Extended Abstract

Access to Technology and Secondary Educational Outcomes: Empirical Evidence from India

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Abstract

Digital resources such as laptops have the potential to improve access to educational resources and provide personalized and uninterrupted learning opportunities. The impacts of these technologies may be especially salient in contexts where classroom sizes are large and schooling quality poor. Here we study the impacts of laptops on educational outcomes in one such context – India – exploiting plausibly exogenous variation in the implementation of a laptop distribution programme among government school students, the Tamil Nadu Free Laptop Scheme. We find strong, positive effects on educational outcomes including math and reading ability among students exposed to the programme. We further find that students use laptops as a substitute for private tuition, which suggests that providing higher quality educational resources could improve learning outcomes. However, the benefits of the programme do not accrue evenly by gender, with boys likely to be the main beneficiaries and girls experiencing minimal impacts.

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Introduction

The United Nations' Sustainable Development Goal 4 (SDG 4) emphasizes the need for quality education for children.[1] With the digitalization of educational resources, access to technologies, such as laptops and computers, constitutes an important part of the infrastructure necessary to achieve SDG 4. Digital technologies not only help to provide a wide variety of learning resources to students but also have the potential to help them to continue their learning in times of crises, such as during the COVID-19 pandemic, or continue learning outside of traditional classroom settings, which in low- and middle-income country (LMIC) contexts can often be crowded, difficult to reach, or inaccessible (Fuller, 1985; Hanushek, 2013; Masino and Niño-Zarazúa, 2016; Orazem and King, 2007; Dhawan, 2020; Adukia, 2017). Technologies such as laptops may in these settings provide opportunities for more focused and private learning than may be possible in classroom settings. Access to technology also have the potential to help adolescents acquire much needed digital skills that are useful when they enter increasingly digitalized labor markets.

Despite the plausible benefits from digital resources, progress in terms of the availability of computers, laptops, and other digital technologies remains uneven in different parts of the world. While there is near universal access to computers in upper secondary schools in high-income countries, low-income countries still lag behind.[2] In an effort to close these gaps, different laptop distribution programmes have been implemented across LMICs. Although the exact features, extent of coverage, and investment in these programmes have varied across settings, the objectives of these policies have been to improve access to laptops among children of school-going age. However, considerable differences still persist, with data suggesting that only 38.5% of households had a computer at home in developing countries when compared to 82.3% of households in the developed nations.[3]

In this study, we explore the effects of laptop accessibility on students' academic achievements in India, specifically delving into the Tamil Nadu Free Laptop Scheme. This state-level

[1] sdgs.un.org/goals/goal4
[2] sdg4-data.uis.unesco.org/
[3] www.itu.int/en/ITU-D/Statistics/Documents/facts/FactsFigures2019.pdf

initiative distributed over 5 million complimentary laptops to students attending government and government-funded institutions.[4] By capitalizing on the potentially exogenous variations in the program's execution, our aim is to discern whether the availability of laptops influenced students' proficiency in mathematics, reading, and other educational outcomes.

In a preliminary overview of our findings, laptop accessibility exhibited a favorable impact on students' academic performance and other educational outcomes. Leveraging the potentially exogenous variations stemming from the rollout of the Tamil Nadu Free Laptop Scheme (TLFS), we observed enhancements in students' mathematics and reading capabilities. Additionally, there were notable reductions in private tuition, increases in the hours students dedicated to school and the time they allocated to homework. We consider these effects as potential mechanisms for the impact of TFLS on students' academic performance.

Apart from contributing to the wider literature on the impacts of digital access on learning outcomes and educational inequalities, our study is unique in three specific ways.

First, most of the research on the subject has focused on the causal impacts of laptops and computing resources on educational outcomes of primary and middle school students (Beuermann et al., 2015; Bulman and Fairlie, 2016; Cristia et al., 2017). Our study, on the other hand, studies these impacts on learning outcomes of upper secondary students. This is an important differentiating factor as upper secondary students are much closer to entering the labor market and any effects of the program at this stage can have potentially positive labor market outcomes later on. Moreover, impacts on educational performance and skills development at this stage of the educational trajectory can have more immediate, short-term implications for access to post-secondary education and/or job training opportunities.

Secondly, our study sheds light on a novel mechanism by which computer accessibility can enhance educational outcomes. This is particularly pertinent in contexts like India, and other analogous settings, where there's a significant dependence on out-of-school private tutoring and supplementary after-school classes (Dang, 2007; Buchmann, 1999; Biswal, 1999; Bray, 1999). This dependency stems from a blend of subpar schooling standards and elevated

[4] https://www.dtnext.in/news/tamilnadu/free-laptop-scheme-on-sleep-mode-735064

educational ambitions. Through a quasi-experimental methodology, our findings indicate that students benefiting from the programme exhibited a reduced propensity for private tuitions. This suggests a potential shift, where students are replacing private tutoring with laptop utilization, which in turn, may contribute to enhanced academic outcomes. Crucially, this highlights that in the resource-limited environments typical of low-income nations, the educational dividends of laptop access might outpace those of private tutoring.

Third, we find that laptop provision affects boys and girls differentially. While boys experience a gain in the learning outcomes on account of the program, we find much lesser (and in some cases no impacts) for girls. While existing literature points to a large gender divide in access to digital technologies among adult women in India (Kashyap et al., 2020), our findings point to the gender divide in access and use of technological resources also among adolescents. These findings suggest that beneficiary girls may have been unable to hold on to their laptops and use them with similar efficacy as boys, or potentially had to share them with other family members.

Apart from the above contributions, to the best of our knowledge, this is the first study that looks at the impact of a government laptop programme in India. The scale of the program is also much larger compared to some of the programs implemented in other countries. For instance, the OLPC, a global attempt to improve the availability of laptops for school children, distributed over 3 million laptops in over 64 countries between 2005-2021. In contrast, the TLFS initiative provided laptops to over 2 million students in the first 3 years of the program in a single state of India [5][6].

Background

Hypotheses

We hypothesize that since technological resources such as laptops form an important input for the education production function, access to the same can have potential impacts on

[5] laptop.org/aboutolpc

[6] www.thehindu.com/news/national/tamil-nadu/who-got-tns-free-laptops/article6999363.ece

the educational outputs such learning and performance of the students (Hanushek, 1979). Laptops provide students with access to a wide range of educational resources, with the flexibility of being able to access them when, where, and at the speed at which they would like. Particularly in the context of LMICs where school classroom contexts can have a large number of students per teacher, the more private learning afforded by laptops has the potential to improve learning outcomes. However, a lack of digital skills or other reasons that limit the ability to leverage the educational resources offered by laptops may limit the realisation of these impacts, and in turn, result in null effects. Conversely, the direction of the impacts may also be negative if students who gain access to laptops use them for other purposes, such as entertainment or leisure, which may in turn reduce time spent on education. In sum, the direction for the impact of laptops can be positive or negative too depending on how students use these resources.

Empirical evidence

Existing empirical evidence on the subject also points towards mixed results (Murnane and Ganimian, 2014). Beuermann et al. (2015), and Cristia et al. (2017) evaluate the impact of One Laptop Per Child (OLPC) program in Peru and find little to no effects on test scores and cognitive skills of the primary school students. Mora, Escardíbul and Di Pietro (2018) study the impact of OLPC program in Catalonia and find negative impacts on language and math skills of secondary school students, with negative impact being larger for boys than girls. Mo et al. (2013) find positive effects of the OLPC program on math scores in China. Malamud and Pop-Eleches (2011) study the impact of home computers in Romania and find negative impacts on grades but positive impacts on cognitive skills. Fairlie and Robinson (2013) find no impacts of home computer ownership in US on educational outcomes of students. Fairlie (2016) also do not find any differential impact of home computers on learning outcomes of boys relative to girls. These studies point to heterogeneous impacts across national contexts, but most largely focus on primary or middle school aged students. Moreover, few studies looking at the impacts of computers or laptops rely on quasi-experimental approaches where these are introduced within a policy reform (with the exception of studies on the OLPC).

Tamil Nadu Free Laptop Scheme

The 'Free Laptop Scheme' or 'Tamil Nadu Free Laptop Scheme' (TFLS) was introduced in the southern state of Tamil Nadu in India in the year 2011 (marked in blue in figure 1). It was the first scheme of its kind in the country that sought to provide free laptops to students studying in government or government aided higher secondary schools and colleges.[7] The rationale behind the program was to invest in the human resource potential of the state and develop digital skills that can open new opportunities to participate in the information technology labor market for the youth. With the government providing free laptops only to students in government schools, it also aimed to bridge the digital divide between students studying in government and private schools as the former are likely to be resource constrained and underinvest in educational resources.[8]

On the operational side, the procurement of laptops was done through the Electronics Corporation of Tamil Nadu (ELCOT) who began the distribution of the same from September 2011. In the initial phase of the program, higher secondary students studying in class 12th (final year of senior secondary school) as well as students studying in undergraduate programmes (in different years) in government institutions were eligible for the programme. The distribution of laptops was done simultaneously in all the districts of the state, with the government incurring an expenditure of over 600 million dollars on distribution of over 2 million laptops in the first 3 years of the programme[9].

Methods and Data

We employ a triple difference (difference-in-difference-in-differences or DDD) design (Gruber, 1994) to examine the causal impacts of the 'Tamil Nadu Free Laptop Scheme' on learning

[7] Government schools and colleges are owned and operated by the central or the state governments. Government aided institutes, on the other hand, receive funds from the government exchequer.

[8] johnsonasirservices.org/web/Download3/LAP%20TOP%20COMP.spi_e_17_2011.pdf

[9] thehindu.com/news/national/tamil-nadu/who-got-tns-free-laptops/article6999363.ece

and education related outcomes of children. For the purpose of the study, we restrict our analysis to school going children as learning and educational outcomes are less likely to be comparable across schools and colleges. Furthermore, the primary source of data that we use for analysis only covers information on schooling level of the children in the age group 5-16 (explained in detail below).

Figure 1: Map of India

In using a triple difference design, we compare the learning outcomes of our *eligible cohort* (class 12th) to that of the *ineligible cohort* (class 11th) across our *treated* state of Tamil Nadu and other *control* states in India, *before* and *after* the program. More specifically, we study the effect of being exposed to TFLS using an intent-to-treat (ITT) analysis by running the regression equation given below for each child i belonging to household h from village v in state s. We restrict our analysis to children studying in government schools as the scheme was only available to them.

$$Y_{ihvs} = \alpha_s + \delta_t + \beta_1 \cdot (Eligible \times Treated \times Post) + \beta_2 \cdot (Eligible \times Treated) + \beta_3 \cdot (Eligible \times Post) + \beta_4 \cdot (Treated \times Post) + \beta_5 \cdot (Eligible) + \beta_6 \cdot (Treated) + \beta_7 \cdot (Post) + \gamma_1 \cdot X_i + \gamma_2 \cdot X_h + \gamma_3 \cdot X_v + \epsilon_{ihvs} \quad (1)$$

, where α_s and δ_t capture state fixed effects and time fixed effects, respectively. Y_{ihvs} captures the learning and other educational outcomes of children. *Eligible* is a dummy variable that takes value 1 for the eligible cohort (Class 12th) who received the program benefits and 0 for the ineligible cohort i.e. class 11th. *Treated* is also a dummy variable that takes value 1 for the treated state of Tamil Nadu and zero, otherwise. The dummy variable *Post* takes value 1 for the period post policy introduction and zero in the pre-policy period. β_1, then, is our coefficient of interest and picks out the effect of the TFLS programme on learning and educational outcomes of children. We also use several individual, household and village level controls for our analysis. These include child age, gender, mother's schooling status, mother's age, number of household members, electricity connection in the household, electricity in the household on the day of interview, type of household, electricity in the village, bank in the village, and availability of a primary, a middle, a secondary, and a private school in the village. We also use robust standard errors clustered at the state level for our analysis.

We rely on the use of two data sources to understand the potential impact of TFLS on learning and other educational outcomes of students. The first data source that we use is the

Annual Status of Education Report (ASER) Survey conducted by Pratham[10]. ASER is a nationally representative annual household survey that provides information on the learning outcomes for math and reading for rural children aged 3-16 years[11][12]. We use data from the surveys conducted in 2008, 2009, 2010, 2011, and 2012 for our analysis. The ASER Survey has previously been used in numerous studies in the education literature to study learning and educational outcomes in India (Adukia, 2017; Chakraborty and Jayaraman, 2019; Shah and Steinberg, 2019). While the nature of the data constrains us to study impacts only for rural children, it is also helpful as inaccessibility to laptops would be much higher in this setting.

The second data source we use is the India Human Development Survey (IHDS) - Round 1 and 2 conducted during 2004-05 and 2011-12, respectively. The survey is also nationally representative in nature and is conducted jointly by University of Maryland and National Council of Applied Economic Research (NCAER). The survey provides information on education related outcomes of children and has also been used extensively in education as well as development studies literature. (Singh and Shemyakina, 2016; Chatterjee and Poddar, 2021; Kaur, 2021).

Results

Main Results

We report the results from our triple identification design (DDD) in Table 1. The results suggest that potential exposure to TFLS program has a positive effect on learning outcomes of children. The effect size ranges from 2.2% for math to 1.69% for reading, when compared to their respective means.

[10] Pratham is a non-governmental organisation in India that was established in 1995

[11] riseprogramme.org/blog/shifting-schooling-learning-aser-shaped-indias-education-discourse-policy-measuring-learning#:~:text=ASER%20is%20now%20the%20largest,%2C%20state%2C%20and%20national%20levels.

[12] asercentre.org/wp-content/uploads/2022/12/2.-frequentlyaskedquestionsaboutaser-2.pdf

Table 1: Impact on Math and Reading Ability

	Math Score	Reading Score
	(1)	(2)
TFLS	0.083***	0.066***
	(0.019)	(0.015)
R^2	0.11	0.12
Observations	22,317	22,344
Mean of Dep. Var.	3.77	3.90

Notes: Robust standard errors clustered at the state level are reported in parentheses. *** p<0.01 **p<0.05 *p<0.1

Potential Channels

We further examine the impact of the TFLS program on other educational outcomes (Table 2) to check if they act as potential mechanisms for our effects on the learning outcomes. We observe that children potentially exposed to the program were less likely to take private tuition (Column 1 and Column 3). This makes sense as children might potentially be substituting away from private tuition as they now have laptops to compensate for it (Whiting, 1985; Bulman and Fairlie, 2016). With the low quality of instruction now being replaced by laptops, it is possible that the learning outcomes of children actually improve (Bulman and Fairlie, 2016). We also find that potential access to the TFLS program also increases the number of school hours as well as homework hours that children spend during the week. This also shows the role laptops play in supplementing classroom education for the children, which might potentially result in improved learning outcomes.

Table 2: Impact on Private Tuition and Other Educational Outcomes

	ASER	IHDS			
	Pvt. Tuition	School Hrs/Week	Homework Hrs/Week	Pvt. Tuition Hrs/Week	Absent Days/Month
	(1)	(1)	(2)	(3)	(4)
TFLS	-0.087***	10.079***	2.735***	-2.276**	1.085
	(0.019)	(1.552)	(0.745)	(0.827)	(0.957)
R^2	0.18	0.12	0.15	0.17	0.15
Observations	18,313	2,488	2,496	2,409	2,476

Notes: Robust standard errors clustered at the state level are reported in parentheses. *** p<0.01 **p<0.05 *p<0.1

Sub-sample Analysis and Heterogeneity

We assess if the exposure to the TFLS had potentially differential impacts on boys and girls. This is possible as some evidence in the education literature points towards differential use of computers for boys and girls (Fairlie and Robinson, 2013; Fairlie, 2016). Moreover, in the Indian setting where girls continue to experience educational disadvantage in school classroom settings, more focused and personalized access to resources through laptops has the potential to provide larger payoffs (Gandhi Kingdon, 2002; Kingdon, 2007; Chatterjee and Poddar, 2021). On the other hand, the literature also suggests that in a resource-constrained setting women and girls might be less likely to retain control over technological assets such as mobiles and laptops as the control might pass on to a male family member or the asset might be sold off (Roessler et al., 2021). We, therefore, perform a sub-sample as well as heterogeneity analysis for boys and girls in Table 3. We observe that boys were likely to be the primary beneficiaries of the TFLS program with the private tuition substitution effect working only for them.

Table 3: Math Ability, Reading Ability, and Paid Tuition: Sub-sample and Heterogeneity Analysis

	Sub-sample: Boys=1			Sub-sample: Girls=1			Interaction Dummy: Boys & Girls		
	Math Score	Reading Score	Paid Tuition	Math Score	Reading Score	Paid Tuition	Math Score	Reading Score	Paid Tuition
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$TFLS$	0.107***	0.157***	-0.147***	0.058**	-0.005	-0.041	-0.062*	-0.169***	0.113**
	(0.030)	(0.030)	(0.032)	(0.023)	(0.010)	(0.027)	(0.036)	(0.029)	(0.042)
R^2	0.11	0.10	0.19	0.12	0.15	0.18	0.11	0.12	0.18
Observations	11,254	11,271	9,253	11,063	11,073	9,060	22,317	22,344	18,313

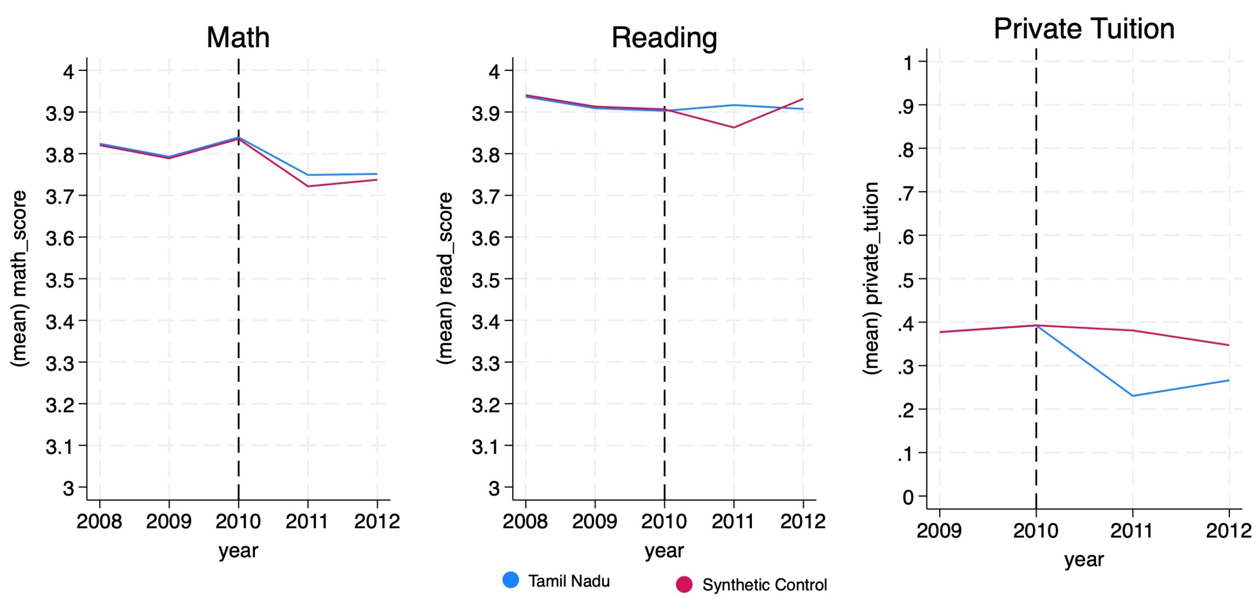
Notes: Robust standard errors clustered at the state level are reported in parentheses. *** $p<0.01$ **$p<0.05$ *$p<0.1$

Robustness Checks

Synthetic Controls

A potential issue with our identification strategy could be that we take all the regions in India as a control group for our treated state i.e. Tamil Nadu. These regions might differ from Tamil Nadu in several observable and unobservable ways and might potentially not serve as a good control. To account for this concern, we now use the synthetic controls design to build a ‘counterfactual’ for Tamil Nadu. Under the method, the ‘control’ unit is build by weighting the observations in the comparison group in a manner that the trends in the covariates and the outcomes of the ‘counterfactual’ match the ’treated unit’ i.e. Tamil Nadu in this case (Abadie, Diamond and Hainmueller, 2010; White and Raitzer, 2017). Furthermore, the method relaxes the parallel trends assumption and we simply compare the trend in the counterfactual with that of the treated unit. Figure 2 presents the results of this exercise. As we can notice, the math and the reading outcomes are much higher and the private tuition much lower in the post treatment period when compared to the synthetic control group.

Figure 2: Synthetic Controls



Impacts for unelectrified households

Our results suggest that access to laptops results in higher learning outcomes for math and reading among students. Since access to electricity serves as a basic prerequisite for the use of laptops, our results should be driven by the households that do have electricity connections. In other words, we should find little to no effects of the program on unelectrified households. We test this and report the results of the exercise in Table 4.

Table 4: Impact on Math and Reading Ability : Unelectrified Households

	Math Score	Reading Score
	(1)	(2)
$TFLS$	-0.002	-0.013
	(0.066)	(0.078)
R^2	0.25	0.24
Observations	2,551	2,553

Notes: Robust standard errors clustered at the state level are reported in parentheses. *** p<0.01 **p<0.05 *p<0.1

Parallel Trends

We also test for the unconditional parallel trends assumption for our triple difference estimates using the pre-period data for the years 2008, 2009, and 2010 (Muralidharan and Prakash, 2017). As we can observe, the coefficient of TFLS is not significant in the pre-period. Furthermore, the coefficient for math score is close to zero as well. Hence, we do not reject the null hypothesis of parallel trends.

Table 5: Impact on Math and Reading Ability : Pre-trends for DDD Estimates

	Math Score	Reading Score
	(1)	(2)
$TFLS$	-0.008	-0.038
	(0.030)	(0.025)
R^2	0.001	0.001
Observations	18,641	18,681

Notes: Standard errors are reported in parentheses. *** p<0.01 **p<0.05 *p<0.1

Cohort Falsification

In identifying the impact of the TFLS program, we take students in class 12th as our eligible cohort and students in class 11th as our ineligible cohort. This classification is based on the institutional features of the program rollout as only students in class 12th were eligible for laptops till year 2012. To ensure that this classification of eligible and ineligible cohort is not leading us to pick up a spurious result, we now run the same regressions but this time take students in class 11th as the eligible cohort and students in class 10th as the ineligible cohort. If our identification strategy is correct, this provision of *fake* treatment to class 11th students should not result in any policy impact as both class 11th and class 10th students were ineligible for the program according to the rollout guidelines. The results for this cohort falsification exercise are provided in Table 6. As expected, we do not find any significant effects of fake treatment to class 11th students. This provides us confidence that our identification design is indeed picking up the true effect of the TFLS program.

Table 6: Impact on Math and Reading Ability : Cohort Falsification

	Math Score	Reading Score
	(1)	(2)
$TFLS$	-0.053	0.008
	(0.031)	(0.013)
R^2	0.08	0.03
Observations	82,801	82,893

Notes: Robust standard errors clustered at the state level are reported in parentheses. *** p<0.01 **p<0.05 *p<0.1

Conclusion

In this study, we provide empirical evidence for the positive impacts of laptops on secondary educational outcomes of students. Using a triple difference design that relies on state, cohort and time variation, we find that both math as well as reading outcomes of the students potentially exposed to the free laptop program improved. We believe that reduction in time spent on private tuition serves as a potential channel for our effects as students now substitute away from them on account of access to laptops. Students also spend more time in school as well as on doing homework post laptop provision. However, our results suggest that benefits of the program are likely to be concentrated among boys with girls experiencing little to no positive effects. Our results suggest that access to technology in the form of laptops can potentially help improve educational outcomes in developing countries that lack high quality educational infrastructure.

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