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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.

Key words: home internet access, productivity, Covid-19, wellbeing

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1. Introduction

Americans supplied half or more of paid workdays from home in spring 2020, ten times the pre-COVID share. They continued to supply more than forty percent 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 paper. 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 including 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 in the post-pandemic economy will boost productivity by 4.6 percent relative to the pre-pandemic situation.² The main source of this

¹ Barrero, Bloom and Davis (2020), 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.

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

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 paper, 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 percent. 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 percent boost in labor productivity implies flow GDP gains of \$160 billion per year, or a present value gain of \$4 trillion at a four percent 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 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.

of working arrangements. To be sure, the pandemic may have additional productivity consequences, positive and negative, through other channels.

Internet access quality was more consequential during the pandemic, because WFH accounted for a larger share of labor services. For the period from May 2020 to April 2021, we estimate that subpar internet access degraded earnings-weighted productivity by 3.0 percent. 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 percent below its pre-pandemic trend in the second quarter of 2020 and about 4.5 percent 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 effects on well-being, our evidence suggests that home internet access mitigates the negative health effects of loneliness and social isolation in a time of pervasive social distancing, and that better access does so to a greater extent.

Before proceeding, we note some limitations of our data and analysis. First, our SWAA sample may underrepresent persons who lack home internet access, leading us to misstate the impact of universal access. Second, we rely on worker assessments of productivity in gauging the consequences of universal access.⁴ Employer assessments may differ. Third, our projections

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

⁴ BBD show that the self-assessed productivity effects of WFH align reasonably well with less subjective measures based on commuting time savings. They also find that desired and planned levels of WFH in the post-pandemic economy rise strongly with the self-assessed relative productivity of WFH. These results give us confidence that our productivity data are meaningful.

neglect static general equilibrium effects. For example, suppose universal access encourages more WFH and thereby drives down the cost of office space in city centers. In turn, cheaper office space could moderate the induced shift to remote work. We think equilibrium effects of this sort are likely to be quite small, especially given the very modest size of our estimate for how universal access would affect the extent of WFH. Fourth, our projections ignore dynamic effects. These could flow from technological advances that promote WFH over time (Bloom, Davis and Zhestkova, 2021) or the longer-term consequences of universal access itself, which could prompt changes in job design that facilitate remote work.⁵ These dynamic effects could be important, but they are also hard to project. Finally, we are silent about costs, which are surely relevant to judgements about the desirability of moving to universal access.

2. Working Arrangements, Productivity, and Internet Access in the Cross Section

2.a. The Survey of Working Arrangements and Attitudes

We have fielded the SWAA since May 2020, collecting 2,500 to 5,000 responses per month. Each survey wave contains 40 to 55 questions on demographics, employment status, working arrangements, earnings, commuting, internet access, expectations and experiences related to WFH, perceptions, and more. Our focused questions and large sample size give us an unparalleled window into the WFH phenomenon during the pandemic and let us make data-based projections for the post-pandemic US economy.⁶

The SWAA target population covers U.S. residents, 20-64 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

⁵ As one example, doctors and patients report that the use of video conferencing to discuss test results and conduct routine follow-up consultations can be more efficient and convenient than in-person visits. Universal access facilitates this type of remote healthcare delivery, which makes it more practical for healthcare professionals to work remotely.

⁶ See Barrero, Bloom and Davis (2021a) for the full set of questions. Our data are available to other researchers at www.WFHresearch.com, and we continue to field the SWAA and update the website about once a month. We do not collect personally identifiable information, do not contact respondents directly, and have no way to re-contact them.

⁷ Following best practice for surveys of this type, we drop persons who complete the survey in less than 2 minutes in May, less than 3 minutes in the July to November 2020 waves, and less than 5 minutes in later waves. Given the nature and number of our survey questions, these “speeders” are unlikely to supply careful responses. After

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 paper, 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 a mobile device that does not require home internet access or using wifi internet outside the home (for example their workplace during a break). 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

After COVID, in 2022 and later, how often is your employer planning for you to work full days at home?

- *Never*
- *About once or twice per month*
- *1, 2, 3, 4, or 5+ days per week* [separate options for each]
- *My employer has not discussed this matter with me or announced a policy about it*
- *I have no employer*

In constructing our projections, we drop persons with no employer in the survey week. We assign zeros to “Never” and “About once or twice per month,” 20 percent for 1 full day per week WFH, 40 percent for 2 full days, and so on. We also assign zeros to “My employer has not discussed this matter with me ...” on the view that employers are unlikely to raise the matter with workers in jobs for which WFH is impractical or infeasible. See BBD on how we estimate the extent of WFH before and during COVID and comparisons to results from other surveys.

dropping speeders, which cuts the sample about 20 percent, median completion time ranges from 3 minutes and 10 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.

Table 1. Working from home before, during, and after the Covid-19 pandemic

Percent of full paid days worked from home					
	Pre-COVID	During COVID		Post-COVID	
Equal-weighted	4.8	47.4	(0.3)	21.9	(0.3)
Earnings-weighted	--	54.4	(0.3)	27.7	(0.3)

Percent of full paid days worked from home					
Education	During COVID		Post-COVID		
Less than high school	24.6	(2.8)	12.8	(2.3)	
High school	32.0	(0.7)	15.5	(0.6)	
1 to 3 years of college	40.4	(0.6)	18.6	(0.5)	
4-year college degree	57.9	(0.5)	27.2	(0.5)	
Graduate degree	63.4	(0.4)	30.7	(0.5)	

Notes: The pre-COVID estimate for the extent of working from home relies on data from the 2017-2018 American Time Use Survey, as described in Barrero, Bloom, and Davis (2021). Estimates for “During COVID” rely on data from the May 2020 through May 2021 waves of the Survey of Working Arrangements and Attitudes (SWAA). Estimates for “Post-COVID” rely on worker responses to questions about employer plans in the six most recent waves of the SWAA, namely December 2020 to May 2021. We re-weight raw responses in the SWAA to match the share of working-age respondents in the 2010-2019 CPS in each {age x sex x education x earnings} cell. Standard errors in parentheses.

As reported in Table 1, we project that WFH will account for 21.9 percent of full paid workdays in the post-pandemic economy, 27.7 percent on an earnings-weighted basis. The higher earnings-weighted figure reflects the strongly positive cross-sectional relationship between the extent of WFH and worker earnings. WFH also rises strongly with educational attainment, as seen in the lower panel. In contemplating these figures, recall that our target population is persons 20-64 who earned at least \$20,000 in 2019. Thus, we under sample low-wage and part-time workers, who tend to be concentrated in Food Services, Retail Trade, and other industries with lesser scope for WFH. For this reason, our results may overstate the equal-weighted WFH share in the post-pandemic economy. This feature of our sample matters little for earnings-weighted results.

2.c. The Relative Productivity of Working from Home

To assess the relative productivity of WFH, the SWAA puts the following question to all persons who report WFH at some point during the pandemic:

How does your efficiency working from home during the COVID-19 pandemic compare to your efficiency working on business premises before the pandemic?

- Better -- I am more efficient at home than I was working on business premises
- About the same -- I'm equally efficient in both places
- Worse -- I am less efficient at home than I was working on business premises

For those who respond “Better” [“Worse”], we follow up with:

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?

Response options are: *Under 5% more [less] efficient; 5 to 10% more [less] efficient; 10 to 15% more [less] efficient; 15 to 25% more [less] efficient; 25 to 35% more [less] efficient; and Over 35% more [less] efficient.*

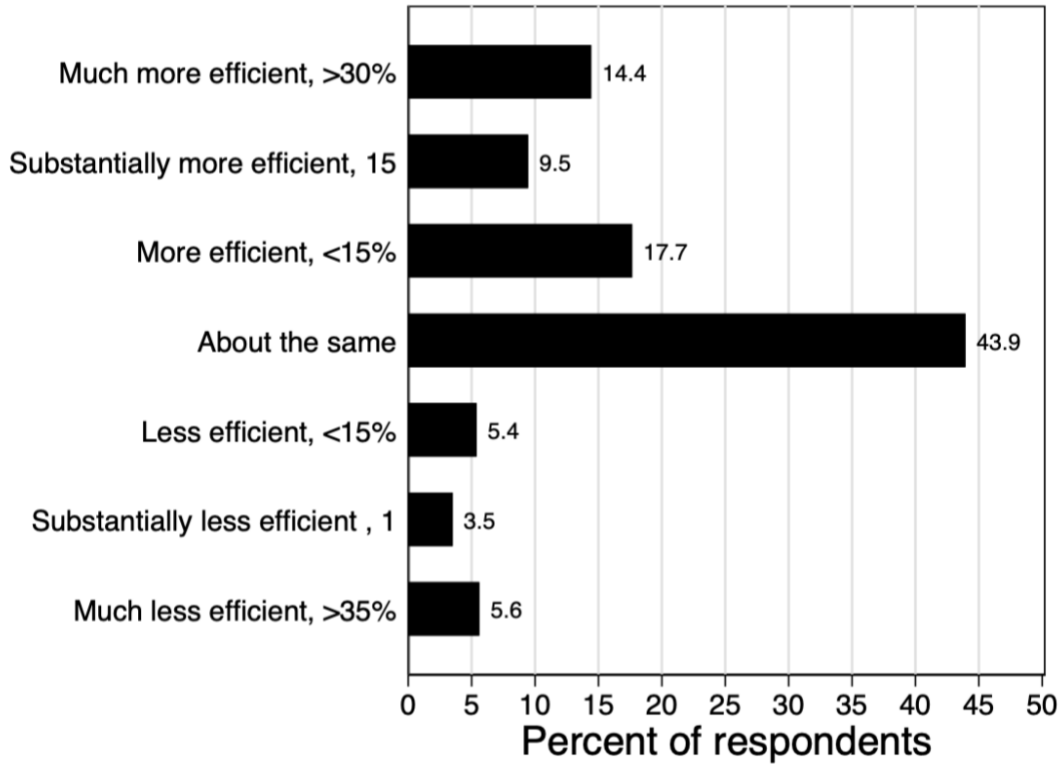
As seen in Figure 1, 44 percent of respondents say that WFH is about as productive as working on employer premises. The balance of the other 56 percent tilts toward greater productivity when WFH. That is, the average worker reports greater productivity when WFH. As shown in BBD, the planned extent of WFH in the post-pandemic economy rises strongly with the relative productivity of WFH. Thus, the productivity boost generated by a shift to WFH in the post-pandemic economy reflects a combination of higher productivity when WFH for many workers *and* the selected nature of who works from home in the post-pandemic economy.

Putting the various pieces of information together, BBD estimate that the post-pandemic shift to WFH will drive an earnings-weighted productivity gain of 4.6 percent relative to the situation with pre-pandemic working arrangements. This gain arises mainly from the savings in commuting time afforded by more WFH. Because they do not account for commuting time, conventional measures of productivity will show a smaller gain. Indeed, when BBD mimic conventional measures, they project that the re-optimization of working arrangements in the post-pandemic economy will boost measured productivity by only 1.0 percent.

2.d. The Cross-Sectional Distribution of Home Internet Access Quality

Figure 2 displays the distribution of home internet access quality based on responses to the question, “How reliable is your internet connection?” About 41 percent of SWAA respondents say they have “perfect” home internet service that “works 100% of the time.” Another 43 percent say their home internet service works “90% of the time,” 12 percent say it works “70% to 80% of the time,” 2 percent say less than “70% of the time,” and 2.5 percent have no home internet connection.

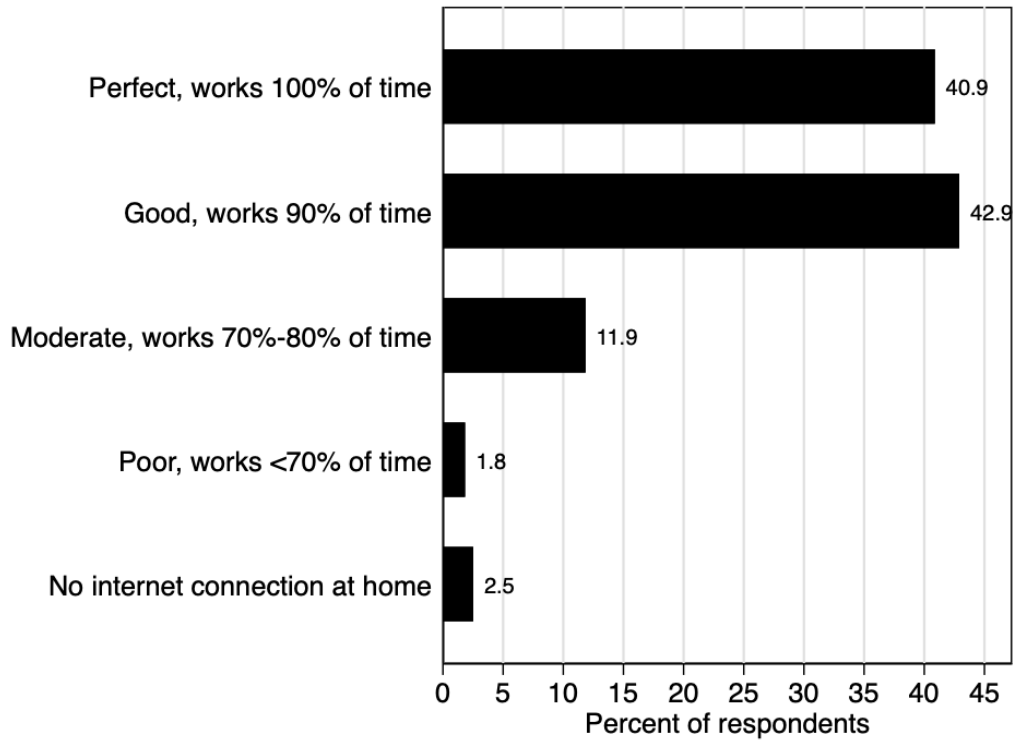
Figure 1. Efficiency of WFH vs. working on business premises



Source: Responses to the question, “How does your efficiency working from home during the COVID-19 pandemic compare to your efficiency working on business premises before the pandemic?”

Notes: Data are from 38,250 survey responses collected from August 2020 to May 2021 by Inc-Query and QuestionPro. We asked a similar question in earlier waves but focus on August 2020 to May 2021 when we kept the question and response options consistent. 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.

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 percent, meaning that home internet service works about 89 percent 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 percent. 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.

Table 2. Average internet access quality by group

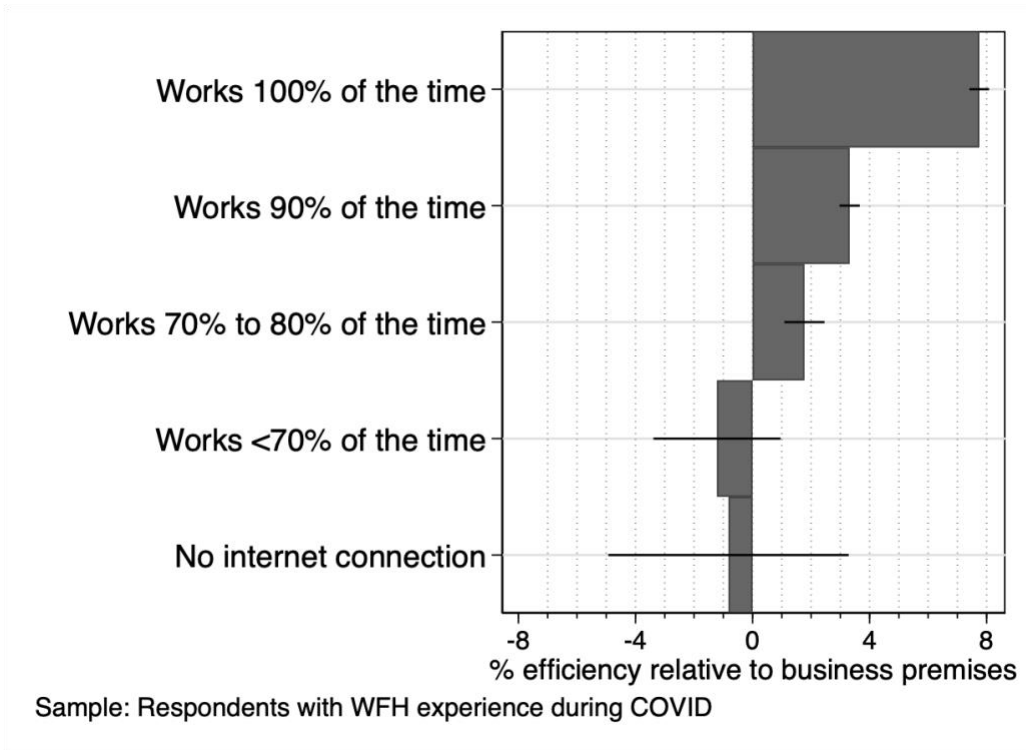
Percent of the time the internet works	Equally-weighted mean (SE)		Mean weighted by number of children (18 & under) in the household (SE)		Percent of the time the internet works	Equally-weighted mean (SE)		Mean Weighted by number of children (18 & under) in the household (SE)	
Overall	88.9	(0.1)	90.8	(0.1)					
Women	88.7	(0.1)	89.9	(0.2)	Less than high school	85.3	(1.3)	89.2	(1.6)
Men	89.1	(0.1)	91.4	(0.1)	High school	86.8	(0.3)	89.3	(0.3)
					1 to 3 years of college	88.6	(0.2)	89.7	(0.3)
Age 20 to 29	89.0	(0.2)	89.6	(0.3)	4year college degree	90.4	(0.1)	91.6	(0.2)
Age 30 to 39	90.3	(0.2)	91.7	(0.2)	Graduate degree	91.6	(0.1)	93.3	(0.1)
Age 40 to 49	89.3	(0.2)	90.9	(0.2)					
Age 50 to 64	87.6	(0.2)	89.4	(0.4)	Ann. Earnings of \$20 to \$50K	87.9	(0.2)	89.6	(0.3)
					Ann. Earnings of \$50 to \$100K	89.9	(0.2)	91.4	(0.2)
Red (Republican-leaning) State	88.6	(0.1)	89.3	(0.1)	Ann. Earnings of \$100 to \$150K	91.1	(0.2)	92.8	(0.2)
Blue (Democratic-leaning) State	89.3	(0.1)	90.9	(0.1)	Ann. Earnings over \$150K	92.0	(0.2)	94.0	(0.2)

Notes: Percent of the time that the internet works, based on responses to the question, "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. The second and fourth columns additionally weight by the number of children present in the household.

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 percent in favor of WFH. At the other end of the scale, persons with internet access that works less than 70 percent of the time and those who lack home internet access report average productivity differences of about 1 percent 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: 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.

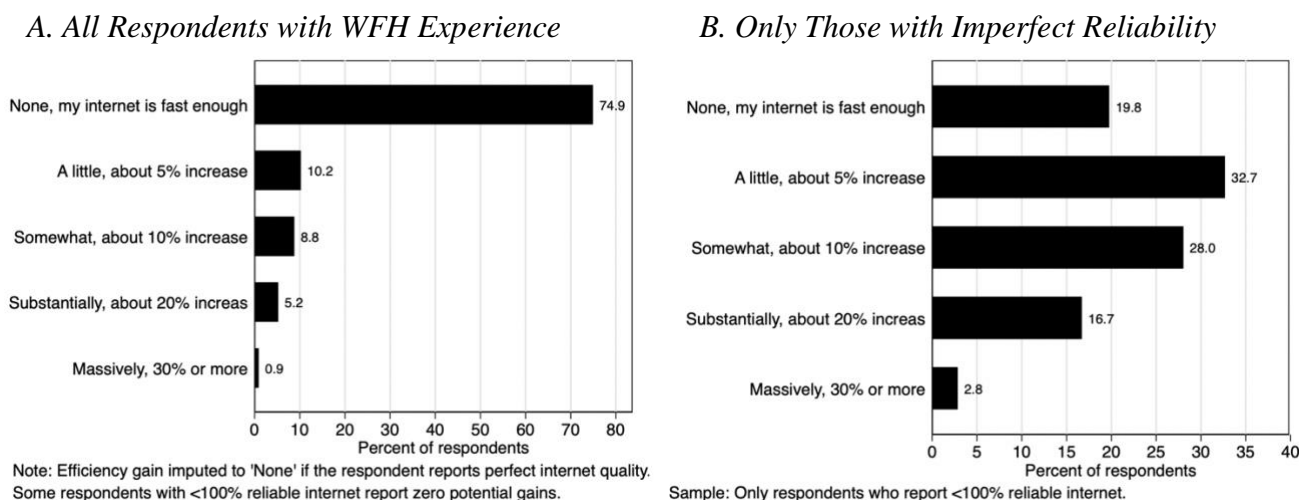
3. Projecting the Effects of Universal Access

3.a. Direct Productivity Effects

We now project the effects of a hypothetical move to universal access, defined as a shift from the current access situation (summarized in Figure 2 and Table 2) to one with high-quality, fully reliable internet access in all households. In forming our productivity projections, we combine individual-level data on the planned extent of WFH in the post-pandemic economy with individual-level estimates for the productivity impact of universal access.

We estimate the individual-level productivity impacts using two distinct approaches. The first exploits responses to the following question: “How much would your efficiency working from home increase if you had perfect high-speed internet?” Responses to this question, summarized in Figure 4, elicit self-assessed causal effects of the hypothetical in question. Accordingly, we interpret the suitably aggregated responses as yielding estimated causal effects, subject to the qualifications sketched above and discussed more fully below. Survey responses to this question for persons with WFH experience during the pandemic say that universal access raises the earnings-weighted average efficiency of time spent WFH by 3.3 percent. Appendix Table A.2 provides information on how the self-assessed efficiency gains vary with observables.

Figure 4. “How much would your efficiency working from home increase if you had perfect high-speed internet?”



Source: Responses to the following questions in the Survey of Working Arrangements and Attitudes:
“How reliable is your internet connection?”
“How much would your efficiency working from home increase if you had perfect high-speed internet?”

Our second approach relies on regression models that relate the productivity of WFH to internet access quality in the cross section. The dependent variable is WFH efficiency during the pandemic relative to that of working on employer premises before the pandemic. Appendix Table A.3 reports our estimated regression models. Our preferred model controls for earnings, education, gender, presence of children, state of residence, and industry of the worker’s current or last job. Using this model, and interpreting the coefficient on internet access quality as a causal effect, we calculate the individual-level productivity change associated with universal access.

Table 3 draws together the pieces of our analysis to report two sets of results: Estimates for the aggregate labor productivity shortfall caused by subpar internet access during the pandemic in

column (1), and estimates for the aggregate labor productivity gains caused by universal access in the post-pandemic economy. The regression approach implies a productivity shortfall due to subpar internet service of 0.7 percent during the pandemic and a productivity gain from universal access of 0.3 percent in the post-pandemic economy. The approach based on self-assessed causal effects yields larger productivity consequences: a 3 percent shortfall during the pandemic and a 1.1 percent gain from universal access in the post-pandemic economy.

Table 3. Earnings-Weighted Productivity Effects of Internet Access Quality

	(1)	(2)	(3)
	Productivity Shortfall During COVID	Post-COVID Gains from Universal Access	
Approach to Estimating the Individual-Level Productivity Effects of Universal Access	(1) Productivity losses due to subpar internet access	(2) Using employer plans for WFH	(3) And adjusted for WFH rise induced by universal access
Regression-imputed (simple)	-0.8	0.4	0.4
Regression-imputed (controls)	-0.7	0.3	0.4
Self-assessed causal effect	-3.0	1.1	1.1

Notes: Column (1) reports the estimated aggregate productivity shortfall during the pandemic due to subpar internet access quality by many Americans who worked from home. See Figure 3 for the distribution of subpar internet service. Column (2) reports the estimated earnings-weighted productivity gains of universal access to high-quality, fully reliable home internet service in the post-pandemic economy when using employer plans for who works from home, and how much. Column (3) also adjusts for the post-pandemic rise in WFH that we estimate, and which we report in Table 5 below. See Figure 4 for the distribution of self-assessed causal effects from gaining access to high-quality, fully reliable internet service. See Table 3 for regression models that relate WFH productivity to internet access quality. We use column (1) in Table 3 for the row titled, “Regression-imputed (simple)”; and we use column (7) in Table 3 for the row, titled “Regression-imputed (simple)”. Data are from 43,250 survey responses collected from May 2020 to May 2021 by Inc-Query and QuestionPro. We re-weight individual-level data 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

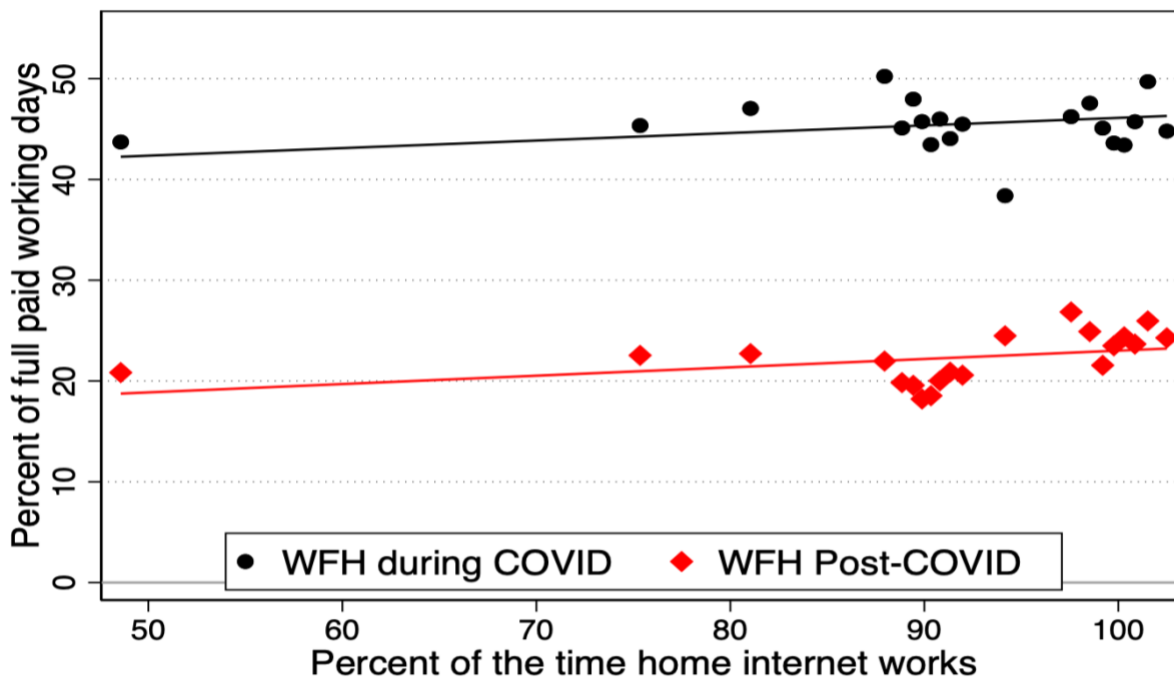
better internet service relies on strong assumptions that might not hold.⁹ Accordingly, we focus on results that rely on self-assessment effects in the rest of the paper.

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 black 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 ten 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.

Figure 5. How the Incidence of WFH Relates to Internet Access Quality Conditional on Industry and Earnings



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.

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 & later survey waves.

Table 5 reports the estimated impact of universal access on the extent of WFH when we interpret the slope coefficients in these regressions as casual 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 4.

Table 5. Extra WFH Induced by Universal Access During and After the COVID-19 Pandemic

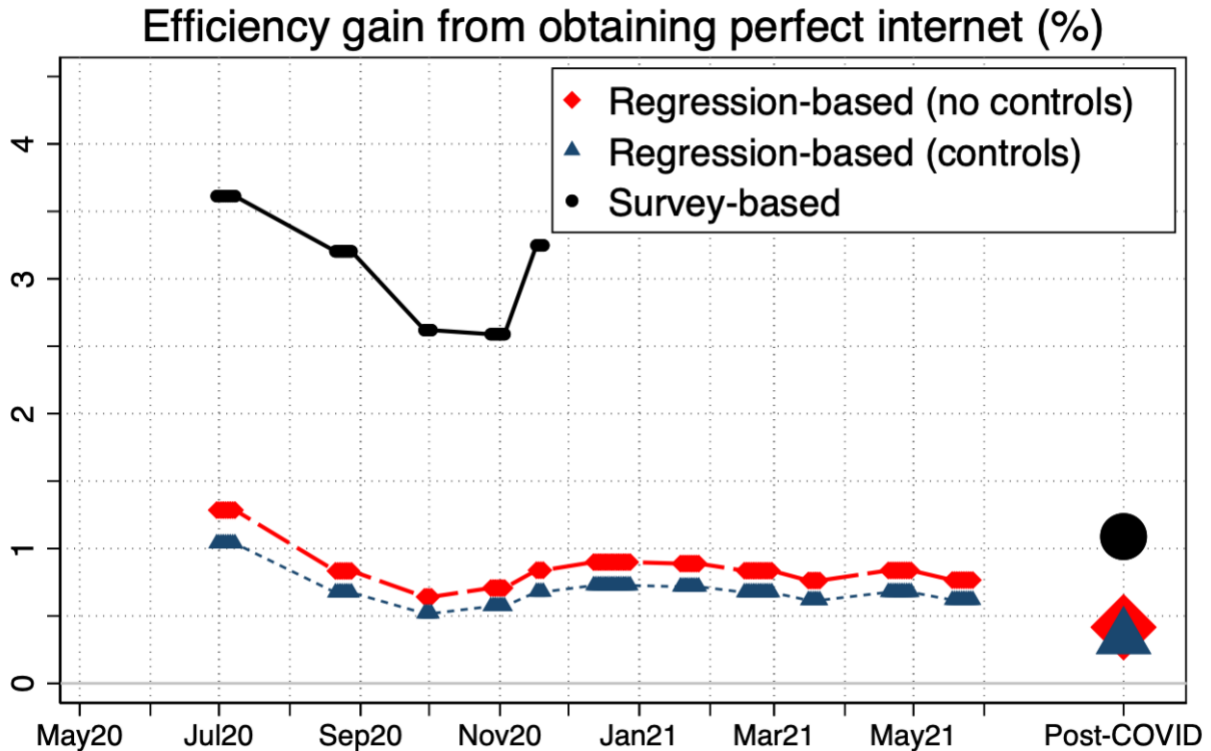
Increase in percent of full paid days WFH induced by universal access to perfect high-speed internet	During COVID	After COVID	Increase in percent of full paid days WFH induced by universal access to perfect high-speed internet	During COVID	After COVID
Overall	0.7	0.7	Ann. Earnings of \$20 to \$50K	0.8	0.8
			Ann. Earnings of \$50 to \$100K	0.6	0.7
			Ann. Earnings of \$100 to \$150K	0.6	0.6
Women	0.7	0.8	Ann. Earnings over \$150K	0.4	0.5
Men	0.6	0.7			
			Less than high school	0.8	0.8
Age 20 to 29	0.7	0.8	High school	0.8	0.9
Age 30 to 39	0.6	0.7	1 to 3 years of college	0.7	0.8
Age 40 to 49	0.7	0.7	4-year college degree	0.6	0.7
Age 50 to 64	0.7	0.8	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 4. 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 percent for the self-assessment approach, fluctuating over time with the extent (and cross-sectional distribution of) WFH during the pandemic. The smaller 1.1 percent 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.

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 percent improvement in labor productivity implies an aggregate output gain of 0.73% ($= (1.011)^{2/3} - 1$) per period in the post-pandemic economy. Similarly, a 3.0 percent labor productivity shortfall due to subpar internet access implies an aggregate output loss of 2.0 percent 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.

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.

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 percent of respondents on an equal-weighted basis and an estimated 34.2 percent on an earnings-weighted basis.¹⁰ 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 healthcare 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.

¹⁰ 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).

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 re-direction 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.

Applying this assumption, we estimate that universal access would raise earnings by 1.0 percent for persons who earned \$20-50 thousand in 2019, 1.2 percent for those who earned \$50-100 thousand, 1.3 percent for those who earned \$100-200 thousand, and 1.1 percent for those who earned more than \$200 thousand in 2019. These estimates reflect employer plans for who will work from home in the post-pandemic economy, and 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 6 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 percent) and the largest for persons with a four-year college degree (1.4 percent).

Table 6. 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	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	Ann. Earnings of \$20 to \$50K	1.0
Men	1.0	Ann. Earnings of \$50 to \$100K	1.2
		Ann. Earnings of \$100 to \$150K	1.3
Age 20 to 29	1.2	Ann. Earnings over \$150K	1.1
Age 30 to 39	1.3		
Age 40 to 49	1.1	Goods-producing sectors	0.8
Age 50 to 64	0.7	Service sectors	1.1
Less than high school	0.3	No children	0.9
High school	0.7	Living with children under 18	1.2
1 to 3 years of college	1.1		
4year college degree	1.4	Red (Republican-leaning) State	1.0
Graduate degree	1.0	Blue (Democratic-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 them to 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. It also suggests 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-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* 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 10 and the bottom step is 0, on which step of the ladder do you feel you personally stand at the present time? We multiply the responses by 10 to put them on a scale that runs from 0 to 100.

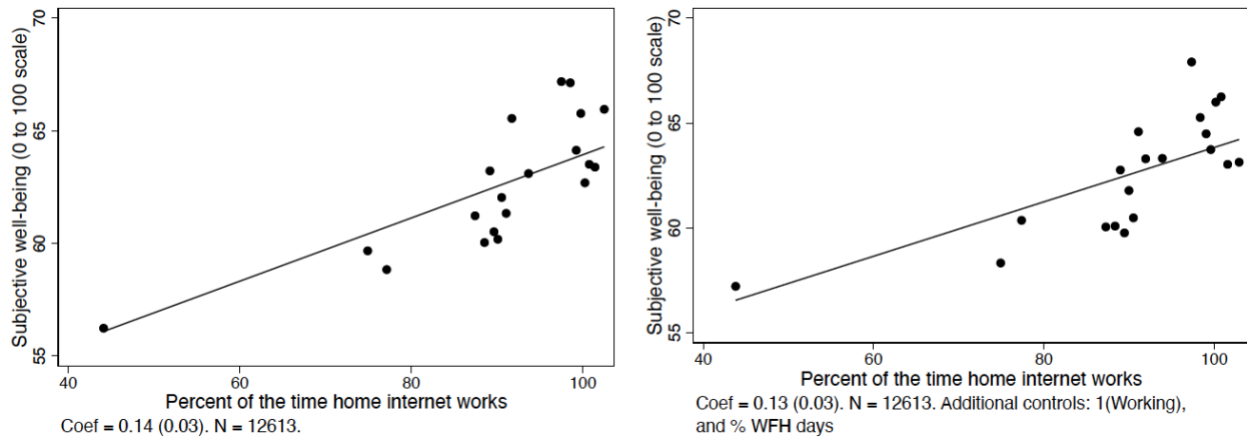
Figure 7 presents binned scatter plots of subjective well-being against the percent of time that the respondent’s home internet service works. The left plot controls for gender, years of education, our four age bins, the log of 2019 earnings, whether the respondent lives with other adults, whether he or she lives with children, and whether the respondent lives with a partner. The slope coefficient of 0.14 says that a ten 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.¹¹ Controlling for other factors, the improvement in subjective well-being associated with working is more than one-third

¹¹ 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.

as large as the standard deviation of well-being in the sample.¹² 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.

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 percent reliable service is associated with a 15 percentage-point improvement in subjective well-being.¹³ 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.

¹² See the coefficient of 8.2 in Column (6) of Table A.4.

¹³ Using column (7) in Table A.4.

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-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. 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 percent in the coming years. The implied output gains are \$160 billion per year, or \$4 trillion when capitalized at a four percent 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.

References

- Ahmad Farida B. and Robert N. Anderson, 2021. “The Leading Causes of Death in the US for 2020.” *Journal of the American Medical Association*, 325, no. 18, 1829–1830.
- Alcott, Hunt, Matthew Gentzkow, and Lena Song, 2021. “Digital Addiction,” NBER Working Paper 28936.
- Altig, David, Jose Maria Barrero, Nick Bloom, Steven J. Davis, Brent Meyer, Emil Mihaylov and Nick Parker, 2020a. “[Firms Expect Working from Home to Triple](#),” *Macroblog*, 28 May.
- Altig, David, Jose Maria Barrero, Nick Bloom, Steven J. Davis, Brent Meyer, Emil Mihaylov and Nick Parker, 2021. “WFH Is Onstage and Here to Stay,” *Macroblog*, 25 February.
- Altig, David, Jose Maria Barrero, Nick Bloom, Steven J. Davis, Brent Meyer and Nick Parker, 2020b. “Surveying Business Uncertainty.” Forthcoming, *Journal of Econometrics*.
- Angelici, Marta and Paola Profeta, 2020, “Smart working: Flexibility without constraints,” CES working paper no. 8165.
- Ayers John W., Adam Poliak, Derek C. Johnson, Eric C. Leas, Mark Dredze, Theodore Caputi, and Alicia L. Nobles, 2021. “Suicide-Related Internet Searches During the Early Stages of the COVID-19 Pandemic in the US.” *JAMA Network Open*, 4, no 1.
- Barrero, Jose Maria, Nicholas Bloom, and Steven J. Davis, 2020a. “[60 Million Fewer Commuting Hours per Day: How Americans Use Time Saved by Working from Home](#),” *VoxEU CEPR Policy Portal*, 23 September.
- Barrero, Jose Maria, Nicholas Bloom, and Steven J. Davis, 2020. “COVID-19 Is Also a Reallocation Shock,” *Brookings Papers on Economic Activity*, Summer, 329-371.
- Barrero, Jose Maria, Nicholas Bloom, and Steven J. Davis, 2021a. “Question Repository for the Survey of Working Arrangements and Attitudes,” available at www.WFHresearch.com.
- Barrero, Jose Maria, Nicholas Bloom, and Steven J. Davis, 2021b. “Why Working from Home Will Stick,” NBER Working Paper 28731.
- Bartik, Alexander W., Zoe B. Cullen, Edward L. Glaeser, Michael Luca, and Christopher T. Stanton, 2020. “What Jobs are Being Done at Home During the Covid-19 Crisis? Evidence from Firm-Level Surveys,” NBER Working Paper No. 27422.
- Behrens, Kristian, Sergey Kichko, Jacques-Francois Thisse, 2021. “Working from Home: Too Much of a Good Thing?” CESifo Working Paper No. 8831.

- Bick, Alexander, Adam Blandin, and Karel Mertens, 2020. "Work from Home After the COVID-19 Outbreak," Federal Reserve Bank of Dallas Working Paper.
- Bloom, Nicholas, Steven J. Davis, and Yulia Zhestkova, 2021. "COVID-19 Shifted Patent Applications toward Technologies that Support Working from Home." *American Economic Association, Papers & Proceedings*, May.
- Bloom, Nicholas, James Liang, John Roberts, and Zhichun Jenny Ying, 2015. "Does working from home work? Evidence from a Chinese experiment," *Quarterly Journal of Economics*, 130, no. 1, 165-218.
- Brynjolfsson, Erik, John J. Horton, Adam Ozimek, Daniel Rock, Garima Sharma, and Hong-Yi TuYe, 2020. "COVID-19 and Remote Work: An Early Look at US Data," NBER Working Paper No. 27344.
- Choudhury, Prithwiraj, Cirrus Foroughi, and Barbara Zepp Larson, 2021. "Work-from-anywhere: The productivity effects of geographic flexibility," *Strategic Management Journal*, 42, no. 4, 655-683.
- Chiou, Lesley and Catherine Tucker, 2020. "Social Distancing, Internet Access and Inequality," NBER Working Paper 26982, April.
- Cicala, Steve, 2020. "Powering work from home," NBER Working Paper No. 27937.
- Davis, Steven J., Dingqian Liu and Xuguang Simon Sheng, 2021. "Stock Prices and Economic Activity in the Time of Coronavirus," NBER Working Paper 28320, revised.
- DeFilippis, Evan, Stephen Michael Impink, Madison Singell, Jeffrey Polzer, and Raffaella Sadun, 2020, "Collaborating during coronavirus: The impact of COVID-19 on the nature of work," NBER Working Paper No. 27612.
- Deole, Sumit, Max Deter and Yeu Huang, 2021. "*Home Sweet Home*: Working from Home and Employee Performance during the COVID-19 Pandemic in the U.K.," working paper.
- Elhai, Jon D., Haibo Yang, Dean McKay, and Gordon JG Asmundson, 2020. "COVID-19 anxiety symptoms associated with problematic smartphone use severity in Chinese adults." *Journal of Affective Disorders*, 274, 576-582.
- Emanuel, Natalia and Emma Harrington, 2021, "'Working' remotely? Selection, treatment and the market provision of remote work," working paper, 9 April.
- Erdsieck, Danial, 2021. "Working from Home During COVID-19 and Beyond: Survey Evidence from Employers," ZEW Mannheim, June.

- Frenette, Marc, Kristyn Frank, and Zechuan Deng, 2020. "School Closures and the Online Preparedness of Children during the COVID-19 Pandemic," *Economic Insights*, Issue 2020001 no.103, April.
- Frey, Bruno S. Alois Stutzer, 2002. "What Can Economists Learn from Happiness Research?" *Journal of Economic Literature*, 40, no. 2 (June), 402-435.
- Garbe, Amber, Uzeyir Ogurlu, Nikki Logan, and Perry Cook, 2020. "COVID-19 and Remote Learning: Experiences of Parents with Children during the Pandemic". *American Journal of Qualitative Research*, 4, no. 3, 45-65.
- Hatayama, Maho, Mariana Viollaz and Herman Winkler, 2020. "Jobs' Amenability to Working from Home: Evidence from Skill Surveys for 53 Countries," Policy Research Working Paper 9241, World Bank Group.
- Holt-Lunstad, Julianne, Timothy B. Smith, Mark Baker, Tyler Harris and David Stephenson, 2015. "Loneliness and Social Isolation as Risk Factors for Mortality: A Meta-Analytic Review," *Perspectives on Psychological Science*, 10, no. 2, 227-237.
- Jiao, Guandong and Melisa Ramirez Tovar, 2020. "Remote Operations Evolve to Offshore Industry Challenges," *Offshore: Drilling & Completion*, 1 November. <https://www.offshore-mag.com/drilling-completion/article/14184916/schlumberger-remote-operations-evolve-to-offshore-industry-challenges>.
- Möhring, Katja, Elias Naumann, Maximiliane Reifenscheid, Alexander Wenz, Tobias Rettig, Ulrich Krieger, Sabine Friedel, Marina Finkel, Carina Cornesse and Annelies G. Blom, 2021. "The COVID-19 pandemic and subjective well-being: longitudinal evidence on satisfaction with work and family," *European Societies*, 23.
- Ozimek, Adam, 2020. "The future of remote work," SSRN Working Paper.
- Pabilonia, Sabrina and Victoria Vernon, 2021. "[Telework, wages, and time use in the United States](#)," GLO Discussion Paper No. 546.
- Sen, Ananya and Catherine E. Tucker, 2020. "Social Distancing and School Closures: Documenting Disparity in Internet Access among School Children" Working Paper, Available at SSRN: <https://ssrn.com/abstract=3572922>, April 10.
- Servidio, Rocco, Maria Giuseppina Bartolo, Anna Lisa Palermiti, and Angela Costabile, 2021. "Fear of COVID-19, depression, anxiety, and their association with Internet addiction disorder in a sample of Italian students", *Journal of Affective Disorders Reports*, 4, 100097.

- Sinyor, Mark, Matthew J. Spittal, and Thomas Niederkrotenthaler, 2020. "Changes in Suicide and Resilience-Related Google Searches during the Early Stages of the COVID-19 Pandemic," *The Canadian Journal of Psychiatry*, 65, no. 10, 741–743.
- Stemers, Frank, Robin Erickson, Amanda Popiela and Gad Levanon, 2020. "[Adapting to the Reimagined Workplace: Human Capital Responses to the COVID-19 Pandemic](#)," Conference Board, October.
- Taneja, Shivani, Paul Mizen and Nicholas Bloom, 2021. "[Working from home is revolutionising the UK Labour market](#)," *VoxEU CEPR Policy Portal*, 15 March.
- Thoits, Peggy A., 2011. "Mechanisms Linking Social Ties and Support to Physical and Mental Health," *Journal of Health and Social Behavior*, 52, no. 2, 145-161.
- Varma, Prerna, Moira Junge, Hailey Meaklim, & Melinda L. Jackson, 2021. "Younger people are more vulnerable to stress, anxiety and depression during COVID-19 pandemic: A global cross-sectional survey." *Progress in Neuro-Psychopharmacology & Biological Psychiatry*, 109, 110236.
- Wallinheimo, Anna-Stiina and Simon L. Evans, 2021. "More Frequent Internet Use during the COVID-19 Pandemic Associates with Enhanced Quality of Life and Lower Depression Scores in Middle-Aged and Older Adults," *Healthcare*, 9, no. 4, 393.

Appendix

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

Dependent variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Percent of the time home internet works									
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)		
1(Children under 18)				0.50* (0.28)	0.54* (0.28)	0.58** (0.27)	0.53* (0.28)	0.49* (0.27)		
1(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	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

Notes: 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)		
1(Minority)					0.48** (0.20)	0.45** (0.20)	0.48** (0.20)		0.43** (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

Notes: 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	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Relative efficiency of WFH						
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)	1.84*** (0.65)
State FE						Y	Y
Industry (of current or most recent job) FE							Y
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

Notes: 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

Notes: We regress subjective wellbeing on self-reported internet quality and the respondent's working and living situation. 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?" 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. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

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