Have Affordable Broadband Plans Helped Connect Low-income Households? Evidence from California (2014-20)

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1. Introduction

In recent years, state and federal regulators have often imposed obligations on Internet Service Providers (ISPs) to offer affordable broadband plans as a condition for approving proposed mergers and acquisitions. These obligations are typically part of a larger set of conditions that seek to mitigate competitive harms and ensure that corporate consolidations align with the public interest. The details vary in each case, but the obligation typically involves making available a basic, standalone broadband plan at a price significantly below market rates for a period of several years, using a predetermined set of rules to determine eligibility. The mandates also involve outreach efforts to promote awareness among potential subscribers.

There is considerable debate about whether the affordable plans that have emerged from these public interest obligations have in fact helped connect low-income Americans to residential broadband. Local advocacy organizations have argued that ISPs often fail to promote affordable plans, and that onerous certification and signup procedures discourage participation.[1] Others have argued that because of lack of network investments in low-income communities, these plans are not available in the areas where they are most needed.[2] At the same time, studies show that affordable plans can meaningfully increase adoption among target groups, and may result in tangible benefits such as increased employment opportunities for connected individuals.[3]

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[1] See Partnership for Los Angeles Schools, "Bridging LA's Digital Divide" (April 2020), at https://partnershipla.org/wp-content/uploads/2020/04/Equity-and-Justice-Alert-Bridging-LAs-Digital-Divide-Final.pdf.

2 See for example NDIA, "Access From AT&T Not Available to 1.5 Mbps Households," at www.digitalinclusion.org/blog/2016/9/5/access-from-att-problem.

3 Zuo, George W. 2021. "Wired and Hired: Employment Effects of Subsidized Broadband Internet for Low-Income Americans." American Economic Journal: Economic Policy, 13 (3): 447-82. See also Rosston, G., & Wallsten, S. (2020). "Increasing low-income broadband adoption through private incentives." Stanford Institute for Economic Policy Research Working Paper No. 20-001.

This study explores the impact of three affordable plans that emerged from regulatory proceedings at the state and federal levels. It examines whether these plans have contributed to narrowing the income gap in residential (fixed) broadband in California, helping connect eligible households that would otherwise not have connected. The mandated period for these plans has now elapsed, although providers have continued to offer the plans (or similar plans) on a voluntary basis. This offers a unique opportunity to take stock of these mandates, and analyze whether regulators should continue using this tool to advance digital equity.

The plans included in this study are:

1) "Access from AT&T," an affordable plan created following the FCC's approval (with conditions) of AT&T's acquisition of DirecTV in 2015.
2) "Internet Assist" by Spectrum, a low-cost plan created by Charter Communications following reviews by the FCC and CPUC of its merger with Time Warner Cable and Bright House Networks in 2016.
3) "Affordable Broadband" by Frontier Communications, a plan mandated by the CPUC as a condition for Frontier's acquisition of Verizon's wireline assets in 2015.

To estimate the impact of these plans, the study uses a difference-in-difference (DiD) strategy similar to Rosston and Wallsten (2020) and Zuo (2021). In a few words, it compares the change in adoption rates among eligible households before and after the introduction of the affordable plan in the areas served by each ISP to the change in adoption rates among eligible households in areas not served by the ISP. This allows for isolating the additional contribution that the plan has had over and above the growth in broadband adoption that would have occurred in absence of the plan. In DiD terms, the households that are eligible (based on each plan's eligibility criteria) but that are located outside the ISP territory serve as the control group to similar households located within the ISP territory (the potentially treated households). Further methodological details are provided in Appendix A.

Overall, the results indicate that affordable plans have had little impact in connecting low-income households to residential broadband. Of the three plans under study, only Frontier's plan is associated with a small but meaningful increase in adoption among eligible households. Weak compliance monitoring and a misalignment between private incentives and public interest goals are the main factors that explain these findings. In broad terms, the findings raise questions about the value of affordable plan obligations as a regulatory remedy in corporation consolidation cases involving large ISPs. The conclusion discusses alternative regulatory tools to promote residential connectivity among low-income households on a sustainable basis.

1. Access from AT&T

In July 2015 the FCC approved AT&T's acquisition of DirecTV subject to a number of conditions. Among these conditions was the requirement that AT&T make available "an affordable, low-price standalone broadband service to low-income consumers in the combined entity's

wireline footprint".[4] This was broadly similar to the commitment made by Comcast a few years earlier as a condition for its merger with NBCUniversal.[5] In both cases, the commission emphasized the need to protect choice for low-income customers by making available a standalone, affordable broadband plan not bundled with video or other services.

The plan was set at a minimum of between 5Mbps and 10Mbps of download speed for no more than $10 per month. Where not "technically available," AT&T could offer 3Mbps for no more than $5 per month. Eligible households were determined to be those where at least one member participated in the Supplemental Nutrition Assistance Program (SNAP). Due to state law that excluded recipients of Supplemental Security Income (SSI) from receiving SNAP benefits, California residents could also qualify based on participation in the SSI program. The mandate was set to expire in four years, and included additional requirements related to marketing and outreach efforts in coordination with schools and community-based organizations. Additionally, AT&T was required to submit semi-annual compliance reports to the FCC. The new plan, called "Access from AT&T", was launched in early 2016.

The analysis of the plan's impact proceeds as follows. Using microdata from the Census Bureau's American Community Survey (ACS), we identify the households that qualify for AT&T's affordable plan over the 2014-20 period. Next, we use service deployment data from the California Public Utilities Commission (CPUC) to estimate the share of households in each PUMA where AT&T broadband service is available (at any speed).[6] We consider a PUMA to be part of AT&T's territory if broadband is available to at least 90% of households.[7]

Figure 1 presents the adoption rate for residential broadband among households eligible for "Access from AT&T" over the study period. The darker line represents the rate for eligible households in AT&T territory, and for which the plan was made available in 2016 (the treated group), while the lighter line shows the rate for eligible households outside AT&T territory (the control group). Note that the figure shows an overall growth in adoption among low-income households over the study period, but also reveals that a very significant share (about a third) remained unconnected (or underconnected through mobile broadband) by 2020, when the mandate expired. A map of the PUMAs within (treated group) and outside AT&T territory (control group) is presented in Figure C1.

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[4] FCC Memorandum Opinion and Order "In the Matter of Applications of AT&T Inc. and DIRECTV For Consent to Assign or Transfer Control of Licenses and Authorization," MB Docket No. 14-90 (2015) at 397.

[5] FCC Memorandum Opinion and Order "In the Matter of Applications of Comcast Corporation, General Electric Company and NBC Universal, Inc. For Consent to Assign Licenses and Transfer Control of Licensees," MB Docket No. 10-56 (2011).

[6] Public Use Microdata Areas (PUMAs) are geographic boundaries defined by the Census Bureau that contain at least 100,000 residents. There are 265 PUMAs in California.

[7] Increasing or decreasing the coverage threshold does not alter the main results. These validity checks are available from the authors upon request.

Figure 1: Residential broadband adoption among HHs eligible for "Access from AT&T"
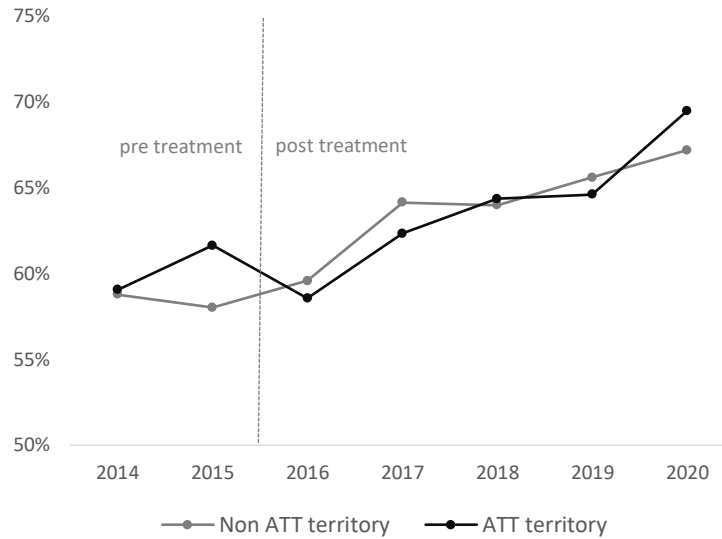
To estimate the impact of AT&T's affordable plan, we first offer a simple calculation of the difference in the average adoption rate in the before (2014-15) and after (2016-20) periods for the treated (those within AT&T territory) and the control households (those outside AT&T territory). As shown in Table 1, broadband adoption among eligible households outside AT&T territory grew from 58.4% in the pre-2016 period to 64.2% in the post-2016 period, thus increasing by 5.8 percentage points. By contrast, the growth in eligible households within AT&T territory was only about half as much (3.3 percentage points). The implied difference-in-difference is -2.5 percentage points, which suggests that the plan did not help increase residential connectivity among eligible households, relative to a control group of similar households outside AT&T territory.

Table 1: Non-parametric difference-in-difference analysis of AT&T's affordable plan

	Non AT&T territory	AT&T territory
(A) Average adoption pre-treatment (2014-15)	58.4%	60.4%
(B) Average adoption post-treatment (2016-20)	64.2%	63.7%
Difference (B-A)	5.8 p.p.	3.3 p.p.

Source: own calculations based on ACS and CPUC.

We use the modelling strategy described in Appendix A to formally test this result. The parameter of interest, which captures the difference-in-difference, is given by the combination between AT&T territory (which denote the treated units) and the post-2016 variable (which denotes post treatment). Table 2 presents three alternative models, each including additional covariates: model 1 is a base model without covariates; model 2 adds controls for the share of households in the PUMA served by other ISPs, which accounts for competition effects; model 3 includes population

density, educational attainment, median household income, Hispanic population and total households as additional controls. Full results are presented in table B1 in the Appendix.

Table 2: Parametric difference-in-difference analysis of AT&T's affordable plan

VARIABLES	(1) Base Model	(2) +ISPs	(3) +Demographics
AT&T territory X post 2016	**-0.0170**	**-0.0181***	**-0.0122**
	(0.0107)	**(0.0109)**	**(0.0109)**
Constant	0.589***	0.607***	0.618**
	(0.00670)	(0.141)	(0.240)
Observations	1,855	1,855	1,855
R-squared	0.569	0.569	0.575
Number of PUMAs	265	265	265
ISP Controls	No	Yes	Yes
Demographic Controls	No	No	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Note: clustered standard errors at PUMA level

The results corroborate the finding that "Access from AT&T" did not result in a meaningful increase in the share of low-income households connected to residential broadband over the study period. As shown, there is a small negative impact in model 2 that essentially disappears as demographic covariates are added in model 3. Overall, this suggests that, in the case of California, the regulatory mandate established by the FCC did not help lower the affordability barrier for low-income households.

2. Internet Assist by Spectrum

Following a lengthy review, in May 2016 the FCC approved the merger of Charter Communications with Time Warner Cable and Bright House Networks, creating the nation's second-largest broadband Internet provider.[8] The approval included a number of conditions, one of them being that the combined company begin offering an affordable, standalone plan with minimum speeds of 30/4Mbps to eligible households for no more than $14.99 per month. Eligibility would be based on two criteria: 1) having at least one child who participates in the National School Lunch Program (NSLP), or 2) being a senior (age 65 or older) enrolled in the Supplemental Security Income (SSI) program. The mandate was set to expire after four years, with a total enrollment target of 525,000 households. Additionally, the order included a mandate for the company to "conspicuously market" the plan.

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[8] FCC Memorandum Opinion and Order "In the Matter of Applications of Charter Communications, Inc., Time Warner Cable Inc., and Advance/Newhouse Partnership For Consent to Assign or Transfer Control of Licenses and Authorizations," MB Docket No. 15-149 (2016) and CPUC Decision 16-05-007 (2016).

Given the large impact of the transaction in California, the CPUC conducted a similar review, which imposed additional conditions. These included the extension of the affordable plan mandate for an additional year (now 5 years in total), and an "aspirational" goal of enrolling 350,000 new broadband subscribers throughout the state. These conditions are laid out as part of a MoU between the new entity and CETF (California Emerging Technology Fund), a digital equity advocacy organization.[9] The plan, called "Internet Assist" by Spectrum, was launched in late 2016.

Figure 2 presents the residential broadband adoption rate among households eligible for "Internet Assist" in California over the study period. As in Figure 1, the darker line represents the adoption rate for eligible households in Charter territory (the treated group), while the lighter line shows the adoption rate for eligible households outside Charter territory (the control group). A similar criterion of 90% coverage is used to identify PUMAs within Charter's service territory. A map of the PUMAs within (treated group) and outside Charter territory (control group) is presented in Figure C2.

Figure 2: Residential broadband adoption among HHs eligible for "Internet Assist" by Spectrum
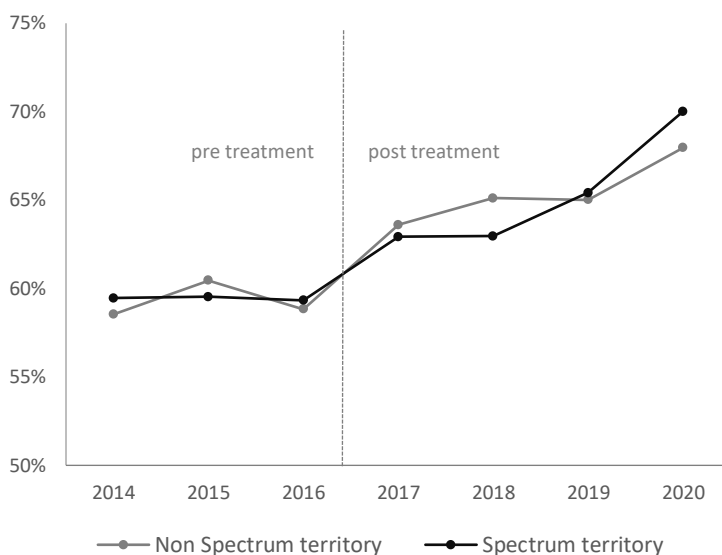
Source: own calculations based on ACS and CPUC

The strategy used to analyze the impact of the plan is similar to the case of AT&T's plan. We first compute the simple difference in the average adoption rates in the before (2014-16) and after (2017-20) periods for the treated (those within Charter service areas) and the control households

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[9] See CPUC Decision In the matter of Joint Application of Charter Communications, Inc.; Charter Fiberlink CA-CCO, LLC (U6878C); Time Warner Cable Inc.; Time Warner Cable Information Services (California), LLC (U6874C); Advance/Newhouse Partnership; Bright House Networks, LLC; and Bright House Networks Information Services (California), LLC (U6955C), May 12, 2016.

(those outside Charter territory). As shown in Table 3, the growth in adoption for eligible households within Charter territory was only marginally smaller than the growth outside Charter territory. With the implied difference-in-difference at -0.2 p.p., the table essentially suggests that the affordable plan did not have a measurable impact on connectivity among target households.

Table 3: Non parametric difference-in-difference analysis of Charter's affordable plan

	Non Charter territory	Charter territory
(A) Average adoption pre-treatment (2014-16)	59.3%	59.4%
(B) Average adoption post-treatment (2017-20)	65.4%	65.3%
Difference (B-A)	6.1 p.p.	5.9 p.p.

Source: own calculations based on ACS and CPUC.

We formally test this finding by replicating the DiD modelling strategy used for the AT&T case. As noted, the parameter of interest, which recovers the DiD estimator, is given by the combination between Charter territory and the post-treatment indicator variable (post 2017). The same models are presented in Table 4, which include a base model without covariates (model 1) and two alternative models, each with additional covariates. Full results are presented in table B2 in the Appendix.

Table 4: Parametric difference-in-difference analysis of Charter's affordable plan

	(1)	(2)	(3)
VARIABLES	Base Model	+ISPs	+Demographics
Charter territory X post 2017	0.000626	0.000781	-0.0119
	(0.0108)	(0.0109)	(0.0110)
Constant	0.589***	0.490***	0.562**
	(0.00677)	(0.167)	(0.258)
Observations	1,855	1,855	1,855
R-squared	0.549	0.549	0.564
Number of PUMAs	265	265	265
ISP Controls	No	Yes	Yes
Demographic Controls	No	No	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Note: clustered standard errors at PUMA level

As expected, the DiD estimator is close to zero and not statistically significant, thus indicating that the introduction of "Internet Assist" by Spectrum in late 2016 did not change the trend in residential adoption among eligible households, relative to a control group of similar households outside Charter territory. This confirms the finding of the non-parametric analysis in Table 3.

3. Affordable Broadband by Frontier

The last plan under study emerged from Frontier Communications' acquisition of Verizon's wireline assets in California, Florida and Texas in 2015. The transaction received relatively light scrutiny from the FCC, which approved it in September 2015.[10] However, the CPUC conducted its own review, and approved the transaction subject to a number of conditions.[11] For the purposes of this study, the relevant conditions are contained in a MoU between Frontier Communications and CETF. In the MoU, Frontier commits to offer its Lifeline voice customers (existing or new) the option to purchase broadband service for no more than $13.99 a month.[12] The speed to be offered was set at 7Mbps downstream, although should these speeds not be available in an area the company committed to offer "the highest available downstream and upstream speeds of service." In addition, in rural areas "where a network build-out is constrained due to the high cost per household" the MoU allowed Frontier to offer a satellite broadband product instead.[13]

The new plan was made available to households subscribing to Lifeline voice service from Frontier, and therefore the relevant eligibility rules were those of the Lifeline program in California. Households were eligible for Lifeline in the state either on the basis of participation in a number of social safety programs (such as Medicaid, SNAP, SSI, and NSLP, among others) or on an income basis (at or below 150% the Federal Poverty Level).[14] According to the MoU, Frontier was to offer the plan "until the FCC enacts a Broadband Lifeline Program and it becomes effective," and agreed to work with CETF and community-based organizations on outreach activities with the "aspirational target" of connecting 200,000 low-income households within three years. The plan, called "Affordable Broadband" by Frontier, was launched in mid 2016.

The analysis follows the same steps as in the two previous sections. Figure 3 presents the residential broadband adoption rate among eligible households, with the darker line representing the adoption rate for households in Frontier territory (the treated group), and the lighter line showing the adoption rate for households outside Frontier territory (the control group). For 2014 and 2015, the areas served by Verizon were recoded as Frontier territory, so that the same areas are followed before and after Frontier's acquisition of Verizon's wireline customers. A similar threshold of 90% availability is used to determine which PUMAs are considered to be within

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[10] FCC Memorandum Opinion and Order "In the Matter of Applications Filed by Frontier Communications Corporation and Verizon Communications Inc. for the Partial Assignment or Transfer of Control of Certain Assets in California, Florida, and Texas," WC Docket No. 15-44 (2015).

[11] CPUC Decision 15-12-005, December 3, 2015.

[12] Lifeline is a federal program established in 1985 that provides a discount on communication services for qualifying low-income households.

[13] Memorandum of Understanding and Agreement between Frontier Communications and CETF, October 23, 2015.

[14] The income threshold for Lifeline in California is different than the 135% of the FPL (Federal Poverty Level) used at the federal level. See
https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M209/K464/209464021.docx

Frontier territory. A map of the PUMAs within (treated group) and outside Frontier territory (control group) is presented in Figure C3.

Figure 3: Residential broadband adoption among HHs eligible for "Affordable Broadband" by Frontier
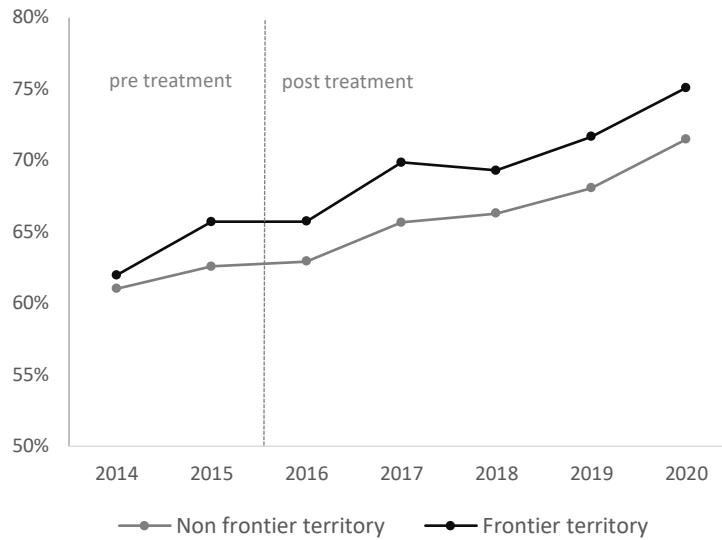
Source: own calculations based on ACS and CPUC

Next we estimate the impact of Frontier's affordable plan by looking at the change in adoption rate for the two groups of households (within and outside Frontier territory) between the before (2014-15) and after (2016-20) period (Table 5). The difference-in-difference calculation yields an implied impact of 1.3 percentage points over and above the expected adoption rate in Frontier territory had the plan not been launched in 2016.

Table 5: Non parametric difference-in-difference analysis of Frontier's affordable plan

	Non Frontier territory	Frontier territory
(A) Average adoption pre-treatment (2014-15)	61.8%	63.8%
(B) Average adoption post-treatment (2016-20)	66.9%	70.2%
Difference (B-A)	5.1 p.p.	6.4 p.p.

Source: own calculations based on ACS and CPUC.

To validate this finding, we turn to the DiD models (Table 6). The results generally confirm that the affordable plan launched by Frontier had a small but significant impact on residential connectivity among eligible households. The magnitude of the impact is almost identical across

the various models, which strengthens the main finding. The remainder of the study uses the more conservative estimation in model 3 (about 1.8 percentage points), which is robust to the inclusion of both sets of covariates (demographic factors and competition factors captured through the share of households in the PUMA served by other ISPs). Full results are presented in table B3 in the Appendix.

Table 6: Parametric difference-in-difference analysis of Frontier's affordable plan

	(1)	(2)	(3)
VARIABLES	Base Model	+ISPs	+Demographics
Frontier territory X post 2016	**0.0216****	**0.0222****	**0.0178***
	(0.00944)	**(0.00959)**	**(0.00962)**
Constant	0.611***	0.480***	0.524***
	(0.00366)	(0.0848)	(0.141)
Observations	1,855	1,855	1,855
R-squared	0.806	0.807	0.811
Number of PUMAs	265	265	265
ISP Controls	No	Yes	Yes
Demographic Controls	No	No	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Note: clustered standard errors at PUMA level

Table 7 offers an approximation to the number of additional households that were connected as a result of Frontier's plan, over and above the natural growth in adoption that occurred over the 2014-20 period. At the time of launch in 2016, about 5.4M households (out of about 12.8M total households statewide) were eligible for Affordable Broadband by Frontier (which had the broadest eligibility criteria of the three plans under study). Extrapolating this eligibility ratio (42.1% of households eligible) to the total number of households served by Frontier in California in 2016, we estimate that about 1.1M households (out of the about 2.6M households served by Frontier) became eligible for the new plan. The adoption rate in Frontier territory among eligible households grew from 65.7% in 2016 to 75.1% in 2020 (Figure 3), or about 9.4 percentage points, which represents about 102,000 households. Of these 9.4 percentage points, we estimate that the affordable plan contributed about 1.8 percentage points (model 3 above), or about 19% of the total growth. This yields about 19,500 households that would not have adopted broadband were it not for Frontier's affordable plan.

Table 7: An estimation of Frontier's plan contribution to adoption among eligible HHs

Total California HHs in 2016	12,807,387
Total HHs eligible for Frontier plan	5,393,191
Eligibility rate	42.1%
Total HHs served by Frontier in 2016	2,581,637
Total HHs eligible for Frontier plan (42.1% eligible)	1,087,127
Total adoption change (2016-20) in number of HHs	101,667
Estimated impact of plan (1.8 p.p.) in number of HHs	19,568

Source: own calculations based on ACS and CPUC.

4. Conclusion

In recent merger proceedings involving telecommunications and media companies, U.S. regulators have often imposed merger-specific conditions aimed at protecting low-income households and more generally advancing digital equity. Among these conditions is an obligation to offer a basic, low-cost access plans to qualifying households. This study raises questions about whether this remedy truly serves the public interest. Empirically, the findings indicate that the affordable plans introduced by AT&T, Charter and Frontier as a result of merger proceedings did not result in a meaningful increase in residential connectivity among eligible California households, above and beyond the levels one would expect had the plans not being introduced. Of the three cases analyzed, only Frontier's plan is associated with a small increase in adoption rates, and even this contribution represents a small fraction of the adoption growth observed among eligible households over the study period.

These results add to a growing list of concerns about affordable plan commitments exacted through regulatory proceedings. Advocacy organizations have pointed out that these plans are inadequately promoted due to lack of effective engagement with local community organizations, and that they fail to meet the quality standards of market-rate alternatives, thus discouraging uptake.[15] As an example, a 2021 study found that only about a third of California households without residential broadband were aware of affordable broadband offerings, and among those who were aware only a quarter have ever applied. The evidence also points to burdensome enrollment, poor information and lack of public trust in affordable programs operated by ISPs as additional barriers.[16] In addition, legal scholars have raised concerns about the arbitrary use of merger-specific conditions and the lack of public input into last-minute agreements struck behind closed doors.[17] As Prof. Susan

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[15] See CETF Petition to Modify Decision No. 15-12-005 to Compel Frontier Communications to Comply with Memoranda of Understand, In the Matter of the Joint Application of Frontier Communications Corporation, Frontier Communications of America, Inc. (U5429C), Verizon California, Inc. (U1002C), Verizon Long Distance LLC (U5732C), and Newco West Holdings LLC for Approval of Transfer of Control Over Verizon California, Inc. and Related Approval of Transfer of Assets and Certifications (March 18, 2015).

[16] See CETF-USC Statewide Broadband Adoption Survey (2021), available at www.cetfund.org/wp-content/uploads/2021/03/Statewide-Survey-on-Broadband-Adoption-CETF-Report.pdf.

[17] Koutsky, T. & Spiwak, L. (2010). Separating politics from policy in FCC merger reviews: A basic legal primer of the "public interest" standard. CommLaw Conspectus, 18, 329-347.

Crawford (2013) notes, voluntary commitments shrouded in vague language about aspirational goals lack teeth and are easily reneged on.[18]

Research suggests that promoting awareness, lowering eligibility barriers and minimizing administrative procedures for enrollment and recertification are key to increased participation in public assistance programs. However, the affordable plans examined in this study present a fundamental misalignment of incentives, since the same operators offering affordable broadband also market comparable plans at standard rates. The monitoring and enforcement of merger-specific affordable plan commitments is therefore critical. This possibly explains why only Frontier's plan achieved a small but measurable impact. Frontier's merger commitments in California were subject to significantly more oversight and compliance monitoring than is the case of AT&T and Charter. Further, these tasks fell to CETF, an organization with extensive policy expertise.[19] This scrutiny was made most apparent in May 2018, when CETF filed a complaint with the CPUC alleging that Frontier had failed to honor its obligations under the 2016 MoU. The complaint led to an amendment of the original agreement in which, among other things, Frontier committed to further its cooperation with CETF and community-based organizations on outreach and marketing of its affordable plan, and to report progress to CETF on a semi-annual basis.[20]

From a regulator's perspective, compelling an ISP to offer an affordable broadband plan is an appealing remedy that seeks to balance public and private goals by shifting the cost of subsidizing access to the regulated entity. This is particularly the case after the reclassification of broadband as an information service under Title I of the U.S. Communications Act, which effectively foreclosed any attempts at rate regulation.[21] However, the findings of this study suggest that this remedy may be fraught with enforcement challenges, and ultimately has only minimal impact. The recent creation of the Affordable Connectivity Program (ACP), a federal program that supports broadband service for low-income households, is a positive signal that suggests a transition from hard-to-enforce obligations on individual ISPs to system-wide solutions to address digital equity.

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[18] Crawford, S. (2013). Captive audience. New Haven, CT: Yale University Press.

[19] By contrast, the conditions imposed on Charter and AT&T were subject to monitoring by independent compliance officers appointed by and reporting exclusively to the FCC, effectively limiting public accountability.

[20] See footnote #15 above.

[21] FCC Declaratory Ruling, Report and Order, and Order ("Restoring Internet Freedom Order") in WC Docket No. 17-108, adopted on December 14, 2017.

About the project

This policy brief is part of the Measuring the Effectiveness of Digital Inclusion Approaches (MEDIA) project, a research program that seeks to analyze existing broadband inclusion initiatives and provide evidence-based recommendations on how best to connect low-income households to broadband on a sustainable basis. This policy brief is the second in a series of publications based on results from the program.

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Appendix A

Methodology

  The difference-in-difference (DiD) strategy used in this study rests on several key estimates. First, households that qualify for each of the affordable plans are identified using data from the American Community Survey (ACS). Because eligibility combines a number of household-level variables (discussed above), this can only be estimated consistently using microdata at the PUMA level. Once eligible households are identified, the ACS provides information about residential broadband adoption, our main outcome of interest.

The units in this study are the PUMAs, for which we observe adoption rates among eligible households before and after the launch of the affordable plans. To distinguish between treated and control units, we estimate the share of households in a PUMA served by each ISP (regardless of service speed), using broadband deployment data from the CPUC. This is computed for the major cable and DSL providers of residential broadband, excluding fixed wireless and satellite-based ISPs. Next, we apply a threshold of 90% households served to determine if a PUMA falls within the ISP territory (and thus will be considered treated) or outside the ISP territory (and thus will be considered control). In DiD terms, this is referred to as intent-to-treat (ITT) estimation, and has been used in similar studies about the impact of affordable broadband plans.[22] For validity check, other coverage thresholds are used, resulting in negligible changes to the main results.[23]

Using this threshold, we obtain a standard DiD setup with two groups of units (treated and control) and two time periods (before and after treatment). This allows for both parametric and a non-parametric estimations. In the non-parametric alternative, the quantity of interest, referred to as the Average Treatment Effect on the Treated (ATT), is given by:

$$ATT = (E[\bar{Y}_{treat}|Post] - E[\bar{Y}_{treat}|Pre]) - (E[\bar{Y}_{control}|Post] - E[\bar{Y}_{control}|Pre])$$

where $\bar{Y}$ is the average residential broadband adoption rate among eligible households for the corresponding group (treated or control) and time period (pre or post treatment).

The parametric alternative, which allows for including PUMA-level covariates as controls, is estimated using the following model:

$$Y_{it} = \alpha + Y_t + \delta_i + \beta D_{it} + X_{it} + \mu_{it}$$

where Y_{it} is the residential broadband adoption rate among eligible households for PUMA i in year t, α is a constant, Y_t are year fixed effects, δ_i are PUMA fixed effects, D_{it} indicates

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[22] See Zuo (2021).
[23] These results available from the authors upon request.

whether PUMA *i* was "treated" at year *t*, X_{it} is a vector of PUMA-level covariates (in models with covariates), and μ_{it} is the error term (clustered at the PUMA level). In this standard two-way fixed-effects (TWFE) model, the parameter of interest is β which recovers the difference-in-difference estimator. The control variables include four PUMA-level demographic characteristics that are known to affect residential broadband uptake (population density, median household income, share of population with a college degree and total households) as well as the share of households served by competing residential ISPs. Demographic data is sourced from the American Community Survey for each year (1 year estimates).

Appendix B

Table B1: AT&T parametric difference-in-difference analysis

VARIABLES	(1) Base Model	(2) +ISP	(3) +Demographics
AT&T territory X post 2016	-0.0170	-0.0181*	-0.0122
	(0.0107)	(0.0109)	(0.0109)
2015.year	0.0112	0.0113	0.0130
	(0.00975)	(0.00977)	(0.0100)
2016.year	0.0102	0.0111	0.0159
	(0.0114)	(0.0115)	(0.0122)
2017.year	0.0518***	0.0527***	0.0675***
	(0.0112)	(0.0114)	(0.0143)
2018.year	0.0599***	0.0607***	0.0873***
	(0.0115)	(0.0119)	(0.0168)
2019.year	0.0698***	0.0708***	0.109***
	(0.0119)	(0.0123)	(0.0209)
2020.year	0.102***	0.102***	0.151***
	(0.0106)	(0.0107)	(0.0237)
Share pop served Charter		0.0321	-0.00115
		(0.0306)	(0.0326)
Share pop served Comcast		-0.128	-0.242
		(0.373)	(0.359)
Share pop served Cox		0.0309	0.0384
		(0.650)	(0.658)
Share pop served Frontier		0.0341	0.0416
		(0.0705)	(0.0723)
Population density			3.24e-05
			(2.46e-05)
Total HHs			3.25e-06
			(4.29e-06)
Median HH income			-2.26e-06**
			(1.05e-06)
Share of college+			-3.62e-06
			(2.47e-06)
Hispanic population			1.40e-06
			(1.39e-06)
Constant	0.589***	0.607***	0.618**
	(0.00670)	(0.141)	(0.240)
R-squared	0.569	0.569	0.575
ISP Controls	No	Yes	Yes
Demographic Controls	No	No	Yes

Robust standard errors in parentheses. Note: clustered standard errors at PUMA level
*** p<0.01, ** p<0.05, * p<0.1

Table B2: Charter parametric difference-in-difference analysis

VARIABLES	(1) Base Model	(2) +ISP	(3) +Demographics
Charter territory X post 2017	0.000626	0.000781	-0.0119
	(0.0108)	(0.0109)	(0.0110)
2015.year	0.0112	0.0110	0.0140
	(0.00975)	(0.00977)	(0.0101)
2016.year	0.00111	7.54e-05	0.0131
	(0.00958)	(0.00961)	(0.0109)
2017.year	0.0435***	0.0419***	0.0761***
	(0.0106)	(0.0107)	(0.0155)
2018.year	0.0520***	0.0500***	0.103***
	(0.0119)	(0.0122)	(0.0193)
2019.year	0.0622***	0.0599***	0.132***
	(0.0119)	(0.0122)	(0.0234)
2020.year	0.0989***	0.100***	0.189***
	(0.0120)	(0.0119)	(0.0269)
Share pop served AT&T		0.0448*	-0.0115
		(0.0269)	(0.0307)
Share pop served Comcast		0.392	0.158
		(0.442)	(0.416)
Share pop served Cox		-0.675	-0.654
		(0.813)	(0.780)
Share pop served Frontier		-0.00273	0.0206
		(0.0747)	(0.0764)
Population density			3.60e-05
			(2.62e-05)
Total HHs			5.10e-06
			(4.63e-06)
Median HH income			-3.66e-06***
			(1.18e-06)
Share of college+			-5.85e-06**
			(2.61e-06)
Hispanic population			3.16e-06**
			(1.57e-06)
Constant	0.589***	0.490***	0.562**
	(0.00677)	(0.167)	(0.258)
R-squared	0.548	0.549	0.564
ISP Controls	No	Yes	Yes
Demographic Controls	No	No	Yes

Robust standard errors in parentheses. Note: clustered standard errors at PUMA level
*** p<0.01, ** p<0.05, * p<0.1

Table B3: Frontier parametric difference-in-difference analysis

VARIABLES	(1) Base Model	(2) +ISP	(3) +Demographics
Frontier territory X post 2016	0.0216**	0.0222**	0.0178*
	(0.00944)	(0.00959)	(0.00962)
2015.year	0.0182***	0.0181***	0.0176***
	(0.00458)	(0.00459)	(0.00478)
2016.year	0.0184***	0.0184***	0.0219***
	(0.00495)	(0.00502)	(0.00590)
2017.year	0.0474***	0.0465***	0.0565***
	(0.00530)	(0.00537)	(0.00752)
2018.year	0.0525***	0.0512***	0.0696***
	(0.00560)	(0.00568)	(0.00955)
2019.year	0.0705***	0.0690***	0.0960***
	(0.00583)	(0.00595)	(0.0119)
2020.year	0.104***	0.106***	0.140***
	(0.00614)	(0.00619)	(0.0138)
Share pop served Charter		0.0190	-0.000874
		(0.0293)	(0.0293)
Share pop served Comcast		0.338	0.236
		(0.236)	(0.223)
Share pop served Cox		0.0894	0.149
		(0.237)	(0.226)
Share pop served AT&T		0.000978	0.0110
		(0.0465)	(0.0471)
Population density			1.85e-05
			(1.52e-05)
Total HHs			-6.93e-07
			(3.03e-06)
Median HH income			-2.17e-06***
			(6.02e-07)
Share of college+			1.52e-07
			(1.62e-06)
Hispanic population			1.19e-06
			(1.04e-06)
Constant	0.611***	0.480***	0.524***
	(0.00366)	(0.0848)	(0.141)
R-squared	0.806	0.807	0.811
ISP Controls	No	Yes	Yes
Demographic Controls	No	No	No

Robust standard errors in parentheses. Note: clustered standard errors at PUMA level
*** p<0.01, ** p<0.05, * p<0.1

APPENDIX C

Figure C1: Map of PUMAs within (treated group) and outside AT&T territory (control group)
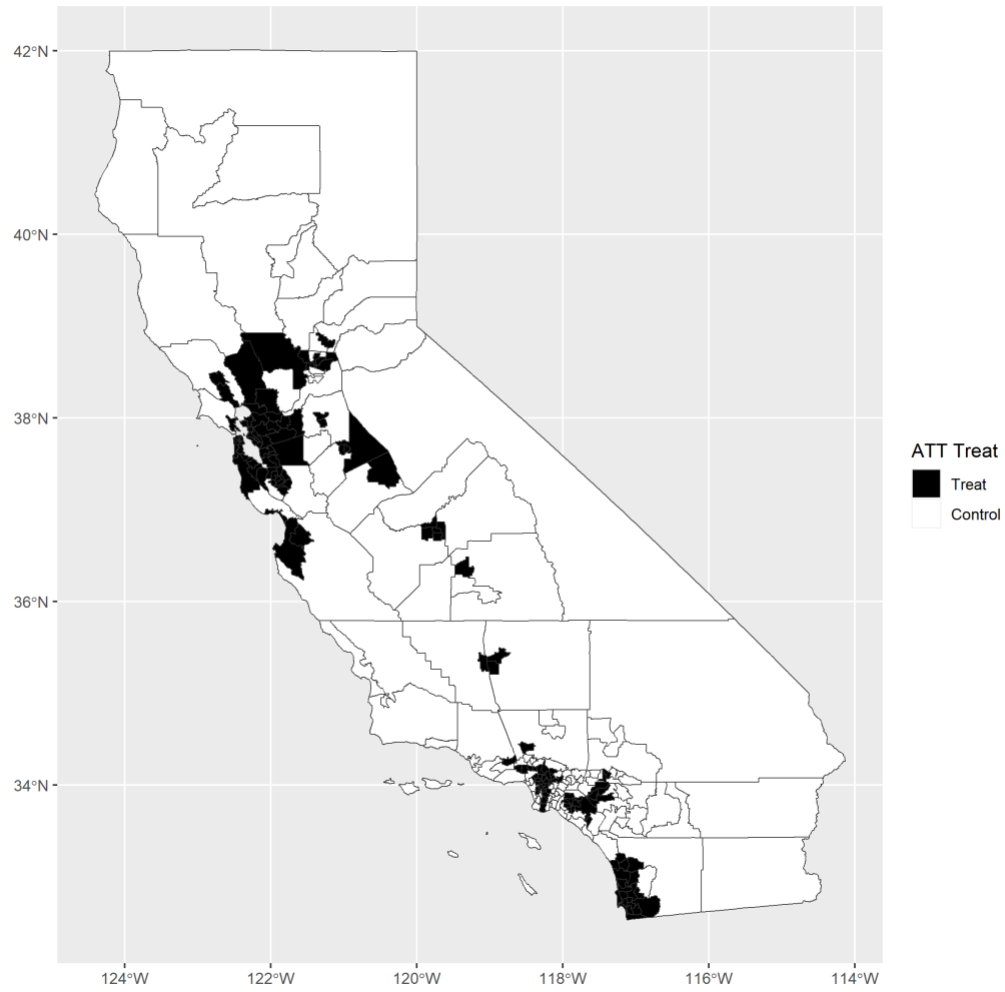
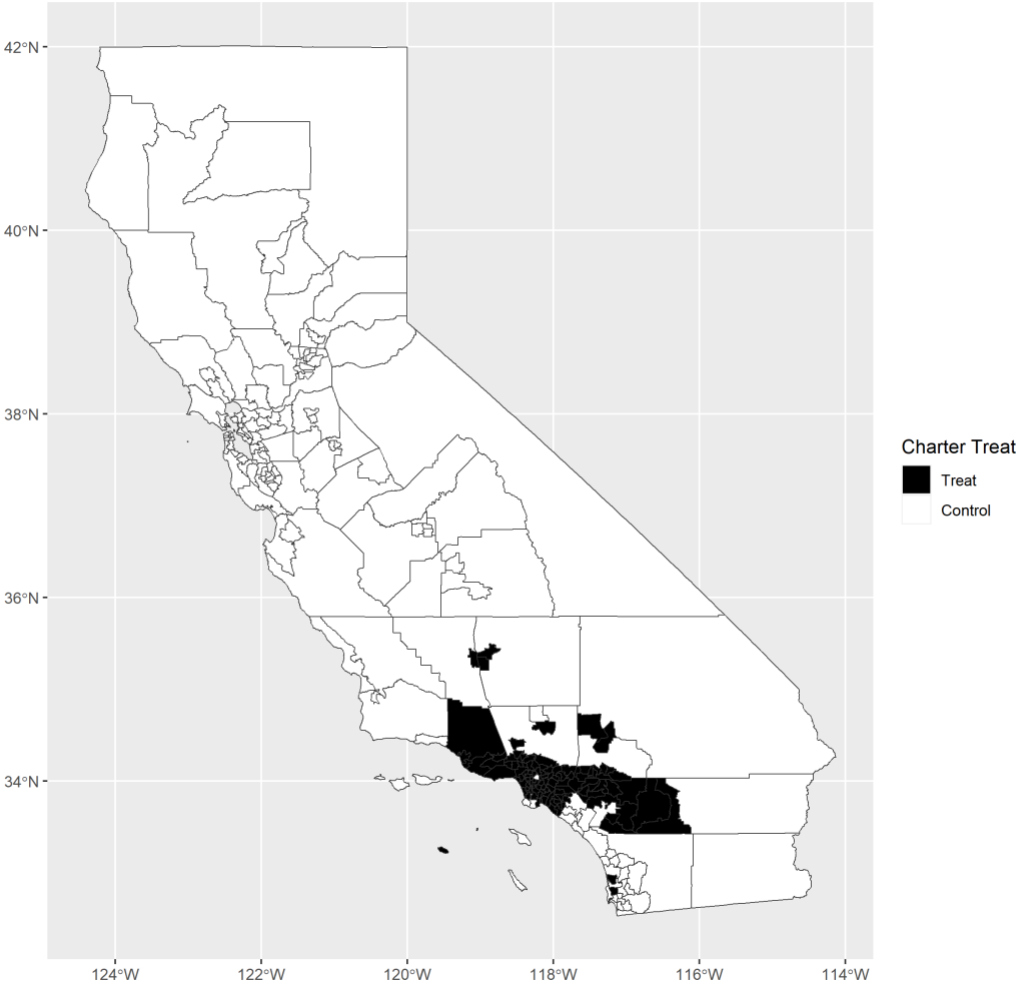## Figure C2: Map of PUMAs within (treated group) and outside Charter territory (control group)

Figure C3: Map of PUMAs within (treated group) and outside Frontier territory (control group)