.0%	72.7%	0.62	97.1%	1.70	9
Providence-Warwick, R.I.-Mass.	99.1%	73.9%	0.61	96.0%	1.70	10
Orlando-Kissimmee-Sanford, Fla.	100.0%	81.3%	0.54	87.4%	1.69	11
San Jose-Sunnyvale-Santa Clara, Calif.	99.9%	80.3%	0.55	88.1%	1.68	12
Worcester, Mass.-Conn.	99.6%	78.3%	0.56	89.7%	1.68	13
San Francisco-Oakland-Hayward, Calif.	99.7%	78.7%	0.55	87.6%	1.66	14
Washington-Arlington-Alexandria, DC-Va.-Md.-W.Va.	98.4%	66.9%	0.62	96.9%	1.64	15
San Diego-Carlsbad, Calif.	98.5%	67.6%	0.59	94.7%	1.62	16
Austin-Round Rock, TX	99.4%	76.7%	0.53	84.3%	1.61	17
Oxnard-Thousand Oaks-Ventura, Calif.	98.8%	71.3%	0.54	87.4%	1.59	18
Hartford-West Hartford-East Hartford, Conn.	99.5%	77.0%	0.52	80.4%	1.57	19
Albany-Schenectady-Troy, N.Y.	99.1%	73.5%	0.53	83.2%	1.57	20
New Haven-Milford, Conn.	100.0%	81.3%	0.50	74.7%	1.56	21
Seattle-Tacoma-Bellevue, Wash.	99.7%	79.1%	0.50	75.4%	1.54	22

Metro	Metro Availability @ 25 Mbps	Availability Z-Score* %	Subscr-iption GINI**	Subscr-iption Z-Score* %	Com-bined Score	Com-bined Rank
Jacksonville, Fla.	99.8%	80.0%	0.49	73.2%	1.53	23
Baltimore-Columbia-Towson, Md.	99.3%	75.7%	0.50	74.8%	1.50	24
Miami-Fort Lauderdale-West Palm Beach, Fla.	99.4%	76.6%	0.48	69.8%	1.46	25
Virginia Beach-Norfolk-Newport News, Va.-N.C.	97.7%	59.4%	0.54	87.0%	1.46	26
Syracuse, N.Y.	98.5%	68.4%	0.51	77.5%	1.46	27
Raleigh, N.C.	99.3%	75.7%	0.48	69.5%	1.45	28
Los Angeles-Long Beach-Anaheim, Calif.	99.7%	79.0%	0.45	58.7%	1.38	29
Buffalo-Cheektowaga-Niagara Falls, N.Y.	99.1%	73.4%	0.46	61.5%	1.35	30
Chicago-Naperville-Elgin, Ill.-Ind.-Wis.	99.5%	77.5%	0.45	56.2%	1.34	31
Las Vegas-Henderson-Paradise, Nev.	99.6%	77.8%	0.43	50.7%	1.28	32
Rochester, N.Y.	99.4%	76.3%	0.43	51.5%	1.28	33
Milwaukee-Waukesha-West Allis, Wis.	99.8%	79.4%	0.43	48.1%	1.28	34
Akron, OH	100.0%	81.3%	0.42	45.9%	1.27	35
Pittsburgh, Pa.	99.0%	73.0%	0.44	54.1%	1.27	36
Riverside-San Bernardino-Ontario, Calif.	96.9%	50.6%	0.50	76.3%	1.27	37
Salt Lake City, UT	100.0%	81.3%	0.42	44.9%	1.26	38
Dayton, OH	99.7%	79.1%	0.42	44.9%	1.24	39
Atlanta-Sandy Springs-Roswell, Ga.	97.5%	57.5%	0.47	65.5%	1.23	40
Lakeland-Winter Haven, Fla.	97.0%	52.3%	0.47	66.9%	1.19	41
Denver-Aurora-Lakewood, Colo.	98.8%	70.9%	0.43	48.2%	1.19	42
New Orleans-Metairie, La.	99.3%	75.8%	0.41	43.0%	1.19	43
Charlotte-Concord-Gastonia, N.C.-S.C.	98.2%	65.3%	0.44	53.1%	1.18	44
Dallas-Fort Worth-Arlington, TX	99.3%	76.0%	0.41	41.8%	1.18	45
Sacramento--Roseville--Arden-Arcade, Calif.	98.0%	62.7%	0.44	54.0%	1.17	46
Greensboro-High Point, N.C.	100.0%	81.3%	0.38	31.2%	1.13	47
Cincinnati, OH-Ky.-Ind.	98.1%	63.6%	0.42	45.5%	1.09	48
Springfield, Mass.	95.5%	35.5%	0.48	69.1%	1.05	49

Metro	Metro Availability @ 25 Mbps	Availability Z-Score* %	Subscr-iption GINI**	Subscr-iption Z-Score* %	Com-bined Score	Com-bined Rank
Cape Coral-Fort Myers, Fla.	100.0%	81.3%	0.35	20.1%	1.01	50
Allentown-Bethlehem-Easton, Pa.-N.J.	100.0%	81.3%	0.35	19.9%	1.01	51
Nashville-Davidson--Murfreesboro--Franklin, Tenn.	96.8%	49.4%	0.43	49.4%	0.99	52
Detroit-Warren-Dearborn, Mich.	96.6%	46.8%	0.43	48.2%	0.95	53
Colorado Springs, Colo.	97.5%	57.2%	0.40	37.4%	0.95	54
Chattanooga, Tenn.-Ga.	96.4%	45.4%	0.42	47.2%	0.93	55
Portland-Vancouver-Hillsboro, Ore.-Wash.	97.0%	51.9%	0.41	40.5%	0.92	56
Stockton-Lodi, Calif.	97.0%	51.6%	0.40	37.9%	0.89	57
San Antonio-New Braunfels, TX	97.7%	59.5%	0.37	28.3%	0.88	58
Harrisburg-Carlisle, Pa.	97.1%	53.1%	0.39	33.0%	0.86	59
Winston-Salem, N.C.	98.4%	66.9%	0.34	18.7%	0.86	60
Knoxville, Tenn.	96.9%	50.4%	0.39	35.2%	0.86	61
Columbus, OH	95.7%	37.0%	0.43	48.3%	0.85	62
Provo-Orem, UT	97.6%	58.9%	0.36	24.6%	0.84	63
Phoenix-Mesa-Scottsdale, Ariz.	96.1%	41.3%	0.41	42.0%	0.83	64
Louisville/Jefferson County, Ky.-Ind.	96.1%	41.7%	0.41	40.4%	0.82	65
Toledo, OH	99.2%	74.8%	0.28	6.5%	0.81	66
El Paso, TX	98.8%	71.1%	0.30	9.8%	0.81	67
Albuquerque, N.M.	99.5%	77.5%	0.24	3.1%	0.81	68
Cleveland-Elyria, OH	97.0%	51.9%	0.36	25.7%	0.78	69
Minneapolis-St. Paul-Bloomington, Minn.-Wis.	96.4%	45.3%	0.38	31.5%	0.77	70
Charleston-North Charleston, S.C.	94.4%	24.9%	0.43	50.0%	0.75	71
Youngstown-Warren-Boardman, OH-Pa.	98.0%	63.1%	0.31	11.7%	0.75	72
Richmond, Va.	92.8%	13.0%	0.45	59.5%	0.73	73
Spokane-Spokane Valley, Wash.	97.6%	58.3%	0.32	12.7%	0.71	74
Indianapolis-Carmel-Anderson, Ind.	94.0%	21.3%	0.43	48.7%	0.70	75
Ogden-Clearfield, UT	95.9%	40.1%	0.37	28.4%	0.68	76

Metro	Metro Availability @ 25 Mbps	Availability Z-Score* %	Subscr-iption GINI**	Subscr-iption Z-Score* %	Com-bined Score	Com-bined Rank
Grand Rapids-Wyoming, Mich.	94.4%	25.1%	0.41	42.7%	0.68	77
Tucson, Ariz.	96.3%	43.7%	0.35	21.8%	0.65	78
Omaha-Council Bluffs, Nev.-IA	95.2%	32.7%	0.38	32.5%	0.65	79
Wichita, Kan.	94.6%	26.6%	0.39	34.8%	0.61	80
St. Louis, Mo.-Ill.	93.6%	18.0%	0.40	39.8%	0.58	81
Madison, Wis.	92.4%	10.6%	0.42	44.5%	0.55	82
Houston-The Woodlands-Sugar Land, TX	92.5%	10.9%	0.40	39.4%	0.50	83
Kansas City, Mo.-Kan.	92.1%	9.4%	0.41	40.2%	0.50	84
Bakersfield, Calif.	93.4%	16.8%	0.38	30.9%	0.48	85
Greenville-Anderson-Mauldin, S.C.	90.5%	3.8%	0.41	42.0%	0.46	86
Baton Rouge, La.	92.2%	9.5%	0.39	34.9%	0.44	87
Memphis, Tenn.-Miss.-Ariz.	94.6%	26.8%	0.32	12.8%	0.40	88
Scranton--Wilkes-Barre--Hazleton, Pa.	95.6%	36.5%	0.23	2.1%	0.39	89
Des Moines-West Des Moines, IA	95.0%	30.1%	0.28	6.9%	0.37	90
Little Rock-North Little Rock-Conway, Ark.	94.1%	22.1%	0.29	8.4%	0.31	91
Oklahoma City, Okla.	88.1%	0.7%	0.35	21.2%	0.22	92
McAllen-Edinburg-Mission, TX	93.9%	20.1%	0.16	0.3%	0.20	93
Columbia, S.C.	90.3%	3.3%	0.33	16.3%	0.20	94
Boise City, ID	92.4%	10.7%	0.25	3.9%	0.15	95
Fresno, Calif.	89.3%	1.8%	0.32	12.6%	0.14	96
Tulsa, Okla.	82.4%	0.0%	0.32	12.9%	0.13	97
Birmingham-Hoover, Ala.	89.5%	2.0%	0.30	9.5%	0.11	98
Augusta-Richmond County, Ga.-S.C.	88.3%	0.8%	0.30	9.8%	0.11	99
Jackson, Miss.	83.9%	0.0%	0.28	6.7%	0.07	100

*Z-score - Statistical measure that indicates how many standard deviations an element is from the mean
**Subscription GINI - GINI coefficient (statistical measure of the degree of variation in data) of the subscription quintiles, where higher scores correlate with a higher proportion of the population living in higher-subscription neighborhoods.

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For More Information

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

Metropolitan Policy Program
at BROOKINGS

1775 Massachusetts Avenue, NW
Washington, D.C. 20036-2188
telephone 202.797.6139
fax 202.797.2965
website www.brookings.edu/metro