PHOENIX CENTER POLICY PAPER SERIES

Phoenix Center Policy Paper Number 56:

Bridging the Digital Divide: What Has Not Worked But What Just Might

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(June 2020)

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Bridging the Digital Divide: What Has Not Worked But What Just Might

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Abstract: America has spent billions trying to close the Digital Divide, but adoption disparities along many dimensions persist. The COVID pandemic has rekindled the strong interest in broadband adoption, with many in Congress now proposing to spend billions more to shrink the adoption gap. In this POLICY PAPER, we first offer an economic analysis of how best to spend broadband subsidies. As might be expected, the analysis prescribes that money should be spent where it is most effective (per dollar) at increasing adoption. Second, we offer an empirical analysis of past broadband adoption programs by quantifying the effect of several programs established by the *American Reinvestment and Recovery Act of 2009*. Applying a Difference-in-Differences model to Census data on adoption, we find no positive effect on home broadband adoption from programs funded by the Broadband Technology Opportunity Program ("BTOP"). Third, we discuss the potential benefits of direct subscriber subsidies considering the successful private sector programs offering low-cost broadband plans to low-income and other qualifying households. Direct subsidies to end-users will increase adoption, but surveys and empirical evidence prescribe sober expectations on their effectiveness at achieving universal adoption. Subsidizing broadband infrastructure deployment in unserved areas is a direct approach to increase broadband adoption, but even so the costs in some regions may outweigh the benefits.

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I. Introduction

At last count, about 94% of American households had access to a fixed-line broadband Internet service with download speeds greater than 25 Mbps, and 85% had access to download speeds greater than 250 Mbps.[1] Adoption rates for home broadband service are about 80%.[2] Broadband service is both widely available and highly subscribed. As with all goods and services, there are broadband "haves" and "have nots," a distinction commonly labeled the "Digital Divide."[3] The COVID-19 pandemic is a stark reminder of this divide as shelter-in-place policies and physical distancing made telecommuting and online education indispensable.[4] Policymakers at the state and federal levels have expressed a renewed interest in closing this Digital Divide, with proposals to spend as much as $100 billion to do so.[5]

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1 *2020 Broadband Deployment Report*, Federal Communications Commission (Rel. April 24, 2020) at ¶¶ 2, 36 (available at: https://docs.fcc.gov/public/attachments/FCC-20-50A1.pdf).

2 *Digital Nation Data Explorer*, National Telecommunications Information Administration (November 2017) (available at: https://www.ntia.doc.gov/data/digital-nation-data-explorer#sel=internetUser&disp=map).

3 *Falling Through the Net: A Survey of the "Have Nots" in Rural and Urban America*, National Telecommunications Information Administration, U.S. Department of Commerce (July 1995) (available at: https://www.ntia.doc.gov/ntiahome/fallingthru.html).

4 M. Melia, *"Homework Gap" Shows Millions of Students Lack Home Internet*, THE DETROIT NEWS (June 10, 2019) (available at: https://www.detroitnews.com/story/tech/2019/06/10/digital-divide-homework-gap/39563613).

5 *House Democrats Release Text of H.R. 2, A Transformational Infrastructure Bill to Create Jobs and Rebuild America*, Press Release (Jun 22, 2020) (available at:

(Footnote Continued. . . .)

Efforts to shrink the Digital Divide are not new. Each year billions in federal and state monies are spent to expand access and adoption with programs like the Rural Digital Opportunities Fund ("RDOF") and the Lifeline Program.[6] Adding to the ongoing programs, the *American Reinvestment and Recovery Act of 2009* allotted $4.7 billion to expand access and adoption through the Broadband Technology Opportunities Program ("BTOP") and $350 million to develop a broadband map.[7] As Congress contemplates new programs like these, it is worth considering the relative efficiency of various broadband adoption programs so that money is spent wisely.

In this POLICY PAPER, we first offer a conceptual analysis of how best to spend broadband subsidies. As might be expected, the analysis prescribes that money should be spend where it is most effective (per dollar spent) at increasing adoption, since it is the lack of adoption that largely defines the Digital Divide. Second, we offer a new empirical analysis of broadband adoption programs by quantifying the effect of the BTOP programs. We find no effect of the BTOP programs on home broadband adoption, a result consistent with prior empirical analysis on BTOP programs. Third, we discuss research on the effects of low-cost broadband programs offered by private broadband providers. These programs have proven effective at increasing adoption, suggesting that direct subsidies may prove useful although it is unclear whether such success will be matched by federal subsidies for home broadband service. However, empirical

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https://energycommerce.house.gov/newsroom/press-releases/house-democrats-release-text-of-hr-2-a-transformational-infrastructure-bill) ("Delivers affordable high-speed broadband Internet access to all parts of the country by investing $100 billion to promote competition for broadband internet infrastructure in unserved and underserved communities, prioritizing those with persistent poverty."); J. Wehrman and J. Shutt, *Broadband Push Gains Traction for Next Virus Aid Package*, ROLL CALL (April 30, 2020) (available at: https://www.rollcall.com/2020/04/30/broadband-push-gains-traction-for-next-virus-aid-package).

[6] C. Cash, *What We Know About the RDOF – the Biggest FCC Auction for Rural Broadband Funds*, COOPERATIVE.COM (January 28, 2020) (available at: https://www.cooperative.com/news/pages/rundown-on-fcc-20-billion-rdof-for-rural-broadband.aspx). Detailed information (available at: https://www.fcc.gov/auction/904); G.S. Ford, *A Fresh Look at the Lifeline Program*, PHOENIX CENTER POLICY PAPER No. 55 (July 2019) (available at: https://www.phoenix-center.org/pcpp/PCPP55Final.pdf).

[7] *Broadband Infrastructure Programs in the American Recovery and Reinvestment Act*, Congressional Research Office R40436 (January 5, 2011) (available at: https://www.everycrsreport.com/files/20110104_R40436_a053e9d57e156ebde1c50b37bc3bbf7dbf3f8b56.pdf).

studies and surveys do not suggest that price reductions, even large ones, may not materially shrink the adoption gap. Extending existing broadband networks to unserved areas is certainly an effective use of subsidy dollars, but such spending warrants a cost-benefit analysis; some connections may cost more than they are worth. Finally, concluding comments are provided.

II. Allocating Broadband Funding

COVID has wreaked havoc on the U.S. economy, but with respect to broadband information technology the COVID pandemic has brought a new sense of urgency. Many in Congress are now proposing to spend additional billions to expand adoption and availability. There are diverse programs on which new funding for broadband could be spent: infrastructure to rural homes; infrastructure to Community Anchor Institutions ("CAIs"); Wi-Fi in school parking lots; digital skills education; and so forth.

But how should these funds be allocated among these potential options? To state the obvious, the answer is that a fixed budget should be spent in a manner that maximizes the objective. Regarding the broadband policy objective, the COVID pandemic has brought clarity. The present objective, it seems to us, is to increase the home adoption of broadband—the complaints regarding access during the pandemic focus squarely on home adoption.

With most non-adopters indicating a lack of interest in what the Internet has to offer and some regions of the country facing exceedingly high deployment costs, universal adoption and availability are unrealistic goals, but there are perhaps meaningful opportunities to expand broadband adoption.[8] With home broadband adoption as the goal, the targets of spending can be broken sensibly into two categories: (1) increase adoption by expanding availability; and (2) increase adoption by increasing the effective demand of persons who have access but choose not to subscribe, either through education, subsidies, or low-cost

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[8] At one time, telephone adoption was viewed as an essential communications service. In 2011, near the peak of telephone adoption, adoption in the U.S. reached about 95.6% of homes, with a range across states of 91.4% to 98.5%. *Telephone Subscribership Report*, Federal Communications Commission (December 14, 2011) (available at: https://www.fcc.gov/general/telephone-subscribership-report). While telephone subscription rates suggest current adoption rates may be "too low," there are reasons why telephone adoption may exceed broadband adoption: (1) computers are far more costly than telephones; (2) some Americans legitimately worry about online privacy and safety; and (3) some persons are content with mobile broadband access or access at public locations. Universal adoption of broadband seems unrealistic.

access. While there are questions about which connection modalities are best, our theoretical analysis is general enough to encompass any broadband modality. The empirical analysis is limited to home broadband adoption by fixed (and not mobile) technologies.

A. *Designing a Policy*

In designing a broadband policy there are several inter-related considerations. How big is the budget? Where is the money spent? On what is the money spent? To keep it relatively simple, let's set aside budget size and assume that the goal of the benevolent social planner is to allocate a fixed budget V among treatable units or areas ($i = 1, 2, 3\ldots n$) so as to maximize the national level of broadband adoption. The various regions differ in initial broadband adoption and availability, and also differ in many other ways. The social planner must decide on how to allocate the aggregate budget across spending levels A_i and D_i for each region, where A_i indicates new spending on availability (e.g., build outs to unserved areas) and D_i indicates demand side spending (e.g., digital skills training, consumer subsidies or advertising). Given these allocations, the resulting broadband adoption rate in the i^{th} region is given as $B_i(A_i, D_i)$, and $B_i(0, 0)$ can be understood as the initial broadband adoption rate before any additional spending. Let w_i be the weight attached to the i^{th} region in the calculation of the national broadband adoption rate. For example, w_i could be the region's share of persons or households in the nation. Thus, we assume that $\sum_{i=1}^{n} w_i = 1$.

The social planner seeks to maximize the objective

$$G = \sum_{i=1}^{n} w_i B_i(A_i, D_i) \tag{1}$$

by choosing A_i and D_i such that $A_i \geq 0$ and $D_i \geq 0$, and $\sum_{i=1}^{n} A_i + \sum_{i=1}^{n} D_i \leq V$ for all $i = 1, 2, 3\ldots n$. We will make some standard assumptions on the regional broadband adoption functions so that the social planner's optimization problem is well defined. We generally assume that each B_i is strictly increasing in both arguments, strictly concave, and contained in the unit interval [0,1]. Furthermore, we will assume that each B_i is continuously differentiable.

The social planner's constrained optimization problem can be analyzed by forming a Lagrangian function and applying the Kuhn-Tucker Theorem. The Lagrangian is given by

$$\sum_{i=1}^{n}[w_i B_i(A_i, D_i) + \alpha_i A_i + \gamma_i D_i] + \lambda\left(V - \sum_{i=1}^{n}[A_i + D_i]\right) \quad (2)$$

where α_i, γ_i, and λ are Lagrange multipliers for the constraints. Since the regional broadband adoption functions are strictly increasing, the aggregate budget constraint will bind and the multiplier λ will be strictly positive as additional resources would result in greater national broadband adoption.

If the optimal A_i^* and D_i^* are positive in regions *i* and *j*, then the associated multipliers α_i and γ_i must equal zero by the complementary slackness condition of the Kuhn-Tucker Theorem. Hence, the first-order necessary condition yields:

$$w_i \frac{\partial B_i(A_i^*, D_i^*)}{\partial A_i} = \lambda = w_j \frac{\partial B_j(A_j^*, D_j^*)}{\partial D_j}$$

for any *i* or *j* such that $A_i^* > 0$ and $D_i^* > 0$. This result says that any positive optimal investment in either availability or the demand side in some region, must have the same marginal impact on national broadband adoption. That is, if money is spent more productively elsewhere, then it should be spent there.

Money need not be spent everywhere and on everything—the optimal A_k^* and D_m^* may be zero for some regions *k* and *m*, and this scenario is likely to happen in regions that start with a high degree of initial availability and broadband adoption. Such regions will generally exhibit a lower marginal return to additional investments. Generally speaking, the private sector generates excess entry into markets from a social welfare perspective and hence, investments in additional availability associated with new entry (overbuilding) may generate very low marginal returns.[9] The Kuhn-Tucker Theorem indicates that when a variable corners at zero, the multiplier (α_k and γ_m) will generally be positive. Hence,

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[9] *See, e.g.,* G.S. Ford, *The Impact of Government-Owned Broadband Networks on Private Investment and Consumer Welfare*, State Government Leadership Foundation (April 6, 2016) at pp. 27-9 (available at: https://sglf.org/wp-content/uploads/sites/2/2016/04/SGLF-Muni-Broadband-Paper.pdf).

$$w_k \frac{\partial B_k(A_k^*, D_k^*)}{\partial A_k} = \lambda - \alpha_k < \lambda \quad \text{and} \quad w_m \frac{\partial B_m(A_m^*, D_m^*)}{\partial D_m} = \lambda - \gamma_m < \lambda \ ,$$

for any k or m such that $A_k^* = 0$ and $D_m^* = 0$. Note that if $k = m$, then it would be optimal to engage in no spending whatsoever in the region.

To summarize, when you spend on something to increase broadband adoption in a region, the marginal effect on national adoption must be equal to the marginal dollar's effect of spending on anything else anywhere else where spending is also positive. If not, then a reallocation of funding provides better outcomes. Some regions will get spending in only one category, or no spending at all if the marginal returns are too small. This is likely to be the case in regions that already have high availability and broadband adoption, or else where the costs of deployment are high due to low household density. Whether or not there is positive investment in a region will be reflected by the values of the multipliers α_i and γ_i. Naturally, money might be sensibly spent where adoption is relatively low, but the reasons adoption is low may make such spending unproductive. Both the adoption rate and the likely productivity of additional spending must be considered in designing and implementing a policy.

Put simply, there is no one size fits all program for expanding broadband adoption. Broadband spending should be directed to regions and programs where the increase in adoption per-dollar of spending is the greatest. Programs that have little or no measurable effect on adoption should not receive funding. Funding programs in regions with high availability and/or adoption are unlikely to have a large effect on adoption. For instance, it makes no sense to use limited funds to construct municipal networks on top of existing networks, since doing so is costly and provides little-to-no new household coverage and little-to-no increase in adoption. This logic underlies the Federal Communications Commission's ("FCC") RDOF program, where subsidy dollars are restricted to areas without broadband service.

B. *Numerical Examples*

A numerical example may be helpful. To keep it simple, say there are three, equally sized areas: A, B and C. Areas A and B are entirely unserved, but area C already has a broadband provider. A fixed budget of $5,000,000 is to be spent on infrastructure to wire presently unserved markets. The expected impacts of spending are summarized in Table 1. In the table are the new adoptions for each dollar spent and the marginal change in adoption for each additional $1 million in subsidy levels. For instance, for the first $1 million in spending, areas A and B have 600 new subscribers, but area C has only 60 subscribers since this area is already served by a broadband provider (the increase in adoption arises only from a competitive price reduction). If $2 million is spent in the areas, then Area A has 1,000 new subscribers (400 new subscribers), Area B has 1,160 new subscribers (560 new subscribers), and Area C has 100 subscribers (40 new subscribers). This difference in the marginal effect of the second million dollars for areas A and B could be due to fewer homes being passed in A than in B (i.e., household density falls more quickly in A than in B) for the same amount of funding. With a budget of only $5 million, it is not possible to spend $2 million in each area, nor is it sensible to divide it equally among the three areas.

Table 1. Numerical Example

	Area A		Area B		Area C	
Spending	Adoptions	Marginal Adoptions	Adoptions	Marginal Adoptions	Adoptions	Marginal Adoptions
$1 Million	600	600	600	600	60	60
$2 Million	1000	400	1,160	560	100	40
$3 Million	1180	180	1,560	400	118	18
$4 Million	1280	100	1,760	200	128	10
$5 Million	1320	80	1,830	70	132	8

How should the $5 million be divided between the two areas? The maximum number of new adoptions (2,560) is obtained when spending $2 million in Area A, $3 million in Area B, and nothing in Area C. It is at this level of spending where the marginal increase in adoptions per $1 million spent is equal (at 400 subscribers), where the marginal expenditure on the new subscribers is $2,500 in both areas. If, instead, $3 million was spent in Area A and $2 million in Area B, then there are only 2,340 new subscribers. Or, if $4 million is spent in area B and $1 million in Area A, then there are only 2,360 new subscribers. If all the money was spent in Area B, then the $5 million produced only 1,830 new subscribers. It is always better to spend money in areas A or B than in C. Funding, if limited, should be directed at the lowest cost homes and to areas where expected adoption is high. Extending networks to unserved areas is almost certain to increase subscriptions, while spending money in served areas has a low return.[10]

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[10] Increasing availability may be expected to increase adoption by the mean adoption rate, which is today around 80%. Yet, this expectation may be naive. A BTOP funded expansion of network to 682 unserved and underserved homes in Kentucky, for instance, produced only 91 subscriptions (at a cost of $6,550 per subscriber)

(Footnote Continued. . . .)

This numerical example covers only the deployment of network in different regions. What about demand-side programs? Demand-side programs may be illustrated by letting the regional broadband adoption function have the following form:

$$B_i(A_i, D_i) = 1 - \frac{1}{A_i + a_i} - \frac{1}{D_i + d_i}. \qquad (3)$$

Further, suppose there are three equally weighted regions such that $a_1 = 4$, $d_1 = 3$, $a_2 = 10$, $d_2 = 3$, $a_3 = 10$, and $d_3 = 10$. The national adoption function will be given as:

$$G = 1 - \frac{1}{3}\left[\frac{1}{A_1 + 4} + \frac{1}{D_1 + 3} + \frac{1}{A_2 + 10} + \frac{1}{D_2 + 3} + \frac{1}{A_3 + 10} + \frac{1}{D_3 + 10}\right] \qquad (4)$$

If the aggregate budget for the social planner to invest is five units, so that $V = 5$, then the optimal allocations are:

$$\begin{aligned} A_1^* &= 1,\ D_1^* = 2 \\ A_2^* &= 0,\ D_2^* = 2 \\ A_3^* &= 0,\ D_3^* = 0 \end{aligned}$$

Hence, the first region would have positive investment in both availability and the adoption programs, but the second region would only have positive investment in demand-side programs. The third region receives no investment at all. Note that all the positive investments have the same marginal effect on national broadband adoption at the optimum:

$$\frac{1}{3}\frac{\partial B_1(1,2)}{\partial A_1} = \frac{1}{3}\frac{\partial B_1(1,2)}{\partial D_1} = \frac{1}{3}\frac{\partial B_2(0,2)}{\partial D_2} = \frac{1}{75} = 1.33\% \qquad ,$$

(https://www2.ntia.doc.gov/files/grantees/nt10bix5570058_apr2012_q4.pdf). It is unclear how many of the newly served homes were not already served by other carriers, though the "underserved" qualifier suggests some were.

C. *Summary*

Our presentation of this conceptual analysis does not suggest we expect policymakers to implement a finely-tuned subsidy program that satisfies the optimality conditions. Rather, our analysis aims to encourage policymakers to contemplate how best to spend any new subsidies by directing the funds to regions and programs where the marginal returns on investment—which here is taken to be an increase in broadband adoption—are likely to be highest. The allocation of BTOP funds did not follow economic logic but seemed somewhat arbitrary and political. To reap the reward of broadband subsidies requires some analysis of deployment costs, adoption rates, and the effectiveness of prior programs, among other considerations.

Take, for instance, the question of whether to subsidize the extension of infrastructure to unserved areas or the direct subsidization of broadband service to households. Since only about 10% of homes do not have access to broadband and about 20% of homes do not subscribe to broadband where it is available, directly subsidizing adoption rather than paying for additional infrastructure may seem, at first glance, to offer a larger return. However, subsidies typically are limited to low-income households, which reduces the 20%-or-so of non-subscribers to something closer to 4%.[11] Moreover, low-income households may not have a computer, or may not be interested in broadband at any price. Moreover, informing low-income households of the program, providing computers, administering the qualification process, and other considerations such as waste, fraud, and abuse adds to the costs of a direct subsidy program. As such, subsidizing adoption may not be cheaper than infrastructure. Say the social planner is considering a $50 monthly subsidy to low-income households. While the annual cost of such a program is a relatively low $600, these subsidies will persist over time. The net present value of a $50 monthly subsidy at a 5% discount rate is about $2,000 over five-years or $3,700 over ten years. These amounts may exceed the cost of deploying new network to unserved homes, which have a naive adoption rate of 70% to 80%. These tradeoffs should be considered, even if crudely.

As for infrastructure investment, a program like the FCC's RDOF may be used to parse opportunities. For instance, a reverse auction process reveals the

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[11] While adoption is lower for low-income households, many higher income households do not subscribe to broadband service. Authors' calculations from the 2017 Computer and Internet Use Supplement indicate that about 20% of non-adopters have incomes less than $25,000.

cost of deploying network to a large collection of areas. With these data alone, a fixed budget could be allocated based on maximizing the number of homes passed for the given budget. The budget's allocation may be improved by incorporating the expected adoption rate, since higher adoption increases the relative return on investment. Adoption rates in neighboring areas and/or the demographics of the area to be subsidized may shed light on expected adoption. And, if educational concerns are the primary motivator for subsidizing broadband, then the number of children in the proposed area may be a useful factor to use in the allocation of funds.

Sorting out the best options for spending is largely an empirical problem. In some instances, it is feasible to look at past federally-funded efforts to expand adoption to determine the relative impact of prior efforts. In other cases, new data on costs can be used to sort regions by their marginal returns. In the next section, we demonstrate the sort of efforts required to better allocate subsidy dollars by quantifying the home broadband adoption impacts of the BTOP funding, including the programs for Sustainable Broadband Adoption, Public Computer Centers, and Community Anchor Institutions. Which, if any, of these programs increased broadband adoption, and the relative impact of each, may be empirically determined to aid in spending new subsidy dollars.

III. A Case Study: BTOP's Sustainable Broadband Adoption Program

Of the $4.7 billion in BTOP funds, the bulk of the funding (along with matching grants) was directed at Sustainable Broadband Adoption ("SBA"), Public Computer Centers ("PCC") and Community Anchor Institutions ("CAI").[12] According to the National Telecommunications and Information Administration ("NTIA"), Comprehensive Community Infrastructure projects (the CAI funding) was $2.9 billion, while the PCC and SBA programs received $445.9 million. NTIA data indicates that SBA rewards totaled $250 million in federal funds (and about $100 million in matching funds).[13] The funding supported 25,948 CAI locations (latitude and longitude points), 3,367 Public Computer Centers, and 4,096 SBA program sites across the nation. While

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12 *See*, *e.g.*, *Broadband Technology Opportunities Program (BTOP) Quarterly Program Status Report*, National Telecommunications and Information Administration, U.S. Department of Commerce (May 2015) (available at: https://www.ntia.doc.gov/files/ntia/publications/ntia_btop_24th_qtrly_report_may_2015.pdf).

13 https://www2.ntia.doc.gov/BTOPmap.

recipients of such funds point to increased adoption in their areas, broadband adoption rises in nearly all geographic areas over time, so the important question is whether this subscription increase is larger than adoption rates generally. If not, then the funds did not increase adoption above-and-beyond a no-subsidy scenario. This question can be answered empirically (using the Difference-in-Differences method). Note, however, that apart from the SBA program, very little of the BTOP spending was directed toward home adoption.

The evaluation of BTOP and similar programs has been done before. As for BTOP generally, econometric analysis by Hauge and Prieger (2015) found that the effect of the BTOP "stimulus spending on broadband adoption may well be zero."[14] With nearly $1 million in BTOP funds (through applicant One Economy) spent on a soap opera allegedly encouraging broadband adoption, the results from Hauge and Prieger (2015) are mostly unsurprising.[15] Manlove and Whitacre (2019) consider the effectiveness of SBA programs conducted by Connected Nation in five states.[16] A Difference-in-Differences estimator was applied to data collected from Connected Nation on its programs that was merged with county-level adoption data from the FCC for years 2008 through 2016. The authors

[14] J.A. Hauge and J.E. Prieger, *Evaluating the Impact of the American Recovery and Reinvestment Act's BTOP on Broadband Adoption*, 47 APPLIED ECONOMICS 1-27 (2015) (draft available at: https://ssrn.com/abstract=2591771).

[15] J. McElhatton, *Online Soap Opera Cleans Up with Stimulus Broadband Cash*, WASHINGTON TIMES (December 1, 2011) (available at: https://www.washingtontimes.com/news/2011/dec/1/online-soap-opera-cleans-up-with-stimulus-broadban) (official trailer available at: https://www.youtube.com/watch?v=SQh3zc5_9nw); R. Chong, *Broadband Stimulus Hearing Turns Contentious Over Allegations of Waste, Fraud and Abuse*, TECHWIRE (February 28, 2013) (available at: https://www.techwire.net/news/broadband-stimulus-hearing-turns-contentious-over-allegations-of-overbuilding-and-waste-fraud-and-abuse.html); *RECOVERY ACT: Agencies Are Addressing Broadband Program Challenges, but Actions Are Needed to Improve Implementation*, GAO-10-18, U.S. Government Accountability Office (November 2009) (available at: https://www.gao.gov/assets/300/298471.pdf); *BROADBAND: Intended Outcomes and Effectiveness of Efforts to Address Adoption Barriers Are Unclear*, GAO-15-473, U.S. Government Accountability Office (June 2, 2015) (available at: https://www.gao.gov/assets/680/670588.pdf).

[16] J. Manlove and B. Whitacre, *An Evaluation of the Connected Nation Broadband Adoption Program*, 43 TELECOMMUNICATIONS POLICY 101809 (2019) (available at: https://www.sciencedirect.com/science/article/abs/pii/S0308596118304269); An earlier version of the paper is J. Manlove, *An Evaluation of the Connected Nation Broadband Adoption Program*, Working Paper (March 15, 2018) (available at: https://ssrn.com/abstract=3141063 or http://dx.doi.org/10.2139/ssrn.3141063).

conclude, based on several empirical models, that the "program had no significant impact on broadband adoption rates." Next, we revisit the empirical question of whether BTOP funding increased adoption in funded areas using different data (but similar methods).

A. *Data*

In this POLICY PAPER, we use a repeated cross-section data on home Internet and broadband adoption from the Computer and Internet Use Supplements of the CPS for years 2009, 2010, 2013, and 2015.[17] This adoption data is merged with NTIA data on CAI, PCC, and SBA sites.[18] The latitude/longitude or zip codes of CAI, PCC and SBA program sites are assigned to counties for merging with the CPS.[19] Counties with program sites are the treated sample, while counties without program sites are the controls.[20] Control and treatment counties are not identical across the three treatment types. About 13% of respondents live in counties that received no treatment, but the mean treatment for each type of program is between 40% to 55% (see Table 2 below).[21] Grants were finalized in October 2010, so years 2009 and 2010 are the pre-treatment period and years 2013 and 2015 the post-treatment period.[22]

To protect privacy, the CPS data does not provide county indicators for all CPS respondents and any respondent not allocated to a county is dropped from the sample. On average, county population is about 100,000 persons. There, but there are several very large counties in the nation, however, and all received the SBA treatment and most received the PCC treatment. These large counties,

17 Data available at: https://www.ntia.doc.gov/page/download-digital-nation-datasets.

18 https://www2.ntia.doc.gov/BTOPmap.

19 A cross walk of zip codes to counties is performed using the Geographic Correspondence Engine of the Missouri Census Data Center (available at: http://mcdc.missouri.edu/applications/geocorr.html). The other geographic indicator is Core-Based Statistical Areas ("CBSA"), which cover larger areas than do counties.

20 Data on the U.S. Virgin Islands is excluded.

21 The correlation coefficients among the treatments are quite small (less than 0.23).

22 *Distribution of Broadband Stimulus Grants and Loans: Applications and Awards*, EveryCRSReport.com (September 9, 2010 – January 4, 2011) (available at: https://www.everycrsreport.com/reports/R41164.html).

therefore, do not offer variation in the treatment. For the control group, the largest county size receiving SBA funding is 1.34 million, but about twenty counties in the treated group have population greater than, often much greater than, this amount. Thus, counties with more than 1.35 million in population are excluded from the sample to ensure common support between the treated and control groups in county size.[23]

Table 2. Descriptive Statistics

	Sample Mean	Mean Treated	Mean Control	Stan. Diff.
Broadband at Home	0.7252	0.7211	0.7458	
Treated BSA	0.5563			
Treated PCC	0.4206			
Treated CAI	0.4280			
Black	0.1195	0.1210	0.1120	0.028
Hispanic	0.1572	0.1672	0.1071	0.175
College	0.3189	0.3183	0.3222	0.008
Age ≥ 65	0.1295	0.1267	0.1435	0.049
Home Own	0.7026	0.6942	0.7446	0.112
Student-HS	0.0257	0.0256	0.0262	0.004
Student-UN	0.0437	0.0447	0.0368	0.040
Less than $25,000	0.1936	0.1968	0.1776	0.049
$25,000 – $49,999	0.2428	0.2426	0.2439	0.003
$50,000 – $74,999	0.1939	0.1925	0.2008	0.021
$75,000 – $99,999	0.1300	0.1289	0.1354	0.019
$100,000 – $149,999	0.1331	0.1341	0.1281	0.018
Greater than $150,000	0.1067	0.1051	0.1142	0.029
Obs.	128,543	111,519	17,024	

Data on the covariates are provided in the CPS. Covariates include indicators for race (including Black and Hispanic), whether the respondent has a college education, is 65 years or older, is a high-school or college student, lives in a owned home (versus rented), and seven indicators for income groups. Table 2 summarizes the descriptive statistics. For purposes of the descriptive statistics, a treated" respondent is any home in a country receiving any of the three treatments (CAI, PCC, or SBA). All analysis, unless otherwise indicated, is

[23] This exclusion has little effect on the coefficient estimates reported below but including the larger counties does cause some large differences in the means of the Hispanic residents between the control and treated group.

weighted using CPS-provided weights.[24] The control and treated groups are demographically similar and the standardized differences do not indicate a lack of common support (a standard cutoff is values larger than 0.25).[25]

B. *Regression Analysis*

We are interested in the question of whether the BTOP programs increased home broadband adoption. But broadband adoption rose in nearly all areas over the sample period. Consequently, we must look for differences in the increase in broadband adoption between the treated and the control counties, which can be quantified using the Difference-in-Differences estimator. The Difference-in-Differences ("DID") estimator, δ, can be estimated from the equation,

$$y_{it} = \delta_1 SBA_{ct} + \delta_2 PCC_{ct} + \delta_3 CAI_{ct} + \beta X_{it} + \lambda_t + \mu_c + \varepsilon_{it}, \qquad (5)$$

where y_{it} is the outcome of interest for respondent i at time t, SBA_{ct} is a dummy variable equal to 1.0 if county c has SBA sites in period t (0 otherwise), PCC_{ct} is a dummy variable equal to 1.0 if county c has PCC sites in period t (0 otherwise), CAI_{ct} is a dummy variable equal to 1.0 if county c has CAI sites in period t (0 otherwise), X_{it} is vector of demographics for person i at time t, λ_t is a time fixed effect, and μ_c is a county fixed effect, and ε_{it} is the econometric disturbance term.[26] The δ coefficients are the DID estimators measuring the difference in differences in adoption for the treated group relative to the control group after the BTOP programs were implemented: (1) δ_1 for the SBA program; (2) δ_2 for the PCC program; and (3) δ_3 for CAI programs. SBA programs aimed at increasing

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24 The weighting variable is pwsswgt.

25 G.W. Imbens and J.M. Wooldridge, *Recent Developments in the Econometrics of Program Evaluation*, 47 JOURNAL OF ECONOMIC LITERATURE 5-86 (2009) (available at: https://www.aeaweb.org/articles?id=10.1257/jel.47.1.5).

26 *See*, *e.g*., B.D. Meyer, *Natural and Quasi-Experiments in Economics*, 13 JOURNAL OF BUSINESS & ECONOMIC STATISTICS 151-161 (1995); J.D. Angrist and J.S. Pischke, MOSTLY HARMLESS ECONOMETRICS: AN EMPIRICIST'S COMPANION (2008); D. Card, *The Impact of the Mariel Boatlift on the Miami Labor Market*, 43 INDUSTRIAL AND LABOR RELATIONS REVIEW 245-257 (1990); S. Galiani, P. Gertler, and E. Schargrodsky, *Water for Life: The Impact of the Privatization of Water Services on Child Mortality*, 113 JOURNAL OF POLITICAL ECONOMY 83-123 (2005); G.S. Ford, *Regulation and Investment in the U.S. Telecommunications Industry*, 50 APPLIED ECONOMICS 1466-4283 (2018); G.S. Ford, *Net Neutrality and Investment in the US: A Review of Evidence from the 2018 Restoring Internet Freedom Order*, 17 REVIEW OF NETWORK ECONOMICS 175-205 (2019).

adoption, so a positive sign on δ_1 is expected. Likewise, CAI programs may increase the use of Internet in schools, which may encourage home adoption, suggesting a positive sign on $\delta_3 > 0$. We have no a priori expectation on δ_2, however, since the availability of public use computers may substitute for home adoption.

An alternative model,

$$y_{it} = \theta_1 SBAN_{ct} + \theta_2 PCCN_{ct} + \theta_3 CAIN_{ct} + \beta X_{it} + \lambda_t + \mu_c + \varepsilon_{it}\,, \quad (6)$$

replaces the dummy treatment variables with a continuous treatment indicator equal to the number of sites per capita ('000). These alternative treatment variables (*SBAN*, *PCCN*, and *CAIN*) are continuous variables and are intended to measure the intensity of the treatment.[27] Thus, the DID coefficients (θ_k) measure the change in adoption given a change in treatment intensity.

C. *Common Trends*

For δ or θ to measure the causal effect, the common trends assumption must hold (a necessary condition). As a check on the common-trends assumption, a variant of Equation (6) is estimated for only the pre-treatment period. This regression may be used to test for group-means differences between the treated and control groups prior to the treatments (in years 2010 and 2011). If no group-means differences are found, then the common trends assumption is supported by the data. The DID estimators for each program and both years are statistically insignificant, so the null hypothesis of "no difference" cannot be rejected at anywhere near standard levels.[28] These results support the common trends assumption.

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27 D. Acemoglu, D.H. Autor, and D. Lyle, *Women, War, and Wages: The Effect of Female Labor Supply on the Wage Structure at Midcentury*, 112 JOURNAL OF POLITICAL ECONOMY 497-551 (2004).

28 The estimated ω coefficients and t-statistics for 2010 and 2011 are: SBA (-0.01, -0.75) (-0.004, -0.27); PCC (0.020, 1.49) (0.017, 1.20); and CAI (0.010, 0.82) (-0.006, -0.40).

D. *Results*

Equation (1) is estimated by the Linear Probability Model ("LPM"). Results are summarized in Table 2.[29] The outcome of interest is broadband adoption in the home. The final sample includes 128,543. Year 2011 is excluded from the sample as a transition year. Standard errors are clustered at the county level. All regressions are weighted by the household weighting variable provided in the CPS, though the unweighted results are not materially different.

Table 2. Summary of Regression Results, Broadband Adoption

	Dichotomous Treatment		Continuous Treatment
δ_1 (*SBA*)	0.0017	θ_1 (*SBAN*)	0.2390
	(0.12)		(0.96)
δ_2 (*PCC*)	0.0078	θ_2 (*PCCN*)	0.1930
	(0.55)		(0.81)
δ_3 (*CAI*)	0.0147	θ_3 (*CAIN*)	0.0174
	(1.11)		(0.46)
Black	-0.081***		-0.081***
Hispanic	-0.099***		-0.099***
College	0.063***		0.063***
Age ≥ 65	-0.139 ***		-0.139 ***
Home Own	0.066***		0.066***
Student-HS	0.040***		0.039***
Student-UN	0.087***		0.087***
Less than $25,000	…		…
$25,000 – $49,999	0.151***		0.151***
$50,000 – $74,999	0.251***		0.251***
$75,000 – $99,999	0.267***		0.267***
$100,000 – $149,999	0.284***		0.284***
Greater than $150,000	0.283***		0.283***
Obs.	128,543		128,543
F-Stat	181.6***		186.9***

* p<0.10, ** p<0.05, *** p<0.01

All the covariates and the F-statistics for the models are statistically different from zero at better than the 1% level (t-statistics are suppressed for exposition), and the coefficients are consistent with prior studies of broadband adoption.

[29] Since the dependent variable is dichotomous, the equations also were estimated by Poisson Regression. The results were materially the same. The LPM is more easily interpreted, so we report those results.

Blacks and Hispanics are less likely to have broadband in the home (relative to other races, mostly White and Asian), as are persons 65 years or older. College educated persons, students, and persons in owned homes are more likely to have broadband or Internet service. Broadband adoption rises with income.

Despite the high power of the tests (given large samples) and the high level of statistical significance for the covariates, none of the DID coefficients (δ or θ) are statistically significant at standard levels.[30] While all the coefficients are positive, it is not possible to reject the null hypothesis that broadband and Internet adoption was the same for persons living in the treated and control counties after the BTOP treatments were applied. If the broadband programs had any effect on adoption, then such an effect is not detected in this sample. These results are consistent with those reported by Hauge and Prieger (2018) and Manlove and Whitacre (2019) and suggest that subsidy spending on programs of these types may not be a productive way to increase home broadband adoption, though the PCC and CAI programs may have served other purposes.

Table 3. Summary of Regression Results, Broadband Adoption
(Untruncated Sample)

	Dichotomous Treatment		Continuous Treatment
δ_1 (*SBA*)	-0.0136	θ_1 (*SBAN*)	0.1540
	(-1.03)		(0.60)
δ_2 (*PCC*)	-0.0025	θ_2 (*PCCN*)	0.0470
	(-0.19)		(0.16)
δ_3 (*CAI*)	0.0209	θ_3 (*CAIN*)	0.0531
	(1.43)		(1.39)
Obs.	179,026		179,026
F-Stat	215.6***		231.0***

* p<0.10, ** p<0.05, *** p<0.01

In Table 3, the results are presented for the full sample that is not truncated on county population. The coefficients and significance levels on the covariates are very similar to those reported in Table 2, so they are excluded for expositional purposes. Again, none of the treatment variables are statistically different from zero, though the signs have changed on two of the δ coefficients.

30 With such a large sample, the power of the statistical tests is very high, with power exceeding 80% for a difference of only 0.0025 percentage points in the adoption rate (assuming a standard deviation of y of 0.50).

The t-statistics on the CAI treatments are somewhat larger and are positive but remain statistically insignificant at even the 10% level.

IV. Subsidies and Low-Cost Broadband Programs

Besides the regular extension of their networks to unserved areas, some private broadband providers are seeking to increase adoption by offering budget broadband plans for certain low-income and other qualifying Americans.[31] Comcast's *Internet Essentials* program, for instance, now offers a 25 Mbps broadband connection for $9.95 per month for homes qualifying by use of programs like the National School Lunch Program, Housing Assistance, Medicaid, Supplemental Nutrition Assistance Program, Supplemental Security Income, among others. These private programs have proven effective at increasing adoption. *Internet Essentials*, for example, has added eight million Americans (or two million homes) to the nation's broadband stock without federal support.[32]

Rosston and Wallsten (2019) use Census data to confirm the adoption increasing effects of *Internet Essentials*.[33] Using CPS data merged with the National Broadband Map, the authors' DID analysis finds that between 2011 and 2015 broadband adoption by eligible households increased more in Comcast's service areas than for providers not offering such programs (at the time), and the bulk of these subscribers were new to broadband service. The magnitude of the effect was consistent with Comcast's claims about subscriptions to the program. No effect is found for other cable providers, however.

How effective lower prices (or subsidized prices) are at closing the Digital Divide depends on how sensitive consumers are to price changes, which is

31 *See*, *e.g.*, S. Cossick, *Guide to Low-Income Internet Options and Affordable Internet Plans*, ALLCONNECT.COM (Mar 24, 2020) (available at: https://www.allconnect.com/blog/low-income-internet-guide).

32 https://corporate.comcast.com/values/internet-essentials; M. Reardon, *Comcast Expands Internet Essentials to All Low-Income Households*, CNET (August 6, 2019) (available at: https://www.cnet.com/news/comcast-expands-internet-essentials-to-all-low-income-households); G.S. Ford, *Welcoming Private Sector Efforts to Increase Broadband Adoption*, @LAWANDECONOMICS BLOG (August 6, 2019) (available at: http://www.phoenix-center.org/blog/archives/2351).

33 G.L. Rosston and S. Wallsten, *Increasing Low-Income Broadband Adoption through Private Incentives*, Working Paper (August 2, 2019) (available at: https://ssrn.com/abstract=3431346).

measured by the own-price elasticity of demand.[34] Though using an admittedly crude calculation, Rosston and Wallsten (2019) estimate the own-price elasticity of demand for broadband (for low-income households) to be only about 0.10 to 0.13. A 10% reduction in price only increases subscriptions by about 1%. This response is quite small. Using data better suited to estimate an own-price elasticity, Carare, McGovern, Noriega, and Schwarz (2015) report an own-price elasticity of demand of 0.67 among non-adopters, indicating that a price cut of 10% would increase adoption by 7%.[35] Both studies report an inelastic response of adoption to price changes, indicating that while subsidies (or other types of price cuts) will increase adoption they may not be a panacea for universal adoption.

Though most of the larger broadband providers today offer low-cost broadband programs, many low-income households remain unconnected. It does not appear that price is the primary reason for non-adoption. Past surveys indicate that over half of unconnected homes say they have no interest in what the Internet has to offer and econometric studies indicate adoption is not highly response to price cuts (even large ones).[36] The latest U.S. Census data from the Computer and Internet Use Supplement reports that 60% of non-adopters have "no need" or "no interest" in Internet use at home. Only 18.8% indicate that broadband (and/or computers) are "too expensive." Figure 1 illustrates the trend in these reasons for non-adoption over time.[37] As the share of non-adopters has shrunk over time, it appears price is becoming less relevant as a determining factor, making price reductions a weaker (though still perhaps relevant) policy instrument. Convincing Americans that do not want a service to buy a service could prove difficult.

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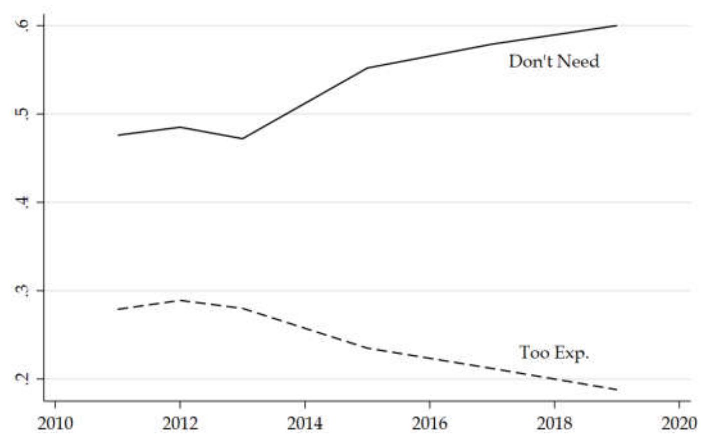
[34] The own-price elasticity of demand is measured as (the absolute value of) the ratio of the percent change in quantity to the percent change in price.

[35] O. Carare, C. McGovern, R. Noriega, and J. Schwarz, *The Willingness to Pay for Broadband of Non-Adopters in the U.S.: Estimates from a Multi-State Survey*, 30 INFORMATION ECONOMICS AND POLICY 19-35 (2015) (draft available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2375867).

[36] G.S. Ford, *"Relevance" and "Price" as Determinants of Internet Non-Adoption: A Review of the Evidence*, PHOENIX CENTER POLICY BULLETIN No. 48 (April 2020) (available at: https://www.phoenix-center.org/PolicyBulletin/PCPB48Final.pdf).

[37] Data obtained from: https://www.ntia.doc.gov/data/digital-nation-data-explorer#sel=wiredHighSpeedAtHome&disp=map.

Figure 1. Why No Home Internet?



Perhaps interest levels have changed during the COVID pandemic; anecdotal evidence shows a rise in demand for broadband connections.[38] If persons do not believe they need an Internet connection during the COVID pandemic, then it is unlikely they ever will have a need for it. Policymakers and analysts should be aware that universal adoption of broadband is unrealistic (many Americans simply do not want broadband, whether they can afford it or not). A more sensible target for adoption might be established.

Moreover, the adoption effects of the low-cost private programs (which are essentially privately-funded subsidies) may not extend directly to federally-subsidized connections. First, many of the private programs have existed for years, so it must be presumed that the low-hanging fruit has been picked. Consequently, subsidy costs are not simply the subsidy level multiplied by the number of subscribers as it will be costly to find and convince non-adopters to participate. Second, some low-income households may be reluctant to participate in federal programs, for a variety of reasons. Third, history shows

[38] *Q1 (and COVID-19) Adds Over 1.6 Million Broadband Subscribers*, INSIDE TOWERS (May 19, 2020) (available at: https://insidetowers.com/cell-tower-news-q1-and-covid-19-adds-over-1-6-million-broadband-subscribers); M. Robuck, *Charter Notches 119,000 New Internet Subscribers in March Due to Free Offer*, FIERCETELECOM (April 14, 2020) (available at: https://www.fiercetelecom.com/telecom/charter-notches-119-000-new-internet-subscribers-march-thanks-part-to-free-60-day-access); M. Balderston, *Broadband Subscriptions' Quarter Growth Hits Five Year High*, TVTECHNOLOGY (May 13, 2020) (available at: https://www.tvtechnology.com/news/broadband-nets-116m-subscribers-in-q1-2020).

that the administration of these programs by federal agencies is troubled by waste, fraud and abuse, so such programs may be very costly per new subscriber.[39] On the other hand, a subsidy for home connections permits broadband providers to receive more income per account, which eliminates, at least with the provider, the qualifying process (only because that process is passed along to the federal agency implementing the program). It seems sensible to conclude, we believe, that a federal subsidy program will be less effective than the private programs already available, but the private programs have been very successful. We do not discourage the use of subsidies, but caution against setting expectations too high.

V. Conclusion

Despite significant effort by both public and private entities, broadband adoption has been relatively stable over the past few years and the Digital Divide persists, in large part due to lack of interest and concerns about security and privacy. The demand for broadband has no doubt risen in the COVID era as education, work, and entertainment has necessarily shifted to the home. While COVID has been a disaster in many ways, it has likely increased the willingness of Americans to pay for broadband connections. That being so, spending scarce federal funds on demand-side adoption programs is likely to be disappointing and inefficient. If a household is not interested in broadband in the COVID era, then convincing them otherwise is probably fruitless. Direct subsidies will increase adoption, no doubt, but empirical and survey evidence prescribes sober expectations.

Surely, any new subsidies for broadband expansion should be carefully considered and expertly allocated. What agency has demonstrated such expertise? The NTIA, the FCC, and the Rural Utilities Service ("RUS") have all been criticized for their management of the broadband subsidies, though the problem is admittedly very difficult to solve. As we see it, direct subsidies will increase adoption as will extending broadband services to unserved areas since the adoption rate is expected to be around 70% to 80% of new homes passed. The FCC has expertise in both types of programs. That said, pushing broadband deeper into rural areas is going to be expensive, and perhaps not worth the effort in some cases. Broadband is valuable, but not infinitely so. Giving billions to

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39 It is not clear, however, whether low-income subsidies for telecommunications service are, or should be, directed only at non-adopters. *See, e.g.*, G.S. Ford, *A Fresh Look at the Lifeline Program*, *supra* n. 6.

municipalities to construct networks is a poor policy, as these networks often overbuild existing networks, thereby presenting households with the same options they had before. Municipalities may be a reasonable option in areas that are unserved, since it is these places that offer a direct opportunity to impact adoption. Incumbent carriers, whether private or public, are presumably the least cost providers in unserved markets, though reverse auctions, like those used by the FCC, can reveal the low-cost solution. While the Digital Divide is the subject of intense rhetoric—now more than ever—if the goal of public policy is to increase broadband adoption in a cost-effective manner, then some careful and unrushed planning is required.