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The Growth of the Broadband Internet Access Market in California: Deployment, Competition, Adoption, and Challenges for Policy

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The Growth of the Broadband Internet Access Market in California

Deployment, Competition, Adoption, and Challenges for Policy

April 11, 2016

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About the report

The research culminating in this report was sponsored by AT&T, and the author gratefully acknowledges their financial support. All analyses and conclusions are those of the author alone.

A shorter version of the report is available as a research brief from sites.google.com/a/pepperdine.edu/jprieger/home/research/ca-bb.

Abstract

This report examines the great progress made in availability and adoption in the broadband market over the past few decades and shows how Californian residents and businesses have come to use broadband widely. The policy issues involved with continuing the tremendous strides already made are discussed, along with recommendations for policy-makers.

The report begins by documenting the rapid growth of Internet usage in the U.S. and California. There is a review of the current state of competition in voice and broadband markets, discussing the decline of traditional telephone service, which is rapidly approaching irrelevance, and the rise of wireless and Internet services.

- California consumers dropped one in five of their remaining traditional voice lines in 2013, leaving only 9 percent residential voice lines in California as traditional POTS lines.
- As of the first half of 2014, 47 percent of U.S. households relied only on wireless phones.

The report discusses policy issues of availability and adoption of broadband. Since availability is nearly ubiquitous, policy focus should switch to the remaining barriers to adoption. State and federal policy toward universal service (CASF, CAF, Lifeline) is reviewed. The report presents detailed statistics on the availability of broadband in California. Growth in availability since 1999 to today's nearly ubiquitous coverage is presented.

- Broadband has been growing at an annualized rate of 30.4 percent since 1999 and more than 130 broadband providers have entered the market in the state.
- Mobile broadband now accounts for 70 percent of broadband connections.
- The data show rapidly increasing quality of service, with speeds rising from 7 Mbps in 2008 to 55 Mbps in 2015. Over the same time period, there was a significant decline in the quality-adjusted price for broadband, from \$12.89/Mbps in 2008 to \$3.42 in 2015.

The report concludes with policy recommendations to expand broadband access and adoption, including deploying low cost options to achieve broadband parity, coordinating state and federal rural access subsidies to prevent waste, and updating state and federal Lifeline programs to support broadband. Other policy implications discussed include the need to remove barriers to deploying broadband infrastructure such as access to municipal rights of way, and retargeting CASF funds to unserved (rather than underserved) areas.

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I. Introduction

Broadband access to the Internet is important for much of modern life. As the information society continues to pervade all aspects of our lives as consumers, students, citizens, and producers, broadband becomes ever more a necessity. Ever more of daily life is moving online, from keeping up with the news to doing homework for school to applying for jobs. As everything from entertainment to civic engagement migrates to the Internet, demand for broadband Internet access has grown apace. The result: broadband Internet access is one of the most rapidly adopted consumer technologies in history. Aiding speedy consumer adoption has been the robust competition among broadband providers. This report examines the great progress made in availability and adoption in the broadband market over the past 15 years and shows how Californian residents and businesses have come to use broadband widely. The policy issues involved with continuing the tremendous strides already made will be discussed, along with recommendations for policy-makers.

As the telecommunications industry looks forward to the transition to an all-IP network, it is appropriate to look back and measure deployment, competition, and adoption of broadband provision in California. Looking at recent history will demonstrate where the market has been successful at filling gaps in broadband availability and creating steadily growing usage of broadband. In an all-IP world, universal connectivity becomes paramount. Therefore, it is also instructive to consider where broadband gaps remain, both geographically on the availability side and demographically on the adoption side.

The exploration of California's broadband market proceeds in five parts. In the next subsection, A, a birds' eye view of the growth of the Internet and the importance of broadband to the economy is covered. In section B, the background is set on what competition currently looks like in the broadband and related communications markets in the state. In section C, policy issues and concerns are discussed, including challenges to access and adoption, universal service, and some issues involved with coordinating state and federal regulation.

The main empirical analysis begins in section D. In section II.A, a detailed analysis points out that broadband Internet access is available in some form to nearly every Californian residence and business, and has been for some time. Section II.B examines mobile broadband coverage in particular. The state of competition in California broadband markets is presented in section II.C. Finally, in section II.D, broadband availability for areas and groups of particular policy concern is brought into sharper focus. The status of availability for rural areas, minorities, low-income residents, senior citizens, the disabled, and small businesses is highlighted.

The issue of broadband adoption, as distinct from availability, is taken up in section III. Overall trends and the unique experiences of rural, minority, and low-income Californians are covered. Trends in the quality and prices in the broadband market are examined next in section IV. The

report concludes in section V with discussion of the implications raised by the analysis for forward-looking policy.

Before getting to the meat of the report, it is important to clarify some terminology. There are many terms researchers and policymakers use to refer to different aspects of the spread of broadband Internet access. The two main terms often appearing in policy discussions are *access* and *adoption*, which usually refer to the possibility to use broadband and the actual usage of broadband, respectively. However, since those terms are not always used consistently in various policy discussions or the academic literature, it is important to be clear about terms used herein. *Availability* refers to broadband of a particular mode or quality being available for subscription in a particular area. Availability depends on investment in deploying and upgrading network infrastructure by broadband providers. In this report, availability and deployment are thus often used interchangeably. *Access* to broadband can have different meanings. When referring to an area, access sometimes is used to mean availability. That is, if an area has broadband available, then people living in the area have access to broadband. To avoid potential confusion, in this report the term *availability* will most often be used instead of *access*, since some authors use the term access when referring to individuals who use broadband at home.¹ A clearer term is *adoption*, which happens when an individual or household subscribes to broadband Internet service. Adoption is measured without regard to availability; thus low adoption rates in a population can occur either because broadband is unavailable or because people choose not to purchase access.

The *take rate* is the ratio of the adoption rate and the percentage of the potential market that has broadband service available. Since at least basic broadband is nearly ubiquitous in California, as will be shown in section II.A, the difference between the adoption rate and take rate (whether for fixed or mobile broadband) is small in recent years. A closely related term is the *subscriber ratio*, a measure calculated by the FCC as the number of residential broadband lines divided by the number of households. The take rate, adoption rate, and the subscriber

Important terms

Availability

The degree to which broadband of a particular type or speed is available for subscription in a particular area.

Access

Most often used to mean availability; depending on the context can also mean use of the Internet.

Adoption

Subscription to broadband connections by end-users.

Subscriber ratio

The number of residential broadband lines divided by the number of households in an area.

¹ Some authors expand the definition of access to include Internet access through libraries and other community institutions. While access through such community anchor institutions can be very important for low-income people in particular, it is beyond the scope of the present report.

ratio will be about the same in most areas for basic broadband.² Trends in the subscribership ratio (as a direct proxy for the adoption rate and as an indirect proxy for the take rate) for broadband in California are presented in section III.A. Broadband *usage* is sometimes used synonymously with adoption, but more strictly refers to an individual actually using broadband to access the Internet rather than just subscribing to service. Usage can also refer to how much or what forms of consumption of Internet access occurs.

A. The Internet – a technology adopted like no other

It is appropriate to begin the examination of the California broadband market with a look back at how far we have come. In the first section below, the rapid growth of the Internet since the 1990s is presented. The second section reviews what is known about the importance of broadband to the modern economy.

1. The phenomenal growth of the Internet

In a day when the Internet is woven into the fabric of daily life for most people—dominating how many of us communicate, learn, entertain ourselves, and otherwise engage with the world—it may be hard to remember that the modern Internet began only about 25 years ago. The Internet as we typically think of it, the World Wide Web with its hypertext links and graphical browsers, began in 1993.³ Internet usage before that time was limited mainly to researchers and others in universities, and altogether only a trivial percentage of the total population used the Internet. Starting from essentially zero in 1993, then, Internet usage exploded into American life. A mere ten years later, more than half (62%) of Americans used the Internet. This rate of adoption is virtually unprecedented in the history of technology. Other important 20th century technologies took far longer to diffuse among users. For example, it took 25 years for the telephone to reach even 10% market penetration, while electrification of homes took even longer to reach that milestone.⁴ Other notable recent technologies with similarly quick rates of diffusion rely on the Internet: Tablet computers gained their first 10% of market penetration and the market penetration of smartphones rose from 10% to 40% in fewer than 3 years.⁵

Figure 1 documents the growth in the fraction of people in the US using the Internet. The first official statistics were collected in 1997 (Newburger, 1999). Four years after the introduction of widely available graphical browsing of the Internet, already 22.6% of people in the US used the Internet. That fraction quickly grew until the recent recession, reaching 75% in 2007. After mild

² Differences between the adoption rate and the subscribership ratio could be caused by households subscribing to multiple broadband lines, home businesses operating out of residences subscribing to business instead of residential broadband, residential broadband lines used by group quarters instead of households, or miscounting of either broadband connections or households. Conceptually, the adoption rate of households is the population quantity of which the subscribership is a practical but imperfect estimate.

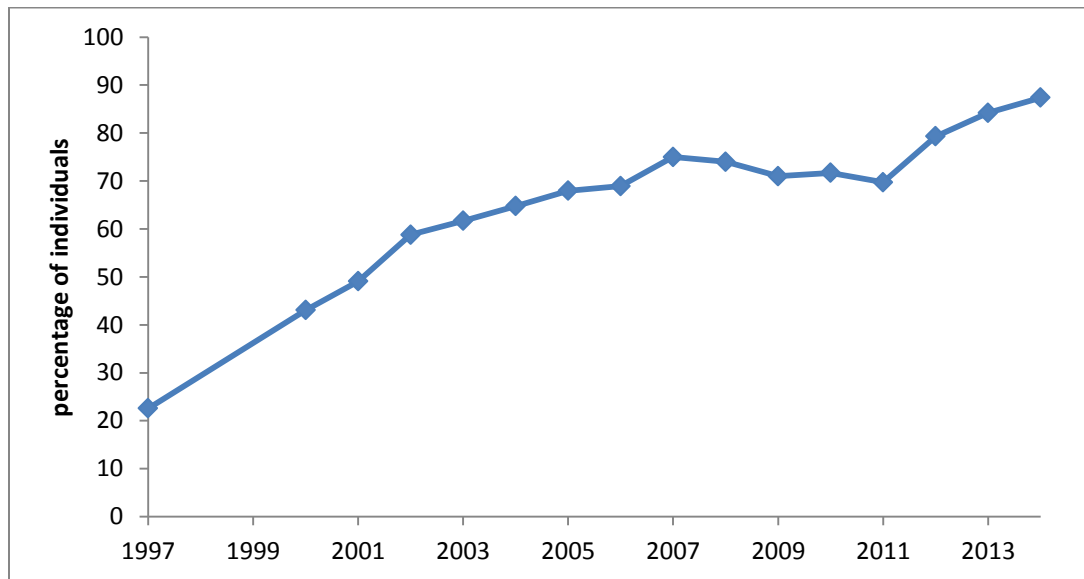
³ The first graphical browser, Mosaic, was introduced in that year.

⁴ See <http://www.technologyreview.com/news/427787/are-smart-phones-spreading-faster-than-any-technology-in-human-history>.

⁵ *Ibid.*

declines in usage in the aftermath of the recession, Internet penetration reached 87% in 2014. Even during the recession, Internet usage did not decrease as much as median household income, indicating the importance of the Internet to users.⁶

Figure 1: Percentage of individuals using the Internet in the U.S., 1997-2014



Notes: Data are from Newburger (1999) for 1997 and ITU (2015c) for later years.

Such large gains in usage represent millions of Americans beginning to use the Internet in the past few decades. In the US, the number of Internet users rose by 144.1 million between 2000 and 2010 alone, with an additional gain of about 10 million users in the current decade.⁷ These astounding gains in use are mirrored in the growth of broadband access lines deployed. Figure 2 shows the trends for California and the nation in the number of broadband connections of all types. As a technology hub and the home of Silicon Valley, penetration in 1999 was higher in California than elsewhere in the nation; consequently the growth rate has been slightly lower in the state since then.⁸ Since 1999, the average annual compound growth rate in broadband lines has been 30.4% in California and 33.3% in the nation. The trend in the state closely matches that of the nation as a whole, except for recent years in which the rate of growth has been a bit higher in California. Since 2008, growth in high-speed access lines has averaged 22.0% per

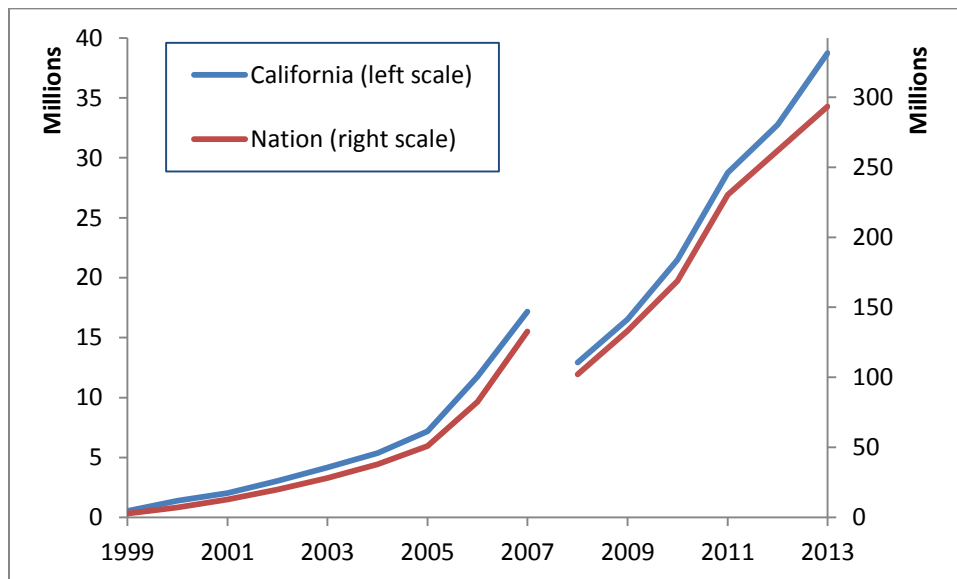
⁶ In 2008, the first year of the recession, Internet usage fell only 1.3% while real median household income fell 3.6%. By 2011, the lowest point during the time for Internet usage, the decline was still smaller than the decline in household income by over a percentage point. By 2012, Internet usage was higher than it was in 2007, while household income was still 8.3% lower than in 2007.

⁷ See <http://www.internetworldstats.com/>.

⁸ There were about 0.016 broadband lines per capita in California in 1999, whereas there were only about 0.011 broadband lines per capita elsewhere. There were 47% more broadband lines in California than elsewhere (source: FCC (2000) for lines, U.S. Census Bureau for population).

annum in the state and 21.1% per annum in the nation. There were only 547,179 broadband lines of any type serving residences and businesses in December 1999 in California. (FCC, 2000). By December 2013, however, there were 38.7 million broadband lines in the state (FCC, 2014a). About 70% of those were mobile broadband connections, which did not even exist as a consumer service when the FCC first began collecting broadband statistics in 1999. In short, the eager adoption of the Internet in such a brief period of human history has been nothing less than amazing. Apart from the personal benefits created by use of the Internet, there are many other positive benefits of broadband for the economy, the topic of the next section.

Figure 2: Number of Broadband Lines of any Type by Year End, 1999 to 2013



Note: The speed threshold is 200 kbps in at least one direction. The discontinuity between 2007 and 2008 is due to a one-time change in how the FCC counts mobile broadband lines. Source: FCC “High-Speed Services for Internet Access: Subscriberhip” and “Internet Access Services: Status” reports, various years.

2. The importance of broadband to the economy

Broadband access and usage is now an essential part of the global information economy. Broadband Internet usage is an example of *general-purpose technology* (GPT).⁹ Bresnahan and Trajtenberg (1995) characterize a general-purpose technology by its pervasiveness, potential for technical improvements, usefulness to businesses, and potential to increase the productivity of R&D in downstream sectors. A general-purpose technology such as broadband thus spreads throughout all aspects of the economy and creates productivity gains in many industries, and thus is important to the economic health of the state’s economy.

⁹ This section draws heavily on Prieger (2013).

In the case of Internet and broadband GPT, the technology directly raises productivity in ICT-intensive industries (Varian, Litan, Elder, and Shutter, 2002). The beneficial effects of improved productivity and lower costs in industries that are heavy users of ICT then ripple outward to other sectors of the economy.¹⁰ Use of broadband leads to indirect productivity enhancements for other firms, which Mayo and Wallsten (2011) term *growth externalities*. For example, a firm designing new products can take advantage of the diffusion of broadband in society. The company can design certain aspects of products and software assuming that consumers will have broadband connections to update firmware, register products, or download additional functionality. Growth externalities also stem from broadband lowering the transaction costs for firms to acquire and use knowledge to improve their products and processes.

Apart from the ways that broadband Internet usage is transforming the economy, the direct impact of investing to deploy broadband infrastructure contributes significantly to employment and GDP. As will be reviewed in section IV.A below, broadband providers in private industry in the US have invested over 1.2 trillion dollars in capital expenditure. A sizeable literature now exists documenting a positive association between broadband availability and economic growth (Holt and Jamison, 2009). However, pinning down the exact answer to the question of how much broadband contributes to the economy is methodologically difficult. Accordingly, estimates differ widely, and only one example with solid econometric footing is reviewed here. Using the same methodology as for official calculation of GDP, Greenstein and McDevitt (2011) find that the direct impact of broadband deployment, net of what would have occurred in the absence of broadband, was approximately \$8.3 to \$10.6 billion of new GDP in 2006. In addition to GDP, broadband Internet access also creates consumer surplus, a measure of benefits enjoyed by consumers of a good or service net of the price paid. Greenstein and McDevitt find that broadband created \$4.8-6.7 billion in consumer surplus (net of what would have accrued with dial-up service).¹¹ Other estimates that consider indirect impacts or that do not carefully net out the benefits from the replaced technology (dial-up Internet access) often arrive at figures that are much higher. Similar calculations show that by 2010, broadband is conservatively estimated to have created \$9.1 billion in new consumer surplus in the US, leading to a total “broadband bonus” for the economy of \$39.8 billion (Greenstein and McDevitt, 2012).¹² After accounting for quality improvements in broadband, mainly in the speed of service, the estimate of consumer surplus rises to \$95 billion and the overall broadband bonus to \$126 billion. About \$16 billion of that bonus accrues to California alone.¹³

¹⁰ Prieger and Heil (2015) review the mechanisms by which the diffusion of ICT leads to general economic growth.

¹¹ Other estimates of net or gross consumer surplus from broadband include those of Goolsbee and Klenow (2006) and Rosston et al. (2010).

¹² The broadband bonus is calculated as broadband revenue less cannibalized dial-up revenue plus new consumer surplus.

¹³ The calculation assumes the benefits are proportional to the state’s share of total broadband access lines.

Broadband is similarly important for job creation in the US. Katz and Suter (2009) and Holt and Jamison (2009) review several studies generally finding a positive link between broadband infrastructure investment and increased employment, particularly during the recent recession years when there was significant slack in the economy. More recently, Jayakar and Park (2013) find that US counties with better broadband availability had lower unemployment rates in 2011, even after controlling for other factors. As with any other form of business investment in infrastructure, broadband thus has clear potential to improve the outlook for employment in the economy.

B. Competition in broadband and related markets in California

This section describes competition and choice in the California communications and broadband market. The voice market is covered first, followed by reviews of the competitive landscape in broadband and video markets.

1. Voice telecommunication

The investigation of the market for voice telecommunication here begins with a look at the great expansion of choice in the modern market. In the second section below, the important role that mobility plays in the voice market is established.

a. The expansion of consumer choices

Between voice calling carried over the legacy wired telephone network,¹⁴ mobile wireless phone service offered by mobile carriers utilizing spectrum, fixed-line Voice over IP (VoIP) service enabled by wired broadband access in the home,¹⁵ and mobile VoIP services, consumers have never had more choices of how to telecommunicate with others. Convergence in technologies and their usage has blurred the lines for many consumers between different ways of making a call. Whereas in the 1990s the car phone stayed in the vehicle and the home phone (or at least its base station) stayed tethered to the wall, today the mobile phone fulfills both roles for many consumers. Consumers may not even be aware of the technology connecting their call to the other end-user; many users view VoIP not so much as an alternative to switched access for call routing but instead mainly as a new set of choices for price and provider.

New technology and the expansion of broadband availability has increased competition in voice telecommunication in California. Twenty years ago before the Telecom Act of 1996, virtually all local access lines for voice calling were provided by the incumbent local exchange companies (ILECs). In 2013, 39% of all end-user switched access lines and VoIP subscriptions in the state were provided by companies other than ILECs. The scale of the new competition is accelerating. As recently as 2009, non-ILECs provided less than a quarter of all voice lines. The competition has also been creative in finding multiple avenues to consumers' homes. In California, while about 70% of non-ILEC lines are VoIP subscriptions, 16% of non-ILEC lines are resold from the

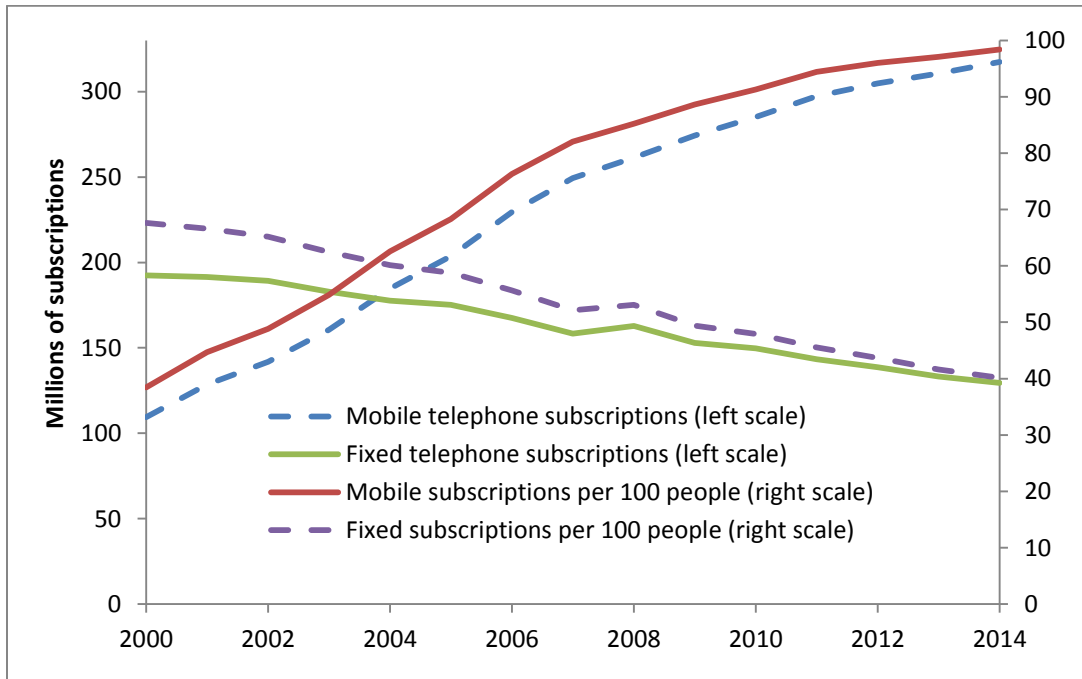
¹⁴ I.e., the PSTN (Public Switched Telephone Network).

¹⁵ VoIP is voice telephony based on the Internet protocol (IP). Essentially, the sound of the voice is encoded as data and sent over an IP network like any other data. VoIP can be provided by over-the-top (OTT) third parties, or by the broadband provider/telecommunications carrier itself.

incumbent, 7% are offered via unbundled network elements leased from the incumbent, and the remaining 6.5% are provided as competitor-owned local loops (FCC, 2014c).

Trends in fixed and mobile services in the US are shown in Figure 3. In these data, fixed telephone subscriptions are defined expansively to include analog fixed telephone lines, fixed VoIP subscriptions, fixed wireless local loop (WLL) subscriptions and other voice-channel equivalents, and fixed public payphones. The first two of those categories may be expected to compose the lion’s share of the total. Fixed voice access peaked in the US in 2000 at 192.5 million lines, the first year shown in the graph. In that year, there were 67.6 fixed telephone lines per 100 inhabitants. At that time, many households used two fixed lines, one for voice and the other for dial-up Internet access. Both the count and ratio of fixed lines slid over the next decade and a half. By 2014, there were only 129.4 million fixed lines, which represented 40.1 lines per 100 people.

Figure 3: Mobile and fixed telephone subscriptions in the US, 2000-2014



Note: Source data are from ITU (2015a; 2015b).

The fixed voice market is clearly in long-term decline, but the aggregate trend obscures the changing composition of the market, from switched access to VoIP. Steady growth in VoIP lines through 2013 offsets some of the decline in switched phone lines. Thus, the percentage decline in traditional voice network lines is even greater than these figures reveal. About 36% of wired retail local telephone service connections were VoIP at the end of 2013, and the fraction rises to one-half for residential lines (FCC, 2014c). Estimates for 2015 show that only 16% of residential

voice lines are switched-access lines from the incumbent telephone companies (ILECs), with the rest being wireless, VOIP, or some other option not from an ILEC (Brogan, 2014b). Subtracting VoIP lines from the total fixed lines represented in Figure 3 implies that the rate of decline in traditional switched access voice lines was 5.8% per annum from 2000 to 2013 and 7.3% per annum since consumer VoIP hit the market around 2004. The switched access market has declined even more in California since 2004, at 8.1% per annum, and with a 12.7% decline from 2012 to 2013 (FCC, 2014c). In fact, in 2013 only 9.2% of residential voice lines in the state were switched access lines from the ILEC. VoIP is projected to make up an ever greater share of fixed voice lines through 2018 globally.¹⁶ Forecasting market shares is difficult in general, and particularly so for the voice communications market. In addition to the usual challenges involved with market forecasting, regulatory uncertainty regarding the IP transition in last-mile networks makes any VoIP forecast for California highly uncertain. Regardless, it is clear that VoIP is a large and growing share of the market and that the public switched network will continue to decrease in importance.

During the same period, mobile telephone subscriptions grew from 109.5 million (38.5 per 100 residents) to 317.4 million (98.4 per 100 residents). There are more than twice as many mobile subscriptions as fixed lines in 2014, and the number of mobile subscriptions has not yet peaked. And, as is well known, consumers are not merely adding mobile lines to their households, they are replacing fixed lines. Much recent research has found a high degree of substitution in demand for mobile and fixed telephony.¹⁷ As of the first half of 2015, 47% of US households had only wireless phones in the home (Blumberg and Luke, 2015).

Mobile voice telecommunication and phone cord-cutting has been eagerly adopted in California, as elsewhere in the nation. Table 1 contains the fraction of people in the state living in households with mobile telephone access but no fixed telephone lines (i.e., cord cutters and cord nevers). Across the state, over 42% of adults and over half of children live in households that have cut the cord as of 2014. An additional 20% of adults and 22% of children live in “wireless mostly” households (defined as households with both landline and cellular telephones in which all or almost all calls are received on cell phones). There is moderate variation in the rate of cord-cutting in different parts of California. In 2012 (the latest period for which sub-state data are available), San Bernardino County had the highest proportion of people in mobile-only households: 38.9% of adults and 45.8% of children. Cord cutting is least prevalent in San Diego County (26.6% of adults and 29.5% of children). There are many factors leading households to adopt mobile-only voice communication. One important difference between these two counties is that San Bernardino County is half Hispanic with almost one quarter of its households earning less than \$25,000 per year, while San Diego County is less than a third Hispanic and less than a fifth of its households have low income.¹⁸ As will be discussed in the

¹⁶ See <https://www.telegeography.com/press/marketing-emails/2014/10/15/fixed-line-telephony-a-far-cry-from-dead/index.html> for the global VoIP and switched access forecast.

¹⁷ Refer to Barth and Heimeshoff (2014) and the studies cited therein.

¹⁸ These statistics are from 2013 American Community Survey (US Census Bureau, five-year estimates).

next section, mobile communication and Internet usage has played an especially important role for low-income and minority communities.

Table 1: Percentage of adults living in mobile telephone-only households in California, 2011–2012 and 2014

	Adults aged 18 and over		Children Under Age 18	
	2014		2014	
California	42.8		50.2	
	<i>July 2011– June 2012</i>	<i>January– December 2012</i>	<i>July 2011– June 2012</i>	<i>January– December 2012</i>
California	30.1	32.6	33.8	38.2
Alameda County	31.4	34.2	34.3	37.0
Fresno County	31.8	33.8	31.6	36.1
Los Angeles County	30.2	31.7	33.7	36.7
Northern counties	27.0	30.5	32.0	38.2
San Bernardino County	33.7	38.9	38.0	45.8
San Diego County	23.5	26.6	23.1	29.5
Santa Clara County	30.9	31.4	32.8	34.9
Rest of California	30.8	33.6	35.4	40.0

Note: Northern counties include Butte, Colusa, Del Norte, Glenn, Humboldt, Lake, Lassen, Mendocino, Modoc, Plumas, Shasta, Sierra, Siskiyou, Tehama, and Trinity counties. Source: U.S. Center for Disease Control (Blumberg et al., 2013; CDC 2016).

b. Mobile voice is the choice for many low-income and minority consumers

Mobile voice—and, as will be discussed below in section III, mobile broadband—has been taken up by many low-income and minority users. Mobile phone ownership is much more common among minorities than computer ownership. In July 2011, non-Hispanic blacks in America were 22% more likely to use a cell phone or smartphone than to have a computer in their household, and Hispanics were 19% more likely (Prieger, 2015). In fact, when it comes to smartphones, usage is higher among Hispanics (45%) and African Americans (33%) than among whites (27%) (Kellogg, 2011). Among new purchasers of mobile phones, the differences in smartphone adoption among groups are even starker. In 2010, when feature phones were still common, 42 percent of whites who purchased a mobile phone in the past six months chose a smartphone. However, 60% of Asians, 56% of Hispanics, and 44% of African Americans who had recently bought cellphones chose smartphones.

As intimated by the comparison of California counties in the previous section, often minority and low-income households are cord cutters or cord nevers. In 2015, many minority and lower income households were mobile-only for voice telecommunication, as seen from Table 2. While 43% of whites live in mobile-only households, 48% of African Americans and 59% of Hispanics are cord cutters (Blumberg and Luke, 2015). The differences among income groups are even

starker. Fifty-nine and 54 percent of those in poor and near-poor households, respectively, were mobile-only, compared to only 46% of households that were not poor. Recognizing the importance of mobile telephony to low-income individuals, federal and state support programs for voice telecommunication (discussed below in section C.2) now allow subsidies for low-income households to be applied to mobile lines as well as to fixed lines.

Table 2: Percentage of adults living in mobile telephone-only households, January-June 2015

Category	Percent in wireless-only households
Race/Ethnicity	
White*	43.2
African American*	48.1
Asian*	47.9
Other race*	52.4
Non-Hispanic multiracial	52.4
Hispanic or Latino	59.2
Household poverty status	
Poor	59.3
Near poor	54.4
Not poor	45.7

* Non-Hispanic, single race.

Notes: Source: U.S. Center for Disease Control (Blumberg and Luke, 2015). Estimates are for the entire US. “Poor” persons are defined by CDC as those below the poverty threshold. “Near-poor” persons have incomes of one to two times the poverty threshold. “Not-poor” persons have incomes of at least twice the poverty threshold.

While the statistics in Table 2 are unavailable for California in specific, other data sources allow at least limited exploration of dependence on mobile voice in the state. As early as 2011, among those Californians with household annual income under \$20,000 who said they have no phone in their living quarters, 61.5% said they used a cell phone or smartphone (see Table 3). Similarly high proportions of blacks and Asians lacking a phone at home used mobile voice, and even higher proportions of similarly situated Hispanic and multiracial residents. Native Americans form the exception to these high rates; only a quarter of those without a phone at home use a mobile phone. This may be because of relatively poorer mobile coverage in the extremely rural areas in which many Native Americans live.

Table 3: Percentage of those Californians without a phone in their living quarters who use a mobile phone

Category	Percent of those without a phone in living quarters who use a mobile phone	95% Confidence Interval
Race/Ethnicity		
African American	64.4	[30.8, 88.0]
Native American	25.3	[2.1, 84.4]
Asian and Pacific Islander	64.6	[37.5, 84.7]
Multiracial	83.8	[34.9, 97.7]
Hispanic or Latino	72.8	[60.7, 82.2]
Household poverty status		
Annual income less than \$20,000	61.5	[46.9%, 74.3%]

Notes: Statistics are for the subpopulation of Californians age 3+ reporting that they do not have a telephone in their living quarters. Statistics calculated by the author using data from the US Census Bureau's Current Population Survey, Internet and Computer Use Supplement, vintage 2011. The confidence intervals account for survey design effects.

2. Broadband

This section provides a high-level overview of competition in the state's broadband markets. The much more detailed examination is deferred until sections 0 and IV. There are many broadband providers in California, altogether offering almost 38.7 million broadband lines of all kinds in the state as of year-end 2013 (Table 4). The rapid overall growth of broadband lines served in the state has already been shown in Figure 2. As mentioned above, the annualized growth rate of broadband lines in California has been 30.4% since 1999. Even starting with the more mature market in 2008, the growth rate for broadband lines served has been 22.0% in the state.

Of the 138 broadband providers shown in Table 4 offering service in California, most do not meet head to head in any particular local market, of course. Yet in most markets there are typically several providers. This is explored in detail in part II.A below, but some highlights are noted here. For some forms of broadband, most notably cable modem service, there is rarely more than a single provider of the same type. Other forms, such as mobile wireless, are almost always available from multiple providers. However, some of the most important benefits of competition are created by *intermodal competition* in the broadband service industry, by providers offering broadband services of a different type than their competitors.

Table 4: Broadband providers in California as of December 31, 2013

Type of Broadband Line	Number of Providers	Number of Connections (thousands)
Asymmetric DSL	38	4,205
Symmetric DSL	18	11
Other Wireline (T-1, EoC, etc.)	53	***
Cable Modem	26	5,735
Fiber	33	830
Satellite	1-3*	***
Terrestrial Fixed Wireless	52	46
Mobile Wireless	8	27,656
Total	138**	38,742

* FCC data are censored; the true figure is presumably three (ViaSat, HughesNet, and Starband).

** If a provider offers multiple types of service, it contributes to the counts in multiple rows. Thus the total number of distinct holding companies offering service is less than the sum of the rows above.

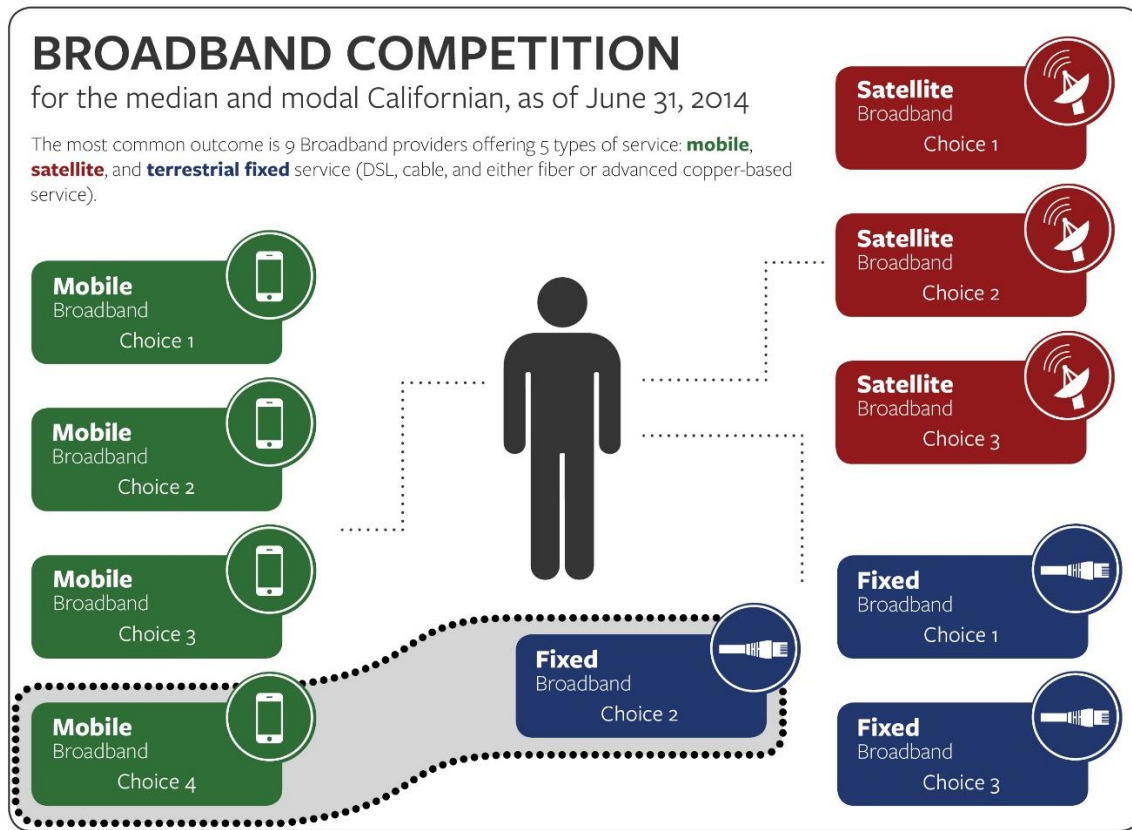
*** FCC data are censored. The total number of lines in the combined category of Other Wireline and Satellite, as calculated by subtracting the counts in the other rows from the total, is 259,000.

Notes: Providers held by the same holding company are counted only once. Data are from Table 21 of FCC (2014a).

The statistics explored below (see section II.C.1) show that the most common scenario is a choice of four modes of fixed broadband service—DSL, cable, either advanced copper-based service or (less commonly) fiber, and satellite—and mobile broadband service. (Note that some of these options may be marketed primarily to businesses.) There are also many firms offering these services. The choices and firms are shown in Figure 4. The median person in the state has access to three providers of terrestrial fixed broadband, four mobile broadband providers, and three satellite broadband providers.¹⁹ One of the mobile broadband providers is typically the same company offering one of the fixed options, noted in Figure 4 with the dotted lines, so that there are nine providers offering these 10 choices. While in some urban areas there are more options than these and in some rural areas there are fewer, the picture painted by the statistics reviewed in section 0 of the report is largely one of competition among several providers in any given area.

¹⁹ The figure for terrestrial fixed broadband providers is taken for the median person from Figure 14 below. The same statistic for mobile broadband is from Figure 19. On satellite broadband, refer to footnote 49 below.

Figure 4: Broadband competition in California



Source: author's analysis of data from the National Broadband Map.

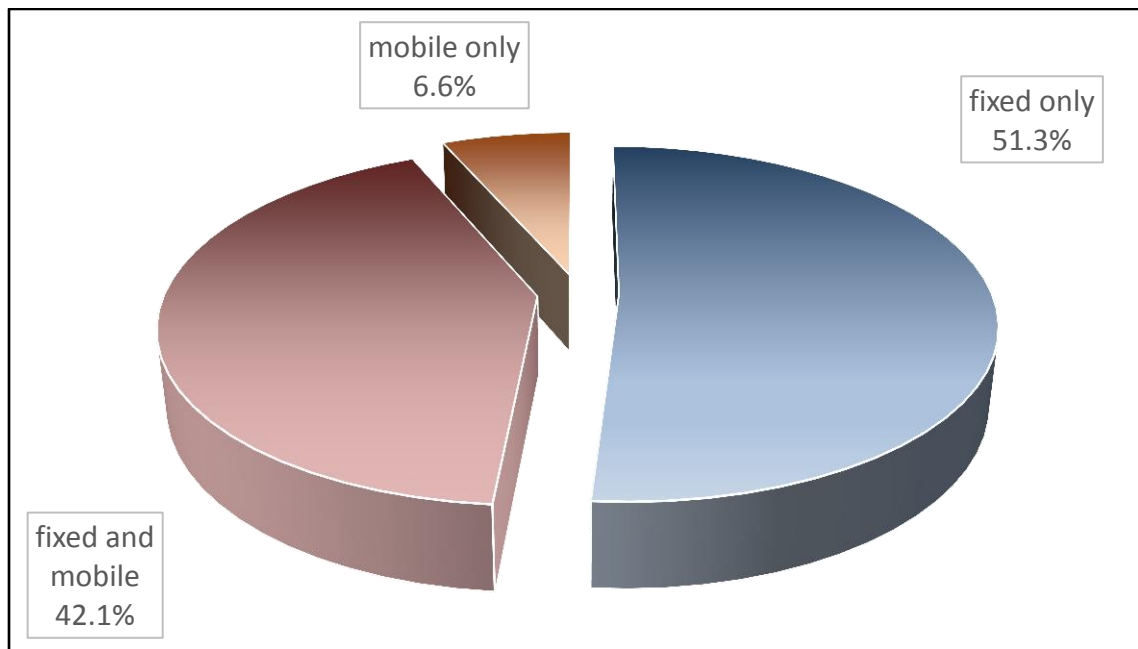
Competition among broadband providers results in higher quality offerings to consumers. In one of the few academic studies focusing on the California broadband market, Prieger, Molnar, and Savage (2014) show that in California, broadband providers in the state actively engage in quality competition by spurring each other to improve their transmission speeds. They find that incumbent telephone companies (ILECs) improved their DSL speeds when a cable broadband provider either entered the market or began to offer speed of 50 Mbps and above. ILEC providers also upgraded their speed of broadband when competing local exchange companies (CLECs) deployed fiber in their areas.

Mobile broadband is an important part of the broadband market. As will be shown below in section III.B, many low-income, minority, and other households choose not to subscribe to fixed-line broadband but have adopted smartphones and other mobile devices to access the Internet. In part this is because mobile broadband coverage helps fill in gaps left by fixed-line service in some areas (Prieger and Church, 2012; Prieger, 2013; Church and Prieger, forthcoming), but in larger part because of consumer preferences given the options and prices. In short, many

people want broadband on the go. Furthermore, as will be discussed in section C.2 below,²⁰ mobile broadband download speeds in California are now in the range of 15 Mbps to 22 Mbps for the top wireless carriers in the state. It is therefore important to avoid arbitrarily dropping any particular form of broadband from policy discussion that millions of California broadband consumers have chosen. Table 4 shows that there are about 28 million mobile broadband lines in the state—by far the largest of any single mode of provision.²¹

In California, many households prefer to have access to both fixed and mobile broadband (see Figure 5). In 2013, 45.1% of people in households with fixed broadband access are dual-mode broadband users who also have a mobile broadband plan for the household.²² Furthermore, a minority of households subscribe only to mobile broadband. Among people in Californian households with broadband, 6.6% of them have a mobile plan only. Consider this phenomenon from another angle: of the 48.7% of people in households with a mobile broadband plan, 13.5% of them rely on it as their only form of access in the household.

Figure 5: Modes of broadband use by California residents using broadband at home, 2013



Source: see footnote 18.

²⁰ In particular, refer to the discussion on page 31.

²¹ The FCC does not release the number of satellite broadband subscribers in California, but if the subscription rate is the same as for the nation as a whole, then there were about 225,000 subscribers in the state.

²² The source for this and the following statistics is the U.S. Census Bureau's 2013 American Community Survey (ACS; 1 year estimates). Data are for California only, and were extracted using American FactFinder. This is the first year the ACS asked questions about home Internet access, and 2013 is the latest year currently publicly available.

3. Video

While the main focus of this report is the broadband Internet access market, the market for the provision and viewing of video programming is closely intertwined, due to technological convergence. The video market today is supplied by three types of providers: multichannel video programming distributors (MVPDs), broadcast television stations, and online video distributors (OVDs) (FCC, 2015d). MVPDs include traditional cable companies, companies that traditionally offered telephone service, and direct broadcast satellite (DBS) providers. Comcast Xfinity, Dish, and AT&T U-verse are all examples of MVPD services. MVPDs typically offer bundled video, Internet, and voice service, although in the case of DBS the Internet and voice services are typically provided through cooperative arrangements with terrestrial providers. An OVD is a provider offering video content by means of the Internet or other IP-based transmissions, excluding paths provided by the OVD. For the reason that OVDs' content rides on broadband paths provisioned by other companies, OVDs are also referred to as over-the-top (OTT) content providers.

Competition has increased greatly in the video programming market in the age of the Internet. Whereas in 1990 options for consumers were mainly limited to analog broadcast and cable,²³ today many areas have access to digital broadcast television, a cable MVPD, a telephone MVPD (AT&T U-verse or Verizon FiOS), and two DBS providers (DIRECTV and DISH Network). Unlike for broadband lines, which are examined in fine geographic detail for the state later in this report, the FCC does not collect detailed geographical data on all types of video providers. However, in 2013, the FCC (2015d) estimates that virtually all homes in the US (99.7%) had access to at least three MVPDs (the two DBS providers and either a cable or telephone MVPD) and 34.7% of homes had access to at least four MVPDs.

Similar statistics from the FCC are not available for California in specific, but the figures may be expected to be approximately the same for the state. To create a level playing field for MVPDs, the state (through the California Public Utility Commission) has taken over the issuance of the local franchises for MVPDs. Before the Digital Infrastructure and Video Competition Act of 2006 (DIVCA) passed by the state legislature, local authorities (typically cities or counties) determined the terms of service and issued the rights to offer video programming over cable and broadband networks in local areas. Some of the potential inefficiencies that can follow from allowing local authorities to issue franchises are discussed in section 0 below. The unification of authority and other provisions of DIVCA to remove barriers to entry were expected to promote "greater diversity in video pricing, service options, and programming" (CPUC, 2007) in the state.

DIVCA also instructed the CPUC to issue annual reports on the state of competition. The latest (CPUC, 2015a) states that in 2013 almost three times as many Californian households have two or more wireline video providers available than was the case in 2007. Altogether, there were

²³ While there was a relatively small installed base of satellite dish users then, the technology was not fully mainstream. By 1990, about half the user base of 1.6 million consisted of pirates who illegally received and decoded the satellites' broadcasts (Calvin Sims, "A New Decoder to Foil Satellite-TV Pirates," *New York Times*, p.D6, Jan. 31, 1990).

over 21.5 million cable or telephone MVPD household-offers in the state in 2013, where multiple options available to a household are counted separately.²⁴ Dividing this figure by the total number of households used in that report yields an average of 1.7 options available for wireline MVPD. Breaking this number down, the CPUC found that the most common outcome by far for a Census tract was to have two state franchisees. In 2013, 69% of households were in tracts with two state-franchised video providers, 21% had one provider, 9% had three providers, and the trivial remainder had zero or four providers (CPUC, 2015a, p.13). Of course, these figures exclude video programming from DBS, broadcast television, and OVD/OTT.

Only a small proportion of American households consume video content directly from terrestrial broadcast sources anymore. In 2013-2014, the FCC (2015d) estimates that only 9.4% of US households were broadcast only. However, the reach of the broadcasters into homes is much greater than that statistic suggests. The major networks and their local affiliates are also carried by MVPDs. Most television stations also offer some of their content online (particularly news programming) and over mobile devices.

There are many types of OVDs, including those which sell or rent television shows or movies (e.g., Apple iTunes, Vudu), subscription services (e.g., Netflix, Hulu), advertiser supported distributors (e.g., Crackle, Pluto TV), broadcast and cable networks making their content available on the Internet, and sports leagues (e.g. NBA League Pass, NHL Gamecenter). Many OVDs fall into multiple categories. For example, Amazon both rents programming and offers subscription service. OVDs are unlike broadcasters and MVPDs in that their service area is not defined by a signal footprint or facilities-based infrastructure. The reach of an OVD extends to anywhere a broadband transmission path exists with enough bandwidth to enable the video service (as little as 1.5 Mbps for SD and 4 Mbps for HD programming).²⁵ Thus such OTT programming can be consumed on televisions (either smart TVs or TVs connected to a game console or other streaming device), computers, and mobile devices. OVDs compete simultaneously against all other OVDs and the local MVPDs and broadcasters for the consumer's screen time.

C. Policy issues and concerns

There are many concerns regarding the broadband market that public policy can address. The main topics discussed here include challenges in promulgating availability and adoption, universal service, and the issues involved with overlapping state and federal regulation.

1. Availability and adoption

Consumer use of broadband to access the Internet requires availability, adoption, and usage. The entire edifice of the market for broadband rests on the foundation of network

²⁴ The DIVCA report states that 21.5 million households were passed by MVPDs holding state-issued franchises. However, some long-term franchises issued by local authorities may still be in effect and would not be counted in this figure, if so.

²⁵ See the FCC's *Broadband Speed Guide* at <https://www.fcc.gov/guides/broadband-speed-guide>, visited October 17, 2015.

infrastructure. Demand for broadband service cannot be satisfied and the enjoyment of the benefits of broadband usage cannot begin until it is locally available. Then, once a household has the opportunity to adopt broadband, it must make the decision to do so. Finally, after adoption, the preferences, needs, and capabilities of the household members will determine how much each uses the Internet. For purposes of policy-making, the distinction between availability and adoption must be clear. Reasons why broadband of a particular type or speed is unavailable in an area may be quite different from the reasons a household chooses not to adopt broadband, and therefore the policy prescriptions to improve each situation differs. Factors involved in availability and adoption are covered in turn in the two sections below.

a. Drivers of availability

There is much evidence in the literature that cost and population density are primary drivers of broadband availability (e.g., Prieger, 2003, 2013; Grubestic and Murray, 2004). Areas that are less densely populated have lower returns on the investment in broadband infrastructure, because the same amount of spending on infrastructure reaches fewer people. For example, in denser areas the same investment at the wire center (for DSL or fiber) or the middle mile network (for cable modem service) reaches more potential subscribers. Also, in areas with low subscriber density, the average DSL customer is farther from the central office and requires stronger (and therefore more expensive) carrier signals to be sent. Similar considerations apply to wireless last-mile networks, although recent evidence indicates that mobile broadband partially fills in geographical gaps in fixed-line broadband coverage (Prieger and Church, 2012; Prieger, 2013; Church and Prieger, forthcoming).

Thus, empirical studies of fixed and mobile broadband deployment typically find that availability (whether measured by the presence of broadband, the number of providers, or the availability of higher speed service) lags in rural areas and is higher in more densely populated areas, even after controlling for income and other demand factors (Prieger, 2003, 2013; Grubestic and Murray, 2004; Prieger and Church, 2012; Wallsten and Mallahan, 2013). Most of these studies examine data across the US, but the same holds for California. For example, the list of areas identified as priorities for improved broadband infrastructure deployment in the state under the California Advanced Services Fund (CASF, described in the next section) is populated mostly with rural, often remote areas of the state.²⁶ Since prohibitively high costs are the main reason areas remain unserved or underserved, the primary policy prescription to encourage service is to subsidize infrastructure deployment. Policies toward this end are discussed in section 2.a below.

Coupled with, but not identical to, the reason of high cost is insufficient demand. For broadband provision to be economically viable, enough operating profit must be available to be gained to pay back the investment costs for the infrastructure. If demand is low for broadband in an area, either due to low population or low income, the area may be unprofitable to serve. Thus,

²⁶ See the CASF priority area spreadsheet (untitled; file dated October 29, 2014) available at <http://www.cpuc.ca.gov/NR/rdonlyres/B67612B8-2061-405E-B51E-AC885621B2FE/0/ConsortiaPriorityAreas.xlsx>

demand factors such as the average income of an area are strong predictors of the presence or number of broadband providers, even holding constant cost factors such as population density and rural location (Prieger, 2003, 2013).

In some rural areas, the reasons of high cost and low demand coincide. In other areas, such as South Los Angeles or Bell Gardens (two urban areas on the CASF priority list),²⁷ households are underserved primarily due to lack of expected demand for the service if it were available. There are many fewer examples of such areas in California, however.²⁸

b. Drivers of adoption

The potential role that policy can play does not end at making broadband available. While access to broadband is a prerequisite for adoption and usage, the latter do not automatically follow from the former. The evidence examined later in the report shows that virtually all households in the state live in areas with some form of broadband available. Yet, in 2013 only 80% of Californians had access to some form of broadband in the home (including mobile broadband).²⁹ The remaining one fifth chose not to subscribe.³⁰ Why?

In some cases, individuals access the Internet through public Wi-Fi or community anchor institutions such as schools and libraries. Less commonly (in the US; not so in many other parts of the world) people choose to access the Internet through paid public kiosks or Internet cafes. It is important to remember that not having access to broadband in the home is not synonymous with not using the Internet at all. However, in California in 2013, 71% of individuals lacking access to the Internet at home do not use the Internet at all.³¹ Only 8.2% of the state's Internet users rely exclusively on Internet access outside the home.³²

The Pew Research Center has collected data for many years asking non-users why they stay offline. The top reasons across the nation are shown in the left panel of Figure 6. The most prevalent answers for not using the Internet involve its perceived irrelevance. Over a third of non-adopters say that they are uninterested in the Internet, that it is a waste of time, that they are too busy, or that they otherwise do not want to use it. The other major answer, with just under a third of respondents, is that the Internet is unusable. People giving this answer say that they are too old, lack the knowledge, or are physically unable to use the Internet, that they find use too difficult or frustrating, or that they are too worried about privacy, viruses, spam,

²⁷ *Ibid.*

²⁸ However, that does not mean that the low-income urban areas involve fewer underserved people, since the urban locations have much more population per priority area on the CASF list than the rural areas.

²⁹ This figure is presented in section III.B.2 below. See that section for the source and methodology.

³⁰ Given the wording of the survey question, it is possible that mobile broadband usage is undercounted, and so the actual number of people in the state without home access to broadband may be less than one-fifth. Improving the instruments to measure broadband adoption is an active area of research.

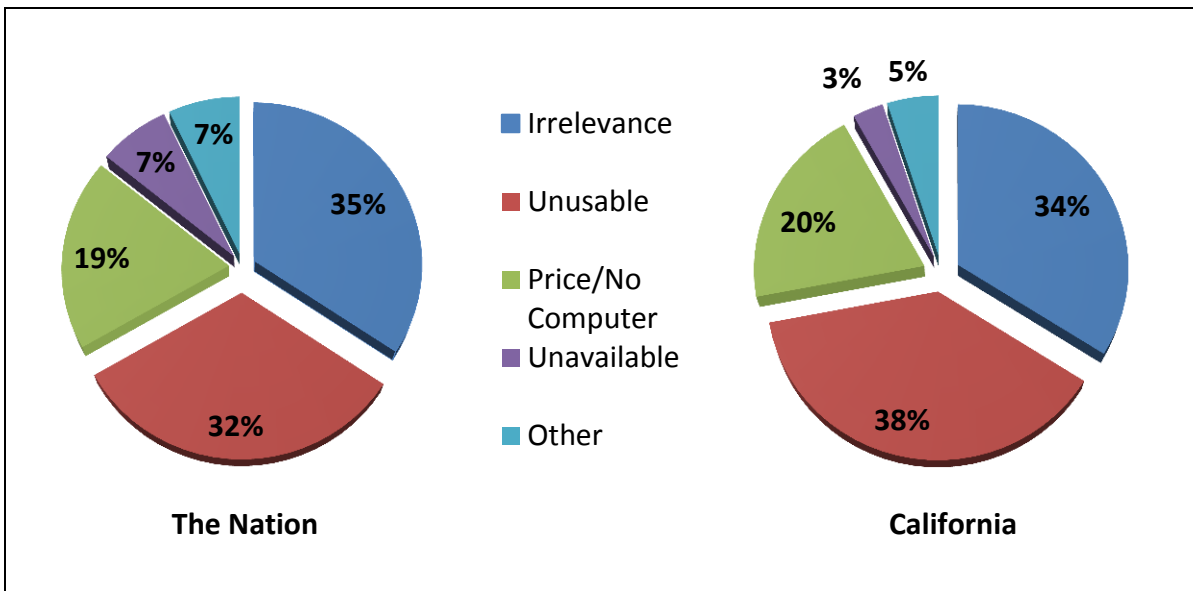
³¹ Statistic calculated by the author using data for California from the US Census Bureau's Current Population Survey, Internet and Computer Use Supplement, vintage June 2013. The 95% confidence interval for the point estimate of 71.0% is [67.4%, 74.3%].

³² See previous footnote. The 95% confidence interval is [7.05%, 9.41%].

spyware, or hackers. A further 19% have issues with affordability, either directly for broadband (6%) or because they do not own a computer (13%). The figure of 6% who say that broadband is unaffordable is much smaller than in earlier years. In 2002, 72 percent of dial-up users stated that broadband was too expensive for them to upgrade from dial-up.³³ Since these percentages are all for adults not using the Internet, the fractions out of all adults are, of course, much smaller: only 5% of all adults say the Internet is irrelevant, 5% say the Internet is unusable, 3% say it is unaffordable.

Finally, note that the 7% of non-Internet users who say that broadband is unavailable to them (1% of all adults) are nearly certainly incorrect. Between fixed, mobile, and satellite broadband, not to mention the presence of community anchor institutions offering access, very few locations in the US truly lack broadband availability. It is likely that the respondent chose the option “don’t have access” to mean merely that their household did not subscribe, perhaps because the particular kind of broadband desired was unavailable.

Figure 6: Summary of reasons for not using the Internet, May 2013



Note: The sources are the Pew Research Center (Zickuhr, 2013; national data) and Public Policy Institute of California (Baldassare et al, 2013; California data). Both samples are of adults aged 18 and older who do not use the Internet or email. *Irrelevance* encompasses survey answers of not interested, waste of time, too busy, and don’t need/want. *Unusable* includes answers of too difficult/frustrating, too old, don’t know how, physically unable, worried about privacy/hackers/etc. *Price* includes answers of too expensive and don’t have a computer. *Unavailable* means respondent said he or she didn’t have access. The margin of error is ± 2.3 percentage points.

³³ The survey statistic is from a Yankee Group survey cited in OTP (2002).

Results for non-Internet using Californians are generally similar, with a few exceptions. Compared with the Pew national data, a survey of Californians from around the same time shows that 38% of non-adopters in the state say that the Internet is unusable (Baldassare et al, 2013). The six additional percentage points for this category, compared to the national survey, mainly come from more Californians saying that the Internet is too difficult or frustrating and that they “just don’t know how” to use the Internet or email. These results suggest that there is a lower level of digital literacy in the state than the nation on average, possibly related to California’s large population of less-educated immigrants. Relatively fewer non-adopters in California gave unavailability as their reason. These data also indicate that Californians use the Internet in some form in the same proportion as the nation as a whole (within the margins of survey error).

These data suggest that efforts to promote adoption must be multi-pronged. Setting aside availability, there are four main barriers to broadband adoption: the price of broadband service, lack of computer ownership, lack of digital literacy, and a lack of perceived value of broadband (Hauge and Prieger, 2010). Price barriers are addressed by universal service policies that offer subsidies to end-users, which will be discussed in section 2.b below. Other policies lower prices for community institutions such as schools and libraries. The federal E-Rate program instituted by the Telecommunications Act of 1996 (TA96) is a prime example of such a subsidy, which has been found to be effective at encouraging adoption of broadband in California schools (Goolsbee and Guryan, 2006). The data above indicate that price is a minor part of the total barrier to increased adoption, however. More important in that regard is lack of access to computers. Many broadband programs and policies run by non-profit organizations target computer ownership as the necessary first step toward Internet connection from home. For example, evaluation of the Wireless Philadelphia (now the Digital Impact Group) Digital Inclusion Project showed that “free computer distribution is a critical element of the [project] and central to any early success” (OMG, 2008, p. i). For California in particular, Lee (2009) similarly found that the computer provision component of ZeroDivide’s digital inclusion programs were crucial in gaining the participation of community members, and that providing broadband access alone would not have provided sufficient incentive for participation.

The third barrier to adoption is digital illiteracy. Digital literacy is the ability to use digital technology to find, use, and create information. Digital illiteracy is a larger problem for certain groups. Unsurprisingly, research finds that digital literacy skills are much less developed than average among the elderly and those with lower levels of education and income. Building digital literacy involves specific education and training in the use of computers and the Internet. Such education may be promulgated through Community Technology Centers (CTCs). CTCs are an important aspect of ZeroDivide’s wireless broadband access projects in low-income, mostly non-white communities in California (Lee, 2009).³⁴ The projects were part of larger digital inclusion efforts in each community that sought to increase digital literacy, train community members in the use of technology, further household computer ownership by providing free or low-cost

³⁴ The communities were in Los Angeles, San Jose, San Diego, Sacramento, and San Francisco.

equipment, and develop community-based web content. In addition to deploying Wi-Fi broadband networks, each project included a community technology center for training and computer access.

The fourth barrier is a perceived lack of value of broadband and Internet usage. Policy aimed at increasing the perceived value of broadband for non-adopters can proceed in two directions. The first is to increase the value of going online by increasing the amount or usefulness of content. E-government initiatives such as placing information about social assistance programs online fall into this category. The second approach, following from the assumption that the consumer does not have enough information to understand the benefits of broadband, seeks to educate the consumer. Programs targeting specific segments of the market with information of particular use may be important. For example, given the relatively quick turnover of small businesses, many owners may be unfamiliar with the business use of the Internet (e-business and e-commerce).

Finally, policy-makers must also understand that while 100% adoption may be an aspirational goal, it is not a practical one. There will always be a small number of individuals who do not want to use the Internet, just as in the heyday of traditional telephone service, even with its myriad implicit and explicit subsidies for local service, there were some households who simply chose not to subscribe.

2. Universal Service

Recognizing that stimulating the diffusion of broadband requires support for both infrastructure deployment and household adoption, universal service mechanisms in California target both sides of the problem. Official support programs and efforts aimed at the supply and demand sides are reviewed in turn here.

a. Supply side

Universal service support mechanisms on the supply side—i.e., with the purpose to promote infrastructure deployment—include state and federal programs.

[The California Advanced Services Fund](#)

Some areas of the state are much higher cost to serve than others, due to low population, low density, or difficult terrain, while other areas have low expected demand for broadband. These factors result in areas where residents are unserved or underserved by broadband Internet access. The CPUC implemented the California Advanced Services Fund (CASF) in 2007. One goal of CASF is to “promote economic growth, job creation, and substantial social benefits” (CPUC, 2014a). The CPUC used the initial funding of \$100 million for CASF to provide grants to broadband providers and others³⁵ to deploy advanced infrastructure in unserved and

³⁵ The law limits support to providers who are categorized as “telephone corporations,” which are defined in the California Public Utilities Code (sec. 234 (a)) as “every corporation or person owning, controlling, operating, or managing any telephone line for compensation” within the state. Said “telephone lines” include wireless communication (sec. 233). In 2009, eligibility was extended to non-telephone entities receiving American Recovery and Reinvestment Act funds. In 2012, eligibility for support was formally

underserved areas. Today, entities eligible to receive the grants include broadband providers,³⁶ local government agencies, and other entities working to provide last-mile access to broadband in unserved and underserved areas (such as public-private partnerships or consortia of non-profit groups).

The original funding for CASF was increased to \$225 million in 2010, with the additional \$125 million to be collected starting in 2011 to be allocated mainly (\$100 million) to the Broadband Infrastructure Grant Account. Smaller amounts were allocated to Rural and Regional Urban Consortia Account (\$10 million) and the Broadband Infrastructure Revolving Loan Account (\$15 million). Funding for the CASF comes from ad valorem surcharges on the revenues of telecommunications carriers, which appear as line items on end-users' bills. Beginning in 2011, \$25 million was to be collected each year for five years. The current statutory goal (from S.B. 740) is to make broadband available to 98% of California households by the end of 2015.³⁷

The CASF operates by offering grants and loans to eligible entities to build out infrastructure for wired and wireless broadband. The support never pays for the entire project, but instead requires that the entity bear part of the cost. The amount of support offered, as a percentage of total capital expenditure, depends on whether the area is unserved or underserved and whether a subsidized loan is also involved. Details of the grant limits in the various cases are in Table 5. For purposes of the program, unserved areas are defined to be those "not served by any form of wireline or wireless facilities-based broadband, such that Internet connectivity is available only through dial-up service" or satellite (CPUC, 2014a, Appdx. 2, p.2). An underserved area has broadband available, but no service with advertised speeds of at least 6 mbps download and 1.5 mbps upload. The CPUC has collated a list of priority areas in need of broadband infrastructure (CPUC, 2014b).

Through the end of 2014, the CASF had disbursed (or authorized for disbursement) \$99.2 million for 47 projects via the Broadband Infrastructure Grant Account. An estimated 291,882 households were covered by the projects (not all of which were necessarily completed by year end). Of those households, only about 5% were previously unserved and the rest were considered underserved. The regional broadband consortia account had funded an additional \$9.3 million in grants, and the revolving loan account had made \$126,624 in loans.

extended to non-telephone entities (i.e., those not holding a regulatory Certificate of Public Convenience and Necessity or a Wireless Identification Registration) meeting certain criteria (CPUC, 2014).

³⁶ I.e., those holding a regulatory Certificate of Public Convenience and Necessity or a Wireless Identification Registration.

³⁷ For purposes of this goal, broadband service is defined as 6 mbps download/1.5 mbps upload and satellite service is not counted (CPUC, 2015a).

Table 5: CASF limits on grant funding

	Infrastructure Grant (% of total project cost)	Broadband Infrastructure Revolving Loan Account (% of total project cost)	Applicant's Funds (% of total project cost)
With Loan			
Unserved Areas	70%	20%	10%
Underserved Areas	60%	20%	20%
Without Loan			
Unserved Areas	70%	0%	30%
Underserved Areas	60%	0%	40%

Notes: Table reproduced from CPUC (2014a), Appendix 2, p. 2. Eligible project costs include capital expenditure only.

The Connect America Fund

The federal government has long supported the goal of universal telephone service with policies and programs stretching back to the early 20th century. Only recently, however, has supply-side support for universal service been extended to cover broadband Internet access. The first major programs were the Rural Utilities Service's (RUS's) Broadband Initiatives Program (BIP) and the National Telecommunications and Information Administration's (NTIA's) Broadband Technology Opportunities Program (BTOP) funded through the American Recovery and Reinvestment Act. Both of those programs were one-time efforts at stimulating the economy by promoting broadband deployment in the wake of the recent recession. The first ongoing federal program to support infrastructure deployment in high-cost areas is the FCC's Connect America Fund (CAF).

The FCC instituted the CAF in November 2011 (FCC, 2011b). The CAF modernized existing high-cost support for voice service by refocusing on efforts to support affordable broadband Internet access. The annual funding for all high-cost support programs, of which the CAF is one, was capped at \$4.5 billion over the first six years. In particular, the FCC provided for up to \$1.8 billion of the Connect America budget to be spent annually to "make broadband-capable infrastructure available to as many unserved locations as possible within these areas served by price cap carriers, while sustaining voice and broadband-capable infrastructure in high-cost areas that would not be served absent support" (FCC, 2014e, at 9). The intention was to phase out other high-cost support programs gradually, so that the CAF will ultimately handle the entire load.

The CAF was conceived as a two-phase endeavor. In the first phase, additional funding was made available for price cap carriers to extend broadband to unserved areas. These carriers are generally the large incumbent (e.g., AT&T and Verizon in California) providers in each state. Carriers receiving CAF support were required to provide broadband with actual (not merely advertised) speeds of at least 4 Mbps downstream and 1 Mbps upstream. So, roughly speaking, the large incumbent carriers—those with economies of scale and experience receiving and administering federal universal service support for voice service—would now also be eligible for

support for broadband. Since the original order, the speed standard has been revised upward to 10 Mbps download/1 Mbps upload (FCC, 2014e). In the second phase, cost modeling would be developed to determine which areas needed how much support for broadband to be deployed. Support is first offered to the incumbent telecommunications provider for its high-cost areas in a state.³⁸ If the incumbent declines the offer of CAF support in a state, the areas are then opened in 2016 to competitive bidding (FCC, 2014e). As a companion to these efforts targeting wired broadband, a CAF Mobility Fund was established to accelerate deployment of networks for mobile voice and broadband services in unserved areas. A Mobility Fund offered one-time support for deployment to areas unserved by 3G mobile broadband in 2013.

Some of the goals of the CAF are to achieve “universal availability of voice and broadband to homes, businesses, and community anchor institutions” and “universal availability of mobile voice and broadband where Americans live, work, or travel” (FCC, 2011b, at 51,53). Unlike California’s specific (and more realistic) goal of 98% coverage, the FCC has set no goal below 100% availability. Data from the FCC indicate that in Phase I, 297 locations in two California counties received support totaling \$227,775.³⁹ Phase II was on a much larger scale: providers receive \$98.3 million per year (for six years) in support to serve over 230,000 end-users.⁴⁰

b. Demand side

Universal service programs targeting the demand side of the adoption equation are predicated upon observations that low-income households are much less likely to subscribe to broadband. The FCC (2015e) notes that while 95% percent of U.S. households with incomes above \$150,000 are connected to the Internet, less than half of households earning below \$25,000 per year subscribe to Internet access at home. Regardless, the process of modernizing low-income support for telecommunication service to include broadband has progressed more slowly than efforts on the supply side.

The FCC plans to reform its Lifeline program, which for 30 years has supported access to the telephone network by low-income households, most likely by allowing the current \$9.25/month subsidy to be applied to broadband as well as voice service (final rules were voted on just as this report was published; see FCC, 2016).

As it sought to reform universal service for the broadband era, the FCC set up an innovative program to learn about ways to encourage broadband adoption. With the Broadband Lifeline

³⁸ The CAF support amount offered for an area will be the difference between the model-determined cost and a benchmark used to identify high-cost areas. The benchmark of \$52.50 is meant to reflect “reasonable end-user rates.” CAF Phase II high-cost support will be offered only for areas below a second, “extremely high cost,” threshold of \$198.60, to keep the program within its budget (FCC, 2011; FCC, 2015d). Thus, the program is not intended to cover all costs of offering broadband everywhere in the country.

³⁹ Data are from the Connect America Fund (CAF) Phase I interactive map at <https://www.fcc.gov/maps/connect-america-fund-caf-phase-i>.

⁴⁰ Data are as of August 28, 2015 (from an FCC spreadsheet available at https://apps.fcc.gov/edocs_public/attachmatch/DOC-335269A5.xlsx).

Pilot Program, the FCC sought for the first time to support providers to do more than just present discounted rates for service to non-adopters. In the Lifeline experiments funded under the program, providers developed strategies to appeal to non-adopting households. The experiments constitute “an interesting behavioral economics approach to encouraging adoption” (Strover, 2014, p.118). California consumers in some areas were part of a multistate pilot project by Nexus, which tested subsidies of varying amounts for mobile broadband. Nexus received \$2.8 million from the FCC to conduct a large, randomized controlled trial (RCT) by offering potential subscribers one of six options, or “treatments” (to borrow language from medical experiments).⁴¹ Treatments varied by the level of the subsidy and whether an offer of digital literacy training accompanied the solicitation. The design of the study was intended to allow estimation of the causal effects of the discount levels and training on consumers’ choices. The results indicate that price discounts appear to be more important consideration in low-income consumers’ choice to adopt mobile broadband than variation in data limits (Frappier and Shoemaker, 2015).

Lifeline today depends on the combined efforts of the federal and state regulatory bodies. In California, the CPUC uses a third-party administrator to verify eligibility for Lifeline, which the state says has reduced waste, fraud, and abuse in the Lifeline program (FCC 2015, fn.167). States can also contribute to “topping off” the federal subsidy. California currently offers an additional \$13.20 per month for eligible carriers serving low-income consumers (Dulin, 2015), so that the total subsidy is \$22.45. In addition, the state offers a one-time service connection discount of up to \$39.⁴² The state subsidies currently only apply to voice, not broadband. However, subscribers can choose mobile or fixed voice communication.⁴³ More than four out of five Lifeline subscribers today choose mobile over fixed voice across America (Ukhaneva, 2015). The income thresholds for eligibility are shown in Table 6.

Table 6: Household income eligibility limitations for California LifeLine for voice telecommunication

Household Size	Income Limit
One or two	\$25,700
Three	\$29,900
Four	\$36,200
Each additional member	\$6,300

Notes: See CPUC (2015b). These limits are effective June 1, 2015 to May 31, 2016.

Finally, in addition to federal and state efforts toward universal service, carriers are allowed to offer low-income discounts on broadband service, either on their own initiative or as part of a regulatory compact. In California, for example, AT&T will offer discounted broadband for \$5 to

⁴¹ Information of the Nexus trials is available at <https://www.fcc.gov/encyclopedia/nexus-pilot-project>. The funding covered their trials in California as well as in seven other states.

⁴² See the California LifeLine webpage at https://www.californialifeline.com/en/discounts_comparison.

⁴³ The only difference is that for cell phone plans with 501 to 999 voice minutes the state provide a monthly discount of only \$5.75. Mobile voice plans with more minutes receive the full discount of \$12.65.

\$10 per month to new low-income subscribers.⁴⁴ The offer stems from conditions agreed upon with the FCC as part of the federal approval of the merger of AT&T and DIRECTV (Eggerton, 2015). Comcast's Internet Essentials option provides another example of a privately funded low-income program. The Internet Essentials plan costs \$9.95 per month for broadband with 10 Mbps download speed. Qualifying families are also offered a computer for \$150.⁴⁵

One current policy issue facing universal service for broadband is how to treat mobile versus fixed broadband. Given that broadband investment is shifting toward wireless infrastructure in recent years, the potential for mobile broadband to satisfy universal service obligations cannot be ignored. The data speeds of the top three wireless carriers in the state (AT&T, T-Mobile, and Verizon Wireless) ranged from almost 15 Mbps to over 20 Mbps download in 2015. The FCC's broadband speed guide indicates that 4 Mbps is adequate for email, general web browsing, audio and video streaming (including HD video), video conferencing, and online gaming (including two-way HD gaming).⁴⁶ These mobile broadband speeds are remarkable improvements over the situation even three years earlier. In 2012, North America's average mobile data connection speed was only 2.6 Mbps (OSTP, 2013). The FCC has solicited comments on how to set service standards for mobile broadband offerings (FCC, 2014e).

3. Coordinating state and federal regulation

The system of federalism in the US and the potential for overlapping state and federal regulation that it creates raises unique challenges for coordinating state and federal policy in the area of broadband, telecommunications, video programming, and other forms of communication. For much of the 20th century, the lines were drawn clearly: any telephone call between two points within the state was subject to state regulation, while interstate calls were subject to federal regulation. In the era of switched access networks and fixed-line telephony, the lines were bright. However, in the modern era of the global Internet, IP-enabled communications services may involve routing packets around the world even when the originating and terminating points are within the same state. Similarly, mobile services do not stop at borders.

In September 2012, Governor Brown signed SB-1161 into state law. The law prevents the CPUC or any other state agency or political subdivision from regulating the provision of VoIP or other

⁴⁴ AT&T stated that where their broadband speed currently exceeds 3 Mbps download, it would offer DSL service of up to 5 Mbps for \$10 for the first 12 months, increasing to \$20 per month for the next three years. Where current speed tops out below 5 Mbps, the company promised to offer DSL service of 1.5 Mbps for \$5 per month for the first 12 months, and \$10 per month for the next three years (Eggerton, 2015).

⁴⁵ See <http://www.cheapinternet.com/low-income-internet/internet-essentials>. Eligibility is determined by whether the family has a child eligible to receive a reduced or free school lunch through the National School Lunch Program. Many programs of all types aimed at low-income households with children peg their eligibility requirements to the National School Lunch Program, which is means tested, instead of coming up with their own income thresholds.

⁴⁶ See footnote 25.

IP-enabled services unless expressly required by existing state or federal law.⁴⁷ The restrictions on regulating VoIP and other IP-enabled services remain in effect until 2020, unless extended by the legislature. Similar legislation exists in more than half of the US states now; California was the 25th state enacting a law exempting VoIP service from state regulation (TechNet, 2012).

Coordination of efforts can play an important role in broadband markets. The joint federal and state involvement with universal service programs is one example of potential for successful cooperation and complementarity. State and federal funding for the Lifeline program, if combined in an efficient and nationally uniform approach, demonstrates how coordination can lead to more resources being made available for low income consumers. On the supply side, as discussed above the state was able to move swiftly to identify specific areas of the state and to raise funding from its own residents to subsidize the deployment of broadband infrastructure.

II. Availability of Broadband Internet Access

Broadband Internet access is available in some form to nearly every Californian residence and business establishment, and has been for some time. In the latest comprehensive federal report on broadband availability, the FCC (2015b) found that in December 2013 only 500,000 Californians, which was 1.3% of total population, lacked access to fixed broadband with speed of at least 3 Mbps download/768 kbps upload. Of those half million, some would have had access to mobile broadband⁴⁸ and nearly all would have had access to several satellite broadband providers; neither of these were included in the FCC's calculations.

The investigation of the current situation in California in this section of the report allows a picture of the typical broadband consumer to be formed. Before delving into the detailed statistics, consider what the typical broadband consumer faces. The most common outcome (i.e., the modal outcome) in 2014 was for the consumer to have three providers and three types of fixed broadband service available (excluding satellite-based service). The fixed-location options for the modal consumer include DSL and cable modem service. The third available fixed type to our typical broadband consumer is either fiber or high-speed services provided over copper other than DSL, although these services are often marketed mainly toward businesses. Mobile broadband service provides a fourth option to the typical customer, with the most common set of options being a choice among four providers. In addition to these options, satellite Internet service by three (soon to be two) providers is available to any location in California with a clear view of the southern sky.⁴⁹ The results in this section detail how prevalent

⁴⁷ The legislative history and text of SB-1161 is available at http://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201120120SB1161.

⁴⁸ Recent research shows that mobile broadband partially fills in geographical gaps in fixed-line broadband coverage in the U.S. (Prieger and Church, 2012; Prieger, 2013; Church and Prieger, forthcoming).

⁴⁹ As of fall 2015 there were two satellite broadband providers in the United States. There have been as many as four in the past and there were three until October 2015. Satellites operated by HughesNet and ViaSat offer 10 to 15 Mbps download and 1 to 3 Mbps upload to nearly any home in the US. See <http://arstechnica.com/business/2013/01/satellite-internet-15Mbps-no-matter-where-you-live-in-the-us>.

these and other outcomes are in California, painting a panoramic view of the broadband landscape of availability. Other aspects apart from availability that are highly relevant to the digital health of the broadband consumer market in the state, such as adoption and usage, quality of service, and price are discussed in later sections of this report.

Quantifying broadband availability is challenging. Broadband providers must choose which geographical markets to enter.⁵⁰ Given the economic considerations imposed by the physical, engineering, marketing, regulatory, and network constraints they generally do not choose “Swiss cheese” market footprints in a neighborhood.⁵¹ Thus, while the relevant market for any one consumer is no larger than its own premises, since the consumer cannot buy useful service at any other location, for the providers markets are typically contiguous areas of varying size.

However, delineating the geographical markets that broadband providers enter is made difficult because the natural areas of deployment for different types of broadband providers, e.g., wire center serving areas and cable franchise areas, do not match.⁵² Furthermore, there is no comprehensive, accurate, publicly available dataset on broadband choices by the address of specific customer premises.⁵³ The choices for market definitions adopted here are driven by the following goal and constraints. The goal is to come as close as possible to characterizing the set of broadband options available to each Californian residential and business location. Then broadband availability can be summarized with measures such as the number of people in the

Dish Network also offers Internet service using the ViaSat and Hughes satellites; since the FCC and National Broadband Map only count ultimate holding companies as distinct firms, service by Dish or other resellers does not add to the number of facilities-based satellite providers. Until discontinuing service on September 30, 2015, StarBand by Spacenet offered slower access on an older satellite system. Wild Blue also operated a competing system before it was acquired by ViaSat in 2009. Any other companies offering satellite Internet service in the state resells service from ViaSat or Hughes satellites.

⁵⁰ Satellite broadband providers are the exception, since once in place their systems can provide service to the entire contiguous U.S.

⁵¹ Engineering considerations in network design (such as the declining unit cost of bandwidth as total bandwidth increases) lead to economies of scale and geographic scope, making it most efficient to serve entire areas. Marketing considerations make it sensible to offer service to all locations in a neighborhood, since highly targeted advertising to specific premises is expensive. An example of a regulatory constraint that leads to whole-neighborhood coverage: local exchange companies and cable companies may have been required to offer service to all premises in the area by state regulators or local franchising authorities when building out their basic telephone and cable television networks, making it natural to add Internet service to the existing network for the entire neighborhood.

⁵² Previous studies have used counties, census tracts, ZIP codes, local telephone exchange boundaries, cable television service areas, and other geography to define the geographical market for broadband Internet (Chen and Savage, 2011; Gillett and Lehr, 1999; Prieger, 2003; Wallsten and Mallahan, 2013; Xiao and Orazem, 2011; Nardotto et. al., 2015; Prieger and Conolly, 2013; Prieger, 2013; Prieger, Molnar, and Savage, 2014).

⁵³ There are many online services, such as the pre-qualification marketing tools of broadband providers and even the National Broadband Map, that purport to show choices available to an address. In actuality all such engines can provide only approximate information on availability. For example, the National Broadband Map takes an address, links it to the Census block into which it falls, and then shows information on providers who offer service to at least one address within the block (not necessarily the focal address).

state with access to one provider, three providers, five providers, and so on. Pragmatic concerns are imposed by the nature of the data that are available. As will be discussed in the relevant sections below, at various times since systematic data on broadband availability began to be gathered by federal agencies, different geographical units were employed for collection of the data: ZIP codes, Census tracts, and Census blocks. Further constraints are imposed in some cases by available data on customer locations. In publicly available data from the Census Bureau, locations of business establishments are aggregated to areas no smaller than a collection of addresses with the same five-digit ZIP code, even though broadband availability data may be observed at finer levels of geographical detail. The decision rule adopted here is to use the smallest geographical area available for broadband availability, aggregated (if need be) to the smallest possible area required for matching to available demographic or business location data.

A. Growth in broadband deployment across California

Over the years covered by this study, various data are available on broadband deployment and availability. Since the disparate nature of the data preclude forming statistics that are comparable throughout the entire period of study, three periods will be presented separately. The first periods are 1999 to 2008 and 2008 to the end of 2013, using data from the Federal Communications Commission (FCC). The third period overlaps the previous, making use of data provided by the National Broadband Map for 2010 through midyear 2014.

1. Broadband deployment at the ZIP code level, 1999 to 2008

The FCC began systematic tracking of broadband deployment at the end of 1999. From then until midyear 2008, the FCC collected data from broadband providers offering service with speed at least 200 kbps in one or both directions.⁵⁴ During this time, that is the only speed threshold available in the publicly released local data. The publicly released data from the FCC take the form of semiannual lists of ZIP codes with a count of the number of broadband providers offering service to at least one household or business in the area. All types of broadband were included in these counts: asymmetric DSL (ADSL), broadband over power line (BPL), cable modem, fiber, satellite, fixed terrestrial wireless (also known as wireless Internet service providers, WISPs), mobile terrestrial wireless (also called “mobile broadband”), symmetric DSL (SDSL), and a residual “other” category for wireline services such as T-1 dedicated lines. These lists compose a set of snapshots as of June 30 and December 31 of each year showing the state of broadband availability, and these data are examined here to provide insight into the growth of broadband deployment in California.

To understand the nature of the graphs and statistics that follow, a few caveats must be understood about the data. The most important of these concerns the nature of the geographic coverage. While the data on deployment are for ZIP codes, any one provider marked as serving a customer in the area need not serve the entire area. To the extent that some providers serve

⁵⁴ Broadband providers completed the semi-annual FCC Form 477, which required them to list each five-digit ZIP code in which they provided service, separately by type of broadband service offered. The lists do not include information on the number of subscribers served within the ZIP code areas.

less than the entire area, the counts of people and businesses served will be somewhat overstated. However, this is mostly an issue in rural areas, where ZIP code areas can be large. The relatively low numbers of people living in rural areas in the state imply that less-than-complete broadband coverage in such areas will affect the population totals in the figures but little.

The second issue involved with creating a dynamic picture of the market is that the universe of ZIP codes changes over time. The US Postal Service constantly creates new codes and removes obsolete codes from use. Since ZIP code areas change over time, the geographical market boundaries used here are ZIP Code Tabulation Areas (ZCTAs) defined for the 2000 Census. The reported ZIP codes in the FCC data each year are linked to the corresponding ZCTAs, the boundaries of which are stable.⁵⁵ Despite the actual use of ZCTAs for market areas, for simplicity the more familiar term “ZIP code areas” will be used below.

Third, not all providers necessarily serve both residential and business customers. While business-oriented broadband providers may be presumed to accept residential customers willing to pay for service, some companies do not actively market to residential subscribers. During this period, the FCC counted all providers regardless of whether they actually served residential customers in the area. Finally, until June 2005 the FCC did not require broadband providers with fewer than 250 subscription lines in a state to file reports. Thus the deployment statistics before then are slightly understated. Given that these providers were very small, however, the impact of this is small, as will be discussed below.

a. Availability to people

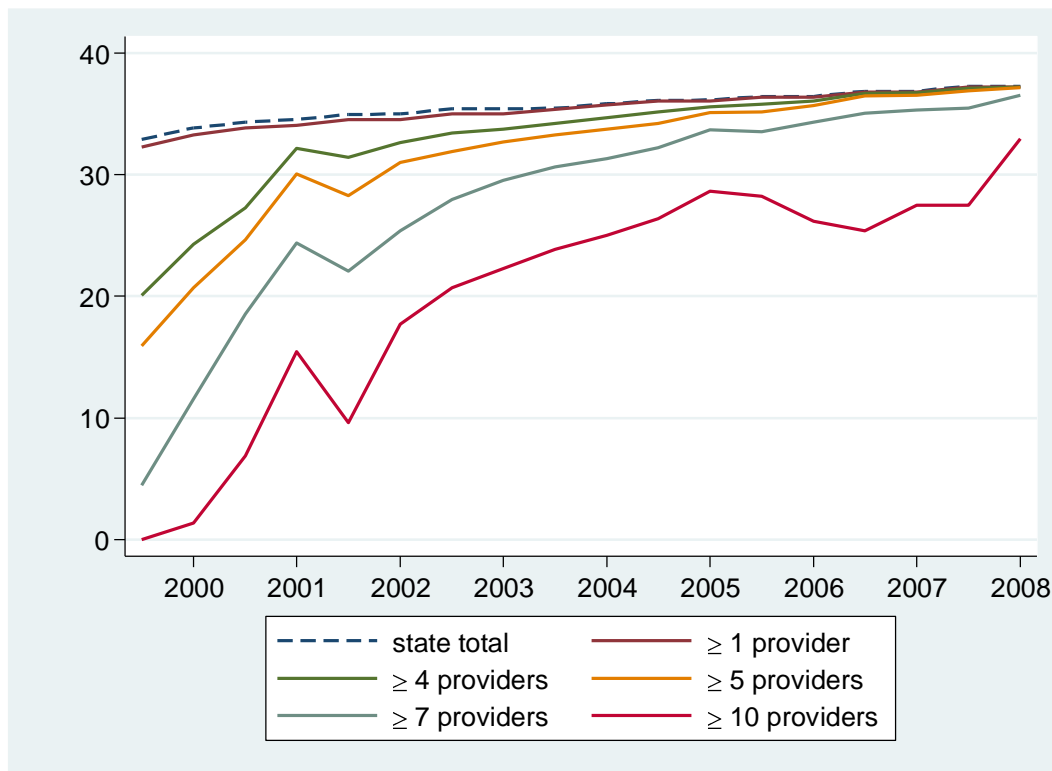
Matching ZIP code areas to demographic data allows us to form a picture of the population served by broadband in California.⁵⁶ Figure 7 shows the population residing in ZIP codes with various numbers of broadband providers, along with population totals for comparison. Again, these trend lines include broadband of all types, including satellite and mobile wireless. Even before 2000, nearly everyone in California lived in a ZIP code with at least one broadband provider, as shown by the tiny gap between the dark red solid line in the figure for this subpopulation and the dashed line for the total population. Deployment was also growing

⁵⁵ The procedure begins with the ZCTAs, which cover all population in the state. Each ZCTA is linked to any ZIP code associated with it. The geographical associations are culled from various crosswalk files for the relevant years, including those provided by The U.S. Department of Health and Human Resources (see Goodman (2005) for methodology) and other calculated by the author using GIS software. In cases for which more than one ZIP code corresponds to a ZCTA, the maximum provider count across ZIP codes is assigned to the ZCTA. Given the highly spatially correlated nature of broadband coverage by providers, the degree of overcounting of providers that this procedure might create is likely to be minimal. The entire procedure ensures that all population is counted in the totals in the figures to follow.

⁵⁶ For 1999 and 2000, the demographic data are from the 2000 Census. Subsequent years of demographic data are estimates from GeoLytics, Inc. Both sources are at the level of the ZCTA. The year-end data from the FCC are matched to demographic data for the next calendar year, given the timing of when within the year the demographics pertain (April 1 for Census, January 1 for GeoLytics).

during this period. The subpopulations living in areas with at least four,⁵⁷ five, seven, or even ten broadband providers grew quicker than the total population and the subpopulation with at least one provider. By June 30, 2008, 36.99 million people (99.1% of all Californians) lived in ZIP codes with at least one provider, and nearly all of those people (36.98 million; 99.1%) also lived in areas with at least four providers, at least five providers (36.94 million; 99.0%), or at least seven providers (36.29 million; 97.2%). There were also 32.77 million (87.9% of all) Californians living in areas with 10 or more providers. While the FCC provides no breakdowns on the nature of these providers, from later data sources with more detail one may expect that an area with 10 or more providers around 2008 was likely to have access to DSL or fiber service from the local exchange company, cable modem service, at least one other fixed broadband option such as fiber or Ethernet over copper from a business-oriented competitive provider, three or four mobile broadband providers, and at least three satellite broadband providers.

Figure 7: Population in ZIP codes with broadband providers, 1999 to 2008



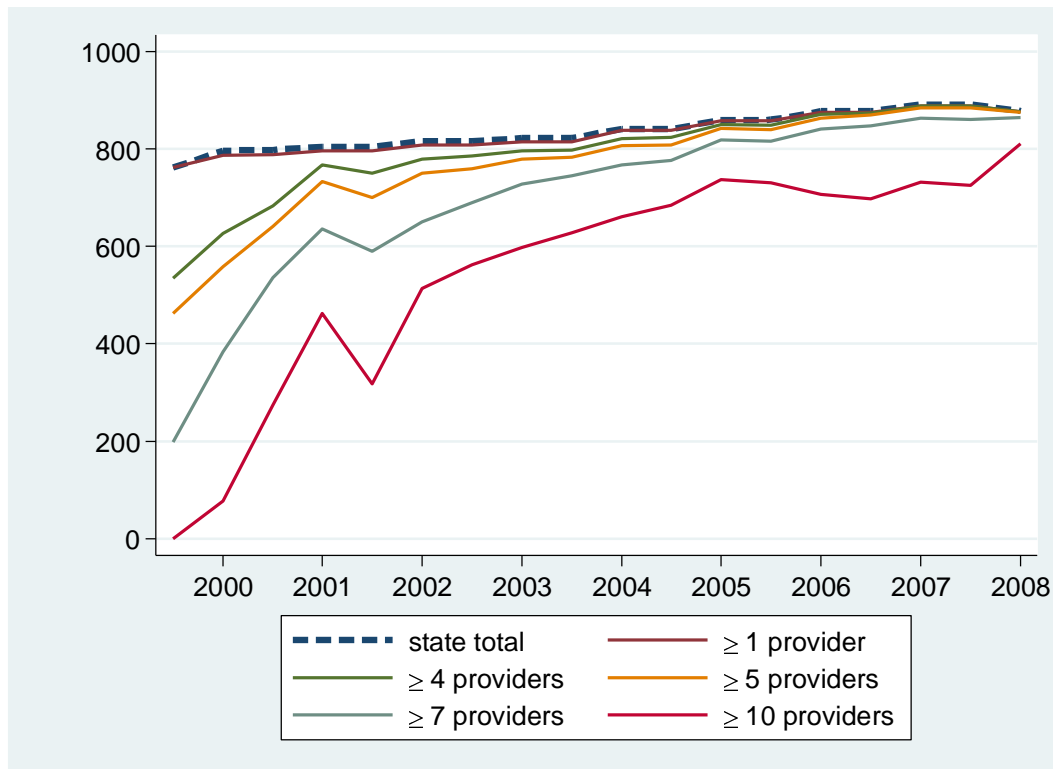
Note: “State total” is the total population for California. The provider count includes all broadband providers (xDSL, cable modem, fiber, other wireline, fixed wireless, satellite, and mobile wireless). The lower speed threshold is 200 kbps in at least one direction. Providers do not necessarily cover all territory within the ZIP code area. Broadband data are from the FCC as described in the text.

⁵⁷ The FCC censors the publicly available data so that one to three providers are grouped into a single category. Thus “four or more providers” is the next possible category after “at least one provider”.

b. Availability to businesses

Broadband Internet access is important for many businesses as well, and there are also many businesses in the areas served by broadband providers. The productivity gains enjoyed by businesses adopting broadband are a driving factor linking broadband to the economic growth discussed in section I.A. Using data on the location of business establishments⁵⁸ from the Census Bureau by ZIP code,⁵⁹ it is possible to count the number of establishments in ZIP codes with various numbers of broadband providers.⁶⁰ The results are in Figure 8. Given that businesses are more likely than people to be in urban areas, where there are more broadband providers, Figure 8 shows more complete coverage than Figure 7. By June 2008, almost all of the business establishments in the state were in areas with 10 or more providers. Out of 878,500 thousand establishments in the state at that time, 865,100 thousand of them are in areas with seven or more broadband providers, and 811,400 thousand are in areas with 10 or more.

Figure 8: Business establishments in ZIP codes with broadband providers, 1999 to 2008



⁵⁸ Business may have multiple establishments. In 2008, Census data from *Statistics of U.S. Businesses* include 717,133 businesses and 879,025 establishments in California, for an average of 1.2 establishments per business.

⁵⁹ The data are from *ZIP Code Business Patterns* from the Census Bureau.

⁶⁰ The establishment data are reported by postal code, not ZCTA, and so the establishment data generally can be matched directly to the FCC data. The few unmatched ZIP codes appearing in the establishment data are aggregated to the ZCTA level and matched to the FCC ZIP codes as described in footnote 55.

Note: "State total" is the total number of business establishments in California. See also notes to Figure 7.

2. Broadband deployment at the Census tract level, 2008 to 2013

Since the end of 2008, the FCC collects data from broadband providers on where they offer service by Census tract instead of ZIP code. The FCC also expanded the types of data that they publicly release, so that more information on broadband speed and specifically residential service became available. The data can be used to extend the series of snapshots of the state of broadband deployment to near the present time.

Of the four caveats regarding the earlier broadband data from the FCC mentioned in the previous section, only the first applies to these data, and only to a lesser extent. It remains the case that the provider count for each tract may include some which do not offer service throughout the entire area. However, in general Census tracts are much smaller than ZIP code areas (there are over 8,000 tracts in California but fewer than 2,000 ZCTAs), and so this issue is of less importance. The other concerns no longer apply: Census tracts do not change except for the decennial censuses, the FCC now tracks residential broadband separately from the total count, and all firms (no matter how small) are required to file information on their broadband coverage twice each year.

There are several ways to count broadband providers after 2008. The total number of fixed broadband providers offering service of at least 200 kbps in at least one direction are examined first. This measure includes residential and business service and provision of every type (xDSL, cable modem, other wireline, fiber, fixed wireless, and satellite) except mobile broadband. Even though the speed threshold is the same as in the previous period, the provider counts here are not directly comparable because of the change in geographical unit and because mobile wireless service is not included in these data.⁶¹ The second way to count broadband providers during this period is by using a higher speed threshold of at least 3 Mbps download and at least 768 kbps upload. This is the highest speed threshold that can be examined during this period. Mobile broadband for this period will be examined in section 0 below.

a. Availability to people

Matching the Census tracts to demographic data allows us to see the trends in population served by broadband in California since 2008.⁶² Trends in three nested sets of fixed broadband provision are calculated in this section: broadband meeting the older standard of 200 kbps in either direction, offered to any type of customer; residential broadband meeting the older standard; and residential broadband satisfying a higher speed requirement of at least 3 Mbps download and at least 768 kbps upload.

⁶¹ Since the FCC stopped collecting broadband data at the ZIP code level in 2008, it is impossible to create figures for this section that are directly comparable to those in the previous section for 1999-2008.

⁶² The demographic data are from GeoLytics, Inc. at the tract level. FCC data from December are matched to demographic data from the following calendar year (see footnote 56).

Figure 9 shows the population in tracts with various numbers of fixed broadband providers. Throughout the entire period of 2008 to 2013, virtually everyone in California lived in a tract with at least one fixed broadband provider—there is essentially no gap between the dark red solid line in the figure for this subpopulation and the dashed line for the total population. Given the relative maturity of the broadband market during this time, growth in coverage is not as pronounced as in the earlier period. Nevertheless, apart from a slight downturn in December 2011 (which may be merely an artefact of the data)⁶³ competition was also growing during this period. Since 2012, the number of people living in areas with at least four,⁶⁴ five, seven, or ten broadband providers grew quicker than the total population (virtually all of which had at least one provider). By December 2013, 38.6 million people lived in tracts with at least one provider, and most of those people (37.4 million) also lived in areas with at least four providers or at least five providers (34.6 million). In addition, there were 23.9 million Californians living in areas with at least seven providers and 8.3 million in areas with 10 or more providers.⁶⁵

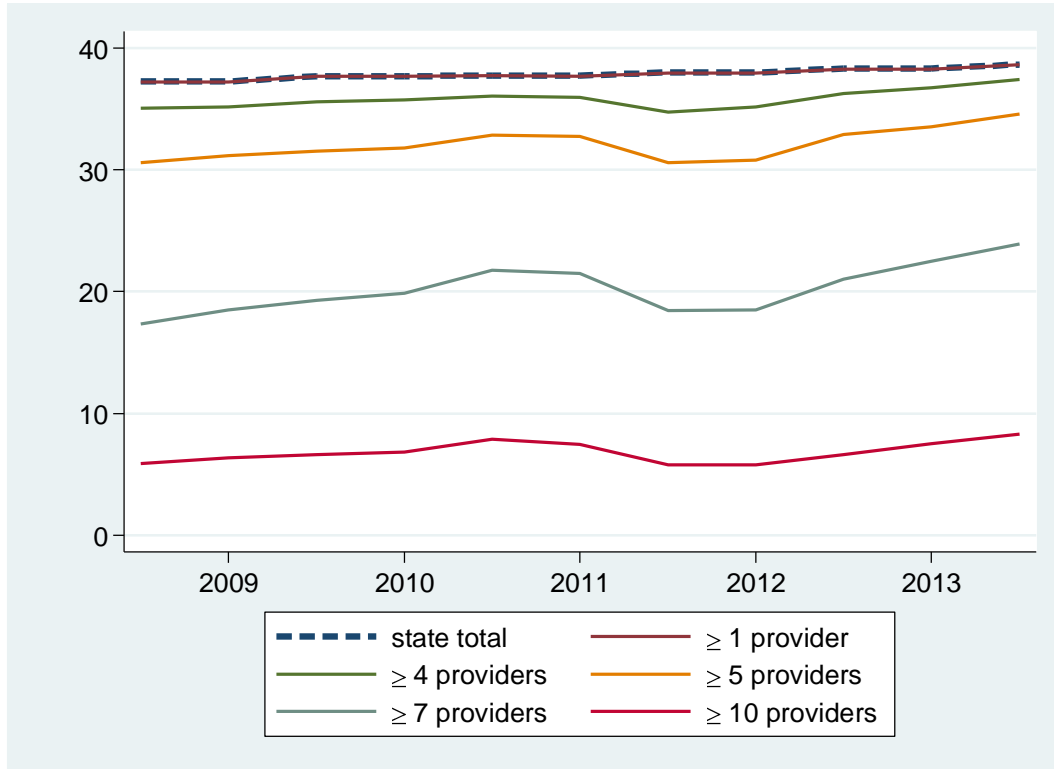
Not all of the providers in Figure 9 offer service to residential customers. Many broadband providers focus solely on the business market. In Figure 10, the count of fixed broadband providers is limited to those offering residential service (at the same speed threshold of 200 kbps as before). While there is little difference between the trend lines for one or more providers in the two figures—virtually everybody lives in tracts with at least one residential provider—there are visible differences between the trends for higher provider counts once the business-only providers are removed. In December 2013, 38.6 million people lived in tracts with at least one provider of residential service, 33.0 million lived in areas with at least four providers, and 20.0 million Californians lived in areas with at least five residential providers.

⁶³ The small downward movement in the trends in December 2011 and June 2012 do not appear in the more-detailed data from the National Broadband Map from the same time, as will be shown in section II.A.3.

⁶⁴ The FCC continued to censor one to three providers into a single group during this time (see footnote 57).

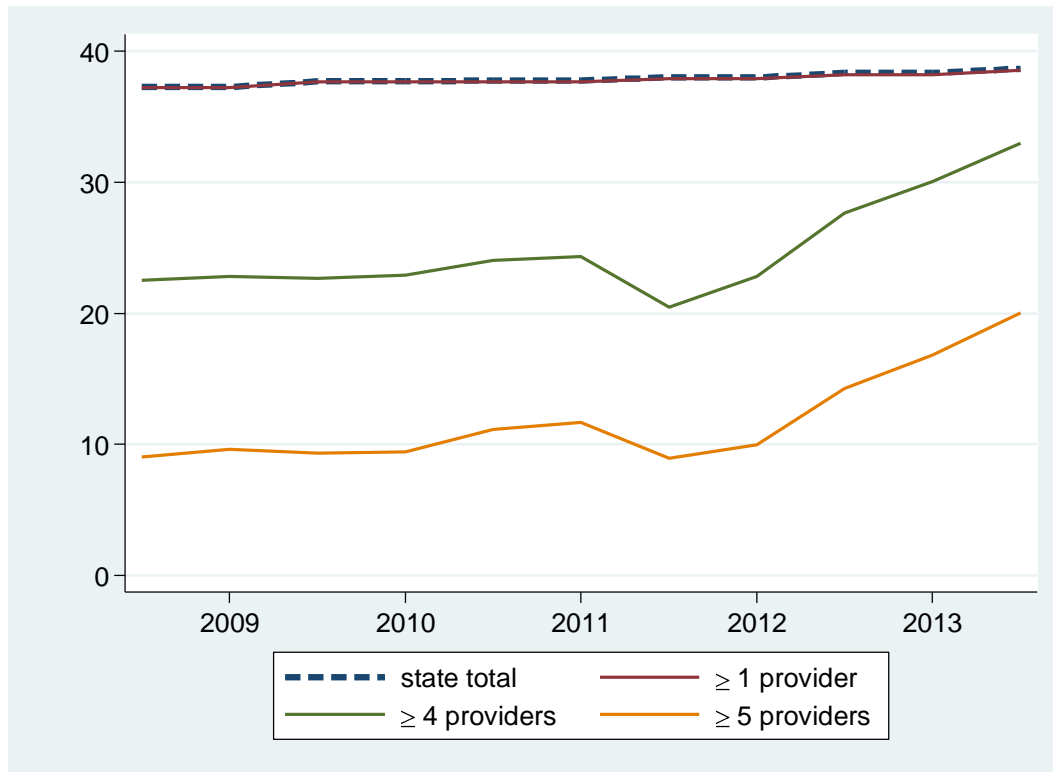
⁶⁵ The latter figures are smaller than in Figure 7 for the earlier period because of the smaller geographical unit being examined here. For example, it is more likely that there are 10 providers in a ZIP code than a tract because the latter is typically a smaller area.

Figure 9: Population in Census tracts with fixed broadband providers, 2008 to 2013



Note: "State total" is the total population for California, and where the line is obscured it is underneath the line for "≥ 1 provider". The provider count includes all fixed broadband providers (xDSL, cable modem, fiber, other wireline, fixed wireless, and satellite) but excludes mobile wireless. The lower speed threshold is 200 kbps in at least one direction. Providers do not necessarily cover all territory within the tract. Broadband data are from the FCC as described in the text.

Figure 10: Population in Census tracts with fixed broadband providers of residential service, 2008 to 2013

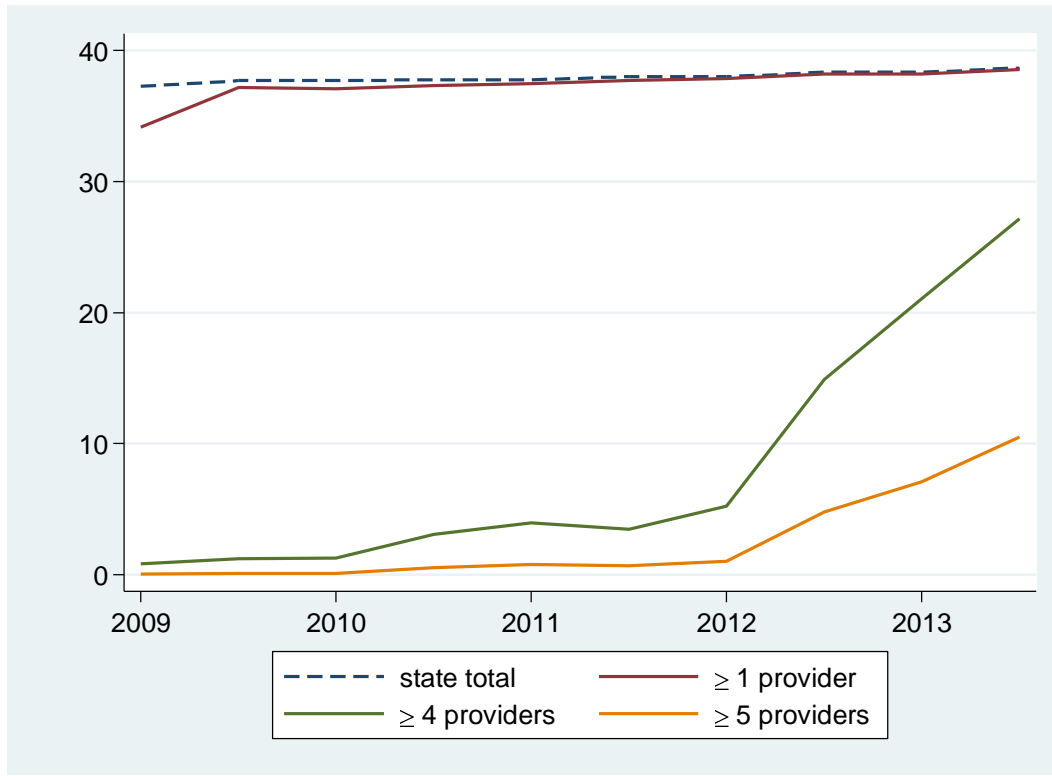


Note: The counts are limited to providers offering service to residences in the tracts. See also notes to Figure 9.

Since June 2009, the FCC also counted providers of residential fixed broadband that meets a speed threshold of at least 3 Mbps download and at least 768 kbps upload.⁶⁶ The California population living in tracts with access to these faster broadband providers is shown in Figure 11. From December 2009 on, nearly everyone in the state lives in a tract with at least one broadband provider satisfying this speed threshold. After June 2012, many more people than before lived in areas with at least four or five such providers, too. In December 2013, 38.6 million Californians resided in tracts where residential fixed broadband service of at least 3 Mbps down/768 kbps up was offered. Of those, 27.2 million were in areas with four or more such providers, and 10.5 million were in areas with five or more.

⁶⁶ As with any of the speed thresholds used in this report, the FCC cautions that “the reported connection speed is typically the advertised speed of the purchased service, and it is possible that the purchased service will not operate at its advertised speed at all times” (FCC, 2014a, p.1). However, in September 2013, measurements overseen by the FCC found that major broadband service providers delivered an average of 101 percent of advertised speeds (FCC, 2014b), an improvement from earlier years (FCC, 2011a).

Figure 11: Population in Census tracts with fixed broadband providers of residential service (3 Mbps down/768 kbps up), 2009 to 2013



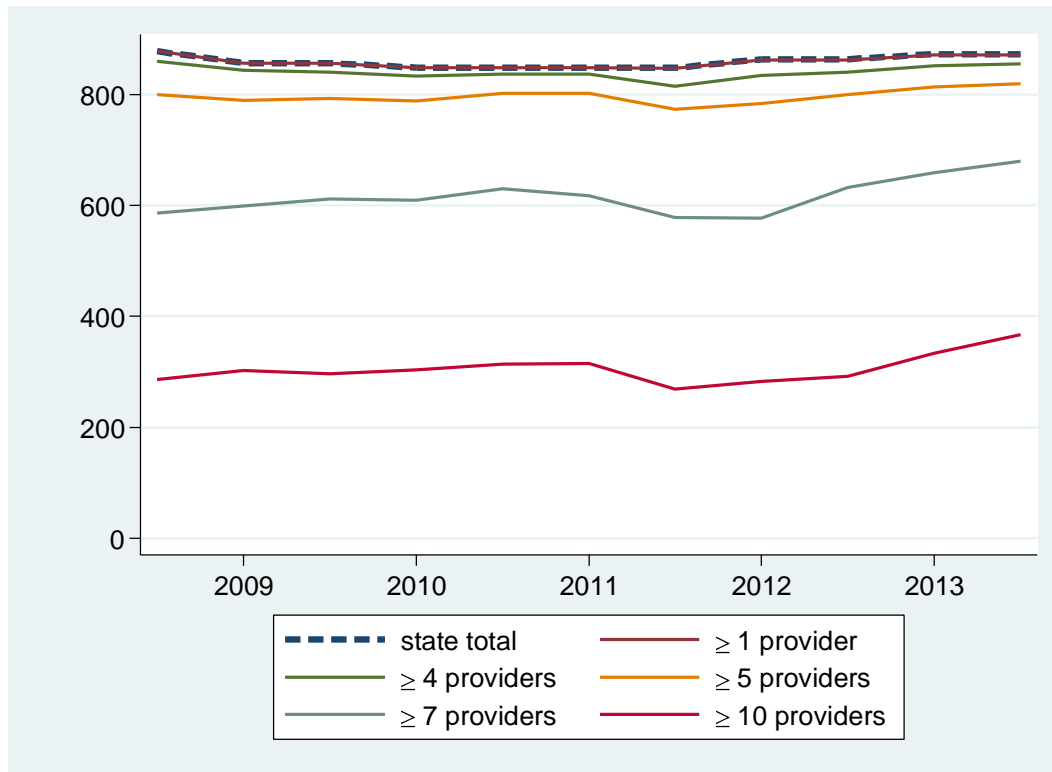
Notes: See notes to Figure 9 and Figure 10. The speed threshold is 3 Mbps download/768 kbps upload.

b. Availability to businesses

As for the earlier period, data from the Census Bureau on business establishments can be linked to the broadband data to count the number of establishments with access to various numbers of providers. Since the business location data are by ZIP code, the FCC tract level data are matched and aggregated to the ZIP code level.⁶⁷ The results are in Figure 12. As in the earlier period examined in section 1.b, coverage for businesses is more complete than for residences (compare Figure 12 with Figure 9) due to the non-rural nature of most establishments. From 2008 through 2013, almost all of the business establishments in the state were in areas with five or more providers offering service at or beyond the 200 kbps threshold. Out of 873,400 establishments at the end of 2013 in California, 856,200 of them are in areas with four or more fixed broadband providers, 820,200 are in areas with five or more, 679,900 are in areas with seven or more, and 366,600 are in areas with 10 or more.

⁶⁷ The centroid of each ZIP code is matched to the Census tract into which it falls and thence to the FCC data on broadband availability. The procedure ensures that the all business establishments are counted in the totals in the figures to follow.

Figure 12: Business establishments in ZIP codes with fixed broadband providers, 2009 to 2013



Note: “State total” is the total number of business establishments in California, and where the line is obscured it is underneath the line for “≥ 1 provider”. The lower speed threshold is 200 kbps in at least one direction. See also notes to Figure 9.

3. Broadband deployment at the Census block level, 2010 to 2014

Beginning in June 2010, the National Broadband Map provides another source of data on broadband deployment. The map is administered by the National Telecommunications and Information Administration (NTIA), and is updated semiannually at the same dates as the FCC broadband data. For California, the raw data are gathered by the California Public Utilities Commission (CPUC) and submitted to the NTIA. The CPUC states that their data cover over 99.9% of the total broadband connections in California (CPUC, 2013).

These data are an improvement over the data from the FCC in three respects. First, the geographical unit is the Census block, which is a very small area in all but rural areas. There are over half a million blocks in California. Second, the data are disaggregated so that the type of broadband service (e.g., ADSL or cable modem) is observed. Third, the maximum advertised speeds are recorded, so that more information on the quality of service is observed.⁶⁸

⁶⁸ While in theory the National Broadband Map also records actual transmission rates, those fields are missing for many firms and so the maximum advertised rates are used instead. Refer to the evidence in

Given the more detailed information on the speed of service, there are many possible ways to count broadband providers after 2010. Three ways are chosen to calculate the figures presented in this section: fixed broadband providers meeting a speed threshold of 200 kbps in both directions (to match the threshold used in the earliest period); fixed broadband providers meeting a threshold of 3 Mbps download/768 kbps upload (to match the threshold used in the previous section); and fixed broadband providers meeting a threshold of 10 Mbps download/1.5 Mbps upload.

a. Availability to people

The procedure for linking the data on the number of providers from the National Broadband Map is as follows. First, providers were counted within each Census block. These geographical units are so small, at least in non-rural areas, that any provider operating in a block is highly likely to serve the whole block. Where so, this implies that the provider counts are also the number of options available for each customer premises in the area, setting aside the distinction between business and residential services for now. Before linking to the population counts, however, the broadband data are aggregated to the Census block level, because most demographic variables explored later in this report are unavailable at the block level. Census block groups still cover small areas.⁶⁹ The maximum number of providers within any single block is then applied to the block group⁷⁰ and matched to demographic variables at that level.⁷¹

The first data examined are for the number of fixed broadband providers. Unlike the FCC data used in the previous sections, these data do not include satellite-based broadband. Like the FCC data, the data here also do not include mobile wireless providers. The results using a speed threshold of 200 kbps in both directions are shown in Figure 13. The provider counts look smaller than in the figures using data from the FCC (Figure 7 and Figure 9), but this is not because of decreasing competition. The counts are lowered for two reasons. First, satellite broadband, which is nearly ubiquitously offered by several providers, is not included. Second, the small geography of the Census block virtually ensures that only head to head competition at an address is included.

Most people live in areas with at least two providers, and that has been true since June 2010. In June 2014, 37.6 million people live in areas with two or more fixed broadband providers, 27.7 million live in areas with three or more providers, and 9.8 million live in areas with four or more providers. Thus the most common outcome is three fixed broadband providers from which to choose. Given the fine geographic detail of the National Broadband Map, these also represent

footnote 66 that (at least by the end of the period studied here) advertised and actual transmission rates are in close accord on average.

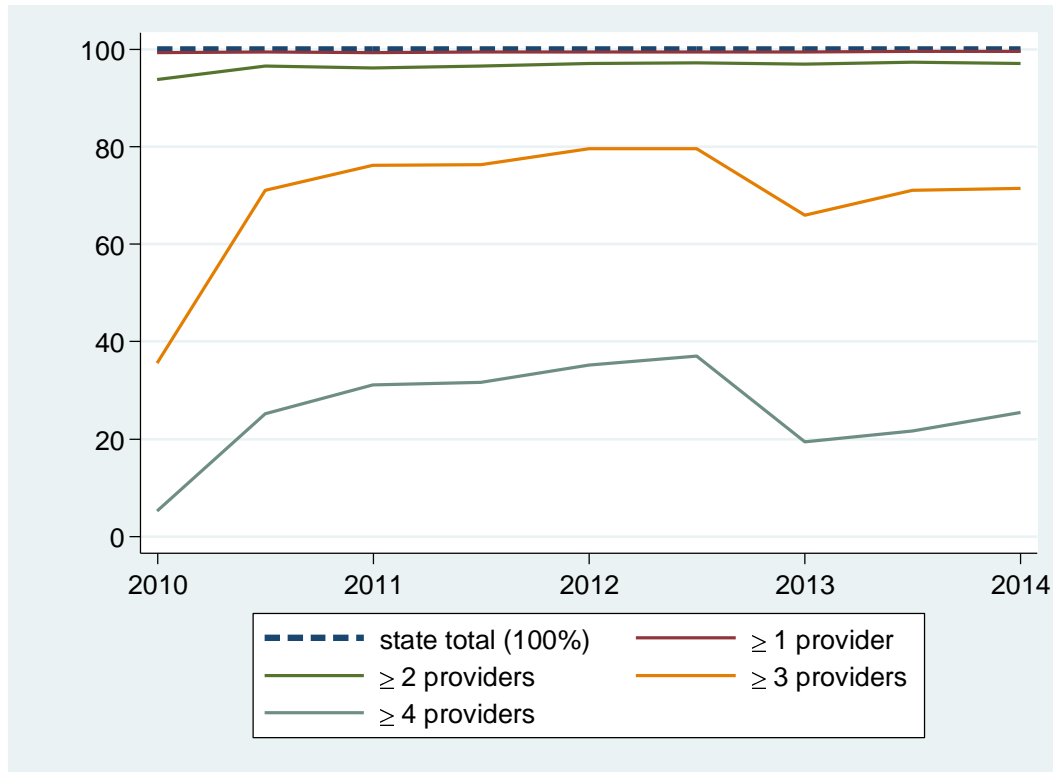
⁶⁹ There are over 220,000 block groups in the state, with land area averaging only 0.7 square miles each. The latter statistic is skewed upward by rural areas—the median Census block group is only 0.5 square miles.

⁷⁰ The maximum number of providers in any block is a good summary statistic for the block group, because there is not a lot of variation in the provider count among blocks in a block group. The standard deviation within block groups of the provider count at the block level has a median of only 0.4

⁷¹ The block group level demographic variables are estimates from GeoLytics, Inc.

the actual choices for non-satellite fixed broadband faced by most subscribers at a given address.

Figure 13: Population in Census block groups with fixed broadband providers, 2010 to 2014



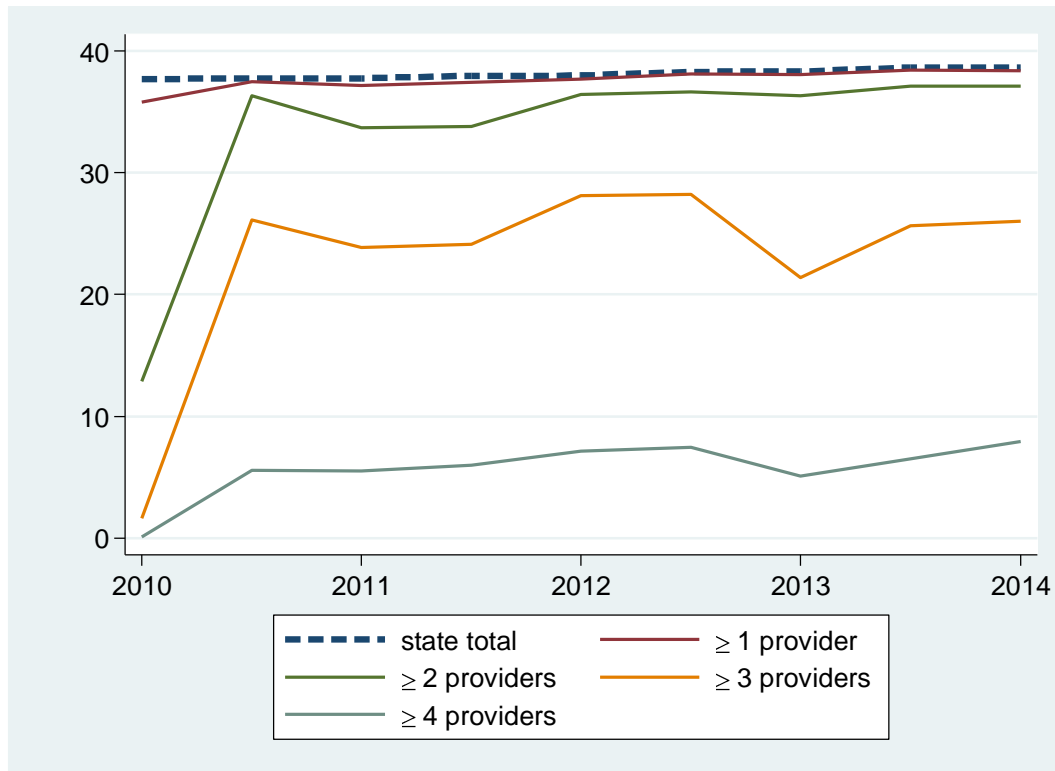
Note: “State total” is the total population for California. The provider count is the maximum number of providers occurring in any one block in the block group, and includes all fixed broadband providers (xDSL, cable modem, fiber, other wireline, and fixed wireless) except satellite. Mobile wireless broadband is not included. The speed threshold is 200 kbps in both directions. Broadband data are from the National Broadband Map as described in the text.

During this period, most fixed broadband lines in California met a higher speed threshold of 3 Mbps download and 768 kbps upload, as shown in Figure 14. In June 2014, out of the 37.6 million people in areas with two or more fixed broadband providers offering service at the 200 kbps threshold, 37.2 million of them also had two or more providers meeting the higher speed threshold. This estimate of 98.9% availability can be compared with the FCC’s (2015b) more granular (Census block level instead of block groups) analysis for December 2013 in its *2015 Broadband Progress Report*, which found that 1% of Californians lived in areas with no access to fixed broadband at the 3 Mbps/768 kbps standard. The comparison shows that aggregating the population data to the block group level, the procedure followed in this report, does not appear to overstate availability (at least for the population as a whole). The FCC’s report also calculated

that only 4% of Californians lacked access to fixed broadband meeting the standard of at least 10 Mbps download/768 kbps upload.⁷²

Similarly, 94% of the people in areas with three or more fixed broadband providers at the 200 kbps threshold also had access to at least three providers at the higher threshold. The comparable figure for population with four or more providers is 82%.

Figure 14: Population in Census block groups with fixed broadband providers (3 Mbps down/768 kbps up), 2010 to 2014



Notes: The speed threshold is 3 Mbps download/768 kbps upload. See also notes to Figure 13.

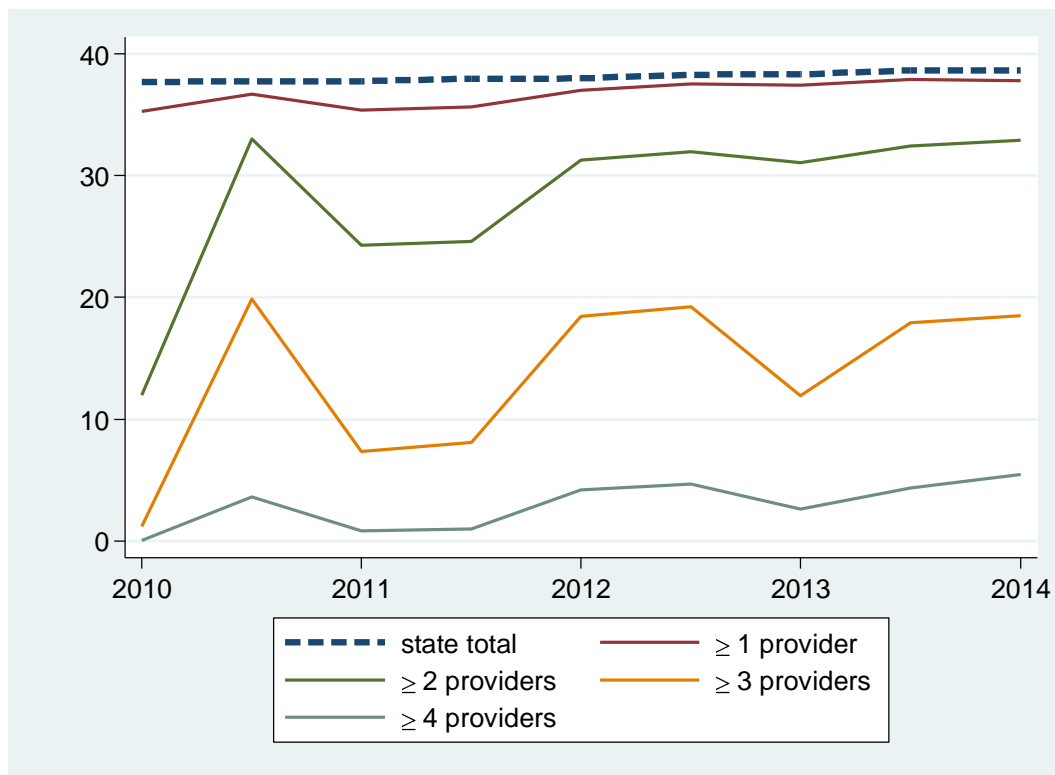
In Figure 15, a higher speed threshold of 10 Mbps download and 1.5 Mbps upload is used to count fixed broadband providers. In June 2014, 97.9% of Californians lived in block groups with access to fixed broadband of 10 Mbps download and 1.5 Mbps upload.⁷³ A further 85.2% of people lived in areas with two or more fixed broadband providers offering service at that speed.

⁷² See Appendix G of FCC (2015b) for these figures.

⁷³ This estimate can be compared with the “official” estimate from the CPUC that 95.5% of California households have access to non-satellite broadband of speed 6 Mbps download/1.5 Mbps upload in June 2014 (CPUC, 2015a). Reasons for the discrepancy include the differing speed threshold, the aggregation to the Census block group level in this report, and the more granular data available to the CPUC. The CPUC works with Census blocks and also has sub-block level data on availability from some providers.

Comparison of Figure 15 with Figure 14 shows that during this time the great majority of fixed broadband lines meeting the 3 Mbps down/768 kbps up threshold also met the higher speed threshold; relatively few people lived in areas in which download speeds maxed out between 3 and 10 Mbps. In particular, almost all (98.7%) areas with service available at 3 Mbps/768 kbps also had access to service at 10 Mbps/1.5 Mbps and 87.3% of people in areas with two or more fixed providers offering 3 Mbps/768 kbps speeds also had access to two or more 10 Mbps/1.5 Mbps providers. The comparable percentages for at least three providers and at least four providers are 69.8% and 67.1%, respectively.

Figure 15: Population in Census block groups with fixed broadband providers (10 Mbps down/1.5 Mbps up), 2010 to 2014



Notes: The speed threshold is 10 Mbps download/1.5 Mbps upload. See also notes to Figure 13.

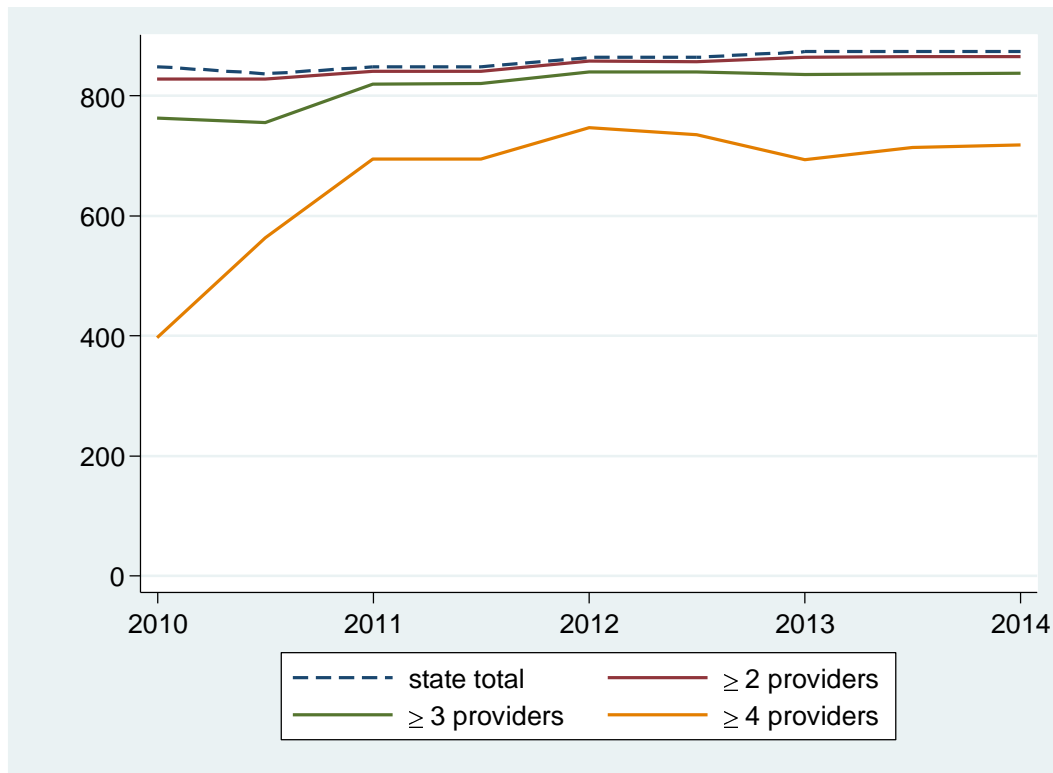
b. Availability to businesses

As for the earlier period, data from the Census Bureau on business establishments can be linked to the broadband data from the National Broadband Map. Since the business location data are by ZIP code, the broadband data at the Census block level are aggregated and matched to the ZIP code level.⁷⁴ The results are in Figure 16. Again, the provider counts look smaller than those

⁷⁴ The ZIP codes in the establishment data are matched to the corresponding ZCTAs and thence to all Census blocks in the ZCTA. The intermediary step involving the ZCTA is necessary because ZIP codes

calculated from the FCC data not because broadband options are actually declining but instead for the reasons mentioned in the previous section. From 2010 through 2014, almost all of the business establishments in California were in areas with three or more providers offering fixed broadband service. Out of 873,500 establishments in California in 2014, 865,100 of them are in areas with two or more fixed broadband providers, 838,000 are in areas with three or more, and 718,300 are in areas with four or more. Some businesses face even more options: 391,100 establishments are in areas with five or more fixed broadband providers, and 168,500 have access to six or more.

Figure 16: Business establishments in ZIP codes with fixed broadband providers, 2010 to 2014

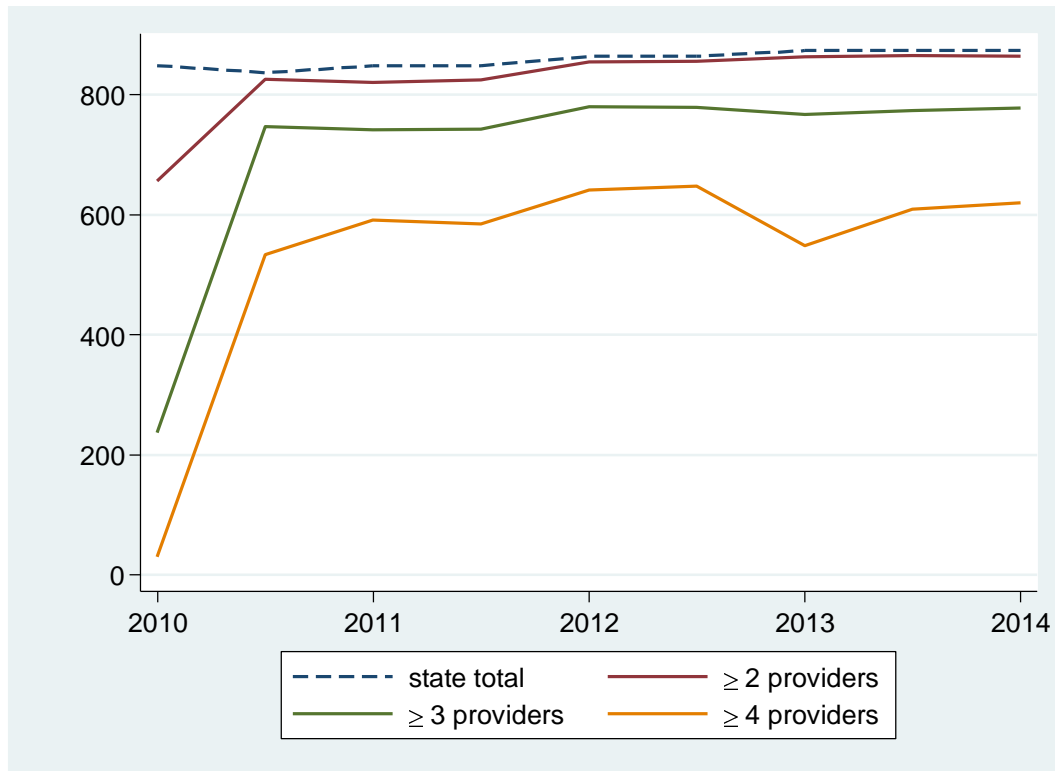


Notes: The provider count is the maximum number of providers occurring in any one block in the ZIP code, and includes all fixed broadband providers (xDSL, cable modem, fiber, other wireline, and fixed wireless) except satellite. Mobile wireless broadband is not included. The speed threshold is 200 kbps in both directions.

“areas” are actually collections of addresses, not proper areas on a map. After matching each ZIP-tract record to the corresponding block-level data from the National Broadband Map, the broadband data are aggregated to the ZIP code level. As described for the population demographics in section II.A.3.a, the maximum count from any block is applied to the whole ZIP code. While this procedure may overstate availability, 1) most businesses are in urban areas where ZIP code areas are smallest, and 2) broadband coverage is highly spatially correlated. Both factors mitigate the extent of any overcounting.

Businesses covered by the various numbers of providers offering service at the higher speed threshold of 3 Mbps download and 768 kbps upload are shown in Figure 17. In June 2014, 864,600 establishments were in areas with two or more providers meeting the higher speed threshold. Similarly, for 93% and 86% of businesses in areas with three or more or four or more providers, respectively, the businesses also had access to as many providers meeting the higher speed threshold.

Figure 17: Business establishments in ZIP codes with fixed broadband providers (3 Mbps down/768 kbps up), 2010 to 2014

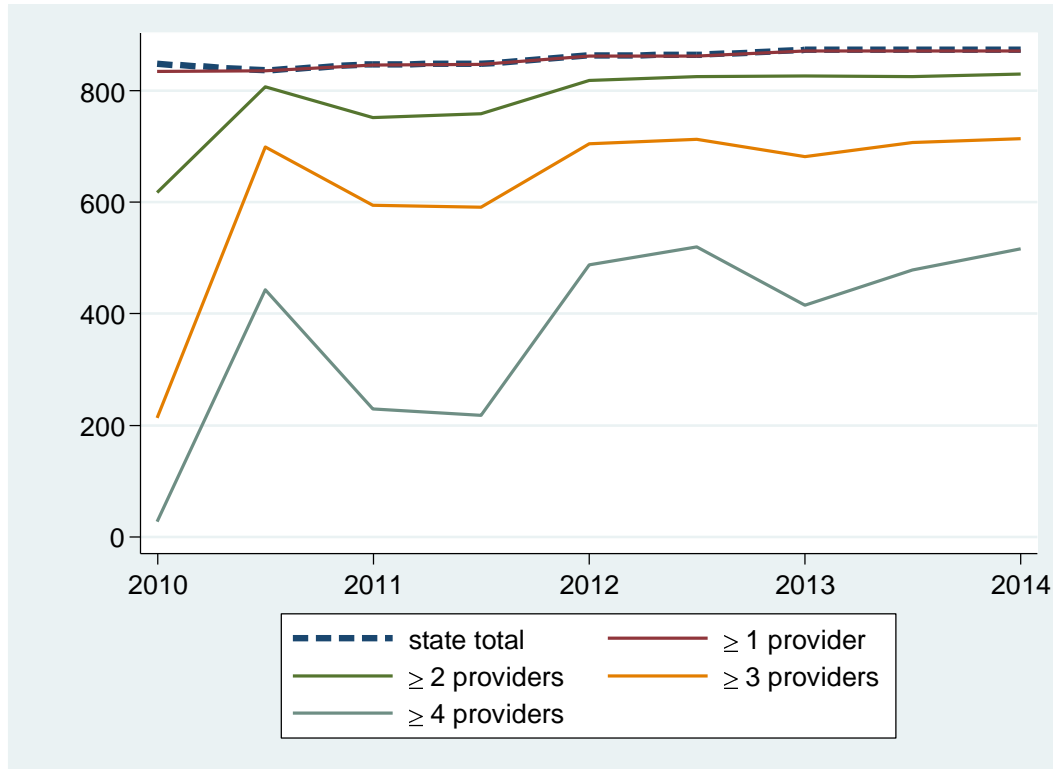


Notes: The speed threshold is 3 Mbps download and 768 kbps upload. See also notes to Figure 16.

Businesses covered by the fixed broadband providers offering service meeting the speed threshold of 10 Mbps download and 1.5 Mbps upload are shown in Figure 18. In June 2014, 99.8% of Californian business establishments were in areas with access to a fixed broadband provider of 10 Mbps/1.5 Mbps service, and 95.0% had access to at least two such providers. A further 81.8% of businesses were in areas with three or more fixed broadband providers offering service at that speed, and 59.1% were in areas with four or more. Comparison of Figure 18 with Figure 17 shows that, as with the broadband coverage for individuals examined above, most fixed broadband lines meeting the 3 Mbps/768 kbps threshold also met the higher speed threshold. In particular, 96.0% of businesses in areas with two or more fixed providers offering 3 Mbps/768 kbps speeds also had access to two or more 10 Mbps/1.5 Mbps providers. The

comparable percentages for at least three providers and at least four providers are 91.8% and 83.3%, respectively.

Figure 18: Business establishments in ZIP codes with fixed broadband providers (10 Mbps down/1.5 Mbps up), 2010 to 2014



Notes: The speed threshold is 10 Mbps download and 1.5 Mbps upload. See also notes to Figure 16.

B. Mobile broadband deployment

1. Mobile broadband and economic development

As with general broadband technology and its impact on development (reviewed in section I.A above), the mobile telecommunications and broadband industry contributes to economic performance through direct and indirect channels. Mobile technology boosts growth directly through deployment of infrastructure and other direct economic activity in the industry. Even more importantly, mobile technology also induces growth indirectly through the positive externalities provided by mobile telecommunications as a general purpose technology. Gruber and Koutroumpis (2011) find a sizable positive impact of mobile infrastructure on GDP across twenty years in 192 countries. The authors calculate that mobile telecommunications

contributed 0.4 percentage points to GDP growth in high-income OECD countries, and about half that in low-income countries. These authors also find that mobile broadband infrastructure increases output per worker-hour, contributing 0.3 percentage points to annual productivity growth in countries with the highest mobile usage penetration and, again, about half that in the low-penetration countries. Another notable finding from their study is that there are increasing returns in the impact of mobile infrastructure deployment. Thus, investment in mobile broadband infrastructure in rural areas may yield more than proportional increases in income and employment growth (although it remains to be measured whether these cross-country findings will also apply directly to rural areas in the United States).

2. Availability

Before 2008, mobile broadband providers were included in the counts of providers in the ZIP codes produced by the FCC. However, from 1999 to 2008, mobile providers were not differentiated from other providers of broadband meeting the speed threshold of 200 kbps in at least one direction. After 2008 the FCC broke out the counts of broadband providers of terrestrial mobile wireless service. The provider counts in this section include only mobile broadband, and exclude other wireless services such as terrestrial fixed wireless and satellite broadband.

a. Availability to people

In addition to the fixed broadband providers in the Census tracts discussed in section A.2.a above, most people in California lived in tracts with multiple mobile broadband providers. Linking people to mobile service availability is necessarily imprecise because many people spend much time outside of the tract in which they live, and may value and use mobile broadband services in many places throughout the day. Nevertheless, mobile coverage is highly spatially correlated; if a provider offers service in one tract, it is highly likely that the provider's spectrum license and infrastructure also covers neighboring tracts and service is also available there.⁷⁵ Therefore, availability at a person's residence will be positively correlated—perhaps highly so—with availability in the other locations to which the person may travel during a typical day. The result is that although the population counts here are more approximate than in the previous sections, they still convey useful information.

Figure 19 shows that nearly everyone lives in tracts where at least one wireless provider offers mobile broadband service. In addition, by the end of 2013, 29.7 million people live in areas with four or more mobile broadband providers, and 5.2 million Californians live in areas with five or more providers.

Incidentally, the regulatory structure of the mobile broadband market allows a test of the accuracy of the provider counts in this section. Any provider of mobile broadband service

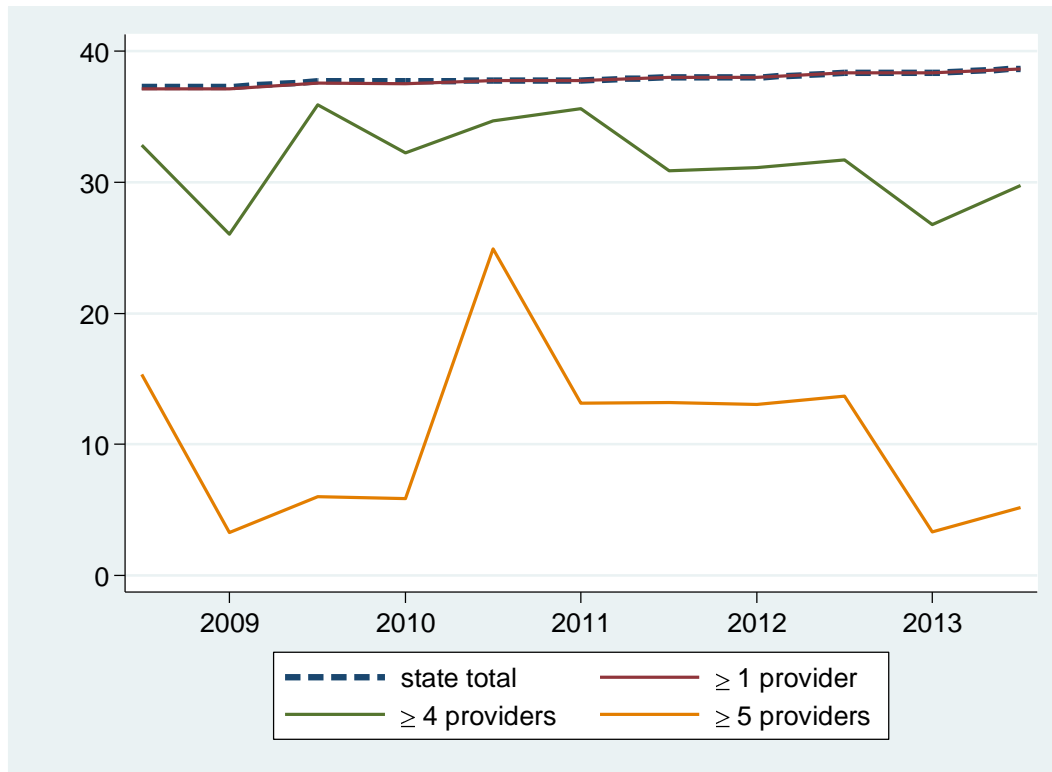
⁷⁵ The areas covered by any one spectrum license vary greatly across the types of licenses. Some licenses cover a city, while others cover larger areas (such as the single PCS Broadband licenses covering Los Angeles and San Diego). Other licenses, such as Verizon's 700 MHz Upper Band block C license, blanket the entire state (and more).

requires a spectrum license from the FCC that covers the geographic area in question. It is therefore possible (unlike with other forms of broadband) to know the maximum number of providers that could possibly be offering service in any one area. In California, there are no more than five distinct holding companies in any one area with spectrum licenses that can be used for commercial mobile broadband service.⁷⁶ For example, in Los Angeles as of 2015 the companies are AT&T, MetroPCS, Sprint,⁷⁷ T-Mobile, and Verizon. These companies may lease a license to another provider, but there still would be no more than five total providers as the upper bound in Figure 19. If the method of data summary and aggregation used here were inaccurate, one symptom would be finding that in some areas people had apparent access to six or more mobile broadband providers. This could happen if the FCC tract coverage data were inaccurate, if coverage within tracts were incomplete so that two providers within a tract actually had non-overlapping footprints, or if mistakes were made in the aggregation procedure. To check this, the number of people in the state living in tracts with apparent access to six or more providers was calculated. At the end of 2013, only 26,033 people were counted in this situation. Compared to the total population, the error rate for the overstating of availability of mobile broadband is thus only 0.067%, a trivial amount.

⁷⁶ Licensing data were examined from an FCC report (FCC, 2015a). The licenses include radio services of many kinds (as designated in the licenses), including cellular, AWS, 700 MHz, etc. Each of these holding companies can hold multiple types of licenses and multiple blocks of spectrum within the same license type within any given area.

⁷⁷ Including the BRS licenses held by Clearwire, which Sprint acquired in 2013.

Figure 19: Population in Census tracts with mobile broadband providers, 2008 to 2013

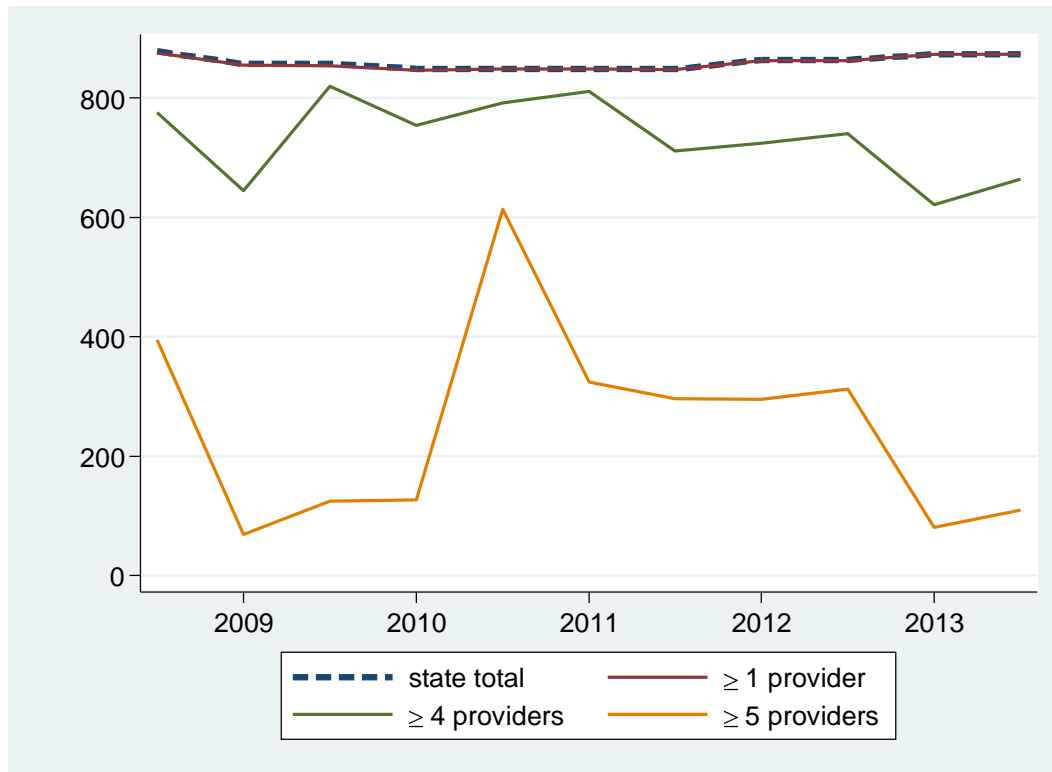


Note: “State total” is the total population for California, and where the line is obscured it is underneath the line for “≥ 1 provider”. The provider count includes only terrestrial mobile wireless broadband providers. The lower speed threshold is 200 kbps in at least one direction. Providers do not necessarily cover all territory within the tract. Broadband data are from the FCC as described in the text.

b. Availability to businesses

Mobile broadband is important to many businesses due to the rise of mobile commerce (m-commerce; Buellingen and Woerter, 2004). For retailers, what matters most for m-commerce is the availability of mobile Internet access for their customers, and therefore the statistics in the previous section apply in this context. However, for wholesalers or other B2B e-commerce and m-commerce firms, the relevant statistic is mobile broadband availability at and around the location of other business establishments (their customers). Availability of mobile broadband is also imperative for many businesses with personnel at remote job sites or on the road making sales or service calls. In Figure 20, the number of business establishments with various mobile broadband options are shown. As with people, linking the establishment to mobile broadband availability at the business’ address captures only part of the service footprint that may be important to the business. Comparing Figure 20 with Figure 19, it is apparent that the fraction of businesses with access to the various numbers of mobile broadband providers is roughly similar to those for people.

Figure 20: Business establishments in Census tracts with mobile broadband providers, 2008 to 2013



Note: “State total” is the total number of business establishments in California, and where the line is obscured it is underneath the line for “≥ 1 provider”. See also notes to Figure 19.

C. Broadband competition

The trends in the number of competing providers of broadband in a given area shown in section A above reveal that there was steady growth in competition up to 2008, followed by a more mature phase of the market with a more or less stable number of competitors. Those figures, however, do not show the types of broadband choices facing subscribers. To a large extent, the major choice facing many residential consumers is which mode to adopt (e.g., DSL or fiber vs. cable modem) rather than choosing among competing providers offering the same type of service. Intermodal competition refers to providers offering broadband services of different types than their competitors. The types included in the analysis of intermodal competition here are xDSL (ADSL and SDSL are grouped), cable modem, terrestrial fixed wireless, fiber, and other copper. The latter category includes all broadband technologies based on copper wire other than DSL (examples include Ethernet over copper and T-1 dedicated high-speed lines).

Intermodal competition has been shown to be more important than intramodal competition in the US broadband industry. Prieger, Molnar, and Savage (2014) show that in California, broadband providers engaging in quality competition are more responsive to the actions of their intermodal rivals than to their intramodal competition. In particular, they find that during 2011

to 2013, incumbent telephone companies (ILECs) improved the quality of their ADSL offerings when a cable broadband provider either entered the market or began to offer DOCSIS 3.0 speeds (50 Mbps and above). ILEC ADSL providers also boosted their speed when CLECs deployed fiber in the market. However, ILEC ADSL providers did not raise their service quality in response to intramodal (i.e., ADSL) competition from CLECs.

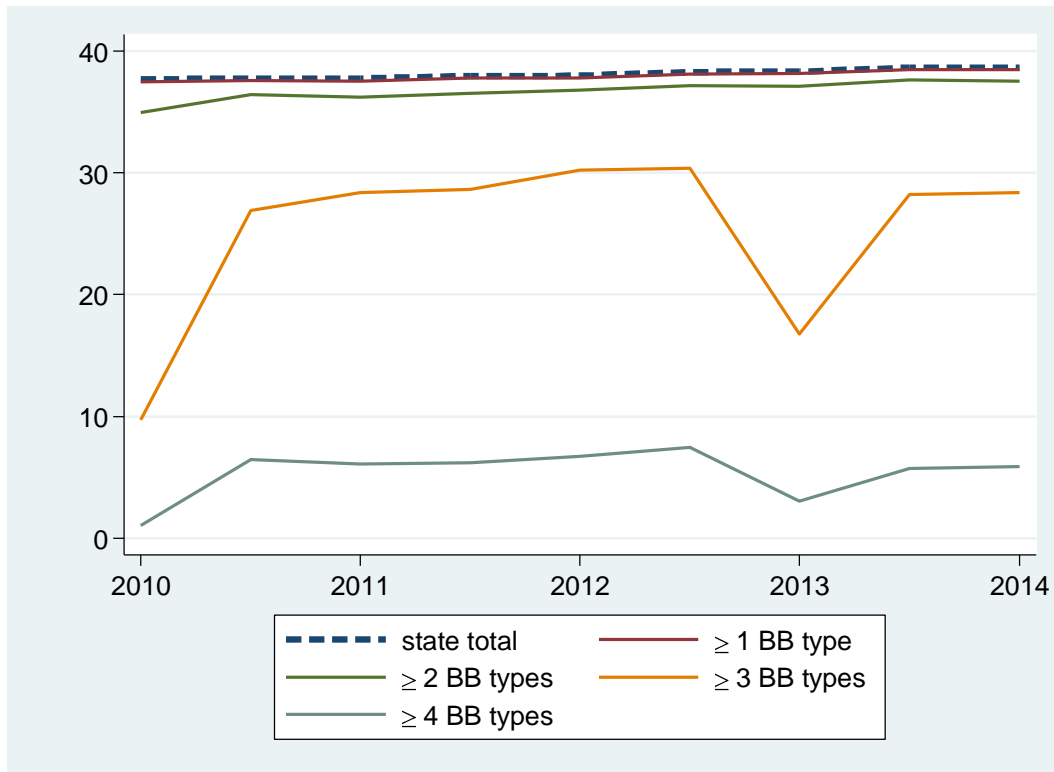
1. Intermodal availability to people

Data from the National Broadband Map can be used to assess the state of intermodal competition among fixed broadband providers in California. The procedure is as follows. First, the number of distinct broadband types offered within each Census block is calculated. Then the maximum is taken over all blocks in a block group, which is then linked to demographic data as above. The resulting level of competition is summarized with the total population in areas with access to various numbers of distinct broadband types. Since mobile broadband is available in nearly all areas where people live (refer to section B.1), including mobile broadband as another type in the figures presented here would essentially increase the number of types by one for each trend line; the same applies to satellite broadband.

Figure 21 reveals that nearly all people live in areas with two or more fixed broadband types. When there are only two types, they are usually DSL and cable modem, but there are also many areas where one of the two is “other copper” or fiber (recall that mobile broadband is not included here).⁷⁸ In a substantial number of areas, however, more than two fixed modes are available. In June 2014, 28.4 million people lived in areas with three or more types of fixed broadband. Of those, 5.9 million people lived in areas with four or more modes of fixed broadband available. Based on these statistics, the most common outcome is therefore to have three types of fixed broadband providers available (excluding satellite service). Since mobile broadband and satellite broadband coverage is nearly ubiquitous in California, the most common number of options across all types is five.

⁷⁸ There are relatively few fixed wireless lines in California. As of 2013 year end, about one-tenth of one percent of broadband lines in California were provided by fixed wireless (FCC, 2014a).

Figure 21: Population in Census block groups with different types of fixed broadband providers, 2010 to 2014

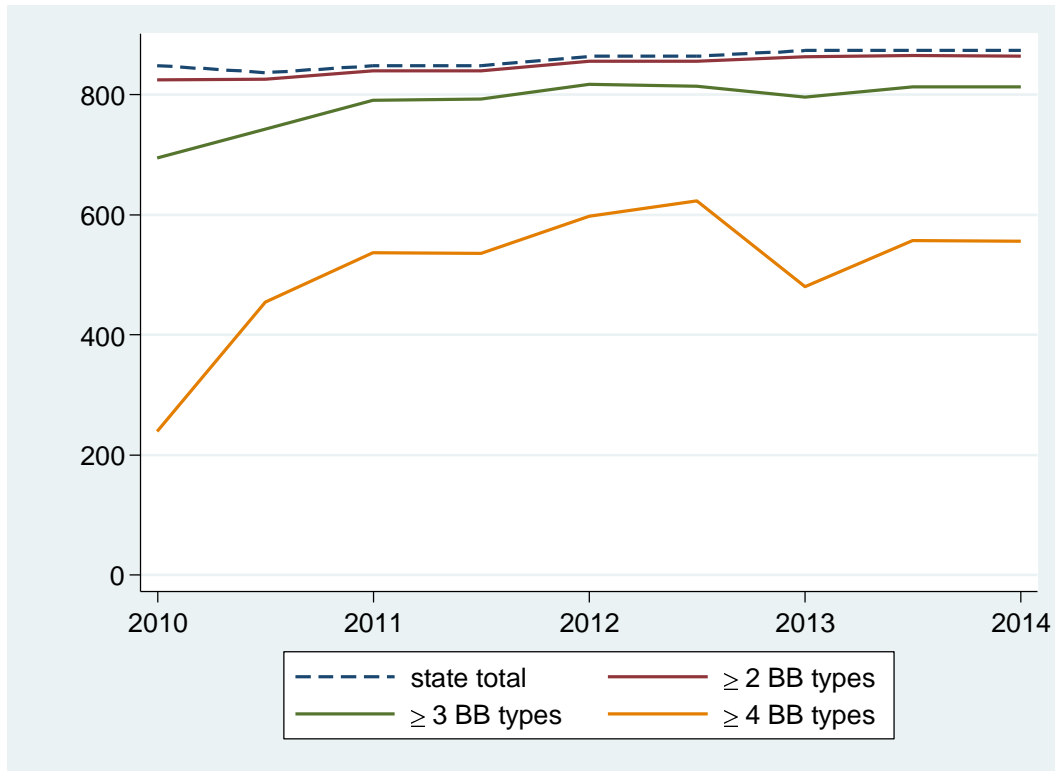


Note: “State total” is the total population for California. The count of broadband types is the maximum number of types of broadband occurring in any one block in the block group. The five types are xDSL, cable modem, fiber, other copper wireline, and terrestrial fixed wireless. The speed threshold is 200 kbps in both directions.

2. Intermodal availability to businesses

Intermodal competition is probably even more important to businesses than it is to residential subscribers. Services such as Ethernet over copper and T-1 services in the category of “other copper” are primarily aimed at the business market. As Figure 22 depicts, nearly all (864,400) business establishments could choose between two or more types of fixed broadband as of midyear 2014. Three or more fixed modes were available to most (812,800) establishments, while over half (555,800) of business locations could choose from among four or five types. The most common number of fixed broadband choices for business locations is four provider types. Adding satellite and mobile wireless options increase the number of broadband modal choices for a typical California business to six.

Figure 22: Business establishments in Census block groups with different types of fixed broadband providers, 2010 to 2014



Note: “State total” is the total number of business establishments in California. See also notes to Figure 21.

D. Growth in broadband availability for areas and groups of interest

Policymakers have long been concerned that broadband may not be evenly accessible to all people and businesses. Thus attention has been paid over the years to making the Internet and broadband available to groups that are economically disadvantaged or for which broadband could potentially reduce inequalities in areas such as access to markets, education, medical care, and jobs. In this section, the potential and demonstrated impacts of broadband on various demographic, geographic, and business groups are discussed, along with a presentation of trends in their access to broadband in the state.

1. Rural coverage and benefits of broadband

The availability of quality broadband service in rural areas is important for several reasons. Most obviously, the benefits of broadband usage for individuals and businesses cannot be recognized without availability. Nationally, broadband availability and differences in infrastructure as recently as 2011 still played a major role in creating an adoption gap between urban and other areas. Whitacre, Stover, and Gallardo (2015) found that differences in broadband infrastructure

were responsible for 38% of the 2011 adoption gap between metro and non-metro areas across the country.⁷⁹ In this section, some of the benefits of broadband for rural areas are reviewed, and the past and current state of availability in rural California is presented.

a. Broadband and Rural Development

There is a substantial body of research on the economic and social benefits that broadband service provides for rural areas (Dickes, Lamie, and Whitacre, 2010).⁸⁰ The benefits of broadband for economic growth in general (discussed in the introduction) also apply to rural areas. Furthermore, some recent work specifically examines the impact of broadband on rural economic development growth. Whitacre, Gallardo, and Stover (2014) show that rural counties with relatively high adoption of broadband enjoyed faster growth in household income and had higher employment and more businesses.⁸¹ Stenberg *et al.* (2009) also found that, compared to a matched set of counties with low broadband availability, rural counties with higher availability experienced more job growth (particularly in the nonfarm sector), more population growth, and (in some years studied) higher personal income and nonfarm earnings growth.

The availability of broadband in rural areas can also strengthen communities through increased community involvement, greater opportunities in the labor market through telework, and increased options to invest in human capital through distance learning and telemedicine (Prieger 2013; Stenberg *et al.*, 2009). The Internet in general and broadband use in particular foster community interaction by making it easier to participate in civic and community affairs (Stern and Adams, 2010; Stern, Adams, and Boase, 2011). For example, it is simpler for a rural resident to inform himself about local land-use planning issues by accessing information online than it would be to go to a municipal records center in town. The possibilities for and promise of rural telework, which require quality broadband connections, are discussed by Stenberg *et al.* (2009). Telework may account for some of the employment growth documented in high-adoption rural areas by Whitacre, Gallardo, and Stover (2014), although the nature of the additional jobs created remains to be studied. Telemedicine is another example a beneficial service enabled by broadband in rural areas. Whitacre *et al.* (2009) found that five rural communities in Oklahoma that participated in telemedicine saved a total of \$3.5M in healthcare cost for teleradiology and telepsychiatry. Whitacre (2011) estimated the impact of telemedicine services on rural areas, finding that it contributed between \$20,000 and \$1.3M annually to the local economies, with an average of \$522,000.

Broadband can also be of considerable importance for rural businesses. Consider rural e-commerce as one growth driver enabled by broadband. Barkley, Markley, and Lamie (2007)

⁷⁹ These authors measure the metro–non-metro gap in residential broadband adoption to be 12 to 13 percentage points in 2011.

⁸⁰ This section draws heavily upon section 3.3 of Prieger (2013), and quotations from that work are not explicitly noted here.

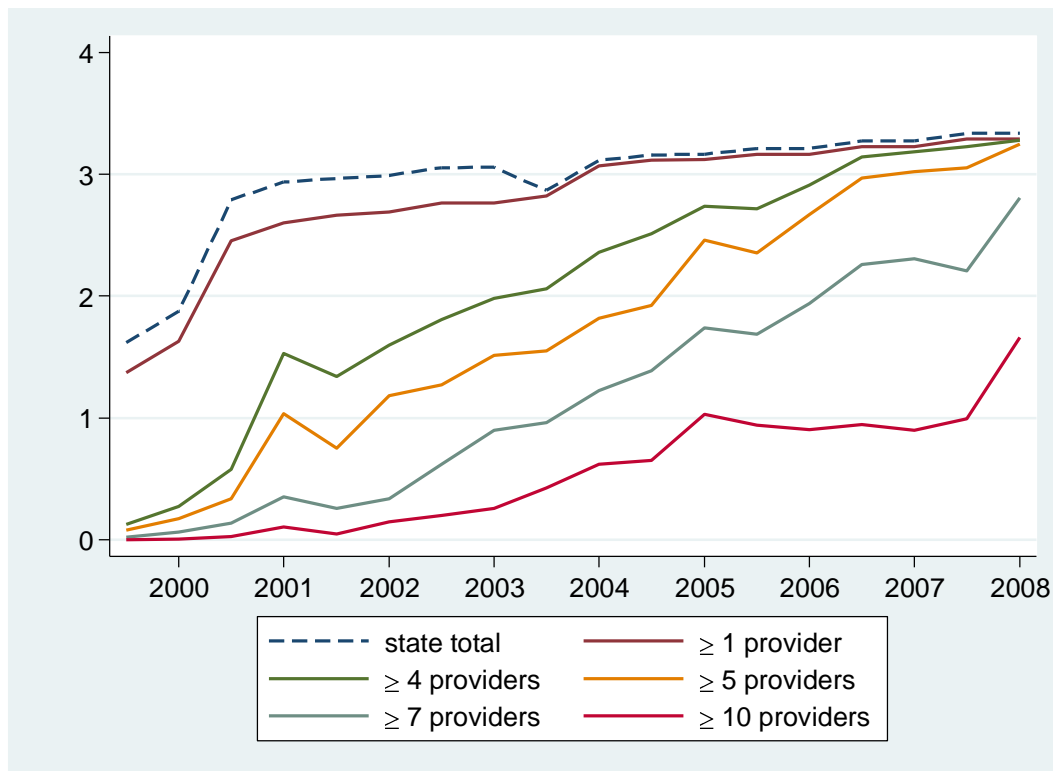
⁸¹ The authors caution that causality cannot be definitively ascertained because of unobserved differences between areas. However, their propensity score matching method, in principle, removes bias due to observed potentially confounding variables.

performed over two dozen case studies on rural businesses that adopted e-commerce. E-business was successfully adopted by most of the firms in the studies, although some were not prepared for the rapid sales growth that occurred.

b. Rural Availability

The economics of deploying terrestrial broadband in rural areas has always been challenging compared to urban areas (Strover, 2003). For a given amount of money spent on deploying infrastructure, more densely populated areas allow broadband providers to realize greater returns on their investments. It is therefore no surprise that, particularly in the earlier years of broadband in America, rural areas on the whole had less access to terrestrial fixed broadband service (Prieger, 2003; Grubestic and Murray, 2004). However, a series of recent studies showed that although rural areas continue to lag non-rural areas in the availability of access to broadband, mobile broadband partially fills in geographical gaps in fixed-line broadband coverage (Prieger and Church, 2012; Prieger, 2013; Church and Prieger, forthcoming). This report therefore examines both fixed and mobile broadband availability in rural California.

Figure 23: Rural population in ZIP codes with broadband providers, 1999 to 2008

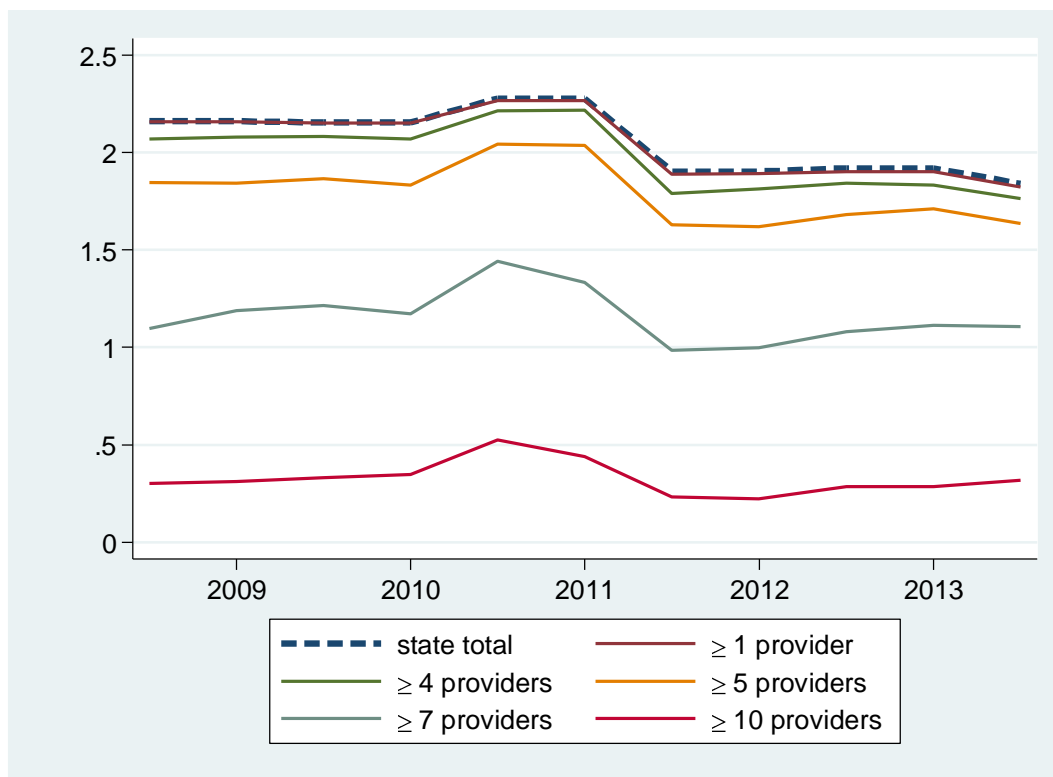


Note: "State total" is the total subpopulation for California of people living in rural areas, as determined by the U.S. Census Bureau. Broadband data are from the FCC as described in the text. See also notes to Figure 7.

The improvement in rural broadband coverage in the state is notable in the period 1999 to 2008. Figure 23 shows that in the early 2000s few rural ZIP codes had four or more broadband providers of any type (including satellite and mobile service).⁸² By 2008, however, most of the rural population lived in ZIP codes with five or more providers.

Figure 24 using the FCC data shows that fixed broadband availability remained nearly ubiquitous in more recent years in tracts in which the rural population lived. Recall that this is not to say that every rural resident in California has access to wired broadband service, given that a provider may not cover every address in the tract.

Figure 24: Rural population in Census tracts with fixed broadband providers, 2008 to 2013



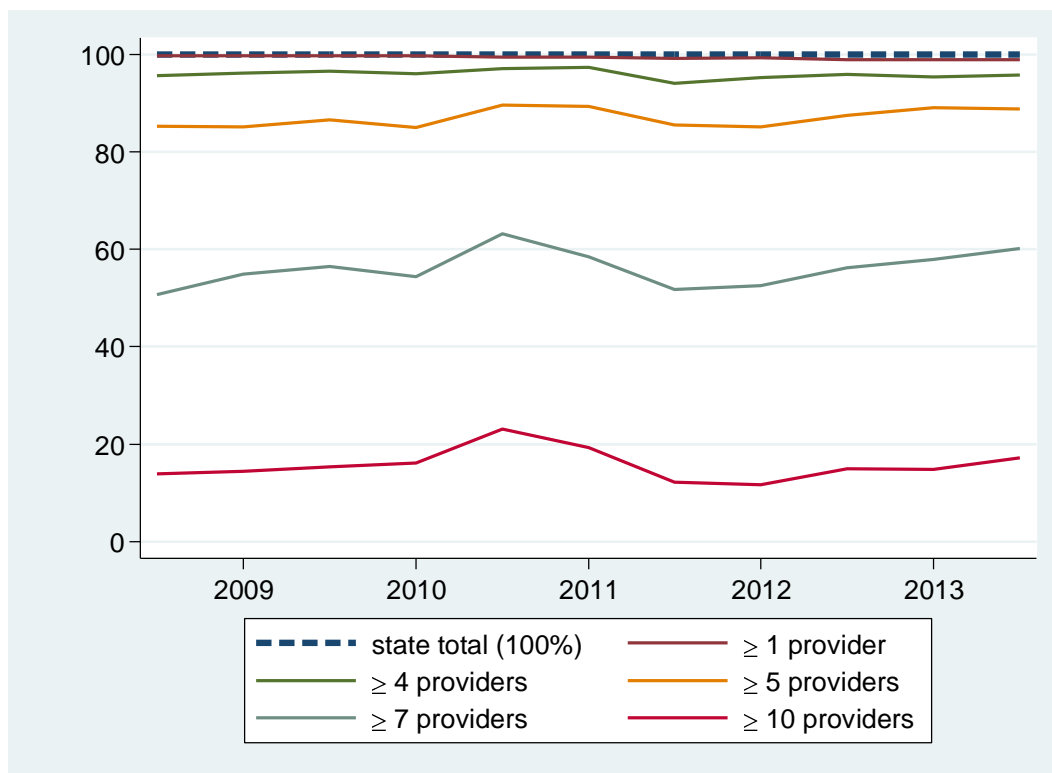
Notes: “State total” is the total subpopulation for California of people living in rural areas, as determined by the U.S. Census Bureau. See also notes to Figure 9.

Before moving on, it is important to explain a puzzling feature of the trend in rural population. Figure 24 shows that number of rural Californians apparently jumped up in December 2010 and then dropped steeply in December 2011. These abrupt movements reflect only unfortunately aspects of the data construction, not actual large changes in the demographics of the state. The

⁸² Note, however, that the number of available providers here is biased downward because several satellite Internet providers offered nearly ubiquitous coverage in the state, but only are counted in the FCC statistics for a ZIP code if they have actual customers there.

apparent increase at the end of 2010 is due to the updating of the demographic variables from GeoLytics to reflect new information from the 2010 Decennial Census data. The apparent decline at the end of 2011 appears to be due to a change in the tract numbering in the FCC data.⁸³ Three practical implications follow. First, trends in 2010 and 2011 are less reliable than for other years, and—importantly—this will be true for the other subpopulations studied below. Second, there are potentially misleading movements in the number of rural residents with access to various numbers of providers, in particular the declines in December 2011. Those declines are only because the total estimated number of rural residents fell then. Third, as a consequence of the second implication, it will be useful to consider trends in percentage terms instead of just the person counts. While the trends in percentage terms are not immune to the problems with the data construction for 2010 and 2011, the effect is muted. Thus, in Figure 25 the trends in fixed broadband provision are recalculated in percentage terms. Figure 25 more clearly shows that at the end of 2013, a slightly greater proportion of the rural population in California has access to at least five, seven, and 10 fixed broadband providers.

Figure 25: Percentage of rural population in Census tracts with fixed broadband providers, 2008 to 2013

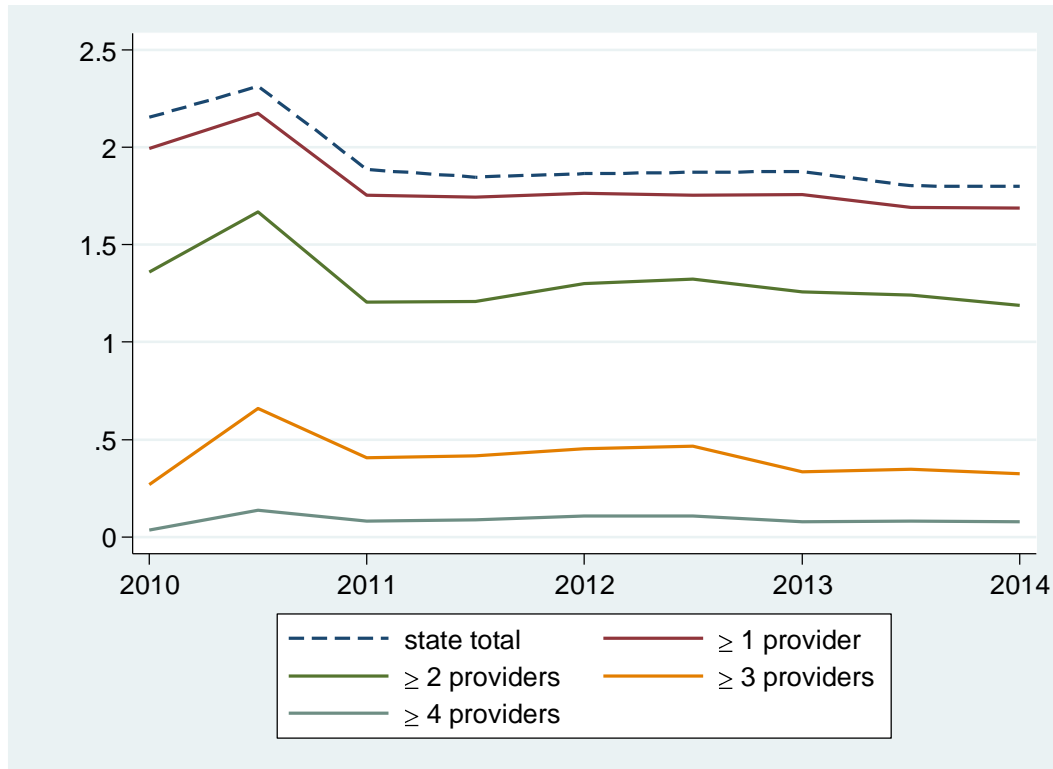


Notes: Graph shows the same data as Figure 24 but expressed as a percentage of the total rural population in California. See also notes to Figure 24.

⁸³ The FCC switched from 2000 Census tracts to 2010 Census tracts at that time. Small differences then resulted in the matching the tracts to the demographic data.

Despite the apparently ubiquitous fixed broadband coverage seen in Figure 25, since a provider may not cover every address in the tract it is not necessarily the case that every rural resident in California has access. Figure 26, for the population count, and Figure 27, for the coverage percentages, demonstrate this using the National Broadband Map data and Census block groups; coverage in blocks groups (which are smaller than tracts) does not appear as complete. Furthermore, the number of providers offering rural coverage evidenced in these figures is not as high as for the whole state, as can be seen from comparison of the figures here with Figure 7, Figure 9, and Figure 13. In 2014, 1.7M out of 1.8M rural residents lived in block groups which fixed broadband service, and 1.2M lived in areas with two or more. Figure 27 also shows that the trends for rural coverage are essentially flat since 2011.

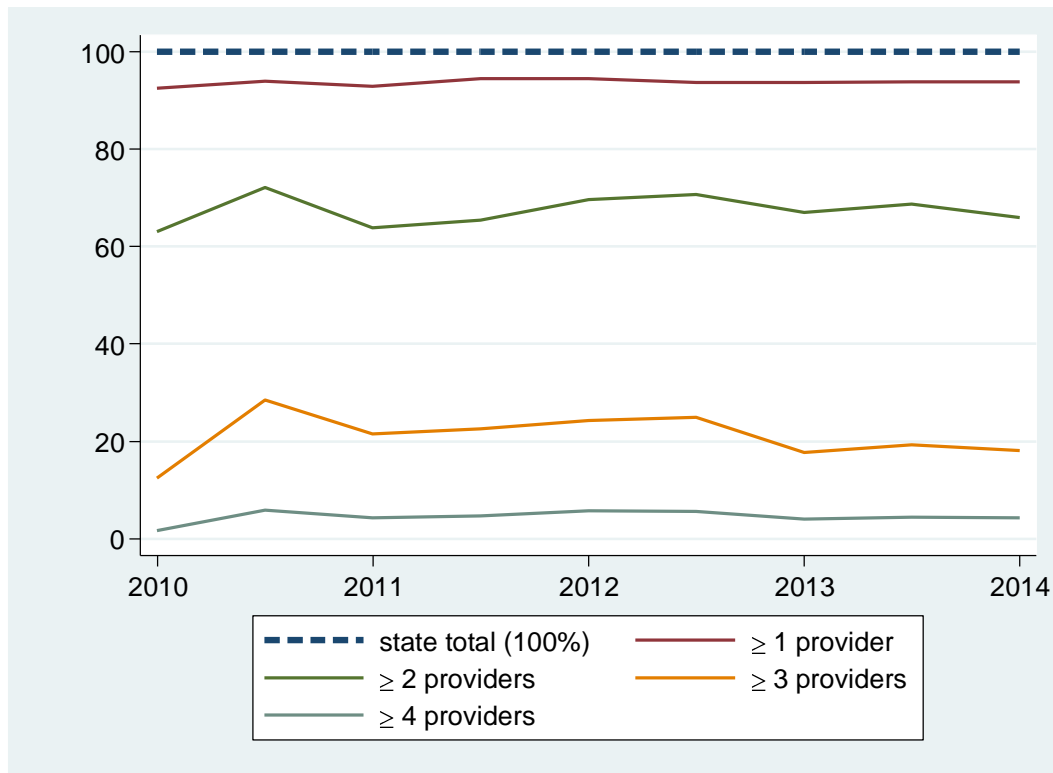
Figure 26: Rural population in Census block groups with fixed broadband providers, 2010 to 2014



Notes: “State total” is the total subpopulation for California of people living in rural areas, as determined by the U.S. Census Bureau, and where the line is obscured it is underneath the line for “≥ 1 provider”. Broadband data are from the National Broadband Map as described in the text. See also notes to Figure 13.

Figure 27 shows that the median person living in rural areas is in a block group with two providers. Given that providers are most likely to offer service where the most people live,⁸⁴ in most cases it is probably reasonable to assume that the median person faces an actual choice between two fixed broadband providers.

Figure 27: Percentage of rural population in Census block groups with fixed broadband providers, 2010 to 2014

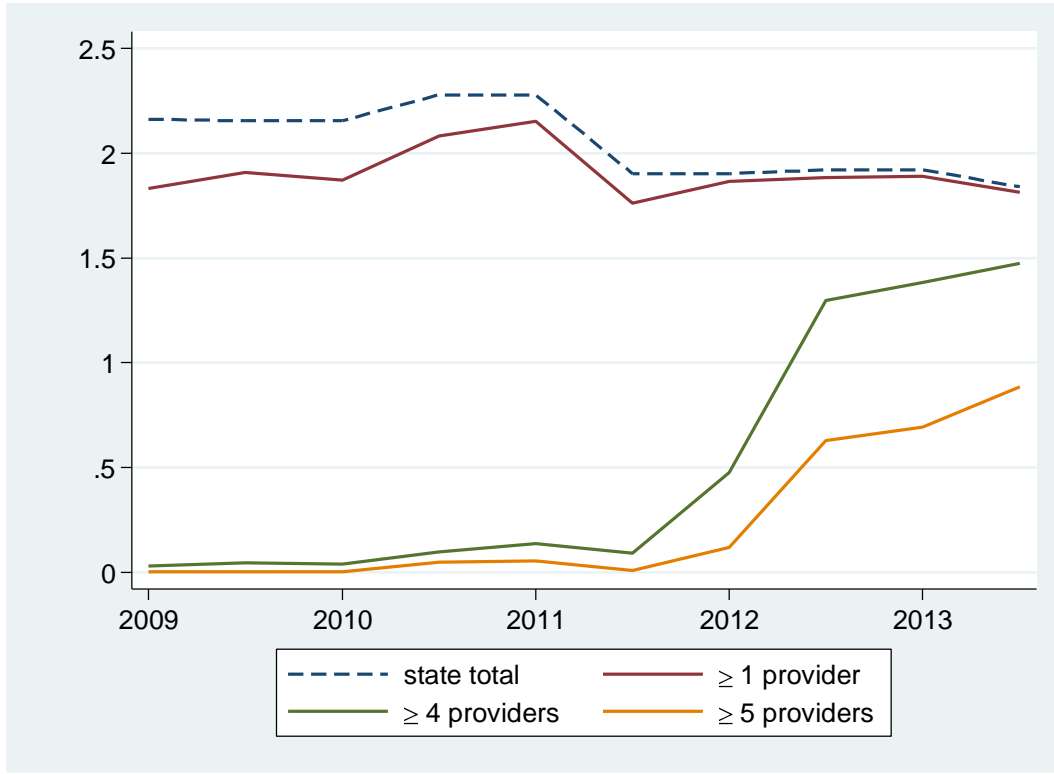


Notes: Graph shows the same data as Figure 26 but expressed as a percentage of the total rural population in California. See also notes to Figure 26.

Even when restricting attention to broadband providers offering service above the 3 Mbps/768 kbps threshold, as in Figure 28 and Figure 29 (FCC data; restricted to residential service) and Figure 30 and Figure 31 (National Broadband Map data; residential or business service), the situation is not much different. This is because in rural areas there are few providers who target business only, given that most businesses in the state are in nonrural areas, and because few providers today are unable to provide service at 3 Mbps even in rural areas.

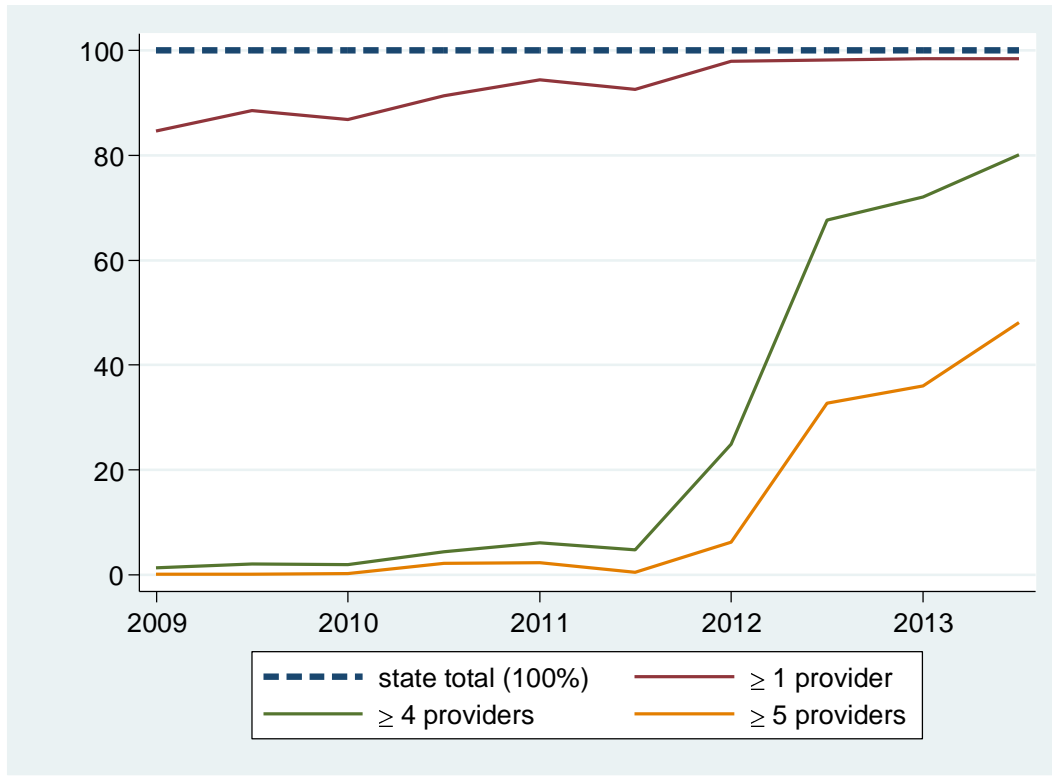
⁸⁴ That is to say, conditional on living in a rural area, it is most likely that any one person lives in the densest part of the tract or block group (by definition). Those most densely populated areas are also where broadband providers are most likely to offer service, given cost considerations, as has been found in numerous studies of broadband deployment (e.g., Prieger, 2003; Grubestic and Murray, 2004).

Figure 28: Rural population in Census tracts with fixed broadband providers of residential service (3 Mbps down/768 kbps up), 2009 to 2013



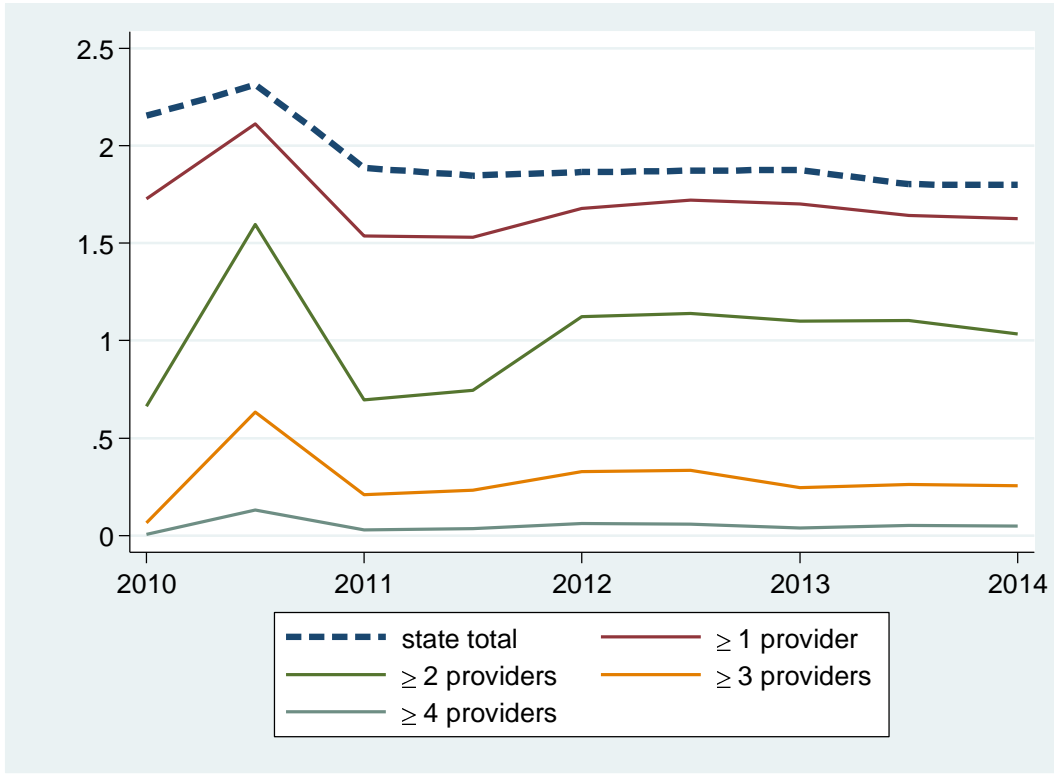
Note: The counts are limited to providers offering service to residences in the tracts. The speed threshold is 3 Mbps download/768 kbps upload. See also notes to Figure 9.

Figure 29: Percentage of rural population in Census tracts with fixed broadband providers of residential service (3 Mbps down/768 kbps up), 2009 to 2013



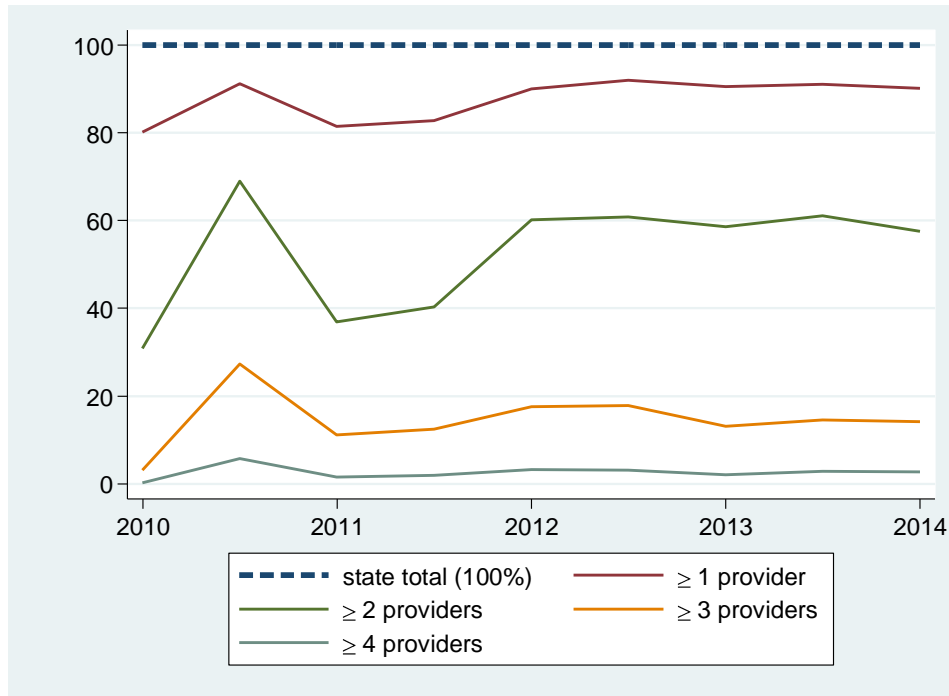
Note: Graph shows the same data as Figure 28 but expressed as a percentage of the total rural population in California. See also notes to Figure 28.

Figure 30: Rural population in Census block groups with fixed broadband providers (3 Mbps down/768 kbps up), 2010 to 2014



Notes: “State total” is the total subpopulation for California of people living in rural areas, as determined by the U.S. Census Bureau. The speed threshold is 3 Mbps download/768 kbps upload. Broadband data are from the National Broadband Map as described in the text. See also notes to Figure 13.

Figure 31: Percentage of rural population in Census block groups with fixed broadband providers (3 Mbps down/768 kbps up), 2010 to 2014

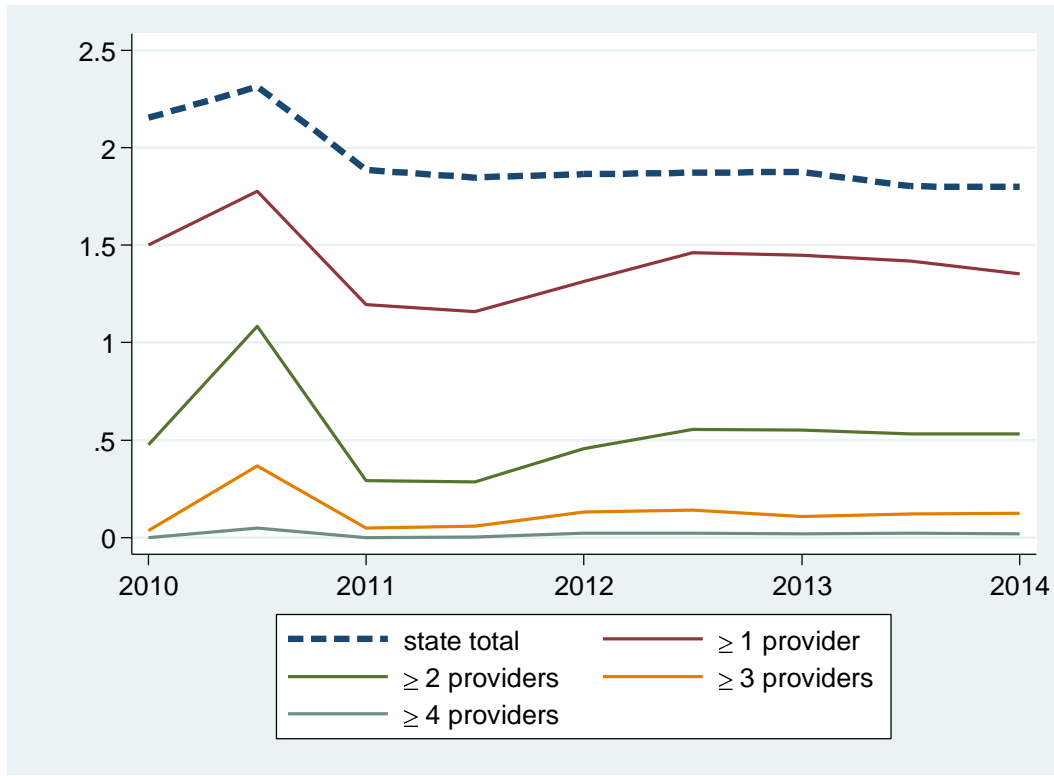


Note: Graph shows the same data as Figure 30 but expressed as a percentage of the total rural population in California. See also notes to Figure 30.

Again, it is important to remember that a provider may not cover every address in the tract or Census block group. In rural areas where tracts and block groups are larger, this may lead to more overstating of availability than for the population as a whole. The comparison of the availability figures calculated here with estimates from the FCC, discussed in section A.3.a, showed that for the whole state overcounting did not seem to be appreciable. However, in 2011 the FCC (2012) calculated in its *Eighth Broadband Progress Report* using block-level data that 35% of people living in rural areas of California lacked access to fixed broadband meeting the 3 Mbps/768 kbps speed benchmark, whereas 90.2% of them appear to have such access that year in Figure 31. If the FCC's calculations are correct, the discrepancy between the two suggests that the procedure followed here leads to some overcounting for rural areas. Thus the direction of the trends displayed in the graphs in this section of the report may be more accurate than the particular levels of availability in the figures.

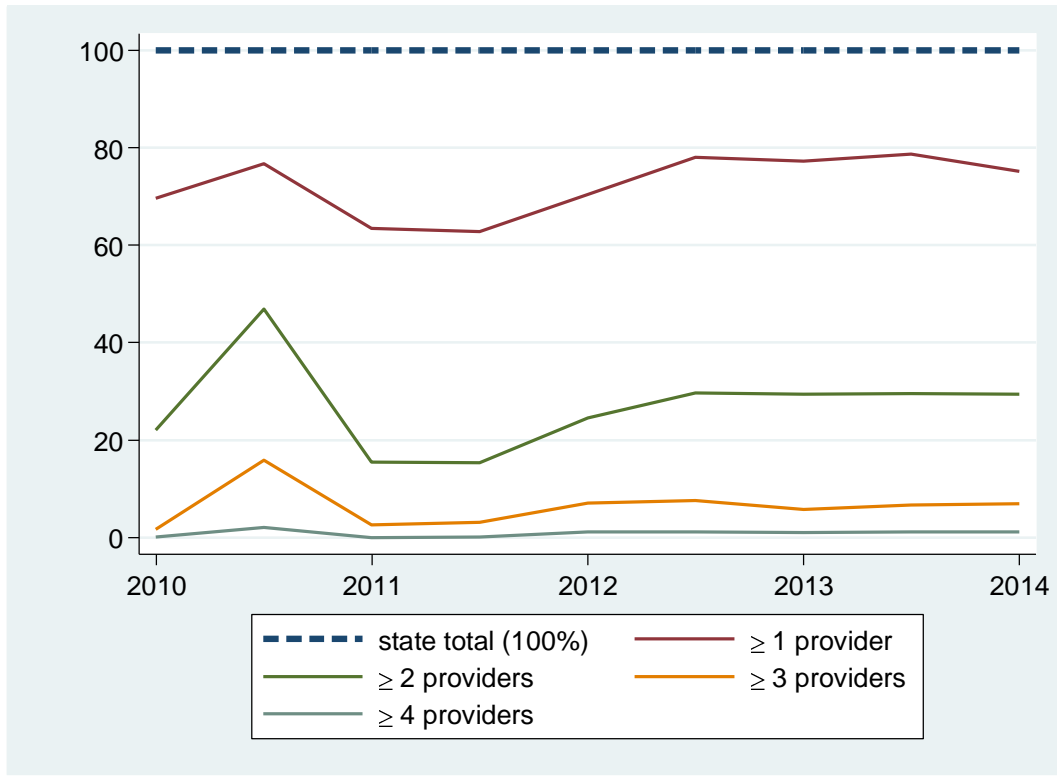
A final pair of graphs in Figure 32 (for levels) and Figure 33 (for percentages) reproduces the preceding two figures using the higher threshold of 10 Mbps download/1.5 Mbps upload. In June 2014, 1.35 million rural residents, or 75.2% of the total rural population, lived in areas with at least one fixed broadband provider offering 10 Mbps/1.5 Mbps service. This fraction of the population covered in rural areas has held fairly steady since the end of 2012.

Figure 32: Rural population in Census block groups with fixed broadband providers (10 Mbps down/1.5 Mbps up), 2010 to 2014



Notes: The speed threshold is 10 Mbps download/1.5 Mbps upload. Broadband data are from the National Broadband Map as described in the text. See also notes to Figure 13.

Figure 33: Percentage of rural population in Census block groups with fixed broadband providers (10 Mbps down/1.5 Mbps up), 2010 to 2014



Note: Graph shows the same data as Figure 32 but expressed as a percentage of the total rural population in California. See also notes to Figure 32.

Mobile broadband may be particularly attractive in rural areas for providers encountering challenging terrain in (for example) mountainous areas, long distances to the users, and relatively lower investment costs (Soldani and Dixit, 2008; Puschita et al., 2014). Figure 34 for the number of people and Figure 35 for the proportions show trends in mobile broadband availability in California. The percentage of people out of the total rural population living in tracts with four or more and five or more mobile broadband providers grew on average through 2012. At the end of 2013, nearly every tract had mobile broadband coverage, 68% of rural residents were in tracts with four or more mobile providers, and 26% were in tracts with five or more.

Figure 34: Rural population in Census tracts with mobile broadband providers, 2008 to 2013



Note: "State total" is the total subpopulation for California of people in rural areas, as determined by the U.S. Census Bureau, and where the line is obscured it is underneath the line for "≥ 1 provider". The lower speed threshold is 200 kbps in at least one direction. See also notes to Figure 19.

Figure 35: Percentage of rural population in Census tracts with mobile broadband providers, 2008 to 2013



Note: Graph shows the same data as Figure 34 but expressed as a percentage of the total rural population in California. See also notes to Figure 34.

2. Minority areas quickly gained access

The progress in availability of broadband to minority communities closely mirrors that of the population at large, as this section shows. This stems from the fact that most urban areas have several broadband providers, and most minorities in California apart from Native Americans live in urban areas. The results here are in accord with previous research. Prieger (2003) found using data from 2000 across the nation that there was no evidence of unequal availability of broadband Internet access based on the black or Hispanic concentration of the local area, once cost conditions, non-racial demand factors, and competition in local telephony were held constant.⁸⁵

For each of the subpopulations examined in this section, data for the period of 1999-2008 includes broadband providers of all types offering service at the 200 kbps threshold, while data for the latter period of 2008-2013 is restricted to residential providers of fixed broadband

⁸⁵ Prieger (2003) shows that broadband in 2000 was indeed less likely to be available for blacks, Hispanics, and Native Americans. However, once other demographic and socioeconomic variables are controlled for in regressions for broadband availability, the evidence for any “redlining” based on black or Hispanic concentration in the community disappeared.

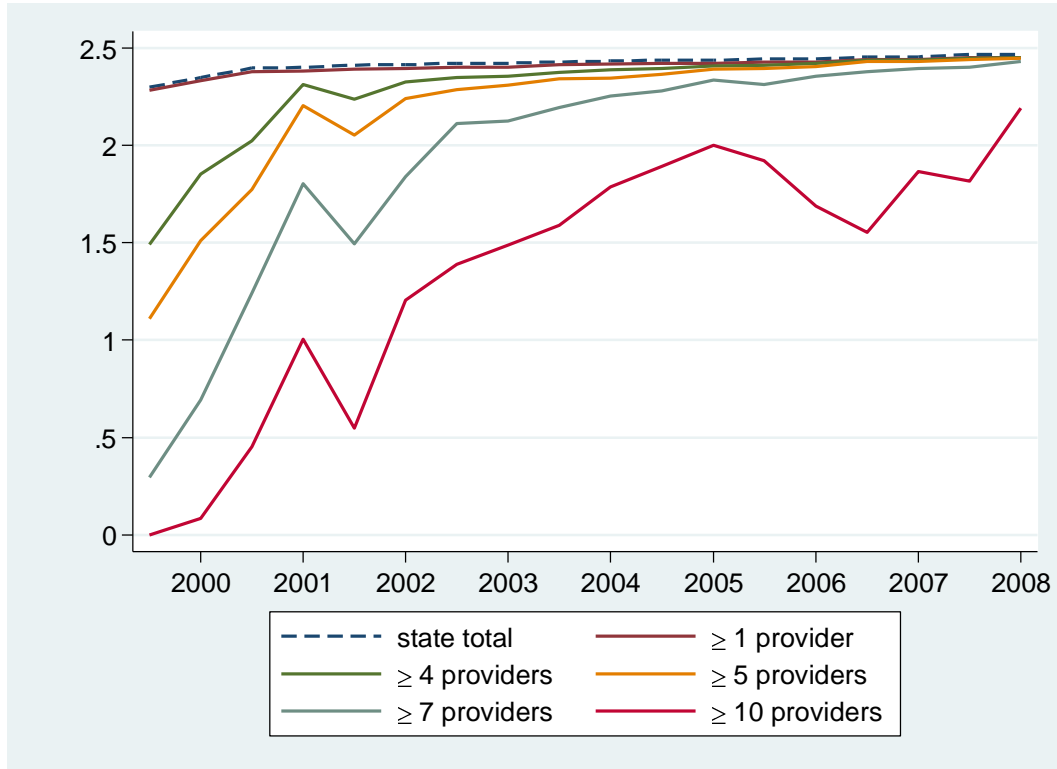
(excluding satellite) meeting the 3 Mbps/768 kbps threshold. Thus, as explained in section 1.b, it is easier to assess the trends in broadband coverage by looking at the data in percentage terms. As with the estimates of rural dwellers, the construction of the data for the minority subpopulations led to noisy estimates for 2010 and 2011 and apparently declines in the numbers of some groups. Also, since figures at the 10 Mbps/1.5Mbps standard cannot be restricted to residential-only service, those figures are not presented here. However, recall from section A.3.a that almost all areas with service available at 3 Mbps/768 kbps also had access to service at 10 Mbps/1.5 Mbps. Therefore, the trends for broadband availability for the subpopulations in this section meeting the 3 Mbps/768 kbps threshold would be similar to those at the higher speeds.

a. African Americans

Figure 36 and Figure 37 depict the African American population in California living in areas with access to various numbers of broadband providers.⁸⁶ Figure 38 repeats Figure 37 in percentage terms. The trends in the improvement of availability and the number of providers for African American closely reflect the experience of the entire population documented in Figure 7 and Figure 11. Where there are small differences, availability is proportionately greater for African Americans than others since they are more likely to live in urban areas.

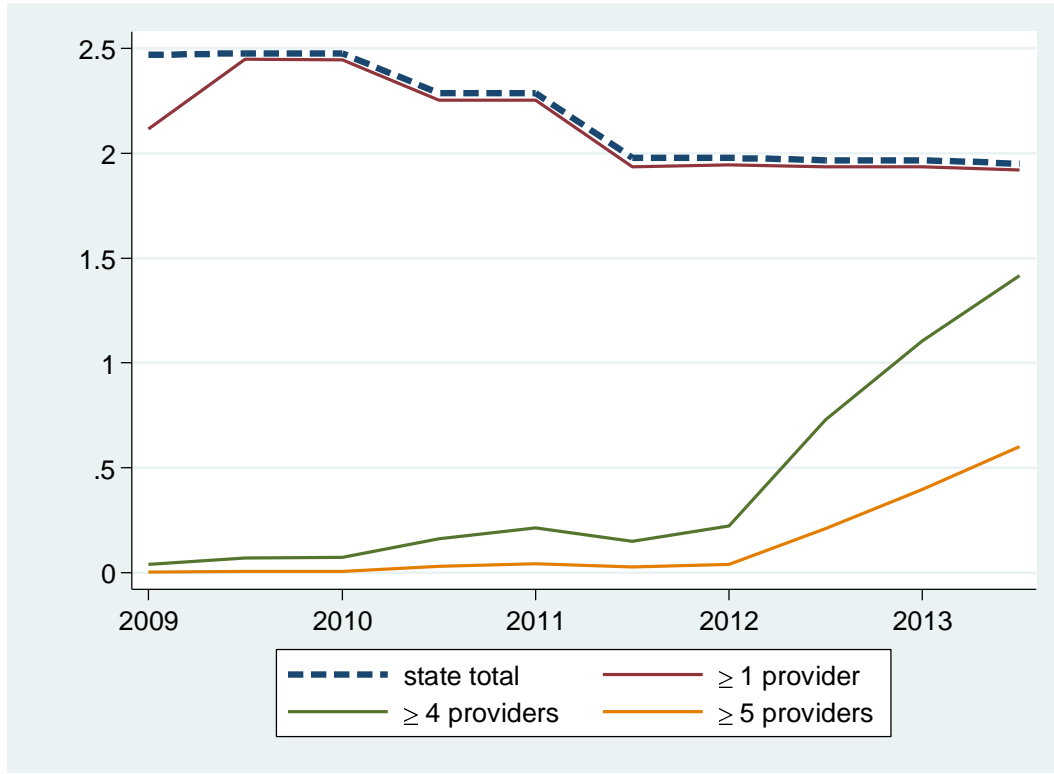
⁸⁶ The decline in the estimates of the number of African Americans in California in 2010 and 2011 seen in Figure 37 merely reflects an updating of the subpopulation estimates from GeoLytics based on new data from the 2010 Census. The questions and categories available for race and ethnicity changed in the 2010 Census, leading fewer people to self-identify as “African American” only (the subpopulation total plotted in the graphs here) and more people to identify as African American in combination with some other race (who are not included).

Figure 36: African American population in ZIP codes with broadband providers, 1999 to 2008



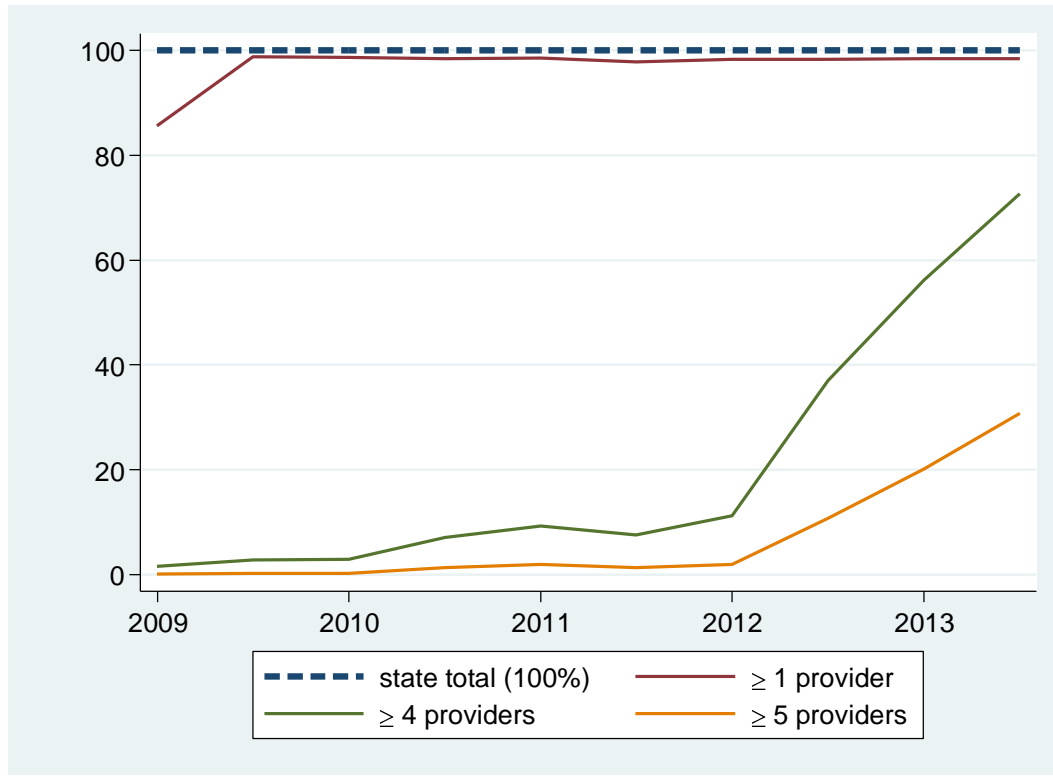
Note: "State total" is the total subpopulation for California of people identifying themselves as African American (black) alone. Broadband data are from the FCC as described in the text. See also notes to Figure 7.

Figure 37: African American population in Census tracts with fixed broadband providers of residential service (3 Mbps down/768 kbps up), 2009 to 2013



Notes: "State total" is the total subpopulation for California of people identifying themselves as African American (black) alone." The counts are limited to providers offering service to residences in the tracts. The speed threshold is 3 Mbps download/768 kbps upload. The provider count includes all fixed broadband providers. Providers do not necessarily cover all territory within the tract. Broadband data are from the FCC as described in the text.

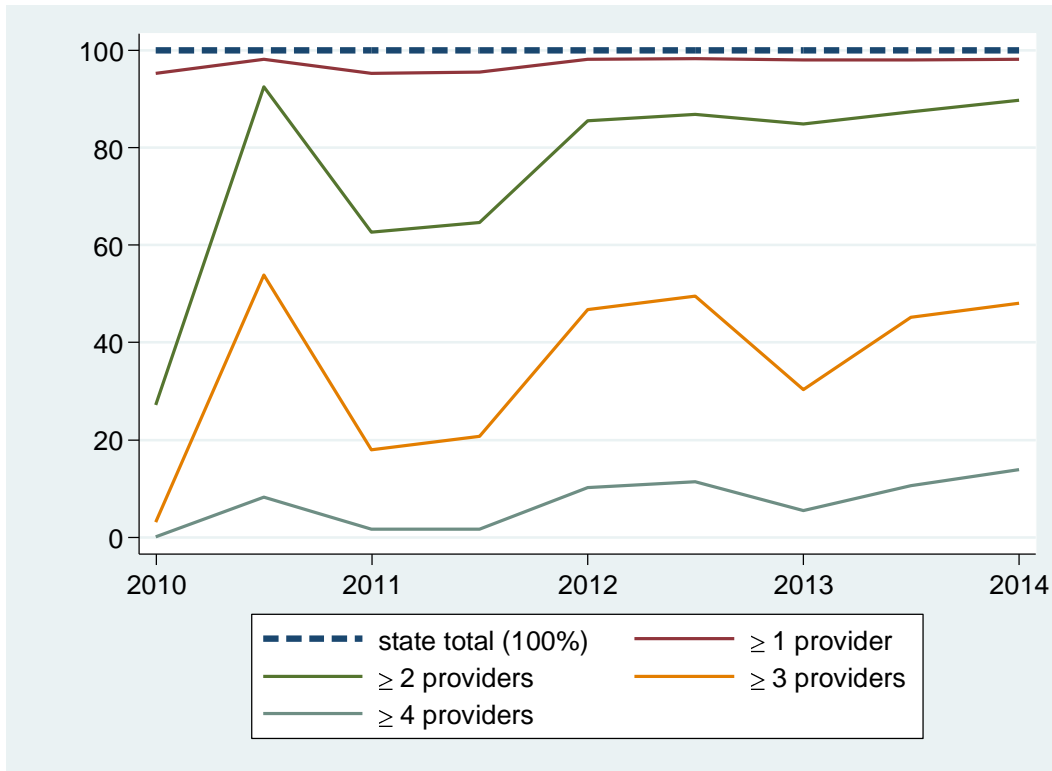
Figure 38: Percentage of African American population in Census tracts with fixed broadband providers of residential service (3 Mbps down/768 kbps up), 2009 to 2013



Note: "State total" is the total subpopulation for California of people identifying themselves as African American (black) alone." Broadband data are from the FCC as described in the text. See also notes to Figure 37...

In 1999, 1.49 million African Americans in California lived in ZIP codes that already had access to four or more providers of any type offering service at the 200 kbps threshold. By 2013 nearly as many (1.42 million) lived in tracts with four or more providers of fixed access alone meeting the 3 Mbps/768 kbps threshold. Figure 39 shows the trends for broadband at the 10 Mbps/1.5 Mbps threshold. Since 2010, more than 95% of African Americans lived in block groups that enjoyed fixed broadband of at least this speed. That figure has hovered around 98.1% since 2012. Additionally, in 2014 about 90% of African Americans were in areas with two or more fixed broadband providers meeting the 10 Mbps/1.5 Mbps threshold.

Figure 39: Percentage of African American population in Census block groups with fixed broadband providers (10 Mbps down/1.5 Mbps up), 2010 to 2014



Notes: The speed threshold is 10 Mbps download/1.5 Mbps upload. Broadband data are from the National Broadband Map as described in the text. See also notes to Figure 13.

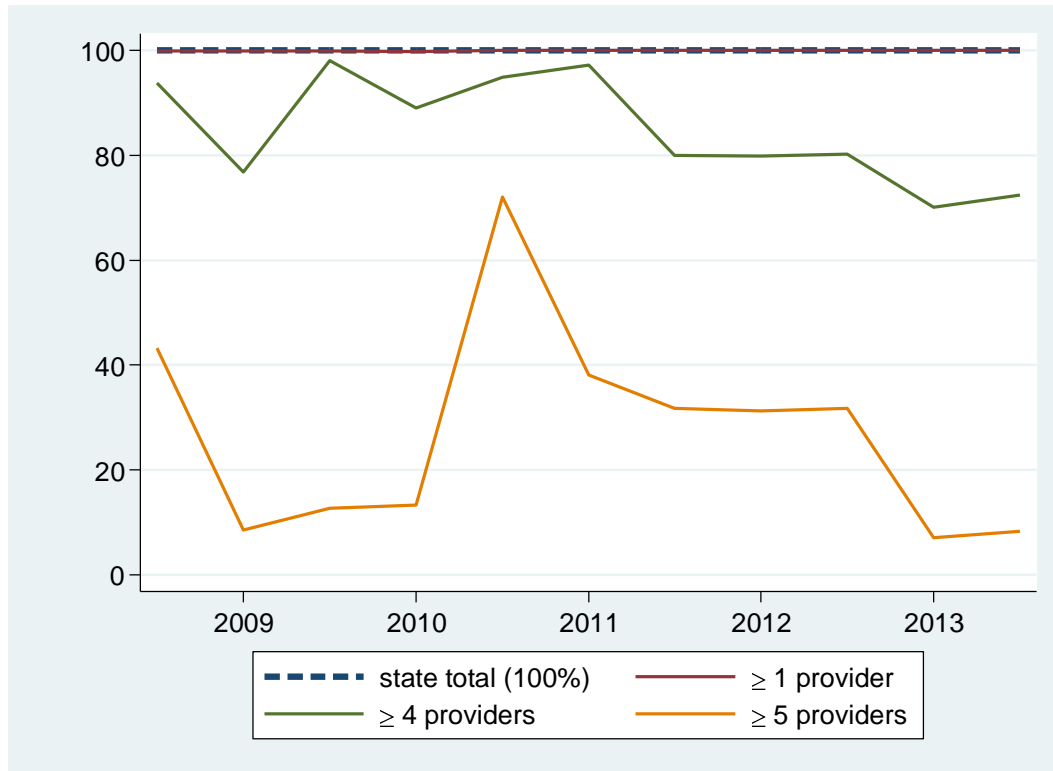
Section I.B.1.b above discussed the importance of mobile phone service to this community. As a consequence, mobile broadband is also highly important to many in the African American community, as will be discussed in the section on their broadband adoption, III.B.2. Figure 40 shows that by 2013, 1.41 million African Americans lived in tracts with four or more providers of mobile broadband. Figure 41 depicts the trends in proportional terms. While virtually all blacks lived in tracts with mobile broadband service, the declines in the percentage with access to larger numbers of providers in the last few years mimics the statewide trends observed in Figure 19 above.

Figure 40: African American population in Census tracts with mobile broadband providers, 2008 to 2013



Note: “State total” is the total subpopulation for California of people identifying themselves as African American (black) alone”, and where the line is obscured it is underneath the line for “≥ 1 provider”. The lower speed threshold is 200 kbps in at least one direction. See also notes to Figure 19.

Figure 41: Percentage of African American population in Census tracts with mobile broadband providers, 2008 to 2013



Note: Graph shows the same data as Figure 40 but expressed as a percentage of the total African American population in California. See also notes to Figure 40.

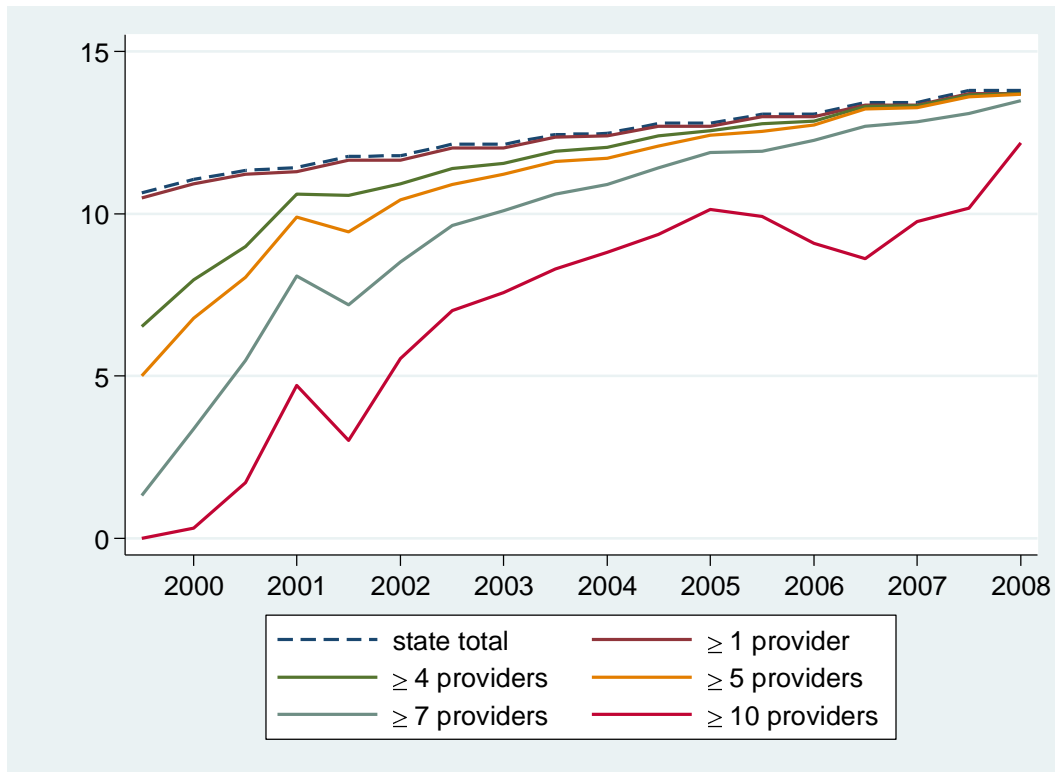
b. Hispanics

Throughout the entire period 1999 to 2013, Figure 42 and Figure 43 show that nearly every Hispanic resident in California lived in an area with broadband access. In 1999, 6.5 million Hispanics lived in ZIP codes that already had access to four or more providers of any type offering service at the 200 kbps threshold. Figure 43 shows trends for how many Hispanics live in areas with fixed broadband access meeting the 3 Mbps/768 kbps threshold. Figure 44 repeats the same information in terms proportional to the Hispanic population, and Figure 45 does the same for fixed broadband at the 10 Mbps/1.5 Mbps threshold. These higher thresholds are important to examine because low quality of broadband speed available has been found in the literature to be an important reason why Hispanics do not subscribe to broadband (Prieger and Hu, 2008).⁸⁷ It is thus good that in California essentially all Hispanics lived in areas with access to service of at least 3 Mbps download. By 2014, 11.1 million Hispanics lived in tracts with four or more providers of fixed broadband access meeting the 3 Mbps/768 kbps threshold (Figure 43).

⁸⁷ Prieger and Hu (2008), in a study of DSL demand in 2000 in the Midwestern US, find that service quality is an important determinant of demand for broadband usage, and that ignoring that factor masks the true size of the DSL gap for Hispanics in evidence at the time.

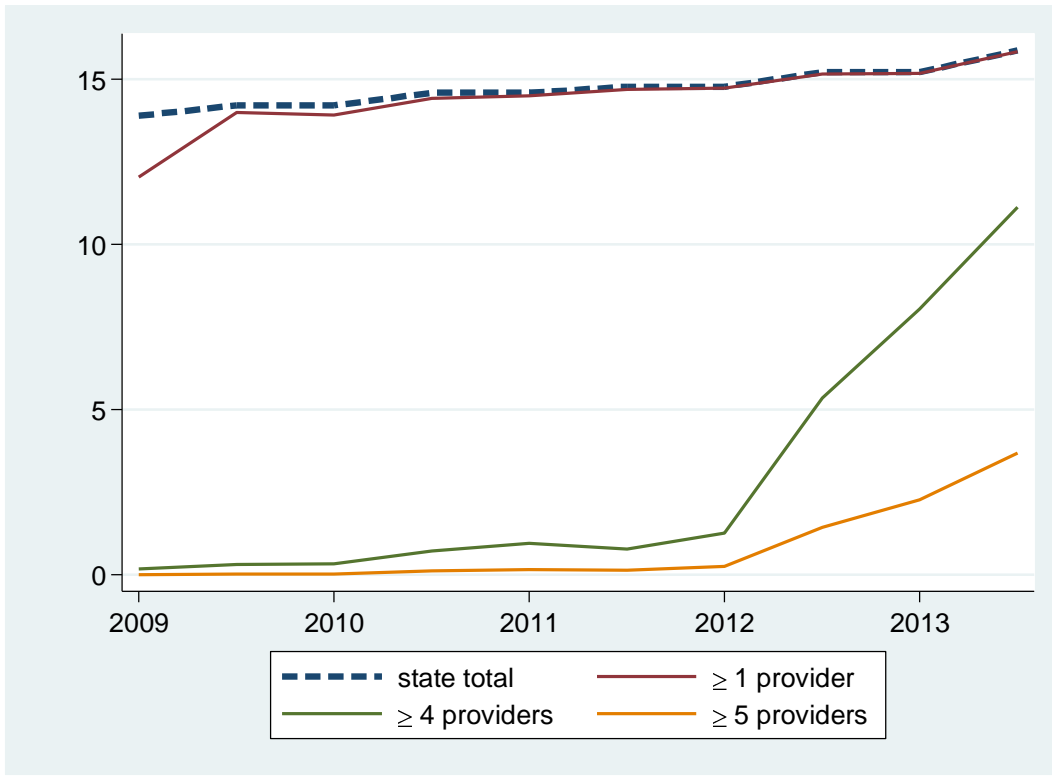
Regarding the 10 Mbps/1.5 Mbps threshold, Figure 45 shows that since 2012 about 97.5% of Hispanics in the state had fixed broadband available at that speed.

Figure 42: Hispanic population in ZIP codes with broadband providers, 1999 to 2008



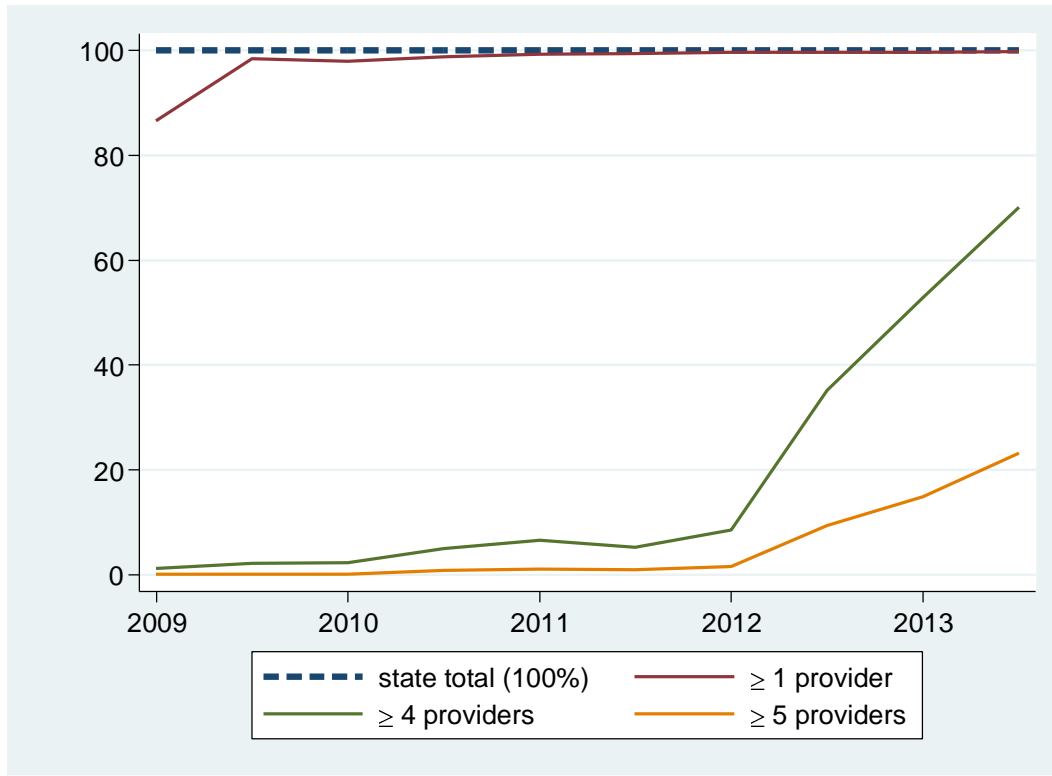
Note: "State total" is the total subpopulation for California of people identifying themselves as Latino or Hispanic. Broadband data are from the FCC as described in the text. See also notes to Figure 7.

Figure 43: Hispanic population in Census tracts with fixed broadband providers of residential service (3 Mbps down/768 kbps up), 2009 to 2013



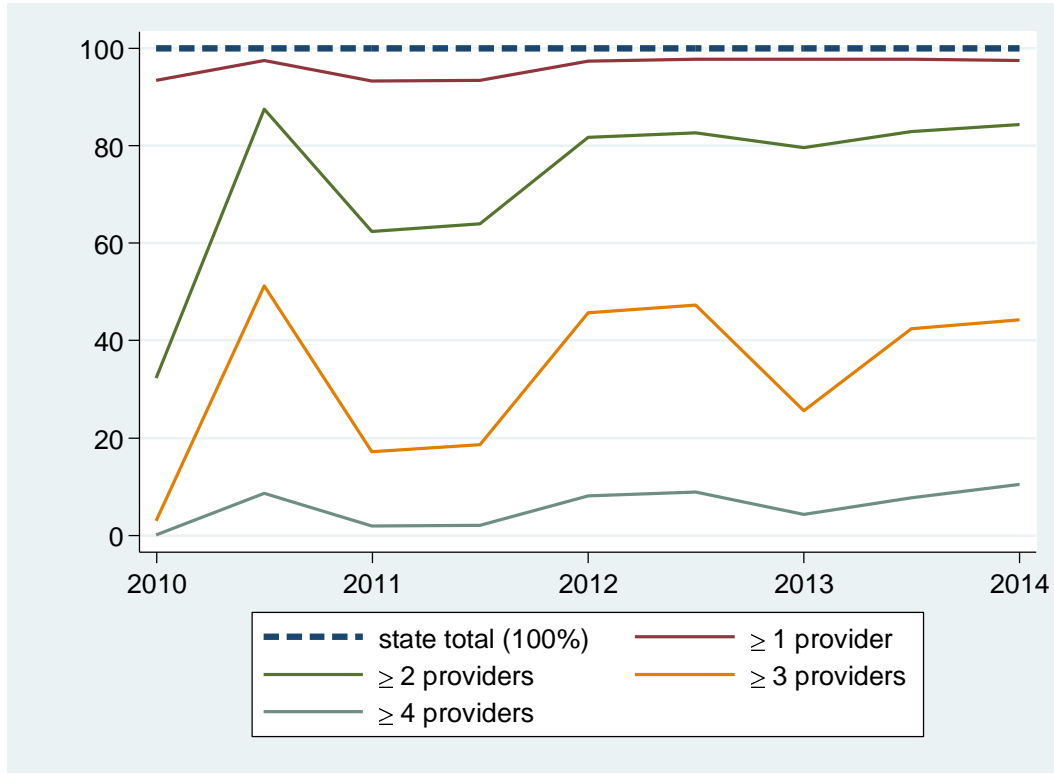
Note: "State total" is the total subpopulation for California of people identifying themselves as Latino or Hispanic. Broadband data are from the FCC as described in the text. See also notes to Figure 37.

Figure 44: Percentage of Hispanic population in Census tracts with fixed broadband providers of residential service (3 Mbps down/768 kbps up), 2009 to 2013



Note: Graph shows the same data as Figure 43 but expressed as a percentage of the total Hispanic population in California. See also notes to Figure 43.

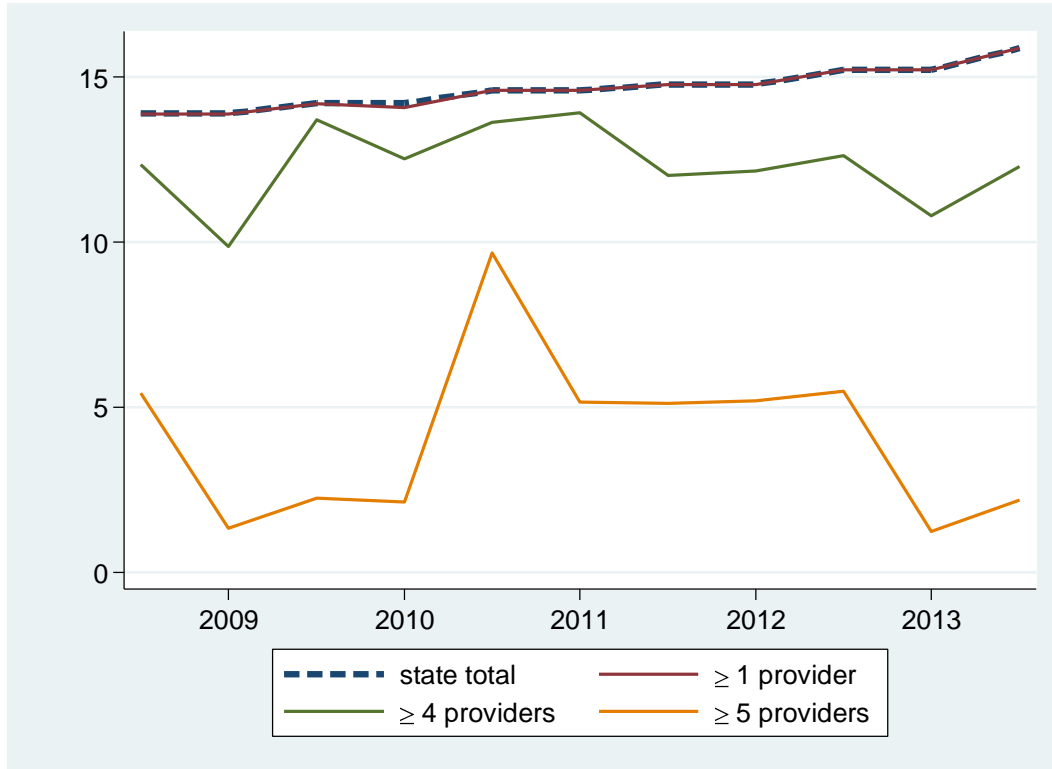
Figure 45: Percentage of Hispanic population in Census block groups with fixed broadband providers (10 Mbps down/1.5 Mbps up), 2010 to 2014



Notes: The speed threshold is 10 Mbps download/1.5 Mbps upload. Broadband data are from the National Broadband Map as described in the text. See also notes to Figure 13.

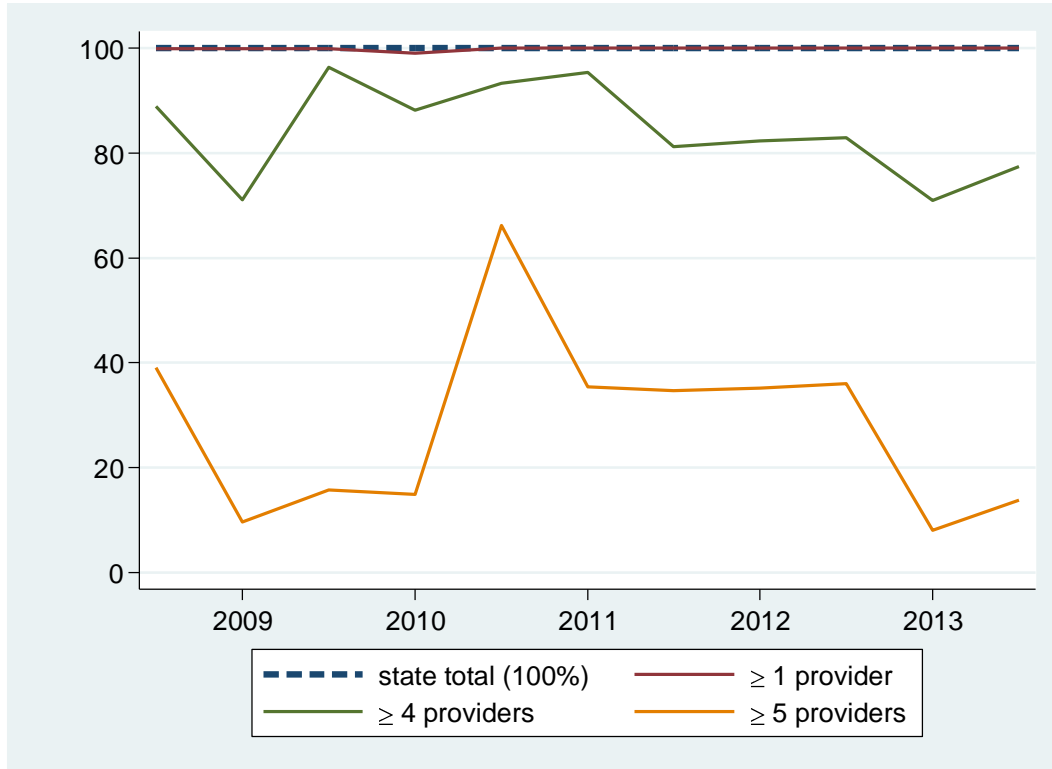
Regarding mobile broadband, Figure 46 shows that by 2013 there were also 12.3 million Hispanics living in tracts with four or more providers. Figure 47, showing the same information in percentages, highlights that nearly every Hispanic resided in a tract with mobile broadband availability.

Figure 46: Hispanic population in Census tracts with mobile broadband providers, 2008 to 2013



Note: “State total” is the total subpopulation for California of people identifying themselves as Latino or Hispanic, and where the line is obscured it is underneath the line for “≥ 1 provider”. The lower speed threshold is 200 kbps in at least one direction. See also notes to Figure 19.

Figure 47: Percentage of Hispanic population in Census tracts with mobile broadband providers, 2008 to 2013



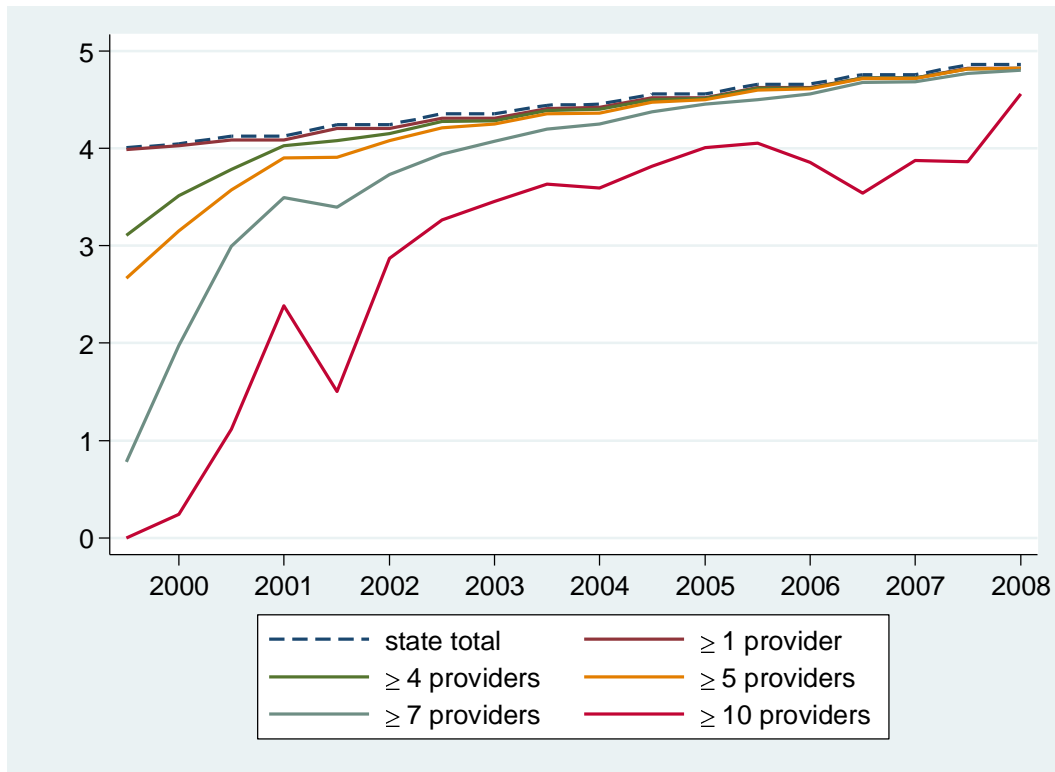
Note: Graph shows the same data as Figure 46 but expressed as a percentage of the total Hispanic population in California. See also notes to Figure 46.

c. Asian Americans

Since most Asian Americans⁸⁸ in California live in nonrural areas, as with African Americans there are generally more broadband providers available to Asians than to the general population on average. Comparison of Figure 48, which shows the number of Asian Americans living in areas with various numbers of providers during 1999 to 2008, with the comparable figure for all Californians (Figure 7) shows that each trend line composes a larger fraction of the whole for Asians. By 2008, 99.0% (4.81 million out of the 4.86 million) of Asian Americans in California lived in ZIP codes with seven or more broadband providers.

⁸⁸ The statistics in this section group native Hawaiians and Pacific Islanders with Asians. The trends are very similar if these two groups are excluded, since they compose only a small part of the whole subpopulation.

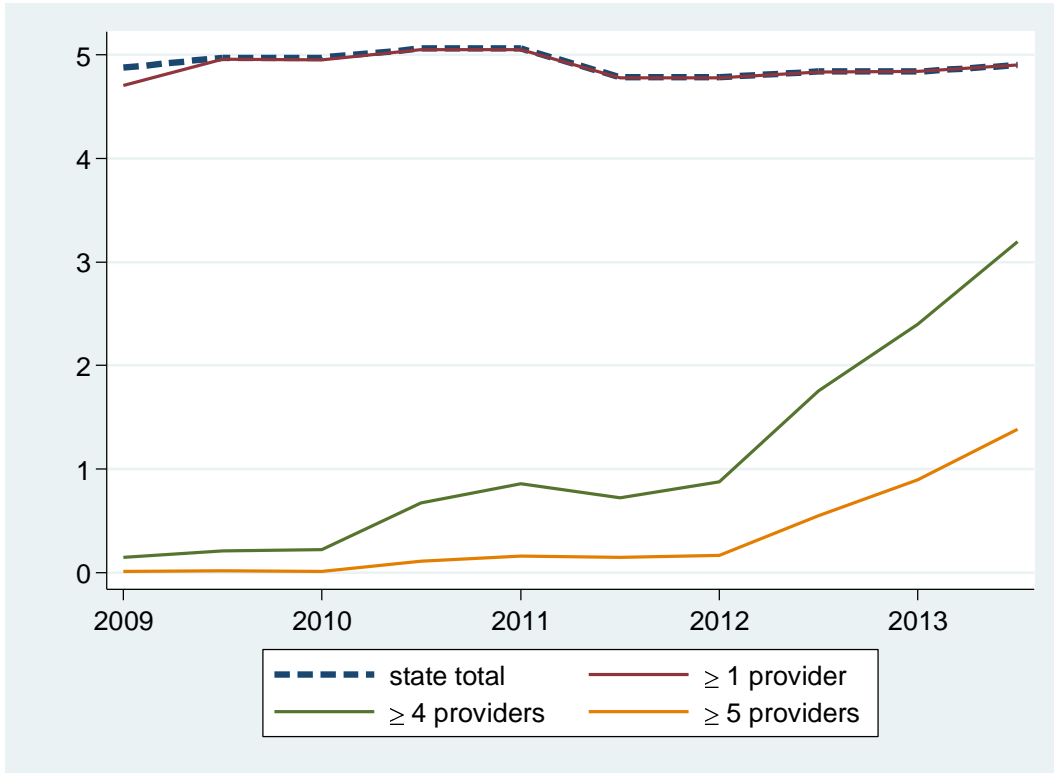
Figure 48: Asian American population in ZIP codes with broadband providers, 1999 to 2008



Note: “State total” is the total subpopulation for California of people identifying their race as Asian, Native Hawaiian, or Pacific Islander. Broadband data are from the FCC as described in the text. See also notes to Figure 7.

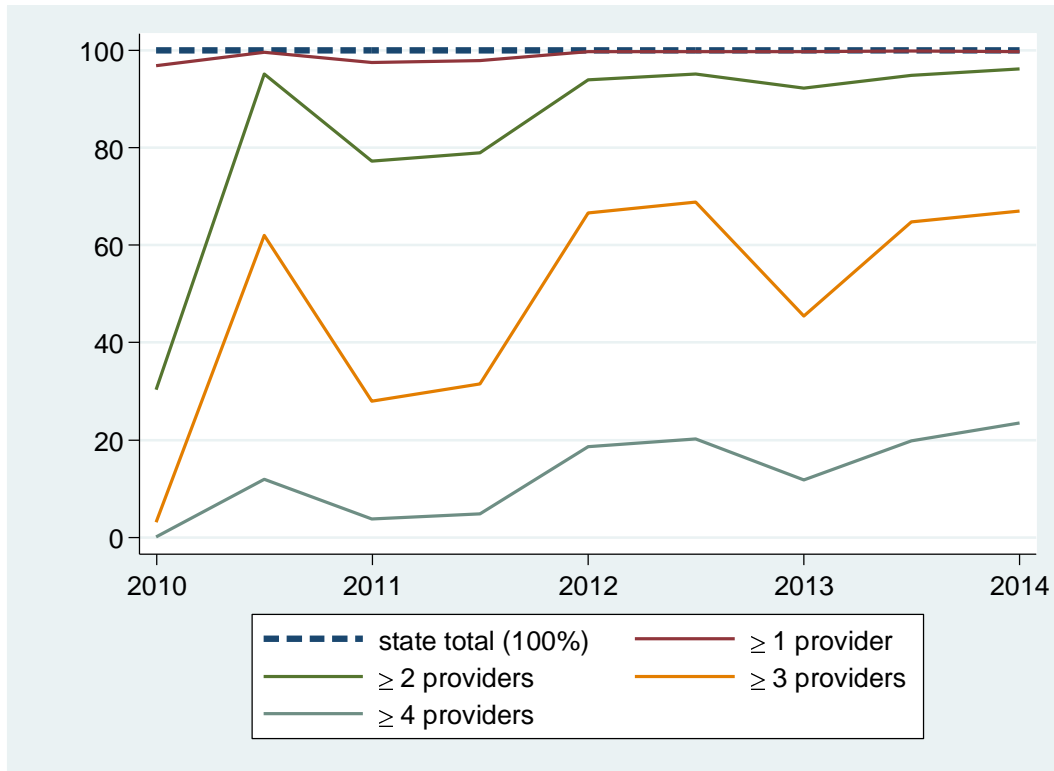
Trends during 2008 to 2013 for fixed broadband providers of residential service satisfying the 3 Mbps/768 kbps threshold, shown in Figure 49, are very similar to those for the whole population in Figure 11. There were 3.2 million Asians living in areas with four or more providers of residential higher speed fixed broadband in December 2013, and 1.4 million living in areas with five or more. The latter period’s trends in percentage terms are shown in Figure 50.

Figure 49: Asian American population in Census tracts with fixed broadband providers of residential service (3 Mbps down/768 kbps up), 2009 to 2013



Note: "State total" is the total subpopulation for California of people identifying their race as Asian, Native Hawaiian, or Pacific Islander. Broadband data are from the FCC as described in the text. See also notes to Figure 37.

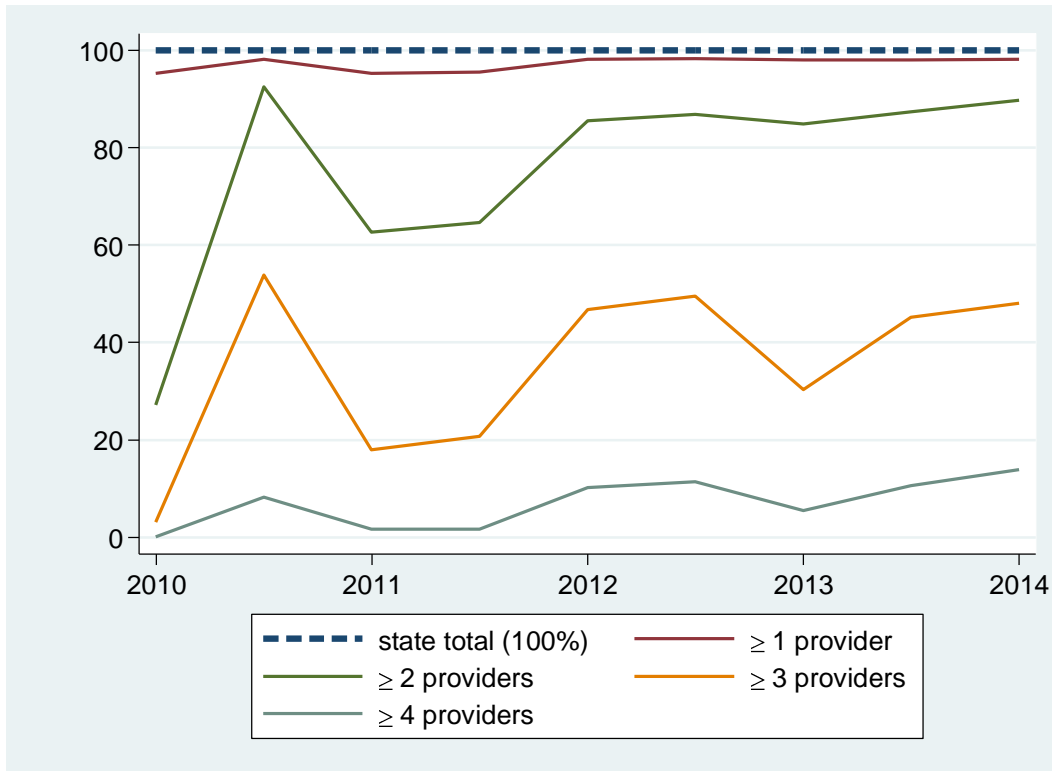
Figure 50: Percentage of Asian American population in Census tracts with fixed broadband providers of residential service (3 Mbps down/768 kbps up), 2009 to 2013



Note: Graph shows the same data as Figure 49 but expressed as a percentage of the total Asian American population in California. See also notes to Figure 49.

Figure 51 shows the trends for broadband at the 10 Mbps/1.5 Mbps threshold. Since 2010, more than 97% of Asian Americans lived in block groups that had access to fixed broadband of at least this speed. That figure has been above 99.8% since 2012. Additionally, in 2014 about 96% of Asian Americans were in areas with two or more fixed broadband providers meeting the 10 Mbps/1.5 Mbps threshold.

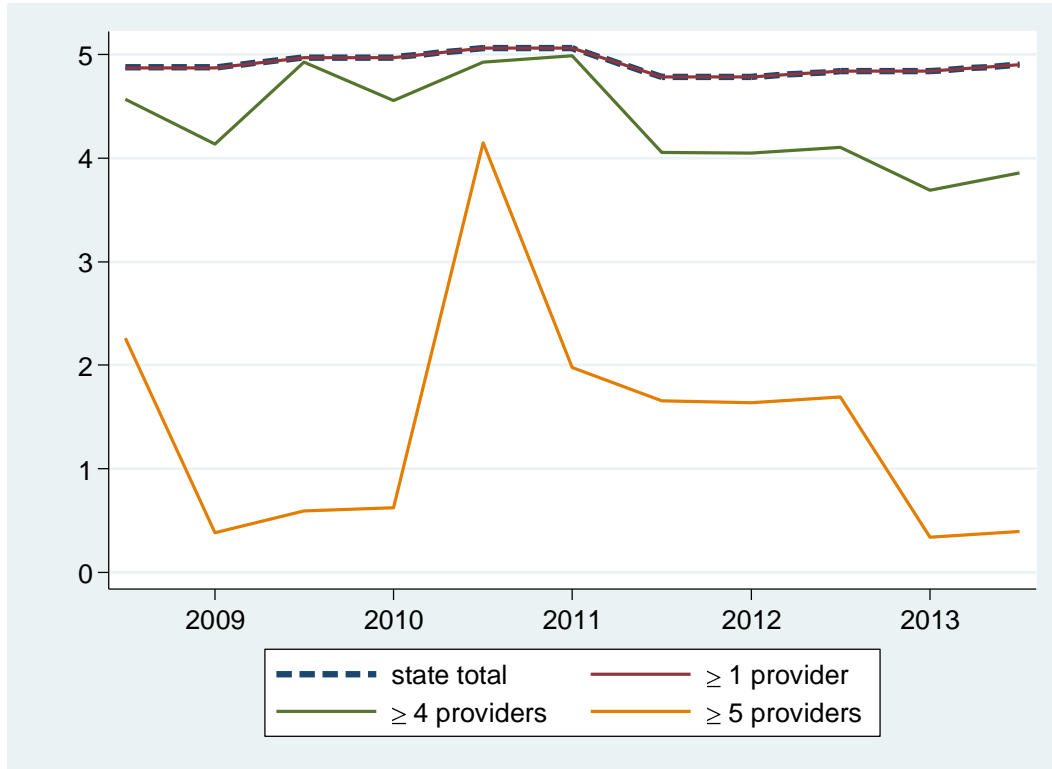
Figure 51: Percentage of Asian American population in Census block groups with fixed broadband providers (10 Mbps down/1.5 Mbps up), 2010 to 2014



Notes: The speed threshold is 10 Mbps download/1.5 Mbps upload. Broadband data are from the National Broadband Map as described in the text. See also notes to Figure 13.

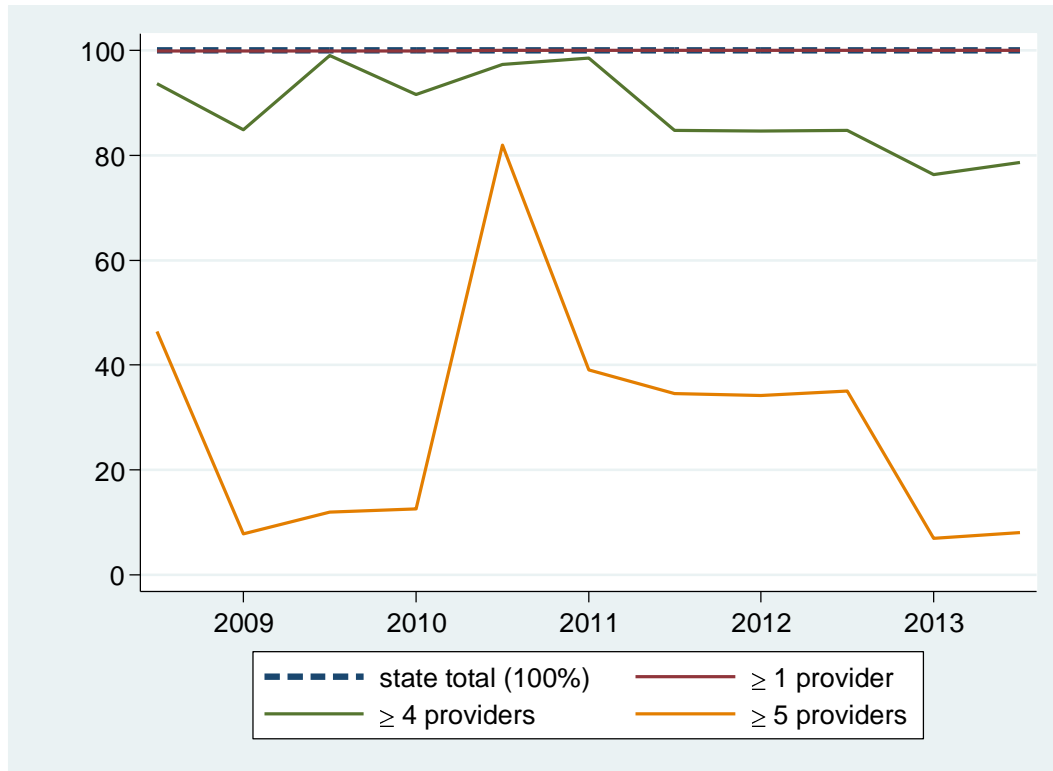
Trends for Asian Americans regarding mobile broadband available (Figure 52) are also similar to trends for all Californians (Figure 19). At the end of 2013, 3.9 million Asians lived in areas with four or more mobile broadband providers. Virtually 100% of Asians lived in tracts with at least one mobile provider, as Figure 53 highlights.

Figure 52: Asian American population in Census tracts with mobile broadband providers, 2008 to 2013



Note: "State total" is the total subpopulation for California of people identifying their race as Asian, Native Hawaiian, or Pacific Islander, and where the line is obscured it is underneath the line for "≥ 1 provider". The lower speed threshold is 200 kbps in at least one direction. See also notes to Figure 19.

Figure 53: Percentage of Asian American population in Census tracts with mobile broadband providers, 2008 to 2013



Note: Graph shows the same data as Figure 53 but expressed as a percentage of the total Asian American population in California. See also notes to Figure 53.

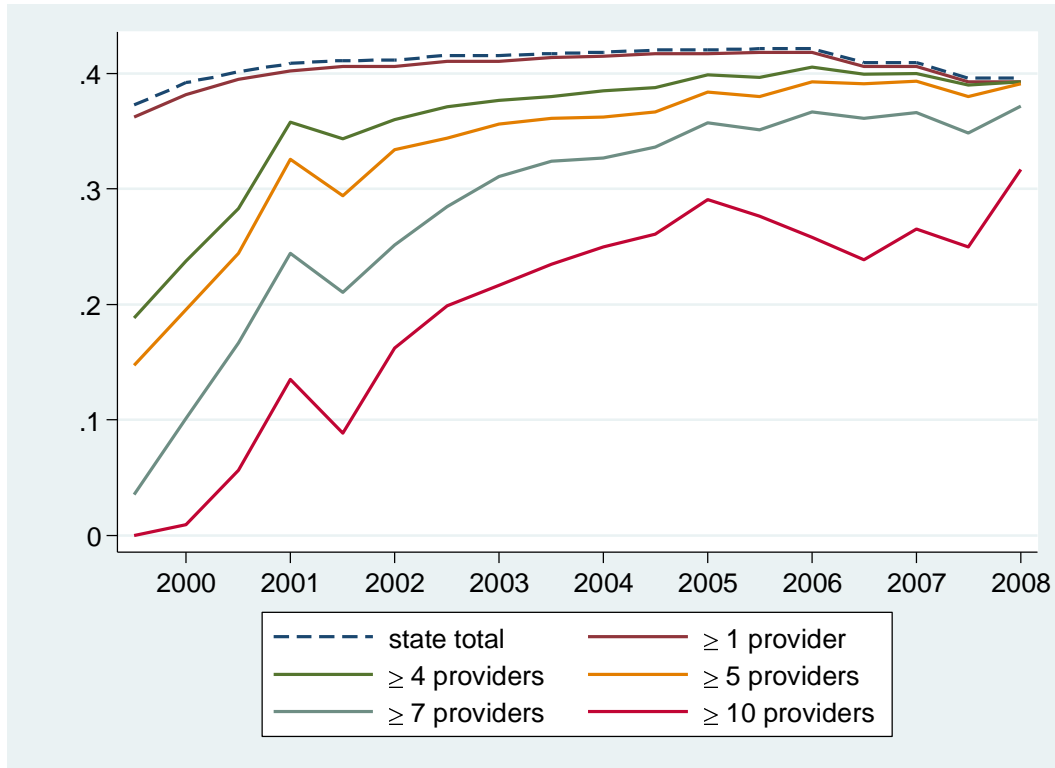
d. Native Americans

Figure 54 and Figure 55 show trends in broadband coverage for Native Americans in California.⁸⁹ Figure 56 repeats the information for the later years in percentage form, which is convenient since the number of people claiming to be Native American alone fell sharply in the 2010 Census. Nearly all Native Americans live in ZIP codes or Census tracts with broadband availability of some sort since at least 1999. However, given that Native Americans are more likely than the general population to live in rural areas, availability is proportionately lower for Native Americans than others for the higher numbers of providers. Nevertheless, by 2013 more than two-thirds (97,700 out of 141,000) lived in tracts with four or more providers of fixed residential broadband with speeds of at least 3 Mbps download /768 kbps upload. Broadband coverage for Native Americans has been furthered in part by the California Advanced Service Fund (CASF), discussed in section I.C.1, which has funded some projects to extend broadband infrastructure

⁸⁹ The apparently declining number of total Native Americans in California in 2010 and particularly 2011 reflects an updating of the subpopulation estimates based on new data from the 2010 Census. The phenomenon is similar to that affecting the counts of African Americans; see footnote 86.

to underserved rural areas and reservations in the state.⁹⁰ The proportion of Native Americans covered by four or more such providers has grown rapidly in the last few years, as can be seen in Figure 55 and Figure 56.

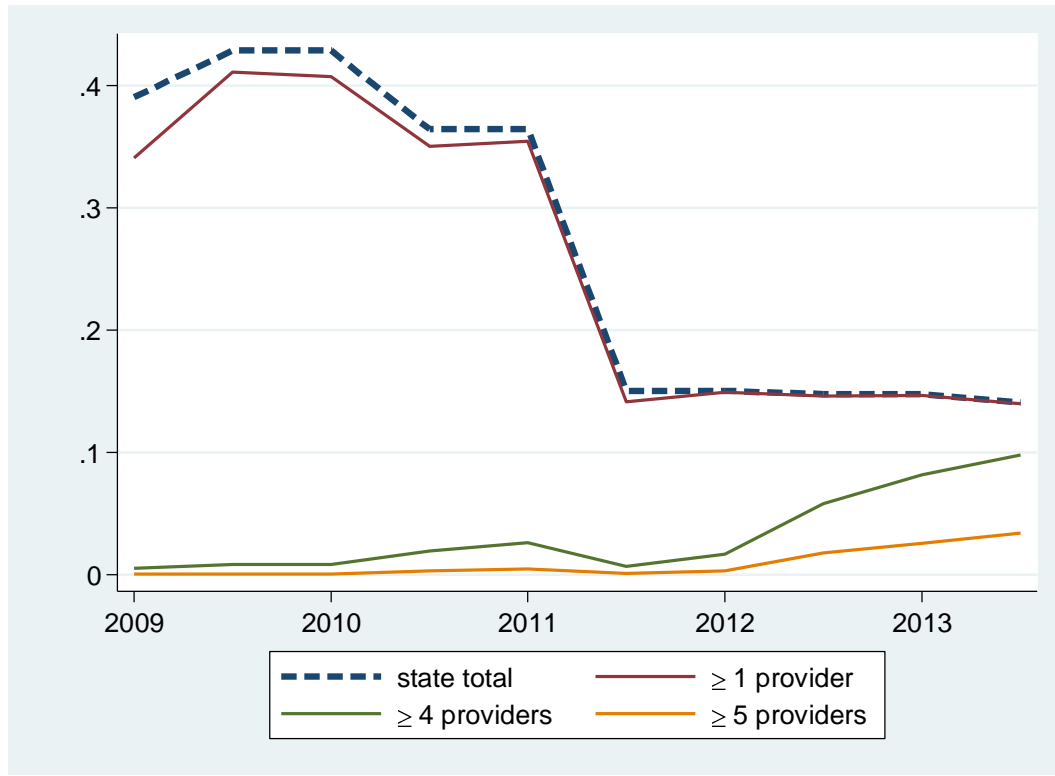
Figure 54: Native American population in ZIP codes with broadband providers, 1999 to 2008



Note: “State total” is the total subpopulation for California of people identifying their race as Native American. Broadband data are from the FCC as described in the text. See also notes to Figure 7.

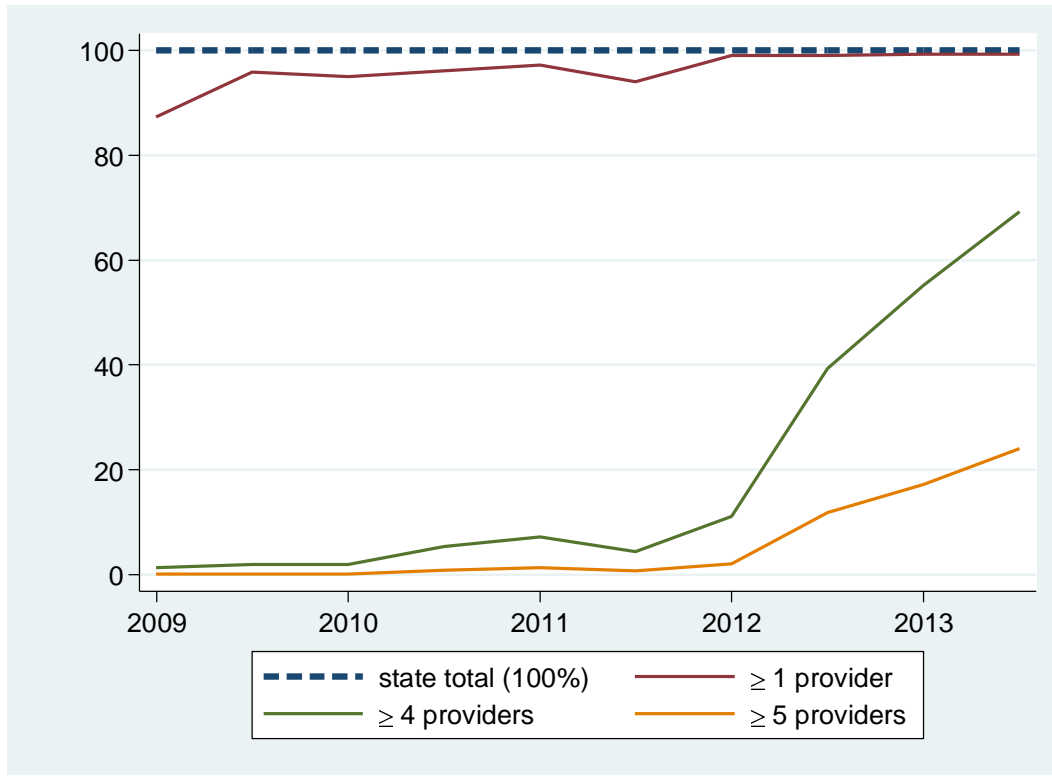
⁹⁰ For example, the Quechan Indian Reservation in Imperial County is one of the intended beneficiaries of a CASF grant in 2013 to Winterhaven Telephone Company (Resolution T-17410, funding of \$2,063,967).

Figure 55: Native American population in Census tracts with fixed broadband providers of residential service (3 Mbps down/768 kbps up), 2009 to 2013



Note: "State total" is the total subpopulation for California of people identifying their race as Native American. Broadband data are from the FCC as described in the text. See also notes to Figure 37.

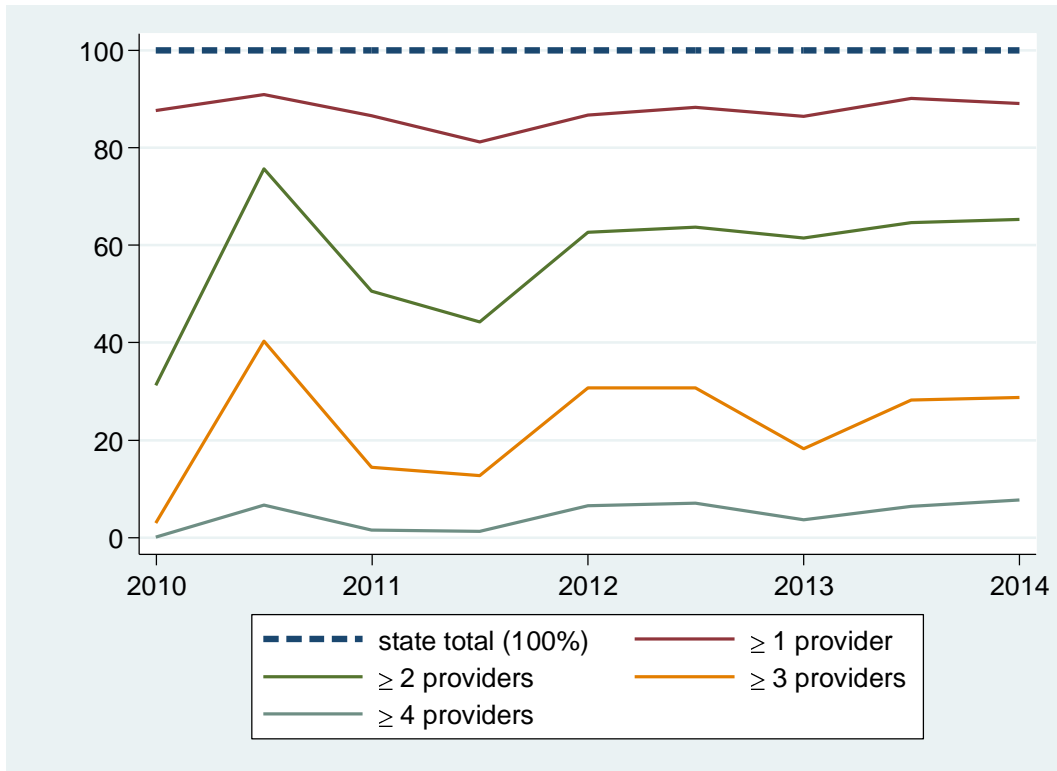
Figure 56: Percentage of Native American population in Census tracts with fixed broadband providers of residential service (3 Mbps down/768 kbps up), 2009 to 2013



Note: Graph shows the same data as Figure 55 but expressed as a percentage of the total Native American population in California. See also notes to Figure 55.

Figure 57 shows the availability of fixed broadband at the 10 Mbps/1.5 Mbps threshold for Native Americans. In 2014, 89% of Native Americans in the state lived in block groups with fixed broadband access meeting this threshold. Sixty-five percent lived in areas with access to two or more providers, and less than a third had access to three or more providers at this threshold. While these figures show more availability than for the rural population (compare Figure 57 to Figure 33), high-speed availability for Native Americans lags availability for the other ethnic and racial groups examined above.

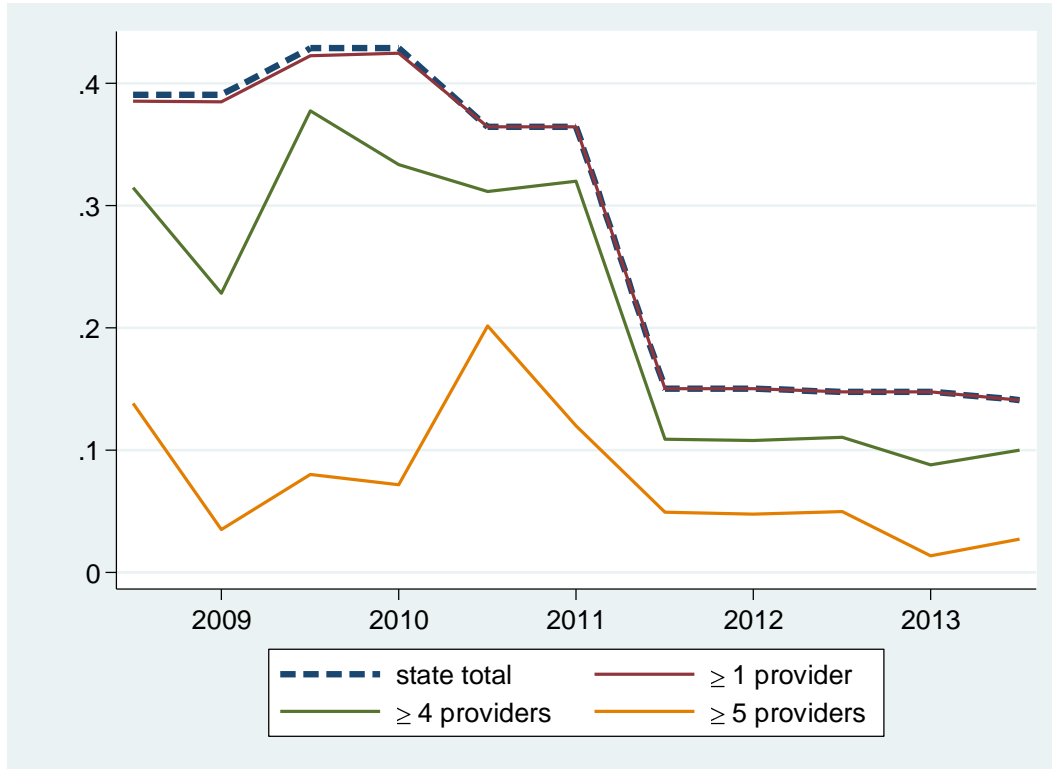
Figure 57: Percentage of Native American population in Census block groups with fixed broadband providers (10 Mbps down/1.5 Mbps up), 2010 to 2014



Notes: The speed threshold is 10 Mbps download/1.5 Mbps upload. Broadband data are from the National Broadband Map as described in the text. See also notes to Figure 13.

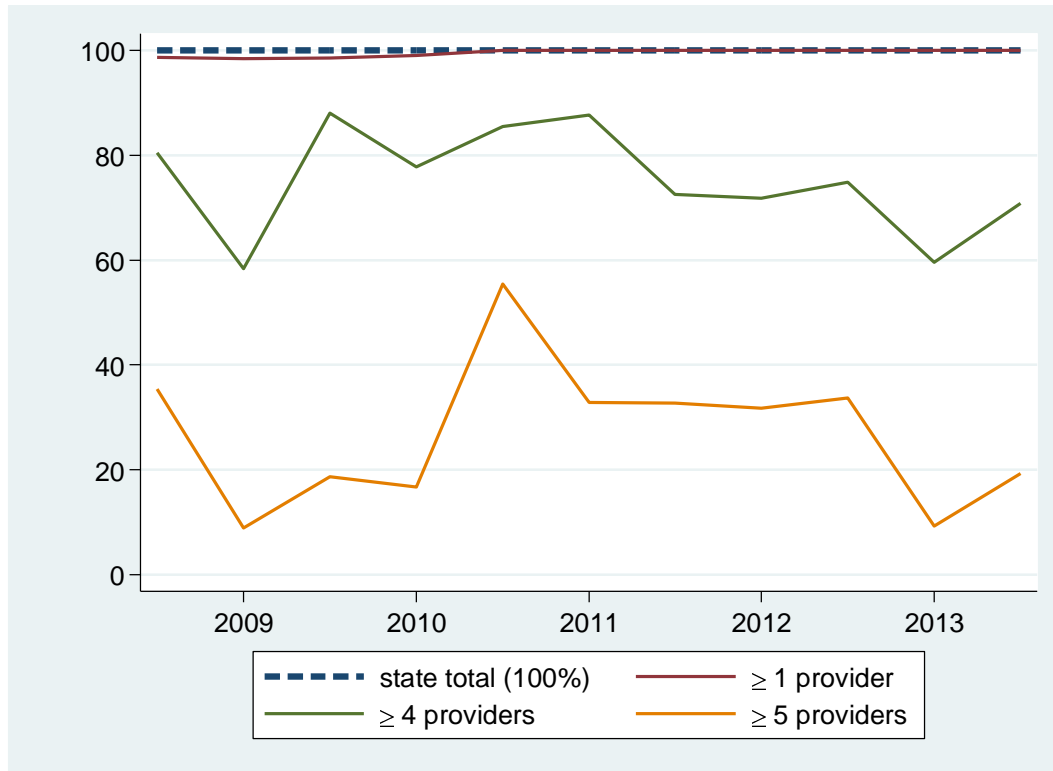
Mobile broadband availability for Native Americans is shown in Figure 58 and Figure 59. By the end of 2013, 99,800 Native Americans lived in tracts with four or more providers of mobile broadband (see Figure 58). Trends in the fraction of Native Americans living in areas with various numbers of mobile broadband providers in Figure 59 are mostly similar to those for the rural population at large (Figure 35).

Figure 58: Native American population in Census tracts with mobile broadband providers, 2008 to 2013



Note: "State total" is the total subpopulation for California of people identifying their race as Native American, and where the line is obscured it is underneath the line for "≥ 1 provider". The lower speed threshold is 200 kbps in at least one direction. See also notes to Figure 19.

Figure 59: Percentage of Native American population in Census tracts with mobile broadband providers, 2008 to 2013



Note: Graph shows the same data as Figure 58 but expressed as a percentage of the total Native American population in California. See also notes to Figure 58.

3. Other groups of policy interest

In the rest of this section, broadband availability is examined for other groups of particular interest to policymakers. Trends in broadband access for low-income households, senior citizens, those with disabilities, and small businesses is presented. As in the previous section, for each of the subpopulations of individuals examined here uses data from the FCC. For the period of 1999-2008, this includes broadband providers of all types offering service at the 200 kbps threshold, and data for the latter period of 2008-2013 is restricted to residential providers of fixed broadband (excluding satellite) meeting the 3 Mbps/768 kbps threshold. For the business groups, data for 1999-2008 are from the FCC as above and data for 2010 to present are from the National Broadband Map using the 10 Mbps/1.5 Mbps threshold.

a. Low-income households

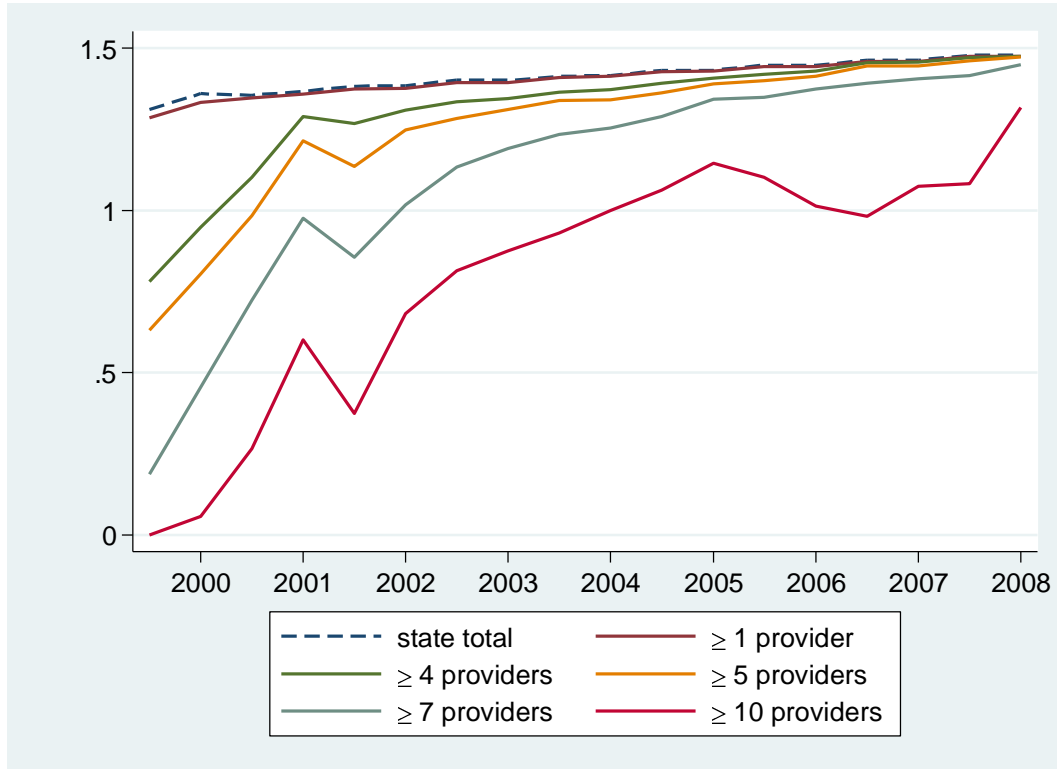
The Internet can help lower-income individuals by expanding access to the online marketplace, where prices for many goods may be lower than in the local neighborhood.⁹¹ Low-income households may also benefit from online access to publicly provided services (e-services and e-government; Taipei, 2013), opportunities for online job search, and entry into the sharing economy (for example, offering lodging through AirBNB or earning income through TaskRabbit).

Estimates for the number of households below the poverty line with access to various numbers of broadband providers are in Figure 60 and Figure 61.⁹² The patterns of increasing availability that were evidenced for the entire California population discussed in section A above also apply to low-income households in the state. While there are challenges to adoption for some low-income families, as will be discussed in section III.B.3 below, availability is not a significant issue. In 2013, nearly all of the 1.6M households below the poverty line in the state had access to broadband, 1.1M such households were in areas with four or more fixed broadband providers available, and 388,000 were in areas with five or more providers available. Even when looking at the trends for fixed-line service meeting the 10 Mbps download/1.5 Mbps upload standard (Figure 62), it can be seen that at least since 2010, more than 90% of low-income households are in block groups with availability. Since 2012, more than 97% of households in poverty were in block groups with fixed broadband at the higher threshold available.

⁹¹ For evidence on how online prices compare to their offline equivalents, refer to the studies cited in Prieger and Heil (2015) and Heil and Prieger (2015). E-commerce need not lower prices in all industries, but there are many examples of significant price reduction from the expansion of e-commerce.

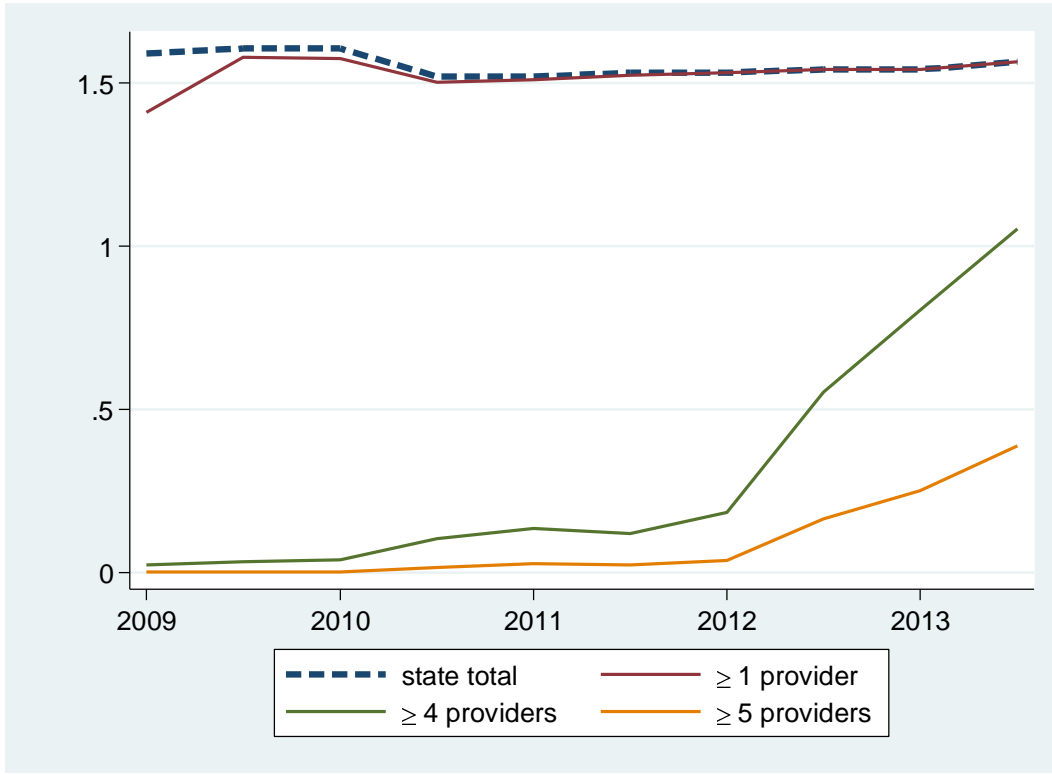
⁹² Statistics on poverty status are calculated as follows. The state totals for 1999-2008 of the number of California households with income below the official poverty line (as determined by the Census Bureau) are calculated using data from the 2000 Decennial Census. The fraction of households below the poverty line in 1999 in the ZIP code is applied to the number of households in other years. A similar method is used for data after 2008, except that the poverty fractions are taken from the 2010 American Community Survey (five year estimates).

Figure 60: Households below the poverty threshold in ZIP codes with broadband providers, 1999 to 2008



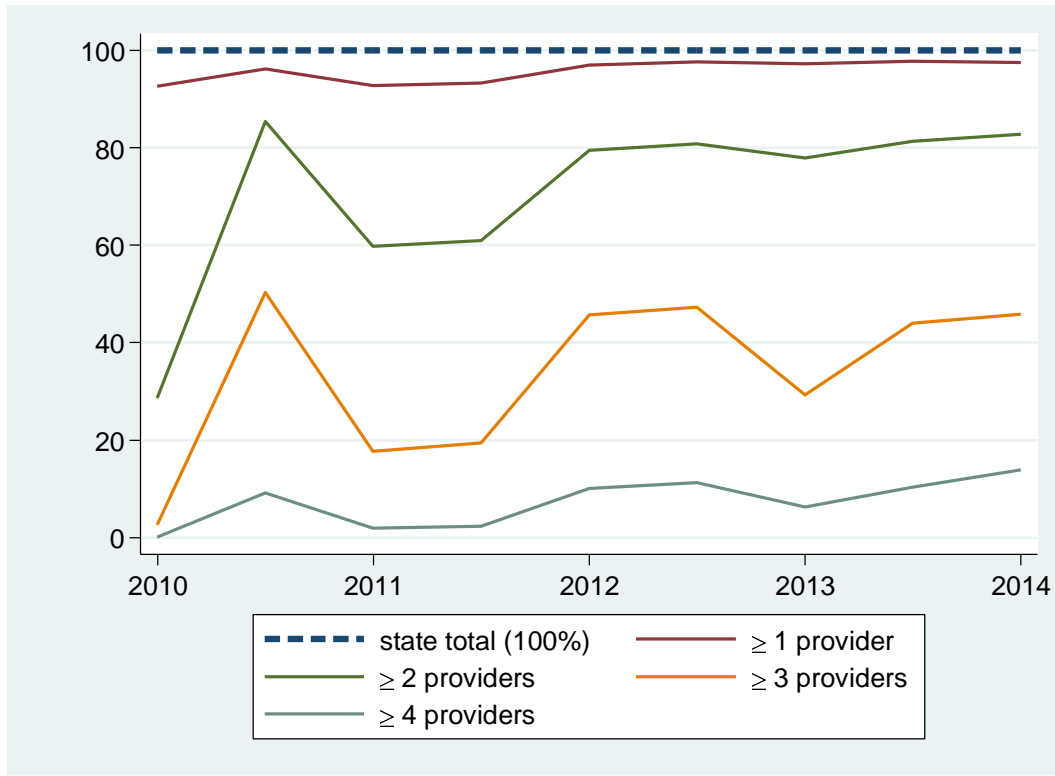
Note: "State total" is the total number of households in California that are below the federal poverty threshold. Broadband data are from the FCC as described in the text. See also notes to Figure 7.

Figure 61: Households below the poverty threshold in Census tracts with fixed broadband providers of residential service (3 Mbps down/768 kbps up), 2009 to 2013



Note: "State total" is the total number of households in California that are below the federal poverty threshold. Broadband data are from the FCC as described in the text. See also notes to Figure 37.

Figure 62: Percentage of households below the poverty threshold in Census block groups with fixed broadband providers (10 Mbps down/1.5 Mbps up), 2010 to 2014



Notes: The speed threshold is 10 Mbps download/1.5 Mbps upload. Broadband data are from the National Broadband Map as described in the text. See also notes to Figure 13.

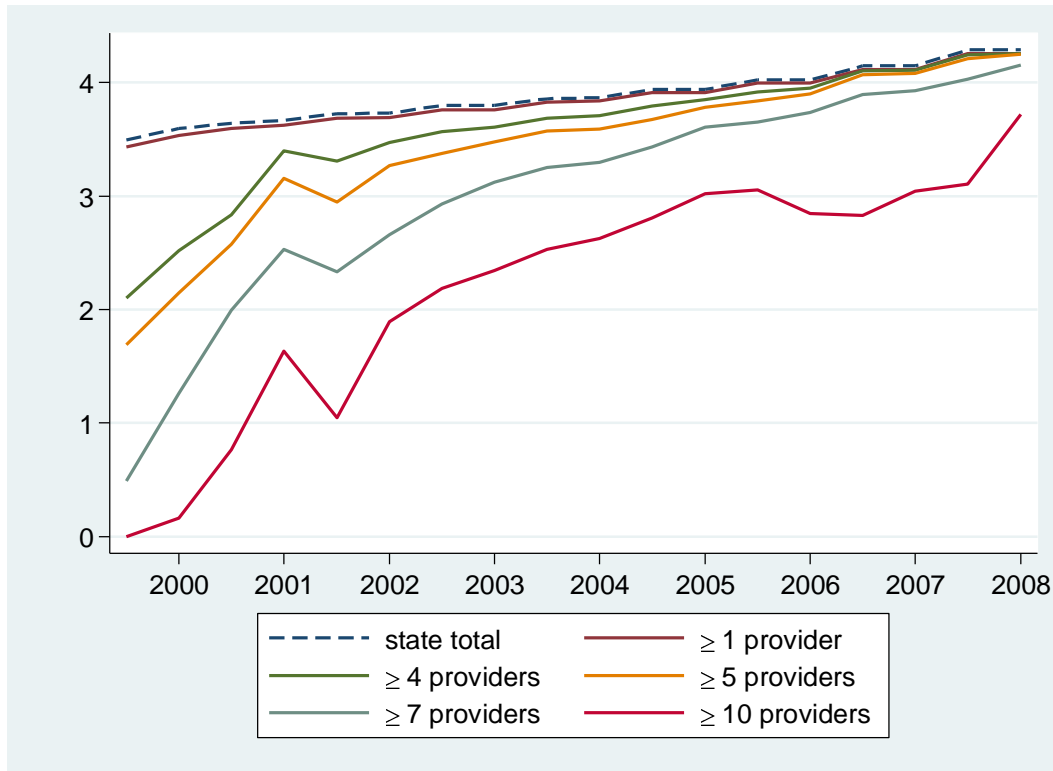
b. Seniors

Internet use has been found to improve the psychological well-being of the elderly (see Chen and Persson (2002) and the studies cited therein). After training or learning on their own how to use to Internet, some seniors report a heightened sense of empowerment, connection to others, a better outlook on life, and lower stress (White et al. 1999; Wright 2000; Chen and Persson, 2002). A recent metastudy of the literature (Forsman and Nordmyr) found that the data indicate that Internet use is a positively associated with mental health in later life. Important contributing factors to the link were enhanced individual interactions with other people, bettered access to community resources, and greater social inclusion. For these reasons and others, Internet use among seniors is growing faster than for other age groups (Choi and DiNitto, 2013). Part of the reason for the high rate of growth is the relatively low starting point for usage, since the elderly lag other age groups in Internet usage.

Seniors have gained greater availability of broadband Internet access along with the rest of the population. Figure 63 and Figure 64 show how the availability of greater numbers of providers

has increased for California aged 65 years and older.⁹³ By December 2013, almost all of the 5.3M senior citizens lived in areas with access to fixed residential broadband, 3.8M seniors were in areas with four or more fixed broadband providers available, and 1.6M were in areas with five or more providers available.

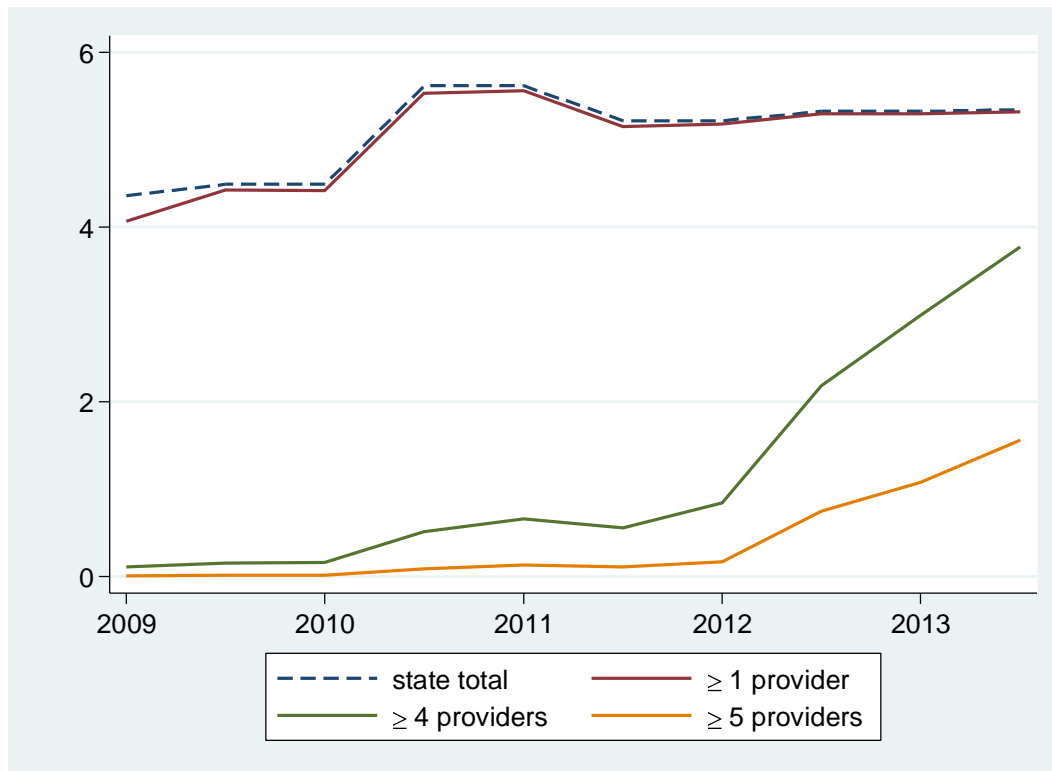
Figure 63: Senior (age 65+) population in ZIP codes with broadband providers, 1999 to 2008



Note: Broadband data are from the FCC as described in the text. See notes to Figure 7.

⁹³ The apparent spike in the total population of seniors in California in 2010 is likely an artifact of the decennial Census, which allows the estimates from GeoLytics (the source of the data used in the figures) to be recalibrated with the updated data from the census.

Figure 64: Senior (age 65+) population in Census tracts with fixed broadband providers of residential service (3 Mbps down/768 kbps up), 2009 to 2013



Note: Broadband data are from the FCC as described in the text. See also notes to Figure 37.

c. The disabled

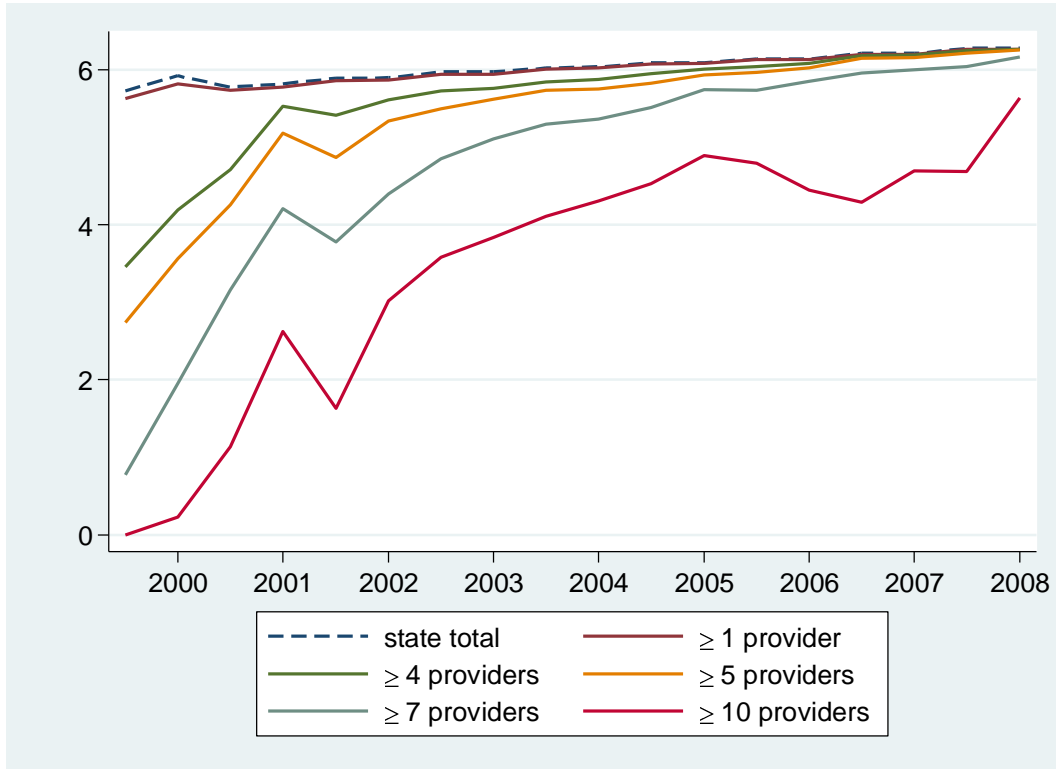
Internet access is very important for some people with disabilities, since the Internet can provide access to medical personnel and healthcare systems, essential information about health and disabilities, and wide communities of others sharing the same challenges (Dobransky and Hargittai, 2006). Some research links Internet access for the disabled to improvements in mental and physical health outcomes. Usage of the Internet can improve social and mental health for the disabled in the areas of communication with others (Bradley and Poppen, 2003), a sense of self-determination (Cook et al. 2005), and the same type of social support that otherwise could only be provided by face-to-face social interaction (Finn 1999; Yao, Zheng, and Fan, 2015). The virtual space of the Internet is more accessible than physical venues for many people with limited mobility, which provides an important way the Internet improves some aspects of the lives of the disabled. Furthermore, the Internet can help alleviate transportation barriers to shopping, socializing, and civic engagement. While broadband per se is not required for some forms of online interaction and the Internet can present a new set of challenges for some disabled persons (e.g., those with visual impairment), the availability of broadband nevertheless can be important for many in the disabled community.

There are many challenges facing the disabled in using the Internet. Research shows that the disabled are less likely to use the Internet than are others, but sometimes for reasons other than direct physical limitations (Vicente and López, 2010). People with disabilities are more likely to be living in poverty, to have lower incomes, and to consider cost to be a barrier to Internet access. Furthermore, the disabled are more likely to be uninterested or intimidated by new technology (Vicente and López, 2010).

Data on the disabled population in California are available from the Census Bureau.⁹⁴ Figure 65 and Figure 66 show how access to broadband Internet has improved since 1999. As with the other subpopulations examined here, nearly all disabled had access to at least one provider at least since 1999, and the number of disabled Californians with access to greater numbers of providers has risen over time. By the end of 2013, very few of the 4.2M senior citizens lived in areas with no access to fixed residential broadband. Furthermore, 3.0M people with disabilities were in areas with four or more fixed broadband providers available, and 1.1M were in areas with five or more fixed broadband providers offering residential service at the 3 Mbps/768 kbps threshold.

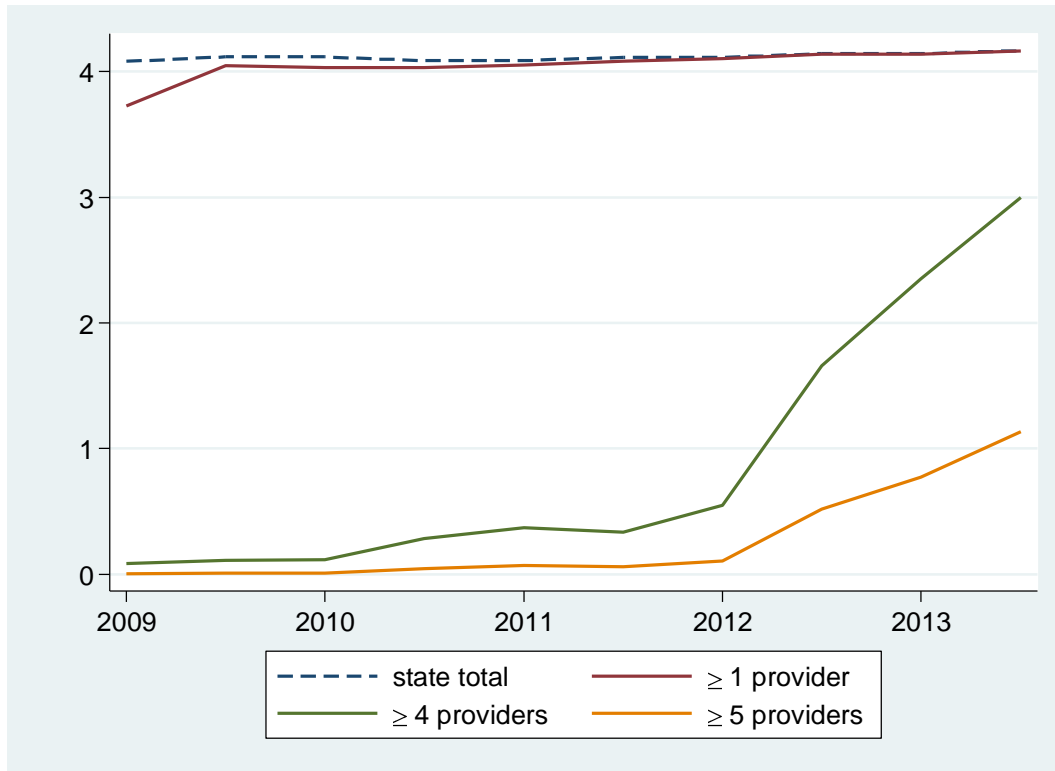
⁹⁴ Unlike most other statistics used in this report, good statistics on people with disabilities by detailed geography are not available for all years. The state totals for the disabled population in Figure 65 are calculated by applying the fraction of the civilian noninstitutionalized population 5 years and over with disabilities in the ZIP code, as found from the 2000 Decennial Census, to the total population in the ZIP code each year. Some Figure 66, a similar method is used but with the tract-level disability data taken from the 2013 American Community Survey (five-year estimates). The 2013 ACS is the first year tract-level data on the disabled are available.

Figure 65: Disabled population in ZIP codes with broadband providers, 1999 to 2008



Note: "State total" is the total subpopulation of disabled persons in California. Broadband data are from the FCC as described in the text. See also notes to Figure 7.

Figure 66: Disabled population in Census tracts with fixed broadband providers of residential service (3 Mbps down/768 kbps up), 2009 to 2013



Note: “State total” is the total subpopulation of disabled persons in California. Broadband data are from the FCC as described in the text. See also notes to Figure 37.

d. Small business

In California, the state Code of Regulations defines small businesses as those having 100 or fewer employees or average annual gross receipts of \$14 million or less.⁹⁵ The Census business data described in section A.1.b allow examination of where business establishments with fewer than 100 employees are located. While the counts are for establishments, not businesses, nearly all small businesses have a single establishment: In 2008, there are only 1032 establishments per 1000 small businesses in California.⁹⁶ Conversely, 84% of small establishments (fewer than 100 employee at the location) are also small businesses.⁹⁷ Thus, while the data for small establishments do not exactly reflect the universe of small businesses in California, they come close.

⁹⁵ These are the small business eligibility requirements for the state Office of Small Business and Disabled Veteran Business Enterprise Services (OSDS).

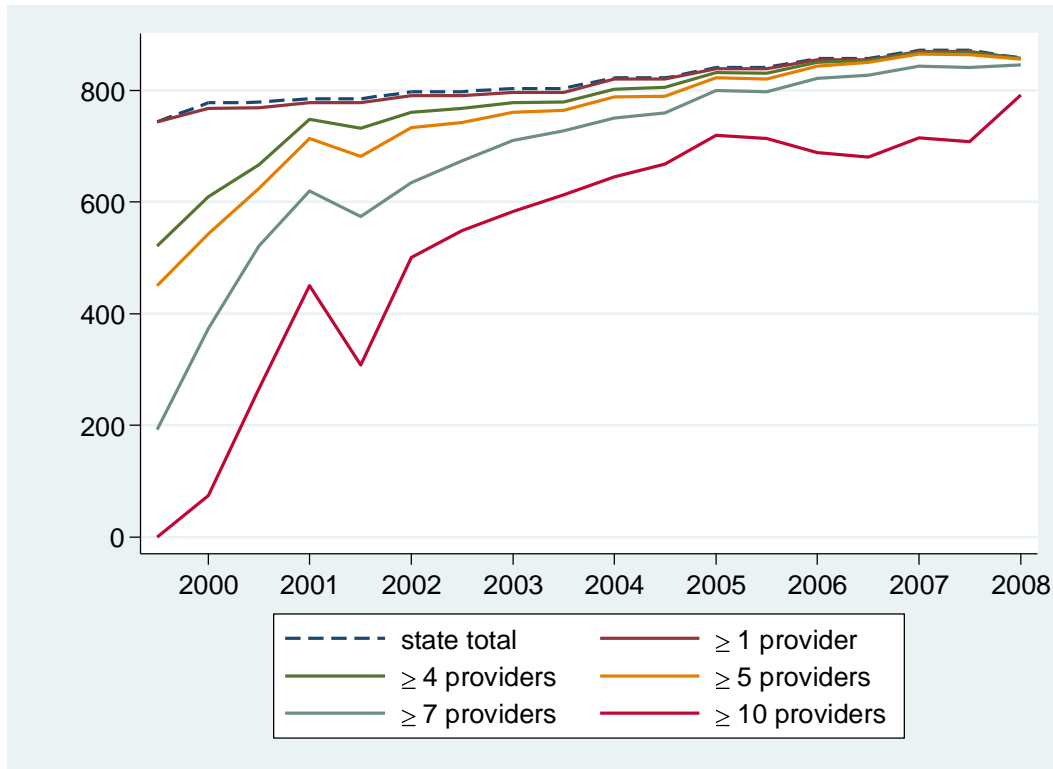
⁹⁶ Author’s calculations using U.S. Census data from *Statistics of U.S. Businesses*.

⁹⁷ Author’s calculations using data for 2008 from *Statistics of U.S. Businesses* and *ZIP Code Business Patterns*, both from the U.S. Census Bureau.

ICT in general and broadband Internet usage in particular can improve the performance of businesses, but successful adoption is not automatic. Research shows that successful adoption of broadband Internet usage by small firms in particular depends on many contingent factors such as the industry, the relevance of the specific broadband applications for the industry; and the ability to change strategy and the organization of the business to capitalize on the new capacity broadband offers. Nevertheless, small business can enjoy sizable productivity increases upon adopting broadband and broadband-enabled applications, at least when these contingent factors are favorable (Colombo, Croce, and Grilli, 2013). It is therefore important to the state's economy that all businesses, not just larger enterprises, have access to high quality broadband.

The data from the FCC, plotted in Figure 67, show that multiple broadband providers were offering service in the areas containing the great majority of small businesses during 1999 to 2008. As early as 2002, more than half of small businesses were in ZIP codes with 10 or more broadband providers. Comparison of Figure 67 with Figure 8 shows that the broadband availability of small businesses is similar to that of all businesses overall.

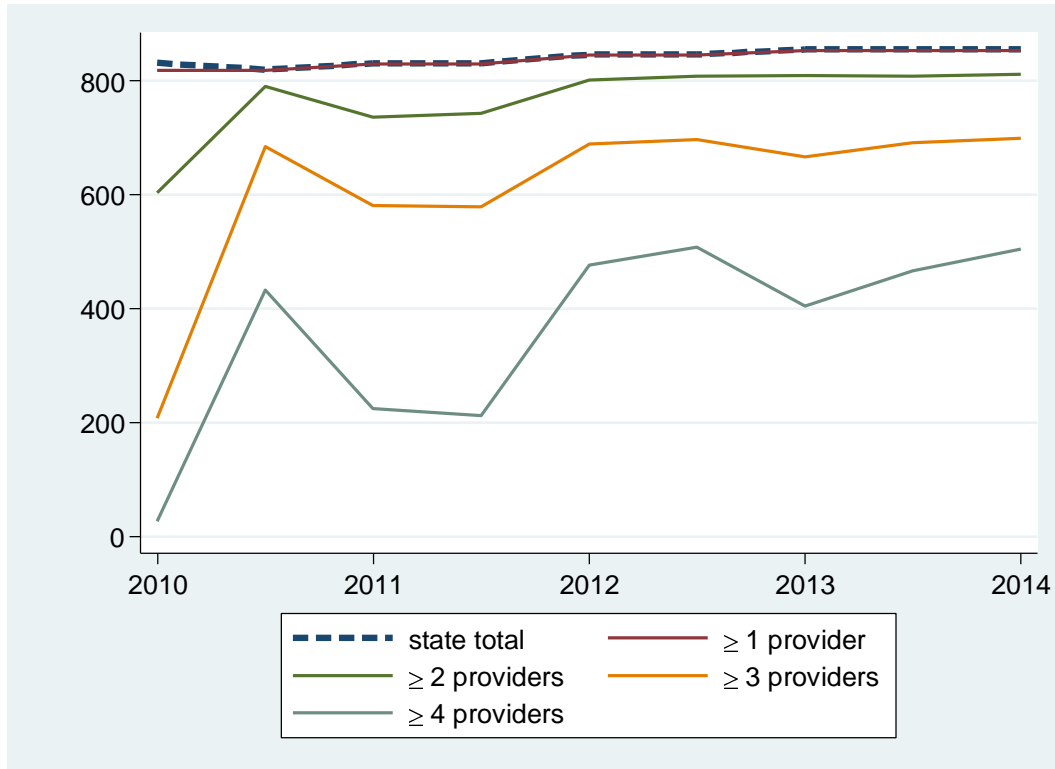
Figure 67: Small business establishments in ZIP codes with broadband providers, 1999 to 2008



Note: "State total" is the total number of small business establishments (fewer than 100 employees) in California. See also notes to Figure 7.

Data from the National Broadband Map, shown in Figure 68, show that in 2014, 853,000 of the 855,000 small establishments in California were in areas with access to broadband of at least 10 Mbps download /1.5 Mbps upload speed. Additionally, 812,000 of these small establishments were in areas with two or more fixed broadband providers, 698,000 were in areas with three or more, and 504,000 were in areas with at least four providers.

Figure 68: Small business establishments in ZIP codes with fixed broadband providers (10 Mbps down/1.5 Mbps up), 2010 to 2014



Notes: “State total” is the total number of small business establishments (fewer than 100 employees) in California. The speed threshold is 10 Mbps download and 1.5 Mbps upload. Data are from the National Broadband Map as described in the text.

e. Microbusinesses

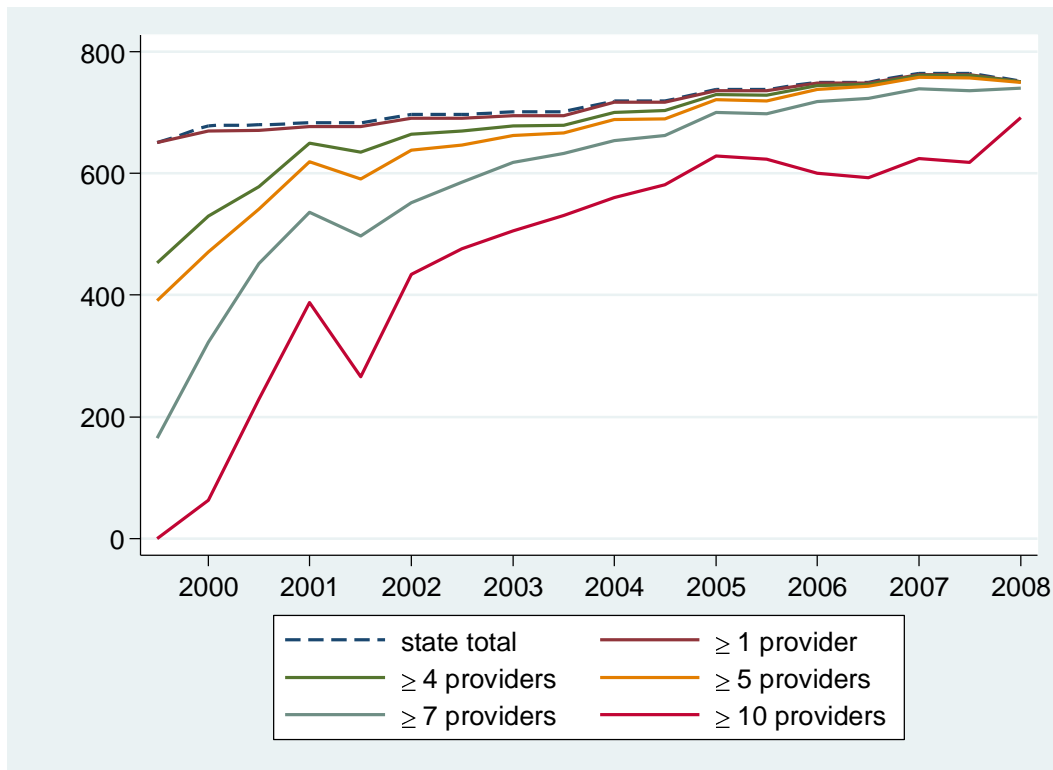
The state defines microbusinesses as a small business with gross annual receipts less than \$3.5M or small business that is a manufacturer with no more than 25 employees.⁹⁸ Within the realm of small firms, the smallest face the most challenges to actively incorporating the Internet and other ICT into their business endeavors. Research shows that the technological “absorptive capacity” of a firm (i.e., its ability to exploit the business advantages offered by broadband, the Internet, and ICT in general; Cohen and Levinthal, 1990) is often lower the smaller the enterprise

⁹⁸ See <http://www.dgs.ca.gov/pd/Programs/OSDS/SBEligibilityBenefits.aspx>.

(Dandridge, 2000). Other research highlights the potential for the location of smaller firms to disadvantage them in adoption of broadband (Arbore and Ordanini, 2006). If microenterprises are more likely to be in areas lacking broadband, then that important environmental factor will contribute to the digital divide among firms.

The closest the business location data from Census allows for examination of microbusinesses is to look at establishments with fewer than twenty employees. In California, the data show that most microbusinesses so defined enjoyed access to multiple broadband providers (Figure 69) over the period 1999 to 2008.⁹⁹ In fact, comparison of Figure 69 with Figure 8 and Figure 67 shows that the smallest businesses in the state appear to face no particular disadvantage in availability of broadband from numerous providers, compared with the larger classes of small business (Figure 67) and all businesses (Figure 8).

Figure 69: Microbusinesses in ZIP codes with broadband providers, 1999 to 2008

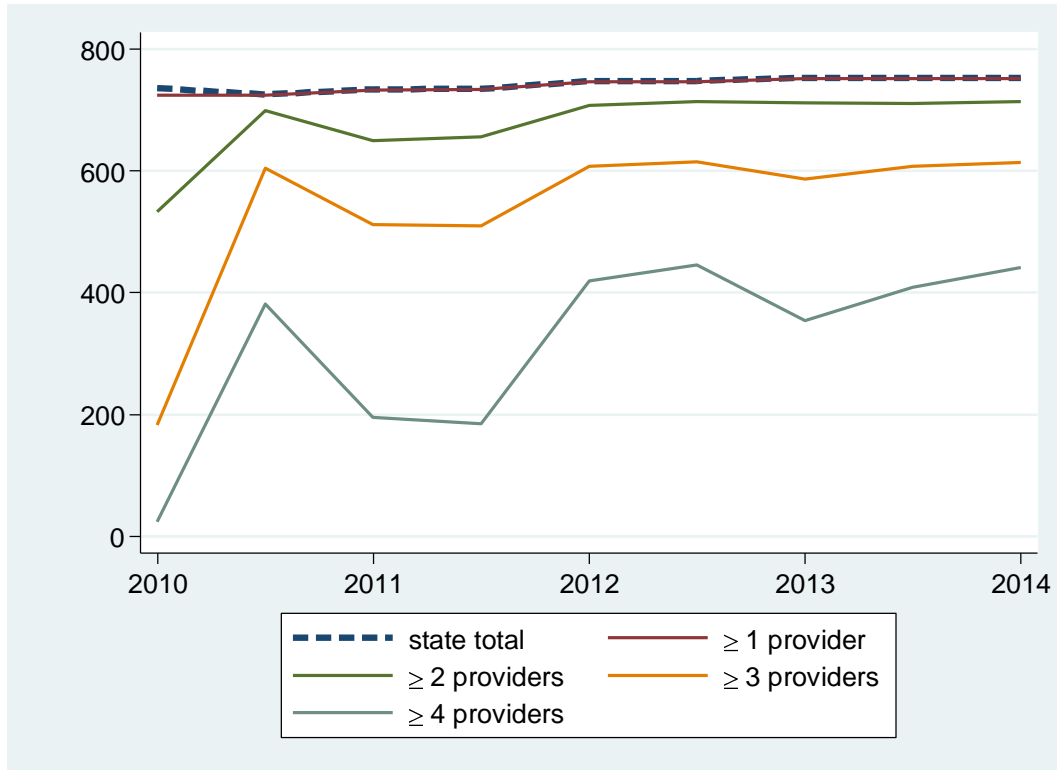


Note: “State total” is the total number of microbusinesses (establishments with fewer than 20 employees) in California. Data are from the FCC as described in the text. See also notes to Figure 7.

⁹⁹ In 2008, there are only 1009 establishments per 1000 microbusinesses in California (author’s calculations using U.S. Census data from *Statistics of U.S. Businesses*), and so the concept of the business and the establishment are nearly interchangeable for microbusinesses. Also, 85% of the establishments with fewer than 20 employees are owned by a microbusiness (author’s calculations using data for 2008 from *Statistics of U.S. Businesses* and *ZIP Code Business Patterns*, both from the U.S. Census Bureau.).

The data from the National Broadband Map in Figure 70 show that since 2010, nearly all microbusinesses had access to fixed service meeting the 10 Mbps/1.5 Mbps threshold. Two or more broadband providers meeting this threshold were available to 715,000 microbusinesses. More than half of microbusinesses (58.7%) had access to four or more providers.

Figure 70: Microenterprises in ZIP codes with fixed broadband providers (10 Mbps down/1.5 Mbps up), 2010 to 2014



Notes: The speed threshold is 10 Mbps download and 1.5 Mbps upload. Data are from the National Broadband Map as described in the text. See also notes to Figure 69.

III. Broadband Internet Adoption

This section reviews progress made in adoption of broadband access to the Internet in California. Due to the nature of the available data, most attention will be paid to fixed broadband adoption. However, mobile broadband will also be discussed to a lesser extent. Since the FCC made much more detailed data available on adoption starting in December 2008, most of the trends analyzed here begin then. The overall picture for the state is discussed in section A. Section B turns to the experiences of rural residents, minorities, and low-income households in California.

A. Growth in adoption across the state

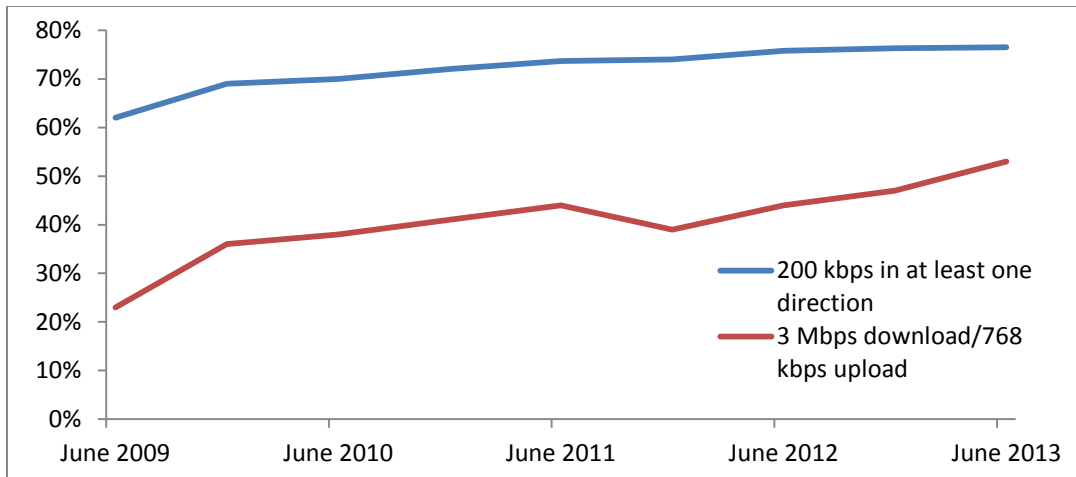
At the end of 2013, California had a 65% household subscribership ratio¹⁰⁰ for residential fixed broadband connections of at least 3 Mbps downstream/768 kbps upstream, as shown in Figure 71. This compares favorably with the subscribership ratio for the rest of the nation, which is 60%. The fastest growth in subscribership came most recently. Including broadband meeting the lower threshold of 200 kbps, California's subscribership ratio was 78%.¹⁰¹ In addition to these residential lines, there were 6.1 million business broadband connections not included in the figure serving the almost 0.9 million business establishments.

While Figure 71 shows the overall subscribership ratio, which is a state-level average, Figure 72 presents more detailed information on how subscribership varies across tracts. The trends are for broadband at the 200 kbps threshold. The figure shows the number of households in tracts with a given level of the subscribership ratio. By 2013 (although not in the earlier years), nearly every household was in a tract with a subscribership ratio greater than 60%. Just over half of households (6.54 million out of 13.0 million) were in tracts with a greater than 80% subscribership ratio. Regardless which subscription category is examined, the number of households in the category increased during this time. Thus, adoption was increasing across the distribution of tracts in the state; the overall upward trend in the subscribership ratios plotted in Figure 71 were not driven solely by a few densely populated areas.

¹⁰⁰ The ratio is calculated by the FCC (2014a) as the number of residential fixed connections meeting the speed threshold divided by the estimated number of households in the state.

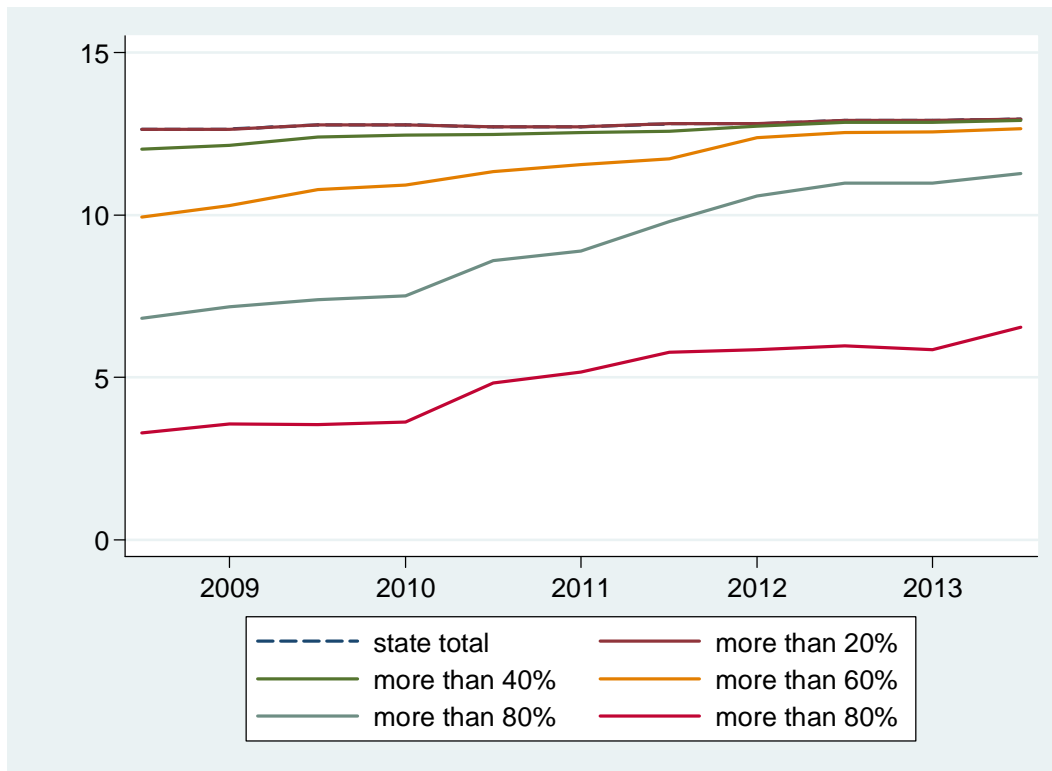
¹⁰¹ California's subscribership ratio as estimated by the FCC is close to the household broadband adoption rate of 80% calculated from the American Community Survey data described in footnote 22 and presented in.

Figure 71: Household subscribership ratio for residential fixed broadband connections in California, 2009-2013



Notes: Source data taken from FCC (2014a) and similar reports from previous years.

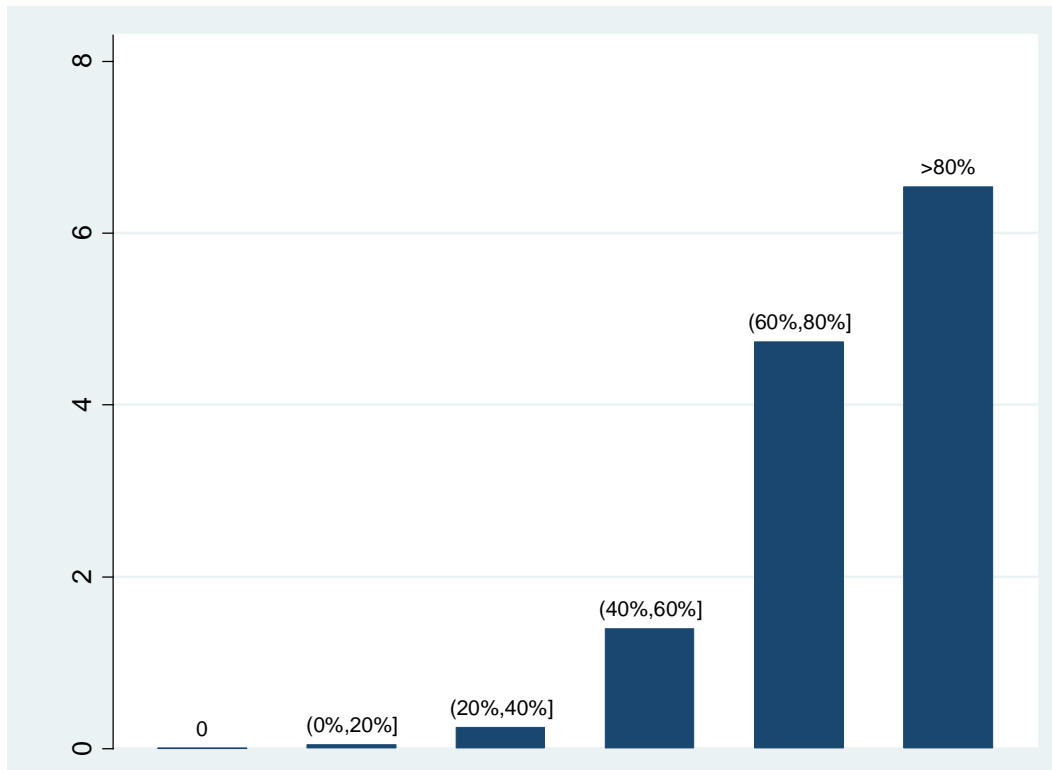
Figure 72: Households by subscription level of Census tract (residential fixed broadband connections), 2009-2013



Notes: Percentages refer to the residential fixed connections per household (i.e., the subscription ratio) in the tract. The counts are the number of million households in tracts with the indicated range for the subscription ratio. "State total" refers to the total number of households in California, and where obscured it lies underneath the line for "more than 20%". The speed threshold for broadband is 200 kbps in at least one direction.

The complete distribution of the adoption categories at the end of the period is shown in Figure 73. The most common category is for a household to be in a tract with the highest subscription category of more than 80%. Only a very small fraction of households (2.2%) are in tracts with subscription ratios of less than or equal to 40%.

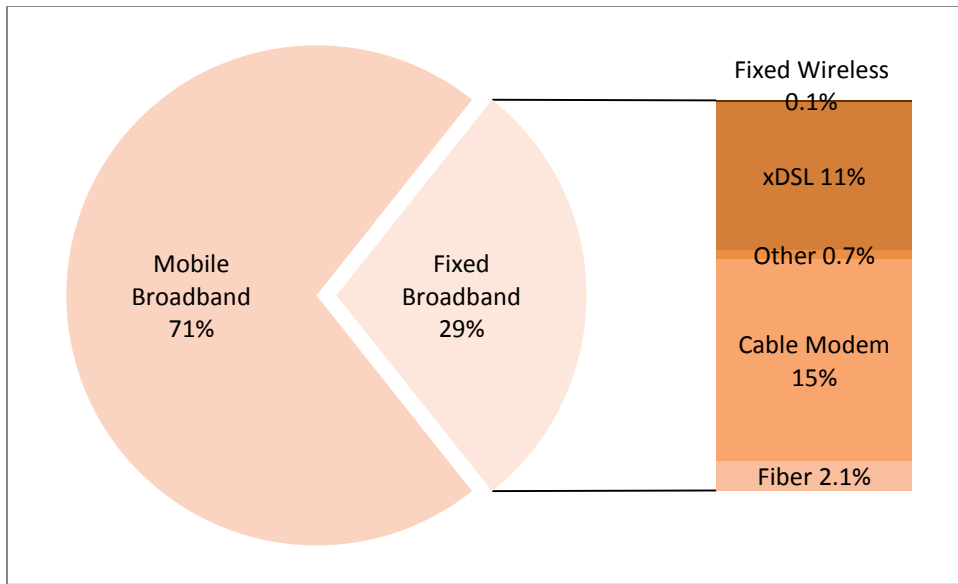
Figure 73: Distribution of household adoption ratio for residential fixed broadband connections in California, December 2013



Note: Chart shows the number of households in tracts with subscribership levels in the indicated ranges. The speed threshold for broadband is 200 kbps in at least one direction.

The figures above in this section have only included fixed broadband access. However, the most common form of broadband access today is mobile. Figure 74 breaks down total broadband lines in California as of year-end 2013 by mode of access. For every fixed broadband line in the state, there are almost two and a half mobile broadband lines. Among fixed broadband lines, cable modem and DSL lines constitute the great majority of lines, with small market shares for fiber, fixed wireless, and other broadband modes of access.

Figure 74: Types of broadband connections in California, December 31, 2013



Notes: Includes residential and business broadband connections of 200 kbps or more in at least one direction. Data are from Table 16 of FCC (2014a).

B. Growth of adoption by subpopulations

In this section, adoption of broadband in California by rural residents, some minorities, and low-income households is examined.

1. Rural residents

Internet and broadband use in rural areas has always lagged that of urban areas in the U.S. The gaps have been closing, albeit slowly. In 2010, the gap between metropolitan and non-metro areas in household broadband usage of any form across the nation was 13.1 percentage points (Prieger, 2013), and the NTIA (2011) found that the urban/rural broadband divide had been shrinking. The most recent *Digital Nation* report from NTIA (2014) showed that the gap had narrowed slightly to 12 percentage points by 2012.

Reasons why rural households lag their urban counterparts in broadband adoption may include differences in the availability, quality, or variety of broadband offerings. Demographic factors may also play a role, since rural households have lower income on average than urban households. Prieger (2013) found that as of 2010 in the nation, for higher-speed fixed broadband, availability and the number of providers in rural areas is lower than in urban areas as expected. However, surprisingly, rural availability appears to be no worse than urban availability for lower-speed fixed broadband (200 kbps or higher).¹⁰² The number of mobile broadband options was lower in rural areas, although few rural tracts lacked at least one mobile

¹⁰² As discussed previously in this report, however, rural availability may still lag urban areas if providers are less likely to cover the entire tract in rural areas than in metro areas.

option. Furthermore, mobile broadband coverage appeared to fill many of the gaps in fixed broadband coverage in rural areas.

Regarding other factors causing the rural adoption gaps, Prieger (2013) finds that income, cost drivers such as population density, the racial and ethnic composition of the area, and the presence of more than three fixed broadband providers all help explain the level of residential fixed broadband subscription in a tract. Nevertheless, even after such factors are controlled for, a rural gap remains. Whether the remaining part of the gap to be explained stems from differences in prices, availability, quality, or consumers' preferences could not be determined.

The FCC data on the subscription ratio examined in section A above cannot be used to look at rural adoption in California, because the state-level statistics are not broken out by urban versus rural areas. However, the FCC tract-level data investigated in section II.A.2 can be adapted to estimate rural adoption. The tract level data contain a categorical variable for the level of residential fixed connections (RFC) per 1000 households (with broadband defined at the 200 kbps threshold). The categories are the same as shown in Figure 73. The observed adoption category of rural tracts can be used to estimate the proportion of rural households with access to residential fixed broadband in the home, a measure comparable to the household subscribership ratio for the state discussed in section A above. While the method relies on econometric methods to back out the underlying level of adoption from the categorical data,¹⁰³ in principle the estimates are the expected value of the adoption level given the observed category of RFC per 1000 households and other relevant characteristics of the tract. However, the method requires identifying and using Census tracts that are nearly exclusively rural, which will be called "deep rural" here.¹⁰⁴ For this reason, the statistics presented here should not be compared with other estimates of rural broadband adoption for the state or nation. The purpose of the examination here is mainly to assess recent trends in rural adoption, not the adoption rate among all rural Californians (which is not presently estimable).

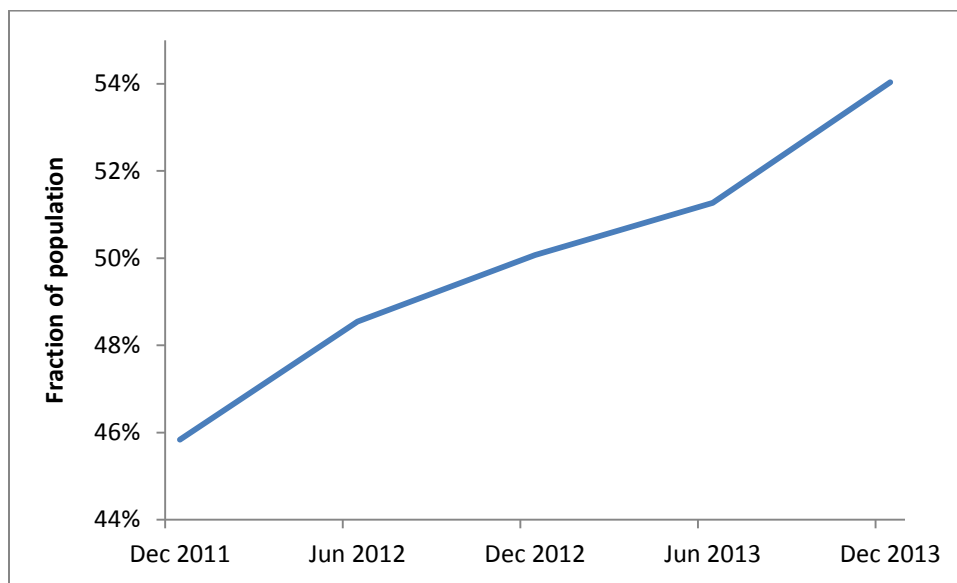
The resulting estimates of the fixed broadband subscribership ratio in deep rural tracts are in Figure 75. For the sake of direct comparability among years, only the final two years of data

¹⁰³ The figures are estimated from an interval-censored regression model as follows. First, Census tracts with at least 95% of the population in a rural area are identified. The dependent variable for the regression is the categorical data from the FCC for residential fixed broadband connections per household (RFC/HH). The FCC groups the data so that (for example) if RFC/HH is 0.67 in a tract, it is reported as "more than 0.6 but no more than 0.8." Assuming the underlying actual RFC/HH is normally distributed, interval-censored regression allows the categorical data to be converted into a point estimate. The categorical dependent variable is regressed on a constant and tract level variables for the fraction Native American, fraction Hispanic, and fraction of households in poverty. (Regressors for the fractions Black and Asian were found to be unimportant because of the small numbers of such people in rural areas.) The predicted RFC/HH from the regression is then calculated as the expected value of RFC/HH conditional on being in the given category and the regressors.

¹⁰⁴ Depending on the year, about 250 California tracts, about 3.5% of the total, are deep rural. Rural population in deep rural tracts compose 2.2% of the state's population, whereas the entire rural population is about 5.4% of the total population.

(December 2011 to December 2013) are shown.¹⁰⁵ For the two year span shown in the figure, estimated deep rural adoption of fixed broadband in the home rose steadily from under 46% to just over 54%. This eight percentage point increase represents an 18% jump in the subscribership ratio. Recall that section II.D.1.b above found little evidence for increasing rural availability, and that most rural areas already had access to broadband in recent years. Thus, growth in the subscribership ratio in deep rural areas would appear to be mostly driven by increasing demand among consumers rather than availability. Despite the improvement in the subscribership ratio, deep rural adoption still lags the statewide subscribership ratio of 78% (refer to section A above).

Figure 75: Estimated deep rural household subscribership ratio in California, 2011-2013



Note: Figures are the fraction of deep rural population living in households with a residential fixed broadband connection (DSL, cable modem, fiber, other wireline, fixed wireless, and satellite; 200 kbps threshold). The figures are estimated as described in footnote 103. Only tracts with at least 95% of population in a rural area are considered “deep rural” and included. Broadband adoption data are from the FCC as described in the text.

2. Minorities

Since statistics were first gathered on Internet and broadband usage, the national data showed sizeable disparities in broadband usage between some minorities and whites.¹⁰⁶ Possible reasons for these broadband gaps include lack of computer ownership, low income, and (in

¹⁰⁵ Refer to the discussion of the problematic demographic data for 2010 and 2011 in section II.D.1.b. In the earlier years there is also steady growth in rural adoption, but there is an apparent but meaningless downward shift in the period that the total rural population figures also change.

¹⁰⁶ This paragraph and the next draw heavily on Prieger (2015). Otherwise unattributed statistics are from that article.

earlier years) lack of broadband availability.¹⁰⁷ The NTIA (2011) concluded that when compared with whites, “[s]ignificant disparities ... remained [in 2010] among other race and ethnic groups [excepting Asian and white non-Hispanics], with none exceeding broadband use of greater than 50 percent” (p.11). While there had been growth in broadband use for African Americans and Hispanics during the period 2007 to 2010, that growth stalled nationally between 2010 and 2011 (Prieger, 2015).

The groups particularly at risk of lacking access to broadband in the home include African Americans, Hispanics, and Native Americans. In July 2011, the overall broadband adoption rate in America was 65%, while white non-Hispanics had a greater likelihood of home broadband access (71%). Hispanics and Native Americans had the lowest usage (49%), with usage among blacks only slightly higher (52%). Broadband usage gaps for blacks have been found since the early days of broadband in the home (Hu and Prieger, 2009). Although some of the broadband gaps for minorities are caused by lower incomes, income alone does not fully explain the broadband digital divide. In 2011, among members of households earning less than \$20,000, 31% of blacks and 25% of Hispanics used broadband at home, compared with 43% of white non-Hispanics. Clearly factors other than income contribute toward the gaps. Similarly, differences in education do not explain the entire usage gap between whites and non-whites either. Among high-school dropouts in 2011, 23% each of African Americans and Hispanics used broadband at home, which lags usage by white dropouts (35%).¹⁰⁸

Turn now to the recent situation in California. The most recently available American Community Survey from the Census Bureau asks respondents for the first time about broadband access in the home. The survey responses allow investigation of broadband access in minority households in California. Note that questions in the survey about broadband access pertain to the entire household, and information about which members use which types of broadband, if any, is not available. Thus the statistics in this section and the next are for people living in households with broadband, with no guarantee that each household member actually uses any particular mode of broadband to access the Internet.

Table 7 shows the proportion of people living in households with various forms of broadband access, for all residents and by race and Hispanic ethnicity. Overall, 80% of Californians are estimated to have access to broadband in the home. The figure is about the same for, higher for non-Hispanic whites, Asian and multiracial residents, and lower for blacks, Native Americans, and Hispanics. The gaps between whites on the one hand and blacks, Native Americans, and Hispanics on the other hand range from 14 to 16 percentage points, which (based on the review of the digital divide in earlier years above) is evidence of some narrowing of these gaps. As recently as 2011, the national broadband access gap between whites and others were 18 points for African Americans and 23 points for Hispanics (Prieger, 2015).

¹⁰⁷ See Prieger and Hu (2008) for a review of the literature on minorities and broadband usage and access.

¹⁰⁸ Gant et al. (2010) also show that the differential Internet adoption rates of minorities are not explained solely by rural versus non-rural location, for blacks and Hispanics lagged whites in both areas.

Table 7: Broadband Adoption in California by race and ethnicity, 2013

	Any Broadband	Fixed Broadband	Mobile Broadband	Mobile Broadband Only	Mobile BB Only ÷ Any BB
	<i>percent total (1000s)</i>	<i>percent total (1000s)</i>	<i>percent total (1000s)</i>	<i>percent total (1000s)</i>	<i>percent</i>
All Californians	80.3% 30,129.5	74.9% 28,108.6	39.3% 14,747.1	5.4% 2,020.9	6.7%
White Non-Hispanic	86.8% 12,630.0	82.3% 11,986.5	43.9% 6,395.4	4.4% 643.5	5.1%
Black	72.5% 1,485.31	66.1% 1,353.29	33.5% 686.13	6.5% 132.02	8.9%
Native American	70.7% 93.0	64.2% 84.4	35.8% 47.1	6.5% 8.6	9.3%
Asian	89.0% 4,630.5	85.7% 4,455.2	44.3% 2,301.7	3.4% 175.3	3.8%
Multiracial	88.8% 1,439.9	83.5% 1,344.3	50.4% 812.5	5.4% 95.6	6.0%
Hispanic	71.2% 9,316.3	64.3% 4,771.6	32.9% 1,004.1	6.9% 3,836.7	9.7%

Notes: Figures are calculated by the author using data from the 2013 American Community Survey (1 year estimates). Column labeled “Mobile BB Only ÷ Any BB” is the proportion of people with access to broadband for whom mobile broadband is their only mode of access available in the home. The categories for each race exclude those of Hispanic ethnicity. The row for Hispanics includes all those who identify with Hispanic ethnicity, regardless of race. The category for Native American includes American Indians and Alaskan Natives. The category for Asian includes Hawaiian Natives and Pacific Islanders. Statistics are weighted to be representative of California’s population.

Regardless of race or ethnicity, most households with broadband access subscribe to fixed broadband. Overall, 75% of the population is in households with fixed broadband access, an estimate that is close to the household subscribership ratio of 78% from the FCC (2014a).¹⁰⁹ However, the reliance on mobile broadband is heavier for some minority groups. People living in African American, Native American, and Hispanic households are more likely than whites to have access to mobile broadband and not fixed broadband (column four of Table 7), even though each of these minority groups is less likely to have any form of broadband access (column one). Similarly, when looking at the fraction of people in households with broadband access who rely on mobile broadband exclusively, the final column of Table 7, Native Americans have the highest relative reliance on mobile, at almost 11%. Hispanics (9.7%) and blacks (9.0%) also have a higher relative reliance on mobile broadband than do whites (7.1%). These figures again point to the high importance that mobile broadband can play in minorities’ lives.

¹⁰⁹ Discrepancies between the two estimates are due to differences in household size between adopters and non-adopters, the fact that no specific speed threshold was given to survey respondents to define broadband while the FCC used the 200 kbps standard, and estimation error, inter alia.

Alternative data from the Pew Research Center show that even starker differences concerning mobile broadband exist among whites, blacks, and Hispanics when it comes to actual Internet usage (as opposed to access in the household). In 2013, while 59% of whites stated that they go online using their mobile phone, 74% of blacks and 68% of Hispanics were mobile Internet users via their phone (Duggan and Smith, 2013). Even greater differences arise when asking about the Internet access mode of choice. Only 27% of whites stated that they go online mostly using their cell phone, but 43% of African Americans and 60% of Hispanics responded that they most often go online using their cell phone.

3. Low-income households

In 2010, about 65% of Americans lived in homes with broadband access, but 65% of low-income households *lacked* broadband at home (Dailey et al., 2010)—a digital divide of 30 percentage points.¹¹⁰ As part of the activity surrounding the creation of the National Broadband Plan, the FCC commissioned the Social Science Research Council (SSRC) to analyze the factors causing the observed low rates of adoption of broadband services in low-income homes. The resulting report (Dailey et al., 2010) highlighted several challenges facing broadband adoption by low-income households. Besides the obvious importance of cost in the household's decision to adopt broadband, equally or more important at the time were lack of availability, difficulty in understanding plan details and billing, lack of the digital literacy required to use the Internet, or technical issues such as lack of a computer or broken modems.

The broadband adoption gap between low-income and other households has narrowed, at least in California. Data from the American Community Survey analyzed for this report show that the broadband gap between low-income and all households had narrowed to slightly less than 20 percentage points by 2013. The latter statistic is calculated for comparability with the 30 point gap from 2010 cited above, although it is better to split the population into mutually exclusive groups for such comparisons, as in Table 8. When comparing households above and below the official poverty threshold in California, 84.2% of higher-income residents were estimated to have broadband of some sort available in the home, but only 60.8% of those living in low-income households had broadband access. Low-income households were more likely to rely on mobile broadband than were higher-income households. About 6.7% of low-income Californians were in households with only mobile broadband, versus 5.1% of higher-income people. Similarly, the proportion of broadband users who rely exclusively on mobile broadband (the final column of Table 8) is higher for the low-income group: 11% versus 6% of higher income broadband users.

¹¹⁰ The statistic refers to households with annual income below \$25,000.

Table 8: Broadband Adoption in California by people in low-income households, 2013

	Any Broadband	Fixed Broadband	Mobile Broadband	Mobile Broadband Only	Mobile BB Only ÷ Any BB
<i>Below poverty line</i>					
Percent	60.8%	54.2%	25.5%	6.7%	11.0%
Total (1000s)	3,836.7	3,415.0	1,618.0	421.7	
<i>Above poverty line</i>					
Percent	84.2%	79.0%	42.0%	5.1%	6.1%

Notes: Figures are calculated by the author using data from the 2013 American Community Survey (1 year estimates). Column labeled “Mobile BB Only ÷ Any BB” is the proportion of people with access to broadband for whom mobile broadband is their only mode of access available in the home.

The Pew Research Center also found that cell phones and smartphones are more central to the online experience for lower income consumers than for others. While only 27% of people in U.S. households with annual income above \$75,000 said they went online mostly using their cell phones, 45% of those in households with income less than \$30,000 mostly used their cell phones to access the Internet (Duggan and Smith, 2013).

IV. Broadband Quality and Prices

The price and quality of broadband Internet access are two key drivers of demand. The quality of the total broadband experience for users depends on many factors, only some of which are under the control of the broadband providers. For example, network latency,¹¹¹ congestion, and packet loss in the Internet, as well as slow performance at web servers and low-quality inside wiring at the customer’s premises, will degrade the end user’s quality of experience, regardless of the speed of the last-mile connection. Nevertheless, a major aspect of broadband quality is the download speed of the ISP’s service. Upload speeds are also important, but usually to a lesser extent unless the user hosts a web site or often uploads huge files. Given its importance, as well as the fact that advertised speed is the easiest dimension of quality to measure, the maximum advertised download and upload speeds offered in the state will be examined here.

Price is also a major determinant of demand for broadband. Characterizing prices across the state and over time is challenging. Some of the difficulty would pertain to analysis of any good or service’s prices. Developing a price index to examine trends in pricing is difficult without detailed data on prices in the marketplace and which consumers choose which option. Other challenges in analyzing prices apply to the broadband market in particular. Most important is a paucity of comprehensive data. Regarding prices for Internet access, the publicly available data do not allow construction of a price index for the US that is minimally sufficient to examine

¹¹¹ Latency is the time it takes for a data packet to travel from one point to another in a network. In practical terms, latency results in delay between (for example) clicking on a website and observing the result of the click.

trends in broadband affordability (Molnar, Savage, and Sicker, 2014). In particular, although the US Bureau of Labor Statistics includes Internet access in its computation of the Consumer Price Index (CPI), it does not adequately account for the improving quality of Internet access over the years (Greenstein, 2002; Molnar, Savage, and Sicker, 2014).¹¹² In this section, therefore, available evidence on the quality and price of broadband is reviewed, with recognition that the picture is incomplete.

Proprietary data from a national research firm on prices and offerings for residential broadband Internet access by a significant subset of broadband providers was aggregated and used in this report. The advertised speed and prices of these offerings are examined in this section, along with other publicly available data. The proprietary data do not offer a complete picture of residential broadband plans in California because neither all areas of the state nor all forms of broadband access are included.¹¹³ Nevertheless, these broadband options reveal how service quality, as measured by download speeds, has increased and prices have fallen over time, at least in this segment of the broadband market. The proprietary sample also has an advantage over many other price surveys of broadband service: it includes every offering by every provider within the class (residential cable modem service).¹¹⁴ The available information on broadband quality in recent years is reviewed in section A and prices are examined in section B.

A. The increasing speed of service

During the period covered by this report, 1999 to present, private broadband providers in the U.S. have invested over 1.2 trillion dollars in capital expenditure.¹¹⁵ Even excluding the telecom boom years, investment by wireline and wireless telecommunications and cable broadband providers totaled over 800 million dollars since 2003. In more recent years, investment in network infrastructure in the U.S. has remained steady since 2009 at about 0.45% of GDP. In 2014, capital expenditure of broadband providers in the nation was \$78 billion. All this investment in deploying infrastructure and improved support systems has led to steady increases in the speeds offered in the broadband marketplace. This section presents some data

¹¹² In particular, Molnar, Savage, and Sicker (2014) criticize the CPI for not hedonically adjusting Internet access prices for changes in speed and for not including prices in rural areas.

¹¹³ Markets examined include these large markets: Anaheim/Orange County, Bakersfield, Fresno/Visalia, Los Angeles, Riverside, Sacramento/Modesto/Stockton, San Diego, San Francisco, San Jose; and these small markets: Chico, El Centro, Eureka, Monterey/Salinas, and San Luis Obispo. Cable companies operating in these California markets include: Bright House, Charter, Comcast, Cox Communications, Suddenlink, Time Warner Cable, Verizon, and Wave Broadband.

¹¹⁴ Subject to the availability of the data. Plan prices were ascertained by examination of offering on the companies' websites and by calling the providers. Not all prices of all plans could be verified.

¹¹⁵ The data on capex are from USTelecom (<http://www.ustelecom.org/broadband-industry-stats/investment/historical-broadband-provider-capex>), who in turn used a variety of industry sources. The data exclude resellers, satellite providers, and electric utilities even if they provide internet access service. USTelecom states that the figures for capex include "investment in property, plant, and equipment, capitalized software, capitalized interest during construction, corporate, directory, and other capital expenditures, and intra-company eliminations."

on how the quality of broadband has improved in California, beginning with a focus on residential broadband.

1. Quality options for residential broadband

The maximum advertised download speeds in the proprietary sample of the residential service options of cable companies in California are characterized in Figure 76. While information on actual download data transfer rates are unavailable, recent FCC investigation has found that cable modem service on average in the US has slightly higher actual speed than advertised speed.¹¹⁶ The figure shows year-by-year “survival curves” for download speed during the period 2008 to present.¹¹⁷ A survival curve presents information about the entire distribution of speed offerings. Each curve shows the proportion of broadband packages offering speed at or higher than the level noted on the horizontal axis. The curves shift to the right over the years, indicating that a greater proportion of the plans offer any given download speed. Thus curves further to the right reflect that quality is increasing across the entire distribution of broadband offerings.¹¹⁸

Figure 76 depicts survival curves for broadband speed for six recent years starting in 2008. With some exceptions at the low end of the distributions (those for the slowest speeds), the survival curves clearly shift out to the right each period. While the curves summarize the entire distribution of the offerings, specific summary statistics can also be examined. For example, by looking at the 50% level on the vertical axis, a curve shows the download speed of the median plan offered in that year.¹¹⁹ The median speeds are shown for all years in Table 9, which shows that the typical speed offered rose from 7 Mbps in June 2008 to 55 Mbps in June 2015. The table also shows the maximum speeds offered, which rose from only 16 Mbps in 2008 to 500 Mbps in 2015. Furthermore, a mathematical implication of the curves shifting to the right over time is that the *average* advertised speed must also have increased.¹²⁰

As with any technology, varied consumer preferences and price sensitivity lead many households to choose broadband options slower than speeds at the technological frontier offered in the market. Actual broadband speeds for subscribers on average thus do not rise apace with the maximum speeds available. The breakdown of actual subscriber speeds for year-end 2013 for all of California is shown in Figure 77. Slightly less than two-fifths of broadband

¹¹⁶ See FCC (2014b). Refer also to footnote 66.

¹¹⁷ Survival curves are so-named from the epidemiology literature, where they refer to the proportion of subjects living longer than a specified time. In general, survival curves are just one minus the cumulative density function of any random variable.

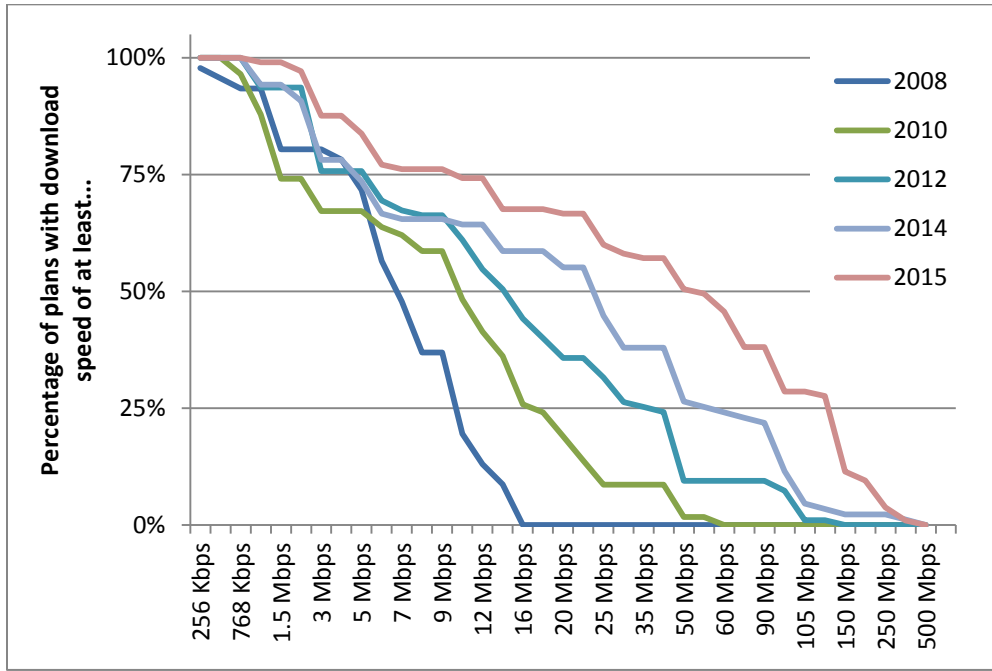
¹¹⁸ The technical term for this sort of increase in the distribution is first-order stochastic dominance. See footnote 120.

¹¹⁹ Note that the plans are weighted equally because no information on the number of subscribers to the plans is available. Thus, the median *subscriber* does not necessarily have the median *plan's* download speed.

¹²⁰ When the survival curve for random variable *A* is to the right of the survival curve for random variable *B*, the distribution of *A* is said to *first-order stochastically dominate* that of *B*. First order stochastic dominance implied that the expected value of *A* must be greater than that of *B* (Hirshleifer and Riley, 1992).

subscribers (residences and businesses, fixed and mobile) chose plans with download speed of 10 Mbps or higher. About half of broadband connections in the state had advertised download speeds above 6 Mbps, and only about a fifth were slower than 3 Mbps.

Figure 76: Download speed advertised by a selection of broadband service providers in California, 2008-2015



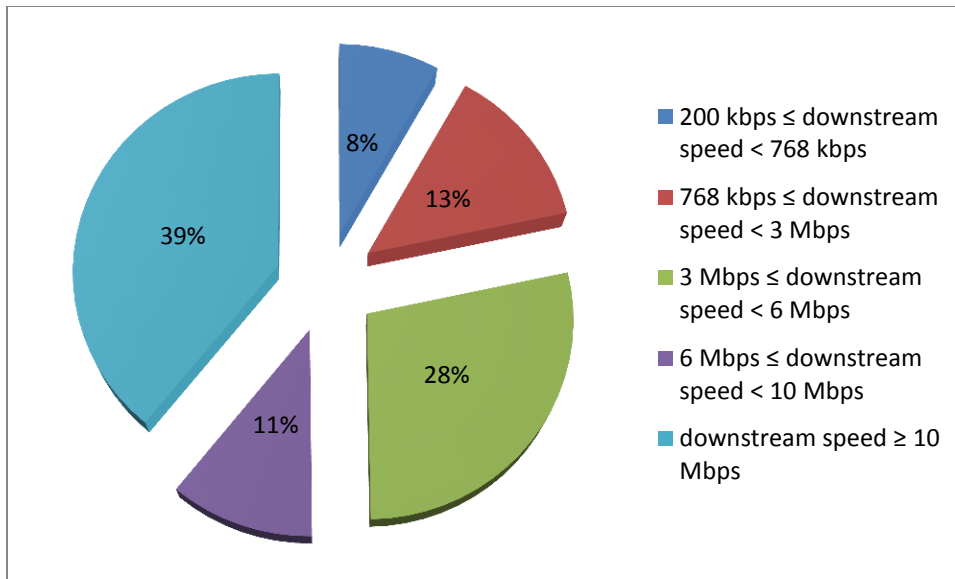
Note: Each curve shows a “survival curve” for speed: the proportion of broadband service plans advertising download speed of at least the rate given on the horizontal axis. Data are provided by a third party research company. Data are as of midyear.

Table 9: Median download speed advertised by a selection of broadband service providers in California, 2008-2015

Year	Download speed of median offering	Maximum download speed
2008	7 Mbps	16 Mbps
2009	9 Mbps	50 Mbps
2010	10 Mbps	60 Mbps
2011	12 Mbps	150 Mbps
2012	16 Mbps	150 Mbps
2013	25 Mbps	300 Mbps
2014	25 Mbps	500 Mbps
2015	55 Mbps	500 Mbps

Note: Median and maximum are calculated across all plans and companies in the data. Data are provided by a third party research company. Data are as of midyear.

Figure 77: Broadband connections in California by downstream speed, December 31, 2013



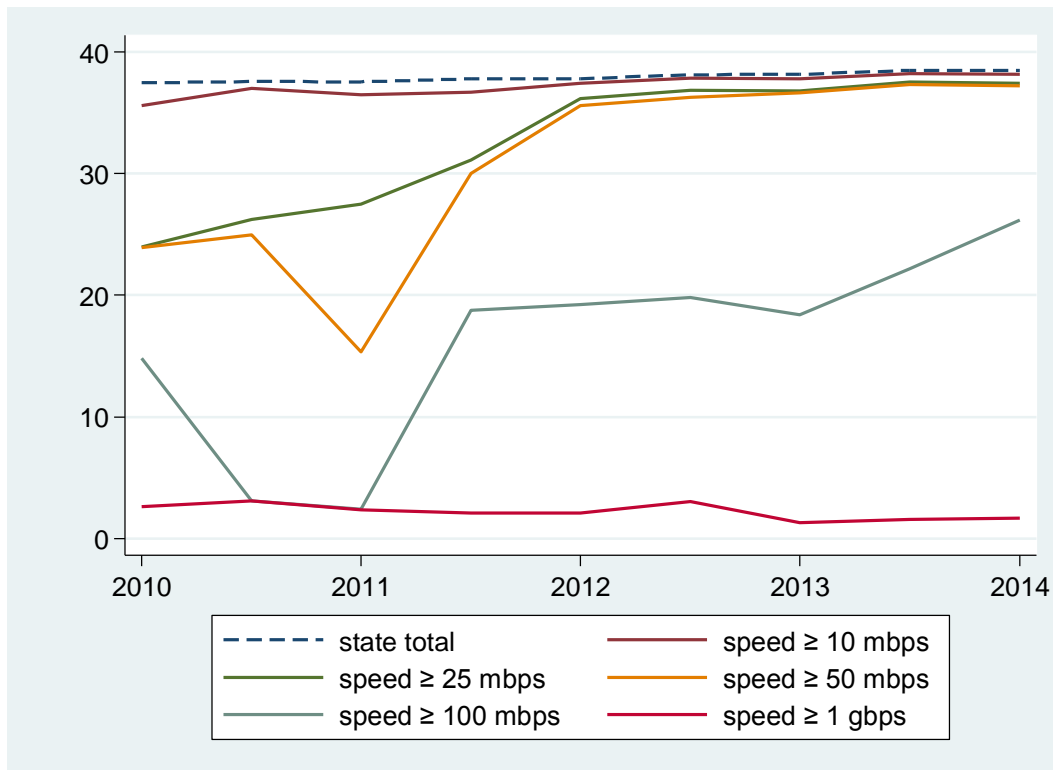
Notes: Includes all connections over 200 kbps in both directions. Calculated from source data from Table 18 of FCC (2014a).

In addition to the proprietary data, the publicly available data from the National Broadband Map contain information on maximum advertised download and upload speed within each Census block. This information is aggregated to the block group level (as described above in section II.A.3.a) for matching to counts of the population. The data include only fixed broadband options, and excludes satellite broadband. Figure 78 shows the number of California residents living in block groups with access to various speeds of fixed broadband. Comparison of the dashed line for total population and the dark red line just below it reveals that at least since 2010, most Californians lived in areas in which broadband of at least 10 Mbps download was deployed. The green and orange lines show that while only about two-thirds of residents had access to broadband in excess of 25 and 50 Mbps in 2010, almost all did by 2014. The expansion of availability of higher speed service was due in no small part to cable broadband providers deploying DOCSIS 3.0 speeds (50 Mbps and above) during this time. Download speeds of 100 Mbps and higher were available where only 14.8 million people lived in 2008, but were available to 26.2 million people in 2014. There is relatively little gigabit service available during this entire period.

Even though most people live where 10 Mbps broadband is available, Figure 77 above showed that many apparently do not subscribe to it. However, no direct comparison between availability in Figure 78 and the purchased access speeds found in Figure 77 is possible, due to the differing sets of broadband lines underlying the figures. The statistics on availability in Figure 78 are for fixed broadband, while the FCC includes mobile broadband—which at the time tended to be slower than fixed-line service—in the connections reflected in Figure 77.

Nationally, at the end of 2013, 58% of mobile broadband connections had download speeds slower than 6 Mbps,¹²¹ and recall from Figure 74 above that 71% of all connections in California were mobile. These figures imply with some calculation that of the half of broadband connections in California with download speed no more than 6 Mbps, 83% of them are mobile.¹²² If a figure comparable to Figure 77 but excluding mobile connections could be constructed, it would show much greater proportions of customers choosing higher speeds.

Figure 78: Population in Census block groups with various fixed broadband download speeds, 2010 to 2014



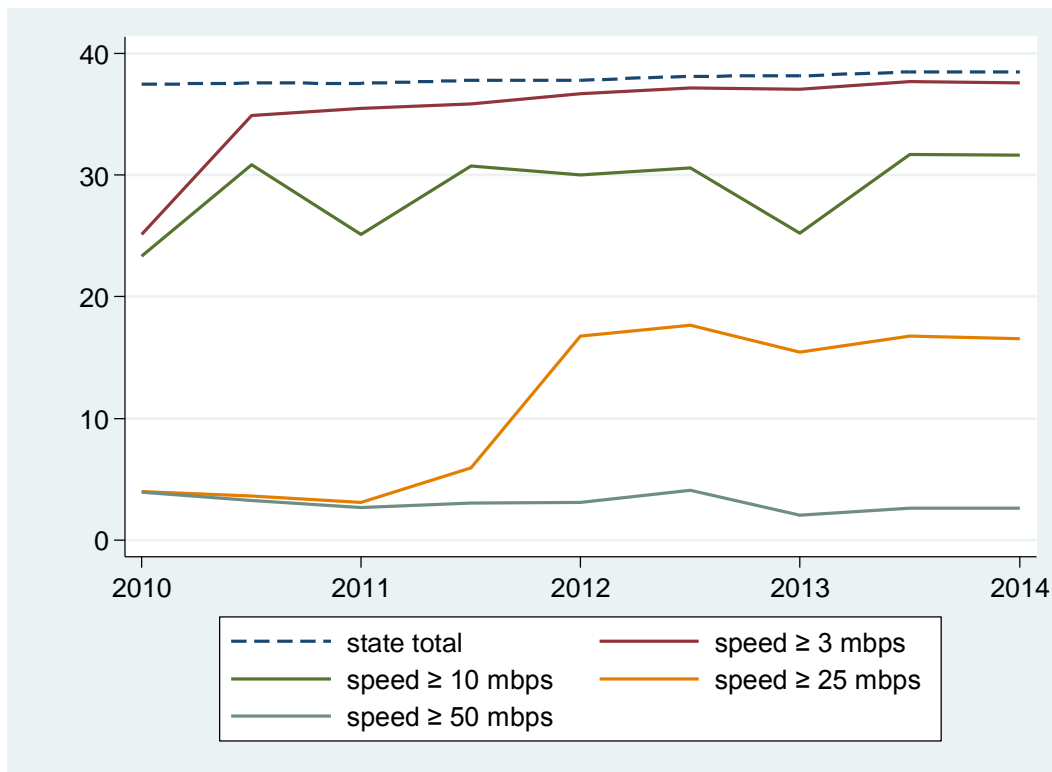
Note: “State total” is the total population for California. The stated speed is the maximum advertised download speed occurring in any one block in the block group, and includes service from all fixed broadband providers (xDSL, cable modem, fiber, other wireline, and fixed wireless) except satellite. Broadband data are from the National Broadband Map as described in the text.

¹²¹ See FCC (2014a), Chart 5. Refer to section I.C.2.b for evidence that mobile broadband speeds in California were much higher in 2015.

¹²² If 58% of mobile connections nationally had speed of no more than 6 Mbps, and (by untestable assumption) the proportion was the same in California, then 16,040 mobile broadband lines in the state were under this speed threshold. There were 19,371 total broadband connections under this threshold. Dividing the former figure by the latter yields the result that 82.8% of the connections under the threshold were mobile.

Upload speeds have also increased over time in California as well, although the change is not as marked as for download speed. Figure 79 shows trends in the availability of various upload speeds. In most areas, maximum upload speeds have been at least 3 Mbps ever since December 2010, and a majority of people have access to upload speed of at least 10 Mbps. The greatest increase has been in the number of Californians living in areas with upload speed of at least 25 Mbps. In 2010, such speed was available to only 4.0 million people in the state. By the end of 2014, 16.5 million had access to it. (Of course, most plans with such high upload speeds are typically marketed to businesses, not residential users.)

Figure 79: Population in Census block groups with various fixed broadband upload speeds, 2010 to 2014



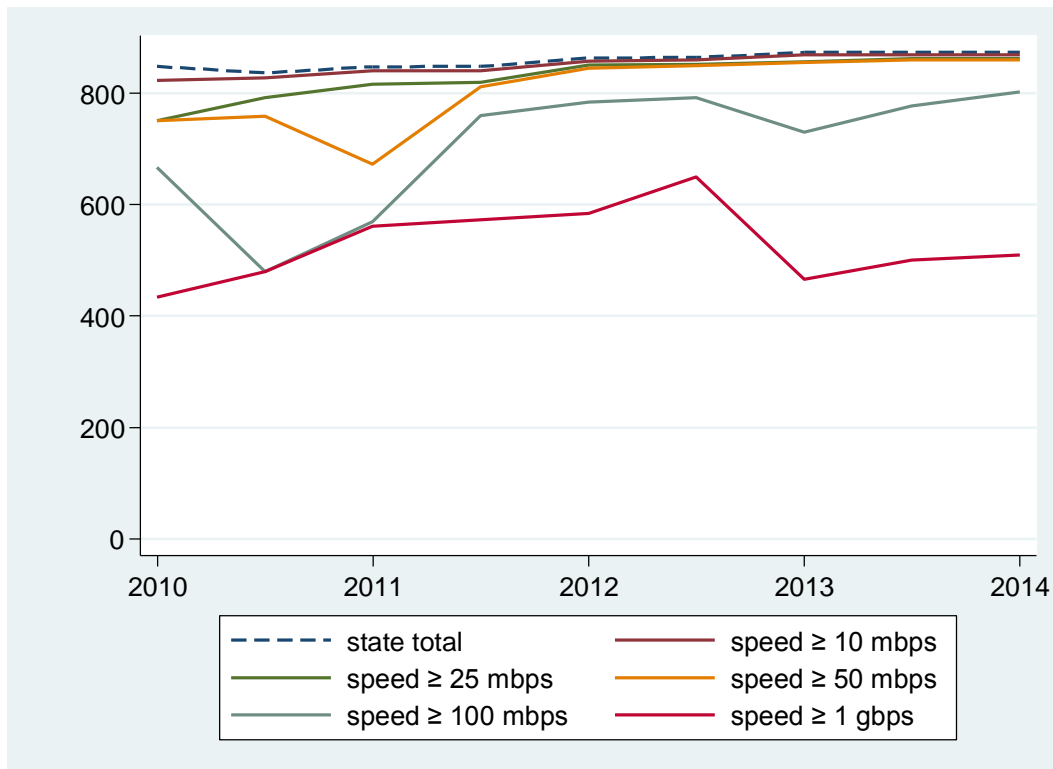
Note: The stated speed is the maximum advertised upload speed occurring in any one block in the block group, and includes service from all fixed broadband providers. See also notes to Figure 78.

2. Quality options for business broadband

Quality of service is highly important for business broadband customers, because their bottom line may depend on it to fulfill orders, procure inputs, restock inventory, and manage administrative and logistical tasks. Since most business establishments are in urban areas where service options are best, and because corporate customers have the greatest demand for bandwidth, a greater proportion of businesses than individuals have access to any given level of download and upload speed.

Figure 80 shows the speed trends for business establishments in the state. As above in section II.A.3.b, the broadband data are aggregated to the ZIP code for matching with business establishment locations. Most establishments were in ZIP codes with access to at least 25 Mbps download speed during the entire period 2010 to 2014. Since year-end 2011, nearly all businesses also had access to 50 Mbps download speeds or higher. By 2014, 802,700 establishments (out of 873,500) were in areas with 100 Mbps service and, of these, about 58% of them (509,900 establishments) had access to gigabit broadband service as well.

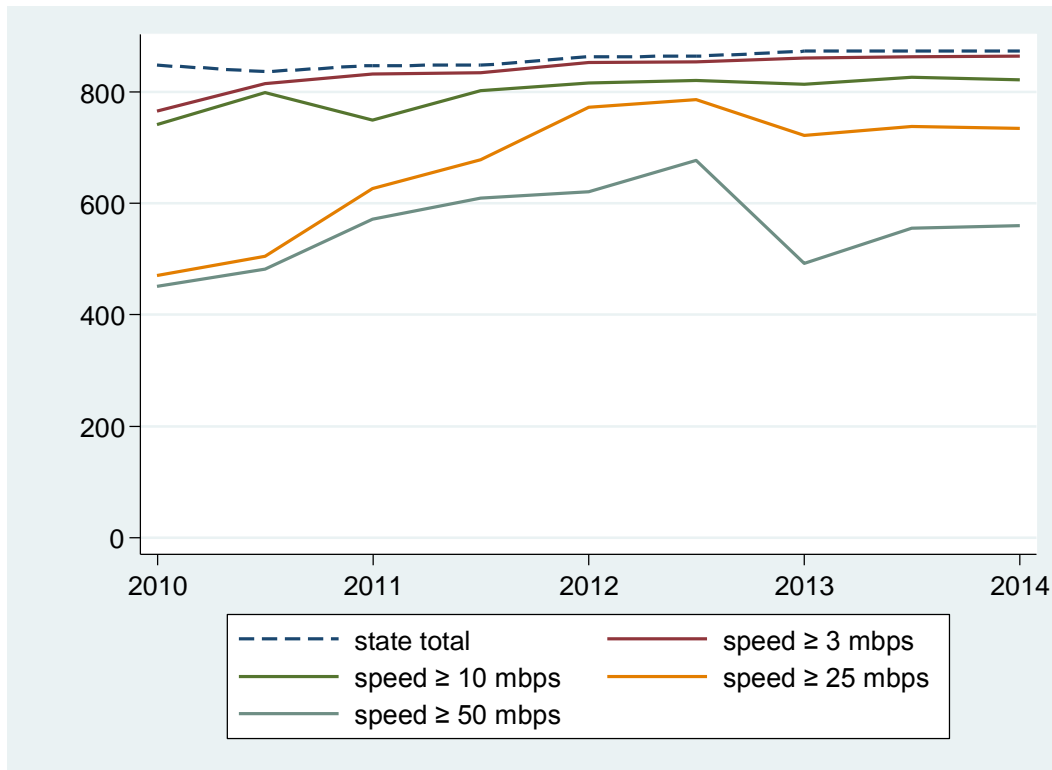
Figure 80: Business establishments in ZIP codes with various fixed broadband download speeds, 2010 to 2014



Notes: “State total” is the total number of business establishments in California. The speed is the maximum advertised download speed occurring in any one block in the ZIP code, and includes all fixed broadband providers (xDSL, cable modem, fiber, other wireline, and fixed wireless) except satellite. Mobile wireless broadband is not included. Broadband data are from the National Broadband Map as described in the text.

Upload speed is more important in general for businesses than for most residential subscribers, since web hosting requires high-speed uploading. Upload speed trends are in Figure 81. The figure shows that during the entire time the median business establishment had access to upload speeds of at least 50 Mbps.

Figure 81: Business establishments in ZIP codes with various fixed broadband upload speeds, 2010 to 2014



Notes: The speed is the maximum advertised upload speed occurring in any one block in the ZIP code. See also notes to Figure 80.

B. The decline in quality-adjusted price for broadband access service

This section presents evidence on the price of broadband service in California. Economists measure the affordability of items in a household's budget various ways. One approach is to express the price of a good or service in terms relative to income. This method is particularly apt when both prices and incomes vary greatly across the units of observation. The ITU measures the affordability of fixed-line household broadband access across the world by calculating the ratio of the price of basic broadband access to gross national income per capita (ITU, 2014). By this measure, the United States ranked third in the world for lowest broadband price (after Macao and Kuwait) in 2013.¹²³ The country ranks much lower in international price comparisons that do not account for *relative* affordability (e.g., Russo and Morgus, 2014; FCC, 2015c).¹²⁴

¹²³ To enable international comparisons, the ITU finds the lowest price fixed-broadband offer in a country providing speed of at least 256 kbps and 1 GB of data volume on the most widely used wired-broadband technology (DSL, cable, etc.). Prices do not include promotions, installation charges, or recurring charges for equipment. Incomes are converted to US dollars using an index of PPP (purchasing power parity).

¹²⁴ There are many reasons why broadband is cheaper in some other countries than in the U.S., including large differences in population density. Exploring such differences is beyond the scope of this report.

However, even when ignoring affordability but accounting for data caps in fixed broadband plans, the United States in 2013 was the fourth least expensive for price per GB of data allowed among the 22 countries with capped plans examined by the FCC's (2015c) International Bureau.

Systematic comparisons among cities or states within the U.S. are harder to come by. A plan offered in San Francisco topped the list among the small number of U.S. cities included in Open Technology Institute's list of "best home broadband deals under \$40" (Russo and Morgus, 2014).¹²⁵

The FCC recently began surveying broadband prices in the US using all plans offered by fixed terrestrial broadband service providers in a random sample of Census tracts.¹²⁶ Results from the latest survey (for 2015) are in Table 9. The FCC collects the data for purposes of determining rate benchmarks for universal service payments, not to construct a quantity-weighted price index. Because the sample is not representative of the popularity of each broadband plan, and the FCC-supplied weights do not account for consumers' choices either,¹²⁷ the data cannot be used to form consistent estimates of the average prices actually paid by consumers.¹²⁸ Even if the weights were ideally constructed to reflect prices facing consumers accurately, the resulting average prices would still be of limited value in assessing consumer welfare. For example, the presence of a legacy high-cost, low-quality plan in a market would inflate the average price without necessarily making any subscribers worse off, if in fact they all chose more advantageous offerings. The same is true of any set of prices for which consumers' choices are unknown, as for the proprietary pricing data examined below. Finally, regional differences in general price levels (e.g., California versus the Midwest or South) make dollar to dollar cross-state comparisons less meaningful.¹²⁹

Table 10 shows both the simple and weighted average price per Mbps of advertised download speed for California and the rest of the nation.¹³⁰ The simple average of the prices in the California subsample, \$6.84 per Mbps of download speed, are quite a bit lower than elsewhere

¹²⁵ U.S. cities included in the comparison were Bristol, VA; Chattanooga, TN; Kansas City; Lafayette, LA; Los Angeles; New York; San Francisco; and Washington, DC. The report also included international comparisons; the San Francisco "best deal" was seventh overall. Data were collected between July and September 2014.

¹²⁶ See the FCC's Urban Rate Survey Data webpage at <https://www.fcc.gov/encyclopedia/urban-rate-survey-data> for details and the data.

¹²⁷ Instead, the weights appear to be intended to approximate the average of the set of prices facing subscribers in the marketplace (the FCC does not state in the documentation to the survey exactly what quantity in the population could be consistently estimated using the weights). Given the ad hoc nature of the construction of the weights, however, the accuracy of the approximation is unknown. As an example of the necessarily arbitrary procedures followed in creating the weights, prices from two similar plans offered by the same provider were given half the weight of two similar plans offered by different providers. This rule is at best only the crudest of approximations to a true quantity-weighted price index.

¹²⁸ The weights account for population in the tract, but not the subscribership of each plan (except in a crude fashion to distinguish "major" from "minor" providers in a tract).

¹²⁹ There are no official price indices at the state-level available for the U.S.

¹³⁰ While the FCC collected data from Puerto Rico, those prices were not included in the analysis here.

in the nation (\$8.53/Mbps). The weighted average price is a bit higher in California than elsewhere (\$9.41/Mbps vs. \$9.15/Mbps, or less than 3% higher in California). The difference in weighted prices is not statistically significant.¹³¹

Table 10: Broadband price survey from the FCC, 2015

	\$/Mbps Download	
	Simple Average	Weighted average
California	\$6.84	\$9.41
Rest of Nation	\$8.53	\$9.15

Notes: Calculations by the author using data from the FCC's *Urban Rate Broadband Survey*.

Similar difficulties in interpretation are present when examining the prices of service offerings in the proprietary data for California cable modem service (described in the introduction to this section). Thus, rather than trying to construct a price index or to weight the data in an ad hoc fashion, simple statistics on the prices of cable modem service in parts of California are presented in Table 11. Data from June 2008 are compared with prices in June 2015. Despite the conceptual difficulty in relating these prices to how well off consumers may be, examining how prices change over time is still useful. While, technically speaking, a decreasing average price of offered plans is neither a necessary nor sufficient condition for consumer welfare to increase, it is of course likely that consumers are better off when prices are declining.

Prices are broken out by the size of market and whether the price for Internet access is part of a bundle of video and voice services. In general, the price of Internet access drops when it is part of a bundle. The prices are calculated as the average charge per month for the first two years of service, including any promotional price offered for the initial months. The results show that the minimum, average, and maximum price per Mbps of download speed dropped dramatically within each market/bundle segment over this time. For example, in large California markets,¹³² the average price for Internet-only service fell from \$14.19/Mbps in 2008 to only \$3.34 in 2015. Thus, the average price in 2008 was over four times the average price in 2015 in large markets. In small markets, the average Internet-only price fell from \$7.87 in 2008 to \$3.84 in 2015. Overall, the data show that while the amount of the price decline varies by area and bundle, all markets enjoyed lower prices per unit of download speed in the later period.

¹³¹ A 95% confidence interval for the differences in prices is [-4.91, 5.45]. A hypothesis test that (weighted) prices are the same in California as elsewhere has a p-value of 0.92, and thus the hypothesis cannot be rejected at any reasonable level of significance. Inference here is conducted using the weights and clustering on provider/state pairs. The small sample size and the highly unequal weights contribute toward large standard errors of the estimates.

¹³² Refer to footnote 113 for the list of large and small markets in the sample.

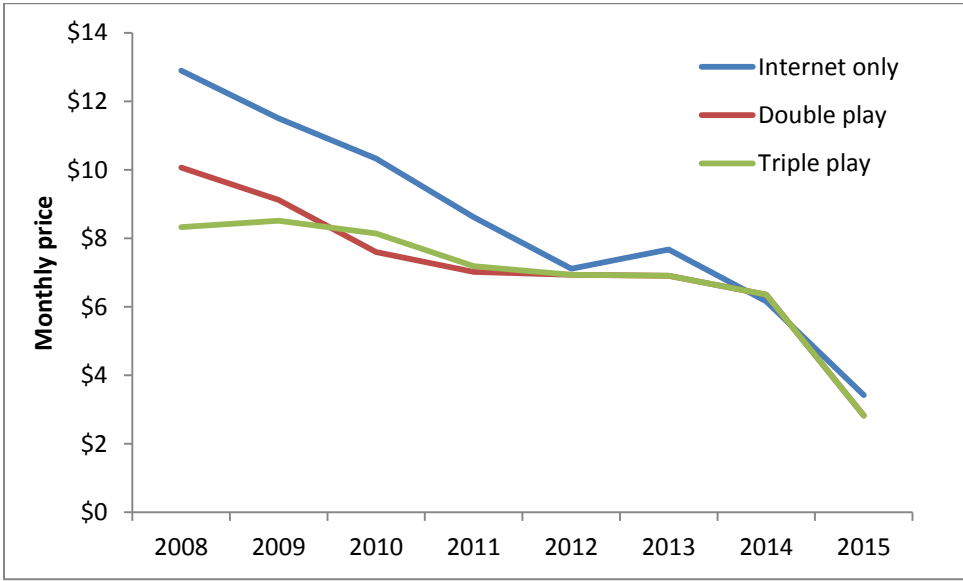
Table 11: Prices of residential cable modem broadband offerings in a subset of California markets

	Standard monthly price per Mbps of download speed					
	2008			2015		
	minimum	average	maximum	minimum	average	maximum
Large markets						
Internet-only	3.66	14.19	99.80	0.36	3.34	21.66
Double play	3.31	11.20	59.80	0.36	2.82	20.00
Triple play	3.31	8.83	26.52	0.36	2.82	20.00
Small markets						
Internet-only	4.18	7.87	13.00	0.53	3.84	13.32
Double play	3.31	6.64	11.00	NA	NA	NA
Triple play	3.31	6.06	7.16	NA	NA	NA
All markets						
Internet-only	3.66	12.89	99.80	0.36	3.42	21.66
Double play	3.31	10.06	59.80	0.36	2.82	20.00
Triple play	3.31	8.32	26.52	0.36	2.82	20.00

Note: Data are provided by a third party research company. Data are for June of each year. Figures are the unweighted average of monthly average prices, where the latter are calculated as the cost for two years of service, including any promotional discounts, divided by 24. Plan cost is then divided by the advertised download speed (excluding any temporary speed boosts). Prices exclude any in-home equipment charges. “Double play” is the price for the Internet component when bundled with phone or TV service. “Triple play” is the price for the Internet component when bundled with phone and TV service. The rows for double and triple play are prices for the Internet access component of the bundle. “NA” indicates that data for bundled offerings were not available.

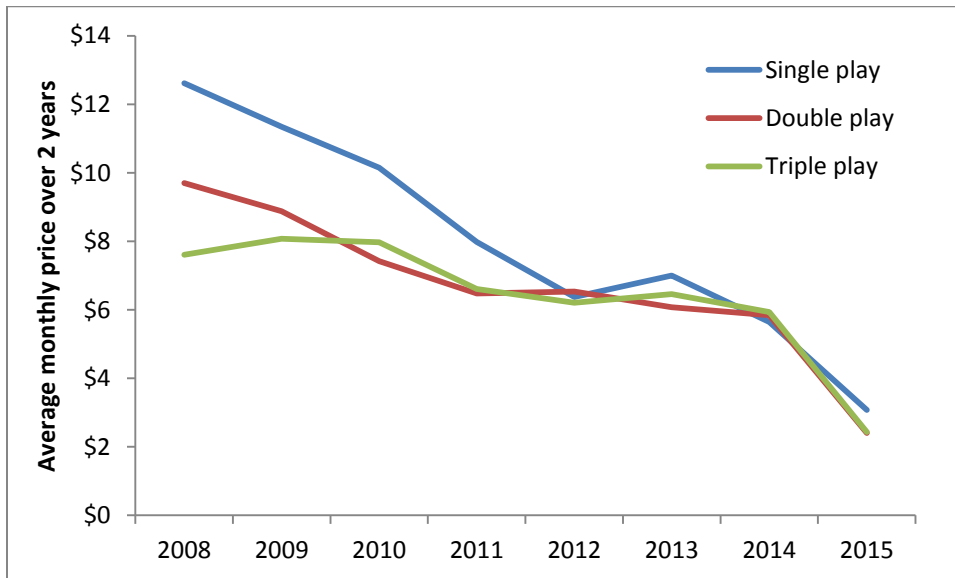
The price declines for all available years of data are plotted in Figure 82. The figures in Table 11 included promotional discounts, which typically apply to the first few months of service only. To show that the price declines are not an artifact of more aggressive promotional pricing, the trends shown in Figure 82 are for recurring monthly charges leaving aside any temporary discounts. Average prices for all types of bundles fell, and the steepest declines came in the past year. The average prices can decline either because existing competitors lower the prices per Mbps (typically by offering a higher-speed service and not proportionally increasing the price) or because new competitors enter the market with lower prices. The same steep declines in average prices are seen when promotional discounts are included, as in Figure 83.

Figure 82: Trends in average standard residential price per MB of download speed in a subset of California markets, 2008-2015



Notes: Figures are monthly service prices calculated as the unweighted average of all plans in the sample, divided by the advertised download speed (excluding any temporary speed boosts). Prices exclude promotional discounts and any in-home equipment charges. See also notes to Table 11.

Figure 83: Trends in average promotional residential price per MB of download speeds in a subset of California markets, 2008-2015



Notes: Figures are service prices calculated as the unweighted average of all plans in the sample, divided by the advertised download speed (excluding any temporary speed boosts). Prices include promotional discounts and exclude in-home equipment charges. Average monthly price is calculated as the price of service for two years (including temporary promotional pricing) divided by 24. See also notes to Figure 82 and Table 11.

V. Policy Implications

The analysis of California’s broadband market above leads to several implications for policy.

A. Tremendous progress but areas for improvement remain

Growth in the availability, quality, price, and adoption of broadband has been remarkable in California in the past few decades. Availability has increased to near ubiquity across the state. Even in rural areas, most residents have access to broadband in some form. The quality of broadband, as measured by speed, is increasing steadily over time. At the same time, the price per unit of download speed has fallen greatly. With rising availability and quality and declining quality-adjusted prices, it is unsurprising that adoption of broadband has also risen much in the 21st century.

Which areas remain for improvement? Certain groups, most notably low-income households, lag in adoption of broadband at home (as shown in section III.B.3). While in some rural areas broadband availability is lacking, the main barrier to increased adoption is not access but the value proposition for consumers, as discussed in section I.C.1.b. Among many non-adopters, particularly those with low income, broadband is just not as attractive as the other uses to which the household budget must be devoted. The value proposition appears particularly unfavorable when digital skills necessary to gain the most benefit from use are lacking,

rendering the perception that the Internet is unusable or irrelevant. Efforts to combat this are discussed in the next section.

Which areas remain for improvement? Certain groups lag in adoption of broadband at home. What would it take to close those gaps in broadband adoption in California? Table 12 shows the proportion of those living in the state with access to broadband in the home. While 80% of the state's residents have broadband access in the home in some form, low-income households, African Americans, Hispanics, and Native Americans lag the average rate by 8 to 10 percentage points. Low income households lag the average by 20 percentage points. There are roughly similar gaps for these groups whether broadband of any form or just fixed broadband in the home is considered.

To close those gaps, a reasonable short-term goal would be to target adoption rates of 85% for any form of broadband and 80% for fixed broadband. These figures lie between the current rates for segments with higher adoption rates and the overall average. The gaps for each group lagging these figures are shown in the third and fourth columns of the table. The overall gap for any broadband is 4.7 percentage points (adoption is currently 80.3% while the goal would be 85%). To meet the goal in five years, therefore, annual progress in home broadband adoption of 0.9 percentage points, or about 353,500 Californians, would be needed.

A. Policy to support access and adoption

California already has mechanisms in place to further broadband infrastructure deployment to new areas and to encourage adoption, as discussed in I.C.2 above. In this section a few issues that arise moving forward are mentioned.

1. Remove barriers to deploying broadband infrastructure

The U.S. has consistently invested in ICT a sizeable share of total private capital investment—more than any other OECD nation.¹³³ Between 2007 and 2012, U.S. investment in broadband in particular was about twice that of Europe in per household terms (Yoo, 2014).¹³⁴ The absolute amount of investment is also a record setter. In 2010, even during the generally weak economic climate after the recession, the US invested \$70 billion in telecommunications investment, twice what the number two nation (China) invested (BFA, 2013).

¹³³ In 2005, for example, almost a third (30%) of private capital expenditure in the U.S. was directed toward ICT (OECD, 2007).

¹³⁴ In 2012, the latest period Yoo (2014) studied, US investment in broadband was \$562 while European investment was only \$244.

Table 12: What Are Reasonable 5-Year Goals for Broadband Adoption?

	Any Broadband	Fixed Broadband	Any Broadband Gap	Fixed Broadband Gap	Annual Progress to Meet Interim Goal in 5 Years
	<i>percent persons (1000s)</i>	<i>percent persons (1000s)</i>	<i>percentage points persons (1000s)</i>	<i>percentage points persons (1000s)</i>	<i>percentage points persons (1000s)</i>
Interim Goal	85.0%	80.0%			
All Californians	80.3% 30,129.5	74.9% 28,108.6	4.7 1,767.5	5.1 1,913.9	0.9 353.5
White non-Hispanic	86.8% 12,630.0	82.3% 11,986.5	NA NA	NA NA	NA NA
Black	72.5% 1,485.3	66.1% 1,353.3	12.5 255.6	13.9 285.1	2.5 51.1
Native American	70.7% 93.0	64.2% 84.4	14.3 18.8	15.9 20.8	2.9 3.8
Asian	89.0% 4,630.5	85.7% 4,455.2	NA NA	NA NA	NA NA
Multiracial	88.8% 1,439.9	83.5% 1,344.3	NA NA	NA NA	NA NA
Hispanic	71.2% 9,316.3	64.3% 4,771.6	13.8 1,804.1	15.7 1,166.0	2.8 360.8
Below poverty line	60.8% 3,836.7	54.2% 3,415.0	24.2 1,523.6	25.8 1,629.3	4.8 304.7
Above poverty line	84.2% 5,306.7	79.0% 4,983.2	0.8 53.6	1.0 61.2	0.2 10.7

Notes: Figures are number of persons and are calculated by the author using data from the 2013 American Community Survey (see footnote 22).

All this investment, and more, will be necessary to keep pace with the burgeoning Internet traffic seen in recent years. In 1990, the equivalent of 3,000 DVD worth of information was sent over the Internet in the US. Ten years later, that traffic had grown to the equivalent of 100 million DVDs per year. By 2010, the figure was 17 billion. By 2018, projections indicate that there will be over 100 billion DVDs' worth of traffic per year on the Internet in the US (Brogan, 2014a). That latter figure represents 37 exabytes¹³⁵ per month—equivalent to delivery *each second* of the total amount of traffic in *all* of 1990. The exponential growth is driven mostly by growing mobile traffic, the fastest growing segment of usage with a five-year annual growth rate of 50%, and fixed-line consumer video, the largest single share of traffic. Basic economic theory predicts that without investment, the unavoidable capacity constraints would cause consumer prices to rise sharply. That prices have not, in fact, risen in recent years¹³⁶ is evidence that continued investment was effective at expanding the capacity of the U.S. broadband network to handle the rapidly growing traffic.

State and local government can play a key role in reducing local barriers to infrastructure investment and deployment caused by the expense and delay involved with local permitting for construction, conduit work, and access to publicly owned rights of way. Often times fees for access to rights of way and pole attachments are far in excess of true economic costs and can double network construction costs (Szoka, Starr, and Henke, 2013). The US National Broadband Plan in 2010 encouraged state and local government to “ensure that network providers have easier access to poles, conduits, ducts and rights-of-way,” but it is hard to point to much progress made on this front.

2. Coordinate state and federal broadband deployment subsidies

The review of CASF in section I.C.2.a pointed out that of the nearly \$100 million spent through CASF to date to stimulate new broadband infrastructure deployment, a mere 5% went to unserved areas. While increasing the speed of broadband in the other areas is not an unworthy endeavor, the expected gains in consumer welfare from first gaining access to broadband are much higher than incrementally improving the quality of an existing service. In the absence of broadband, *none* of the potential benefits of broadband access to the Internet can be realized for users. When merely improving speeds in an area, the incremental gains in welfare are likely to be lower. It is hard to imagine that the benefit calculus truly calls for 19 out of every 20 dollars spent to go toward areas already enjoying at least lower-speed access. Plans for efficiently allocating funding from CASF and the CAF should be creatively steered toward unserved areas wherever feasible.

¹³⁵ An exabyte is one million terabytes.

¹³⁶ There is no widely available price index for broadband service. Evidence on prices in section below shows that quality-adjusted prices for broadband in California in a subset of the cable market have decreased greatly. Furthermore, Mandel (2015b) finds that the share of consumer spending going for communication services has barely risen since 2000.

3. Coordinate private, state, and federal efforts to encourage adoption

How might progress toward closing gaps in adoption be achieved? Between the federal Lifeline support that will be available for broadband,¹³⁷ the \$5 and \$10 per month “broadband starter” offers from AT&T, Comcast, and other private sources, support for very affordable broadband could be attainable for at least the lowest income households. Very affordable broadband for low-income households would be even more attainable if the state were to reform its own subsidies for voice service to be used equally for broadband. However, even without a significant cost barrier, the obstacles of digital illiteracy and lack of computer ownership are at least as large for non-adopters. Public-private partnerships (or for-profit/non-profit partnerships between broadband providers and public interest groups) could supplement the pecuniary incentives with access to training, reduced-cost computers, and other digital literacy efforts.

How much might such efforts cost? The figures in Table 12 imply that about 580,000 low-income households would have to adopt broadband of some sort to achieve parity with households above the poverty rate.¹³⁸ Assuming for the sake of calculation that the average low-cost broadband offer is \$7.50 per month (an even mixture of \$5 and \$10 offers), then Lifeline-type funding of around \$17.4 million per year would be required to lower the household’s out-of-pocket cost to \$5.00 per month. For comparison, that is comparable to about an eighth of the amount of the \$136 million in federal funding paid to carriers in California in 2014 under the existing Lifeline program (USAC, 2014). Note if discounted computers or instruction in digital literacy are included in the efforts to close the broadband gap, additional funding would be required. While the figures in these example calculations are not trivial, they are also within reach if the goal is deemed socially desirable.

¹³⁷ While final rules have yet to be issued, it appears likely that the FCC will allow the current \$9.25/month Lifeline subsidy for voice service to be applied to broadband as well.

¹³⁸ The table shows the “any broadband gap” is 1.523 million persons in low-income households. Dividing this figure by the average household size of 2.63 persons for low-income households lacking broadband yields approximately 580,000 households.

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