RESEARCH & POLICY

INSIGHTS

Who is using the internet at faster speeds?

Publication 110

May 2024

by

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PURDUE UNIVERSITY

Center for Regional Development

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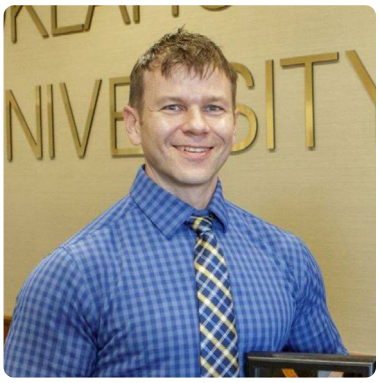

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Factors Affecting Internet Speeds

ABSTRACT

Recent research found that as the share of White non-Hispanics increases, average download and upload speeds decreases. To delve deeper into this finding and better understand the factors affecting internet speeds, this research conducted spatial error regression models looking at different groups across two points in time (2019 and 2022). Results indicate that rural, older, and poorer groups continue to be associated with slower speeds and that by 2022, these relationships became stronger, widening the divide. Remote work and educational attainment had a positive impact on speeds, particularly average upload speeds. These positive impacts increased over time, providing evidence of the need for symmetrical networks (download and upload speeds are identical). Lastly, the finding that White non-Hispanics are associated with slower internet speeds remained: it was in place as early as 2019 and became stronger by 2022, also widening the divide. Five research and policy insights are discussed to better inform broadband stakeholders and policymakers.

INTRODUCTION

Efforts to better understand the digital divide increased significantly over the past several years, particularly during and after the COVID-19 pandemic, when individuals, businesses, and organizations scrambled to engage online. Better understanding this issue leads to more efficient and effective interventions to ensure all groups can benefit and participate fully in the increasingly digitizing economy and society.

The digital divide has evolved over time ranging from a first level or dichotomous yes/no access to a second level or internet use focus to a third level looking at the personal, social, economic, and other outcomes (Wei, Teo, Chan, & Tan, 2011; Van Deursen & Helsper, 2018; Ragnedda, 2018; Lai & Widmar, 2021). Studies have found that several factors affect home broadband subscription placing certain groups on the wrong side of the divide (Anderson, Perrin, & Jiang, 2018; Atske & Perrin, 2021).

However, this divide has primarily been defined with broadband availability and/or broadband home subscriptions. Increasingly, and as data becomes available, internet quality—measured by average download and upload speeds—has been used to broaden our understanding of this issue. Internet speeds are not the perfect metric—particularly to gauge broadband availability (Paul, Liu, Gu, Gupta, & Belding, 2022), yet they do capture what the user ultimately experiences.

More importantly, as online applications become more sophisticated, these require faster, more reliable connections. For example, latency—time delay between two users in a network—is considered the next frontier regarding consumer experience (Ookla, n.d.). Hence, utilizing internet speeds provides another lens to understanding the digital divide.

Recent research looked at 2021 data to see which groups used the internet at faster speeds (Gallardo & Whitacre, 2024). Results from this study mostly aligned with previous studies focusing on home subscriptions in its finding that rural areas, poorer, and older populations used the internet at slower speeds. However, a surprising finding emerged: as the share of White non-Hispanics increased, average internet speeds decreased. This relationship remained after controlling for age, rurality, and educational attainment, among other variables.

On the contrary, when looking at the two largest minority groups in the country, Black non-Hispanics and Hispanics, average speeds increased with shares of these groups. Potential explanations range from 2021 being an unusual year due to COVID-19 to minorities becoming more trustful of internet while Whites, particularly conservative Whites, becoming more distrustful (Smith, 2018). At the end of the day, any group on the wrong side of the divide will not be able to benefit and fully participate in this digital society and economy.

For this study, we replicate a spatial econometric model used by Gallardo & Whitacre (2024) and compare 2019 (pre-COVID-19) and 2022 (latest year available) data. Additional variables known to affect internet speeds (e.g., working from home) were included as well. In other words, we want to understand the factors affecting internet speeds—looking at download and upload speeds separately—before and after COVID-19. More importantly, this should shed light as to whether this unexpected finding is a result of COVID-19, or if it was in place before the pandemic.

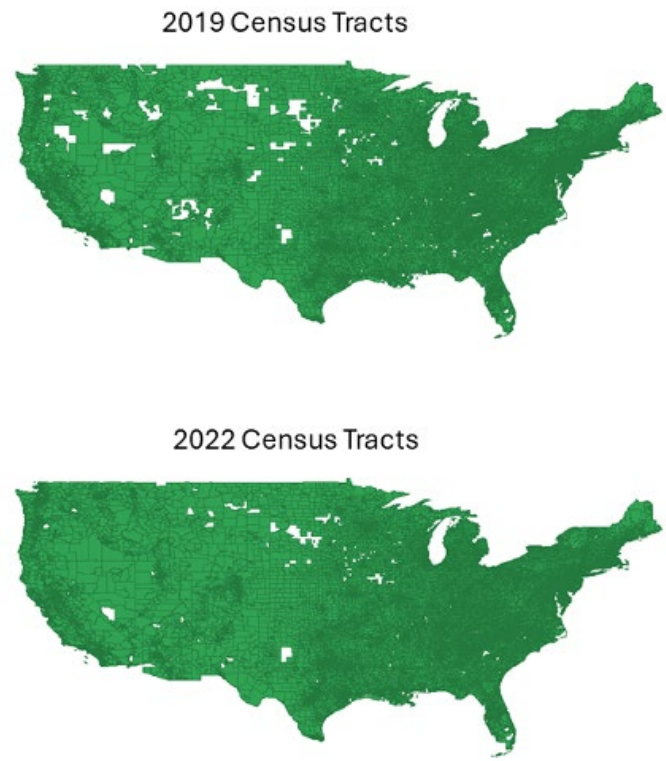
DATA & METHODS

Average speed tests were obtained from the Speedtest® by Ookla Global Fixed Network Performance Maps. These tests do not include mobile networks, are customer-initiated, publicly available, and are published quarterly in "quads" of roughly 600 meters by 600 meters (Ookla, 2023). This data includes number of speed tests, average download and upload speeds, and average latency. Speed test quarterly data was averaged by number of speed tests to calculate an annual number and were then meshed with Census tracts containing socioeconomic variables from the 2015-2019 and 2018-2022 American Community Survey (ACS) five-year data.

A spatial error regression model was utilized to look at the relationship between variables as described in the article published by Gallardo & Whitacre (2024). Not accounting for variation over space or influence by neighboring values can result in biased estimated coefficients (Anselin, 1988). The spatial error model was preferred over the spatial lag model because the robust Lagrange Multiplier value for spatial error was higher than the spatial lag value (Anselin & Getis, Spatial statistical analysis and geographic information systems, 1992). Also, the same queen contiguity spatial weight matrix was used[1].

All data was gathered at the Census tract level and tracts with no population or households, with less than 50 speed tests (to avoid outliers), and outside the continental United States (due to spatial econometric models) were removed. A total of 71,352 tracts (out of 72,401) were included in the 2019 dataset and a total of 82,519 tracts (out of 82,729) were used in the 2022 dataset. The number of speed tests completed was 79.7 million in 2019 and 78.1 million in 2022. **Figure 1** shows the 2019 and 2022 maps with the Census tracts used.

Figure 1. *Census Tracts Used: 2019 and 2022*



[1] A Rook contiguity spatial weight matrix was used and results did not change.

The variables utilized were like those used by Gallardo & Whitacre (2024) with some minor differences. The dependent variables remained the same (average download and upload speeds). Most of the independent variables were also used, except that the percent of housing units with fiber-optic availability and maximum advertised speeds were not included due to data availability[2]. The percentage working from home was added. These variables were selected to see if the factors known to affect broadband home subscriptions also affect internet speeds.

Table 1 provides a statistical summary of the variables used. Variables of interest or dependent variables (at the bottom of the table) were average download and upload speeds (in Megabits per second or Mbps). Independent variables included percent rural population (aggregated from Census blocks), percent population age 65 or older, percent population age 25 or older with a bachelor's degree or higher, percent individuals in poverty, percent households with children, percent workers age 16 and older working from home, and number of speed tests (logged). The number of speed tests were included because research has found that more speed tests are completed in areas with slower, unreliable internet (Riddlesden & Singleton, 2014).

Table 1. *Statistical Summary of Variables Utilized: 2019 and 2022.*

Variable	2019	2022	Source
% Rural	0.203	0.225	ACS
% Pop. Age 65+	0.164	0.173	ACS
% Minorities	0.385	0.401	ACS
% White, non-Hispanic	0.615	0.599	ACS
% Black, non-Hispanic	0.135	0.130	ACS
% Hispanic	0.168	0.176	ACS
% Bachelor's or higher	0.308	0.331	ACS
% Individual Poverty	0.146	0.136	ACS
% Household with children	0.309	0.302	ACS
% Working from home	0.051	0.111	ACS
No. of Tests (Ln)	7.149	7.066	Ookla
Avg. Download (Mbps)	106.9	209.9	Ookla
Avg. Upload (Mbps)	32.4	63.4	Ookla

Source: ACS; Ookla

The average share of the population living in rural areas increased slightly from 20.3% in 2019 to 22.5% in 2022. Likewise, the share of the population age 65 or older also increased from 16.4% to 17.3% between 2019 and 2022 as did the share of those with a bachelor's or more (from 30.8% to 33.1%), the share of minorities (from 38.5% to 40.1%), and Hispanics (from 16.8% to 17.6%). On the other hand, the average share of White non-Hispanics (from 61.5% to 59.9%), individual poverty (from 14.6% to 13.6%), and number of tests

[2] Original models in Gallardo & Whitacre (2024) using 2021 data were run without including these two variables and main results were not affected.

decreased slightly between 2019 and 2022. The share of households with children (roughly 30%) and Black non-Hispanics (roughly 13%) remained the same.

Note how the average download and upload speeds increased significantly and almost doubled between 2019 and 2022. Average download speeds went from 106 Mbps in 2019 to 209 Mbps in 2022 while average upload speeds went from 32 Mbps to 63 Mbps. Likewise, the share of those working from home more than doubled from 5.1% to 11.1%.

RESULTS

Multiple spatial error regression models were completed using GeoDa software. Models 1-4 looked at average download speeds as the dependent variable while models 5-8 looked at average upload speeds. The independent variables of interest were race/ethnicity like those used by Gallardo & Whitacre (2024). The share of minorities (all but White, non-Hispanic) was analyzed (models 1 and 5) as well as the share of White non-Hispanics (models 2 and 6), Black non-Hispanics (models 3 and 7), and Hispanics (models 4 and 8). **Tables 2 & 3** show the results for download and upload speeds, respectively.

Table 2. *Spatial Error Regression Models Results – Average Download Speeds*

Average Download (Mbps)	2019				2022			
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 1**	**Model 2**	**Model 3**	**Model 4**
R^2	0.79	0.79	0.79	0.79	0.72	0.72	0.72	0.71
S.E.	17.4	17.4	17.4	17.4	31.4	31.4	31.4	31.4
Observations	71,352	71,352	71,352	71,352	82,490	82,490	82,490	82,490
% Rural Pop.	-30.4***	-30.4***	-30.6***	-30.7***	-64.0***	-64.0***	-65.1***	-64.7***
% Age Pop. 65 or older	-14.3***	-14.3***	-16.2***	-15.6***	-29.1***	-29.1***	-32.9***	-31.3***
% Minority	+6.7***	-----	----	----	+12.3***	-----	----	----
% White, non-Hispanic	-----	-6.7***	----	----	-----	-12.3***	----	----
% Black, non-Hispanic	-----	----	+5.5***	----	-----	----	+6.8***	----
% Hispanic	-----	----	----	+5.1***	-----	----	----	+11.7***
% Bachelor's or more	+0.3	+0.3	-1.1	-0.5	+2.3*	+2.3*	-0.6	+1.5
% Individual Poverty	-8.8***	-8.8***	-7.7***	-6.4***	-19.3***	-19.3***	-17.0***	-15.7***
% Households with children	+8.2***	+8.2***	+9.5***	+8.8***	+14.0***	+14.0***	+15.9***	+14.3***
% Working from home	-16.5***	-16.5***	-17.7***	-17.5***	-11.7***	-11.7***	-12.5***	-11.5***
Ln Tests	+4.9***	+4.9***	+5.0***	+4.9***	+5.5***	+5.5***	+5.5***	+5.3***
Lambda	+0.8***	+0.8***	+0.8***	+0.8***	0.7***	0.7***	+0.7***	+0.7***

Statistical Significance: * p<0.1; ** p<0.05; *** p<0.01

Some interesting results are worth discussing when looking at **Table 2**. First, the 2019 model had a higher R^2 compared to the 2022 model. This means that the same variables in 2022 explained less of the variance in average download speeds compared to 2019. Rural areas continue to be associated with slower download speeds and in fact, the magnitude more than doubled between 2019 and 2022. In 2019, for every percentage point increase in the share of the rural population, average download speeds decreased by roughly 30 Mbps. By 2022, this same percentage point increase in the share of rural population was associated with an average download speed decrease of 64 Mbps. A similar trend is seen with an older population and individual poverty rates, where they too continue to be associated with slower average download speeds. The magnitude of these two variables more than doubled between 2019 and 2022, widening the divide.

Households with children were associated with faster average download speeds and became stronger (doubled in magnitude) by 2022. For every percentage point increase in the share of households with children in 2019, average download speeds increased by roughly 8 Mbps compared to roughly 16 Mbps in 2022. Regarding the share of the population 25 years or older with a bachelor's or higher, this relationship was not statistically significant in 2019 but became statistically significant by 2022 (except when including the share of Black non-Hispanics and Hispanics). Surprisingly, as the share of those working from home increased, average download speeds decreased. However, the magnitude of the impact decreased: in 2019, every percentage point increase in those working from home was associated with an average download speed decreased of roughly 16 Mbps. By 2022, this same relationship was associated with an average download speed decrease of roughly 11 Mbps.

More interesting is the fact that the unexpected finding documented using 2021 data by Gallardo & Whitacre (2024) remained: as the share of White non-Hispanics increased, average download speeds decreased. Moreover, this relationship was in place in 2019, before the COVID-19 pandemic, and became stronger by 2022, widening the divide. As the share of White non-Hispanics increased by one percentage point in 2019, average download speeds decreased by roughly 7 Mbps. By 2022, average download speeds decreased by roughly 12 Mbps.

The opposite trend is seen when looking at both Black non-Hispanics and Hispanics (models 2 and 3). When their share increased by one percentage point, average download speeds increased by roughly 5 Mbps in 2019 and rose to almost 7 Mbps and 12 Mbps in 2022, respectively. Lastly, the presence of children in the home had a larger impact in 2022 compared to 2019 when including the share of Black non-Hispanics (almost 18 Mbps faster) compared to White non-Hispanics and Hispanics (roughly 14 Mbps faster for both groups).

Different dynamics are observed when looking at upload speeds in **Table 3**. Like download speeds, the 2022 model explained less of the variance in upload speeds compared to the 2019 model. In other words, there are other factors at play not captured by these models, such as post-COVID-19 policy environments, including potential changes in user preferences and behaviors, or state digital inclusion efforts.

Rural areas continue to be associated with slower average upload speeds, though the magnitude is lower compared to download speeds. Consider that in 2019, for every percentage point increase in the share of the rural population, average upload speeds decreased by roughly 3 Mbps (ten times lower than what is observed with download speeds). By 2022, average upload speeds decreased by roughly 10 Mbps, significantly lower than the 60 Mbps decrease in download speeds.

Likewise, as the share of the population 65 or older as well as individual poverty increases, average upload speeds decrease. These relationships became stronger by 2022 compared to 2019, but weaker compared to the effect on average download speeds.

Table 2. *Spatial Error Regression Models Results – Average Download Speeds*

Average Upload (Mbps)	2019				2022			
	Model 5	**Model 6**	**Model 7**	**Model 8**	**Model 5**	**Model 6**	**Model 7**	**Model 8**
R^2	0.78	0.78	0.78	0.78	0.71	0.71	0.71	0.71
S.E.	12.2	12.2	12.2	12.2	24.8	24.8	27.8	24.8
Observations	71,352	71,352	71,352	71,352	82,490	82,490	82,490	82,490
% Rural Pop.	-3.0***	-3.0***	-3.2***	-3.2***	-10.2***	-10.2***	-10.5***	-10.2***
% Age Pop. 65 or older	-11.8***	-11.8***	-12.7***	-12.4***	-16.6***	-16.6***	-17.1***	-16.3***
% Minority	+3.2***	-----	----	----	+0.8	-----	----	----
% White, non-Hispanic	-----	-3.2***	----	----	-----	-0.8	----	----
% Black, non-Hispanic	-----	----	+1.9***	----	-----	----	-2.7***	----
% Hispanic	-----	----	----	+2.0***	-----	----	----	+3.1***
% Bachelor's or more	+5.7***	+5.7***	+4.9***	+5.1***	+6.7***	+6.7***	+6.0***	+7.2***
% Individual Poverty	-3.0***	-3.0***	-2.3***	-1.9***	-9.6***	-9.6***	-8.7***	-9.4***
% Households with children	+1.1*	+1.1*	+1.7***	+1.4**	+5.9***	+5.9***	+6.1***	+5.7***
% Working from home	+0.5	+0.5	-0.0	+0.0	+3.7**	+3.7**	+3.6**	+3.9**
Ln Tests	+3.4***	+3.4***	+3.4***	+3.3***	+6.2***	+6.2***	+6.1***	+6.2***
Lambda	+0.8***	0.8***	+0.8***	+0.8***	+0.8***	+0.8***	+0.8***	+0.8***

Statistical Significance: * p<0.1; ** p<0.05; *** p<0.01

The relationship between higher educational attainment and average upload speeds was statistically significant in 2019 and in 2022, unlike average download speeds. Furthermore, the magnitude was higher in 2022, regardless of race/ethnicity. Similarly, while the share of those working from home was negatively correlated with average download speeds and the magnitude weakened by 2022, remote workers were positively correlated with average upload speeds in 2022 but not in 2019. In other words, after COVID-19, work from home and higher educational attainment affected average upload speeds more than average download speeds. This is an expected result as upload speeds are a crucial component of working from home.

The share of White non-Hispanics was negatively associated with average upload speeds in 2019 but became statistically insignificant by 2022. This was not the case with the share of Black non-Hispanics and Hispanics. The share of both minorities was associated with higher average upload speeds in both 2019 and 2022. The presence of children had a larger impact when also including the share of Black non-Hispanics in the model, like the pattern observed with average download speeds.

CONCLUSIONS

The digital divide landscape is very complex. When measured by binary yes/no access or adoption variables, specific groups are more affected and certain types of dynamics are observed. However, when measuring this digital divide by average download and upload speeds across two points in time, a more nuanced landscape emerges.

This study has some limitations. There is still close to 20-30% of average download and upload speed variance not explained by these models. This suggests that there are other variables in place that likely influence on-the-ground speed differences within groups and locations. In addition, these models (and data) do not shed light on behavioral differences affecting the choices different groups make when subscribing to available faster broadband service. For example, the Ookla data does not allow us to differentiate between a consumer who chooses to subscribe to a slower-speed service from one who is receiving slower speeds despite subscribing to a faster plan. Future research can help address these limitations.

The following research and policy insights are discussed to better inform digital divide stakeholders and policymakers based on the analysis conducted here:

1. **Rural, older, and poorer groups continue to be on the wrong side of the divide by using the internet at slower speeds.** Not only are these groups associated with slower average download and upload speeds, but the "divide" is widening considering that the magnitude of these correlations increased between 2019 and 2022. Efforts to continue to build broadband in rural areas (particularly by investing in technologies that provide faster download AND upload speeds), increase relevancy and digital literacy among older residents, and address affordability (faster plans tend to be more expensive) must continue.

2. **Children in the household results in faster average download and upload speeds regardless of race/ethnicity.** Not only is the presence of children in the home a factor to consider when looking at home broadband subscriptions, the effect of children on faster internet speeds is clear and becoming stronger. Efforts to identify and subsidize these households so they can subscribe to faster internet speeds must continue. Increasingly sophisticated e-learning and gaming applications are leveraged by children, helping them learn higher digital skills and ensuring a more digitally literate future workforce. Furthermore, more digitally savvy children can increase internet relevancy among their parents and grandparents.

3. **The impact of the COVID-19 pandemic on remote work and faster upload speeds is clearly discernible.** Even though the association between the share of workers working from home and average download speeds was negative, it became weaker between 2019 and 2022. More importantly, the association between remote workers and faster average upload speeds is evidence that upload speeds are increasingly important for remote workers. For many years the emphasis has been on download speeds, but as more and more workers not only consume but produce, symmetrical broadband (identical download and upload speeds) will become not only instrumental but a competitive economic advantage.

4 **Higher educational attainment results in faster internet use, particularly average upload speeds, regardless of race/ethnicity.** The relationship between average download speeds, higher educational attainment, and specific race/ethnicity groups is not clear. However, when looking at average upload speeds, as the share of more educated residents increased, so did average upload speeds regardless of race/ethnicity groups. In other words, educational attainment is more of a factor than race/ethnicity when explaining faster average upload speeds. This is also evidence of the need for symmetrical broadband networks as discussed in the previous point.

5 **White non-Hispanics residents are increasingly on the wrong side of the digital divide.** The most significant finding of this study is the fact that White non-Hispanics use the internet at slower average download and upload speeds even after controlling by rurality, age, and educational attainment. Moreover, this correlation became stronger in 2022 compared to 2019. Digital inclusion assumptions and interventions need to be reassessed, specifically on how to engage with a group that traditionally has not been engaged with. This is not to say that minorities are not affected by the digital divide, but the fact that White non-Hispanics are lagging their racial/ethnic counterparts may require broadening digital equity assumptions and interventions.

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Publication 110 May 2024

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