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

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Research Brief

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About the author

JAMES E. PRIEGER is Associate Professor of Economics and Public Policy at the Pepperdine University School of Public Policy, where he teaches classes in microeconomics, science and innovation policy, regulation and antitrust economics, and econometrics. Prieger spent a year as Senior Economist with the Federal Communications Commission during 2008-2009, advising on broadband and telecom merger policy. He has published many articles for scholarly journals and books concerning broadband Internet access and the digital divide, as well as on other topics in industrial organization, regulatory economics, and econometrics. He has consulted for major companies on regulatory issues, and sits on the editorial boards of the academic journals *Applied Economics Quarterly* and the *International Journal of Business Environment.* He received his BA (Magna Cum Laude) in Economics and Mathematics from Yale University and his PhD in Economics from the University of California, Berkeley. He previously taught at the University of California, Davis. The complete C.V. of Dr. Prieger is available at sites.google.com/a/pepperdine.edu/jprieger/home/cv.

About the report

This report is a brief version of a longer study of the California broadband market. Readers interested in more background information, more empirical analysis, and more complete documentation of sources and methodology can refer to the longer report, which is available from sites.google.com/a/pepperdine.edu/jprieger/home/research/ca-bb.

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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 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 will be discussed, along with recommendations for policy-makers.

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

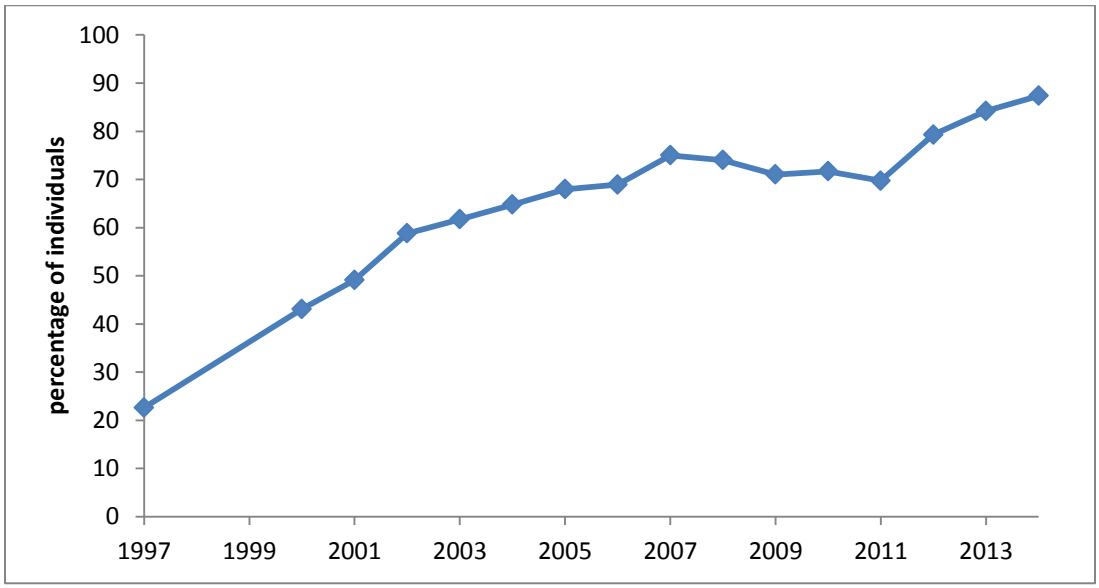
In a day when the Internet is woven into the fabric of daily life for most people—dominating how many of us communicate, learn, entertain ourselves, and otherwise engage with the world—it may be hard to remember that the modern Internet began only about 25 years ago. The Internet as we typically think of it, the World Wide Web with its hypertext links and graphical browsers, began in 1993. 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. Figure 1 documents the growth in the fraction of people in the US using the Internet. In 1997, four years after the introduction of widely available graphical browsing on the Internet (and the first year official statistics were collected), already 22.6% of people in the US used the Internet (Newburger, 1999). By 2001, about half of Americans used the Internet. That fraction grew quickly to 75% in 2007; by 2014, Internet penetration had reached 87%.

The Internet's 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. 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.

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. 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. Since 1999, the average annual growth rate in broadband lines has been 30.4% in California. This is a bit lower than growth for the rest of the nation, since California as an important technology hub had higher penetration in 1999. 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 broadband lines has averaged 22.0% per 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 adoption of the Internet in such a brief period of human history has been nothing less than amazing.

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



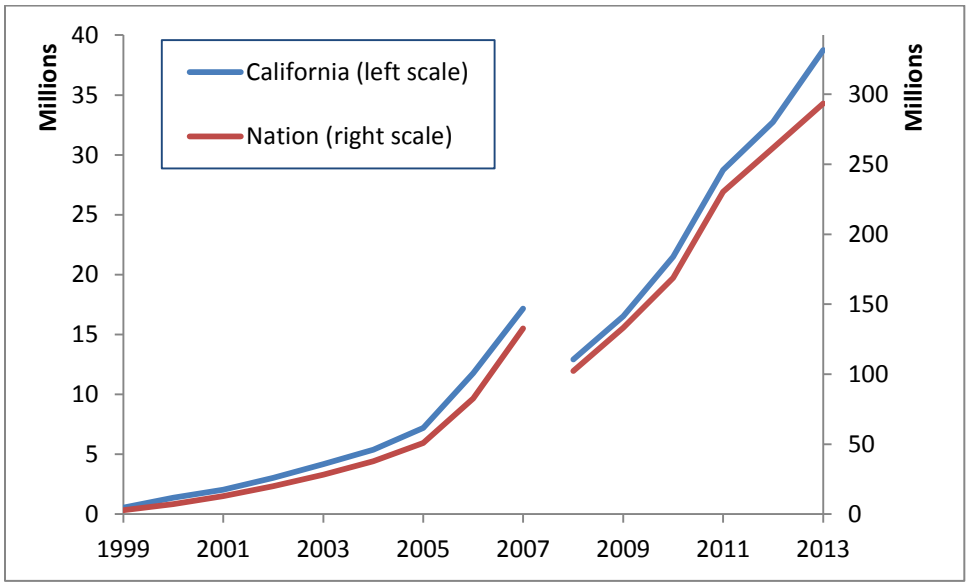
Notes: Data are from Newburger (1999) for 1997 and ITU (2015c) for later years.

2. The importance of broadband to the economy

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. 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). 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). 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).[1] 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.[2]

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 to allow comparison between time periods. 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: Subscribership" and "Internet Access Services: Status" reports, various years.

Broadband is similarly important for job creation in the US. Katz and Suter (2009) and Holt and Jamison (2009) review several studies that generally find a positive link between broadband infrastructure investment and increased employment, particularly during the recent recession years when there was significant slack in the economy. For more recent impacts, Jayakar and Park (2013) find that US counties with better broadband availability had lower unemployment rates in 2011 (after controlling for other

[1] The broadband bonus is calculated as broadband revenue less cannibalized dial-up revenue plus new consumer surplus.
[2] The calculation assumes the benefits are proportional to the state's share of total broadband access lines.

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 voice and broadband markets in California

1. Voice calling: the expansion of consumer choices

Between voice calling carried over the legacy wired telephone network,[3] 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,[4] and mobile VoIP services, consumers have never had more choices of how to communicate with others. Convergence in technologies 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.

Trends in fixed and mobile services in the US are shown in Figure 3. In these data, fixed telephone subscriptions 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 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.

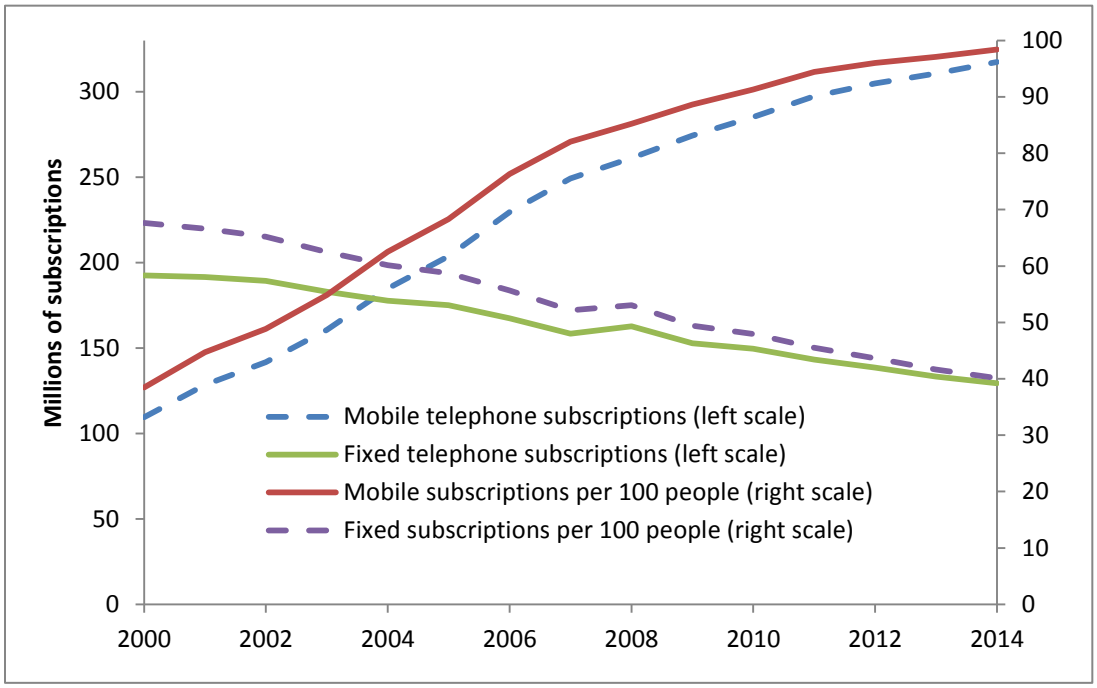
The fixed voice market is clearly in long-term decline, but the aggregate trend obscures the changing composition of the market, from switched access to VoIP. Steady growth in VoIP lines through 2013 offsets some of the decline in switched phone lines. Thus, the percentage decline in traditional voice 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 from a provider other than an ILEC (Brogan, 2014). 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, with a 12.7% decline from 2012 to 2013. When looking at residential service only, the decline is even steeper: California consumers dropped 19.8% of their remaining traditional voice lines in 2013, so that

[3] I.e., the PSTN (Public Switched Telephone Network).

[4] 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.

only 9 percent of all residential voice lines in California were switched access anymore. VoIP is projected to make up an ever greater share of fixed voice lines through 2018 globally.[5]

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



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

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. As of the first half of 2014, 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. Across the state as of 2014, over 42% of adults and over half of children live in households with mobile telephone access but no fixed telephone lines (i.e., cord cutters and cord nevers; CDC, 2016). 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).

[5] See TeleGeography (2014) for the global VoIP and switched access forecast.

In 2014, many minority and lower income households were mobile-only for voice telecommunication. While 43% of whites live in mobile-only households, 48% of African Americans and 59% of Hispanics are cord cutters across the nation (Blumberg and Luke, 2015). The differences among income groups are even starker. Fifty-nine and 51 percent of those in poor and near-poor households, respectively, were mobile-only, compared to only 41% of households that were not poor. Recognizing the importance of mobile telephony to low-income individuals, federal and state support programs for voice telecommunication now allow subsidies for low-income households to be applied to mobile lines as well as to fixed lines.

2. Broadband

There are many broadband providers in California, altogether offering over 38.7 million broadband lines of all kinds in the state as of year-end 2013 (see Table 1). 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.

Table 1: 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 were the only facilities-based providers at the time).

** 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).

There are 138 broadband providers offering service in California. In most markets there are several providers. 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.

The most common scenario is a choice of four modes of fixed broadband service—DSL, cable, either fiber or advanced copper-based service, and satellite—and mobile broadband service. The choices and firms are shown in Figure 4. (Note that some of these options may be marketed primarily to businesses.) There are also many firms offering these services. The median person in the state has access to three providers of terrestrial fixed broadband, four mobile broadband providers, and three satellite broadband providers.[6] 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 II of the report is largely one of competition among several providers in any given area.

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 ILECs improved their DSL speeds when a cable broadband provider either entered the market or began to offer speed of 50 Mbps and above. ILECs also upgraded their speed of broadband when competing local exchange companies (CLECs) deployed fiber in their areas.

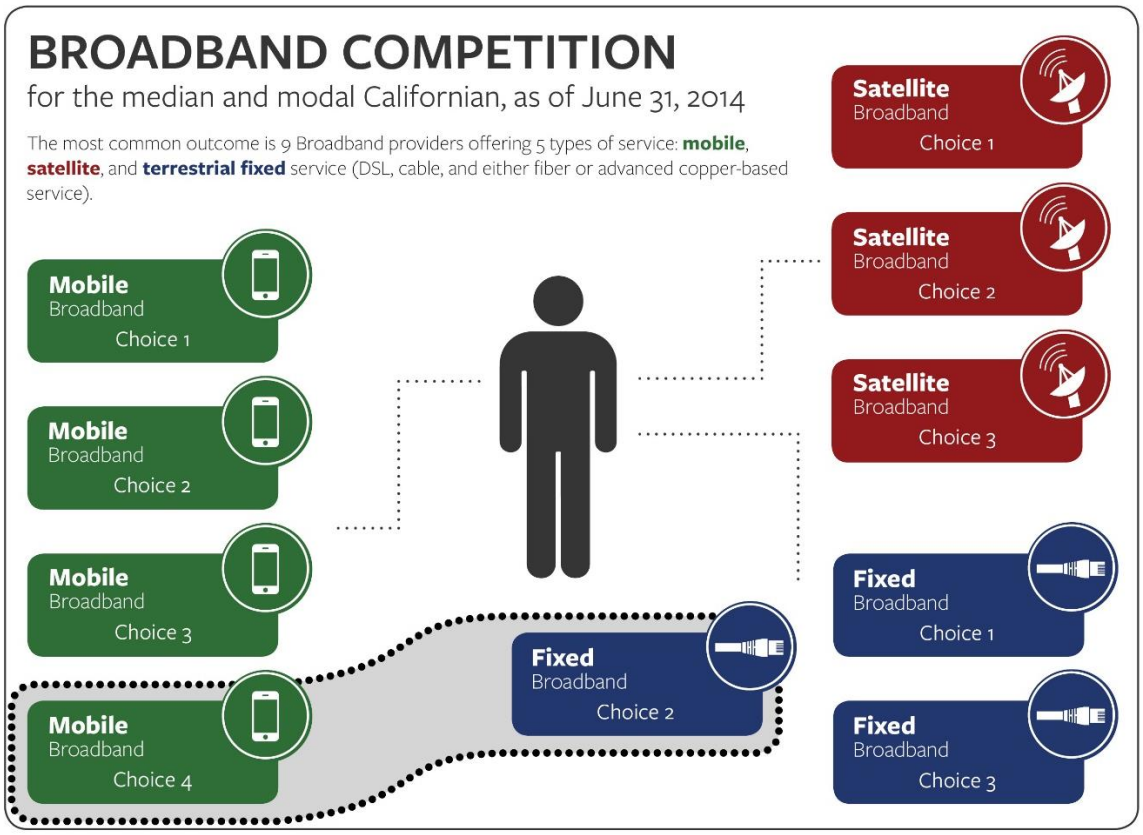
Mobile broadband is an important part of the broadband market. Many low-income, minority, and other households choose not to subscribe to fixed-line broadband but have adopted smartphones and other mobile devices to access the Internet. In part this is because mobile broadband coverage helps fill in 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 below,[7] 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.

In California, many households prefer to have access to both fixed and mobile broadband (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.[8] 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

[6] The figure for terrestrial fixed broadband providers is taken for the median person from Figure 9 below. The same statistic for mobile broadband is from Figure 11. On satellite broadband, refer to footnote 14 below.
[7] In particular, refer to the discussion on page 18.
[8] 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.

households with a mobile broadband plan, 13.5% of them rely on it as their only form of access in the household.

Figure 4: Broadband competition in California



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

C. Policy issues and concerns

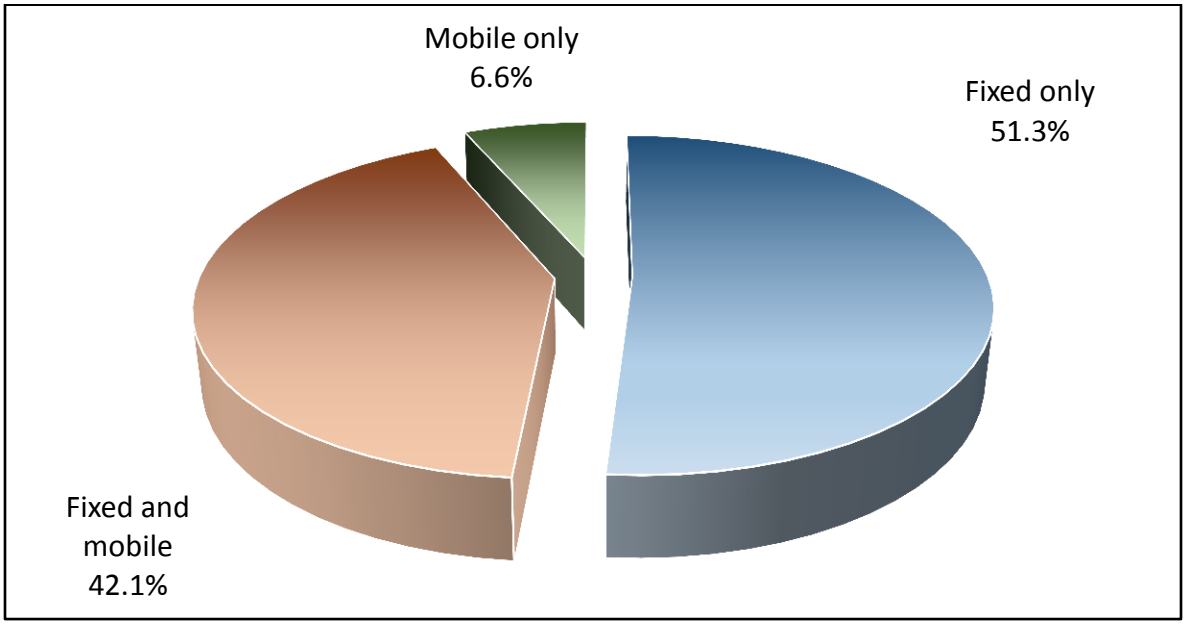
There are many concerns regarding the broadband market that public policy can address. The main topics discussed here include challenges in promulgating availability and adoption, universal service, and the issues involved with overlapping state and federal regulation.

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 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 here.

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



Source: see footnote 8.

a. Drivers of availability

There is much evidence in the literature that cost and population density are a primary drivers of broadband availability (e.g., Prieger, 2003, 2013; Grubesic 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. Since prohibitively high costs in relation to the available number of subscribers 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.

b. Drivers of adoption

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 adopted some form of broadband in the home (including mobile broadband).[9] The remaining one fifth chose not to subscribe.[10] Why?

[9] Refer to Table 5 presented below.

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 Figure 6. The most prevalent answers for not using the Internet involve its perceived irrelevance. Over a third of non-adopters (or 5% of all adults) 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 (representing less than 5% of all adults), 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, spyware, or hackers. A further 19% of non-adopters (3% of all adults) have issues with affordability, either directly for broadband (6%) or because they do not own a computer (13%).

Finally, note that the 7% of non-adopting respondents who say that broadband is unavailable to them (or 1% of all adults) are nearly certainly incorrect. Between fixed, mobile, and satellite broadband, not to mention the presence of community anchor institutions such as libraries 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.

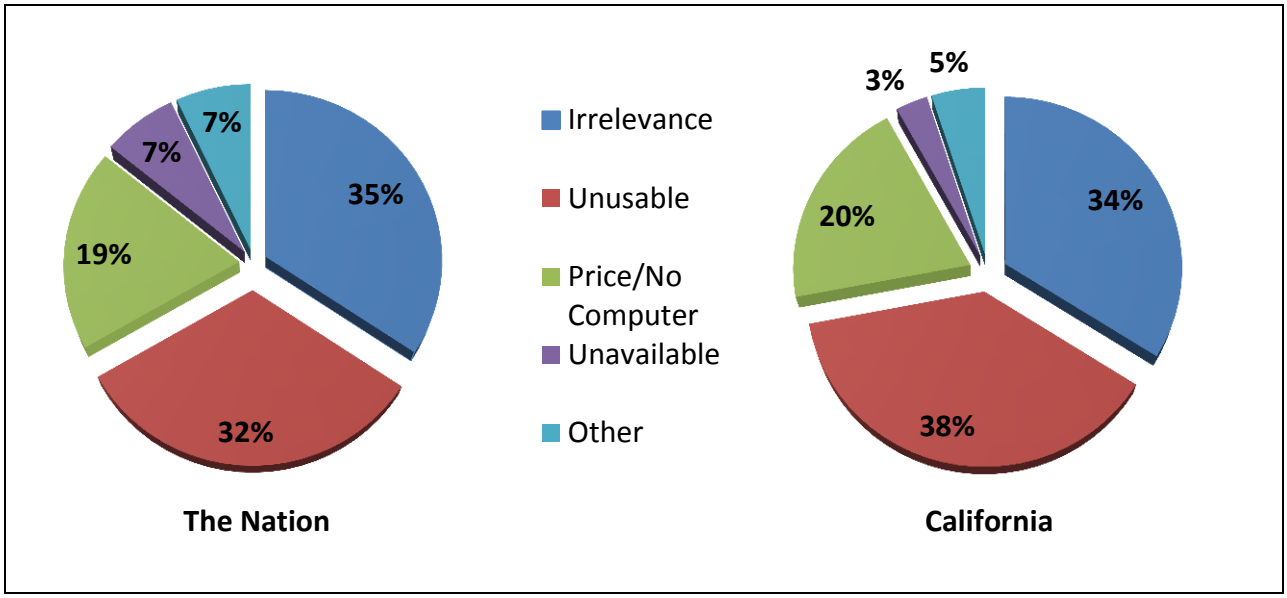
A comparable survey of Californians found generally similar results, although there was a higher fraction of responses in the "unusable" category and fewer related to lack of availability (Baldassare, et al., 2013). These data suggest that efforts to promote adoption must be multi-pronged. Setting aside 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 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). 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,

[10] 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 20%.

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).[11] 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 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.

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 the 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.

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

[11] The communities were in Los Angeles, San Jose, San Diego, Sacramento, and San Francisco.

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, policymakers 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

Stimulating the diffusion of broadband requires support for both infrastructure deployment and household adoption. Therefore, 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 others to deploy advanced infrastructure in unserved and underserved areas. Today, entities eligible to receive the grants include broadband providers, 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.

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 2. 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).

Table 2: 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. Eligible project costs include capital expenditure only.

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.

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, 2014b, 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, 2014b). 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.[12] If the incumbent declines the offer of CAF support in a state, the areas are then opened in 2016 to competitive bidding (FCC, 2014b). 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" (CPUC, 2015). Unlike California's 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. Phase II was on a much larger scale: providers received $98.3 million in support to serve over 230,000 end-users.

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 (2015b) notes that while 95% percent of U.S. households with incomes above $150,000 are connected

[12] 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.

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 have yet to be issued; FCC, 2015b).

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 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 by offering potential subscribers one of six options. Options 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 2015b, 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. The state subsidies currently only apply to voice, not broadband. However, subscribers can choose mobile or fixed voice communication. More than four out of five Lifeline subscribers today choose mobile over fixed voice across America (Ukhaneva, 2015).

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 $10 per month to new low-income subscribers. 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.

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). 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, 2014b).

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 IP-enabled services unless expressly required by existing state or federal law. 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 (2015a) 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 broadband[13] 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. As shown above Figure 4, 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 two (recently three) providers is available to any location in California with a clear view of the southern sky.[14]

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 using 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. During this time, that is the only speed threshold available in the publicly released local data.

Matching ZIP code areas to demographic data allows us to form a picture of the population served by broadband in California. 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

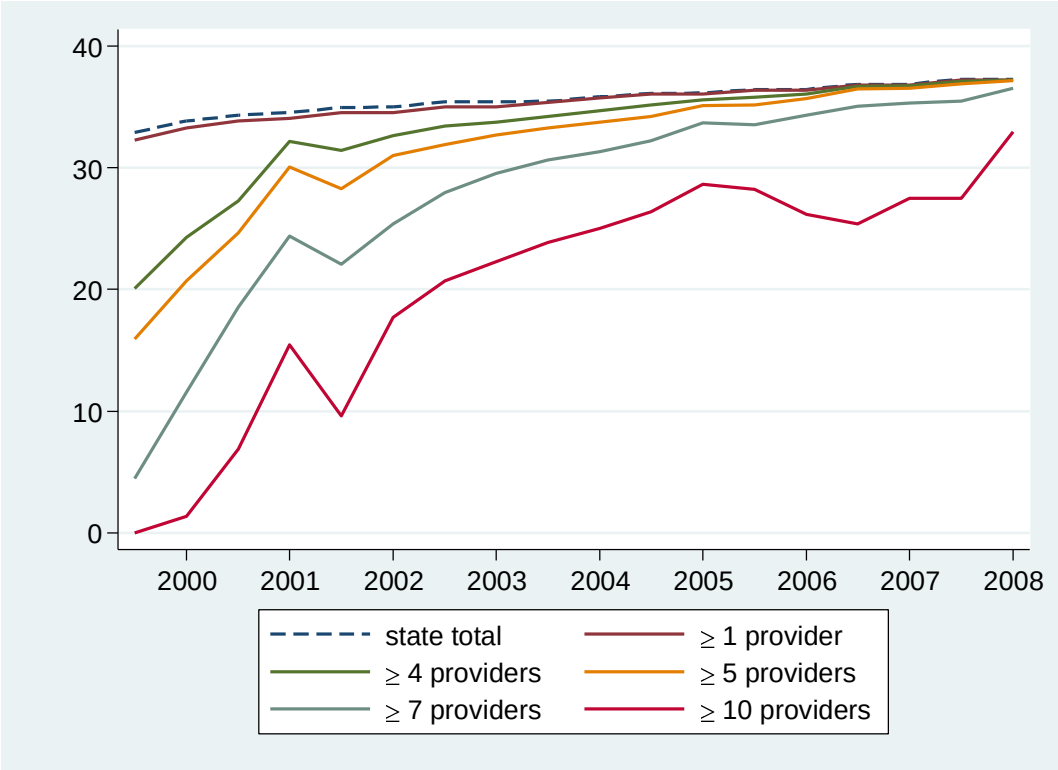
[13] Recent research shows that mobile broadband partially fills in geographical gaps in fixed-line broadband coverage in the U.S. (Prieger and Church, 2012; Prieger, 2013; Church and Prieger, forthcoming).

[14] As of fall 2015 there were two satellite broadband providers in the United States. 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 arstechnica.com/business/2013/01/satellite-internet-15Mbps-no-matter-where-you-live-in-the-us. Service by Dish Network or other resellers using the ViaSat and Hughes satellites are not included in the count, since the FCC and National Broadband Map only count distinct holding companies of facilities-based satellite providers.

the dark red solid line in the figure for this subpopulation and the dashed line for the total population. Deployment was also growing during this period. The subpopulations living in areas with at least four, 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 lived in ZIP codes with at least one provider, and nearly all of those people (36.98 million) also lived in areas with at least four providers, at least five providers (36.94 million), or at least seven providers (36.29 million). There were also 32.77 million Californians living in areas with 10 or more 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 (*x*DSL, 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.

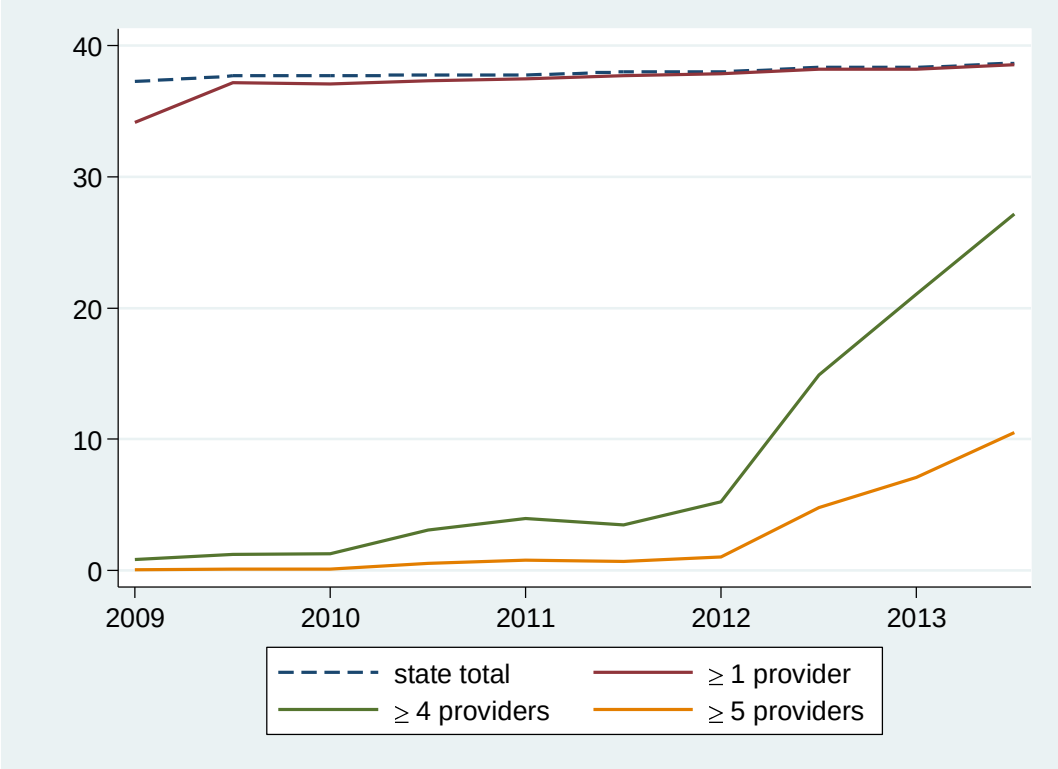
2. Broadband deployment at the Census tract level, 2008 to 2013

Beginning in December 2008, the FCC collected 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. The highest speed threshold that can be examined during this period is at least 3 Mbps download and at least 768 kbps upload

From December 2009 on, nearly everyone in the state lived 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.

Figure 8: Population in Census tracts with fixed broadband providers of residential service (3 Mbps down/768 kbps up), 2009 to 2013



Note: The speed threshold is 3 Mbps download/768 kbps upload. The provider count includes all fixed broadband providers (*x*DSL, cable modem, fiber, other wireline, fixed wireless, and satellite) but excludes mobile wireless. Providers do not necessarily cover all territory within the tract. Broadband data are from the FCC as described in the text. See also notes to previous figure.

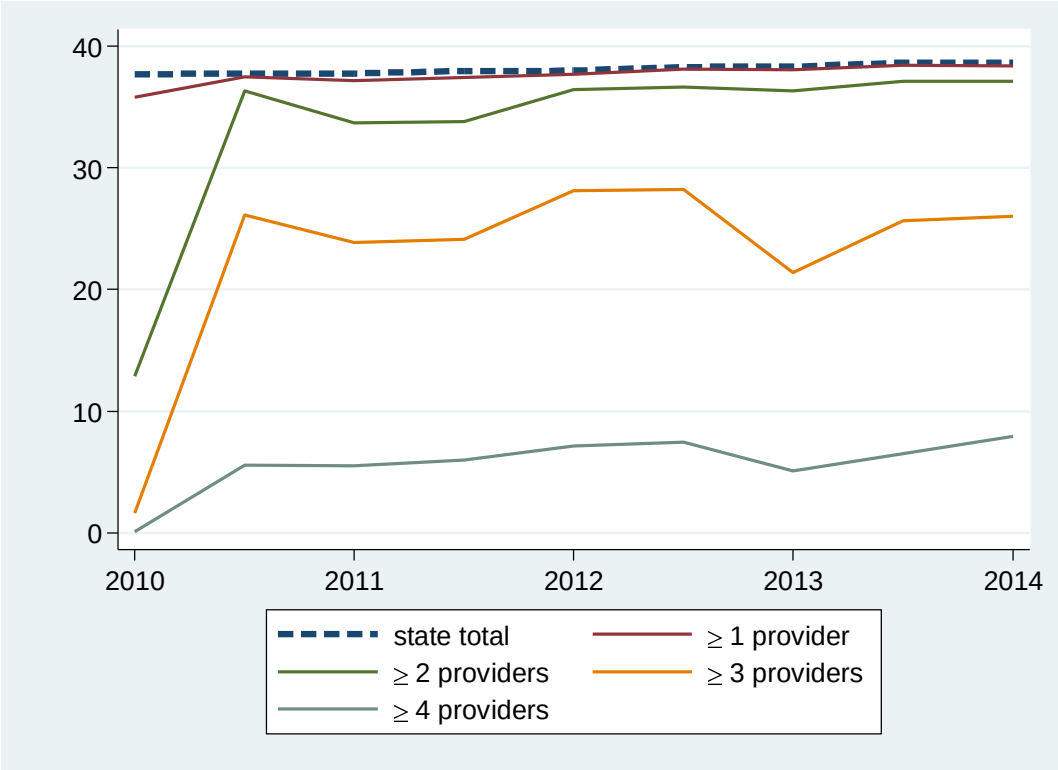
3. Broadband deployment at the Census block level, 2010 to 2014

Beginning in June 2010, the National Broadband Map provided another source of data on broadband deployment, including ways to count 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.

In June 2014, 37.2 million had two or more providers meeting the 3 Mbps speed threshold. This estimate of 98.9% availability can be compared with the FCC's (2015a) 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 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.[15]

Figure 9: Population in Census block groups with fixed broadband providers (3 Mbps down/768 kbps up), 2010 to 2014



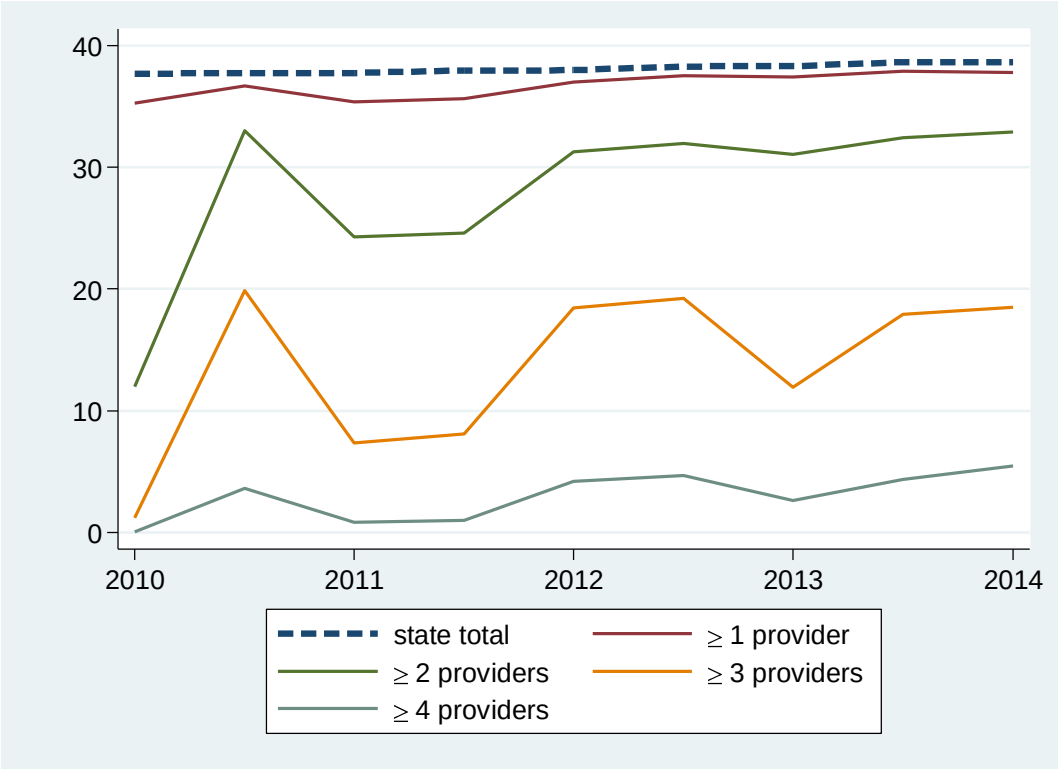
Notes: The speed threshold is 3 Mbps download/768 kbps upload. The provider count is the maximum number of providers occurring in any one block in the block group, and includes all fixed broadband providers (xDSL, cable modem, fiber, other wireline, fixed wireless) except satellite. Mobile wireless broadband is not included.

In Figure 10, 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

[15] See Appendix G of FCC (2015a) for these figures.

broadband of 10 Mbps download and 1.5 Mbps upload.[16] A further 85.2% of people lived in areas with two or more fixed broadband providers offering service at that speed. Comparison of Figure 10 with Figure 9 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 10: 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 9.

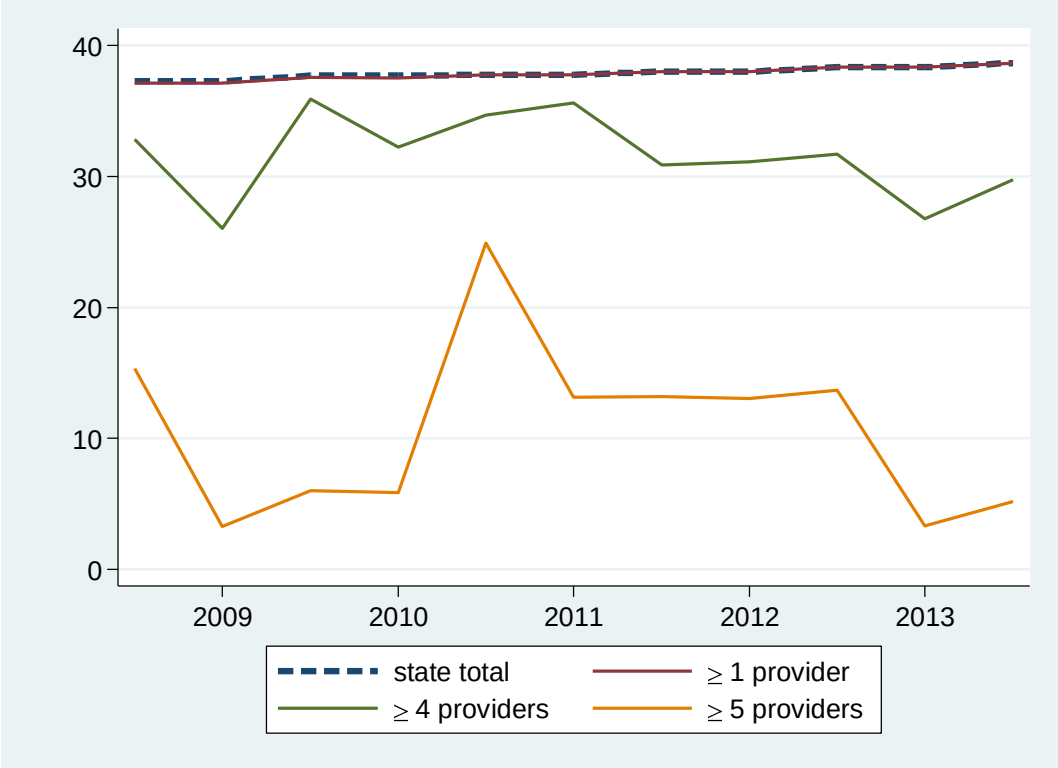
[16] This estimate can be compared with the "official" estimate from the CPUC that 95.5% of California households have access to non-satellite broadband of speed 6 Mbps download/1.5 Mbps upload in June 2014 (CPUC, 2015a). Reasons for the discrepancy include the differing speed threshold, the aggregation to the Census block group level in this report, and the more granular data available to the CPUC.

B. Mobile broadband deployment

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. In addition to the fixed broadband providers in the Census tracts discussed above, most people in California lived in tracts with multiple mobile broadband providers.

Figure 11 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.

Figure 11: Population in Census tracts with mobile broadband providers, 2008 to 2013



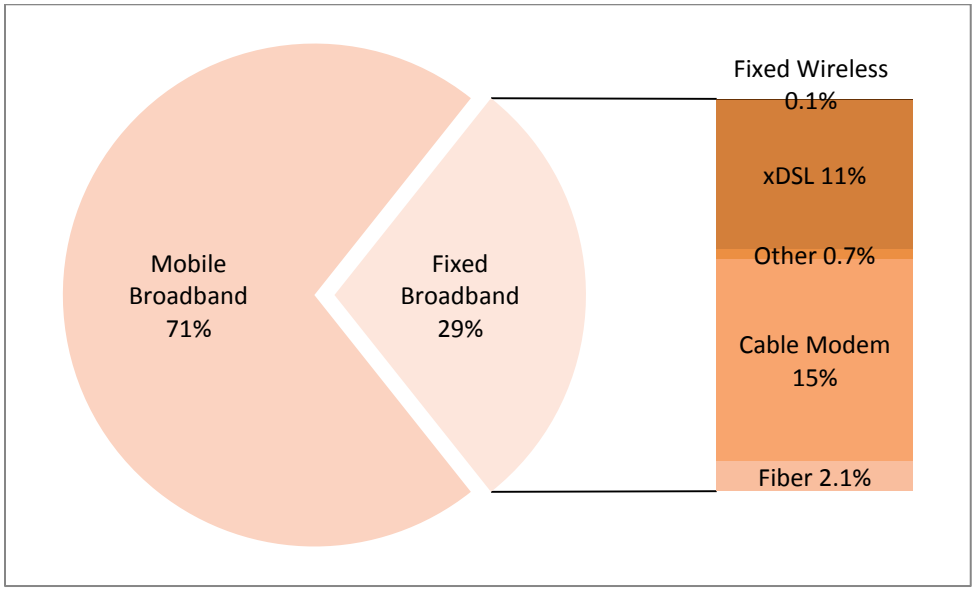
Note: "State total" is the total population for California. The provider count includes only terrestrial mobile wireless broadband providers. The speed threshold is 200 kbps in at least one direction. Providers do not necessarily cover all territory within the tract. Broadband data are from the FCC as described in the text.

III. Broadband Internet Adoption

At the end of 2013, California had a 65% household subscribership ratio[17] for residential fixed broadband connections of at least 3 Mbps downstream/768 kbps upstream. 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%.[18] 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.

The figures above in this section included fixed broadband access only. However, the most common form of broadband access today is mobile. Figure 12 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 12: 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).

[17] 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.

[18] 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 8 and presented in Table 5.

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, 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 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). 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. 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). 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

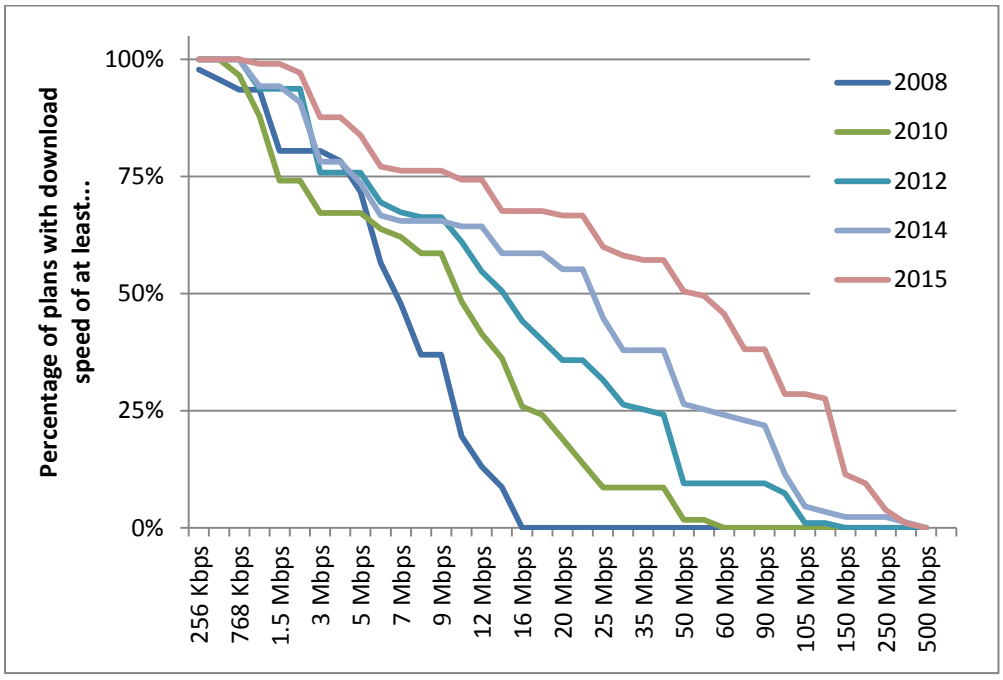
During the period covered by this report, 1999 to present, private broadband providers in the U.S. have invested over 1.2 trillion dollars in capital expenditure. Even excluding the telecom boom years, investment by wireline and wireless telecommunications and cable broadband providers totaled over 800 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.

1. Quality options for residential broadband

The rest of this section presents some data on how the quality of broadband has improved in California for residential customers. The maximum advertised download speeds in the proprietary sample of the residential service options of cable companies in California are characterized in Figure 13. While information on actual download data transfer rates are unavailable, recent FCC (2014) investigation has found that cable modem service on average in the US has slightly higher actual speed than advertised speed. The figure shows year-by-year "survival curves" for download speed during the period 2008 to present. 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.

Figure 13: 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.

Figure 13 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. The median speeds are shown for all years in Table 3, 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.

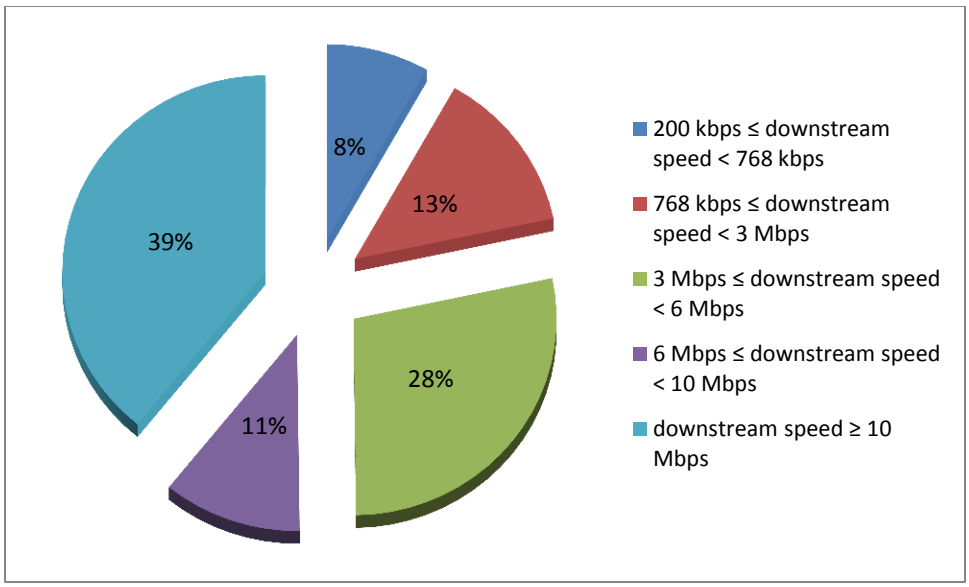
As with any technology, varied consumer preferences and price sensitivity lead many households to choose broadband options slower than speeds at the technological frontier offered in the market. Actual broadband speeds for subscribers on average thus do not rise apace with the maximum speeds available. The breakdown of actual subscriber speeds for year-end 2013 for all of California is shown in Figure 14. Slightly less than two-fifths of broadband 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 of connections were slower than 3 Mbps.

Table 3: 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.

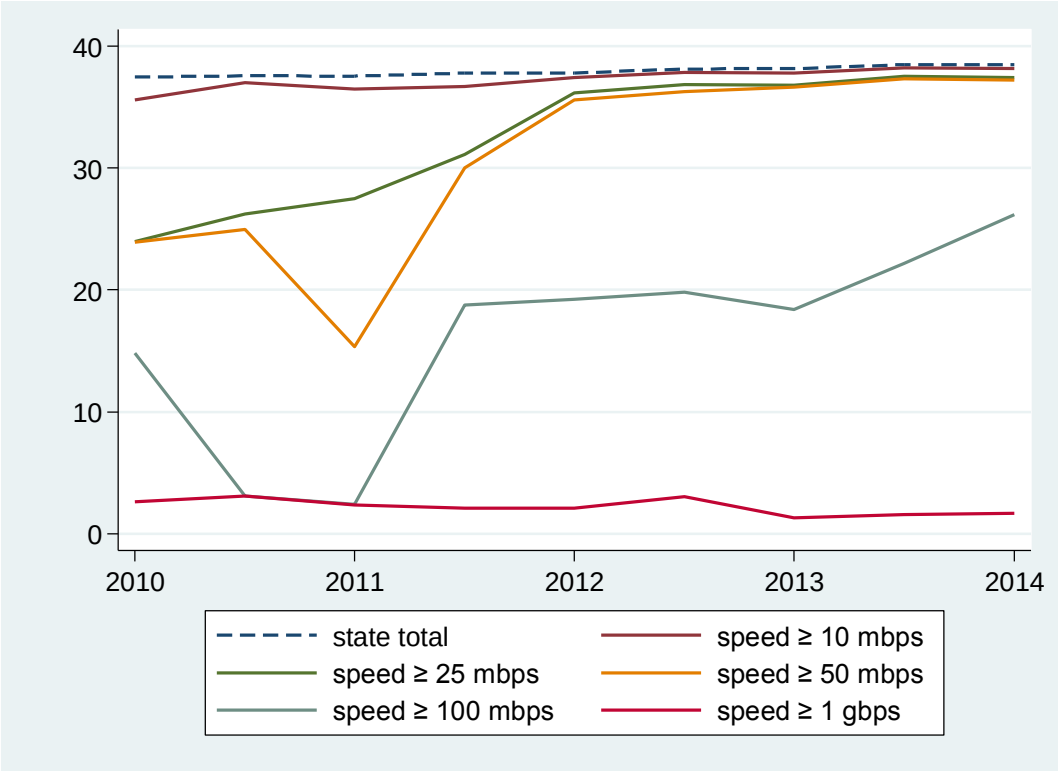
Figure 14: Broadband connections in California by downstream speed, December 31, 2013



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 for matching to counts of the population. The data include only fixed broadband options, and excludes satellite broadband. Figure 15 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.

Figure 15: Population in Census block groups with various fixed broadband download speeds, 2010 to 2014



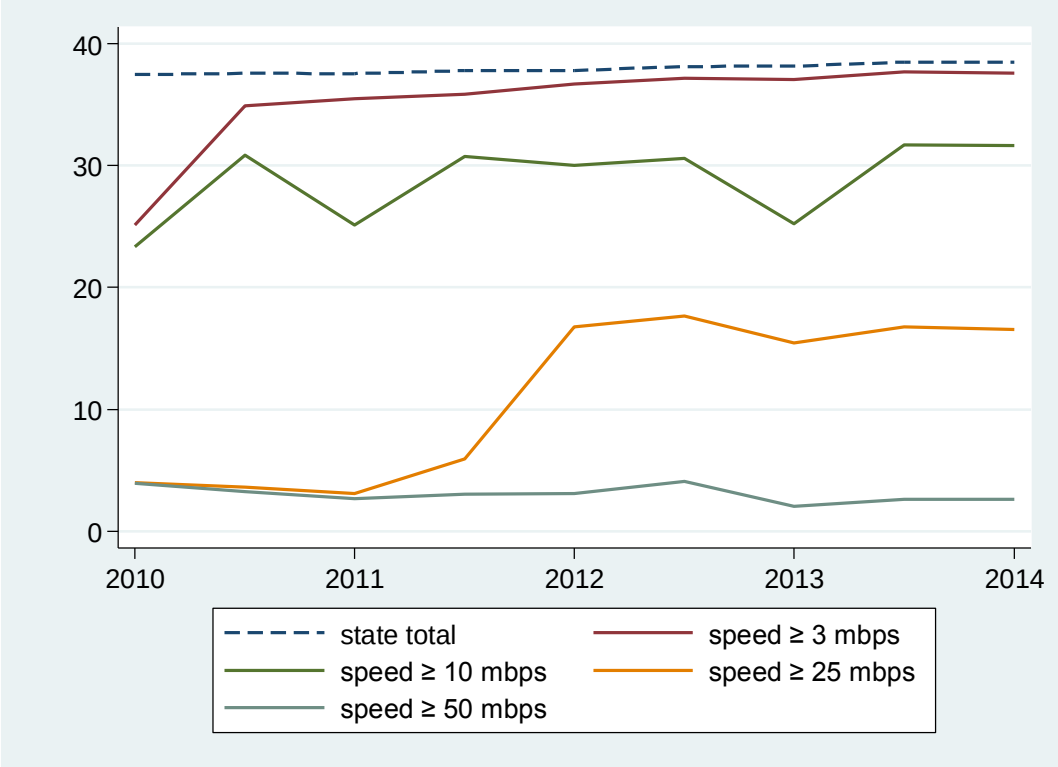
Note: "State total" is the total population for California. The stated speed is the maximum advertised download speed occurring in any one block in the block group, and includes service from all fixed broadband providers (xDSL, cable modem, fiber, other wireline, fixed wireless) except satellite. Broadband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

Even though most people live where 10 Mbps broadband is available, Figure 14 above showed that many apparently do not subscribe to it. However, no direct comparison between availability in Figure 15 and the purchased access speeds found in Figure 14 is possible, due to the differing sets of broadband lines underlying the figures. The statistics on availability in Figure 15 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 14. Nationally, at the end of 2013, 58% of mobile broadband connections had download speeds slower than 6 Mbps, and recall from Figure 12 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. If a figure comparable to Figure 14 but excluding mobile connections could be constructed, it would show much greater proportions of customers choosing higher speeds.

Upload speeds have also increased over time in California as well, although the change is not as marked as for download speed. Figure 16 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.

Figure 16: 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 15.

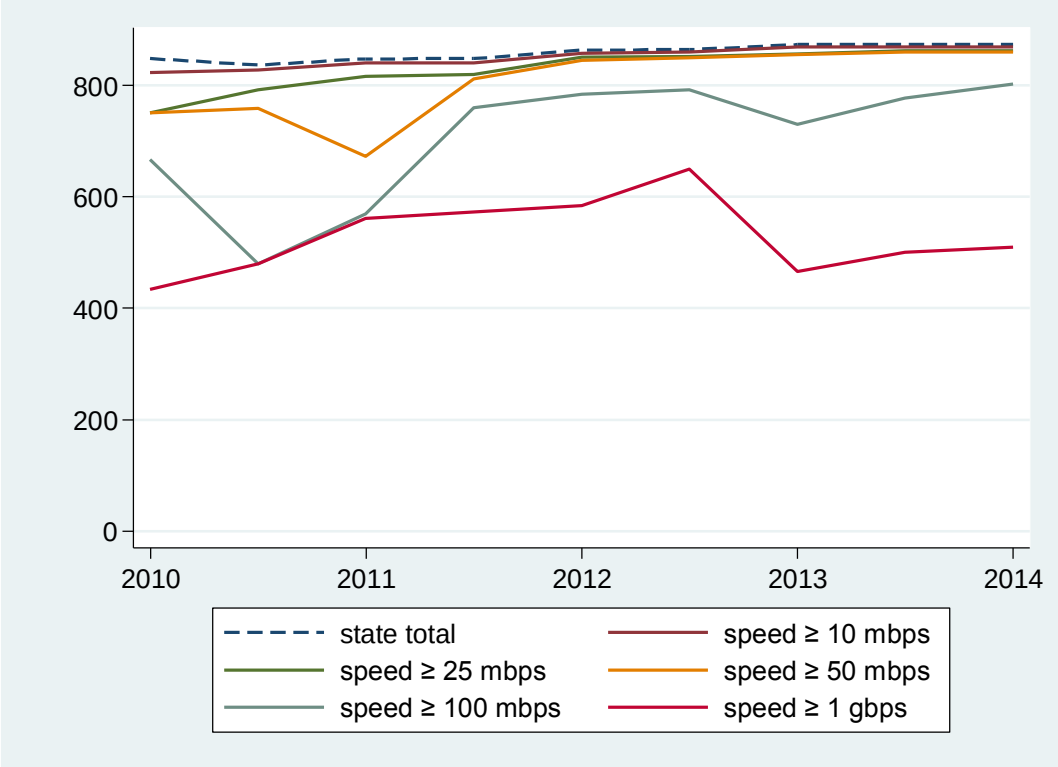
2. Quality options for business broadband

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 17 shows the speed trends for business establishments in the state. As above in section II.A.3, 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.

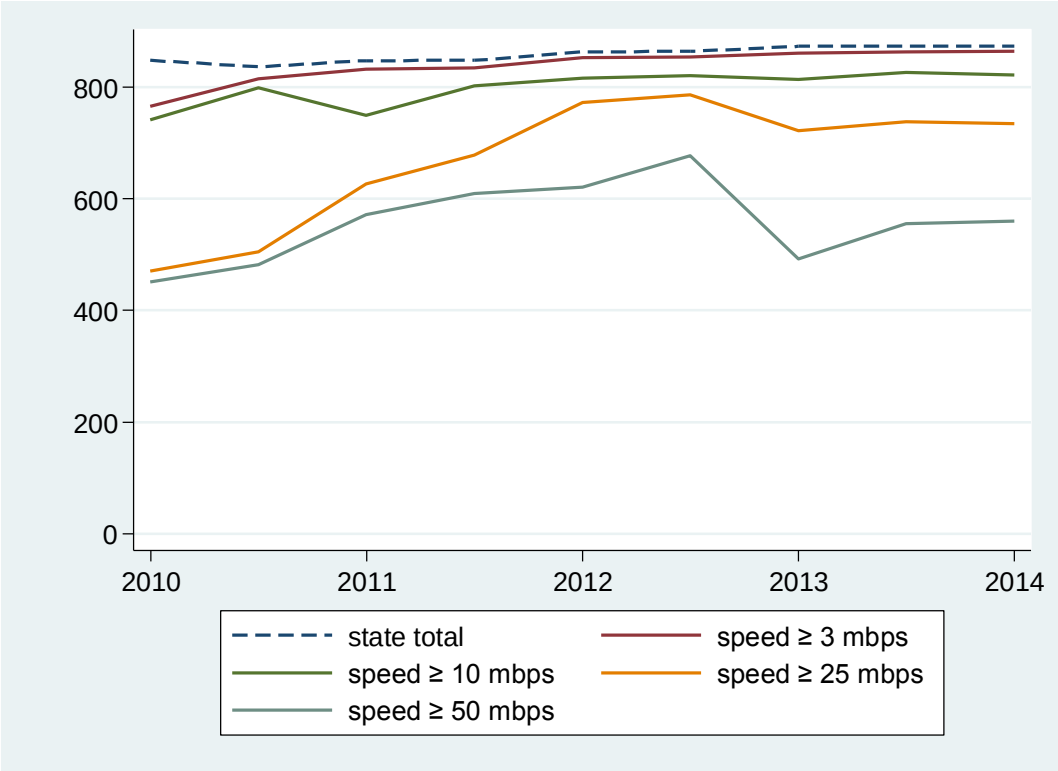
Figure 17: Business establishments in ZIP codes with various fixed broadband download speeds, 2010 to 2014



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, 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 18. The figure shows that during the entire time the median business establishment had access to upload speeds of at least 50 Mbps.

Figure 18: 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 17.

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.[19] The country ranks much lower in international price comparisons that do not account for *relative* affordability (e.g., Russo and

[19] 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).

Morgus, 2014; FCC, 2015c).[20] 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.

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 in Table 4 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, 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.

The price declines for all available years of data are plotted in Figure 19. The figures in Table 4 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 19 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 both 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.

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.

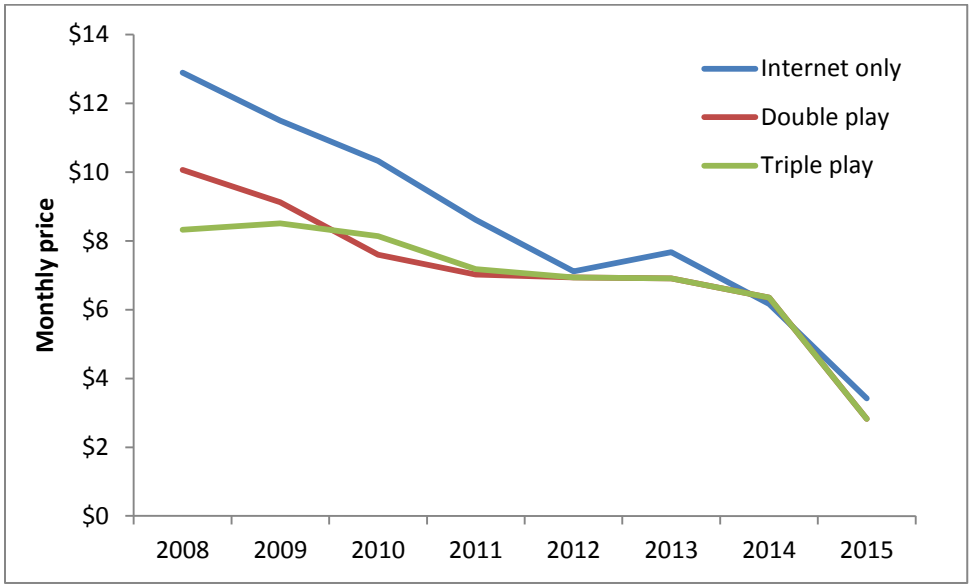
[20] There are many reasons why the price of broadband is cheaper in some European and Asian country than in the U.S., including large differences in population density, a key driver of infrastructure cost. Given the focus on California here, exploring such difference is beyond the scope of this report.

Table 4: 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. Prices exclude 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.

Figure 19: 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 4.

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 5 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.

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

Notes: Figures are number of persons and are calculated by the author using data from the 2013 American Community Survey (see footnote 8).

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.

B. Policy to support access and adoption

1. Remove barriers to deploying broadband infrastructure

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

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.

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,[21] 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

[21] 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.

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 5 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.[22] 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.

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[22] 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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