Economic Benefits of Fiber Deployment

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Executive Summary

Currently, about 62 million Broadband Serviceable Locations (BSLs), which include at least 56 million households – *i.e.,* over half the BSLs and forty percent of the households in the United States, do not have fiber broadband. There is an ongoing debate about the existence and magnitude of economic benefits that would be realized if fiber was deployed to locations that are already served by high-speed broadband, but do not have fiber broadband.

Our study is the first to show that fiber deployment has significant incremental economic benefits even in the presence of other high-speed broadband technologies. The report also argues that because private actors will not capture all the benefits of fiber deployment the marketplace will not deploy enough fiber on its own. Based on these findings we suggest a few policy takeaways.

- First, because the social return on investment is higher for fiber, directing more of the existing public funds towards fiber deployment will generate greater economic returns compared to investment in other high-speed broadband technologies such as hybrid fiber-coaxial (HFC). Thus, the various public programs, such as the Rural Digital Opportunity Fund (RDOF), the Broadband Equity, Access, and Deployment (BEAD) program, ReConnect, Capital Projects Fund and the federal Broadband Infrastructure Program (BIP), which are prioritizing fiber builds are on the right policy path. This prioritization needs to continue if the gains from deploying fiber are to be realized.

- Second, based on available data, our research implies that even if fiber is deployed as an overbuild to existing high-speed technologies, the incremental benefits are sizeable. Thus, when the federal or local governments are measuring the underserved population, one important metric may be using a fiber-unserved metric and not just a speed-based metric. This will allow these entities to better target funding towards a fiber solution.

- Third, federal and local governments that promote fiber deployment, such as BIP, Louisiana's Granting Unserved Municipalities Broadband Opportunities (GUMBO) program and Maine's ConnectMaine fund, should be encouraged and expanded. Additionally, the focus on fiber that some of these programs have, should be supported, and used as a model for other private-public initiatives.

- Last, fiber is a future-proof solution and when the benefits and costs are evaluated on a long-run horizon, fiber becomes the optimal choice for delivering fixed high-speed broadband.

- We find that deploying fiber to the 56 million households that are in tracts unserved by fiber, has the potential to generate at least **$3.24 trillion** in terms of net present value (NPV) in incremental economic impact.

- Deploying fiber has the potential to increase **housing values** by **$1.64 trillion** (in NPV terms).

    - It could **increase average household values** between **14% - 17%** depending on non-urban versus urban areas.
    - This translates to an average increase of **$27,000 - $41,000 per house** per year.
    - The effect on housing values in non-urban areas is fives times greater than in urban areas and is driven by the greater number of unserved households in non-urban areas.
    - For the 56 million unserved households, in net present value (NPV) terms, this implies a **$1.4 trillion** total increase in house values for **non-urban areas** and **$242 billion** total increase for **urban** areas.

- Deploying fiber to all fiber-unserved locations can potentially lead to a one-time increase in **income by $1.6 trillion** (in NPV terms).

    - The income effect comes from non-urban areas. U.S. households in **non-urban areas** with new access to fiber will likely experience an **increase in their average income** by **$1,450** in one year.

    - This translates to a total increase of **$81 billion in one year**.

- Fiber deployment also has the potential to create **at least 380,000 new jobs** for the U.S. economy.

- Fiber deployment also has a significant impact on remote work, environmental benefits, and is best equipped to handle the increased connectivity needs in a 5G world and beyond. In addition, it improves educational outcomes, reduces health costs (thereby increasing health savings), and accelerates technology adoption.

- Additionally, a significant advantage of fiber is that it is a future-proof technology due to its ability to provide the critical broadband infrastructure required to deliver high speeds, scalability, reliability, and support for emerging applications and technologies. An optimal lower cost data network today will likely not meet the needs of tomorrow. Consequently, the least costly way of providing a given level of service today may create greater upgrade costs in the future. Fiber has the potential to handle all future capacity needs. Even if it is not the least-costly solution today, the government should target more current funding towards fiber deployment, with an eye towards the future.

I. Introduction

Investing in fiber is not just a technological upgrade; it is a strategic move that underpins long-term productivity and economic growth in the United States. The importance of high-quality broadband is beyond doubt, and the highest quality broadband is delivered over fiber optic cables. With the demand for high-definition content, low latency applications such as video conferencing, remote surgeries, industrial automation and millions of gigabytes of data being transferred, having a fast and reliable internet connection is essential for businesses and consumers.[1] As we build out our nation's critical broadband infrastructure, fiber is absolutely necessary to deliver the future-proof speed, capacity, and ultra-low latency that will enable future innovations. When data does not make its way to an end user (referred to as last mile) over a fiber optic cable, one of four technologies are typically used: cable (typically hybrid fiber-coaxial), copper (typically a digital subscriber line (DSL) connection, delivered over a twisted-pair telephone line), a terrestrial wireless link (fixed or mobile), or satellite (Low Earth Orbit (LEO) such as Starlink or geo-stationary orbit, such as Hughes or Viasat). All these technologies have advantages in certain circumstances, but network upgrades all point in the direction of pushing fiber further out into the network, which offers a range of technological, economic, and societal benefits, making it a strategic investment for improving overall connectivity and internet services.

So far, the speed of the transition to fiber-based network connections in the U.S. has been slower than is ideal. The United States lags many other developed nations in fiber penetration. Countries such as South Korea, Singapore, and China exhibit significantly higher overall fiber performance compared to the U.S.[2]

We find that private actors will not deploy fiber as fast as is socially optimal, because their investment decisions are based on their private profitability and do not consider social benefits, *i.e.*, the positive externalities or spillovers that they cannot capture in their profits.[3] For example,

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1 Neos Networks, "What is Low Latency and Why is it Needed?" January 24, 2024, https://neosnetworks.com/resources/blog/what-is-low-latency-why-is-it-needed/.

2 Ofcom, "International Broadband Scorecard 2023: Interactive Data – 1 – Fixed Broadband Coverage," last accessed August 5, 2024, https://www.ofcom.org.uk/research-and-data/telecoms-research/broadband-research/eu-bbroadand-scorecard/international-broadband-scorecard-2023-interactive-data.

3 Thomas Helbling, "Externalities: Prices Do Not Capture All Costs," International Monetary Fund, https://www.imf.org/en/Publications/fandd/issues/Series/Back-to-Basics/Externalities, last accessed August 5, 2024, ("Externalities: Prices Do Not Capture All Costs"). Note, Arthur Pigou's seminal work in *The Economics of*

Continued on next page

in the wake of the Covid-19 pandemic, the positive side effects stemming from swift and dependable internet service have been driven by its capacity to mitigate the adverse effects of pandemic.[4] It is important to note that this represents only a fraction of the overall societal advantages derived from voice and broadband connectivity. Additional instances include the expansion of telemedicine,[5] enhanced equity in accessing education,[6] and an elevated standard of education.[7]

The remedy for this situation is well-established, and economic policy interventions are called for when a market will not provide the efficient level of a good or service. In the U.S., the government has partially recognized this and stepped in to provide added support for fiber deployment through its American Rescue Plan Act (ARPA), U.S. Department of Agriculture (USDA) Rural Utility Service (RUS) ReConnect Program, U.S. Department of Treasury Capital Projects Fund (CPF), NTIA's Broadband Infrastructure Program (BIP), Federal Communications Commission (FCC) Rural Digital Opportunity Fund (RDOF) and the NTIA Broadband Equity, Access, and Deployment

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Welfare defines market failures and externalities, and he argues that governments should subsidize those who create positive externalities. *See*, Arthur Pigou, *The Economics of Welfare,* 1932, https://oll.libertyfund.org/titles/pigou-the-economics-of-welfare.

4 Canan Birimoglu Okuyan and Mehmet A. Begen, "Working from Home During the COVID-19 Pandemic, Its Effects on Health, and Recommendations: The Pandemic and Beyond," Perspectives in Psychiatric Care, 58(1) (2022): 173-179, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8242705/ ("Working from Home During the COVID-19 Pandemic").

5 Yosselin Turcios, "Digital Access: A Super Determinant of Health," Substance Abuse and Mental Health Services Administration, March 22, 2023, https://www.samhsa.gov/blog/digital-access-super-determinant-health; Ambrish A. Pandit, et al., "Association Between Broadband Capacity and Telehealth Utilization Among Medicare Fee-for-Service Beneficiaries During the COVID-19 Pandemic," Journal of Telemedicine and Telecare, (2023): 1-8, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10076155/; Adie Tomer, et al., "Digital Prosperity: How Broadband Can Deliver Health and Equity to All Communities," The Brookings Institution, February 27, 2020, https://www.brookings.edu/articles/digital-prosperity-how-broadband-can-deliver-health-and-equity-to-all-communities/.

6 Thomas McElroy, "Addressing The Digital Divide an Education: Technology and Internet Access for Students in Underserved Communities," Forbes, December 3, 2021, https://www.forbes.com/sites/forbestechcouncil/2021/12/03/addressing-the-digital-divide-in-education-technology-and-internet-access-for-students-in-underserved-communities/?sh=355949d25cec; Adie Tomer, et al., "Digital Prosperity: How Broadband can Deliver Health and Equity to All Communities," The Brookings Institution, February 27, 2020, https://www.brookings.edu/articles/digital-prosperity-how-broadband-can-deliver-health-and-equity-to-all-communities/.

7 Internet Society, "Internet Access and Education: Key Considerations for Policy Makers," November 20, 2017, last accessed March 11, 2024, https://www.internetsociety.org/resources/doc/2017/internet-access-and-education/; North Carolina Department of Information Technology, "Why Broadband is Important," last accessed August 5, 2024, https://www.ncbroadband.gov/digital-divide/why-broadband-important.

(BEAD) Program.[8] However, as we explain later in the report, there is a mismatch in where the funding is targeted and where it should be targeted. If policy makers appropriately assess economic spillovers from fiber investment relative to other broadband technologies, current funding efforts would be geared towards increased fiber deployment.

In this report we will discuss the market failure that leads to sub-optimal investment in fiber deployment and estimate the positive externalities generated by fiber deployment. In Section II, we discuss the status of fiber deployment in the U.S., including the evolution over the past few years, and benchmark the U.S. performance against other countries. In Section III, we briefly discuss the Economics literature on externalities and investment and show why there is a market failure in the fiber deployment market. In Section IV, we discuss the contemporaneous externalities associated with the deployment of fiber and estimate the effect of fiber deployment on various economic indicators. In Section V, we discuss current funding and why, in addition to the contemporaneous externalities, the existence of temporal externalities also push the needle in favor of increased fiber deployment today. Section VI concludes.

II. Fiber Broadband and U.S. Fiber Deployment

A. Fiber Optic Networks Perform Better Compared to Other Fixed Broadband Technologies and are Future-Proof

Comparing the performance characteristics of the fixed broadband technologies discussed above, fiber optic technology stands out from other fixed broadband technologies due to its

[8] The White House, "Fact Sheet: Biden-Harris Administration Announces Over $25 Billion in American Rescue Plan Funding to Help Ensure Every American Has Access to High Speed, Affordable Internet," June 7, 2022, https://www.whitehouse.gov/briefing-room/statements-releases/2022/06/07/fact-sheet-biden-harris-administration-announces-over-25-billion-in-american-rescue-plan-funding-to-help-ensure-every-american-has-access-to-high-speed-affordable-internet/; U.S. Department of Treasury, "Capital Projects Fund," last accessed August 27, 2024, https://home.treasury.gov/policy-issues/coronavirus/assistance-for-state-local-and-tribal-governments/capital-projects-fund; USDA, "ReConnect Loan and Grant Program," last accessed August 27, 2024, https://www.usda.gov/reconnect; NTIA, "Broadband Infrastructure Program," last accessed August 27, 2024, https://broadbandusa.ntia.doc.gov/broadband-infrastructure-program; FCC, "Auction 904: Rural Digital Opportunity Fund," https://www.fcc.gov/auction/904; Broadband USA, "Broadband Equity Access and Deployment Program," https://broadbandusa.ntia.doc.gov/funding-programs/broadband-equity-access-and-deployment-bead-program.

superior speed, bandwidth, reliability, low latency, symmetrical speeds, longer transmission distances, and enhanced security features.[9]

- *Higher Speed and Bandwidth* Fiber has significantly higher data transfer speeds compared to cable broadband and can support symmetric gigabit and even multi-gigabit speeds, providing much greater bandwidth for data-intensive applications like video streaming, online gaming, and cloud computing.[10] Fiber optic technology has the potential to support future advancements in telecommunications technology for decades to come. This makes fiber optic infrastructure a long-term investment that can adapt to evolving technological requirements and consumer demands.

- *Lower Latency* Fiber optic networks offer ultra-low latency, which is crucial for real-time applications such as online gaming, video conferencing, and financial transactions.[11] As more low latency applications are developed, fiber will be able to meet their network needs without the need for expensive upgrades or replacement of the fiber optic cable.

- *Greater Reliability* Fiber optic cables are more reliable and can transmit data over longer distances without signal degradation.[12] This allows fiber optic networks to cover larger geographic areas with consistent high-speed connectivity, thus offering greater reliability and consistency in delivering high-quality internet connectivity.[13]

- *Greater Security* Fiber optic cables are inherently more secure than other broadband technologies because they do not emit electromagnetic signals that can be intercepted.[14]

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9 Mobile broadband is not considered separately as its performance is constrained by the fixed broadband backhaul used by the mobile network.

10 Rebecca Brill and Corinne Tynan, "DSL vs. Cable vs. Fiber Internet: Major Differences, Pros And Cons," Forbes, last updated April 4, 2024, https://www.forbes.com/home-improvement/home/dsl-vs-cable-vs-fiber/#which_internet_is_best_section.

11 DCS Content Team, "How Fiber Optic Cables Improve Data Center Speed and Latency," Data Center Systems, April 4, 2023, https://blog.datacentersystems.com/how-fiber-optic-cables-improve-data-center-speed-and-latency.

12 Gateway Fiber, "Why Fiber Internet is More Reliable," March 7, 2023, last accessed April 9, 2024, https://www.gatewayfiber.com/blog/why-fiber-internet-is-more-reliable; Genius Modules, "Is Fiber Optic Good for Long Distance?" January 5, 2024, https://www.genuinemodules.com/is-fiber-optic-good-for-long-distance_a3375.

13 Ziply Fiber, "Fiber Internet and the Rise of Remote Work," February 16, 2024, https://ziplyfiber.com/blogs/article/fiber-and-the-rise-of-remote-work ("Fiber Internet and the Rise of Remote Work").

14 PeakOptical A/S, "Why Fiber Optic Networks Are More Secure Than Copper Cable Networks For Businesses," LinkedIn, January 9, 2023, https://www.linkedin.com/pulse/why-fiber-optic-networks-more-secure-than-copper-cable-.

Fiber optic networks are more resistant to hacking and eavesdropping, enhancing data security for users, which is increasingly becoming a critical issue for broadband networks.

- *Greater Sustainability* Fiber optic cables significantly reduce the carbon footprint as it enables the deployment of Passive Optical Networks (PON), which eliminated the active (powered) network components, improving network reliability and reducing power consumption.

- *Greater Durability* Fiber broadband's inherent resilience, cost-efficiency, and repairability make it a superior choice for maintaining reliable internet connectivity, especially in the face of natural disasters. Fiber optic cables are made of glass or plastic, which are not susceptible to corrosion or electrical interference, and this makes them more resilient to extreme weather conditions such as floods, high winds, and lightning strikes compared to metal-based cables. Additionally, fiber optics do not conduct electricity, which means they are not affected by electrical surges and lightning strikes that can damage other broadband services.

These characteristics make fiber optic networks a *future-proof technology*, highly desirable for meeting the growing demands of modern high-speed internet applications. As discussed below, although fiber deployments in the U.S. have increased over the last decade, there are significant gaps in fiber connectivity.

B. Despite Increases in Deployment Almost Half of the U.S. BSLs Lacks Access to Fiber

Over the past decade, access to fiber technology has increased in the U.S., making it more widely available now than it was in the past.[15] As shown in Figure 1, the U.S. is lagging behind most developed countries in terms of fiber deployment. In South Korea, Japan, Iceland, Spain and Sweden, fiber comprises of 80% or more of their broadband deployment. In the U.S. it is around 20%.[16]

15 Fiber access refers to the availability of fiber lines at a specific location. Fiber penetration refers to the rate at which fiber is adopted by consumers.

16 Petroc Taylor, "Fiber share of total broadband connections in OECD countries 2023," Statista, last accessed August 27, 2024, https://www.statista.com/statistics/604623/share-of-fibre-connections-in-broadband-oecd/.

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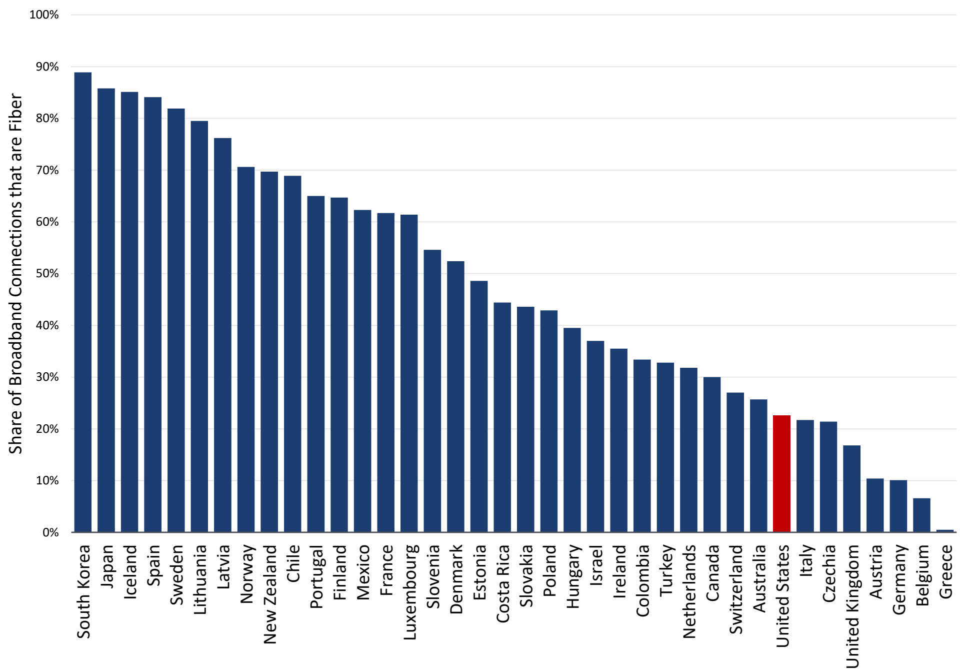
FIGURE 1: FIBER SHARE OF TOTAL BROADBAND CONNECTIONS ACROSS COUNTRIES



Sources and Notes:
Petroc Taylor, "Fiber share of total broadband connections in OECD countries 2023," *Statista,* last accessed March 21, 2024, https://www.statista.com/statistics/604623/share-of-fibre-connections-in-broadband-oecd/.

According to the Fiber Broadband Association (FBA), as of 2023, fiber broadband passed nearly 69 million of the 132 million homes in the U.S., which reflected a 13% growth for that year.[17] Additionally, approximately 5.6 million new households have subscribed to fiber since December 2021.[18] However, even with all the progress, a little over half of the serviceable locations (an FCC metric that is a combination of homes and businesses) in the U.S. were unserved by fiber in 2023 as seen from Table 1 below. The table shows what percentage of broadband serviceable locations (BSLs) in the U.S. are served, unserved and underserved for two types of technology. As can be seen from the table, 63 million BSLs or 54.6% are still unserved by fiber. This implies that 56 million households (which are a sub-set of the BSLs) are unserved by fiber.[19]

[17] Sean Buckley, "North American Fiber Broadband Industry Passed 9M Homes in 2023," December 14, 2023, https://www.lightwaveonline.com/home/article/55030843/north-american-fiber-broadband-industry-passed-9m-homes-in-2023. *See also*, Statista, "Number of Households in the U.S. from 1960 to 2023," last accessed May 30, 2024, https://www.statista.com/statistics/183635/number-of-households-in-the-us/.

[18] Tyler Cooper, "Over Half of America Now Has Access to Fiber," BroadbandNow Research*,* November 14, 2023, https://broadbandnow.com/research/fiber-penetration-trends ("Over Half of America Now Has Access to Fiber Article").

[19] We overlay the BDC shapefiles (fiber availability) with census shapefiles (tract boundaries) to estimate the number of households that are unserved by fiber.

TABLE 1: OVERVIEW OF SERVICE IN THE U.S. (2023)

	Total [1]	Cable [2]	**Fiber [3]**
Total Broadband Serviceable Locations (BSL)	115,342,228	115,342,228	**115,342,228**
Served BSL	105,089,107	94,935,898	**52,325,639**
% of Total	91.1%	82.3%	**45.4%**
Underserved BSL	3,041,565	475,618	**60,543**
% of Total	2.6%	0.4%	**0.1%**
Unserved BSL	7,211,556	19,930,712	**62,956,046**
% of Total	6.3%	17.3%	**54.6%**

Sources and Notes:
FCC Broadband Data Collection June 2023. The data was collected from https://www.arcgis.com/home/item.html?id=22ca3a8bb2ff46c1983fb45414157b08#overview and published by juliah_esri on March 12, 2023 and last updated January 3, 2024. We last accessed this data on March 28, 2024.
Served: low latency fiber, cable, copper or licensed terrestrial fixed wireless offering speeds greater than or equal to 100/20 Mbps.
Underserved: low latency fiber, cable, copper or terrestrial licensed fixed wireless offering speeds greater than or equal to 25/3 Mbps but less than 100/20 Mbps.
Unserved: all service that is not low-latency or less than 25/3 Mbps and all geostationary satellite, non-geostationary satellite, unlicensed terrestrial fixed wireless and other.

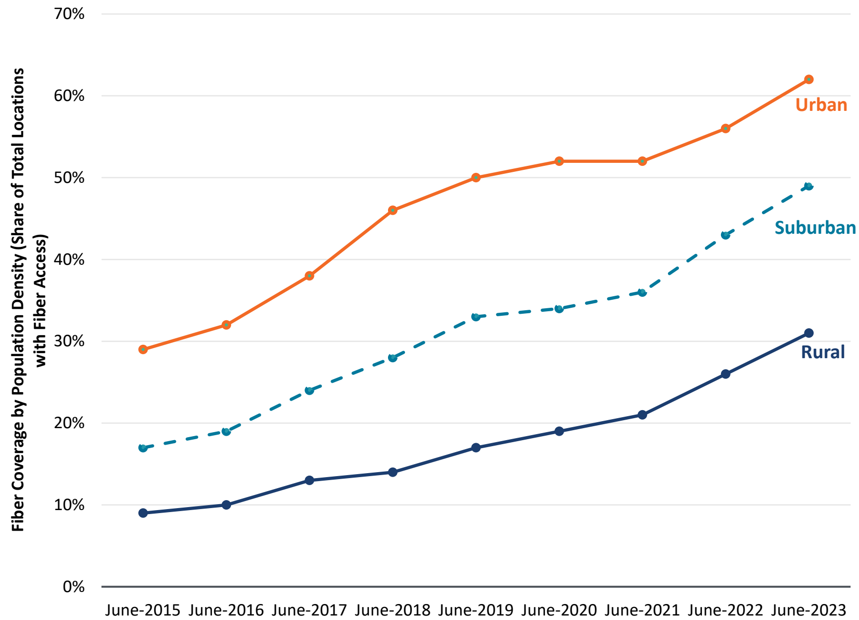
In addition, there is a large disparity in the percentage of households with fiber internet access between urban and rural states. In December 2021, the difference in average percent of households with fiber access between rural and urban areas was approximately 24.0%.[20] In June 2023, this difference grew to 25.1% even though access has grown in both urban and rural areas.[21] Figure 2 below shows fiber coverage by population density. The disparity between urban and rural areas is quite large and narrowing this gap is crucial to ensure that people living in rural areas can keep pace when it comes to technological advancements such as artificial intelligence, telemedicine, and education technology.[22]

[20] Tyler Cooper, "Over Half of America Now Has Access to Fiber," BroadbandNow Research, November 14, 2023, https://broadbandnow.com/research/fiber-penetration-trends ("Over Half of America Now Has Access to Fiber").

[21] *See*, Over Half of America Now Has Access to Fiber.

[22] *See,* Section IV.

FIGURE 2: FIBER COVERAGE BY POPULATION DENSITY



Sources and Notes:
Fiber Broadband Association, Fiber Deployment Annual Report 2023, https://fiberbroadband.org/wp-content/uploads/2024/01/Fiber-Deployment-Annual-Report-2023_FBA-and-Cartesian.pdf, p. 8.

III. Externalities, Market Failure and Sub-Optimal Fiber Investment and Deployment

Why is there a fiber connectivity gap? To understand this, we focus on the economic concept of market failures and how the presence of positive externalities leads to a socially sub-optimal level of investment in the fiber market.

A. The Theory of Externalities and Underinvestment

A market failure occurs when the price signals in a market do not reflect the underlying costs of the resources used. This leads to a situation where the choices made based on those price signals do not lead to the efficient use of resources. In general, in a well-functioning market where private actors fully capture the benefits from their investment decisions, the level of investment is both privately and socially optimal. In such a situation, the private benefit and the benefit to society as a whole (social benefit) are identical and fully captured by the entity incurring the cost of the decision. This has the benefit of market prices for goods and services reflecting the actual cost of resources needed to produce those goods and services. Externalities occur when the actions of one party in a transaction affect the well-being of a third party, without compensation or consent. Externalities can be positive (beneficial) or negative (harmful), and they often lead to market failures because the prices of goods and services do not reflect the full social costs or benefits.[23] Positive externalities can result in a misallocation of resources, where resources are diverted away from activities that generate positive externalities towards activities with private benefits only. This misallocation leads to an inefficient allocation of resources and suboptimal social outcomes.[24]

Underinvestment can often be linked to externalities, particularly when positive externalities are present.[25] For instance, a firm might underinvest in research and development because it cannot fully capture the benefits (externalities) that spill over to other firms or society as a whole.[26] In this case, society corrects this market failure by creating patents and other intellectual property rights so that inventors are incentivized to invent more. Similarly, education generates positive externalities by enhancing the productivity of individuals and fostering innovation and economic growth. However, individuals may underinvest in education due to the inability to fully capture the societal benefits, leading to suboptimal levels of human capital accumulation.[27] Thus positive externalities create a situation where the social benefits from an economic decision such as investing in a particular technology or sector is greater than the private benefit captured by the entity incurring the costs of those investments.

Figure 3 below illustrates such a situation. Equilibrium is characterized by where the lines cross because at that point the incremental benefit is just offset by the incremental cost. Left to the private market, investment will be at I_1 where the private marginal cost (PMC) and private marginal benefit (PMB) curves intersect. The PMB curve shows the incremental benefit that a private investor can expect if they invest $1 extra. The social marginal benefit (SMB) curve shows how much society stands to gain from the $1 investment. The SMB curve is higher than the private benefit curve due to the positive externalities – that is, at each level of investment society benefits more than the private actor making the investment. Thus, if one factors in all the positive

[23] *See*, Externalities: Prices Do Not Capture All Costs.

[24] *See*, Externalities: Prices Do Not Capture All Costs.

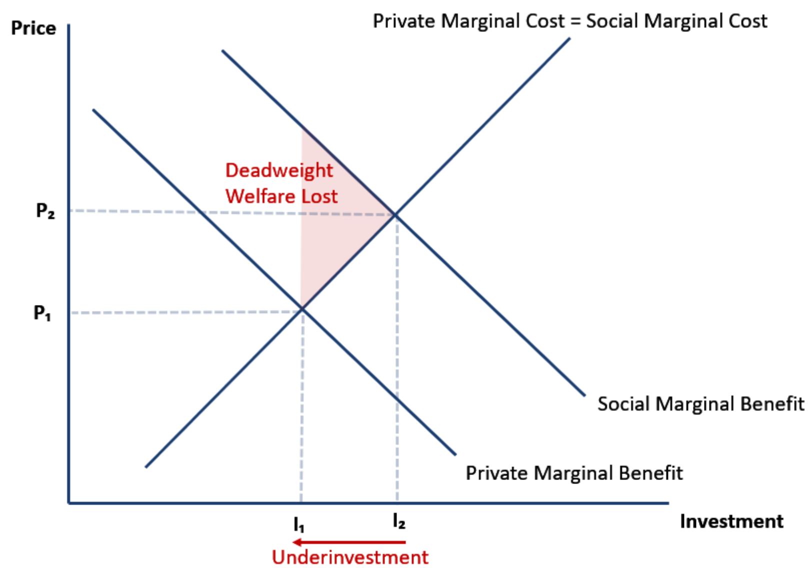
[25] Stiglitz, J. E. (1989). "The Economic Role of the State." Oxford Review of Economic Policy, 5(1), 1-20. Romer, P. M. (1990). "Endogenous Technological Change." Journal of Political Economy, 98(5), S71-S102.

[26] Griliches, Z. (1992). "The Search for R&D Spillovers." The Scandinavian Journal of Economics, 94(0), S29-S47. Jaffe, A. B. (1986). "Technological Opportunity and Spillovers of R&D: Evidence from Firms' Patents, Profits, and Market Value." The American Economic Review, 76(5), 984-1001.

[27] Heckman, J. J., Lochner, L. J., & Todd, P. E. (2006). "Earnings Functions, Rates of Return and Treatment Effects: The Mincer Equation and Beyond." Handbook of the Economics of Education, 1, 307-458.

externalities or spillovers, *i.e.,* social benefits, the optimal level of investment should be I_2. The private market equilibrium generates a sub-optimal level of investment. In the next section that follows, we are estimating the gap between the PMB and the SMB curve for fiber deployment. We will demonstrate that these significant positive externalities and spillovers are substantial, underscoring the need for increased investment in fiber infrastructure.

FIGURE 3: POSITIVE EXTERNATILITIES AND UNDERINVESTMENT



B. Estimating Positive Economic Spillovers from Fiber Deployment Even in the Presence of Other High-Speed Broadband Technologies

As discussed above, when examining where fiber is deployed and adopted, there exist economic externalities that suggest private market transactions alone will not create the optimal level of fiber investment. There are two types of externalities that are associated with fiber deployment – contemporaneous externalities and temporal externalities. Contemporaneous externalities, for example, imply that fiber expansion will lead to various economic gains for the area where fiber is deployed, such as increased income, more employment, higher housing values, improved 5G deployment in rural America, increased connectivity options for anchor institutions, such as hospitals and libraries, and increased health and social benefits – none of which is fully captured by the private broadband operator investing in the fiber. In this section we will focus on these contemporaneous externalities. Temporal externalities are tied to fiber providing the highest quality connections but the benefits occurring far into the future and not being fully captured by the private actors who invest in fiber. These will be addressed in Section V.

The existence of externalities implies that increasing the current access to fiber broadband has spillover effects on economic activity, today and tomorrow.[28] Recognizing or internalizing these externalities would encourage more fiber investment. To do so requires quantifying these externalities. In this paper, we will estimate a sub-set for these positive externalities and their effect on economic metrics such as housing values, income, employment, and work patterns.

There are numerous studies that show the positive spillovers and economic benefits that occur when high speed broadband is deployed to a community.[29] This paper, in contrast, focuses on the incremental benefits of fiber deployment controlling for the presence of availability of other high-speed broadband. We find that fiber presence in a geography is linked to many positive economic spillovers. We define general economic spillovers as externalities which show up in high-level economic indicators such as housing values, income and unemployment, in contrast to benefits that accrue to a specific industry (say, healthcare and education).[30] We empirically quantify these spillovers with publicly available data and well-established econometric techniques which estimate causal effects.[31] In particular, we find a positive statistically significant relationship of varying magnitudes between fiber deployment and employment, housing value, household income, and rates of remote work, *i.e.*, fiber deployment is observed to increase these indicators.

To quantitatively assess the economic impact of expanded fiber access, we restrict our analysis to census tracts that had at least one HFC provider in all years and exclude tracts that already had fiber in 2014. We use broadband availability data from the FCC's 477 and Broadband Data Collection (BDC) data collection merged with economic indicators from the U.S. Census American Community Survey (ACS) to construct a difference in differences estimator at the census tract level. Difference in differences analysis uses a "treatment" group that is affected by the policy or

[28] Speed Matters, "Economic Growth & Quality Jobs," accessed September 4, 2024, https://speedmatters.org/economicgrowthqualityjobs.

[29] Wolfgang Briglauer, Carlo Cambini, and Klaus Gugler, "Economic Benefits of High-Speed Broadband Network Coverage and Service Adoption: Evidence from OECD Member States," Research Paper, No. 23, 2023, EcoAustria – Institute for Economic Research, Vienna, https://www.econstor.eu/bitstream/10419/279415/1/186569830X.pdf.

[30] These industry specific spillovers are discussed in the subsections below.

[31] We use a difference in difference regression model to estimate the impact of fiber deployment on general economic indicators. *See,* Appendix A for a detailed description of the data and econometric methodology used.

event in question, and a "control" group that is unaffected (*i.e.*, untreated), and measures the difference in outcome between the two groups before and after the treatment. This is done in order to properly isolate the effect of the treatment from other confounding variables that might otherwise contribute to the difference in outcomes between the two groups. In our analysis, we define the control group as census tracts that do not have fiber access in any year of the sample, 2014 through 2021. Our treatment group is the subset of the sample that gained fiber access in either 2017 or 2018. Our estimates for fiber presence effects on economic indicators should be interpreted as the incremental effect conditional on having broadband of fiber over not having fiber, and accounts for any potential pre-existing trends, HFC deployment, and demographic similarities that fiber deployed geographies might have. We estimate this model separately for non-urban (rural and suburban) and urban census tracts where data variation allows such disaggregated estimation (*i.e.* for housing values and household income). Below we report and interpret our findings.

TABLE 2: GENERAL SPILLOVER EFFECTS OF FIBER PRESENCE

Impact on:		Sample Average without Fiber	Impact of Fiber Presence	Implied % Change
Median Housing Value	[1]			
Non-Urban		$192,827	$27,061	14.0%
Urban		$241,736	$41,201	17.0%
Household Income	[2]			
Non-Urban		$56,260	$1,613	2.9%
Urban		$52,354	-	-
Employment Rate	[3]	67.90%	+0.5%	0.74%
Work from Home Rate	[4]	5.34%	+1.2%	22.5%

Sources and Notes: *See,* Appendix A for details on data sources and econometric methodology.

[1]: Note that the employment rate in the American Community Survey is defined as the percent of employed people out of the population. In contrast to the commonly cited unemployment statistic which considers the percentage of people that are unemployed and out of the labor force. The U.S. Bureau of Labor Statistics defines the labor force as the number of people who are either working or actively looking for work. *See*, U.S. Bureau of Labor Statistics, "Labor Force Statistics from the Current Population Survey," https://www.bls.gov/cps/definitions.htm#laborforce.

[2]: Brattle analysis of Census and FCC 477 Data.

* Our econometric model for household income effects in urban tracts show that median income is on average higher in tracts that have fiber, however this difference between the tracts that do and do not have fiber is not statistically significant.

[3]: Brattle analysis of Census and FCC 477 Data

[4]: Brattle analysis of Census and FCC 477 Data

As shown in Table 2 we find that fiber deployment in a given census tract has different effects in urban and non-urban areas for housing value and household income. For urban and non-urban areas, housing values increase by 17% and 14% respectively. For non-urban areas household income increases by 2.9% but the income effect is not statistically significant in urban areas.[32] From the US-wide model we find that there is a 0.05% increase in the employment rate, and a 22.5% increase in the remote work rates. The relatively modest positive impacts on the employment rate and household income are unsurprising, as these economic indicators are more directly impacted by a plethora of macro-economic forces. In the following section we illustrate the significance of these impacts created by fiber over other broadband deployments.

IV. Access to Fiber Can Generate Billions of Dollars of Economic Impact

In this section, we explain the economic impacts found in our model by focusing on some illustrative small, medium and large cities. In addition, we also estimate a U.S.-wide effect. It is worth reiterating, that the model isolates the effect of fiber deployment and estimates the positive economic spillovers from that investment separately in urban and non-urban areas. This effect is incremental to any benefits that may occur when any high-speed broadband is deployed. By isolating the effect of fiber, we show that investing in fiber has large and significant added economic benefits to communities that are generated solely by fiber and not other technologies. From the FCC's 2023 BDC, we find that there are approximately 56 million households in census tracts that have no fiber broadband.[33] This constitutes of 50 million non-urban (rural and suburban) households and about 6 million urban households. This includes tracts that don't have fiber but have HFC or other non-fiber broadband options, as well as tracts that have no broadband at all. We do not consider tracts that are partially served by fiber, i.e. homes without fiber that are partially served are not in our 56 million estimate.

32 When we estimated the econometric model, the income effect in urban areas couldnot be estimated with precision and was thus statistically indsignificant. In other words, this implies that the evidence is insufficient to conclude that there is a meaningful effect of fiber deployment (in areas with existing high-speed broadband) on urban income, in the context of the model being estimated.

33 We overlay the BDC shapefiles (fiber availability) with census shapefiles (tract boundaries) to estimate the number of households that are unserved by fiber. *See,* Appendix A.

A. Housing Values

We find that with access to fiber broadband (where there was only non-fiber broadband before) the median housing values (which was approximately $200,000 in 2023) increase by around 14% or $29,000 on average.[34] This is a substantial impact because these are places where there was already high-speed non-fiber internet. Just the deployment of fiber is enough to show this significant increase in home values.

This increase in home values can positively impact the local economy through enhanced spending, investment, and tax revenues. Higher home values generally lead to increased property tax revenues for local governments leading to increased public spending. Homeowners with higher home equity often feel wealthier and more financially secure, which can lead to increased consumer spending. This boost in spending can stimulate local businesses and support job creation in retail, services, and other sectors. Also, with more valuable homes, homeowners might be more willing to invest in local businesses or start their own enterprises. This can spur entrepreneurship and economic diversification in the community.

- For example, for a city such as Detroit, with 311,291 housing units and $83,600 in median housing value, if say, 35% of the housing units are unserved by fiber, then deploying fiber to all the unserved households would increase housing value by $1.6 billion.[35]
- For example, for a small rural town such as Iron Mountain, Michigan, with 3,631 housing units and $112,600 in median housing value, if say, 31% of the housing units are unserved by fiber, then deploying fiber to all the unserved households would increase housing value by $18 million.[36]

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[34] These numbers are a weighted average of the urban and non-urban values. *See*, Appendix A.

[35] For households and housing values *see*, Census Reporter, "Iron Mountain, MI," accessed September 4, 2024, https://censusreporter.org/profiles/16000US2640960-iron-mountain-mi/ ("Census Reporter: Iron Mountain, MI"). *See also*, Census Reporter, "Detroit, MI," accessed September 4, 2024, https://censusreporter.org/profiles/16000US2622000-detroit-mi/ ("Census Reporter: Detroit, MI"). For fiber availability, *see*, United States Census Bureau, "American Community Survey S2801: Types of Computers and Internet Subscriptions Detroit," accessed September 4, 2024, https://data.census.gov/table?q=internet%20access%20in%20Detroit ("American Community Survey S2801: Types of Computers and Internet Subscriptions Detroit"). We calculate fiber unserved households as the total households minus those served by cable or fiber. Hence this is an underestimate.

[36] For households and housing values *see*, Census Reporter: Iron Mountain, MI. For fiber availability, *see*, American Community Survey S2801: Types of Computers and Internet Subscriptions Detroit. We calculate fiber unserved households as the total households minus those served by cable or fiber. Hence this is an underestimate.

- We find that deploying fiber to 56 million fiber-unserved households has the potential to generate at least these economic impacts in terms of housing values (expressed in NPV for a permanent one-time increase in housing value):
    - $1.4 trillion for rural and suburban areas and $242 billion for urban areas.
    - The aggregate U.S. impact in net present value terms (NPV) is $1.64 trillion.

B. Household Income and Employment

1. Household Income

From the econometric model, we have found that access to fiber broadband (where there was broadband, but no fiber) increases the median household income (which is $56,000 in 2023) by 3% or $1450 on average.[37] This is significant because these areas all had high-speed internet, but no fiber, and our estimate isolates the effect of fiber broadband from other high-speed internet. For a city this can have a tremendous economic impact, both in terms of direct and indirect effect. This income increase will have positive spillovers on other parts of a local economy.

- When we estimate the incremental effect of fiber deployment for urban and rural areas separately, for urban areas such as Detroit, our model predicts negligible incremental income effect of fiber. Note that this is an underestimate as this does not account for the effect of deploying fiber in areas that are unserved by any broadband.
- For example, for the small rural town such as Iron Mountain, Michigan, deploying fiber to all the unserved households would increase household income value by approximately $2 million annually.[38]

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[37] The urban effects are not statistically significant. There the effect on urban households is considered to be zero. These numbers are a weighted average of the urban and non-urban values, where the urban increase is $0. See Table 2 and Appendix A.

[38] For households and income *see* Census Reporter: Iron Mountain, MI. For fiber availability, *see,* https://data.census.gov/table?q=internet%20access%20in%20iron%20mountain,%20MI. For fiber availability, *see*, United States Census Bureau, "American Community Survey S2801: Types of Computers and Internet Subscriptions Iron Mountain, Michigan," accessed September 4, 2024, https://data.census.gov/table?q=internet%20access%20in%20iron%20mountain,% ("American Community Survey S2801: Types of Computers and Internet Subscriptions Michigan"). We calculate fiber unserved households as the total households minus those served by cable or fiber. Hence this is an underestimate.

- For the U.S.-wide effect we find that deploying fiber to 56 million fiber-unserved households has the potential to generate at least these economic impacts in terms of income:
    - On an annual basis income will increase by:
        - $81 billion, which is approximately $1,450 per households with new fiber access if applied to all unserved U.S. households. [39]
    - On a perpetuity basis income will increase by:
        - $1.6 trillion (NPV)for non-urban areas and negligible impact for urban areas.
        - The aggregate U.S. impact is $1.6 trillion (NPV).

2. Employment

High-speed broadband is a critical infrastructure that supports modern economies. As part of his Budget Request for the $42 billion in BEAD funding, the Biden administration said that the installation of high-speed internet creates high-paying jobs and strengthens local economies.[40] Broadband can boost job creation in various ways. It initially creates jobs through construction and deployment programs, which act as short-term economic stimulants. It allows businesses to move functions to regions with lower costs, potentially shifting jobs from cities to rural areas, thus creating a more sustainable rural economy. Lastly, broadband expands market reach, enabling businesses to set up physical operations in remote locations, like satellite clinics in healthcare, which can create jobs in those underserved areas.

39 When our model is estimated separately for rural and urban census tracts, we find that the income effect is not significant for urban areas. *See,* Appendix A for the estimated model.

40 NTIA, "Broadband Equity, Access, and Deployment Program Notice of Funding Opportunity," last accessed August 5, 2024, https://broadbandusa.ntia.doc.gov/sites/default/files/2022-05/BEAD%20NOFO.pdf. NTIA states that "[t]his program will lay critical groundwork for widespread access, affordability, equity, and adoption of broadband, create good-paying jobs; grow economic opportunities, including for local workers, provide increased access to healthcare services, enrich educational experiences of students, close long-standing equity gaps, and improve the overall quality of life across America."

There is extensive literature that documents the effects of increases in employment levels (both direct from the fiber construction and indirect from spillovers).[41] This literature shows that for every 1% increase in the broadband penetration rate, employment increases between 0.14% to 5.32%.[42] However, these estimates are calculating broadband's impact in the early 2000s, approximately 20 years ago. This time spans when broadband was first getting deployed, thus, the effects are likely larger than what we would expect today. In this paper, since we study the incremental effect of fiber broadband in areas that already have high-speed internet, one of the primary channels of fiber deployment on increases to employment levels is likely through the construction effect.[43] This can create jobs through several channels.[44] First, there will be a direct effect in employment growth during the network deployment phase. For instance, jobs may be created in roles related to telecommunications technicians, construction workers, and engineers. There are also additional jobs created through indirect channel. For instance, secondary economic activity, like employment opportunities for individuals with experience relating to metal products, electrical equipment, and professional services, are driven by the spending of businesses supporting the network rollout. Third, there will be an induced effect where jobs are generated by increased household spending from incomes earned through direct and indirect job effects. This includes roles in consumer goods, retail, and services.

Our analysis shows the incremental impact of fiber deployment on job creation beyond what occurs due to general high-speed broadband penetration. We estimate that:

- Access to fiber incrementally increases the employment rate by a small but measurable 0.74%. This is equivalent to a 0.5% increase in employment.[45]

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[41] Crandall, R., C. Jackson, and H. Singer, "The Effect of Ubiquitous Broadband Adoption on Investment, Jobs, and the U.S. Economy, 2003, Washington, DC: Criterion Economics. Atkinson, R., D. Castro, and S.J. Ezell, "The Digital Road to Recovery: A Stimulus Plan to Create Jobs, Boost Productivity and Revitalize America., 2009, Washington, DC: Te Information Technology and Innovation Foundation. Liebenau, J., R.D. Atkinson, P. Kärrberg, D. Castro, and S.J. Ezell, "The UK's Digital Road to Recovery, 2009, https://ssrn.com/abstract=1396687. Raul L. Katz, "The Impact of Broadband Internet on Employment," in Lorenzo Pupillo et al., Digitized Labor: The Impact of the Internet on Employment, (New York: Palgrave Macmillan, 2018), pp. 95-108, https://business.columbia.edu/sites/default/files-efs/imce-uploads/CITI/Articles/Katz%20Impact%20of%20Broadband%20Internet%20on%20Employment.pdf, ("Katz (2018)"

[42] *See*, Katz (2018).

[43] *See*, Katz (2018) p. 3.

[44] *See*, Katz (2018) p. 3.

[45] The jobs impact number is low because these places already have high-speed internet and this is only the incremental impact on jobs if fiber is deployed to these areas. The effect would be higher if these were unserved areas. *See* Appendix A.

- For a city such as Detroit, with a labor force of approximately 356,408 people, deploying fiber to all the unserved households would create 36 new jobs.[46]

- For a small rural town such as Iron Mountain, Michigan, with a labor force of approximately 4,363 people, deploying fiber to all the unserved households would create at least 14 new jobs.[47]

- For the U.S.-wide effect we find that deploying fiber to 56 million fiber-unserved households, or 77 million Americans in the workforce who are without fiber, has the potential to generate at least 380,000 new jobs.[48]

C. Remote Work

We also find a large positive impact on indicators that are more directly associated with access to reliable and high-speed internet. The incremental increase in the number of workers working from home in census tracts with fiber over tracts without fiber is expected and intuitive. The availability of a more reliable home broadband option should encourage more workers to choose to work from home. As more people consider fully remote or hybrid work as a long-term option for employment, housing demand in geographies with fiber access should increase. In fact, our findings suggest that more broadly funding fiber deployment may help even out housing value disparities across the nation. This may also help explain our high estimated impact on housing value.[49]

To investigate a possible contribution to the stark increase in remote work, we also conduct a separate analysis of the trend in work from home rates for census tracts with and without fiber access. In particular, we conduct another difference in differences analysis with our control group. Our control group is once again defined as census tracts never gaining fiber access, and our treatment group is now defined as any census tract with fiber access (according to our 15% threshold) by 2019. We then measure the differential effect of the Covid-19 pandemic as a

46 For labor force data, *see*, United States Census Bureau, "Labor Force in Detroit, MI," last accessed August 7, 2024, https://data.census.gov/table?q=labor%20force%20in%20detroit,%20MI. We define labor force as population between 20 – 64 years.

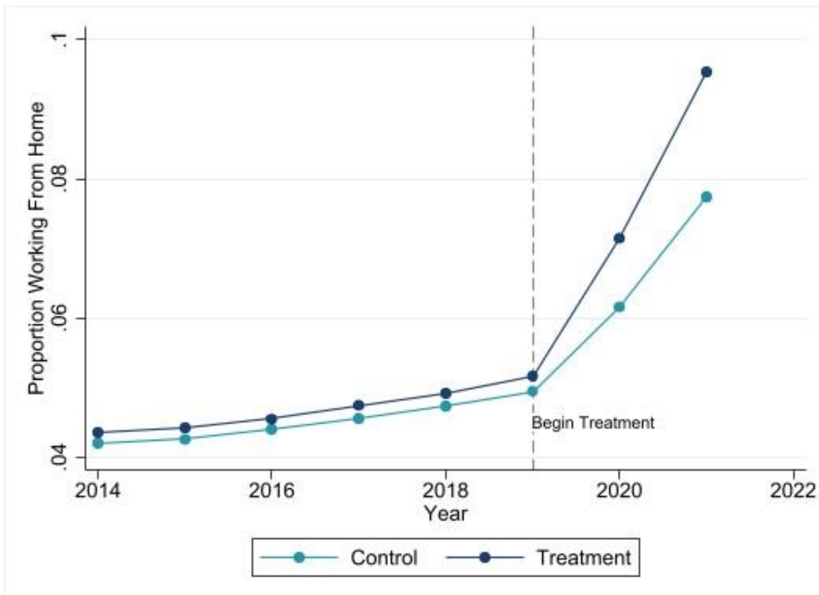
47 For labor force data *see*, United States Census Bureau, "Labor Force in Iron Mountain, MI," last accessed August 7, 2024, https://data.census.gov/table?q=labor%20force%20in%20iron%20muntain,%20MI.

48 *See*, Row [G] of Table 6 shows that the workforce without fiber is estimated to be approximately 77 million. 77 million multiplied by 0.5% equals approximately 380,000.

49 *See*, Section IV.A.

substantial exogenous shock to work from home rates, defining our pre-treatment period as 2014 to2019 and using 2020 and 2021 as our post-treatment period. We find that work-from-home rates increased by 2.4 percentage points (a whopping 54% increase) for the control group, and the rate increased by an additional 1.2 percentage points (27%) in census tracts with fiber access prior to the pandemic. This is despite virtually identical work from home rates prior to the treatment. This effect can be clearly seen in Figure 4 below.

FIGURE 4: TRENDS IN WORK FROM HOME RATES FOR TRACTS WITH AND WITHOUT FIBER ACCESS PRIOR TO THE COVID-19 PANDEMIC



The onset of the COVID-19 pandemic shifted large swathes of workers to a work-from-home format. As of 2023, 12.7% of full-time employees were working from home while 28.2% had hybrid work models.[50] High-speed broadband access is critical for successful work-from-home arrangements and fiber has played a critical role in enabling this as we have shown in our econometric analyses.[51]

50 Dr. John W. Mitchell, "The State of Hybrid Workplaces in 2024," Forbes, January 24, 2024, https://www.forbes.com/sites/forbesbooksauthors/2024/01/24/the-state-of-hybrid-workplaces-in-2024/#:~:text=Statistics%20That%20Tell%20the%20Story&text=As%20of%202023%2C%2012.7%25%20of,still%20work%20in%20an%20office.

51 S&P Global, "U.S. Broadband Expansion: Bridging Access Gaps," April 6, 2023, https://www.spglobal.com/_assets/documents/ratings/research/101575133.pdf.

Precisely measuring the impact of remote work enabled by fiber deployment on the environment is an extremely complex empirical exercise which needs to account for a multitude of factors.[52] However, recent studies show that remote work can bring environmental benefits of working from home. For example, a 2023 study found the working remotely for 4 or more days a week can reduce people's carbon footprint by 54% when coupled with additional sustainable habits.[53]

D.Environmental Benefits That Should Be Considered When Deciding Between Investments in Fiber and Other Technologies

Fiber is considered a greener alternative to HFC cable deployment for several reasons. A recent FBA study finds that fiber significantly reduces the carbon footprint compared to HFC (DOCSIS 4.0).[54] For instance, the network operational carbon footprint of fiber is up to 96% less than HFC.[55] Similarly, fiber networks have a 60% lower carbon footprint associated with network component manufacturing compared to HFC.[56] The most significant benefit from an environmental perspective is that fiber has a much smaller carbon footprint than its alternatives. Fiber networks use "passive" (non-powered) devices such as optical splitters, whereas HFC cable use "active" (powered devices such as amplifiers and powered taps).[57] A 2017 European study found that at 50 Mbps, fiber networks emit 1.7 tons of carbon dioxide per year, while the most efficient copper networks emit 2.7 tons.[58] The study also noted that at higher speeds, the savings would be even greater since fiber-optic networks require less power for signal transmission over

[52] *See, for e.g.*, Ganga Shreedhar, Kate Laffan, and Laura M. Giurge, "Is Remote Work Actually Better for the Environment?" March 7, 2022, https://hbr.org/2022/03/is-remote-work-actually-better-for-the-environment.

[53] Cornell University, "Remote Work Can Slash Your Carbon Footprint — If Done Right," September 18, 2023, last https://www.eurekalert.org/news-releases/1001874.

[54] Fiber Broadband Association, "Fiber Broadband Deployment is Paramount To Achieving Zero Carbon Footprint," FBA Sustainability Working Group, July, 2024, https://fiberbroadband.org/wp-content/uploads/2024/07/FBA-059_Sustainability_WhitePaper_FIN.pdf, ("Fiber Broadband Deployment is Paramount To Achieving Zero Carbon Footprint").

[55] *See*, Fiber Broadband Deployment is Paramount To Achieving Zero Carbon Footprint.

[56] *See*, Fiber Broadband Deployment is Paramount To Achieving Zero Carbon Footprint.

[57] FS, "Environmental Consideration: Are Fiber Optic Cables More Sustainable?" December 18, 2023, https://community.fs.com/article/environmental-consideration-are-fiber-optic-cables-more-sustainable.html ("Environmental Consideration: Are Fiber Optic Cables More Sustainable?").

[58] European Commission, "Fibre is the Most Energy Efficient Broadband Technology," November 24, 2020, https://digital-strategy.ec.europa.eu/en/library/fibre-most-energy-efficient-broadband-technology ("European Commission: Fibre is the Most Energy Efficient Broadband Technology").

long distances.[59] The use of "active" devices in the non-fiber networks also imply that these active devices use energy (power) which generates carbon output and reduces reliability. As powered devices tend to fail over time, they drive up operating expenses of HFC when, compared to fiber, increases truck rolls required to maintain the non-fiber network. Thus, in the long run, fiber cables require less maintenance than alternatives.

Due to their ability to transmit larger amount of data, fiber optic cables require less plastic-based cladding materials than copper cables, which further reduces the amount of mining and extraction required for their production.[60] Second the installation of fiber optic cables is significantly less disruptive to the environment due to their lightweight and compact nature. This can support the preservation of delicate ecologies while ensuring expanded access.[61] Fiber is also considerably more resilient and are estimated to last up to 25 years or more.[62] Updates to fiber cables do not require replacing the cables themselves, which makes them more cost-effective and environmentally friendly.[63] Repairs are required much less frequently, and by some estimates, repair times are up to 67% faster than for other wired technologies.[64] Additionally, their overall energy efficiency benefits organizations and homes relying on them as well by passing on energy savings.[65]

E. Enhanced Wireless Connectivity with 5G and IoT

5G and the Internet of Things (IoT) are expected to be game changers for our time. The evolution of 5G networks is expected to facilitate the deployment of new applications including the IoT. IoT refers to the linking of and communication between physical objects, such as roadways and bridges communicating with cars, or agricultural sensors and farm management systems, using wired and wireless networks.[66] Ericsson estimates that worldwide, there could be 5.6 billion 5G

59 *See*, European Commission: Fibre is the Most Energy Efficient Broadband Technology.

60 Harry Guinness, "How Does Choosing Fiber Internet Benefit the Environment?" Frontier, September 30, 2022, https://blog.frontier.com/2022/09/how-does-choosing-fiber-internet-benefit-the-environment/.

61 FiberMart, "4 Environmental Benefits of Fiber Optic Cables," May 19, 2023, https://www.fiber-mart.com/news/4-environmental-benefits-of-fiber-optic-cables-a-6194.html.

62 STL, "Environmental Considerations for Sustainable Fibre Deployment," June 5, 2023, https://stl.tech/blog/environmental-considerations-for-sustainable-fibre-deployment/ ("Environmental Considerations for Sustainable Fibre Deployment").

63 See, Environmental Consideration: Are Fiber Optic Cables More Sustainable.

64 See, Environmental Considerations for Sustainable Fibre Deployment.

65 See, Environmental Consideration: Are Fiber Optic Cables More Sustainable.

66 Michael Chui, Markus Löffler, and Roger Roberts, "The Internet of Things," McKinsey Quarterly, March 2010, http://www.mckinsey.com/industries/high-tech/our-insights/the-internet-of-things.

mobile subscriptions by 2029.[67] By 2034, 5G is expected to generate $12.3 trillion of global economic activity, $2.2 trillion in GDP for the global economy and 22 million jobs by 2035.[68] For the United States, 5G is expected to result in $719 billion of gross output, and generate 3.4 million jobs by 2035.[69]

All of these benefits depend on high bandwidth and low latency services powered by fiber backhaul connectivity. For these wireless solutions to provide low latency, fiber needs to be deployed as close to the end user application as possible, getting the broadband signal "out of the air and into the ground" as the first available point.[70] For the latency-sensitive applications in the context of 5G, latency is an important component of gauging the quality of experience for broadband users. Many new technologies with the potential to greatly benefit society require the speed and capacity of 5G networks (fiber in particular). 5G is expected to decrease end-to-end latency by 10 times, thereby improving user experiences for current technologies and providing an opportunity for innovation.[71] In particular, IoT technologies, such as robotic surgery, autonomous vehicles, and drones will require extremely low latency. 5G will also enhance the online gaming experience as small lags can drastically alter a game. There are a fair number of applications that would benefit significantly from low latencies. Thus, the tradeoff should not be evaluated just in terms of current uses of broadband technology, but also with an eye towards building in potential capacity for future needs.

F. Other Economic Benefits

Fiber's demonstrated benefits over other fixed broadband alternatives very likely extend to many other areas. Here we examine several areas that are sensitive to the availability and, especially, quality of broadband connections. Although we do not have any incremental fiber benefits to

67 Ericsson, "Ericsson Mobility Report," June 2024, p. 3, https://www.ericsson.com/49ed78/assets/local/reports-papers/mobility-report/documents/2024/ericsson-mobility-report-june-2024.pdf.

68 IHS Economics and IHS Technology, "The 5G Economy: How 5G Will Contribute to the Global Economy," January 2017, https://cdn.ihs.com/www/pdf/IHS-Technology-5G-Economic-Impact-Study.pdf ("The 5G Economy"), p. 4. For GDP estimate, *see*, GSMA, "Study on Socio-Economic Benefits of 5G Services Provided in mmWave Bands," The WRC Series, December 2018, https://www.gsma.com/spectrum/wp-content/uploads/2019/10/mmWave-5G-benefits.pdf, pp. 9, 21.

69 *See*, The 5G Economy, p. 19.

70 Asset Essentials, "Why Fiber Is the Key to Getting Faster 5G Everywhere," July 26, 2023, https://www.assetessentials.com/why-fiber-is-the-key-to-getting-faster-5g-everywhere/.

71 Mohammed Al Khairy, "How 5G Low Latency Improves Your Mobile Experiences," Qualcomm, May 12, 2019, https://www.qualcomm.com/news/onq/2019/05/how-5g-low-latency-improves-your-mobile-experiences.

measure here, it is highly likely that the noted benefits from quality broadband connections would only be enhanced if that broadband was delivered over fiber.

1. Improved Health Benefits of Fiber Deployment

Internet provided over fiber is generally more reliable and lower latency than other high-speed broadband technologies (such as HFC cable internet).[72] Hence, it is the ideal technology on which various healthcare services can be provided on. In particular, telemedicine is well suited for patients who medically or socially find it difficult to see physicians in-person.[73] These patients likely have high marginal value for access to healthcare. Furthermore, advancements in technology now allow healthcare providers to monitor patients outside the traditional care environment. [74] This type of monitoring is especially beneficial for patients with chronic health conditions.[75] Remote patient monitoring (RPM) allows healthcare providers to access health data in real-time and based on this data, allow them to adjust prescriptions or change a diagnosis.[76] For chronic care management, 93% of surveyed physicians state that they would take advantage of telehealth services, including RPM.[77] RPM require internet and bad internet connectivity can cause obstacles to patient monitoring.[78] Accessibility and connectivity issues would be especially pronounced in rural areas where high speed internet is less frequently available.[79]

Additionally, from the healthcare provider's perspective, there are cost savings realized through reduced overhead expenses as less physical clinic space and administrative staff are needed to operate.[80] Telemedicine also increases the likelihood of early detection and treatment of

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72 Lauren Hannula, "Cable vs. Fiber Internet," WhistleOut, last updated December 7, 2023, https://www.whistleout.com/Internet/Guides/cable-and-fiber-internet-differences.

73 Michael X Jin, Sun Young Kim, Lauren J Miller, Gauri Behari and Ricardo Correa, "Telemedicine: Current Impact on the Future," Cureus, Vol. 12(8), August 20, 2020, last accessed March 22, 2024, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7502422/.

74 Colton Hood, Neal Sikka, Cindy Manaoat Van, and Sarah R. Mossburg, "Remote Patient Monitoring,"PSNET*,* March 15, 2023, last accessed March 22, 2024, https://psnet.ahrq.gov/perspective/remote-patient-monitoring ("Remote Patient Monitoring").

75 *See*, Remote Patient Monitoring.

76 Prognocis, "Pros and Cons of Remote Patient Monitoring," last accessed March 22, 2024, https://prognocis.com/pros-and-cons-of-remote-patient-monitoring/ ("Pros and Cons of Remote Patient Monitoring").

77 *See*, Pros and Cons of Remote Patient Monitoring.

78 *See*, Pros and Cons of Remote Patient Monitoring.

79 *See,* Section II.B.

80 *See*¸ Smart Clinix, "How Does Telemedicine Reduce Costs," November 23, 2023, https://smartclinix.net/how-does-telemedicine-reduce-costs/ ("Smart Clinix: How Does Telemedicine Reduce Costs").

diseases, which can prevent the increased costs of treating more serious diseases.[81] Lastly, remote monitoring of diseases prevent readmission into the hospital which can be another source of cost savings for consumers.[82] When considering widening gaps in programs like Medicaid, the cost savings from early preventative care become even more pronounced.[83] This, once again, underscores the importance of universal availability for high speed two-way internet lines, which is best provided by fiber deployment.

2. Positive Educational Outcomes of Fiber Deployment

During the COVID-19 pandemic, 93% of parents reported that their children received online instruction of some form and 34% reported experiencing at least one technology-related obstacle related to schoolwork during this time.[84] These obstacles disproportionately affected children from rural and/or lower-income households. This phenomenon is known as the homework gap, which remains a persistent issue as the use of internet-based learning has increased.[85] During the COVID-19 pandemic, students worldwide that were unable to participate in remote learning due to lack of internet and reliable connectivity, risk losing $17 trillion in lifetime earnings.[86] Regional studies in various countries revealed substantial losses in math and reading and the learning losses were approximately proportional to the length of the closures.[87]

As of the fall of 2022, 6% of all U.S. college students attended primarily online institutions.[88] Over the 2021 to 2022 school year, these institutions enrolled over 560,000-full-time students and

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81 *See*¸ Smart Clinix: How Does Telemedicine Reduce Costs.

82 *See*¸ Smart Clinix: How Does Telemedicine Reduce Costs.

83 Center on Budget and Policy Priorities, "The Medicaid Coverage Gap: State Fact Sheets," April 3, 2024, last https://www.cbpp.org/research/health/the-medicaid-coverage-gap.

84 Katherine Schaeffer, "What We Know About Online Learning and the Homework Gap Amid the Pandemic," Pew Research Center, October 1, 2021, https://www.pewresearch.org/short-reads/2021/10/01/what-we-know-about-online-learning-and-the-homework-gap-amid-the-pandemic/ ("What We Know About Online Learning and the Homework Gap Amid the Pandemic").

85 Lauraine Langreo, "The 'Homework Gap' Persists. Tech Equity Is One Big Reason Why," EducationWeek, June 7, 2022, last accessed April 10, 2024, https://www.edweek.org/technology/the-homework-gap-persists-tech-equity-is-one-big-reason-why/2022/06.

86 World Bank-UNESCO-UNICEF, "Learning Losses from COVID-19 Could Cost this Generation of Students Close to $17 Trillion in Lifetime Earnings," December 6, 2021, https://www.worldbank.org/en/news/press-release/2021/12/06/learning-losses-from-covid-19-could-cost-this-generation-of-students-close-to-17-trillion-in-lifetime-earnings ("World Bank-UNESCO-UNICEF: Leaning Losses from COVID-19").

87 *See*, World Bank-UNESCO-UNICEF: Leaning Losses from COVID-19.

88 Ilana Hamilton, Veronica Beagle, and David Clingenpeel, "By the Numbers: The Rise of Online Learning In the U.S.," March 22, 2024, https://www.forbes.com/advisor/education/online-colleges/online-learning-stats/ ("By

Continued on next page

559,000 part-time students and female students made up 66% of all students.[89] According to data collected across 10 states, virtual school enrollment rose to 170% compared to pre-pandemic levels in 2020-2021 and 176% in 2021-2022.[90] Even in traditional classroom settings, educators are incorporating technology more than before. Education technology (EdTech) has made it possible for educators to incorporate new tools and technologies in their teaching.[91] Lack of high-speed internet access is one of the major barriers to incorporating EdTech tools in classrooms.[92] And the substantial increase in the capacity and speeds requirements, and the expected increase in the future can be best addressed with fiber deployments.

We observe that, as shown in Figure 5, below, the share of students learning online amongst graduate and undergraduate students is considerably high. This effect is even more pronounced at lower levels of household income. Given that rural households will benefit greatly from online learning in the U.S., it is important to ensure that rural areas of the U.S. have sufficient fiber access to facilitate online learning. As we discussed earlier, rural areas of the U.S. still lack sufficient access to high-speed internet, and it is essential for regulators to narrow the gap in fiber access rates between urban and rural areas.

the Numbers: The Rise of Online Learning in the U.S."). Note, "NCES defines primarily online schools as those enrolling 90% or more of their student body in distance education.")

89 *See*, By the Numbers: The Rise of Online Learning in the U.S. For student enrollment, *see*, National Center for Education Statistics, "Table 311.33. Selected statistics for degree-granting postsecondary institutions that primarily offer online programs, by control of institution and selected characteristics: Fall 2022 and academic year 2021-22," accessed September 4, 2024, https://nces.ed.gov/programs/digest/d23/tables/dt23_311.33.asp.

90 Asher Lehrer-Small, "Virtual School Enrollment Kept Climbing Even As COVID Receded, New Data Reveal,", updated November 16, 2022, https://www.the74million.org/article/virtual-school-enrollment-kept-climbing-even-as-covid-receded-new-data-reveal/.

91 All Assignment Help, "Major Barriers Education Technology Faces in the Modern Times," November 28, 2022, https://www.allassignmenthelp.com/blog/major-barriers-education-technology-faces-in-the-modern-times/ ("Major Barriers Education Technology Faces in the Modern Times").

92 *See*, Major Barriers Education Technology Faces in the Modern Times.

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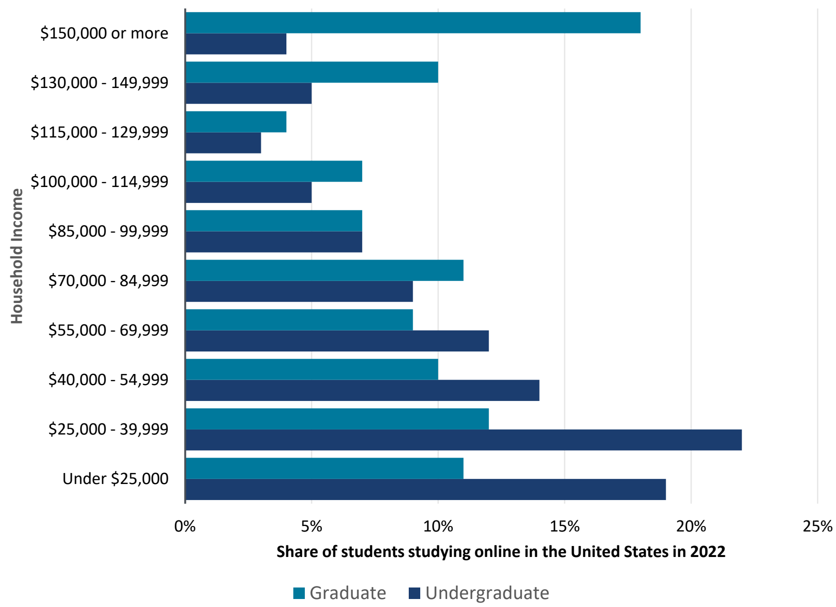
FIGURE 5: SHARE OF STUDENTS STUDYING ONLINE IN THE U.S. (2022) BY TOTAL HOUSEHOLD INCOME



Sources and Notes:
Veera Korhonen, "Share of Students Studying Online in the U.S., by Income 2022," August 3, 2023, last accessed March 25, 2024, https://www.statista.com/statistics/956154/share-students-studying-online-income-education-level/.

3. Improved Adoption of Up-and-Coming Artificial Intelligence Technology

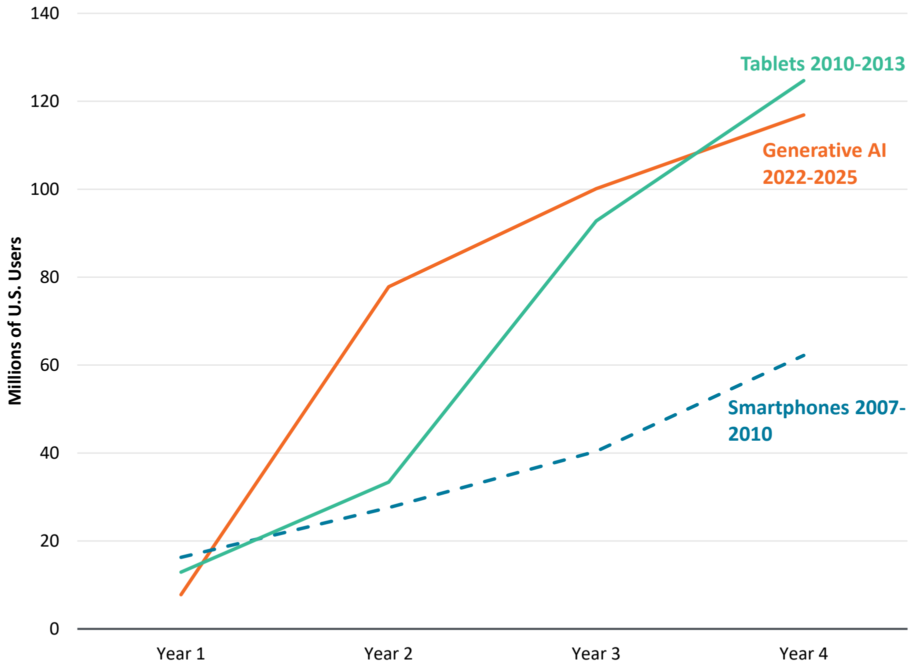
In recent years, there have been significant advancements in the field of artificial intelligence (A.I.) and looking ahead, we can expect these developments to continue pushing the frontier of A.I. technology. Especially for small businesses, AI can provide efficiency gains and cost savings.[93] According to a report by Small Business and Entrepreneurship Council (SBEC), 75% of all surveyed small businesses utilized AI tools in their operations and some of the most popular use cases included financial management tools, email marketing automation, cybersecurity and inventory management.[94] Furthermore, 54% of businesses have reported increased cost savings and efficiencies from A.I. implementation and 64% of businesses expect A.I. to improve

93 Neil Hare, "How Small Businesses Are Using AI—And How Your Business Can Benefit Too," Forbes, November 17, 2023, https://www.forbes.com/sites/allbusiness/2023/11/17/how-small-businesses-are-using-ai-and-how-your-business-can-benefit-too/?sh=231fee142344.

94 Small Business & Entrepreneurship Council, "Small Business A.I. Adoption Survey," October 2023, https://sbecouncil.org/wp-content/uploads/2023/10/SBE-Small-Business-AI-Survey-Oct-2023-FINAL.pdf, p. 4.

productivity.[95] Improving fiber access can lead to positive knock-on effects such as efficiency gains from greater adoption of A.I technology.

FIGURE 6: A.I. ADOPTION RATES COMPARED TO OTHER TECHNOLOGIES



Sources and Notes:
Sara Lebow, "Generative AI Adoption Climbed Faster Than Smartphones, Tablets," eMarketer, August 11, 2023, last accessed March 27, 2024, https://www.emarketer.com/content/generative-ai-adoption-climbed-faster-than-smartphones-tablets.

As shown in Figure 6, there is evidence that suggests that the rate of adoption for A.I. significantly exceeds the initial rates of adoption for smartphones.[96] For instance, in Year 2 (which in 2024 for A.I. and 2008 for smartphones) the adoption rate of A.I. is expected to be around 78% whereas smartphone adoption was around 30%.[97] A wide gap in internet access can contribute to wider gaps in A.I. adoption amongst rural and urban consumers. In the U.S., one in three people do not use internet at speeds high enough to support applications like Zoom, and as A.I. becomes more

95 Susie Marino, "43 Insane AI Statistics & What They Mean for Your Business," July 21, 2023, https://localiq.com/blog/ai-statistics/.

96 Jochai Ben-Avie, "Don't Let AI Become the Newest Digital Divide," January 18, 2024, Council on Foreign Relations, https://www.cfr.org/blog/dont-let-ai-become-newest-digital-divide ("Don't Let AI Become the Newest Digital Divide").

97 Sara Lebow, "Generative AI Adoption Climbed Faster Than Smartphones, Tablets," eMarketer, August 11, 2023, last accessed March 27, 2024, https://www.emarketer.com/content/generative-ai-adoption-climbed-faster-than-smartphones-tablets.

sophisticated, these same consumers will face challenges in accessing the benefits of A.I. driven technology.[98] There are growing concerns that A.I. will become the "new digital divide."[99]

V. Government Funding and Temporal Externalities

As discussed, and demonstrated above, society as a whole benefits from the positive externalities of fiber deployment. However, no group of private investors can fully capture these benefits. As a result, a private market equilibrium that balances the marginal revenue and marginal cost of fiber deployment will lead to an under-provision of fiber resources, resulting in market failure..[100] The solution to this issue is well-established: economic policy interventions are necessary when the market fails to provide an efficient level of a good or service.[101] The U.S. government has acknowledged this underinvestment in broadband and has implemented several funding mechanisms to bridge this gap.

A. Existing Government Funding

There are several federal programs to fund the expansion of high-speed internet offered by the U.S. government. BEAD is the largest such program, offering over $42 billion to all 50 U.S. states, Washington, D.C., and all U.S. territories.[102] In October 2020, the FCC held the RDOF Phase I auction that provided subsidies around $20.4 billion for terrestrial broadband deployment.[103] Another major program focused on improving rural broadband connectivity is the USDA's ReConnect Program. Established in 2018 via the Consolidated Appropriations Act, the ReConnect

98 *See*, Don't Let AI Become the Newest Digital Divide.

99 *See*, Don't Let AI Become the Newest Digital Divide.

100 Thomas Helbling, "Externalities: Prices Do Not Capture All Costs," International Monetary Fund, https://www.imf.org/en/Publications/fandd/issues/Series/Back-to-Basics/Externalities ("Externalities: Prices Do Not Capture All Costs").

101 *See,* Externalities: Prices Do Not Capture All Costs.

102 BroadbandUSA, "Broadband Equity Access and Deployment Program," BEAD, https://broadbandusa.ntia.doc.gov/funding-programs/broadband-equity-access-and-deployment-bead-program, accessed September 4, 2024.

103 FCC, "Auction 904: Rural Digital Opportunity Fund," https://www.fcc.gov/auction/904 ("Auction 904: Rural Digital Opportunity Fund").

Program provides grants, loans, and loan-grant combinations.[104] ARPA and Treasury's $9.6 billion Capital Projects Fund (CPF) are also major sources of federal funding for broadband.[105] While some of these programs target fiber connectivity to some extent, these are not exclusively for funding fiber deployment.

Despite these programs, there still remains a significant gap between the amount of funding that is directed towards fiber deployment and the amount required to ensure ubiquitous fiber deployment nationwide. For instance, a 2023 study argued that the BEAD funding was insufficient to effectively fix the digital gap using FTTH networks.[106]

Given these results, what does the government need to consider if it has to focus its subsidies on fiber deployment over other types of broadband? The first consideration is that there are incremental positive spillovers (contemporaneous externalities discussed earlier) of fiber deployment over other technologies. Additionally, there is a need to articulate the existence of temporal externalities and why that too moves the needle in favor of fiber over other technologies. We explain this below.

B. Future Proofing

Temporal externalities play a significant role in economic analysis, particularly in understanding the dynamics of intertemporal decision-making and its implications for market outcomes and social welfare. It refers to the effects that the timing of economic activities or decisions of one party have on others, which are not reflected in the market prices. Temporal externalities can lead to inefficient outcomes in markets because market prices fail to fully capture the long-term costs or benefits associated with certain actions.

The existence of temporal externality implies that the low-cost solution today may not be the low-cost solution over time. It is important to recognize that an optimal data network today will likely not meet the needs of tomorrow. Consequently, what is the least costly way of providing

[104] USDA, "ReConnect Program: Funding to Facilitate Broadband Deployment in Underserved Rural Areas," last updated May 2024, https://www.rd.usda.gov/sites/default/files/usda-rd-rus-reconnect-factsheet-02212024.pdf ("ReConnect Program: Funding to Facilitate Broadband Deployment in Underserved Rural Areas"), p. 2.

[105] U.S. Department of Treasury, "Capital Projects Fund," last accessed May 30, 2024, https://home.treasury.gov/policy-issues/coronavirus/assistance-for-state-local-and-tribal-governments/capital-projects-fund.

[106] Light Reading, "BEAD Funding Falls Short for Fiber-Only Options – Study," April 26, 2023, https://www.lightreading.com/digital-divide/bead-funding-falls-short-for-fiber-only-options-study.

a given level of service today may create greater upgrade costs in the future, and thus one needs a longer time horizon, *i.e.*, longer than what private industry uses, to evaluate the deployment of fiber.

Decision-making based on short-term costs and benefits analysis can lead to the wrong outcome when considering longer-lived assets. A myopic cheaper solution today may not necessarily be the optimal outcome in the long run. This is true for broadband deployment. Fiber typically costs more to deploy than HFC or FWA, but investments in fiber last longer. As a consequence, the shorter your planning horizon, the more distorted your choice will be about which technology to deploy. This problem is exacerbated with fiber deployments because the outyear benefits that are ignored in a shorter planning horizon are even larger due to the externalities noted in previous sections. Thus, the government needs to step in to correct this market failure. Government policies and regulations on broadband funding priorities will significantly influence market outcomes. To address the market failure and increase fiber access, government funding should prioritize fiber. Thus, the various public programs, such as RDOF, BEAD, Reconnect, CFP and BIP, that are prioritizing fiber builds are on the right policy path. This prioritization needs to continue if the gains from deploying fiber are to be realized.

Take, for example, a program that provides subsidies to extend broadband coverage further into a rural area. It may take a lower subsidy to incentivize a FWA deployment than a fiber deployment because the initial capital expenditures are lower and deployment costs can be recovered over a shorter period of time. But a decade later, as broadband capabilities expand (higher bandwidths, lower latencies, etc.) the FWA deployment will likely need significant additional capital expenditures to meet those future needs. A fiber deployment, in contrast, will be able to meet those future needs with a much lower incremental investment. From this perspective, society would be better off initially subsidizing the fiber deployment both because it would cost less over the long run *and* because we would enjoy the incremental benefits of fiber over other broadband modes now and into the future.

The significant advantage of fiber is that it is relatively future-proof technology due to its ability to deliver high speeds, scalability, reliability, and support for emerging applications and technologies. It has the potential to handle increasing data demands as technology continues to advance and can ensure that the internet infrastructure remains relevant and capable of meeting the evolving needs of businesses, education, healthcare, and entertainment. Fiber optic infrastructure enables future technology innovations such as Quantum Networking, the Metaverse, and AI/Machine Learning which will accelerate a wide range of applications beyond traditional internet access, such as remote surgery, smart city initiatives, autonomous vehicles, and more – *i.e.*, applications that may require functionality such as greater reliability and lower latency than can be handled by other high-speed broadband technologies. As new technologies and applications emerge, fiber optic networks provide the necessary infrastructure to support these innovations and drive economic growth.[107] Fiber optic cables have a longer expected lifespan compared to copper or coaxial cables, and this minimizes the need for frequent upgrades or replacements, reducing maintenance costs and ensuring the continued reliability of the network infrastructure over time.[108]

This particular externality, future-proofing the network, does not appear to be fully accounted for in the deployment subsidies given by the FCC or other government entities. The incremental nature of public broadband infrastructure investment over the last decade and the need for continual upgrades shows that the government may not be using the correct social benefit curve or discounting rate. Thus, government agencies and entities are not investing in a future-proof technology such as fiber, where the upfront costs would be larger, but longer-term upgrade costs would be minimal or nil. Even without accounting for the contemporaneous externalities, which would shift the benefits curve, if the government had internalized the temporal externalities, then we would potentially see larger fiber investment funding in the shorter term.

VI. Conclusion

Investing in fiber is not merely a technological upgrade, it's a strategic decision that bolsters long-term productivity and economic growth in the U.S. The critical role of high-quality broadband is indisputable, and the highest quality broadband is delivered via fiber optic cables. With the increasing demand for high-definition content, low-latency applications such as video conferencing, remote surgeries, and industrial automation, alongside the transfer of millions of gigabytes of data, a fast and reliable internet connection is essential for both businesses and consumers. As we expand our nation's critical broadband infrastructure, fiber is indispensable for providing the future-proof speed, capacity, and ultra-low latency necessary to drive future innovations.

[107] CLTEL, "The Role of Fiber Internet in Fostering Community Growth," January 31, 2024, https://www.cltel.com/articles/the-role-of-fiber-internet-in-fostering-community-growth/.

[108] Hayden Beeson, "Fiber Broadband Association Research Explores Scalability and Longevity of Fiber Broadband," Broadband Technology Report, March 18, 2024, https://www.broadbandtechreport.com/fiber/article/14310423/fiber-broadband-association-research-explores-scalability-and-longevity-of-fiber-broadband.

Currently 55% of the BSLs, *i.e.*, about 63 million locations, which include at least 56 million households do not have fiber broadband. Why is there a fiber connectivity gap? To understand this, we focus on market failures in broadband marketplace and how the presence of positive externalities leads to a socially sub-optimal level of investment in the fiber market. As explored above, there are two types of externalities that are associated with fiber deployment: contemporaneous externalities and temporal externalities. These positive externalities drive a wedge between private decision-making and the socially optimal outcome, leading to socially sub-optimal investment.

Several federal programs fund the expansion of high-speed internet offered by the U.S. government. While some of these programs target fiber connectivity to some extent, these are not exclusively for funding fiber deployment.[109] This report shows that fiber deployment has incremental economic benefits compared to other high-speed broadband technologies and thus, directing more of the existing funds towards fiber deployment will generate greater economic spillovers compared to other high-speed broadband technologies such as HFC.

We find that:

- Deploying fiber to 56 million fiber-unserved households has the potential to generate at least $1.64 trillion of total value (NPV) in terms of increased housing values.
- We also find a similar impact on income of an increase of $1.6 trillion (NPV) in total household income in the U.S. This effect primarily comes from non-urban areas.
- Fiber deployment also has the potential to create at least 380,000 new jobs for the U.S. economy.

Additionally, fiber deployment has a significant impact on remote work and has significant environmental benefits and is the best equipped to handle the increased connectivity needs in a 5G world and beyond, increases educational outcomes and health cost savings, and increases technology adoption.

[109] What States Need to Know About Federal BEAD Funding; NTIA, "Broadband Equity, Access, and Deployment Program," Notice of Funding Opportunity, https://broadbandusa.ntia.doc.gov/sites/default/files/2022-05/BEAD%20NOFO.pdf, p. 7. Auction 904: Rural Digital Opportunity Fund. USDA, "ReConnect Program: Program Overview," https://www.usda.gov/reconnect/program-overview. USDA, "ReConnect Program FY 2023 Funding Opportunity Announcement Awardees," https://www.usda.gov/reconnect/round-four-awardees.

Another significant advantage of fiber is that it is relatively future-proof technology due to its ability to deliver high speeds, scalability, reliability, and support for emerging applications and technologies. It has the potential to handle increasing data demands as technology continues to advance and can ensure that the internet infrastructure remains relevant and capable of meeting the evolving needs of businesses, education, healthcare, and entertainment.

Key Policy Takeaways:

Our study is the first to show that fiber deployment has significant incremental economic benefits even in the presence of other high-speed broadband technologies. The report also argues that because private actors will not capture all the benefits of fiber deployment the marketplace will not deploy enough fiber on its own. Based on these findings we suggest a few policy takeaways.

- First, because the social return on investment is higher for fiber, directing more of the existing public funds towards fiber deployment will generate greater economic returns compared to investment in other high-speed broadband technologies such as HFC. Thus, the various public programs, such as RDOF, BEAD, ReConnect, Capital Projects Fund, and BIP funding, that are prioritizing fiber builds are on the right policy path. This prioritization needs to continue if the gains from deploying fiber are to be realized.

- Second, based on available data, our research implies that even if fiber is deployed as an overbuild to existing high-speed technologies, the incremental benefits are sizeable. Thus, when the federal or local governments are measuring the underserved population, one important metric may be using a fiber-unserved metric and not just a speed-based metric. This will allow them to better target funding towards a fiber solution.

- Third, federal and local governments that promote fiber deployment, such as the federal Broadband Infrastructure Program, Louisiana's GUMBO program and Maine's ConnectMaine, should be encouraged and expanded. Additionally, the focus on fiber, that some of these programs have should be supported, and used as a model for other private-public initiatives.

- Last, fiber is a future-proof solution and when the benefits and costs are evaluated on a long-run horizon, fiber becomes the optimal choice for delivering high-speed broadband.

Appendix A: Quantitative Analysis Methodology

To quantitatively assess the economic impact of expanded fiber access, we use internet availability data from the FCC's Form 477 merged with economic indicators from the U.S. Census American Community Survey (ACS) to construct a difference in differences estimator at the census tract level. Difference in differences analysis uses a "treatment" group that is affected by the policy or event in question, and a "control" group that is unaffected (*i.e.*, untreated), and measures the difference in outcome between the two groups before and after the treatment. This is done to properly isolate the effect of the treatment from other confounding variables that might otherwise contribute to the difference in outcomes between the two groups.

In our analysis, we define the control group as census tracts that do not have fiber access in any year of the sample, 2014 through 2021. Our treatment group is the subset of the sample that gained fiber access in either 2017 or 2018. This is done for several reasons. First, using these two years as our treatment period gives us a symmetric pre- and post-treatment period which allows us to properly analyze the trends. Using an earlier treatment period would limit our ability to assess the necessary assumption that the treatment and control groups have parallel trends before the treatment. Using a later treatment period would prevent us from seeing the full effect as we suspect that many of our outcome variables may take time to respond to a stimulus such as fiber expansion. Second, using these two years gives us a larger sample size than we could get from a single period or any other two-year period as the largest group of tracts (about 28% of our sample) gained fiber access in 2017 or 2018.

Finally, because fiber expansion happened in different years for different census tracts, we are concerned that combining all of the treatment groups in a two-way fixed effects model could suffer from bias introduced in the presence of heterogeneity in treatment effects across either time or groups, which frequently arises in cases of difference in differences with staggered treatments.[110] Restricting our analysis to a single treatment period ameliorates these issues.

Importantly, we define fiber access at the tract level as at least 15% of the blocks in the tract having fiber access in the FCC 477 data and BDC data. This is roughly the 50th percentile in terms of the percentage of blocks with access among tracts with at least one fiber enabled block and is just above the average rate of fiber access in rural areas signifying a significant access threshold.

[110] Seth M. Freedman, Alex Hollingsworth, Kosali I. Simon, Coady Wing, Madeline Yozwiak, "Designing Difference in Difference Studies with Staggered Treatment Adoption: Key Concepts and Practical Guidelines," NBER Working Paper 31842, https://www.nber.org/system/files/working_papers/w31842/w31842.pdf.

We restrict our analysis to census tracts that had at least one HFC provider in all years and exclude tracts that already had fiber in 2014. Because our data is annual, it is not possible to tell precisely when fiber access was gained and whether this was before or after our outcomes were measured in a given year, and so we exclude 2017 and 2018 from the analysis in order to isolate the pre-treatment and post-treatment outcomes.[111]

We analyzed four main economic indicators as our outcomes of interest: the percent of 20–64-year-olds employed (employment rate), the percentage of 18-24 year olds with a bachelor's degree or higher (educational attainment), median household income, and median house value. Results are presented in Table 3 below, where the coefficients on the interaction between the treatment group and time period indicator show the isolated treatment effect.

TABLE 3: DIFFERENCE IN DIFFERENCES REGRESSION RESULTS

VARIABLES	(1) Pct. Employed (20-64)	(2) Median House Value	(3) Median HH Income
Post-Treatment	0.0269**	48,752**	10,818**
	(0.00120)	(2,432)	(331.9)
Treatment Group	0.0208**	61,476**	726.0*
	(0.00122)	(2,483)	(338.2)
Treatment Group x Post-Treatment	0.00480**	46,874**	2,195**
	(0.00176)	(3,589)	(489.4)
Constant	0.678**	195,708**	56,020**
	(0.000826)	(1,678)	(229.1)
Observations	61,008	59,073	60,685
R-squared	0.029	0.062	0.038

Standard errors in parentheses
** p<0.01, * p<0.05

We also analyzed these same economic indicators separately for urban and non-urban census tracts. These results are presented in Table 4 and Table 5 below, respectively. Note that the employment effects are insignificant for both urban and non-urban populations when studied separately. We believe this is because the employment effects are driven primarily by urban census tracts, but on their own, urban tracts are too small a sample size with too few control tracts to get statistical significance given the small magnitude of the effect. As such, we use the pooled regression in Table 3 as our primary result for the marginal employment effects of increased fiber access.

[111] This leaves us with a sample size of over 60,000 observations, of which roughly 46% are in the treatment group.

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Table 6 contains our estimate for the number of households and population with and without fiber. This is done by aggregating census blocks containing fiber technologies using the FCC National Broadband Map and the respective population and number of households in each census block.[112] To estimate the population of the workforce without fiber, we multiply the population without fiber by the percentage of population aged 20-64.[113]

[112] For the FCC's National Broadband Map, *see,* "FCC National Broadband Map," FCC, last accessed June 4, 2024, https://broadbandmap.fcc.gov/data-download. We use fixed broadband data from each state as of December 31, 2023. We separately use shapefiles containing the population and number of households in each census block in 2020 to estimate population and household totals. *See,* "TIGER/Line Shapefiles," United States Census Bureau, last accessed June 4, 2024, https://www.census.gov/geographies/mapping-files/2020/geo/tiger-line-file.html.

[113] We estimate the percentage of the population aged 20-64 to be 58%. *See*, "Age and Sex Composition in the United States: 2020," United States Census Bureau, last accessed June 4, 2024, https://www.census.gov/data/tables/2020/demo/age-and-sex/2020-age-sex-composition.html.

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TABLE 4: DIFFERENCE IN DIFFERENCES REGRESSION RESULTS FOR URBAN CENSUS TRACTS

VARIABLES	(1) Pct. Employed (20-64)	(2) Median House Value	(3) Median HH Income
Post-Treatment	0.0404**	107,333**	13,097**
	(0.00461)	(12,283)	(1,284)
Treatment Group	0.0205**	81,339**	-4,113**
	(0.00362)	(9,616)	(1,007)
Treatment Group x Post-Treatment	0.00313	41,201**	2,050
	(0.00516)	(13,720)	(1,437)
Constant	0.656**	241,736**	52,354**
	(0.00324)	(8,609)	(900.5)
Observations	10,356	9,763	10,304
R-squared	0.046	0.083	0.062

Standard errors in parentheses
** p<0.01, * p<0.05

TABLE 5: DIFFERENCE IN DIFFERENCES REGRESSION RESULTS FOR NON-URBAN CENSUS TRACTS

VARIABLES	(1) Pct. Employed (20-64)	(2) Median House Value	(3) Median HH Income
Post-Treatment	0.0261**	44,660**	10,675**
	(0.00124)	(2,302)	(342.2)
Treatment Group	0.0284**	38,423**	3,953**
	(0.00137)	(2,539)	(377.3)
Treatment Group x Post-Treatment	0.00107	27,061**	1,613**
	(0.00198)	(3,683)	(547.6)
Constant	0.679**	192,827**	56,260**
	(0.000855)	(1,588)	(236.0)
Observations	50,652	49,310	50,381
R-squared	0.031	0.035	0.040

Standard errors in parentheses
** p<0.01, * p<0.05

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TABLE 6: HOUSEHOLDS, POPULATION WITH FIBER

		Urban	Non-urban
Households	[A]	22,627,697	117,871,039
With fiber	[B]	16,751,576	67,809,402
Without fiber	[C]	5,876,121	50,061,637
Population	[D]	55,935,176	275,514,105
With fiber	[E]	40,484,114	158,368,358
Without fiber	[F]	15,451,062	117,145,747
Without fiber (in workforce)	[G]	8,954,323	67,889,240

Notes:
[A], [D]: Households and Population are estimated using 2020 census data provided at the census block level.
[B], [C], [E], [F]: The FCC's National Broadband Map is used to determine census blocks with fiber (as of December 31, 2023). *See,* https://broadbandmap.fcc.gov/data-download.
[G]: To estimate the population without fiber in the workforce, we use the percentage of the population aged 20-64 (approximately 58%) in 2020 multiplied by the population without fiber. *See,* https://www.census.gov/data/tables/2020/demo/age-and-sex/2020-age-sex-composition.html.