

CHAPTER

Internet Access and its Implications for Productivity, Inequality, and Resilience

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Internet Access and its Implications for Productivity, Inequality, and Resilience

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ABSTRACT

About one-fifth of paid workdays will be supplied from home in the post-pandemic economy, and more than one-fourth on an earnings-weighted basis. In view of this projection, we consider some implications of home internet access quality, exploiting data from the new Survey of Working Arrangements and Attitudes. Moving to high-quality, fully reliable home internet service for all Americans (“universal access”) would raise earnings-weighted labor productivity by an estimated 1.1% in the coming years. The implied output gains are \$160 billion per year, or \$4 trillion when capitalized at a 4% rate. Estimated flow output payoffs to universal access are nearly three times as large in economic disasters like the COVID-19 pandemic. Our survey data also say that subjective well-being was higher during the pandemic for people with better home internet service conditional on age, employment status, earnings, working arrangements, and other controls. In short, universal access would raise productivity, and it would promote greater economic and social resilience during future disasters that inhibit travel and in-person interactions.

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1. Introduction

Americans supplied half or more of paid workdays from home in spring 2020, 10 times the pre-COVID share. They continued to supply more than 40% of workdays from home through spring 2021.¹ We explain why the shift to working from home (WFH) will endure in Barrero, Bloom, and Davis (2021b). Our analysis and forward-looking survey evidence suggest that WFH will settle at about one-fifth of paid workdays in the coming years, and at higher levels for the well-educated and highly compensated. This abrupt, enormous, persistent shift to remote work has been greatly enabled by home internet access and a host of complementary technologies.

These remarkable developments prompt several questions that we tackle in this chapter. First, if everyone had high-quality, fully reliable home internet service in the coming years, how much would it boost productivity? Second, how much did subpar internet service degrade productivity during the pandemic? Third, would universal access to high-quality, reliable internet service materially increase WFH in the coming years and, if so, by how much? Fourth, would universal access raise or lower earnings inequality? As we explain, the implications for earnings inequality are unclear a priori, even as to the sign of any effect. Fifth, video conversations and virtual meetings yield some of the emotional and psychological benefits that humans normally enjoy in person, raising another question: How do subjective and objective indicators of well-being relate to internet access quality during the pandemic, a time of pervasive (physical) social distancing?

To address these questions, we tap multiple waves of data from the Survey of Working Arrangements and Attitudes (SWAA), an original cross-sectional survey of our design. We have fielded the SWAA monthly since May 2020, thus far collecting 43,000 responses from working-age Americans who earned at least \$20,000 in 2019. The survey asks about working arrangements during the pandemic, internet access quality, productivity, subjective well-being, employer plans about the extent of WFH *after* the pandemic ends, and more. The SWAA asks explicitly about working “full days at home.” Thus, our WFH measures do not encompass workdays split between home and office or work at satellite business facilities.

Many SWAA respondents report higher productivity when WFH during the pandemic than when working on employer premises before the pandemic. Using SWAA data on the relative productivity of WFH, employer plans about who will work from home in the post-pandemic economy and commuting times, Barrero, Bloom, and Davis (2021b, hereafter “BBD”) estimate that a re-optimization of working arrangements

1 Barrero, Bloom, and Davis (2020b), Bick et al. (2020), Brynjolfsson et al. (2020) and Ozimek (2020) provide evidence on the extent of working from home in the spring of 2020. Barrero, Bloom, and Davis (2021b) provide evidence on its evolution at a monthly frequency through April 2021.

in the post-pandemic economy will boost productivity by 4.6% relative to the pre-pandemic situation.² The main source of this productivity gain is the savings in commuting time afforded by WFH. The productivity boost reflects a combination of higher productivity when WFH for some workers *and* the selected nature of who works from home in the post-pandemic economy.

The productivity projections in our earlier work are conditioned on the prevailing level of internet access quality, which varies considerably across households. In this chapter, we instead estimate the productivity effects of universal access to high-quality internet service. We approach the matter in two ways: First, using responses to the SWAA question, “How much would your efficiency working from home increase if you had perfect high-speed internet?” Second, using regression models that relate SWAA data on the relative productivity of WFH to internet access quality. Under both approaches, we exploit SWAA data on employer plans for who will work from home in the post-pandemic economy, and how much.

To preview our main results, we estimate that universal access to high-quality home internet service (hereafter, “universal access”) would raise earnings-weighted productivity in the post-pandemic economy by 1.1%. To obtain this figure, we combine employer plans for who will work from home, and how much, with self-assessed productivity effects of universal access. For many workers, the implied productivity effect is zero—either because they don’t plan on WFH in the post-pandemic economy, already have high-quality home internet service, or don’t anticipate a productivity effect in any event. However, some workers who plan on WFH in the post-pandemic economy also expect a productivity gain from better internet service.

Given an aggregate output elasticity with respect to labor services of two-thirds, a 1.1% boost in labor productivity implies flow GDP gains of \$160 billion per year, or a present value gain of \$4 trillion at a 4% discount rate. Our data also suggest that better home internet access increases the propensity to work from home. Universal access would, according to our estimate, raise the extent of WFH in the post-pandemic economy by about seven-tenths of a percentage point. When we account for this effect, it slightly raises our estimate for the earnings-weighted productivity benefits of moving to universal access.

To assess the distributional consequences of universal access, we adopt the benchmark assumption that earnings are proportional to productivity in the cross section. Under this assumption, the SWAA data let us estimate the impact of universal

2 This estimate is a projection of how the pandemic will affect future productivity through the pandemic-induced re-optimization of working arrangements. See BBD and Erdziek (2021) on how the pandemic drives a re-optimization of working arrangements. To be sure, the pandemic may have additional productivity consequences, positive and negative, through other channels.

access on the earnings distribution. Two basic effects are in play: On average, lower-income workers have home internet service of lower quality and lesser reliability. In isolation, this fact suggests that moving to universal access would reduce inequality. However, planned levels of WFH in the post-pandemic economy rise strongly with earnings in the cross section. This effect cuts the other way. On net, we find that universal access would be of little consequence for overall earnings inequality and for the distribution of average earnings across major demographic groups.

Internet access quality was more consequential during the pandemic, because WFH accounted for such a large share of labor services. For the period from May 2020 to April 2021, we estimate that subpar internet access degraded earnings-weighted productivity by 3%. As before, our counterfactual is universal access to high-quality, fully reliable internet service. For perspective, consider the size of the U.S. output shortfall during the pandemic. Real GDP per capita was about 11% below its pre-pandemic trend in the second quarter of 2020 and about 4.5% below trend in the third quarter.³ These figures imply that universal access would have materially moderated the U.S. output shortfall during the pandemic. They also imply that the flow payoffs to universal access are larger in other disaster scenarios (*e.g.*, another pandemic) that inhibit travel and in-person interactions but do not cut off the internet itself. Partly for this reason, we see universal access as even more valuable to society than suggested by a simple capitalization of its expected flow benefits.

More broadly, our societal experience with remote work and virtual connectivity during the COVID-19 pandemic highlights the resilience value of the internet and other technologies that facilitate commerce and socializing at a distance. These technologies enabled large sectors of the economy to function well during the pandemic, even as people sheltered in place and socially distanced. They also facilitated a swift expansion of online commerce and delivery services, making it much easier for people to socially distance and curtail the spread of the virus. Similarly, universal access would promote economic resilience in the face of future pandemics and other disasters that inhibit travel and in-person interactions.

Universal access also promotes other forms of resilience. To see this point, start with the fact that loneliness and social isolation are harmful to mental and physical health. This observation leads naturally to the conjecture that social distancing during the pandemic had negative health effects for many Americans. It also raises the question of whether internet access alleviates the harmful health effects of social distancing. In this regard, we find that subjective well-being increases with internet access quality during the pandemic conditional on work status, working arrangements, and a battery of other controls. While we do not estimate causal

³ See Figure 6 in Davis, Liu, and Sheng (2021).

The SWAA target population covers U.S. residents, 20 to 64 years old, who earned at least \$20,000 in 2019. Given these parameters, QuestionPro and Inc-Query recruit respondents on our behalf from lists of verified persons supplied by leading market research aggregators, who gather potential respondents from multiple sources. One reason to tap multiple sources is that the form of respondent compensation depends on where and how they are recruited. Some respondents receive airline miles in exchange for survey participation, for instance, while others receive cash or credits that unlock internet game features. No respondents sign up specifically for our survey.⁷

The resulting distribution of SWAA respondents appears similar to that of working-age respondents in Current Population Survey (CPS) data from 2010 to 2019, except the SWAA features notably larger shares of high earners and persons with advanced degrees. Throughout this chapter, we reweight raw SWAA responses (after dropping speeders) to match the distribution of respondents in the 2010–2019 CPS over cells defined by the cross product of four age bins, sex, six education categories, and four earnings bins. The resulting marginal distributions by age, sex, education, earnings, major industry, and Census division in the reweighted SWAA data are very similar to the corresponding CPS distributions (Figure 2 in BBD).

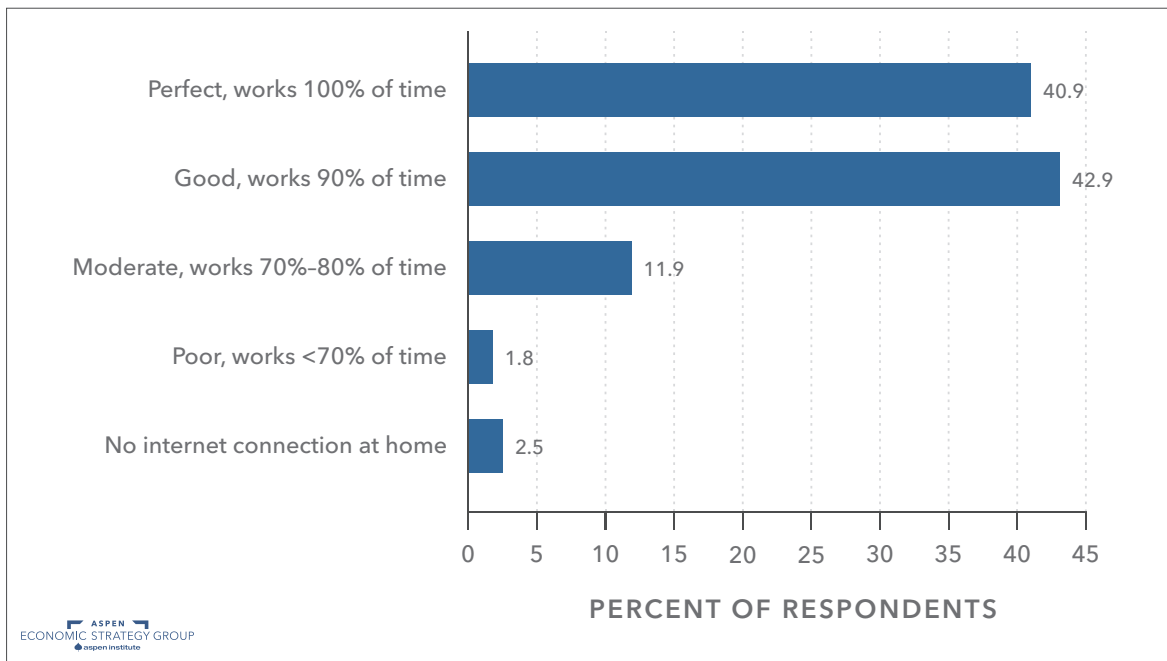
Respondents can, and sometimes do, take our survey using mobile devices (that do not require home internet access) or by accessing the internet outside their homes. Still, our sample may be skewed away from persons who lack home internet access. Insofar as our sample is skewed in this manner, we may understate the impact of universal access for the simple reason that it would involve a bigger change for persons who currently lack access. Other sources of sample selection may affect some of our results, as we discuss below.

2.b. The extent of working from home

Table 1 summarizes the extent of WFH before, during, and after the COVID-19 pandemic. Our post-COVID projections rely on responses to the following SWAA question:⁸

7 Following best practice for surveys of this type, we drop persons who complete the survey in less than two minutes in May, less than three minutes in the July to November 2020 waves, and less than five minutes in later waves. Given the nature and number of our survey questions, these “speeders” are unlikely to supply careful responses. After dropping speeders, which cuts the sample about 20%, median completion time ranges from three minutes and ten seconds in May 2020 to 10 minutes and 55 seconds in December 2020.

8 Before the August 2020 wave, the question specified “After COVID in 2021...” instead of 2022.

Figure 2: Distribution of internet quality among SWAA respondents

Source: Respondents to the question, “How reliable is your internet connection?” in the Survey of Working Arrangements and Attitudes.

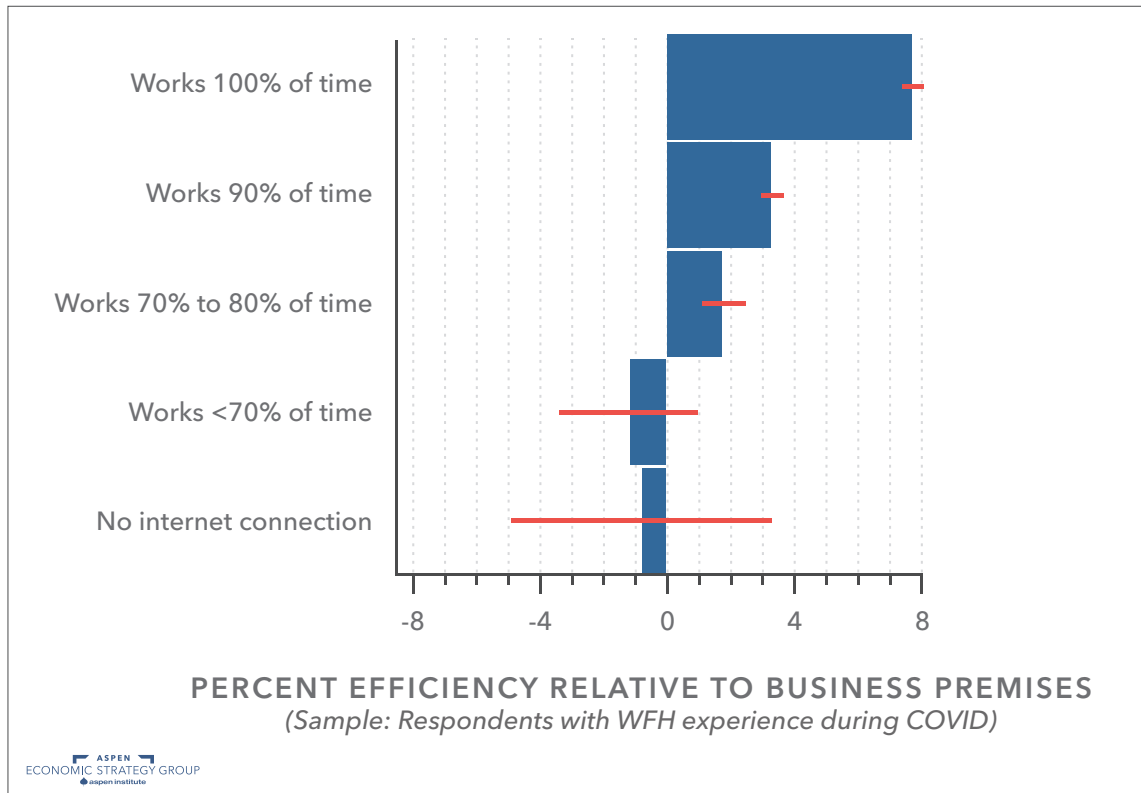
Notes: Data are from 43,250 survey responses collected from May 2020 to May 2021 by Inc-Query and QuestionPro. We re-weight raw responses to match the share of working age respondents in the 2010-2019 CPS in each {age x sex x education x earnings} cell.

Table 2 provides information about how the average quality of internet access varies by demographics and other respondent characteristics. The overall average access quality is 88.9%, meaning that home internet service works about 89% of the time for the average person with WFH experience during the pandemic. Average access quality is similar for men and women and somewhat smaller for persons 50–64 years of age. Average access quality rises with education and with earnings in 2019. When we further weight responses by number of children in the household, overall average access quality is somewhat higher at 90.8%. Here, it’s worth keeping in mind that households with no working parent, or no parent who earned at least \$20,000 in 2019, are not in-scope for our sample. Appendix Table A.1 provides more information about how internet access quality varies with observables in the SWAA.

2.e. How WFH productivity relates to home internet access quality

Figure 3 summarizes how the relative productivity of WFH relates to internet access quality in the cross section. Persons with internet access that works all the time report an average productivity difference of nearly 8% in favor of WFH. At the other end of the scale, persons with internet access that works less than 70% of the time and those who lack home internet access report average productivity differences of about 1% in favor of employer premises. Figure 3, in conjunction with Figure 2, clearly points to the potential for universal access to raise productivity for persons who work from home. Since WFH is projected to account for more than one-fourth of all earnings-weighted workdays in the post-pandemic economy, Figures 2 and 3 also imply that universal access would raise overall productivity in the economy.

Figure 3: Self-assessed efficiency while WFH by reported internet quality



Source: Responses to the following questions in the Survey of Working Arrangements and Attitudes:
 "How reliable is your internet connection?"
 "How does your efficiency working from home during the COVID-19 pandemic compare to your efficiency working on business premises before the pandemic?"
 "How much more [less] efficient have you been working from home during the COVID-19 pandemic than on business premises before the COVID-19 pandemic?"

Notes: The red lines show 95 percent confidence intervals. Data are from 38,250 survey responses collected from August 2020 to May 2021 by Inc-Query and QuestionPro.. We re-weight raw responses to match the share of working age respondents in the 2010-2019 CPS in each {age x sex x education x earnings} cell.

The regression approach might seem more familiar than the approach that relies on the self-assessed efficiency effects of better internet access. However, we see the self-assessment approach as superior, precisely because it relies on survey questions that seek to elicit a causal effect. In contrast, our regression-based approach to quantifying the causal productivity effects of better internet service relies on strong assumptions that might not hold.⁹ Accordingly, we focus on results that rely on self-assessment effects in the rest of the chapter.

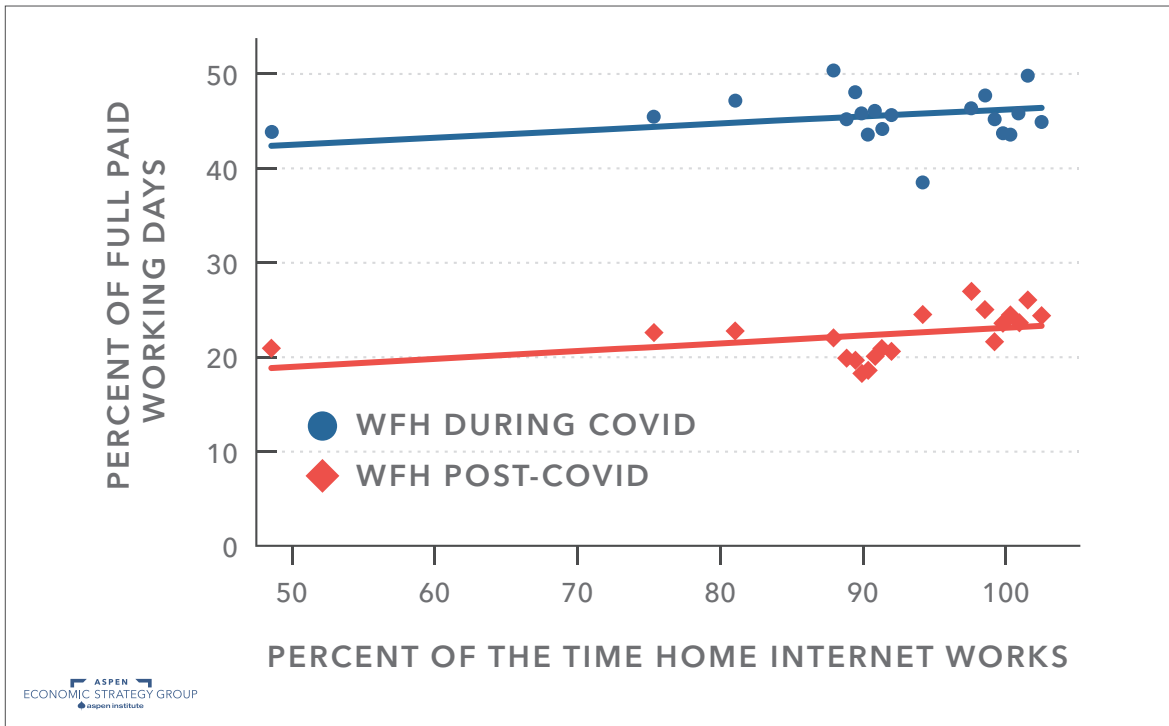
3.b. The response of WFH to universal access and knock-on productivity effects

Thus far, we have ignored any effect of home internet access quality (and availability) on the extent of WFH. If better access improves WFH efficiency, as our foregoing evidence strongly indicates, we expect universal access to increase the extent of WFH. The question is how much.

Figure 5 confirms that the extent of WFH rises with internet access quality conditional on the worker's earnings and industry of employment, which we interpret here as crude controls for the nature of the worker's job. The upper regression line and blue dots reflect data on reported levels of WFH during the pandemic as of the survey week. The lower regression line and red dots reflect employer plans for WFH in the post-pandemic economy, as reported by the worker. In both cases, a 10 percentage-point increase in the working availability of home internet access brings a 0.8 percentage-point increase in the extent of WFH. This effect is statistically significant but modest in size.

⁹ The slope coefficient on internet access quality has a causal interpretation only under strong assumptions, including the assumption that the variation in internet access quality is conditionally uncorrelated with omitted determinants of WFH efficiency.

Figure 5: How the incidence of WFH relates to internet access quality conditional on industry and earnings



Notes: Coef during COVID = 0.08 (0.03). Coef post-COVID = 0.08 (0.02) N = 24890. Controls for industry, survey wave FE, and 2019 earnings. 7/2020 and later survey waves.

Table 4 reports the estimated impact of universal access on the extent of WFH when we interpret the slope coefficients in these regressions as causal effects. The overall estimated impact on the extent of WFH—an increase of 0.7 percentage points—is quite modest both during and after COVID. The impact also varies little across demographic groups. Hence, when we account for the impact of universal access on the extent of WFH in the post-pandemic economy, our estimates for the aggregate labor productivity effects of universal access barely budge. This point can be seen by comparing the results in columns (2) and (3) of Table 3.

Table 4: Extra WFH induced by universal access during and after the COVID-19 pandemic

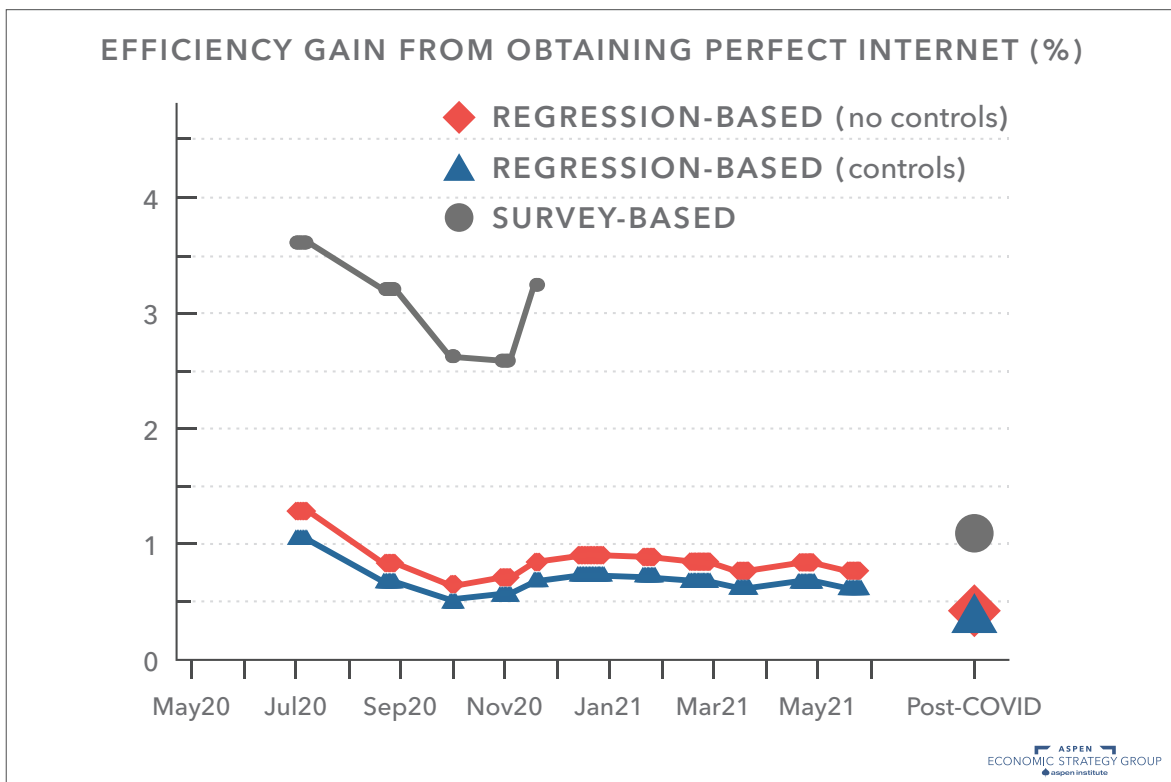
Increase in percent of full paid days WFH induced by universal access to perfect high-speed internet	During COVID	After COVID
Overall	0.7	0.7
Women	0.7	0.8
Men	0.6	0.7
Age 20 to 29	0.7	0.8
Age 30 to 39	0.6	0.7
Age 40 to 49	0.7	0.7
Age 50 to 64	0.7	0.8
Ann. Earnings of \$20 to \$50K	0.8	0.8
Ann. Earnings of \$50 to \$100K	0.6	0.7
Ann. Earnings of \$100 to \$150K	0.6	0.6
Ann. Earnings over \$150K	0.4	0.5
Less than high school	0.8	0.8
High school	0.8	0.9
1 to 3 years of college	0.7	0.8
4-year college degree	0.6	0.7
Graduate degree	0.6	0.6

Notes: Estimated percent of full paid WFH days are 45.4 during COVID and 22.2 post-COVID. Average increase in percent of WFH days are based on a regression and imputation method that estimates the relationship between WFH days and internet quality with controls for 2019 earnings and industry of the current or most recent job. We multiply the slope coefficient by the increase in internet reliability that takes each respondent to 100% reliable internet. The sample includes respondents who are working during COVID. Data are from over 40,000 survey responses collected between May 2020 and May 2021 by Inc-Query and QuestionPro. We reweight raw responses to match the share of working age respondents in the 2010-2019 CPS in a given {age x sex x education x earnings} cell.

3.c. Assessing the estimated productivity and output effects

Figure 6 summarizes our results on the aggregate labor productivity effects of universal access. The “Post-COVID” data points are from column (2) in Table 3. The other data points trace out our estimates for the productivity shortfall caused by subpar internet access during the pandemic. The magnitude of the shortfall ranges from 2.6 to 3.6% for the self-assessment approach, fluctuating over time with the extent (and cross-sectional distribution of) WFH during the pandemic. The smaller 1.1% gain that we estimate for the causal effect of universal access in the post-COVID economy reflects a lower incidence of WFH.

Figure 6: Earnings-weighted productivity gains from universal access to high-quality, reliable home internet service



Notes: Adjusts for each respondent’s amount of WFH during COVID and employer plans post-COVID. Data are from over 40,000 survey responses collected from July 2020 to May 2021 by Inc-Query and QuestionPro. We re-weight raw responses to match the share of working age respondents in the 2010- 2019 CPS in each {age x sex x education x earnings} cell.

As remarked in the introduction, we can use these labor productivity estimates and a standard aggregate production function to derive implications for aggregate output. In particular, we work with a production function that exhibits constant returns to scale and a value of two-thirds for the elasticity of output with respect to labor services. Given this production function, and holding fixed the values of

non-labor inputs, a 1.1% improvement in labor productivity implies an aggregate output gain of 0.73% ($= (1.011)^{2/3} - 1$) per period in the post-pandemic economy.¹⁰ Similarly, a 3% labor productivity shortfall due to subpar internet access implies an aggregate output loss of 2% during the pandemic. In other words, the flow output loss during the pandemic is nearly three times as large as the projected flow benefits from universal access in the post-COVID economy. This comparison underscores the economic resilience value of universal access: the output payoff is much larger in pandemic-like disaster states when output is unusually low and the marginal value of output is unusually high.

Our estimates for the impact of universal access on productivity and output could be biased for various reasons. As explained above, we may under sample persons who lack home internet access. Moving to universal access would be a very large change for persons who currently lack access. Thus, if our sample is selected against those who currently lack access, it may downwardly bias our estimated productivity effects. Perhaps, however, under-represented persons have smaller productivity responses to better internet service because their jobs offer less scope for WFH. This effect cuts the other way. In any event, persons with no internet access tend to have low earnings and productivity. Thus, a given percentage change in their productivities would have relatively modest effects on earnings-weighted mean productivity. In light of these observations, we think sample selection against persons who lack home internet access is a small concern in our analysis of aggregate productivity and output effects.

Two other sources of bias strike us as potentially more important. First, insofar as pandemic-related stresses, the presence of kids at home due to school closures, a lack of familiarity with remote work technologies, and other forces pull down WFH productivity *during* the pandemic, our regression models understate the likely strength of any relationship between the relative efficiency of WFH to internet access quality *after* the pandemic. To a lesser extent, this point also applies to our estimated individual-level productivity effects under the self-assessment approach. For example, an initial lack of familiarity with remote work technologies may pull down the self-assessed impact of better internet service on the relative efficiency of WFH. Such transitory negative effects on WFH productivity during the pandemic lead us to understate WFH efficiency in the post-pandemic economy and, hence, to understate the productivity and output benefits of universal access in a post-pandemic setting.

¹⁰ See Kessler et al. (2021) for an assessment of how better internet access would affect output and economic development in one Tennessee county. Zuo (2021) provides evidence that subsidizing internet access raises employment and earnings among low-income Americans.

Second, we have no data on the relative efficiency of WFH for respondents with no WFH experience during the pandemic (as of the survey date). That's 43.3% of respondents on an equal-weighted basis and an estimated 34.2% on an earnings-weighted basis.¹¹ Thus, the Table 3 and Figure 6 estimates rest on an implicit assumption that persons with no WFH experience during the pandemic have the same average productivity responsiveness to better internet service as persons in the analysis sample. If excluded persons disproportionately hold jobs that are poorly suited for WFH, which seems likely, their exclusion leads us to overstate the effects of universal access on productivity and output.

A few additional observations are helpful in thinking about the potential effects of universal access on future productivity and output. First, we expect the structure of the economy to continue evolving in ways that expand opportunities for remote work. Examples include greater remote service delivery by health care professionals, social workers, educators, and customer-service staff in government agencies, all of which shifted to greater remote work in reaction to the pandemic. Even activities as seemingly unsuitable as operating oil and gas wells are seeing a shift to remote workers (Jiao and Tovar 2020). Looking across countries, Hatayama et al. (2020) find a strong positive relationship between GDP per capita and the extent to which jobs in the country are amenable to WFH. In light of these observations, it seems likely that the flow productivity and output benefits of universal access will rise over time.

Advances in complementary technologies is another reason to expect the flow benefits of universal access to rise over time. In this regard, Bloom, Davis, and Zhestkova (2021) find that the pandemic drove a rise in the share of new U.S. patent applications that advance technologies in support of video conferencing, telecommuting, and remote interactivity. This finding suggests that a redirection of technical change in reaction to COVID-19 and a persistent shift to WFH will raise the quality and efficiency of remote work in the future. Insofar as complementary technologies improve, universal access is likely to have larger payoffs.

3.d. Earnings inequality

Since the foregoing productivity analyses are built up from micro data, we can easily consider the implications of universal access for the distribution of individual-level productivities. If, in addition, we assume that individual earnings are proportional to productivities in the cross section, we can estimate the consequences of universal access for the distribution of earnings. Clearly, the proportionality assumption is only an approximation, but we regard it as a useful and transparent one.

¹¹ To derive the earnings-weighted estimate, we assign respondents to the midpoints of their 2019 earnings bins (or \$1 million for the top bin of \$500,000 or more).

Applying this assumption, we estimate that universal access would raise earnings by 1% for persons who earned \$20,000–50,000 in 2019, 1.2% for those who earned \$50,000–100,000, 1.3% for those who earned \$100,000–150,000, and 1.1% for those who earned more than \$150,000 in 2019. These estimates reflect employer plans for who will work from home in the post-pandemic economy, how much, and self-assessed productivity effects of better internet service. The proportional earnings gains are smaller at the bottom end, because low-wage jobs offer little scope for WFH. In short, moving to universal access would not materially affect earnings inequality according to our analysis.

Table 5 reports estimated productivity effects of universal access for demographic and other groups. Here as well, our projections imply that universal access would have modest effects on the (log) earnings distribution. Using the self-assessment approach, we find the smallest estimated effect of universal access for persons who did not finish high school (0.3%) and the largest for persons with a four-year college degree (1.4%).

Table 5: Efficiency gains from universal access to high-quality internet by group

Efficiency gain from perfect high-speed internet post-COVID (adjusted for the amount of WFH post-COVID)	Self-assessed
Overall	1.1
Women	1.1
Men	1.0
Age 20 to 29	1.2
Age 30 to 39	1.3
Age 40 to 49	1.1
Age 50 to 64	0.7
Less than high school	0.3
High school	0.7
1 to 3 years of college	1.1
4-year college degree	1.4
Graduate degree	1.0
Ann. Earnings of \$20 to \$50K	1.0
Ann. Earnings of \$50 to \$100K	1.2
Ann. Earnings of \$100 to \$150K	1.3
Ann. Earnings over \$150K	1.1
Goods-producing sectors	0.8
Service sectors	1.1
No children	0.9
Living with children under 18	1.2
Red (Republican-leaning) State	1.0
Blue (Democrat-leaning) State	1.1

Notes: Average WFH efficiency gain post-COVID from universal access to high-quality internet, based on responses to "How much would your efficiency working from home increase if you had perfect high-speed internet?" The sample includes respondents who responded to the self-assessment question and the question about how much their employer is planning for them to work from home, except those who said they have no employer. For each respondent we multiply the potential efficiency gain from perfect internet by the fraction of working days their employer is planning for them to be WFH post-COVID. Data are from over 40,000 survey responses collected between May 2020 and May 2021. We reweight raw responses to match the share of working age respondents in the 2010-2019 CPS in a given {age x sex x education x earnings} cell.

4. Internet access and subjective well-being during the pandemic

That loneliness is negatively associated with physical and mental health is well documented in the psychology literature. As remarked in the opening paragraph of a highly cited article by Holt-Lunstad et al. (2015), “Being socially connected is not only influential for psychological and emotional well-being but it also has a significant and positive influence on physical well-being and overall longevity.” Similarly, a highly cited article by Thoits (2011) opens by remarking, “Substantial evidence has accumulated over the past few decades showing that social ties and social support are positively and causally related to mental health, physical health, and longevity.... Evidence also documents that social support buffers the harmful physical and mental health impacts of stress exposure.”

This body of evidence suggest that social distancing during the pandemic and pandemic-related stresses had negative health effects for many Americans.¹² It also motivates the hypothesis that better internet access during the pandemic alleviated the harmful psychological and other health effects of social distancing and pandemic-related stresses. Consistent with this hypothesis, Wallinheimo and Evans (2021) find higher life quality and lower depression scores for middle-age and older Americans who used the internet more often during June and July 2020. These positive associations were concentrated among people who used the internet mainly for communication, while those who used it for government or health-related searches experienced more depression symptoms. Varma et al. (2021) find that younger people were particularly vulnerable to stress, anxiety, and depression during the pandemic. Suicides and internet queries about suicide fell during the pandemic, contrary to concerns when lockdowns were first implemented. See, for example, Ahmad et al. (2021), Ayers et al. (2021), and Sinyor et al. (2020). Ability to connect over the internet may be one reason why suicides did not rise during the pandemic.

Other studies point to a broader potential for internet use and social media to be sources of harmful effects on well-being. See, for example, Alcott et al. (2021), Servidio et al. (2021), and Elhai et al. (2020). We do not aim to assess the overall effects of internet usage on well-being. Our much more limited objective is to provide evidence as to whether better internet access is associated with positive effects on well-being during a period with sharply restricted in-person interactions. The effects of better internet access during normal periods may well be different. Also, in contrast to most other studies, we examine the relationship of well-being to internet *access quality*

¹² Indeed, U.S. drug-overdose deaths rose nearly 30% in 2020 to a record high level (McKay 2021). The rise was especially sharp from March 2020, which coincides with the onset of the pandemic in the United States, lockdowns, and social isolation.

rather than internet *usage* or *usage patterns*. Access quality is arguably more exogenous with respect to well-being than usage intensity or usage patterns.

To quantify subjective well-being among SWAA respondents, we ask the following question: “Please imagine a ladder with steps numbered from zero at the bottom to ten at the top. The top of the ladder represents the best possible life for you and the bottom of the ladder represents the worst possible life for you. If the top step is ten and the bottom step is zero, on which step of the ladder do you feel you personally stand at the present time?” We multiply the responses by ten to put them on a scale that runs from zero to 100.

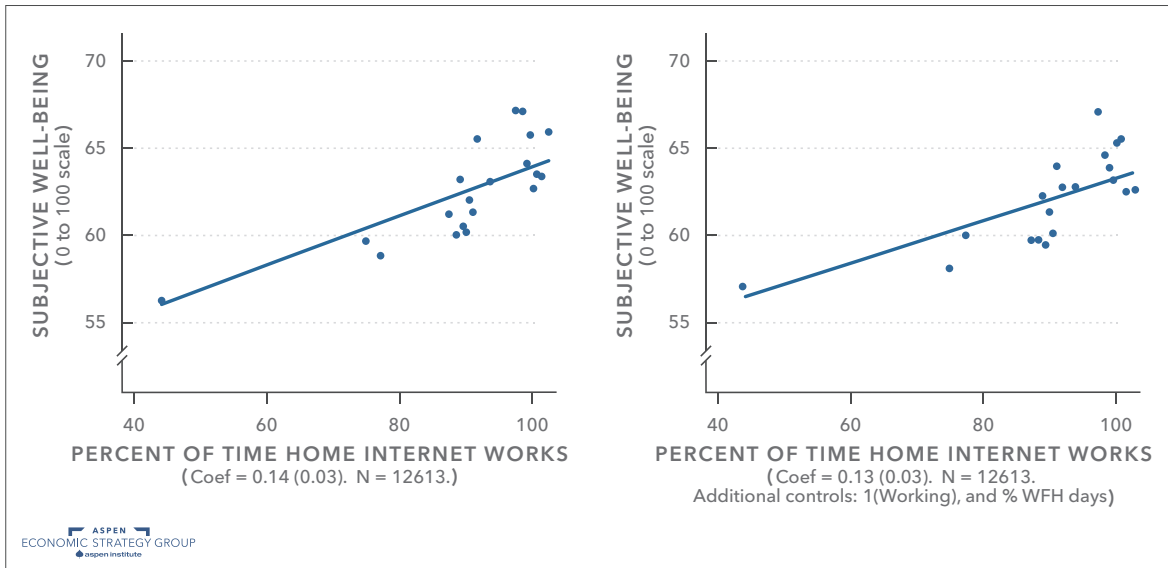
Figure 7 presents binned scatter plots of subjective well-being against the percent of time that the respondent’s home internet service works. The left plot controls for gender, years of education, our four age bins, the log of 2019 earnings, whether the respondent lives with other adults, whether he or she lives with children, and whether the respondent lives with a partner. The slope coefficient of 0.14 says that a 10 percentage-point increase in internet availability is associated with a 1.4 percentage-point higher value of well-being. The right plot, which adds controls for employment status and working arrangements, yields a very similar relationship.

Appendix Table A.4 considers more flexible statistical models and extra controls. One additional result is that employed persons enjoy substantially higher well-being.¹³ Controlling for other factors, the improvement in subjective well-being associated with working is more than one-third as large as the standard deviation of well-being in the sample.¹⁴ For those who work, well-being is higher for persons who work from home a larger percentage of the week. Perhaps surprisingly, we find little evidence that the association of well-being with internet access quality is weaker for persons living with a partner or other adult.

13 In line with a large body of evidence that job loss and unemployment bring sizable declines in subjective well-being (Frey and Stutzer 2002). To see this point, recall that the SWAA sample is limited to persons who earned at least \$20,000 in 2019. Thus, SWAA respondents who are jobless in the survey week recently had jobs but became unemployed or left the labor force.

14 See the coefficient of 8.2 in Column (6) of Table A.4.

Figure 7: How subjective well-being relates to internet access quality during the pandemic



Notes: Binned scatter plots of subjective well-being against internet quality. Both specifications control for gender, years of education, log(2019 earnings), age bin FE, whether living with other adults, whether living with children, and whether living with a partner. Subjective wellbeing is 10 times the response to the following question:

“Please imagine a ladder with steps numbered from zero at the bottom to ten at the top. The top of the ladder represents the best possible life for you and the bottom of the ladder represents the worst possible life for you. If the top step is 10 and the bottom step is 0, on which step of the ladder do you feel you personally stand at the present time?”

Data are from over 40,000 survey responses collected between May 2020 and May 2021 by Inc-Query and QuestionPro. We reweight raw responses to match the share of working age respondents in the 2010–2019 CPS in a given {age x sex x education x earnings} cell. Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Returning to the link between well-being and access quality, our preferred model says that moving from no home internet service to 100% reliable service is associated with a 15 percentage-point improvement in subjective well-being.¹⁵ That’s two-thirds as large as the standard deviation of well-being in the sample. Interpreted causally, this result says that universal access would materially improve well-being during pandemic-like disasters for persons who currently lack home internet service. Smaller improvements in well-being would accrue to persons who currently have subpar access.

5. Universal access as a source of economic and social resilience

By raising output in the face of infectious disease outbreaks, biological attacks, and other disaster states that involve physical social distancing, universal access to high-

¹⁵ Using column (6) in Table A.4.

quality home internet service would strengthen U.S. economic resilience. For society as a whole and for individual firms and workers, the capacity to quickly switch between production modes of roughly equal productivity is a valuable option that pays off especially in bad states of the world. Firm-level examples include contamination events, flood damage, explosions, and destructive fires that temporarily sideline the employer premises as a place of work. At the macroeconomic level, our analysis says that the output payoff to universal access during pandemic-like disasters is nearly three times as large as the payoff during normal periods. Our evidence also suggests that universal access promotes resilience by providing a ready means of engagement and socializing when circumstances compel physical distancing.

Universal access has other important benefits that we do not quantify, and that are likely to be especially valuable during pandemic-like disasters. For example, better internet access improves the ability of households to turn to online shopping and home delivery services during a pandemic-like disaster. As another example, Chiou and Tucker (2020) find that compliance with stay-at-home orders during the COVID-19 pandemic rose with access to high-speed internet service, even after controlling for household income. As a third example, better internet access promotes student engagement in remote-learning settings. Obviously, the value of remote learning is greater when a pandemic or other disaster leads to school closures. Using data from the early stages of the COVID-19 pandemic, Sen and Tucker (2020) find that areas with lower test scores, more poor children, and more non-White children faced greater problems with internet access. Thus, universal access may ameliorate the gap in learning opportunities between children from more and less advantaged families.

In sum, high-quality home internet access and complementary technologies enhance economic and social resilience in the face of pandemics and certain other disasters that inhibit travel and in-person interactions. In this regard, we note that there are sound reasons to fear that the SARS-CoV-2 virus “will ping pong back and forth across the globe for years to come,” triggering recurrent outbreaks of COVID-19 (Brilliant et al. 2021). If that somber possibility materializes, the value of high-quality home internet access will be even greater than our analysis suggests. That said, we recognize that internet access is not a general-purpose source of resilience in the face of all disasters. For example, extended electricity outages over a large area would prevent most people in the area from accessing the internet to work, socialize, or study remotely. Cyberattacks that disable the electrical power grid or the internet itself would be hugely disruptive in any event, and possibly more disruptive insofar as the economy is highly adapted to remote work. As this remark suggests, widespread reliance on the internet and remote work can intensify other vulnerabilities.

6. Conclusion

The COVID-19 pandemic triggered a huge shift to working from home, and much of that shift will endure. Using our forward-looking survey data, we project that more than one-quarter of earnings-weighted workdays will be supplied from home after the pandemic ends.

Motivated by these developments, we examine data on how internet access quality affects productivity when working from home. According to our analysis, moving to high-quality, fully reliable home internet service for all Americans would raise earnings-weighted labor productivity by an estimated 1.1% in the coming years. The implied output gains are \$160 billion per year, or \$4 trillion when capitalized at a 4% rate. Estimated flow output payoffs to universal access are nearly three times as large in COVID-like disaster states. Better home internet service during the pandemic is also associated with greater subjective well-being, conditional on employment status, working arrangements, and a battery of other controls. The extra economic and social benefits of universal access during the pandemic underscore its resilience value in the face of disasters that inhibit travel and in-person interactions.

We express our main quantitative results as the benefits of moving to universal access, but the underlying empirical analysis rests on linear models and relationships. Thus, closing half the gap between universal access and the current household distribution of internet access quality has, according to our analysis, productivity and output effects that are half as large. This feature of our analysis simplifies a comparison of the benefits to the costs of better home internet access. There is an obvious need to quantify these costs to inform judgments about the wisdom of moving part or all the way to universal access. We hope that our work encourages a study of the cost side as well as further examinations of the benefits. We also hope to encourage additional research into sources of economic and social resilience in the face of disasters, which we see as an important but understudied topic.

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Appendix

Table A.1.: What predicts high-quality internet?

Dependent variable	Percent of the time home internet works									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
log(Population Density of Zipcode of Residence)	1.38*** (0.15)	1.20*** (0.15)	1.11*** (0.16)	1.11*** (0.16)	1.24*** (0.16)	1.31*** (0.19)	1.26*** (0.19)	1.22*** (0.19)		
log(2019 Earnings)		1.42*** (0.16)	0.99*** (0.16)	0.96*** (0.16)	0.87*** (0.16)	0.92*** (0.16)	0.90*** (0.16)	0.93*** (0.16)		
Years of education			0.85*** (0.20)	0.84*** (0.20)	0.82*** (0.20)	0.83*** (0.20)	0.77*** (0.20)	0.80*** (0.20)		
I(Children under 18)					0.50* (0.28)	0.58** (0.27)	0.53* (0.28)	0.49* (0.27)		
I(Minority)					-1.16*** (0.31)	-0.88*** (0.31)	-0.78** (0.31)		-0.83*** (0.31)	
Black or African-American									-0.03 (0.47)	-0.17 (0.45)
Hispanic or Latino/a (of any race)									0.00 (0.50)	-0.25 (0.52)
Asian									-1.78*** (0.54)	-1.19*** (0.55)
Native American or Alaska Native									-3.31*** (1.03)	-3.50*** (1.08)
Native Hawaiian or Pacific Islander									-8.36*** (2.05)	-9.25*** (2.10)
Other									-2.04*** (0.92)	-2.24*** (0.94)
State FE						Y		Y		
Industry of current/most recent job FE							Y		Y	
Dependent variable mean	90.24	90.24	90.24	90.24	90.24	90.24	90.24	90.24	90.24	90.24
Observations	30,646	30,646	30,646	30,646	30,646	30,646	30,646	30,646	30,646	30,646
R-squared	0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.03	0.00	0.00

Note: We standardize continuous explanatory variables to mean zero and unit standard deviation so the coefficients reflect a one-standard deviation change.

Table A.2.: How the self-assessed efficiency gains from “perfect high-speed internet” services relate to observables in the SWAA data

Dependent variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Efficiency increase from getting perfect internet (self-assessed)									
log(Population Density of Zipcode of Residence)	0.30*** (0.10)	0.26*** (0.10)	0.20** (0.10)	0.20** (0.10)	0.15 (0.10)	0.16 (0.11)	0.15 (0.11)	0.16 (0.11)		
log(2019 Earnings)		0.27*** (0.09)	0.02 (0.11)	-0.03 (0.11)	0.01 (0.11)	0.01 (0.11)	0.02 (0.11)	0.03 (0.11)		
Years of education			0.49*** (0.11)	0.48*** (0.11)	0.49*** (0.11)	0.49*** (0.11)	0.42*** (0.10)	0.41*** (0.10)		
1(Children under 18)				0.49*** (0.18)	0.49*** (0.18)	0.49*** (0.17)	0.48*** (0.17)	0.47*** (0.17)		0.43** (0.20)
1(Minority)					0.48** (0.20)	0.45** (0.20)	0.48** (0.20)			
Black or African-American								0.08 (0.27)		-0.08 (0.27)
Hispanic or Latino/a (of any race)								0.64*** (0.32)		0.66** (0.32)
Asian								1.03*** (0.40)		1.28*** (0.39)
Native American or Alaska Native								0.97 (0.66)		0.55 (0.79)
Native Hawaiian or Pacific Islander								0.57 (0.83)		0.64 (0.76)
Other								0.99 (0.94)		0.83 (0.92)
State FE						Y	Y	Y		
Industry of current/most recent job FE							Y	Y		
Dependent variable mean	2.61	2.61	2.61	2.61	2.61	2.61	2.61	2.61	2.61	2.61
Observations	7,179	7,179	7,179	7,179	7,179	7,179	7,179	7,179	7,179	7,179
R-squared	0.00	0.00	0.01	0.01	0.02	0.03	0.04	0.04	0.00	0.00

Note: We standardize continuous explanatory variables to mean zero and unit standard deviation, so the coefficients reflect a one-standard deviation change.

Table A.3.: Regression models for the relative efficiency of WFH

Dependent variable	Relative efficiency of WFH						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Internet quality	2.53*** (0.22)	2.29*** (0.22)	2.25*** (0.22)	2.25*** (0.22)	2.25*** (0.22)	2.20*** (0.22)	2.04*** (0.22)
log(Earnings)		2.24*** (0.19)	1.97*** (0.19)	1.79*** (0.19)	1.73*** (0.19)	1.72*** (0.19)	1.36*** (0.19)
Years of education			0.57** (0.23)	0.58*** (0.22)	0.57*** (0.22)	0.55** (0.22)	0.69*** (0.24)
1 (Male)				0.35 (0.33)	-0.88* (0.48)	-0.92* (0.48)	-1.24** (0.49)
1 (Children under 18)				1.70*** (0.33)	0.32 (0.43)	0.35 (0.43)	0.43 (0.43)
1 (Male) x 1 (Children under 18)				2.51*** (0.66)	2.41*** (0.65)	2.41*** (0.65)	1.84*** (0.65)
State FE						Y	Y
Industry (of current or most recent job) FE							
Dependent variable mean	4.93	4.93	4.93	4.93	4.93	4.93	4.93
Observations	22,237	22,237	22,237	22,237	22,237	22,237	22,237
R-squared	0.01	0.02	0.03	0.03	0.03	0.04	0.06

Note: We standardize continuous explanatory variables to mean zero and unit standard deviation so the coefficients reflect a one-standard deviation change. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A.4.: Regression models for the relationship of subjective well-being to internet access quality during the pandemic

Dependent variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Subjective well-being (0 to 100 scale)						
% time home internet works	0.14*** (0.03)	0.13*** (0.03)	0.12** (0.05)	0.12*** (0.03)	0.14*** (0.05)	0.15*** (0.04)	0.12*** (0.04)
x 1(Working)			0.02 (0.06)				
x 1(Working on business premises)				0.03 (0.02)			
x 1(Live with other adults)					-0.02 (0.05)		
x 1(Live with a partner)						-0.03 (0.05)	
x 1(Live with children under 18)							0.03 (0.05)
1(Working)		8.22*** (0.89)	6.26 (5.08)	8.23*** (0.89)	8.22*** (0.89)	8.22*** (0.89)	8.22*** (0.89)
% WFH days in the current week		0.03*** (0.01)	0.03*** (0.01)	0.05** (0.02)	0.03*** (0.01)	0.03*** (0.01)	0.03*** (0.01)
Controls for gender, years of education, log(2019 earnings), age bin FE, whether living with other adults, or with children, and whether living with a partner	Y	Y	Y	Y	Y	Y	Y
Dependent variable mean	62.6	62.6	62.6	62.6	62.6	62.6	62.6
Dependent variable SD	23.5	23.5	23.5	23.5	23.5	23.5	23.5
Observations	12,613	12,613	12,613	12,613	12,613	12,613	12,613
R-squared	0.08	0.10	0.10	0.10	0.10	0.10	0.10

Note: We regress subjective wellbeing on self-reported internet quality and the respondent's working and living situation. Subjective wellbeing is ten times the response to the following question: "Please imagine a ladder with steps numbered from zero at the bottom to ten at the top. The top of the ladder represents the best possible life for you and the bottom of the ladder represents the worst possible life for you. If the top step is 10 and the bottom step is 0, on which step of the ladder do you feel you personally stand at the present time?" Internet quality is based on a question of "How reliable is your internet connection?" Data are from over 40,000 survey responses collected between May 2020 and May 2021 by Inc-Query and QuestionPro. We reweight raw responses to match the share of working age respondents in the 2010–2019 CPS in a given {age x sex x education x earnings} cell. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.