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Public Investment in Broadband Infrastructure: Lessons from the U.S. and Abroad

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Executive Summary

The U.S. Government is considering spending an additional $200 billion to $1 trillion on infrastructure projects. Members of Congress and others are urging that some of the money go towards subsidizing broadband. The U.S. currently spends about $10 billion annually subsidizing broadband service, about $5 billion of which goes specifically to rural areas.

This paper reviews experiences with subsidizing telecommunications services, and broadband in particular, in the United States and around the world. Based on those lessons it proposes a path forward intended to yield the biggest broadband bang for the subsidy buck.

Studies by independent researchers and the U.S. government itself consistently document the lack of evaluation, clear goals, and effectiveness of the existing programs. However, experience in the U.S. and abroad demonstrates that it is possible to design cost-effective programs when the political will exists.

In particular, a program intended to increase broadband coverage should use a reverse auction mechanism to distribute subsidies. The auction should include defined geographic areas with no existing service that meets some minimum quality threshold, which is based on what consumers value. Because consumers value the broadband services they can use rather than the technology that brings it to them, any technology should be eligible to participate. Bids would then be ordered based on a pre-determined measure of cost-effectiveness and projects funded beginning with the most cost-effective, followed by the second-most cost effective, and so on, until the budget is exhausted.

Specifically, an effective broadband subsidy program would:

- Set a single, clear objective: bring broadband service to populated areas that do not have it.
- Define “broadband” by taking into account consumer demand characteristics. This definition should be use-centric, not technology-centric. Any technology should be eligible to participate in the auction.
- Make the program a one-time subsidy.
- Rank-order the bids in terms of cost-effectiveness in terms of new locations, not area, connected per subsidy dollar. Fund the most cost-effective project first, the next most cost-effective second, and so on until the budget is exhausted.
- Rigorously evaluate the results and have organizations other than the one implementing the program conduct the evaluations.

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Introduction

The U.S. Government is considering spending an additional $200 billion to $1 trillion on infrastructure projects. Members of Congress and others are urging that some of the money go towards subsidizing broadband. This paper reviews experiences with subsidizing telecommunications services, and broadband in particular, in the United States and around the world. Based on those lessons it proposes a path forward intended to yield the biggest broadband bang for the subsidy buck.

This paper sets aside the fundamental question of whether we should spend more on broadband subsidies than $10 billion we already spend each year or the nearly $100 billion we have spent subsidizing telecommunications since 1995 without evidence that it improved adoption. Instead, it reviews experiences subsidizing broadband and draws lessons about how a cost-effective subsidy program might work.

Experience in the U.S. and abroad demonstrates that it is possible to design cost-effective programs when the political will exists. In particular, a program intended to increase coverage should use a reverse auction mechanism to distribute subsidies. The auction should include defined geographic areas with no existing service that meets some minimum quality threshold. The quality threshold should be based on services that consumers use and value. Additionally, because consumers value the broadband services they can use rather than the technology that brings it to them, the program should be technology-neutral: any technology that can provide the defined service should be eligible to participate. Bids would then be ordered based on a pre-determined measure of cost-effectiveness and fund the projects beginning with the most cost-effective, followed by the second-most cost effective, and so on, until the budget is exhausted.

Broadband Subsidies in Theory

Telecommunications subsidies, in general, are based on three rationales: the presence of network externalities, the idea that all residents deserve access to some minimum level of services, and political or regional development objectives.[1] The externalities argument tends not to hold up to scrutiny as a reason to subsidize telecommunications.[2] The other two, however, are not about

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[1] Cremer Helmuth et al., "The Economics of Universal Service: Practice," *Economic Development Institute Discussion Paper*, 1998, http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.484.5119&rep=rep1&type=pdf.

[2] First, externalities might make it economically efficient to subsidize prices for those who cannot afford the service at cost. Positive externalities imply that the total benefits from providing service to an individual exceed the benefits to an individual subscriber. If the private marginal cost of service exceeds the private marginal benefit by less than the amount of the external benefit, then some individuals will not subscribe even though the social benefit of serving them exceeds their cost of service. In that case, subsidizing service can be one way to achieve an efficient outcome. The typical economics argument in support of universal service policies in telecommunications is that inherent network externalities result in not enough service being provided or used. Network externalities mean that the benefits a new consumer accrues from connecting (the private benefits) are less than the total benefits to society, because when an additional person connects to the network all other subscribers benefit by being able to communicate with the new subscriber. Therefore, individuals may not face a strong enough incentive to subscribe, thus requiring subsidies to induce socially optimal subscription.

economics but rather reflect collective decisions about how to organize society. While both support providing some type of subsidy, each creates incentives for different types of subsidies.

Arguments for subsidies are typically presented in ways consistent with the idea of broadband as a "merit good." That is, in general, there seems to be wide agreement that we want all residents to have access to some minimum level of service, although less agreement as to what, exactly, that service should include. The implication is government support for broadband subsidies in places that are too costly to justify private investment.

This civic-minded, merit-good, approach argues in favor of a subsidy program that allocates funds in a rigorous, cost-effective manner. After all, if the goal is to reach as many residents as possible then it is incumbent upon policymakers to make any subsidy program as cost-effective as possible to reach the largest number of people for any given level of expenditure.

Like any subsidy program, however, subsidies for broadband are not entirely about helping to provide merit goods. They are also attractive to legislators as gifts they can bestow on their constituents. Unfortunately, this creates incentives that work counter to rigorous, objective approaches to distributing subsidies. Cost-effectiveness is not consistent with evenly sprinkling subsidies around the country or ensuring that every congressional district receives funding.

As a result, an ongoing subsidy program is unlikely to be politically compatible with an approach based on cost-effectiveness. And, indeed, as we discuss in detail below, the high-cost part of the universal service program does not put much, if any, emphasis on cost-effectiveness. Instead, it guarantees ongoing subsidies to companies that have historically been subsidized, regardless of changes in costs, technology, or demand.

A one-time broadband subsidy, such as that being discussed now, creates a unique opportunity. Without a constituency dependent in one way or another on the subsidy, the program has more freedom to use a rigorous project selection mechanism, especially when it is only a small part of a much larger infrastructure program. It is in that spirit that this report proposes a mechanism to determining how to allocate subsidies in a cost-effective manner and, therefore, yield the biggest bang for the buck.

This argument, however, is incomplete and therefore misleading. Even if the benefits to the new subscriber are less than the total benefits, the private benefit may still exceed the cost for nearly all subscribers, in which case a general subsidy of service is mostly wasted. Second, because services become more valuable when more people are connected, the firm providing access captures some of the benefits from network externalities. Consequently, although network externalities are external to the individual, they are not necessarily external to firms providing the service, potentially removing the need for subsidies. In other words, network externalities by themselves do not necessarily imply telecommunications under-subscription. Third, all subscribers receive an external benefit from subscriptions by others, implying that each person should subsidize the service of the other. Consequently, on average the subsidy a subscriber receives to take service ought to be roughly equal to the amount of subsidy that subscriber should be willing to pay to induce others to subscribe

Broadband Subsidies in Practice

Historically, telecommunications companies were considered natural monopolies. In most countries, this meant a state-owned operator and in the United States a single company operating under heavy regulation. The single firm was generally expected to provide coverage everywhere, with service in unprofitable regions being cross-subsidized by profitable service elsewhere.[3] Competition made it impossible to continue cross-subsidies, so countries began explicitly subsidizing service in unprofitable areas.

Without adequate evaluation, simply increasing funds to upgrade connections may lead to economically inefficient results. Large public investments with vague requirements are prone to rent-seeking, waste and fraud. This report looks at federal and municipal public investment in the U.S. and around the world to understand under what circumstances can such interventions be cost-effective while accomplishing their policy goals.

These examples of public investment in broadband infrastructure show the inefficiency that results from not using cost-effectiveness or other economic criteria for subsidizing rural areas. They generally turn out to be inefficient income transfer mechanisms that do not increase subscriptions, especially when they do not take into account demand characteristics. Furthermore, rural universal service programs can deter additional entrants from places that could support competition because of the presence of a subsidized competitor.

United States

All told, the United States has spent nearly $100 billion[4] subsidizing broadband in rural areas since 1995. This includes the Federal Communication Commission's High Cost Fund portion of the Universal Service program, loans and grants from the Rural Utilities Service, and the 2009 Broadband Technology and Opportunities Program. A major problem with all telecommunications subsidy programs in the U.S. is the lack of interest in evaluation by the managers of the programs. It is therefore not surprising that independent analyses consistently find that they have failed to have much effect on the penetration of subsidized services.

The Universal Service Fund

Launched by the 1996 Telecommunications Act, the Universal Service Fund (USF) distributes nearly $10 billion[5] through four mechanisms: High Cost Support, Low Income Support, Rural Health Care Support, and Schools and Libraries support (also known as E-rate). The High Cost Fund was designed to extend telephone service to sparsely populated areas where, presumably, private companies did not have sufficient economic incentives to extend build. In 2011 the FCC approved a six-year transfer process to support the expansion of broadband services through the

[3] Residential service was also generally cross-subsidized by business service.
[4] In constant, 2016 dollars.
[5] http://www.usac.org/about/

$4.5 billion a year Connect America Fund. Evidence suggests that instead of improving network coverage or benefiting telecommunications users, USF subsidies have been wasted, padding the costs of rural phone companies and delivering little social value.[6] Furthermore, government assessments already note that "a lack of transparency and accountability of high-cost spending and poor accessibility and usability of data and information" still make evaluation difficult.[7]

The High-Cost Fund and the Connect America Fund

The High Cost Fund (HCF) was established in 1997 with the goal to further advance broadband connectivity. Spending on the high cost program increased from $2.6 billion in 2001 to over $4 billion in 2011.[8] In 2011 the High Cost Fund was reorganized into the Connect America Fund, which will completely replace it by 2018. The 2011 reform mainly switched subsidies from narrowband to broadband services but did not alter the basic, flawed structure of the USF. Figure 1 shows High Cost Fund distributions from 1995 through 2016.

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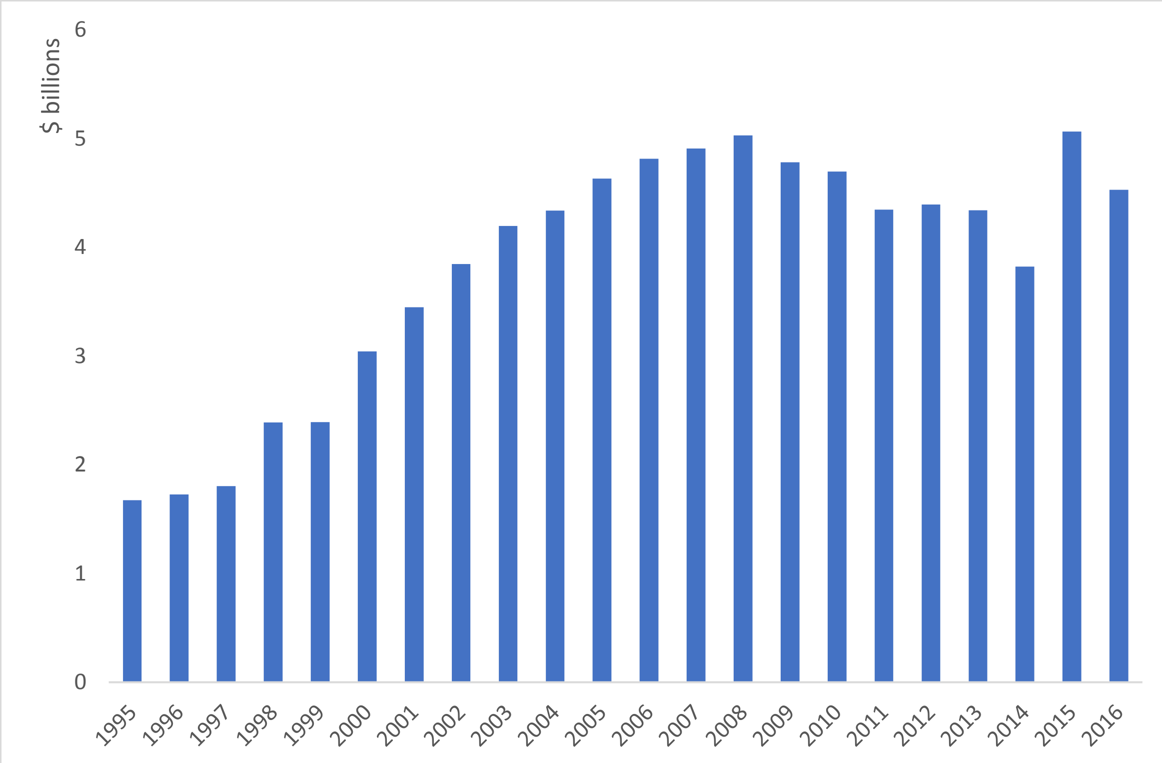
[6] See, for example, David Kaserman and John Mayo, "The Quest for Universal Telephone Service: The Misfortunes of a Misshapen Policy," in *Telecommunications Policy: Have Regulators Dialed the Wrong Number?* (Praeger Publishers, 1997); Robert W. Crandall and Leonard Waverman, *Who Pays for Universal Service?: When Telephone Subsidies Become Transparent* (Washington, D.C: Brookings Institution Press, 2000); Thomas Hazlett, "'Universal Service' Telephone Subsidies: What Does $7 Billion Buy?," 2006; Gregory L Rosston and Wallsten, Scott, "The Path to Universal Broadband: Why We Should Grant Low-Income Subsidies and Use Experiments and Auctions to Determine the Specifics," *The Economists' Voice* 8, no. 1 (April 2011). Appendix 1 of Hazlett & Wallsten (2013) has a detailed literature review of these studies.

[7] Government Accountability Office, "FCC Should Improve the Accountability and Transparency of High Cost Program Funding," July 2014, http://gao.gov/assets/670/664939.pdf.

[8] In nominal dollars. Government Accountability Office, "FCC Has Reformed the High-Cost Program, but Oversight and Management Could Be Improved. Report to Congressional Requesters," July 2012, http://www.gao.gov/assets/600/592957.pdf.

Figure 1: High Cost and Connect America Fund Expenditures (in 2016 dollars)



Hazlett and Wallsten (2013) find that among the biggest limitations, the USF discourages more build-out than it funds. The distributional effects are highly regressive when taking into account the mechanism by which the program raises money to distribute. USF taxes particularly burden low-income phone users who spend a relatively high proportion of income on international calls and are more likely to have only wireless phone service. Furthermore, the benefits of HCF subsidies go to inefficiently small and opportunistically expensive rural telephone company owners.

Despite the long history of subsidies for rural areas in the U.S., especially for telephone service, there is no economic justification for these programs. Rosston and Wimmer (2000) show that only a small fraction of the money designated to provide service in rural areas goes to serve low income rural residents. The funding has little effect on telephone penetration and results in large taxes.[9] Wallsten (2011) finds that about $0.59 of each dollar distributed by the Universal Service Program goes to general and administrative expenses rather than making telephone service more affordable.[10]

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[9] Bradley S Wimmer and Gregory L Rosston, "The 'State' of Universal Service," *Information Economics and Policy* 12, no. 3 (2000): 261–83, doi:10.1016/s0167-6245(00)00011-1.

[10] Scott Wallsten, "The Universal Service Fund: What Do High-Cost Subsidies Subsidize?" (Technology Policy Institute, 2011), https://techpolicyinstitute.org/policy_paper/the-universal-service-fund-what-do-high-cost-subsidies-subsidize/.

At the state level, Wallsten (2005) finds that Universal Service mechanisms and programs for underserved areas were ineffective and could even slow broadband penetration by giving artificial advantage to one provider over another. Furthermore, targeted rural broadband grants had no effect on broadband availability. General RUS subsidies did appear to have an effect, but the high investment per person connected suggests that the program was not cost effective.[11]

Mobility Fund Auctions

The FCC's Mobility Fund is funded via "reserves accumulated in the USF" and is intended to

> significantly improve coverage of current-generation or better mobile voice and Internet service for consumers in areas where such coverage is currently missing, and to do so by supporting private investment. The Mobility Fund would use market mechanisms – specifically, a reverse auction – to make one-time support available to service providers to cost-effectively extend mobile coverage in specified unserved areas.[12]

The unique feature of the Mobility Fund is that it uses reverse auctions to distribute funds. This makes the FCC the only U.S. agency moving towards auction processes for distributing subsidies. Reverse auctions are described in more detail below, but involve the FCC defining the type of coverage desired, identifying eligible geographic areas, and asking providers to state via an auction mechanism how much they would need in subsidies in order to provide service. The Mobility Fund was to hold two such subsidy auctions: Phase 1 in September 2012 and Phase 2, which should take place in 2017.

On September 2012, the FCC held Phase 1 of the Mobility Fund auction, distributing $300 million to 33 winning bidders via a reverse auction. Winners could receive one-time support to provide 3G service within two years or 4G within three.[13] Eligible areas included census blocks without mobile broadband service, and carriers could not receive support for areas they had already stated they planned to serve. The key to maximizing cost-effectiveness was allowing requested subsidies to be rank-ordered by road-miles covered per subsidy dollar requested and then granting the subsidies in order from most to least cost-effective, stopping when the $300 million was exhausted.

Figure 2 shows the results of the auction. The figure shows the wide variation in cost-effectiveness of bids and that the auction allowed the FCC to distribute the funds more effectively than other approaches that would have funded different areas.[14]

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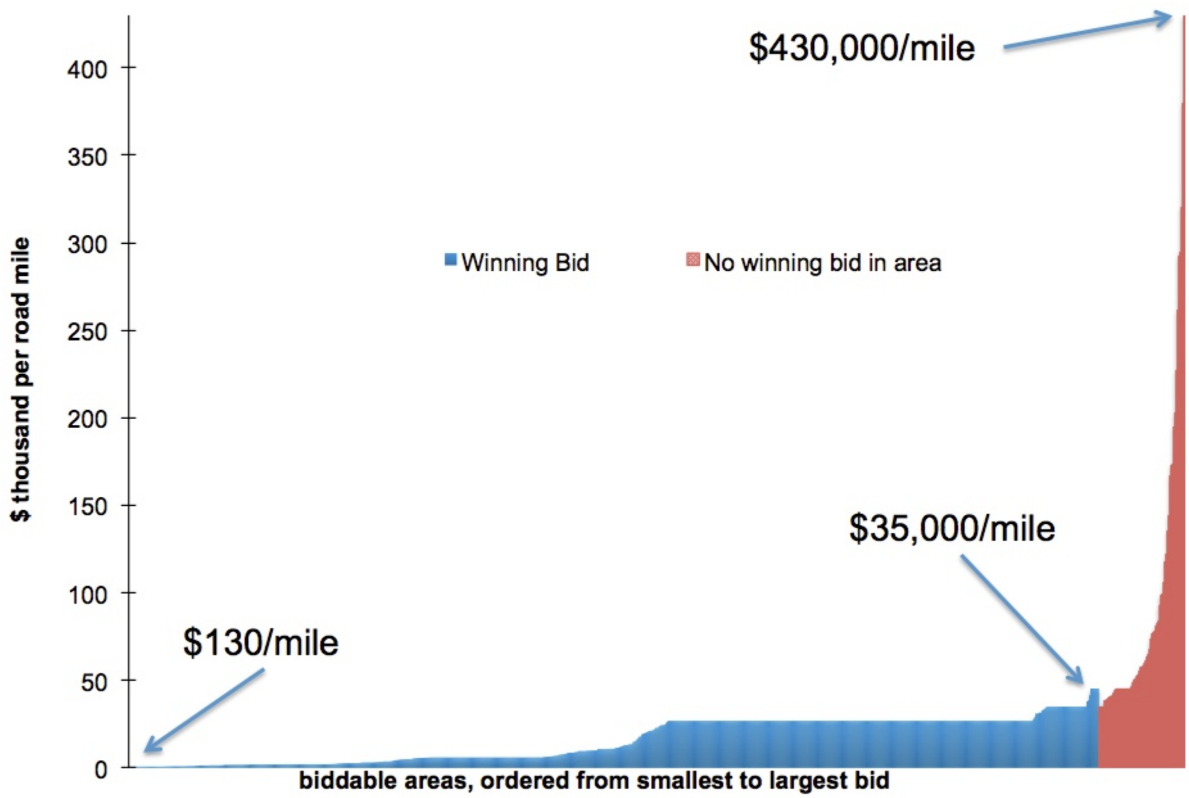
[11] Scott Wallsten, "Broadband Penetration: An Empirical Analysis of State and Federal Policies" (AEI-Brookings Joint Center for Regulatory Studies Working Paper, 2005), https://works.bepress.com/scott_wallsten/42/.
[12] FCC, "Universal Service Reform Mobility Fund," https://www.fcc.gov/rulemaking/10-208.
[13] FCC, "Auction 901 Mobility Fund Phase I," 2014, http://wireless.fcc.gov/auctions/default.htm?job=auction_factsheet&id=901.
[14] Scott Wallsten, "Two Cheers for the FCC's Mobility Fund Reverse Auction" (Technology Policy Institute, 2013), https://techpolicyinstitute.org/wp-content/uploads/2013/04/two-cheers-for-the-fcc-s-mobil-2007562.pdf.

Figure 2: Mobility Fund Phase 1 Bids



Source: Wallsten (2013)

However, later analysis by the FCC revealed the importance of carefully considering how to define the areas on which providers can bid. The method the FCC used to define geographic areas that supposedly had insufficient wireless coverage turned out to have included many areas that were adequately covered. Approximately 34 percent of the blocks that received Phase 1 support already had full LTE coverage while only six percent of blocks that received support had none.[15] The result of inaccurately identifying unserved areas caused $49 million to be spent in areas that would have been ineligible under the alternate approach.

The Mobility Fund Phase II is intended to auction up to $4.5 billion over ten years for areas without LTE coverage.[16] Before the auction can begin, however, the FCC must identify the eligible geographic areas and allow companies that provide service in those areas to challenge their inclusion. That is, a provider can petition the FCC to remove a region from eligibility if it is already providing service there.[17]

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[15] FCC, "Working Toward Mobility Fund II: Mobile Broadband Coverage Data and Analysis," September 30, 2016, https://apps.fcc.gov/edocs_public/attachmatch/DOC-341539A1.pdf.
[16] Federal Communications Commission, "In the Matter of Connect America Fund Universal Service Reform – Mobility Fund," February 23, 2017, https://apps.fcc.gov/edocs_public/attachmatch/FCC-17-11A1.pdf.
[17] Ibid., para. 65.

Connect America Phase II

The Order creating the CAF stated that "support in price cap areas would be provided through a combination of 'a new forward-looking model of the cost of constructing modern multi-purpose networks' and a competitive bidding process," together called "Phase II support."[18] Under Phase II, broadband providers under the universal service price-cap regime are offered subsidies based on the results of the FCC's cost model. The providers choose whether or not to accept the amount offered. The amount that providers do not accept is then supposed to be auctioned off via the Phase II auction process.

For example, in 2015 providers were offered $1.7 billion in annual Phase II model-based support and accepted $1.5 billion.[19] The remaining $174 million would be auctioned off. The results thus far imply that of total Phase II subsidies, about 90 percent will be provided based on the results of cost models and ten percent will be auctioned.

The Commission has nearly completed the preparations necessary to auction the remaining Phase II funds, which it estimates will be $1.98 billion over ten years.[20] We describe details of the planned auction in the section describing how to implement a subsidy auction, below.

While the FCC is the only agency moving to auction processes for distributing subsidies, at least one other agency continues distributing funds in a more traditional and less transparent fashion.

Rural Utilities Service

The Rural Utilities Service was created in the 1930's to promote rural electrification and later expanded to include loans for telephone services. It began requiring all networks it financed to be broadband capable in 1995.[21] Since 2009 the RUS has given out about $7 billion in grants and loans for telecom programs.[22]

RUS subsidies are difficult to evaluate because the agency does not make data easily available. It also does not evaluate their effectiveness. The Government Accountability Office even suggested

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[18] Recipients of support from the High Cost Fund receive subsidies based on either a rate-of-return model, in which the rate has been set at 11.25 percent for more than two decades, or a price cap model. The CAF reforms included modifications to subsidies received under the price cap model. Federal Communications Commission, "In the Matter of Connect America Fund ETC Annual Reports and Certifications," Report and Order and Order on Reconsideration, (February 23, 2017), para. 4, https://apps.fcc.gov/edocs_public/attachmatch/FCC-17-12A1.pdf.
[19] Federal Communications Commission, "Carriers Accept Over $1.5 Billion in Annual Support from Connect America Fund to Expand and Support Broadband for Nearly 7.3 Million Rural Consumers in 45 States and One Territory," August 27, 2015, http://transition.fcc.gov/Daily_Releases/Daily_Business/2015/db0827/DOC-335082A1.pdf.
[20] Federal Communications Commission, "In the Matter of Connect America Fund ETC Annual Reports and Certifications."
[21] NTIA, "BroadbandUSA: Guide to Federal Funding of Broadband Projects," 2015, https://www2.ntia.doc.gov/files/broadband_fed_funding_guide.pdf.
[22] https://www.rd.usda.gov/files/USDARDProgressReport2016.pdf

in the title of a 2014 analysis that "USDA should evaluate the performance of the rural broadband loan program."[23]

More than a decade ago, Wallsten (2005) found that the RUS broadband program was not associated with any increase in rural access to broadband telecommunications.[24] Since 2013, RUS has administered the Rural Broadband Access Loan and Loan Guarantee Program, which provides low interest rate loans and loan guarantees to corporations, limited liability companies, cooperative or mutual organizations, Indian tribes, and state or local governments. A 2014 GAO study found that USDA's loan program does little to help promote broadband deployment and economic development. Based on this report, Brown et al. (2015) found "modest but statistically significant relationships between [RUS] loans and county employment and payroll, but no relationship between the program and the number of business establishments." The authors found no economic effect of RUS loans in the most rural counties.[25]

American Recovery and Reinvestment Act

The 2009 American Recovery and Reinvestment Act included $7 billion for broadband development: $4.7 billion for the Broadband Technology Opportunities Program (BTOP) administered by the National Telecommunications Information Agency (NTIA) and $2.5 billion for the Broadband Initiatives Program (BIP) managed by the Rural Utilities Service (RUS).[26]

Broadband Technology Opportunities Program

The NTIA, which at the time did not have a grant administrating office, was tasked with distributing $4.7 billion in BTOP grants.[27] NTIA faced personnel shortage, lack of qualified independent reviewers, and limited time to review applications.[28]

NTIA did not use an auction or any other systematic mechanism to compare proposals across geographies or technologies and the process took fourteen months for the first set of grants to be distributed and nineteen months for subsequent grants from the signing of ARRA.[29] NTIA used volunteers to evaluate proposals. These volunteers were generally accepted on a "first-come, first

[23] http://www.gao.gov/assets/670/663578.pdf
[24] Wallsten, "Broadband Penetration: An Empirical Analysis of State and Federal Policies."
[25] Michael E Clements, Kyle G Browning, and Stephen M Brown, "Rural Utilities Service Broadband Loans and Economic Performance in Rural America," in *TPRC 43: The 43rd Research Conference on Communication, Information and Internet Policy Paper*, 2015, doi:10.2139/ssrn.2586016.
[26] "American Recovery and Reinvestment Act of 2009," Pub. L. No. PUBLIC LAW 111 - 5, 123 (2009). (codified as amended in scattered sections of 6, 19, 26, 42, and 47 U.S.C.).
[27] "Oversight of the Department of Commerce's Broadband Technology Opportunities Program," § Subcommittee of the Committee on Appropriations United States Senate (2010), https://www.gpo.gov/fdsys/pkg/CHRG-111shrg58013/pdf/CHRG-111shrg58013.pdf.
[28] Office of the Inspector General, "NTIA Must Continue to Improve Its Program Management and Pre-Award Process for Its Broadband Grants Program," April 2010, https://www.oig.doc.gov/OIGPublications/ARR-19842.pdf.
[29] NTIA, "Quarterly Reports on BTOP to Congress," http://www2.ntia.doc.gov/Broadband-Resources#overview.

served" basis and many were never interviewed in person by anyone at the DoC.[30] Additionally, NTIA did not make explicit its scoring rules in advance of the application process nor did it have objective metrics for how it would compare grants.[31]

Rosston and Wallsten (2013) found high variance among expected cost-effectiveness of awards. Grants ranged from about $65 million for the most cost-effective 10,000 miles of fiber and close to $820 million for the least cost-effective 10,000 miles. In other words, awards differed by more than a factor of 100 in terms of expected cost-effectiveness, indicating that many high cost projects were funded that likely should not have been funded.[32]

A study by LaRose et al. (2014) concluded from project application abstracts that BTOP selected proposals consistent with stated objectives and goals, but did not evaluate implementation or outcomes.[33] Jackson and Gordon (2011), however, found in a sample of 27 projects that BTOP and BIP did not always operate in ways consistent with its stated objectives. In particular, in that sample it failed to engage community based organizations (CBOs), identified as a key target of both programs.[34] CBOs struggled to meet the formal evaluation, reporting, and management requirements.[35] Participants had only 45 days to submit an application for the first set of grants the time between first and second set of grants was too short to improve applications, and some organizations still had pending applications by the second round deadline. Furthermore, CBOs were not prepared to administer large sums of money. In some cases, BTOP grants exceeded annual operational budgets by a factor of ten.[36]

BTOP awarded $201 million to public computing centers (PCCs), which was a small share of overall funding but unprecedented in this category.[37] PCC grants had typically been smaller in size and made to a larger number of local entities including library consortia, state and county governments, state agencies, non-profits and municipalities. Jayakar & Park (2012 & 2013) found that the PCCs BTOP supported were in areas of high broadband availability and high demand, contrary to the BTOP's stated purpose, and that funding was not cost-effective.

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[30] NTIA, "Call for Reviewers Broadband Technology Opportunities Program," July 6, 2009, https://www.nsf.gov/cise/news/2009_ntia.pdf; Oversight of the Department of Commerce's Broadband Technology Opportunities Program.

[31] Gregory Rosston and Scott Wallsten, "The Broadband Stimulus: A Rural Boondoggle and Missed Opportunity" (Technology Policy Institute, 2013), https://techpolicyinstitute.org/wp-content/uploads/2013/11/the-broadband-stimulus-a-rural-2007592.pdf.

[32] Ibid.

[33] Robert LaRose et al., "Public Broadband Investment Priorities in the United States: An Analysis of the Broadband Technology Opportunities Program," *Government Information Quarterly* 31, no. 1 (January 2014): 53–64, doi:10.1016/j.giq.2012.11.004.

[34] Mostly independent non-profit groups with roots in the local community.

[35] Andrew Gordon and Steven J. Jackson, "Building Community Broadband: Barriers and Opportunities for Community-Based Organizations in the Federal BTOP and BIP Broadband Development Programs," *Proceedings of the American Society for Information Science and Technology* 48, no. 1 (2011): 1–11, doi:10.1002/meet.2011.14504801169.

[36] Ibid.

[37] Centers in schools, libraries, community centers and other locations that provide broadband access to low-income and marginalized populations.

Broadband Improvement Program

While NTIA ran BTOP, the Rural Utilities Service was directed to distribute $2.5 billion for construction and operation of broadband facilities in underserved and unserved rural areas under the Broadband Initiatives Program (BIP).[38] Unlike BTOP, BIP had no explicit adoption or training component, focusing exclusively on network development.

According to the GAO, RUS provided loans or grants to 297 projects. 42 were terminated "for a variety of reasons," had difficulties completing inspections due reduced staffing and limited travel funding, and could not systematically track projects.[39]

An RUS administrator reported that the investment would connect nearly 7 million rural Americans.[40] However, RUS's BIP Final Report noted that 83% of the projects were fully operational, 14 percent were rescinded and that 334,830 broadband subscribers received new or improved service. Although this number includes 310,539 connected households and 24,293 businesses or institutions, it remains distant from its goal and does not "highlight the success of BIP" as the report claims.[41] Furthermore, of the original $3.4 billion awarded, $2.9 billion was disbursed perhaps because of the 297 approved projects, roughly half had not drawn the full awarded amounts by July 2015.[42] Additionally, taking the report at face value implies that each connection cost almost $9,000.

BTOP and BIP failures are both disappointing but not surprising. Ongoing universal service programs have large constituencies that lobby against changes to the status quo. A one-time program may be more likely to try more rigorous approaches for distributing subsidies, but the agencies chose not to pursue that option. At the same time, it is not fair to place all the blame on the agencies. The ARRA was passed during an economic crisis and was primarily intended as economic stimulus. Thus, the agencies charged with implementing this component of the ARRA were directed to improve broadband and create short-term economic stimulus. Those two objectives are not necessarily consistent.

Municipal broadband

Some local governments fully or partially finance, build, or operate municipal networks, although as of 2016, 23 states had passed laws that prohibit or restrict on municipal

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[38] USDA, "Broadband Loan and Grant Program," https://www.rd.usda.gov/recovery/broadband.html.

[39] GAO, "Program Review: USDA's Broadband Initiatives Program | Following the Money," 2014, http://www.gao.gov/recovery/bimonthly/programs/.

[40] USDA, "Advancing Broadband: A Foundation for Strong Rural Communities," 2011, https://www.rd.usda.gov/files/reports/RBBreportV5ForWeb.pdf.

[41] Ibid.

[42] Tony Romm, "Wired to Fail," *Politico*, July 28, 2015, http://www.politico.com/story/2015/07/broadband-coverage-rural-area-fund-mishandled-120601.

broadband.[43]. Municipal broadband is often justified using the same arguments that have been applied to municipal-based utilities, like those that supply water, natural gas, and electricity. Financing models can include public-private partnerships, cooperatives, and outright government ownership. In the U.S. about 500 municipalities have undertaken some form of municipal broadband including 89 communities with publicly owned FTTH networks.[44]

As with any government investment, the expected benefits should exceed the costs if it is to be worthwhile. A key question is whether local investment in broadband crowds out or stimulates private spending. In theory, either is possible. Competition from a publicly-owned network could create incentives for additional investment or lower prices by existing providers. On the other hand, the costs—and thus the opportunity costs to the locality—of building and operating a network are high, and private firms may be hesitant to invest where they face subsidized competitors.

Local governments typically finance broadband projects through bonds, financial transfers from a municipality or utility, loans, or grants. The funding mechanism does not affect the true total cost of the project. Instead, the mechanism affects how the costs are distributed across groups and over time. Regardless of the funding mechanism, the project has a cost that can be estimated in terms of net present value, and this NPV should be compared to the NPV of other uses of local revenues when choosing spending priorities.

For example, cities may be able to borrow money at favorable interest rates, but their ability to do so is limited. Borrowing for one purpose may make borrowing more costly the next time. Additionally, payments over time push responsibilities to future generations. A sales tax may have distributional consequences depending on what is taxed and at what level, in addition to the economic consequences that result from any tax. Neither of those options, meanwhile, affects the total NPV of obligations for which the city becomes responsible.

A number of projects underestimated costs and overestimated potential demand.[45] Deignan (2014) finds that local public initiatives produce small economic benefits and increase the size of local government.[46] Public networks also face financial uncertainty, which can lead to taxpayers bearing financial risk that would otherwise be borne by private investors. Ford (2016) argues that

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[43] For a summary of state laws that restrict or prohibit municipal broadband see Lauren Sisneros and Brian Sponsler, *Inhibiting Connection State Policy Impacting Expansion of Municipal Broadband Networks* (Education Commission of the States, 2016), http://www.ecs.org/ec-content/uploads/Inhibiting-Connection_State-policy-impacting-expansion-of-municipal-broadband-networks.pdf.

[44] "Community-Based Broadband Solutions: The Benefits of Competition and Choice for Community Development and Highspeed Internet Access" (The Executive Office of the President, January 2015), https://www.whitehouse.gov/sites/default/files/docs/community-based_broadband_report_by_executive_office_of_the_president.pdf. For an interactive map of municipal broadband initiatives see https://muninetworks.org/communitymap.

[45] Sharon E Gillett, William H Lehr, and Carlos Osorio, "Local Government Broadband Initiatives," *Telecommunications Policy* 28, no. 7–8 (August 2004): 537–58, doi:10.1016/j.telpol.2004.05.001.

[46] Brian Deignan, "Community Broadband, Community Benefits? An Economic Analysis of Local Government Broadband Initiatives," Mercatus Graduate Policy Essay, 2014, https://asp.mercatus.org/system/files/MGPE_Deignan_0.pdf.

municipal broadband reduces competition, threatens private investment, and associated economic gains stem from business relocation rather than new growth.[47] Ford also concludes that building a new subsidized network is an inefficient way to obtain the intended social benefits because they depend on subscriber growth for economic viability. In addition, municipally-owned networks take market share from private incumbents weakening incentives to invest.[48]

Yoo and Pfenninger (2017) find that out of twenty municipal projects that report broadband financial data separate from electric power operations, eleven had negative cash flows in net present value.[49] Of the nine cash-flow positive projects only two–Vernon, CA and Bristol, TN–are on track to cover their total project costs and meet debt obligations.[50] However, Vernon's project costs were significantly higher than expected, increasing the payback period from two to 100 years.[51] Furthermore, Vernon is unique because it has fewer than 30 households.[52] Bristol is the most successful case from the sample; it is expected to pay off its cost within 34 years only if it continues to generate cash flows at previous levels. The authors attribute Bristol Tennessee's success to higher-than-average revenue per household and efficient operation.[53]

Several examples, including those viewed as successful, cast doubt on the wisdom of investing taxpayer dollars into publicly-owned networks. The biggest problem tends to be underestimating future costs. For example, BVU Opt-Net from Bristol, VA sold its network to a local ISP for $50 million after investing about $185 million and without the resources to continue operating without cross-subsidizing services which is prohibited by state law.[54, 55] FiberNet from Monticello, MN defaulted on its revenue bond in 2014 and Utopia –a $250 million investment multi-city owned network in Utah–was unable to become financially stable after construction delays and cost overruns.[56] In other cases, cities changed the business models of their networks

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[47] George Ford, "The Impact of Government-Owned Broadband Networks on Private Investment and Consumer Welfare" (State Government Leadership Foundation, 2016), http://sglf.org/wp-content/uploads/sites/2/2016/04/SGLF-Muni-Broadband-Study-1.pdf.
[48] Ibid.
[49] Christopher S Yoo and Timothy Pfenninger, "Municipal Fiber in the United States: An Empirical Assessment of Financial Performance" (Philadelphia, PA: University of Pennsylvania Law School's Center for Technology, Innovation and Competition, May 2017), https://www.law.upenn.edu/live/files/6611-report-municipal-fiber-in-the-united-states-an.
[50] Project costs used to calculate NPV do not include state and federal government subsidies.
[51] Yoo and Pfenninger, "Municipal Fiber in the United States: An Empirical Assessment of Financial Performance," 19.
[52] Yoo and Pfenninger, "Municipal Fiber in the United States: An Empirical Assessment of Financial Performance," 6.
[53] Ibid, 18.
[54] Tina Bohner, "Bristol, Va. Approves Sale of BVU's Optinet to Sunset Digital," *WCYB News*, March 15, 2016, http://www.wcyb.com/news/bristol-va-approves-sale-of-bvus-optinet-to-sunset-digital/14609711.
[55] Virginia Auditor of Public Accounts, "Review of Bristol Virginia Utilities Authority" (Bristol, VA, October 2016), http://www.apa.virginia.gov/reports/BVUA2016-web.pdf.
[56] Charles Davidson and Michael Santorelli, "Understanding the Debate over Government-Owned Broadband Networks: Context, Lessons Learned, and a Way Forward for Policy Makers" (ACLP New York Law School, 2014), http://www.nyls.edu/advanced-communications-law-and-policy-institute/wp-content/uploads/sites/169/2013/08/ACLP-Government-Owned-Broadband-Networks-FINAL-June-2014.pdf. Utopia also received a $21 million loan from RUS and a $8.6 million in grants from BTOP. Yoo and Pfenninger, "Municipal Fiber in the United States: An Empirical Assessment of Financial Performance."

when they did not find sufficient retail demand, but still could not become financially viable. Marietta, Georgia's FiberNet and Ashland, Oregon's Fiber Network both began as retail networks and switched to wholesale in hope of meeting operating and debt expenses, but still failed to do so.[57] Marietta sold its network at an $11 million loss, and Ashland is still unable to meet its total expenditures.[58, 59]

Other examples of failed municipal owned networks include in sum, finance models that do not foresee future costs, overestimate penetration rates, assume future revenue streams without response from competitors and underestimate operating costs.[60]

The next section presents some mini-case studies of publicly-funded broadband networks.

Chattanooga, TN

Chattanooga's municipal network cost $347 million to build, including $162 million from a bond issue, $74 million from several loans and an $111 million 2011 ARRA grant. The FTTH network run by the local public electric utility, the Electric Power Board (EPB).[61] By comparison, the city's entire annual budget is $212 million.[62] Its broadband spending translates to approximately $43,300 per fiber mile and $4,100 per subscriber.[63] As expensive as the network was, Chattanooga began with some advantages relative to other cities. EPB began constructing a fiber optic network in 1998 to control and monitor its electrical grid. Because its network was underutilized, in 2003 it started offering internet services.[64]

Dubbed 'Gig City' for offering 1Gbps, EPB initially rolled out its network with a monthly bill of about $350 for that speed tier with competitive rates at lower connection tiers.[65] By 2016, it had lowered the price for 1 Gbps to about $70 a month.[66] EPB serves approximately 77,000 residential and 6,500 commercial customers, about 50 percent of the local residential market;

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[57] Ashland Fiber Network, "Proposed 2010-2013 Strategic Business Plan City of Ashland Information Technology Department" (Information Technology Department, 2010), https://www.ashland.or.us/Files/Proposed%20AFN%20Business%20Plan.pdf.
[58] Davidson and Santorelli, "Understanding the Debate over Government-Owned Broadband Networks: Context, Lessons Learned, and a Way Forward for Policy Makers."
[59] Ashland Fiber Network, "Strategic Business Plan October 2014" (Ashland, Oregon: Information Technology Department, 2015), https://www.ashland.or.us/Files/2014%20AFN%20Strategic%20Business%20Plan.pdf.
[60] Balhoff Michael and Rowe Robert, "Municipal Broadband: Digging Beneath the Surface" (Balhoff & Rowe, LLC, September 2005), http://broadband.cti.gr/en/download/Municipal-Broadband--Digging%20Beneath%20the%20Surface.pdf.
[61] Kevin McCarthy, "Chattanooga High Speed Broadband Initiative," 2012, https://www.cga.ct.gov/2012/rpt/2012-R-0515.htm.
[62] FY2014.
[63] Based on 2016 numbers for 83,500 subscribers and 8,000 fiber miles built.
[64] Christopher Mitchell, "Broadband at the Speed of Light: How Three Communities Built Next-Generation Networks" (Institute for Local Self-Reliance, April 2012), http://ilsr.org/wp-content/uploads/2012/04/muni-bb-speed-light.pdf.
[65] Ibid.
[66] Unbundled service dependent on location. EPB website, https://epb.com/home-store/internet#pricing

however, only about 9 percent of residential (5,341 of 58,334 internet subscribers) and 0.73 of commercial customers (53 of 4,774) subscribed to its 1-Gbps service.[67]

Supporters contend that the publicly-owned network stimulated economic development, helped launch its high-tech sector, and enhanced the city's overall quality of life.[68] Lobo (2011) estimated the economic value of the fiber infrastructure and the smart grid in Hamilton County at $590 million in added income and taxes and indirect social benefits, with total capital expenditures at $396 million over four years.[69] An updated 2015 report revises previous estimates to be 27-95 percent higher and states that new job creation ranged between 2,800 and 5,200 –suggesting that benefits of Chattanooga's municipal fiber network outweighed its costs.[70] Even setting aside the question of whether the city could have made better use of those funds, those studies do not hold up to scrutiny. While municipal investments can provide social benefits, the studies tend to ignore many real costs, as well as costs that were not paid by the city itself.

Davidson & Santorelli (2014) contend that the costs of building this network outweigh its benefits.[71] Chattanooga residents now hold about $ 1 billion in debt, about 40 percent accruing to EPB. These obligations imply there are fewer resources available to the city for other priorities. Ford (2016) additionally argues that EPB shifts the costs to electricity customers which acts as a cross-subsidy from captive ratepayers of a monopoly electric utility to its affiliated broadband network –a practice that could face antitrust litigation.[72] Data from the U.S. Energy Information Agency suggest that such a cross-subsidy may be taking place. Figure 3 shows the average price across residential, commercial, and industrial users for the EPB and across the U.S. for full-service electricity providers. The figure shows that while electricity in Chattanooga is less expensive than the U.S. average, the gap between the two began to narrow after the city launched its broadband network. This simple comparison is by no means definitive—other reasons could explain the narrowing gap—but it suggests that the cross-subsidy concern has merit.

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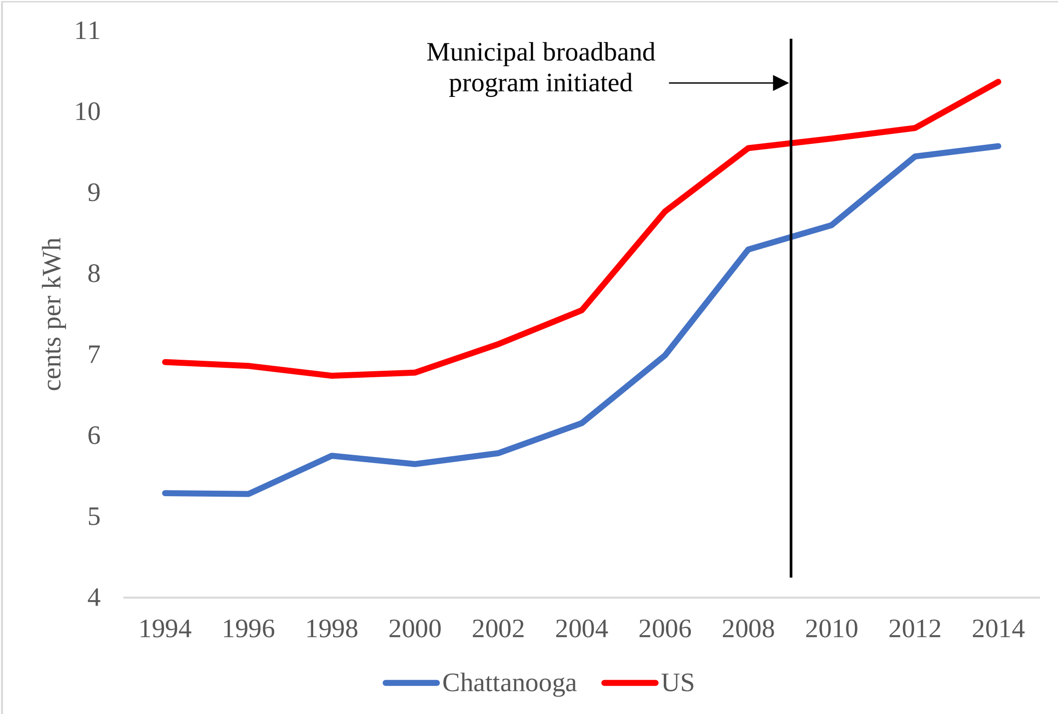
[67] Bento J Lobo, "The Realized Value of Fiber Infrastructure in Hamilton County, Tennessee" (The University of Tennessee at Chattanooga, 2015), http://ftpcontent2.worldnow.com/wrcb/pdf/091515EPBFiberStudy.pdf.
[68] Mitchell, "Broadband at the Speed of Light: How Three Communities Built Next-Generation Networks."
[69] Bento J Lobo, "The Economic and Social Value of EPB's Fiber Optic Infrastructure in Hamilton County" (University of Tennessee at Chattanooga, October 2011), https://ecfsapi.fcc.gov/file/7521737342.pdf.
[70] Lobo, "The Realized Value of Fiber Infrastructure in Hamilton County, Tennessee."
[71] Michael Santorelli and Charles Davidson, "Chattanooga Case Study (updated)" (ACLP New York Law School, 2015), http://www.nyls.edu/advanced-communications-law-and-policy-institute/wp-content/uploads/sites/169/2013/08/ACLP-Chattanooga-Case-Study-updated-October-2015.pdf.
[72] Ford, "The Impact of Government-Owned Broadband Networks on Private Investment and Consumer Welfare."

Figure 3: Average Electricity Prices Across Sectors in Chattanooga and U.S.



Source: U.S. Energy Information Administration[73]

Furthermore, Yoo and Pfenninger find that although EPB's operations were cash flow positive from 2010 to 2014 it would take 412 years to pay its cost, not including the $111 million ARRA grant.[74] Finally, even if the benefits exceed the costs to the city, it does not necessarily demonstrate that the project itself would pass a cost-benefit test. The city received a large one-time ARRA grant that generates obligations on other taxpayers.[75] A similar per-person amount granted across the country would imply a $200 billion subsidy, which is unlikely to be a wise use of funds.

Lafayette, LA

Like Chattanooga, Lafayette supplies broadband via the municipally-owned Lafayette Utility System (LUS). In 2005, 62 percent of voters voted in favor of a $125 million bond offering to fund the system.[76] Lafayette issued is first $110 million bond in 2007 and subsidiary LUS Fiber

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[73] EIA, "Electric Sales, Revenue, and Average Price," October 6, 2016, https://www.eia.gov/electricity/sales_revenue_price/index.cfm.
[74] Yoo and Pfenninger, "Municipal Fiber in the United States: An Empirical Assessment of Financial Performance," 20.
[75] Ford, "The Impact of Government-Owned Broadband Networks on Private Investment and Consumer Welfare."
[76] "Timeline," *LUS Fiber*, n.d., http://www.lusfiber.com/index.php/about-lus-fiber/historical-timeline.

began building a FTTH network in 2008 connecting its consumers a year later.[77] LUS Fiber invested $148 million in total, $10,600 per subscriber as of 2013 and $18,500 per fiber mile.[78] Although cited as a success by a White House report for offering 100 Mbps to all subscribers, lowering prices, and promoting local economic development, six years into operation the project was 30 percent short of its business plan revenue projection.[79, 80]

LUS Fiber's projected costs were close to its actual expenses, but operating expenses exceeded operating revenues. To complete construction, LUS Fiber submitted two broadband stimulus applications under ARRA but received no funding and, instead, took out a series of loans.[81] By 2012 it had borrowed $16.4 million from LUS for the acquisition of fiber infrastructure, start-up costs and operation.[82] LUS Fiber expected to break even in 2012 but ended up with a $10 million revenue shortfall.[83] In 2011, LUS issued bonds for the remaining $15 million authorized by the referendum and an additional $7 million in bonds was issued in 2012.[84,85] LUS Fiber lost $36.1 million between 2010 and 2014, but has recently became cash positive, with revenues of $34 million in 2015.[86, 87]

One report found that LUS Fiber's entrance initially drove down prices and led some companies to locate in Lafayette. However, the report continued, LUS Fiber initial revenues were below its goal and expenses higher than projected, incurring in a $40 million deficit six years into operation.[88] Additionally, the economic development stemming from population and job growth was associated with the region's oil and gas boom, not the broadband network.[89] LUS fiber responded, stating the report had erroneous deductions and conclusions. It did not deny its lower than projected revenues, but stated that its financial position has consistently improved and is on track to become self-sufficient.

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77 Mitchell, "Broadband at the Speed of Light: How Three Communities Built Next-Generation Networks."
78 Based on 14,000 subscribers in 2013 and 8,000 fiber miles built. Davidson and Santorelli, "Understanding the Debate over Government-Owned Broadband Networks: Context, Lessons Learned, and a Way Forward for Policy Makers."
79 "Community-Based Broadband Solutions: The Benefits of Competition and Choice for Community Development and Highspeed Internet Access,"15-16.
80 Titch, Steven, "Lessons in Municipal Broadband from Lafayette, Louisiana" (Reason Foundation, 2013), http://reason.org/files/municipal_broadband_lafayette.pdf.
81 Mitchell, "Broadband at the Speed of Light: How Three Communities Built Next-Generation Networks," 24.
82 "Utilities Revenue Refunding Bond, Series 2012" (City of Lafayette Louisiana, November 2012), 43, http://emma.msrb.org/EA494408-EA384388-EA781227.pdf.
83 Lafayette Consolidated Government, "Proposed Operating & Capital Budget 2013–2014" (City and Parish of Lafayette, LA, 2013), http://www.lafayettela.gov/pdf/Finance/Budget/proposed/2014proposedbudget.pdf.
84 Mitchell, "Broadband at the Speed of Light: How Three Communities Built Next-Generation Networks."
85 Davidson and Santorelli, "Understanding the Debate over Government-Owned Broadband Networks: Context, Lessons Learned, and a Way Forward for Policy Makers,", 61.
86 Lafayette Consolidated Government, "Comprehensive Annual Financial Report FY 2015" (Lafayette, Louisiana, 2015), http://www.lafayettela.gov/Finance/SiteAssets/Files/Accounting/LCG2015CAFR.pdf.
87 Yoo and Pfenninger, "Municipal Fiber in the United States: An Empirical Assessment of Financial Performance," 22.
88 Steven Titch, "Muni Broadband: The Gift That Keeps on Taking" (R Street, 2014), http://www.rstreet.org/2014/05/30/muni-broadband-the-gift-that-keeps-on-taking/.
89 Ibid.

The most recent audit states that LUS Fiber has a cumulative operating loss of $47 million for FY2008 to FY2012, indicative that its long-term stability is uncertain.[90] Davidson & Santorelli (2014) highlight that the network's significant debt has limited needed investment in its local school system and key infrastructure such as roads and drainage.[91] Lafayette's primary goal to attract new business with ultra-fast connectivity was not met, primarily reflected in its information sector employment decrease by 24 percent between 2008 and 2013.[92]

Provo, UT

Provo's wholesale FTTH municipal network is generally recognized as an unsuccessful, as illustrated by the terms of its sale. Provo invested $59.5 million in its network –$39.5 million through a bond issue, $1 million in loans and $19 million in subsidies– and sold it after five years to Google for $1.[93, 94]

In 2001, the city built a fiber backbone network. Wanting to expand the network to residents and businesses, Provo adopted a wholesale model –as opposed to retail due to resistance from incumbents and the state legislature.[95] After a 300 residential and 30 apartment building pilot program, the city issued its revenue bond to launch iProvo.[96] By 2005, HomeNet –iProvo's only ISP– failed to build a subscriber base sufficient to cover the costs of building and maintaining the network. HomeNet reached only 2,400 costumers and subsequently lost one third of these subscribers, leading it to leave the market and declaring bankruptcy.[97] HomeNet costumers migrated to new ISPs Veracity and MStar, but the subscriber base did not grow fast enough to be sustainable and faced total losses of $8 million.[98]

In 2008, the network was sold to a private company, which later defaulted on its purchase agreement, reverting control to the city. To pay for the bond, Provo residents where charged a $5.35 monthly fee and commercial customers were charged a $10 flat rate plus 2.3 percent of their utility bill.[99] After difficulties finding a new buyer, Provo sold its $39 million network to

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[90] Louisiana Public Service Commission, "Commission Audit of Lafayette Utilities System for the 2011 and 2012 Fiscal Years" (Baton Rouge, LA, 2014), http://lpscstar.louisiana.gov/star/ViewFile.aspx?Id=7e4ce38c-1d04-43e4-a35a-d4bf8fb3eef2.
[91] Davidson and Santorelli, "Understanding the Debate over Government-Owned Broadband Networks: Context, Lessons Learned, and a Way Forward for Policy Makers," 63-64.
[92] Ibid.
[93] Ibid, 49.
[94] Charlie Osborne, "Google to Buy $39m Provo Fiber Service for $1," *ZDNet*, April 19, 2013, http://www.zdnet.com/article/google-to-buy-39m-provo-fiber-service-for-1/.
[95] Steven Titch, "Spinning Its Wheels: An Analysis of Lessons Learned from iProvo's First 18 Months of Municipal Broadband" (Reason Foundation, 2006), http://reason.org/files/33224c9b01e12f3b969f4257037c057e.pdf.
[96] Ibid.
[97] Ibid.
[98] Steven Titch, "iProvo's Losses at $8 Million and Counting" (Reason Foundation, 2008), http://reason.org/news/show/1002992.html.
[99] John Curtis, "A Possible New Utility Charge to Pay for iProvo," *Provo Insider*, 2011, http://provomayor.com/2011/09/16/a-possible-new-utility-charge-to-pay-for-iprovo/.

Google for one dollar in 2013.[100] The city remains responsible for its $40 million debt over 12 years. This case illustrates the risks of investing in a broadband network, especially one intended to sell only wholesale access.

Danville, VA

Danville, Virginia is a small city that had access to a 700 middle-mile fiber network built by the Mid-Atlantic Broadband Communities Corporation (MBC)[101] and a local ISP that could provide retail IPTV, FTTH and wireless services.[102] Using a wholesale model, "nDanville" first connected utilities and public works infrastructure facilities in 2004. In 2007, it started connecting businesses near utility substations and in 2012 it expanded to residential.

nDanville was funded by a $2.5 million loan from the city's electric fund which was paid back in 2012 and receives about $1 million E-Rate funds every year.[103] In an interview, Danville's interim Director of Utilities noted that by 2015, nDanville had passed 2,500 homes out of 26,000 in the city limits and had a 20 percent take up rate –approximately 500 subscribers.[104]
He also said that nDanville holds no debt and contributes $300,000 to the city general fund each year.[105] However, the city's budget suggests things may not be so straightforward.[106] Figure 4 shows Danville's Telecommunications Fund, which includes nDanville.

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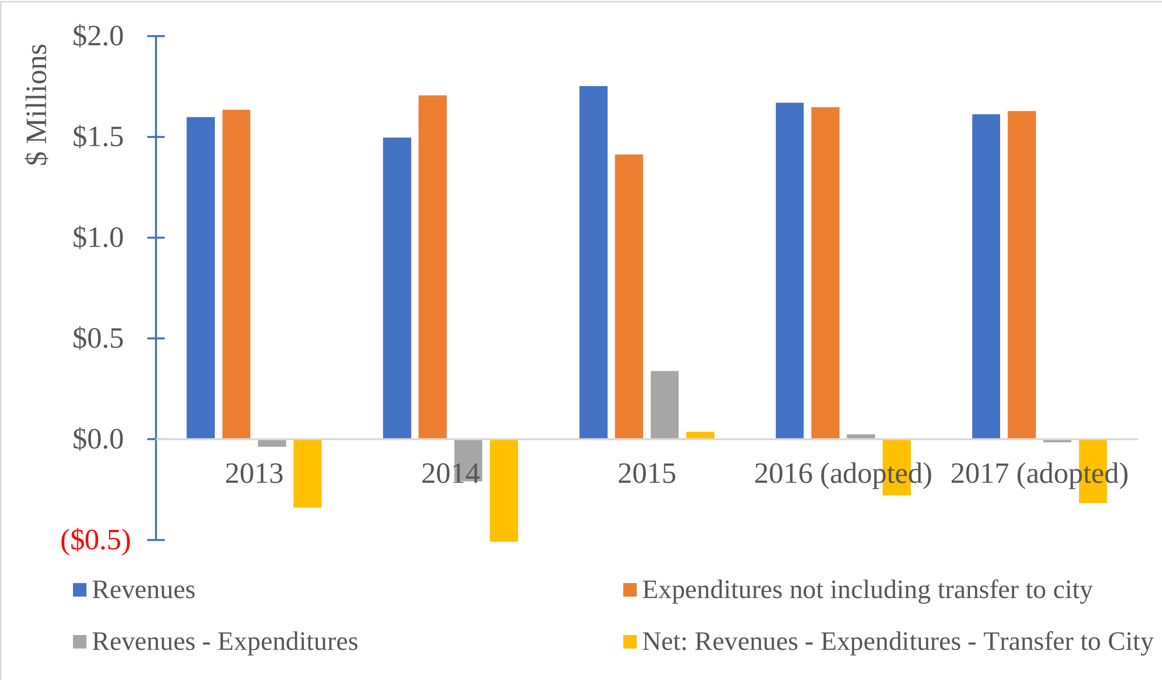
[100] Dave Smith, "Google Fiber in Utah: Why Provo Sold Its $39 Million Internet Service to Google for Just $1," *International Business Times*, April 19, 2013, http://www.ibtimes.com/google-fiber-utah-why-provo-sold-its-39-million-internet-service-google-just-1-1205081.
[101] The MBC network was funded by federal and state grants that stemmed primarily from the state's tobacco settlement proceeds totaling over $40 million.
[102] "State-of-the-Art Broadband Builds Communities," December 2012, http://www.bbpmag.com/MuniPortal/EditorsChoice/1212editorschoice.php.
[103] Davidson and Santorelli, "Understanding the Debate over Government-Owned Broadband Networks: Context, Lessons Learned, and a Way Forward for Policy Makers."
[104] Jason Grey, Community Broadband Bits, October 1, 2015, https://muninetworks.org/content/transcript-community-broadband-bits-episode-166.
[105] Ibid.
[106] "FY 2016 Adopted Budget Telecommunications Fund" (Danville, VA: City of Danville, 2015), http://danvilleva.gov/DocumentCenter/View/16205.

Figure 4: Danville, Virginia Telecommunications Fund Budget



Sources: Danville City Budget.[107]

The Figure shows that revenues tend to be close to expenditures, although net expenditures over the five years shown here are negative. Those expenditures, however, do not include the $300,000[108] the network transfers to the city. Including those expenditures yields a net loss of $300,000 to $500,000 except for 2015, which yielded a net positive gain of about $36,000.

The budget raises the question of how the network can contribute $300,000 annually when that ensures that expenditures continuously exceed revenues. These numbers would suggest that the network has other sources of funds, perhaps the $1 million annual E-Rate grants mentioned above. If that is the case, however, it would imply that the city is taking advantage of the inherent fungibility of money to transfer a third of the funds to general use.

Europe

Government subsidies of private firms in the European Union, generally called "State aid," are constrained by the European single-market rules preventing national governments from aiding local industries.[109] Any aid provided by member countries to local firms should not crowd out

[107] Ibid, table 17-1; "FY 2017 Adopted Budget" (Danville, VA, July 1, 2015), http://www.danville-va.gov/ArchiveCenter/ViewFile/Item/1928.
[108] $302,000 each year, to be precise.
[109] Investment considered state aid is not approved or permitted.

private investment or distort competition.[110] However, the rules permit public investment if a project is expected to include significant private investment participation or the business plan shows an adequate expected return on investment.[111]

A 2013 modernization program for state aid rules to encourage more efficient public investment allowed member states to provide certain types of broadband infrastructure support without notifying the Commission.[112] Specifically, governments were allowed to subsidize basic broadband infrastructure in regions where no infrastructure is available, undertake small measures related to next-generation networks (e.g., FTTH or cable Docsis 3.0), and provide aid for broadband engineering works and passive infrastructure.[113]

Previous state aid project rules did not measure impact. Projects were approved based on pre-defined criteria with no requirement to evaluate market impact over time.[114] Ex-post evaluation was limited to monitoring compliance in a sample of cases and annual reports, which merely provided data related to ongoing implementation.[115] The European Commission may now subject certain broadband projects to evaluation to verify "i) whether the assumptions and conditions which led to the compatibility decision have been realized; ii) the effectiveness of the aid measure in light of its predefined objectives; and, iii) its impact on markets and competition and that no undue distortive effects arise under the duration of the aid scheme that is contrary to the interests of the Union."[116]

The European Union Digital Agenda strategy states that by 2020 all Europeans should have access to internet speeds of at least 30 Mbps ('fast' or NGA[117]) and that at least 50 percent of households subscribe to connections at least 100 Mbps ('ultra-fast').[118] On September 2016, the European Commission expanded its targets to include 1 Gbps connectivity to all public

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[110] European Commission, *Application of State Aid Rules to the Deployment of Broadband Networks* (Digital Single Market, 2014), https://ec.europa.eu/digital-single-market/en/news/application-state-aid-rules-deployment-broadband-networks.
[111] Ben Slocock, "The Market Economy Investor Principle," *Competition Policy Newsletter* 2 (2009), http://ec.europa.eu/competition/publications/cpn/2002_2_23.pdf.
[112] European Commission, *Evaluation in the Field of State Aid*, 2013, http://ec.europa.eu/competition/state_aid/modernisation/evaluation_issues_paper_en.pdf.
[113] Conor Quigley, "The European Commissions' Programme for State Aid Modernization," *Maastricht Journal of European and Comparative Law* 20, no. 1 (2013), 45 http://www.maastrichtjournal.eu/pdf_file/its/mj_20_01_0035.pdf.
[114] European Commission, *Evaluation in the Field of State Aid,* 2.
[115] Ibid.
[116] European Commission, "EU Guidelines for the Application of State Aid Rules in Relation to the Rapid Deployment of Broadband Networks," 2013, para 53, http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.C_.2013.025.01.0001.01.ENG#ntc67-C_2013025EN.01000101-E0067.
[117] The European Commission (EC) defines NGA networks as fixed broadband networks capable of achieving download speeds of at least 30 Mbps. The European Commission sometimes uses the term for any technology (e.g. including wireless LTE) that can deliver this download speed and hence meets the fast broadband target of the Digital Agenda.
[118] "Pillar IV: Fast and Ultra-Fast Internet Access," *Digital Single Market*, https://ec.europa.eu/digital-single-market/en/our-goals/pillar-iv-fast-and-ultra-fast-internet-access.

institutions, 5G coverage in all urban areas, and services that offer a minimum 100 Mbps download and capable of offering 1Gbps.[119]

Compared to the U.S., however, the EU has not shown willingness to spend large amounts of money to achieve these objectives. The EC stated its intent to invest €100 million through the Connecting Europe Broadband Fund (CEBF) and intends to raise at least €500 million through other public and private investors.[120] The CEBF is intended to act as an "equity investment platform" that will fund approximately 7 to 12 broadband projects per year in twenty countries by 2021.[121] The Commission also allocated €120 million to an initiative called WiFi4EU to fund free public Wi-Fi under a voucher scheme.[122]

In addition to public support at the EU level, individual countries have also undertaken various subsidy programs. We now turn to those.

Netherlands

The Netherlands has tried two programs to encourage broadband: Kenniswijk and Citynet.

Kenniswijk

Between 2000 and 2006, the Dutch government set up a national research and development program called "Kenniswijk" (Knowledge Neighborhood) to stimulate private investment in new infrastructure and services.[123] Kenniswijk was intended to provide up to €45.5 million in subsidies when matched with municipal and private funding.[124] Fifteen cities applied to pilot the program, with the Eindhoven region awarded funding.[125] Kenniswijk distributed €12.5 million in the form of an €800 per household subsidy to companies. The rest was available as up to

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[119] European Commission, "Connectivity for a Competitive Digital Single Market - Towards a European Gigabit Society" (Brussels, September 14, 2016).

[120] European Commission, "European Commission and EIB Launch Connecting Europe Broadband Fund," December 12, 2016, https://ec.europa.eu/digital-single-market/en/news/european-commission-and-eib-launch-connecting-europe-broadband-fund.

[121] European Commission, "Commission and European Investment Bank Announce a Fund for Broadband Infrastructure Open to Participation of National Promotional Banks and Institutions and of Private Investors," December 12, 2016, http://europa.eu/rapid/press-release_IP-16-4351_en.htm.

[122] European Commission, *WiFi4EU | Free Wi-Fi for Europeans*, 2017, https://ec.europa.eu/digital-single-market/en/wifi4eu-free-wi-fi-europeans#Article.

[123] Marc de Rooij, Alberto Nucciarelli, and Bert M. Sadowski, "Providing Incentives for Private Investment in Municipal Broadband Networks: Evidence from the Netherlands," *Telecommunications Policy* 33, no. 10–11 (2009): 582–95, doi:10.1016/j.telpol.2009.08.005.

[124] R. D. J. Kramer, A. Lopez, and A. Koonen, "Municipal Broadband Access Networks in the Netherlands - Three Successful Cases, and How New Europe May Benefit," *Proceedings of the 1st International Conference on Access Networks - AcessNets '06*, 2006, doi:10.1145/1189355.1189367.

[125] The municipalities of Helmond and Eindhoven applied as the Eindhoven Region. OECD, "Development of High Speed Netoworks and the Role of Municipal Networks" (Working Party on Communication Infrastructures and Services Policy, 2015), 39 http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=DSTI/ICCP/CISP(2015)1/FINAL&docLanguage=En.

€400,000 grants to businesses and non-profit institutions for projects to research, test or provide broadband services in Eindhoven.[126]

Incumbent operators were initially reluctant to participate.[127] Despite the subsidy and subsequent investment from former government monopoly KPN, the number of subscribers was about 10% of the total connections.[128] To increase subscriptions, the project was expanded in 2004 to include the town of Nuenen, located 10km north-east of Eindhoven.[129]

Nuenen's OnsNet is an open access network initiative that aggregated demand through a cooperative model where members requested the Kenniswijk subsidy and pooled their investments.[130] NEM Nuenen BV –jointly held by the investment company Reggefiber, the housing corporation Helpt Elkander, and the OnsNet cooperation– installed, owned, and operated the network. The network, which included 3,000 km of fiber, was installed within three months and offered 10Mbps internet subscriptions at €35.95 per month after the first subsidized year and free installation.[131] Within six months, 97 percent of the households had subscribed.[132] The network cost €15 million, or €1,765 per household.[133]

Citynet

In 2005, the city of Amsterdam partnered with five housing corporations and two financial companies –ING and Reggeborgh– to invest in the physical FTTH infrastructure for 10 percent (37,000) of Amsterdam households already served by several competing broadband networks.[134] The partnership Glasvezelnet Amsterdam (GNA) owned and managed the infrastructure. The municipality, private investors, and subsidiaries of the housing corporations each owned one third of shares for a total investment of €18 million.[135] National authorities argued that the public funds did not violate State aid rules because the investment was pursued on market terms. After a lengthy process, the EC concluded that the investment was compatible with MEIP.[136]

[126] "Grant Scheme Available for Innovative Services in Kenniswijk," *Telecompaper*, March 12, 2002, https://www.telecompaper.com/news/grant-scheme-available-for-innovative-services-in-kenniswijk–297721.
[127] OECD, "Development of High Speed Networks and the Role of Municipal Networks."
[128] Kramer, Lopez, and Koonen, "Municipal Broadband Access Networks in the Netherlands - Three Successful Cases, and How New Europe May Benefit."
[129] Ibid.
[130] Neunen is a small town of approximately 9,400 households and 23,000 inhabitants. A quarter of the population is over 65 which tend to have lower adoption rates.
[131] Bernd Holznagel, *Strategies for Rural Broadband an Economic and Legal Feasibility Analysis* (Wiesbaden: Gabler, 2010).
[132] Kramer, Lopez, and Koonen, "Municipal Broadband Access Networks in the Netherlands - Three Successful Cases, and How New Europe May Benefit."
[133] Rod Mitchell and Malcom Matson, "Study on Local Open Access Networks for Communities and Municipalities" (Oplan Foundation, 2006).
[134] The passive layer includes ducts, fiber and street cabinets. The active layer includes the management, control and maintenance systems necessary to operate the network, such as switches, routers or splitters. EC, *Investment by the City of Amsterdam in a Fibre-to-the Home (FTTH) Network*, 2007, http://ec.europa.eu/competition/state_aid/cases/218055/218055_760366_119_1.pdf.
[135] Ibid.
[136] Ibid.

In its first phase Citynet passed 46,087 homes by 2009, exceeding its 43,000 homes objective. However, after two years of operation, it had connected only 8,000 homes and only 3,000 subscribed, yielding a 6.5 percent adoption rate.[137] Low adoption was attributed to limited demand for high-speed broadband and low commercial interest by operators for municipal fiber.[138] Reggefiber acquired ING's share increasing its stake in GNA to 70 percent.[139]

In 2005, Reggefiber started investing in smaller towns throughout Netherlands.[140] To ensure sufficient demand to justify construction, Reggefiber would lease to retail service providers and would not begin construction until at least 30 percent of households in the targeted area committed to subscribe to one of the retail service providers.[141] One unique feature of Reggefiber is that cities allowed it to dig up streets and repave at the expense of the company rather than leaving it to the municipality.[142] Labor costs in cities, however, were high and accounted for about 70 percent of the total cost.[143] In 2009, incumbent KPN acquired a stake in Reggefiber and in 2014 purchased all its shares giving it full control. By 2014, KPN owned 45 percent of the fixed broadband retail market.[144]

United Kingdom

The United Kingdom has one of the largest public broadband subsidy programs in Europe, comprised of both direct government investment and vouchers. Since 2012, the UK government has invested approximately £866 million to increase broadband access and adoption.

Broadband Delivery UK

In 2012, the UK adopted the three-phase "Superfast Broadband Program" administered by the Broadband Delivery UK (BDUK). Under Phase 1, formerly the Rural Broadband Program, the government invested £530 million aimed at providing 'superfast' broadband (24 Mbps) to 90 percent of premises by local authorities on a technology-neutral basis by 2016. The government intended to spend an additional £250 million in Phase 2 to extend 'superfast' broadband to 95 percent of the UK, while Phase 3 would test via pilot programs ways of using smaller providers

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[137] Stratix, "Netherlands FTTH 1Q2009" (Hilversum, June 2009), www.stratix.nl/academy/.../1-download-reports?...12:ftth...netherlands-2009q1-stratix.
[138] Vasilis Maglaris and Costas Troulos, "Factors Determining Municipal Broadband Strategies across Europe," *Telecommunications Policy* 35, no. 9–10 (2011): 842–56, doi:10.1016/j.telpol.2011.07.008.
[139] European Commission, "Fibre To The Home (FTTH) Case Study - Amsterdam Citynet," *Digital Single Market*, March 2014, https://ec.europa.eu/digital-single-market/en/news/fibre-home-ftth-case-study-amsterdam-citynet.
[140] Reggefiber is a subsidiary of Reggeborgh, a private investment firm.
[141] OECD, "Development of High Speed Networks and the Role of Municipal Networks."
[142] Ibid.
[143] Berkman Center, "Next Generation Connectivity: A Review of Broadband Internet Transitions and Policy from Around the World," in *Competition and Access*, 2010, 175, https://cyber.harvard.edu/sites/cyber.law.harvard.edu/files/Berkman_Center_Broadband_Final_Report-C4_15Feb2010.pdf.
[144] Authority for Consumers & Markets, *Telecom Monitor for Q4 2014*, 2015, https://www.acm.nl/en/publications/publication/14306/Telecom-Monitor-for-Q4-2014/.

to roll out superfast broadband past 95 percent coverage. [145] An additional £150 million were originally available to 22 UK cities under the related SuperConnected Cities Program for ultrafast fixed and mobile broadband access, but was changed to a voucher and public Wi-Fi scheme following legal challenges.[146]

In Phase 1, municipalities solicited bids from suppliers to build and operate wholesale access networks. The total public subsidy of £1.2 billion came from national and local governments.[147] Incumbent BT, however, was the only bidder and obtained all the 43 contracts.[148] The Public Accounts Committee criticized the procurement process, stating that it "failed to ensure meaningful competition".[149] UK met the Phase 1 90 percent target on April 2016 but missed the original May 2015 target established by the Rural Broadband Program before it was turned into BDUK.[150]

A study commissioned by the BDUK reported that BT charged approximately 20 percent less than the estimated cost for "an alternative subscriber,"[151] possibly due to its greater economies of scale than smaller providers. However, BT provided 23 percent of the projected funding of £1.5 billion, or about £207 million less than the 36 percent BDUK had expected it to supply.[152]

A 2013 National Audit Office (NAO) expressed concern over the program's lack of competition and transparency, as well as an inability to track roll-out delays.[153] A Parliament Report later concluded that lack of transparency in BT's costs and deployment plans stifled competition and discouraged other network providers from investing.[154] The report also noted that BT connected easier-to-reach premises first, leaving a "patchwork" of unconnected premises. Additionally, many premises considered covered are unlikely to receive superfast speeds because of the poor quality or length of copper lines.[155]

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[145] DCMS, "2010 to 2015 Government Policy: Broadband Investment," 2015, https://www.gov.uk/government/publications/2010-to-2015-government-policy-broadband-investment/2010-to-2015-government-policy-broadband-investment.
[146] DCMS, "Ten Super-Connected Cities Announced," March 21, 2012, https://www.gov.uk/government/news/ten-super-connected-cities-announced; Juliette Garside, "George Osborne's High-Speed Broadband Plan Ends in Vouchers," *The Guardian*, 2013, https://www.theguardian.com/politics/2013/jun/25/george-osborne-broadband-legal-challenge.
[147] DCMS, "Government Major Projects Portfolio Data," September 2015.
[148] Ibid.
[149] Public Accounts Committee, "The Rural Broadband Programme. Conclusions and Recommendations," 2014, https://www.publications.parliament.uk/pa/cm201314/cmselect/cmpubacc/834/83403.htm.
[150] Daniel Rathbone, "Superfast Broadband Coverage in the UK" (House of Commons Library, 2016).
[151] National Audit Office, "The Superfast (Rural) Broadband Programme: Update" (Memorandum for the House of Commons Committee of Public Accounts, 2015), https://www.nao.org.uk/wp-content/uploads/2015/01/The-Superfast-Rural-Broadband-Programme-update.pdf.
[152] National Audit Office, "The Rural Broadband Programme" (Report by the Comptroller and Auditor General, 2013), https://www.nao.org.uk/wp-content/uploads/2013/07/10177-001-Rural-Broadband_HC-535.pdf.
[153] Ibid.
[154] UK Parliament, "BDUK Programme: Conclusions and Recommendations," 2016, https://www.publications.parliament.uk/pa/cm201617/cmselect/cmcumeds/147/14713.htm.
[155] Ibid.

BT was awarded contracts in Phase 2 of the program without an assessment of first phase contracts.[156] The company reported that it is unlikely to meet the target of delivering 24 Mbps coverage to 95 percent of premises by 2017.[157]

The Phase 3 pilot program to reach the final 5 percent began in March 2014 with seven bids for projects now being deployed. A Department for Culture Media & Sport (DCMS) report on the pilot finds that technology neutral projects can be cost-effective solutions for hard to reach areas.[158] Projects that delivered services through satellite and fixed wireless provided superfast speeds with positive consumer satisfaction ratings. Two small providers mixed fiber and fixed wireless technologies and achieved near full coverage in hard to reach areas with subsidies of £800 and £1,220 per premise passed.[159] DCMS concluded that the pilots demonstrate that smaller suppliers could deliver broadband via procurement projects with local authority guidance on planning requirements.[160]

Overall, the BDUK's public investment model seemed to decrease provider competition, as the majority of funds were awarded to a single, well established company.[161] As a result, the UK seems likely to change its regulatory and subsidy strategy. Parliament, in agreement with Ofcom, stated that "the future must be about infrastructure competition as well as service competition"[162] and in May 2016 the government announced its intention to legislate for a broadband Universal Service Obligation.

Vouchers

The UK has also experience with various voucher schemes. The £40 million Broadband Connection Voucher Scheme, supervised by the DCMS, operated from December 2013 to October 2015. The vouchers were available to small and medium businesses as subsidies to superfast (30Mbps+) broadband subscriptions through up to £3,000 in vouchers.[163] Vouchers were redeemed through 770 suppliers, with the three largest – BT, Virgin Media and TalkTalk – receiving 14 percent of the value of the vouchers and the rest going to smaller regional and local suppliers.[164]

The Better Broadband Subsidy Scheme was launched at the end of 2015 to run until December 2017. The scheme provides up to £350 to eligible businesses to subsidize the cost of installing

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[156] House of Commons, "Rural Broadband and Digital-Only Services. Seventh Report of Session 2014-15" (London, 2015), https://www.publications.parliament.uk/pa/cm201415/cmselect/cmenvfru/834/834.pdf.
[157] Ibid.
[158] DCMS, "Emerging Findings from the BDUK Market Test Pilots," 2016, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/497369/BDUK_Market_Test_Pilots_-_Emerging_Findings_Feb_2016.pdf.
[159] Ibid.
[160] Ibid.
[161] Oxera, "The UK's National Broadband Scheme—an Independent Ex Post Evaluation of the UK's Broadband State Aid Measure," March 27, 2015.
[162] UK Parliament, "BDUK Programme: Conclusions and Recommendations."
[163] DCMS, "Connection Vouchers," http://www.connectionvouchers.co.uk/.
[164] Ibid.

"affordable" broadband.[165] Businesses that do not receive the Universal Service Commitment's (USC) minimum required download speed of 2Mbps and do not benefit from the BDUK rollout are eligible.[166] Originally designed to subsidize satellite services, it was expanded to include fixed wireless providers and other ISPs, including BT's Openreach.[167]

Wales has two voucher schemes. The Access Broadband Cymru (ABC) launched in October 2013 originally provided £1,000 grants to homes and businesses with less than 2Mbps speeds to upgrade through any technology. The Ultrafast Connectivity Voucher (UCV) started on July 2014 provided up to £10,000 to businesses in Enterprise and Local Growth Zones to cover installation costs of 100Mbps broadband.[168]

At the beginning of 2016 both programs were expanded and extended two years. The ABC scheme is now available to all homes and businesses without a 30 Mbps+ connection and all businesses can now apply to UCV's.[169] Since it was expanded, ABC received 722 applications, granted 128 vouchers, and offered funding for 302 premises whose owners did not contract a service. Under UCV, 50 applications were received, 8 approved and 12 did not contract.[170]

Sweden

Sweden's approach to subsidies is unique. The state subsidizes dark fiber to within a few kilometers of every home, but residents pay 50 percent of the last mile connection.[171]

In 2000, Sweden adopted a broadband policy that targeted providing 100 Mbps connections to 90 percent of households and businesses by 2020. The program allocated €600 million for an open access national backbone through the Swedish National Grid operator, €700 million in

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165 "Better Broadband Subsidy Scheme," *GOV.UK*, December 6, 2016, https://www.gov.uk/better-broadband-subsidy-scheme#what-you-need-to-know."Better Broadband Subsidy Scheme," December 6, 2016, https://www.gov.uk/better-broadband-subsidy-scheme#what-you-need-to-know.

166 Ibid. It is unclear from the website exactly who is eligible. The page cited here says it is available to businesses, but pages providing additional detail say that households are also eligible (https://basicbroadbandchecker.culture.gov.uk/faqs-better-broadband-subsidy-scheme.pdf).

167 Mark Jackson, "UPD BT Make Use of 2Mb USC Subsidy to Rollout Rural FTTC Broadband," *ISPreview UK*, November 7, 2016, http://www.ispreview.co.uk/index.php/2016/11/bt-make-use-2mbps-usc-subsidy-rollout-rural-fttc-broadband.html.

168 Ofcom, "Connected Nations 2016 - Wales," December 16, 2016, https://www.ofcom.org.uk/__data/assets/pdf_file/0032/95882/CN16-Wales.pdf.

169 There are two tier vouchers one for £400 for10 Mbps and 20 Mbps packages and another for £800 for 30Mps+ packages. Llywodraeth Cymru Welsh Government, "Access Broadband Cymru Eligiblity Criteria & Scheme Conditions," 2016, https://beta.gov.wales/sites/default/files/2016-10/160104-abc-eligibility-en.pdf.

170 Mark Jackson, "Changes Coming for Struggling Broadband Voucher Schemes in Wales," *ISPreview UK*, January 30, 2017, http://www.ispreview.co.uk/index.php/2017/01/changes-coming-struggling-broadband-voucher-schemes-wales.html.

171 Residents pay 100% of the cost directly and are reimbursed via a tax rebate. Fiber to the Home Council of Europe and Nadia Babaali, "Sweden: A Showcase for Rural FTTH" (Brussels, June 26, 2013), http://www.ftthcouncil.eu/documents/Opinions/2013/Rural_FTTH_Nordics_Final.pdf.

grants for municipal wholesale networks, and €290 million in tax relief to homes and businesses.[172]

About 180 municipal networks, covering over 200 of Sweden's 290 municipalities, have deployed fiber networks through public-private partnerships, making up 58 percent of fiber networks.[173] Municipalities had to provide at least 10 percent of the cost of building the network with government support limited to a one-time subsidy for 5-year contracts.[174]

Stokab is an early dark-fiber project funded by the city of Stockholm, in 1994. The city invested $100 million a dark fiber network and leased capacity to ISPs. One key to Stokab's ability to increase connections was that 90 percent of households were in multi-family units which are less expensive to connect than stand-alone houses. Stokab generated positive cash flows since it began operation and started generating profit in 2008.[175] Additionally, more than 90 service providers offer services on its network. Forzati and Mattsson (2013) estimate Stokab's socio-economic return to be $2.5 billion.[176] By 2013, about 90 percent of 1.1 million households in Stockholm subscribed to FTTH.[177]

Sweden's FTTH take-up rate of 44% by September 2015 is higher than the 27 percent average for the EU, and indicates that demand is equally important to achieving policy goals. Sweden achieved significant fiber penetration through government investment but it took longer to achieve NGA coverage.[178] By 2015 Sweden's NGA coverage was 76 percent but still lags in rural NGA at 14 percent, below the EU average of 28 percent.[179]

Denmark

Denmark's model differs from other European countries in that it does not define which broadband technology citizens should have and uses few public subsidies.[180] The ownership structure of its broadband providers is also unusual. The regulator mandates wholesale access to

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[172] Marco Forzati and Crister Mattson, "Sweden," in *The Dynamics of Broadband Markets in Europe*, ed. Wolter Lemstra and William Melody, 1st ed. (Cambridge University Press, 2014). Robert Atkinson, Daniel Correa, and Julie Hedlund, *Explaining International Broadband Leadership* (Information Technology and Innovation Foundation, 2008), Appendix G: Sweden, http://www.itif.org/files/ExplainingBBLeadership.pdf.
[173] OECD, "Development of High Speed Networks and the Role of Municipal Networks," 50.
[174] Atkinson, Correa, and Hedlund, *Explaining International Broadband Leadership*.
[175] Benoît Felten, "Stockholm's Stokab: A Blueprint for Ubiquitous Fiber Connectivity?," July 2012, https://www.stokab.se/Documents/Stockholms%20Stokab%20-%20A%20Blueprint%20for%20Ubiquitous%20Fiber%20Connectivity%20FINAL%20VERSION.pdf.
[176] Under the implicit assumption that without Stokab nothing would have been built, which is, of course, untrue. Forzati and Mattson, "Sweden."
[177] FTTH Council, "AB Stokab: Stockholm Makes Hi-Tech Economy and Society a Reality," May 2013, http://www.ftthcouncil.eu/documents/CaseStudies/STOKAB.pdf.
[178] Yoo, "U.S. vs. European Broadband Deployment: What Do the Data Say?, 26"
[179] European Commission, "Broadband Coverage in Europe 2015," 2016, https://ec.europa.eu/digital-single-market/en/news/broadband-coverage-europe-2015.
[180] Roslyn Layton, "The European Union's Broadband Challenge" (Washington, D.C.: AEI, 2014), https://www.aei.org/publication/the-european-unions-broadband-challenge/.

fiber, but that option remains unused because the incumbent TDC (formerly Tele Denmark Communications) owns most of the cable companies and new entrants, comprised primarily of energy companies, invest in ultrafast fiber infrastructure themselves without investment overlap.[181] As a result, competition between cable and telecom high-speed broadband operators happens entirely outside of the regulatory framework, making Denmark like the US facilities-based model.[182]

Aside from some early support for cable and some minor initiatives in municipal broadband, Denmark has largely avoided public subsidies from the federal government. The OECD estimates that in 2014 regional utilities –owned by cooperatives, not municipalities– contributed about one fourth of broadband investments and approximately almost as many broadband subscriptions.[183]

In 2003, four small municipalities (later established as Vejen municipality) wanted to connect their city halls through fiber and decided to build their own network after receiving a quote from incumbent TDC they considered too high.[184] They partnered with regional utilities SE (previously co-operative SydEnergi) and TRE-FOR who had expanded into broadband after the liberalization of the electricity market.[185] By 2007, Vejen achieved 80 percent household coverage and connected all public institutions at 1Gbps speeds.[186] The total investment was €83.6 million, of which only €2 million was public investment.[187]

Despite its high coverage numbers, Denmark has low ultra-fast household take-up. By 2014, 70 percent of households had access to 100 Mbps broadband but only 1.85% subscribed to it.[188] This low take up is probably not attributed to cost as 90-100 Mbps connections range between $44-55. One potential explanation is that consumers complement data usage with LTE connections that can achieve average speeds of 30 Mbps.[189] To increase adoption, Denmark included broadband services as part of a Kr 12,000 ($765) maximum tax deduction for households.[190]

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181 Yoo, "U.S. vs. European Broadband Deployment: What Do the Data Say?"
182 Wolfgang Briglauer, Carlo Cambini, and Michal Grajek, "Why Is Europe Lagging on Next Generation Access Networks?" (Brussels: Bruegel, 2015), http://bruegel.org/wp-content/uploads/2015/10/pc_2015_14.pdf.
183 OECD estimate based on Danish Business Authority, telestatistics, first half year 2014. TDC, Telenor, TeliaSonera and Dansk Kabel-TV have 71% of the fixed broadband subscribers. OECD, "Development of High Speed Networks and the Role of Municipal Networks," 33.
184 EU Regional Policy, "Guide to Broadband Investment," Smart Specialization Platform, September 2011, http://www.umic.pt/images/stories/publicacoes5/broadband2011_en.pdf."
185 OECD, "Development of High Speed Networks and the Role of Municipal Networks."
186 Of approximately 8,500 households. OECD, "Development of High Speed Networks and the Role of Municipal Networks," 32.
187 EU Regional Policy, "Guide to Broadband Investment."
188 Knud Erik Skouby et al., "Need for Broadband Infrastructure in a 2020 Perspective," *Wireless Personal Communications* 76, no. 2 (May 2014): 271–89, doi:10.1007/s11277-014-1688-0.
189 OpenSignal, "State of Mobile Networks: Nordics," May 2016, https://opensignal.com/reports/2016/05/nordic/state-of-the-mobile-network/.
190 "Country Information - Denmark," *Digital Single Market*, 2017, https://ec.europa.eu/digital-single-market/en/country-information-denmark.

Furthermore, in 2016 it also set up a broadband fund of Kr 200 million (about $30 million) over four years to promote rural coverage of broadband financed with revenue from spectrum auctions.[191] The fund is supposed to operate for two years and then be evaluated.

How to Structure a Broadband Subsidy Program

It is possible to draw some broad conclusions from the above discussion of broadband subsidy programs. First, true evaluations of these programs are rare, at best. This nearly universal lack of interest in evaluation is consistent with using the subsidies to help achieve political goals rather than correcting market failures. While political goals are related to equity or societal objectives, one would hope that politicians interested in societal objectives would want to know whether these projects achieved those goals.

Second, nearly all programs focus on supply, while ignoring demand. In particular, most programs target some quality level of broadband service without regard to how those features compare to what consumers can truly use. This lack of focus on demand matters because higher quality comes at a higher cost, suggesting that some of the spending is inefficient. An exception is the UK's voucher schemes, which, notably, allowed eligible consumers to use their vouchers on satellite service.

Third, no rural subsidy program appears to have been especially successful, although it is difficult to know without evaluations, as discussed above. To the extent we can gauge cost-effectiveness, only reverse auctions have demonstrated an ability to deliver.

These observations suggest three important broad components of any new broadband infrastructure subsidy program. First, given the lack of effectiveness of our existing programs and the large amounts of money already going to them, any additional spending should be a one-time event to avoid creating a constituency advocating for another program to continue in perpetuity.

Second, it should define its objectives clearly. Ideally, the objective should be to make broadband service of some minimum quality available to as many households and businesses that currently cannot access it, maximizing the additional connectivity per subsidy dollar spent. Third, and relatedly, it should facilitate evaluation in a way that measures success towards the defined objective and provides lessons for the future. The metrics should be defined so that they measure returns to the subsidy, not simply changes over time. For example, an increase in the number of subscriptions or homes passed over the relevant time period is less likely to be a result of the subsidies if those increases simply continue an existing trend than if the trend changes after the subsidy or if the increases are larger in areas that received subsidies than in areas that did not.

[191] Idongesit Williams et al., "New Investment Models for Broadband in Denmark and Sweden," *Nordic and Baltic Journal of Information and Communications Technologies* 2016, no. 1 (2016): 1–18, doi:10.13052/nbict.2016.001.

Once Congress puts in place these broad goals, the next issue is how to distribute the subsidies. Telecommunications subsidies have traditionally been distributed in two ways. The first is via cost models. Cost models are notoriously inaccurate and generate perverse incentives, such as encouraging companies to remain inefficient so as to maintain a high level of subsidies. The second is through an application process, which requires firms to submit and government to review lengthy applications, as in BTOP. But this application process makes it difficult to compare projects and, as with cost models, creates incentives for providers to overestimate the minimum subsidy required due to their having more information about their costs than the regulator.

Auctions for subsidies solve these problems. While auctions are not simple, they make it possible to distribute funds for the most cost-effective projects at low cost to the government.

Subsidy Auctions

Most understand the word "auction" to mean a crowd of people bidding up the price of a good or service, such as on eBay or at a Christie's art auction. Those involved in telecommunications are also familiar with spectrum auctions, in which companies bid for wireless licenses. However, auctions also can be designed to lead to lower bids. Governments and companies put out requests for proposals for any number of projects, and bidders compete along a number of dimensions, including price. Auctions in which the price goes down are called "reverse auctions." In the case of subsidies, providers compete against each other in terms of how much money they request to complete a given project.

Reverse auctions for universal service subsidies have been used successfully around the world for many years.[192] A group of 71 "concerned economists" argued for the use of reverse auctions in the BTOP program on the grounds that they would "relieve the government of the task of identifying the 'best' projects," "use competition among providers [rather than government analysis] to determine the subsidy required to achieve any particular goal," and "inherently induce firms to contribute their own investment to increase the chance that their bid is accepted."[193] Unfortunately, as discussed above, BTOP chose not to use that approach.

Although BTOP did not distribute subsidies using reverse auctions, just a few years later the FCC was eventually able to use an auction mechanism to distribute universal service funds.

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[192] Scott Wallsten, "Reverse Auctions and Universal Telecommunications Service: Lessons from Global Experience" (Technology Policy Institute, 2008), https://techpolicyinstitute.org/wp-content/uploads/2008/05/reverse-auctions-and-universal-2007167.pdf; Irene Wu, "Maximum Impact for Minimum Subsidy: Reverse Auctions for Universal Access in Chile and India" (Federal Communications Commission, 2010), https://apps.fcc.gov/edocs_public/attachmatch/DOC-302511A1.pdf.
[193] Paul Milgrom et al., "Comments of 71 Concerned Economists: Using Procurement Auctions to Allocate Broadband Stimulus Grants," 2009, http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1377523.

Particularly, as described above, the Mobility Fund Phase I used a reverse auction to distribute subsidies in a cost-effective fashion.[194]

The Mobility Fund Phase I auction demonstrated that it is possible to auction subsidies. As discussed earlier, however, much of the funding ended up in places that probably would not have been eligible if the geographic areas had been defined differently, highlighting the importance of the auction details. For an auction to succeed, certain factors must be carefully defined. In particular, the auction must define the geographic areas up for bid, the minimum quality services eligible to receive subsidies, and whether to weigh certain parts of a bid, say, bandwidth or latency, more heavily than other parts.

The Connect America Fund Phase II Auction offers a model for how to develop and structure such an auction, as its objectives and approach are broadly similar to the goal of a broadband subsidy included as part of an infrastructure package.[195]

Define Eligible Geographic Areas

Targeting areas that do not have a particular level of service inherently means finding ways to define relevant geographic areas. Identifying these areas has two challenges: finding areas that do not have the desired service quality and defining geographic boundaries that make bidding possible.

Identifying areas without the desired service quality turns out to be fairly difficult. BTOP included about $300 million to develop broadband maps showing the extent of coverage across the country. The map have been useful for evaluating the evolution of broadband overall, but because of the way the data are collected they have been less useful at identifying populated areas without terrestrial coverage.

The CAF Phase II Auction determined that geographic areas eligible to be included were "high-cost census blocks located in price cap carrier territories that, based on June 30, 2015 Form 477 data, are not served by the incumbent price cap carrier or an unsubsidized competitor with voice and broadband at speeds of 10/1 Mbps or higher."[196] Providers would then be able to bid on Census tracts or block groups. Providers were allowed to challenge the resulting list of unserved areas if they could demonstrate that they provided service in those areas. Eligible areas are shown on the FCC's website.[197] The challenge process was to help ensure that funding did not inadvertently subsidize service in areas already served.

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[194] The FCC was able to further refine its skills in running a reverse auction in the Broadcast Incentive Auction. That auction involved broadcasters engaging in a reverse auction for how much they would need to be compensated to go off the air and then a forward auction in which wireless providers bid for the newly-cleared spectrum.

[195] Federal Communications Commission, "In the Matter of Connect America Fund ETC Annual Reports and Certifications Rural Broadband Experiments," May 26, 2016, http://transition.fcc.gov/Daily_Releases/Daily_Business/2016/db0613/FCC-16-64A1.pdf; Federal Communications Commission, "In the Matter of Connect America Fund ETC Annual Reports and Certifications."

[196] https://www.fcc.gov/reports-research/maps/caf-2-auction-preliminary-areas/

[197] https://www.fcc.gov/reports-research/maps/caf-2-accepted-map/

An advantage of the process the FCC used is that it uses existing data and an incentive for providers to check whether they offer service in areas to identify unserved areas. The alternative would be another expensive map that would still face the problem of proving the negative (i.e., that no service exists in certain places).

It is also necessary to define the geographic areas since it is not feasible to auction subsidies for each unconnected household separately. If an area must be unserved to be included in the auction, however, the larger the defined area the more likely it will be considered "served" even if it has some households without availability. For the CAF Phase II Auction the Commission decided to use Census Blocks, which matches the geographic areas at which it collects data.

Define Minimum Desired Broadband Quality, Not Technology

"Broadband service" has no single definition. It can vary by speed, latency, bandwidth caps, and other reliability measures. If the government is going to subsidize it, we need to define what "it" is. Ideally, the minimum quality that would be eligible would be based on demand—how much are people willing to pay for different levels of quality. For example, setting a minimum speed of 50 Mbps would be wasteful if consumers tend not to place much value on the increment between 25 and 50 Mbps and it is more costly to build to the higher standard.

The CAF Phase II Auction set the minimum service eligible for subsidies at 10 Mbps downstream, 1 Mbps upstream, and a data cap of 150 GB per month.[198] One key point is that the auction defines a desired service, not a desired technology. Consumers value aspects of their service, not the type of wire or spectrum band it comes in.

The CAF auction, however, somewhat negated its technological neutrality by weighting bids based on a nonlinear combination of the subsidy requested, speed tier, and latency. In particular, it will use the following formula to determine each bid's score:

$$score = 100\frac{subsidy\ requested}{reserve\ price} + performance\ weight + latency\ weight$$ [199]

The lower the score, the more competitive the bid. Table 1 shows the performance weights the FCC will apply to the bids. While the Commission did not base the weights on any particular empirical analysis, the performance weights are consistent with the general finding that consumers see diminishing marginal returns to increased speeds.[200]

[198] Federal Communications Commission, "In the Matter of Connect America Fund ETC Annual Reports and Certifications," para. 10.
[199] Ibid., para. 15.
[200] Gregory Rosston, Scott Savage, and Donald Waldman, "Household Demand for Broadband Internet Service," *The B.E. Journal of Economic Analysis and Policy* 10, no. 1 (September 9, 2010).

Table 1: Phase II Auction Performance Weights[201]

Performance Tier	Speed	Usage Allowance	Weight
Minimum	≥10/1 Mbps	≥ 150 GB	65
Baseline	≥25/3 Mbps	≥ 150 GB or U.S. median, whichever is higher	45
Above Baseline	≥100/20 Mbps	2 TB	15
Gigabit	≥ 1 Gbps/500 Mbps	2 TB	0

The latency penalty, shown in Table 2, however, reveals a technology preference. The 25 points for latency over 750 ms applies only to satellite service.

Table 2: Phase II Auction Latency Weights[202]

Latency	Requirement	Weight
Low	≤ 100 ms	0
High	≤ 750 ms & "mean opinion score" of ≥ 4	25

Latency can affect the performance of certain applications, like telephony and gaming. Yet, the penalty implies that the FCC believes consumers value the difference in latency between terrestrial and satellite service at somewhat more than they value the difference between 10 Mbps download / 1 Mbps upload and 25 Mbps down / 3 Mbps up. In other words, the FCC believes consumers would be indifferent between a terrestrial connection that offers less than 10/1 and a satellite connection that offers 25/3. This equivalence is not inconceivable, of course, but it is in place despite any lack of research on how much consumers actually value lower latency.

The penalty undercuts the natural cost advantage held by satellite and, therefore, will reduce the cost-effectiveness of the program. A broadband subsidy auction created as part of an infrastructure program should bring some analysis to bear on the question of latency to determine how much it should weigh relative to other factors, including cost. It is conceivable that this penalty will make the outcome less cost-effective than it would be without any offsetting benefit in consumer well-being.

Define How to Select Winning Bids

The extent to which subsidies are distributed in a cost-effective way depends, in large part, on how the bids are ranked and funded. Ideally, bids would be ranked according to the ratio of $\frac{number\ of\ new\ locations\ served}{subsidy\ \$}$, where a location is a home, business, or other institution rather than

[201] Federal Communications Commission, "In the Matter of Connect America Fund ETC Annual Reports and Certifications," para. 17.
[202] Ibid.

amount of land covered and funded from most cost-effective to least cost-effective until the budget is exhausted.

As discussed above, the Mobility Fund Phase I auction distributed subsidies using a version of this approach, ranking bids by number of road miles covered per subsidy dollar. Other ways of evaluating bid cost-effectiveness might have involved using traffic data—if it existed—to determine how many people were likely to benefit from the new service.

The CAF Auction undoes some of the benefits of the auction in its selection and ranking mechanism. Most importantly, it normalizes the bids by the reserve price and then ranks them, after applying the weights, although the CAF auction scores based on geographic area covered rather than number of new physical locations with access. The reserve price will be determined by a cost model. Any biases or inaccuracies in the cost model's inputs will filter through to the final result. Arguably a better ratio would be, as mentioned above, the subsidy requested per new locations served.

The FCC notes, however, that it made this choice for political reasons:

> While one of our objectives is to maximize the number of locations that are served with our finite budget and ranking bids based on the dollar per location would achieve that goal, we have also made clear that we are focused on adopting an auction design that balances this objective with other goals, including efficiently and effectively allocating support among the states.[203]

While an infrastructure bill is likely to face similar political pressures to sprinkle money around the country, it should still attempt to build in cost-effectiveness to the greatest extent possible.

Evaluation

Evaluating subsidy (or any) programs is important not just to learn whether public funds were well-spent, but also to learn what worked and what did not in order to apply those lessons in the future. A proper evaluation requires considering the question at the beginning of designing the program.

BTOP provides a cautionary tale of how not to evaluate a program. Its primary flaw was directing the agency in charge of designing and handing out the subsidies to conduct the evaluation. In other words, it was asked to evaluate itself—an inherent conflict of interest. The agency hired a contractor, which prepared a report to the exact specifications provided, including case studies only of approved projects already determined to have been successful.[204] The amount of money that went to a single contractor—$5 million—could have supported a large

[203] Federal Communications Commission, "In the Matter of Connect America Fund Universal Service Reform – Mobility Fund," para. 62.
[204] Scott Wallsten, "New Study of Broadband Stimulus Is Not so Independent," *The Hill*, January 23, 2015, http://thehill.com/blogs/pundits-blog/technology/230483-new-study-of-broadband-stimulus-program-is-not-so-independent.

number of academic projects by scholars and students alike, yielding a host of research approaches and conclusions. Alternatively, the Government Accountability Office could have conducted a thorough, rigorous analysis.

A Simple Outline for a Reverse Auction for Infrastructure Subsidies

Our long experience with telecom subsidy programs and more recent experiences with reverse auctions suggests a productive way to design a program to subsidize broadband infrastructure.

- Set a single, clear objective: bring broadband service to populated areas that do not have it.
- Define "broadband" by taking into account research on consumer demand characteristics. This definition should be use-centric, not technology-centric. Consumers care about what they can do with a broadband connection, not the technology used to deliver it. Thus, no particular technology—cable, fiber, DSL, terrestrial wireless, or satellite—should be considered inherently superior to another. Any technology should be eligible to participate in the auction.
- Make the program a one-time subsidy. Many programs already exist that provide ongoing subsidies. If bidders believe they will require ongoing support their bid will reflect that belief. That is, the bid will be the net present value of the total subsidy the provider believes it will need over the course of the project. To the extent a bidder believes it will need ongoing support it will include that amount in the single bid it makes. It is likely, however, that such projects will turn out to be less cost-effective than others.
- Rank-order the bids in terms of cost-effectiveness in terms of new locations, not area, connected per subsidy dollar. Fund the most cost-effective project first, the next most cost-effective second, and so on until the budget is exhausted.
- Rigorously evaluate the results, but ensure that the evaluation is conducted by organizations other than the one implementing the program.

A relevant question is which agency in the government should be responsible for implementing the program. On the one hand, it seems sensible to want an agency without a built-in subsidy constituency to implement the program to help ensure an objective approach. On the other hand, it is also sensible to want an agency in charge with some experience running the necessary mechanisms. The BTOP program chose the former approach, but NTIA's lack of experience arguably led to a largely incoherent grant review process. The FCC, meanwhile, has more experience running auctions than perhaps any other government agency in the world. As long as additional subsidy spending does not become part of the existing universal service program it makes sense for the FCC to manage the program.

Conclusion

The U.S. already spends well over $5 billion subsidizing broadband in rural areas, with little evidence that it has been helpful. The FCC, meanwhile, is poised to auction off an additional $2 billion in subsidies in the next year. It is therefore difficult to argue that we should allocate even more money to these subsidies. Nevertheless, if Congress does choose to include broadband in a larger infrastructure package it should maximize cost-effectiveness by following certain guidelines described above.

In particular, it should use a reverse auction approach similar to that proposed in 2008 by the “71 Concerned Economists” or the FCC is planning for the Connect America Fund Phase II Auction, with some exceptions. First, it should define broadband and the way it ranks bids by taking into account what consumers value in broadband connections. Any technology that meets those definitions should be eligible to participate. Second, it should maximize cost-effectiveness by evaluating based on cost per newly connected household or business, not area. Finally, it should facilitate evaluation by a third party, such as the Government Accountability Office or academic researchers.

Following these guidelines will help create a cost-effective program that might actually increase availability and adoption in rural areas, rather than a continuous stream of subsidies that have little benefit to the households who need them.