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Broadband Access and Standardized Test Scores: A Causal Analysis

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ABSTRACT

This paper examines the relationship between broadband speed and access and student performance. I use internet access data published by the FCC, internet speed data provided by Speedtest, and a rich dataset of NY State standardized test scores. My empirical strategy exploits plausible variation in broadband access among NY counties driven by the New NY Broadband Program to test if counties that received increased broadband access also had an increase in standardized test scores. I also test for any correlation between broadband *speed* and test scores. My Differences in Differences framework finds no evidence of a causal relationship between broadband access and test scores. Given the mixed consensus of broadband's effect on student performance, more research is needed on a larger scale to understand broadband's role in education.

Introduction

Since its inception in 1983, the internet has been one of the most critical components of our economy. The internet has had a rapid adoption from 14% of Americans using the internet in 1995 to 87% in 2014 (Statista). With the shift from traditional to technology-driven systems came a drastic change in professional and educational life. Most notably, in the past two decades, the way educators teach has considerably changed; in 2019, 37% of US schools reported having a computer for each student (National Center for Education Statistics). Educators now use technologies like Google Classroom, G-Suite, Canvas, and communication systems like Zoom and email to foster learning.

However, empirical evidence on the benefits of greater internet access or speed on academic performance is still inconclusive despite a great deal of government funding to increase broadband access. With our growing digital world, assessing the internet's academic implications is essential, especially in our youth, where the potential consequences of digitalized classrooms may be irreversible. With such an emphasis being placed on technologies that require an internet connection in schools, one would intuitively think that these technologies improve academic performance in students. In 1998, over $5 billion was spent on educational technology in the US, and that figure has grown every year since (Public School Review). However, despite the substantial usage of the internet in educational settings, the relationship between academic performance and internet access and speed is not proven.

Most believe that high-quality internet access positively affects educational outcomes: technology helps students interact with one another and allows teachers to promote student engagement (Nagasubramani et al., 2018). During the Covid-19 pandemic, we witnessed internet-based learning firsthand. While purely online learning, much of which was done through the activities described above, could not replace traditional learning, it certainly helped (EducationWeek), indicating the value of internet-based teaching methods.

However, the internet also offers distractions that can affect student learning and attention. Leisure activities such as video games, movies, and non-educational websites become easily accessible with high-quality internet access. Some studies show that increased broadband use in young children results in lower grades (Vigdor et al., 2014), especially with a lack of monitoring internet usage (Bremer, 2005). The internet also has cheating concerns: with a wealth of information available to students and the ability to copy and paste, plagiarism becomes easier for students (National Education Association). Students also may be tempted to use artificial intelligence programs to unfairly complete assignments.

In this paper, I analyze the relationship between internet broadband access and speed and standardized test scores. Beyond examining the correlation between broadband and test scores, I employ a Difference and Differences (DID) technique to test a causal relationship between broadband access and test scores. My empirical strategy exploits plausible exogenous variation in broadband access driven by the staggered introduction across counties of the New NY Broadband Program, launched by the New York State government in 2015.

The New NY Broadband Program was intended to expand internet coverage in counties with low broadband adoption, defined as having access to at least a download speed of 25 megabits per second (Mbps). The program consisted of three phases: Phase 1, Phase 2, and Phase 3, each receiving investments of $75.8 million, $256.7 million, and $389.3 million, respectively, serving approximately 36,000, 85,000, and 134,000 households (Program Audit). As a result of the program, internet coverage drastically increased—today, sufficient broadband access is available to 98.95% of the state—with some counties being supported by the program earlier than others (Program Audit).

Through my empirical strategy, I compare "treated" counties (counties that received funding from the program in Phase 1) with "control" counties (counties that did not receive funding in Phase 1). Assuming that treated and control counties experienced a similar evolution of average test scores in the absence of broadband funding, we can attribute any observed effect to the program. Ideally, if increased internet access had a positive effect on test scores, we would see that counties that received the treatment had a greater average treatment effect than those that did not. Moreover, in studying the relationship between test scores and internet access and speeds, correlation and causation are both essential. While correlation might show a potential relationship, it does not prove that test scores are directly caused by internet access. Confounding variables such as socioeconomic status, parental employment, and home environment may all be associated with higher broadband access and have their own impact on test scores. Therefore, the DID technique is critical as it allows us to isolate broadband's effect on test scores—providing us with more information than mere correlation.

Data

To implement my empirical strategy, I collect and merge data from four different sources. First, I use internet access data published by the Federal Communications Commission (FCC). This provides me with information regarding the proportion of households that have access to download speeds of at least 25 Mbps. Second, to obtain internet download speeds, I use internet speed data provided by Speedtest, an internet measurement application with over 10 million daily users. Unlike the FCC data, the Speedtest data provides me with numerical mean internet download speeds, allowing me to create a weighted mean for each of the 62 NY counties. Finally, for the main outcome of interest, I use the most widely available standardized test in NY—the New York State Test. Conducted in both English Language Arts (ELA) and Math in grades 3-8 each year, the New York State Test remains the only examination in NY that is widely adopted by schools aimed to measure student intelligence and capabilities. I aggregate test scores by grade level and subject at the county level to create a mean test score for each of the 62 NY counties. As discussed above, the FCC data includes the New NY State Broadband Program, allowing me to leverage the staggered introduction of the program through the DID technique. The combination of these data allows me to examine the relationship between internet speed and test scores in terms of both correlation and causation.

Results

While both broadband access and broadband speeds among counties in NY have been increasing since 2014, standardized test scores in NY do not relate to these data at the county level (see Figures 5 and 6). There is no correlation between the average internet download speed and average test scores in any grade level in both Math and ELA tests. When plotting internet speed and Grade 8 Math scores, for example, I find a slope estimate of 0.023 and a p-value of 0.263, indicating no correlation between these data. Additionally, the DID estimates indicate an average treatment effect of approximately -2.801 with a p-value of approximately 0.620. The regression shows that these estimates were not statistically significant, indicating that the treatment imposed by the NY State had no significant effect on test scores. In other words, in 2016, when the treatment was first introduced, counties that received treatment saw a similar trend in test scores to counties that did not. This also suggests a lack of relationship between test scores and internet access and allows us to conclude that increased internet access did not cause greater test scores in NY.

Discussion

The lack of causation and correlation between broadband and test scores in this study, does not mean high-quality internet access cannot improve education. Empirically, however, the lack of causation between internet access and test scores suggests that, on average, increased broadband access did not directly affect test scores. This could be for several reasons: students could not have shown such results on a standardized test in such a short period, or students did not take advantage of increased internet access. Further work must be done to conclude that broadband access and educational outcomes have a null relationship in all scenarios. Other studies with various factors like location, grade level and environment have produced mixed results. For example, Belo et al. (2013) analyzed the impact of broadband in student performance in Portuguese schools and found that high quantities of internet usage in classrooms had a negative impact on student performance, across all grade levels. Bessone et al. (2021) finds that 3G access in Brazil had no effect on student test scores in both Portuguese and math. Campbell (2022) finds that increased broadband improves educational outcomes and increases the search volume for online resources like Khan Academy. All three of these recent studies with similar questions to that in this paper find different results, indicating the need for further research.

That said, the lack of causation found in this paper should prompt governments, which pour billions of dollars into broadband development (National Telecommunications and Information Administration) to ensure that high quality broadband access has its desired effects on students. Broadband is certainly helpful in some respects like employment ability and workforce development, (National Telecommunications and Information Administration) but there is conflicting evidence regarding broadband's effect on student performance. Further work, perhaps on a larger scale that addresses multiple states and grade levels, needs to be done to fully understand broadband's role in student performance and achievement.

It is worth noting that the question of whether internet access directly causes an increase in test scores is intrinsically difficult to answer. For example, simply having access to greater internet speed does not ensure students will take advantage of this access. Therefore, our data of internet access may not necessarily mean greater usage, especially among young children in grades 3-8. Even if students did promptly adopt higher internet usage with higher internet speeds, it is possible that standardized test scores would not show any potential increased intelligence. Many argue that standardized test scores are not a good predictor of student intelligence (National Education Association; Sacks, 201); it is possible that any intelligence gained through internet access would not be shown in students' test scores.

Background

Setting: NY Broadband Program

Launched in 2015 by the New York State under the Broadband Program Office (BPO), the New NY Broadband Program was established with the goal of achieving statewide broadband access by 2018. The BPO describes sufficient broadband access as having an internet download speed of at least 100 Mbps in most areas; in rural areas, download speeds of 25 Mbps were said to be acceptable (Program Audit). The program was split into phases—Phase 1, Phase 2, and Phase 3—each having its own evaluation process to identify housing units in underserved areas. This multiphase structure allowed for households that were with undocumented broadband data to still request aid. The three phases received over $721 million in investment serving approximately 255,994 units (Program Audit). Through the program, around 3% of the State (which were previously underserved) obtained sufficient broadband speeds (Program Audit).

That said, the State declares its work in expanding broadband access is not complete for several reasons: 1) The State believes that broadband availability data is inflated. Because the FCC Broadband's Deployment data considers an entire census block served, even if only one household in that block has sufficient broadband access, they believe that the number of households they have documented as served is higher than it is truly us. 2) There are still approximately 14,000 households that do not have broadband access—about 10,200 being unserved and 3,800 being underserved (Program Audit). The State is in the process of creating and deploying nine additional broadband projects to give these remaining 14,000 households broadband access (Program Audit).

Despite such efforts and plans to increase broadband access, its impact on educational outcomes is not well-established. In the context of this study, I exploited the multiyear length of the New NY Broadband Program as well as its staggered introduction to test if test scores increased in treated counties.

Data

I use FCC data which shows households in NY State that have sufficient broadband access, deemed as a download speed of at least 25 Mbps. I then aggregate this information by county, providing the proportion of households in each NY county that have sufficient broadband access.

Figure 1 below uses the FCC data to confirm that the program achieved great success in raising the proportion of counties with sufficient access. The average fraction of households in NY with sufficient broadband access went from 89% to 100% between 2014 and 2017. Figures 2 and 3 display broadband coverage in 2016 and 2017. As we can see from the maps, the program greatly contributed to the number of households which obtained sufficient broadband access.

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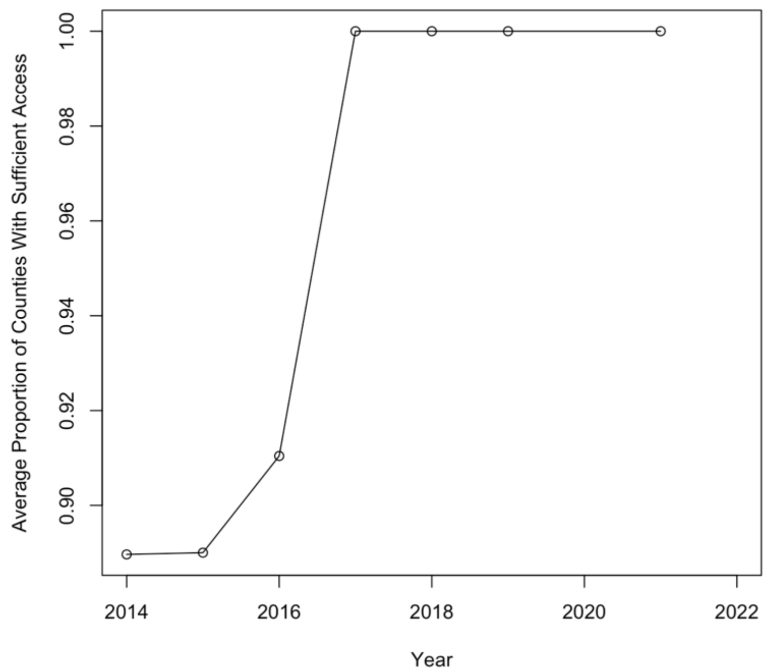
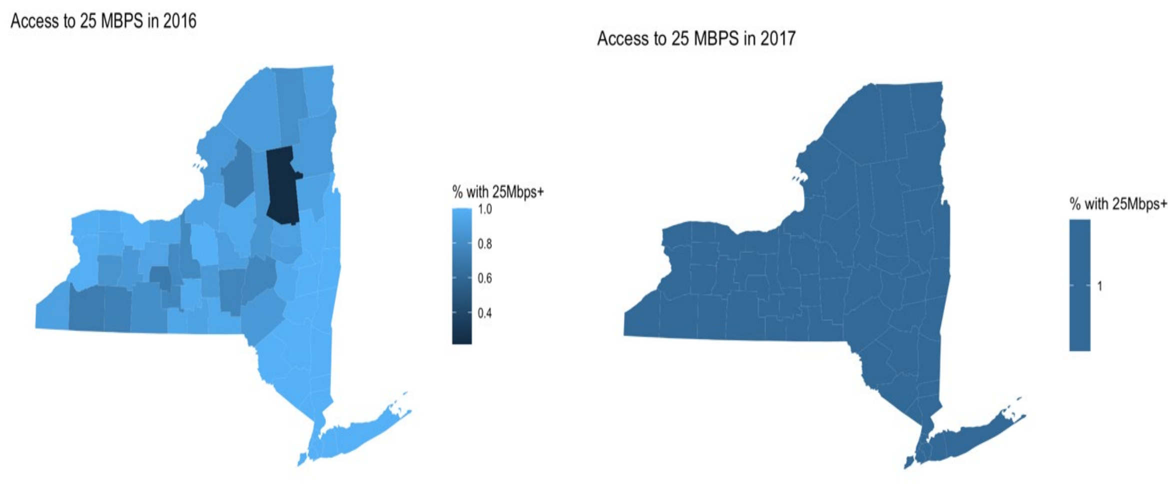


Figure 1. Average proportion of households in all counties that have "sufficient broadband access."



Figures 2 & 3. Map of NY State showing the proportion of households in each county that have "sufficient broadband access" in 2016 and 2017 respectively.

While the FCC provides valuable broadband access data, it does not provide any data regarding the internet download speed of households. Consequently, I reached out to Speedtest, an internet measurement application, which provided me with internet speed data for all its clients in NY State from 2017-2022.

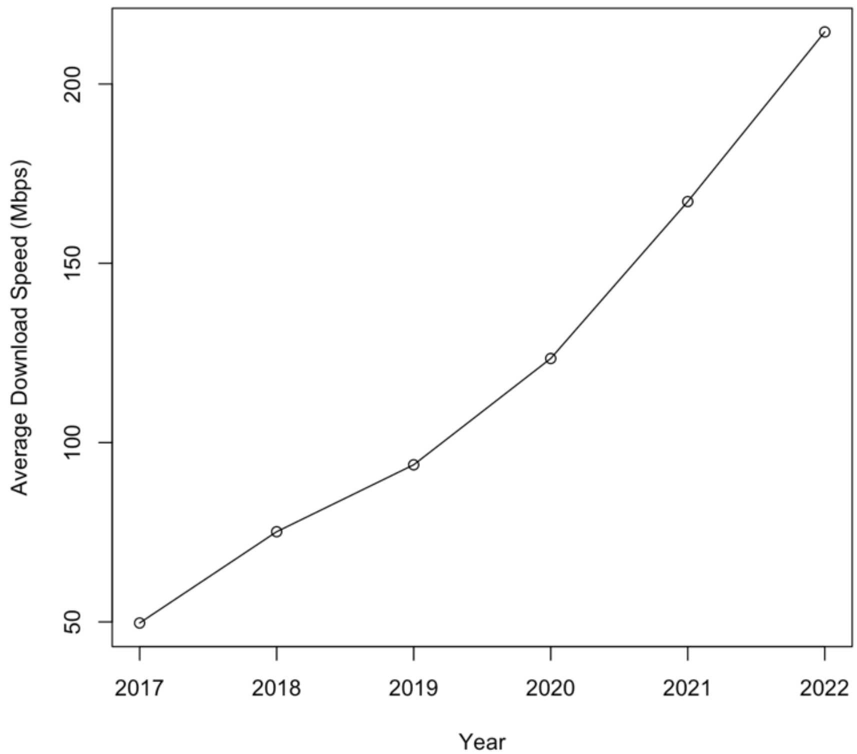


Figure 4. Average download speed in all 62 NY counties from 2017 to 2022.

Similar to internet access, internet speed in NY counties has also increased over the past few years. These two metrics indicate that technological developments and funding provided by governments have resulted, and continue to result, in improvements in high quality internet access.

For the main outcome of interest, test score data, I use the only widely adopted standardized test in NY state: the New York State Test. The New York State Test is given to all public high schools in NY state in grades 3-8, in math and ELA. Although the precise scoring method of the test has changed over the years, the fundamental goal has remained the same—to obtain an accurate measurement of a student's ability to understand NYS learning standards. There also exists ample data of students' results from many years. Like broadband data, I aggregate this test score data by county to obtain a mean test score (for each grade and subject) in all 62 NY counties.

Empirical Strategy

It is essential that this paper studies both the correlation and causal relationship between internet broadband and test scores. While a correlation may indicate a potential relationship between interest broadband and test scores, it fails to account for confounding variables (e.g., socioeconomic status, home environment, tutor access, etc). For example, households with higher internet speeds could, naturally, have a higher household income, allowing parents to provide learning resources to their children—like tutors—to help their children perform better on standardized tests. Therefore, testing for a causal relationship between internet broadband access and test scores is imperative as it allows us to isolate the effect of broadband access on test scores.

To test for this causal relationship, I employ the Difference in Differences (DID) technique. This technique has some necessary assumptions. Importantly, we must assume parallel trends in absence of treatment.

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This means that if the treatment (counties that were treated by the New NY Broadband Program) was not provided, both control and treated counties would see a similar evolution in test scores. This assumption allows us to implement a counterfactual line—a predictive slope that would estimate the evolution of treated counties in the absence of a treatment, based on the control counties evolution. Additionally, I must assume the absence of any spill-over effect from treated counties to control counties. If, for example, the funding given to treated counties had some sort of indirect effect to control counties, the DID would be biased. However, because social interactions in a county are quite local, it is unlikely that scores in one county would be able another county's scores.

Difference in Differences Technique

With these fundamental assumptions, I can now perform a DID regression to test for causation. I estimate it by comparing mean test scores in treated and controlled counties in Grade 3 ELA, Grade 3 Math, Grade 8 ELA, and Grade 8 Math. The average treatment effect (ATE) is given by the following expression:

$$\delta = \left(y_{yearA}^{treatment} - y_{yearB}^{treatment}\right) - \left(y_{yearA}^{control} - y_{yearB}^{control}\right)$$

where $y_{yearA}^{treatment}$ and $y_{yearA}^{control}$ denote the mean value of y in time period $yearA$ for the treatment and control groups respectively. This provides me with my average treatment effect for each of the four instances I am testing (Grade 3 ELA, Grade 3 Math, Grade 8 ELA, and Grade 8 Math). The hypothesis that I am interested is whether there is a statistically significant causal effect:

$$H_0: \delta = 0$$
$$H_A: \delta \neq 0$$

Results

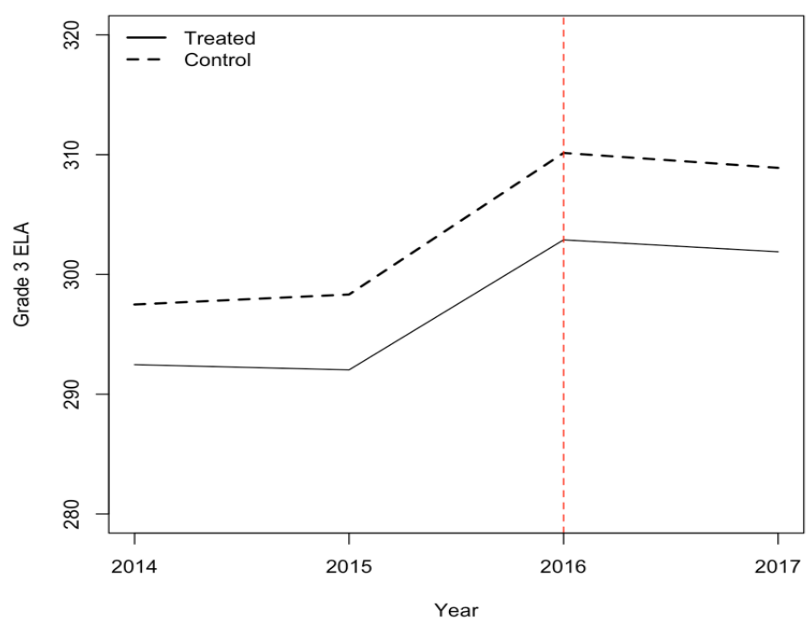

Figure 5. DID analysis[1]

[1] For simplicity, only the figure for Grade 3 ELA is included. Grade 3 Math, Grade 8 ELA, and Grade 8 Math figures are available upon request.

Figure 5 compares the average Grade 3 ELA scores over time between treated and control counties, where the red line represents the treatment year, 2016. This provides descriptive evidence that the test scores evolved in a parallel fashion between treatment and control counties, providing credibility to the identification assumption. While the treatment certainly had a profound effect broadband access wise (see Figures 2 & 3), the same cannot be said about test scores. Figure 5 shows that after the treatment was imposed, treated counties saw a similar evolution to control counties. Without performing any calculations, we can anticipate that the treatment will not have a statistically significant effect on test scores.

Table 1 below presents estimates of the average treatment effects, which I calculated using the equation described above. For example, the estimated coefficient for Grade 3 ELA was 0.248 points. This means that on the Grade 3 ELA Test an additional 0.248 points, on average, was scored in the treated versus control counties after the broadband program was introduced. Although there is a difference, this difference is only slight, supported by our p-value of 0.953. In fact, all p-values for each are greater than 0.05, suggesting that the effect of the broadband program on test scores was not statistically significant.

Table 1. The average treatment effects and p-values (both truncated to three decimal places) for the DID regression in Grade 3 ELA, Grade 3 Math, Grade 8 ELA, and Grade 8 Math.

Grade	Variable	ELA	Math
3	ATE	0.248	-1.536
3	p-value	0.953	0.738
8	ATE	-0.007	-2.801
8	p-value	0.998	0.620

Correlational Evidence

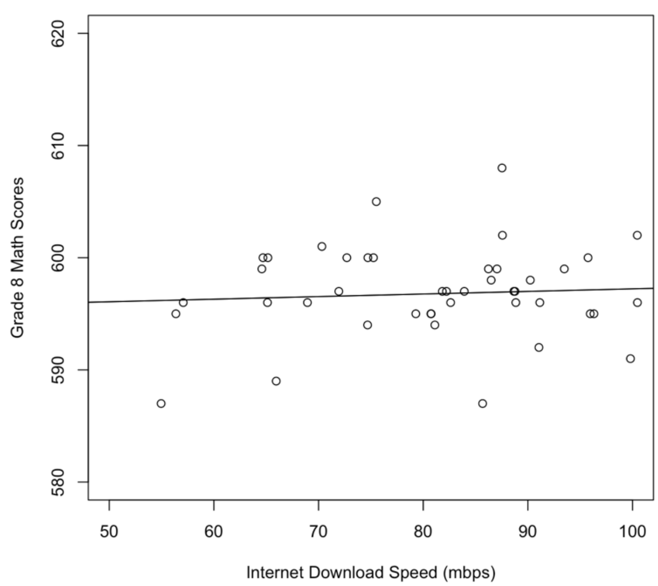

Figure 6. Scatterplot showing mean Grade 8 Math scores and mean internet download speeds in all 62 NY counties.[2]

[2] Figures and regression statistics for Grade 3 Math, Grade 3 ELA, and Grade 8 ELA are available upon request.

Table 2. Regression statistics for Figure 6.

	Estimate	Std. Error	t-value	p-value
Intercept	594.91873	1.98522	299.674	**<2e-16**
Slope	0.02305	0.02038	1.131	0.263

Table 2 presents results from a simple regression of Grade 8 Math scores on internet download speeds in 2019. In this instance, and the other three instances (Grade 3 Math, Grade 3 ELA, and Grade 8 ELA), there is no evidence of any correlation between broadband *speed* and test scores, as shown with our p-value of approximately 0. These consistent results suggest that there was no issue in using internet access from the FCC as a metric to measure internet broadband quality—broadband speed as a metric to assess internet broadband quality yields similar results. Instead, it reinforces our null results, on both a correlational and causal level, between internet access/speed and test scores.

Conclusion

It is undeniable that governments pour billions of dollars into broadband infrastructure. These initiatives have been proven highly successful; in recent years, we have seen a significant increase in broadband access and speed among New Yorkers, a direct outcome of broadband funding. However, we often fail to analyze the actual effects of increased broadband. We intuitively believe that broadband is intrinsically a positive thing—for schools, the economy, the workforce, and society as a whole.

Through my empirical strategy, including a comprehensive DID analysis, I find a null relationship between broadband speed and test scores, including no evidence of a causal relationship between the two. While these results cannot be extrapolated to say that high-quality internet access does not improve education in all environments (different factors such as grade level and location could produce different results), it should motivate governments to conduct further research surrounding this dilemma. One primary concern is that this analysis did not have enough observations or a long enough time frame to detect a statistical relationship. It is possible that any positive effects broadband may have on education could take multiple years to reflect in test score data. Moreover, given that the literature has shown mixed results—for instance, Bremer (2005) finds the internet can be harmful to children if their usage is unmonitored, whereas Bessone et al. (2021) found that 3G access in Brazil did not affect student test scores—more research on a larger scale is vital to better understand broadband's true effect on educational outcomes.

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Based on analysis of Speedtest Intelligence® data from Quarter 1 2017 to Quarter 4 2018. Ookla® trademarks used under license and reprinted with permission.

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