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Access to ICTs during middle education: Who may benefit in the case of Colombia.

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DOCUMENTOS DE TRABAJO
Saber Investigar

La serie de Documentos de Trabajo Saber Investigar del Icfes tiene como propósito hacer divulgación de los resultados de investigaciones sobre evaluación y análisis de la calidad de la educación.

Acceso a las TIC en la educación media: Quiénes pueden beneficiarse en el caso de Colombia.

Jorge Leonardo Rodríguez Arenas

Luis Fernando Gamboa

Este documento aprovecha la existencia de una muestra longitudinal de estudiantes de secundaria en Colombia entre 2017 y 2019 para evaluar los efectos que genera el acceso a las tecnologías de la información y la comunicación (TIC) en el rendimiento académico de la prueba estandarizada Saber 11°. Al utilizar diversas especificaciones de las TIC, se encuentra que hombres y mujeres obtienen ganancias diferentes según el área (matemáticas y lectura crítica). Es decir, tener acceso a una computadora e Internet aumenta la puntuación entre 0,057 y 0,079 desviaciones estándar en matemáticas para hombres y mujeres, respectivamente. En el caso de lectura crítica, no hay un efecto significativo en la puntuación. También se encuentra que las TIC funcionan solo con acceso a internet porque la sola disponibilidad de una computadora en el hogar no hace ninguna diferencia.

Palabras clave: Tecnologías de la Información y las Comunicaciones, Pruebas estandarizadas, Brechas de género, Colombia

Access to ICTs during middle education: Who may benefit in the case of Colombia.*

Jorge Leonardo Rodríguez Arenas§

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May 2023

Abstract.

This document exploits the existence of a longitudinal sample of middle school students in Colombia between 2017 and 2019 to assess the effects caused by access to Information and Communication technologies (ICTs) at the academic performance in a Saber 11 standardized test. By using various ICTs specifications, it is found that males and females obtain different gains according to the area (mathematics and reading). That is, having access to a computer and the internet increases the score between 0.057 and 0.079 standard deviations on math for males and females, respectively. In the case of reading, there is no significant effect on the score. It is also found that ICTs work only with access to the internet because the sole availability of a computer at home does not make any difference.

Keywords: Information and Communication Technologies, Standardized tests, Gender gaps, Colombia

JEL: C13, C21, I24, H44

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Contents

1. Introduction

During recent years, increasing concerns about the availability of information and communication technologies (ICTs) proxied by access to the internet, computer, or similar devices has taken place in the field of economics of education. There is still no consensus about how they affect the educational process, which means that having recent evidence about the role played by ICTs on academic achievement is crucial for public policies design. Some authors such as Skryabin et al. (2015) found a positive association between the national ICT development level and academic performance in reading, mathematics, and sciences.

However, the availability of ICT-related educational devices (such as computers, tablets, smartphones, software or educational programs and the internet) is not easy to measure in low-income countries. This fact is important since there are multiple channels through which ICTs influence students during their first years. The access and the type of use determine alternative benefits or drawbacks for learning. On one hand, more time online reduces the time dedicated to other activities such as study. On the other hand, internet use might foster some skills in the students (Posso (2016), Lei and Zhao (2007), Hunley et al. (2005)).

Some studies estimate the causal effect of ICT on students' performance and find either little or no effect (Barrera-Osorio and Linden (2009), Checchi et al. (2019), Cristia et al. (2017), Goolsbee and Guryan (2006), Leuven et al. (2007), Román Carrasco and Murillo Torrecilla (2012)).

The effects of ICT-based social media factors on adolescent's digital reading differ according to whether the access was at school or at home. (e.g., Hu and Yu (2021), Feng et al. (2019), Junco (2012), Kirschner and Karpinski (2010), Lambic (2016), Muls et al. (2020), Gil-Flores et al. (2012), Lim and Jung (2019) Lee and Wu (2013), Wu and Peng (2017)).

This document provides new evidence about the role played by ICTs while assessing whether it has any effect on gender gaps in test performance. For the case of Colombia, Muñoz (2018) proposes opportunity cost as a source of the gap and Ome and Gamboa (2021) state that permanence in the school system is biased between boys and girls.

Given that ICTs include a wide set of devices and services, it is not easy to disentangle their respective contributions to individuals. Therefore, access to ICTs will be measured through the availability of computers and the internet at home. Although a complementarity between computers and the internet exists, most of the recent technological advances allow the people to obtain access to the internet throughout other different devices (smartphones or tablets among others). For example, 23.39% of the Colombian ninth-grade students reported internet access without home computer in 2017.

We exploit the existence of an unbalanced panel of middle school students constructed by the Icfes (a public institution in charge of the measurement of the quality of education in Colombia), between 2017 and 2019 that allows the reduction of bias in the estimated gaps caused by the importance of unobserved factors.[1] However, there was no record that would allow a reliable follow-up of the evolution of the students' process until now. In 2017, Icfes applied the Saber 9 test to evaluate mathematics and reading comprehension in more than 10,000 schools for all ninth-grade students (520,013).

[1] This is possible through the Icfes standardized tests at different levels (5th, 9th, 11th). However, the Saber 9th-2017 test was carried out under two schemes. First, the application of the test is controlled by the Icfes in a sample of 402 educational establishments stratified by area and nature of the school (ICFES 2021). Second, the remaining sample took the test under the supervision of the own schools.

The empirical strategy adopted in this paper consists of estimating a traditional difference-in-differences (DiD) model that explains the test score achieved in mathematics and reading scores in the Saber 11 test after controlling for the Saber 9th score which allows us to control for initial differences in basic competencies.[2] The treatment variable is access to ICTs, so two different variables are constructed to consider different intensities. The first variable is whether the student has access to a computer at home, and the second variable adds access to the internet to the first indicator. This strategy is because not all the students have access to both at home, but it is important to mention that technological advances during the last decades have increased the set of devices for getting access to the internet. Then, access to ICTs can be underestimated in the sample but we assume that this access is not gender biased.

Our results indicate that access to ICTs benefits middle school students in Colombia. The effect on mathematics scores is greater for females than for males. Considering that a student without access to ICTs in 9 grade is under limited socioeconomic conditions, it is possible to understand that having internet and computer access at home generates considerable academic benefits for them. Although the absence of an experimental approach may lead to higher estimations than were expected (positive bias), the additional exercises carried out seem to indicate that our estimates are robust.

The document is divided as follows. Section 2 presents a brief description of the information available in the Saber 9 and 11 test databases and the main characteristics of the student population considered. Section 3 presents the empirical strategy, section 4 the main results, and section 5 presents the robustness of the results. Finally, in section 6 we discuss our main findings.

2. Data

The evaluation of the quality of education in Colombia has been carried out by the ICFES, which designs and applies the SABER (Saber 5, 9, 11, among others). The Saber 9 test includes the evaluation of reading (textual writing, textual comprehension, and interpretation, literature, which involves an approach to the aesthetic perspective of language, media and other symbolic systems), and mathematics competencies. Mathematics test includes items related to numbers and numeration (meaning and structure of the numerical system; operations, their properties, their effect, and the relationships between them), geometric analysis (representations of objects in space and their transformations), and a random analysis component (data analysis and inferences).

The application of the Saber 9th test for 520,013 ninth-grade students in 2017 allowed Icfes to construct a panel data of Colombian students using Saber 9 and Saber 11. The Saber 11th test is the high school mandatory exit exam and is considered an indicator of the competencies achieved by students at the end of middle education with multiple uses such as being a criterion for admission to higher education and for the granting of scholarships in Colombia[3] As of 2014, the exam is divided into five areas of knowledge: critical reading, mathematics, natural sciences, social sciences, and English; students receive a separate result per area and an aggregate score corresponding to the overall score obtained in the test. The overall

[2] Although the design of the tests does not intend to evaluate the same competencies in the two courses, they do allow evaluating progress in them. Icfes (2013)

[3] This exam is applied twice a year because of the coexistence of two alternative academic schedules. The first application takes place around march and is intended for students belonging to B-calendar (from august to June), and the second application is for A-calendar schools. This last modality represents approximately 95% of students who take the Saber 11.

score is between 0 and 500, and each of the areas has a score between 0 and 100; the test is adjusted so that each of the five areas has a mean of approximately 50 points and a standard deviation of about 10.

Table 1 shows that females represent 52% of the population and are younger in average age than males in the Saber 9 test from 2017. About 75% of students attend a school managed by the public sector and 94% of the total students come from mixed-gender schools. There is a higher proportion of females than males in official schools, while males predominate in rural and mixed-gender-school. In terms of household characteristics, the proportion of students who have a mother with some type of higher education is approximately 30 percent, and less than 30 percent of both male and female students lack Internet and computer access. In Saber 11, the panorama is very similar, 533% are women, and more than two-thirds of the population are in public schools, with a predominance of women. The proportion of students with a mother with some type of higher education decreases as compared to Saber 9th, and the number of students with no home access to a computer or internet increases in this exam.

In this paper we will analyze the scores attained in mathematics and reading because of their importance and their availability in both Saber 9 and Saber 11.[4] Joensen, J. S., & Nielsen, H. S. (2009) indicate in their study that it is well-established that individuals who perform better in mathematics during high school achieve higher scores on tests, have easier access to higher education, and earn up to 30% higher incomes when they enter the job market. Given that the scale of test scores is different, we opt for standardized scores (national average equal to zero and standard deviation equal to 1) to facilitate comparability.

Table 2 summarizes the average scores by gender controlling by different variables (panel a). In both tests (Saber 9 and 11), the scores obtained in mathematics are lower than those in reading. In addition, while there seems to be a gender advantage in Saber 9th (higher scores achieved by boys in mathematics and the opposite in language), this pattern does not seem to hold in reading at the end of the educational cycle (Saber 11).

Moreover, this pattern is similar when the averages are obtained for different samples of schools. That is, in Saber 9, male students outperformed their female counterparts in math, despite their school location (rural or urban) or sector (public or private), while female students obtained higher reading scores. In mathematics, females obtained a standardized score of -0.06 and -0.1 in Saber 9 and Saber 11, respectively. That is, below the national average. In reading, the same pattern is not observed since women in Saber 9 are above the national average but not in Saber 11. It is interesting to note that both females and males obtained higher average scores in these areas when they attended single-gender schools than in mixed-gender schools. Figure 1 shows that there are small average changes in men between Saber 9 and 11 but this pattern is not observed in females. These subjects have a high positive correlation (greater than 0.65 in Saber 11) between them (Fig. 2) and over time (Fig. 3).

Considering the degree of population concentration and economic activity present in Colombia, a comparison is presented at the municipal level. The maps in Figure 4 plot the relationship between the scores obtained by women and men at the municipal level. A value of 1 indicates the same average performance between men and women. There are no indications of notable regional differences in this indicator, although women have a higher performance in reading in Saber 9 in most municipalities (dark purple).

[4] The verbal analysis test assessed at Saber 9 is different from the critical reading test in Saber 11 since the same competencies are not exactly evaluated. Communicative-reading and communicative-writing competencies are evaluated in saber-9, while Saber 11th includes three competencies, two of them oversee evaluating the comprehension of the content of a text and the other competency evaluates the critical approach to the text.

In relative terms, 78.5% municipalities had a higher average performance of females in reading in the Saber 9th test, representing 93.56% of the total number of Saber 9 students in 2017 (486,524). While in the Saber 11th of 2019 the number of municipalities decreases to 521 or 32.40% (178,054 students). On the other hand, the number of municipalities with higher female performance in mathematics in Saber 9/2017 was 240 (50,026 students, 9.62% of the students). In the Saber 11 test, only 107 municipalities (7,818 students) had higher female performance in mathematics.[5]

Our database was obtained by pairing the Saber 9th and Saber 11th tests using a unique individual key. In Saber 9, there are initially 520,013 students, of which only 357,060 students appear in Saber 11, 31.3% of the students who do not appear may be repeaters or dropouts and this will be considered in the analysis of the estimated model.

3. Empirical Strategy

The identification strategy exploits access to various ICTs at the time of taking the Saber 11 test and having information related to this access 2 years earlier. The sample to be used in the empirical exercise includes those who take both tests and who have reported information on ICT access in both tests.[6] For the purposes of the exercise, the sample is also limited to those who have not had access to ICT in ninth grade (79,302 students). In this way, it is possible to approximate the effect of changes in the condition of ICT access between ninth and eleventh grades on educational achievement in mathematics and reading.

In the basic model, three different variables related to access to ICTs are introduced in order to consider different levels of intensity of access (intensity of treatment). First, the variable D is equal to 1 if the student in Saber 11 already had access to computer and the internet and zero if not (6,587 students). Second, equal to 1 if the student in Saber 11th only had access to a computer (5,789 students) and zero otherwise. Finally, D equals 1 if the student in Saber 11 only had access to the internet (8,643 students) and zero otherwise. On the other hand, the control group includes those who did not report ICT access (58,283 students).

Table 3 shows the balance between control and treated individuals for different covariates in the pre- and post-treatment period. Statistically significant differences can be observed between students belonging to the control and treatment groups for the pre-treatment year in variables such as age, the proportion of students from official, rural and mixed-gender schools, and in the percentage of students who have more human capital at home (mother with some type of higher education). These differences are also found in the post-treatment period. However, differences in variables such as age, proportion of students in rural and mixed schools remain constant over time. To account for these differences between groups and over time in our estimates, we control for sample balancing covariates in the econometric model that are estimated because accounting for them improves the precision of the estimator as they reduce the residual variance and assume parallel trends more plausible.

Formally, using the subscript i to denote individuals, s to denote schools, and t to denote year, we estimate the following difference in differences model of two periods:

[5] Municipalities with higher differences in reading in favor of women at Saber 9: Morichal, Almeida, Vetas, San Benito and Berbeo. In Saber 11 they were San Felipe, Almeida, Puerto Santander, Labranzagrande and Coper. In the case of math: the higher differences are in Morichal, Busbanzá, Sativanorte, Almeida and Medio Atrato; while in Saber 11th they were San Felipe, Almeida, Bituima, Susacón and Labranzagrande.

[6] The table A in the appendix shows the characteristics of the sample entering the empirical exercise compared to the matched sample.

$$y_{ist}^{g} = \alpha_s + Post_t + \tau(D_i \times Post_t) + \boldsymbol{X}_{is}\beta + \epsilon_{ist} \quad (1)$$

where y_{ist}^{g} is any of the educational achievement outcome variables (math score or reading score) and g indicates whether the estimated equation is for all, males or females, D_i indicates whether a student has access to ICTs in grade 11, and $Post_t$ is a dummy variable that takes the value one for the year 2019 and α_s are school fixed effects that control for any observed or unobserved time-invariant heterogeneity at the school level. $\boldsymbol{X_i}$ are the student characteristics in the baseline period (2017) when they took the Saber 9 test. The vector $\boldsymbol{X_i}$ includes the age of the students, mother schooling, the location of the school (rural or urban), the number of people living in the household, and whether the student was part of the controlled sample in Saber 9. Finally, ϵ_{ist} is the error term, which we group at the individual level.

The main identifying assumption in this difference-in-differences (DID) model is that, in the absence of the treatment (access to ICTs), the educational achievement results of those who had access to ICTs at the time of taking the Saber 11 test would have evolved similarly to the results of those students without access to ICTs. Given that we have a two-period panel we cannot empirically test this assumption, however, it is plausible to think that students in grade 9 who did not have access to technologies in that year did not have it before since the percentage of students without access to technologies is higher in lower grades[7]. In addition, we carried out a placebo exercise which consists of randomly assigning the treatment and determine whether the estimated coefficient exceeds the real effect of the treatment; the results of this exercise will be discussed in the robustness section.

4. Results

Table 4 summarizes the estimated coefficients of eq. (1) for each of the three treatments separated by total, women, and men. In the even columns we present the estimated coefficients including baseline controls and in the odd columns without these controls. School fixed effects are included in all specifications. Panel A shows the estimated coefficients for the first treatment (Computer and Internet access), panel B presents the estimations for the second treatment (Computer access) and panel C includes the estimated coefficients for the third type of treatment (Internet access). Finally, the standard errors are presented in parentheses and are grouped at the individual level.

The results in Panel A indicate that access to ICTs has a positive and large effect on math scores and that it is larger for females. That is, having access to these technological tools contributes to closing the gender gaps in high school mathematics. One of the possible explanations for the difference in these effects for each gender may come from the fact that there is a greater probability for girls to remain in the educational system until they reach grade 11 and to take the Saber 11 test. However, the apparent differences in the estimated coefficients for the case of men and women are not statistically significant as the standard errors reveal.

Given this possible imbalance in the sample at the gender level, in the robustness section the estimation is carried out using different specifications to strengthen the results that attribute this effect to the use of ICTs in mathematics results. On the other hand, it should be noted that no statistically significant effects are found in reading.

[7] For the year 2017, the proportion of students who took the test Saber 5th had lower access to technologies compared to the proportion of Saber 9 students for that year. This proportion was calculated from the Saber 5th database available in Data Icfes.

Additionally, having a computer at home without access to the internet does not generate any significant effect on mathematics and reading scores with respect to those who do not have one (Panel B). This result can be explained by the fact that the great advantage offered by computers for the school-age population comes from access to the world wide web of knowledge and the possibility of interacting through it.

Also, Internet access does generate a statistically significant increase of approximately 0.04 standard deviations on average in mathematics scores relative to students who did not have access. Once school-related and initial individual conditions are controlled for, we find that the contribution of the Internet is greater for males (0.047 standard deviations) than for females (0.028 sd) in mathematics, and in the case of reading it is only significant for males.

Furthermore, the difference between the coefficients of Panel A and Panel C can be seen as the contribution generated by having a computer over those who have access to the Internet.

5. Robustness

We present some evidence designed to rule out that the results in Table 4 may be seriously influenced by the existence of outliers in the Saber test results, by changes in the sample, or by the gender imbalance in the number of males and females taking the Saber 11 test.

First, the estimation aims to identify whether there are departments that may generate very different results and therefore each estimation is performed excluding the population of a department with replacement. Figure 5 shows for the case of mathematics that the results are robust and are not conditioned by a particular department, since after excluding a specific department and estimating the model for all 32 departments, in general all coefficients remain stable and statistically significant for the case of the first treatment (computer and internet) and the third treatment (internet) in the mathematics score, for the second treatment it remains stable but is not significant, which is consistent with what was found in the results section. Figure 6 shows the results for the same exercise over reading score. Then, it shows that the estimations do not depend on the characteristics of any department.

These results could also be explained, by changes associated with gender-imbalanced dropout rates between grade 9th and grade 11th. To discard that results do not depend on these changes in the sample of those who took the Saber 9 test but did not reach Saber 11, we estimate an econometric model that predicts math and reading scores using a vector of individual, household and school characteristics reported in the Saber 9 test. The predicted values provide us an approximation of the expected Saber 11 score that would have been achieved by those students who did not take the test.

As can be seen in Figure 7, if those who did not take the test had been able to take the test, the average scores of these students tend to have low levels of performance because the distribution of scores would have been shifted to the left with respect to the scores that were observed. Then, an estimation was performed by removing from the sample the 5 percent of students with the lowest scores to verify how stable the coefficients are (Table 5). It is obtained that the coefficients are stable and statistically significant to those presented in Table 4, so these effects do not change significantly with sample changes in the tails of the distribution.

In addition, we carried out an exercise in which 500 random gender-balanced samples were drawn and the main equation was estimated for each of them. Graphs 8 and 9 summarize the distribution of the effect of each treatment in the case of a gender-balanced sample. We find that the estimated effect in our central model in 4 corresponds approximately to the average of the simulated gender-balanced effects, thus indicating that the gender imbalance problem does not affect the findings found in our main specification.

Furthermore, to show that the estimated results are not determined by the probability of being "treated", the effects were estimated using the inverse probability weighting (IPW) methodology which considers the probability of being treated given a set of individual, household, and school controls. Table 6 shows that the results obtained using the IPW method are consistent with those found in the main specification as these do not change significantly, thus indicating that the results are not sensitive to the various factors that may be mediating the probability of being treated.

Finally, we perform a placebo exercise that simulates the treatment, i.e., we randomly assign those who are treated and controls to rule out the possibility that our coefficient of interest does not arise by chance. After performing this random assignment 1000 times and plotting the distribution of the placebo effect on the mathematics score (Figure 10), it is found that the placebo effect is always smaller than the estimated effect for the whole sample and for the group of females for the case of the first treatment on the outcome in mathematics score. For males, the placebo effect only exceeds it 0.61% of the cases; for the third treatment and giving reassurance about the estimated effect, our coefficient is above the 99th percentile of the distributions resulting from the placebo exercise.[8]

6. Discussion

The empirical strategy adopted throughout this paper suggests that access to ICTs benefits middle school students in Colombia. Although the absence of an experimental approach may lead to higher estimations than were expected, the additional exercises carried out seem to indicate that the estimates are robust.

The effect of access to ICTs on mathematics scores is greater for females than for males. Considering that a student without access to ICTs in 9th grade is under limited socioeconomic conditions, it is possible to understand that having internet and computer access at home generates considerable benefits for her. However, a very telling result of this work comes from the fact that having a computer without being able to use it to exploit the benefits of the worldwide network of knowledge available on the Internet it does not contribute to academic achievement measured through the Saber 11 test. In addition, for those who only have access to internet, it generates a greater effect on mathematics for males in terms of standard deviations. However, when the size of the effect is measured in terms of the average score, it is about 32.1% for males and 35.8% for females.

A drawback of our document stems from the fact that the Icfes data records do not allow us to know whether students have tablets or smartphones through which they can access the Internet. These devices could increase the population that has access to ICTs. However, taking into account that the main objective of the study is to identify whether access to ICTs contributes to reducing gaps in academic scores, there are no arguments that allow us to affirm that there is a gender-biased distribution in these modern devices.

[8] This exercise is not performed for the second treatment as this one is not statistically significant in our main estimate.

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Tables

Table 1: Difference of means of control variables by gender.

	All						Matched in Saber 11					
	Saber 9/17			Saber 11/19			Saber 9/17			Saber 11/19		
	Male	Female		Male	Female		Male	Female		Male	Female	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Panel A: *Student characteristics*												
Age	15.41	15.18	***	17.50	17.29	***	15.24	15.05	***	17.24	17.05	***
Panel B: *Schools characteristics*												
Official school	0.79	0.81	***	0.72	0.76	***	0.76	0.78	***	0.75	0.78	***
Rural school	0.19	0.18	***	0.16	0.15	***	0.18	0.17	***	0.17	0.16	***
Mixed school	0.98	0.95	***	0.98	0.95	***	0.98	0.94	***	0.98	0.94	***
Panel C: *Household characteristics*												
Mother with more than high school	0.31	0.29	***	0.27	0.26	***	0.34	0.32	***	0.28	0.28	
Internet and computer	0.55	0.52	***	0.52	0.48	***	0.58	0.55	***	0.54	0.51	***
Computer	0.67	0.64	***	0.60	0.56	***	0.70	0.67	***	0.62	0.59	***
Internet	0.62	0.60	***	0.64	0.61	***	0.65	0.63	***	0.66	0.63	***
Without internet nor computer	0.25	0.28	***	0.27	0.31	***	0.23	0.25	***	0.26	0.29	***
Observations												
By gender	250,816	269,197		255,653	293,899		162,904	194,156		162,904	194,156	
All	520,013			549,552			357,060			357,060		

Source: Author's calculations, based on ICFES information. *** p<0.01, ** p<0.05, * p<0.1

Table 2: Average Scores in Saber test

	a. All								b. Matched in Saber 11							
	Saber 9/17				Saber 11/19				Saber 9/17				Saber 11/19			
	Math		Reading		Math		Reading		Math		Reading		Math		Reading	
	Average score	Std. Score	Average score	Std. Score	Average score	Std. Score	Average score	Std. Score	Average score	Std. Score	Average score	Std. Score	Average score	Std. Score	Average score	Std. Score
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Overall	308.11	0.02	316.04	0.02	51.28	0.03	52.69	0.02	316.41	0.14	324.85	0.15	52.88	0.16	53.90	0.13
Sex																
Female	303.06	-0.06	319.69	0.07	49.71	-0.10	52.48	-0.00	310.35	0.05	327.70	0.20	51.29	0.03	53.67	0.11
Male	313.99	0.10	312.49	-0.04	53.08	0.18	52.93	0.04	323.99	0.25	321.87	0.11	54.83	0.32	54.19	0.16
Official schools																
Female	291.85	-0.22	309.32	-0.08	48.35	-0.21	51.22	-0.12	298.23	-0.13	316.74	0.03	49.56	-0.11	52.14	-0.04
Male	302.48	-0.07	302.15	-0.20	51.86	0.08	51.71	-0.08	311.23	0.06	310.56	-0.07	53.07	0.18	52.58	0.00
Private schools																
Female	350.33	0.63	363.44	0.75	54.02	0.25	56.48	0.37	354.46	0.69	367.59	0.81	57.47	0.53	59.13	0.62
Male	357.96	0.74	352.02	0.57	56.17	0.43	56.03	0.33	364.57	0.84	357.82	0.66	60.06	0.74	58.98	0.60
Rural schools																
Female	286.90	-0.29	295.65	-0.30	45.95	-0.40	48.77	-0.35	292.39	-0.21	302.60	-0.19	46.61	-0.35	49.22	-0.31
Male	295.07	-0.18	288.43	-0.41	49.04	-0.15	48.99	-0.33	303.42	-0.05	296.76	-0.28	49.84	-0.08	49.50	-0.28
Urban schools																
Female	306.55	-0.01	324.89	0.15	50.39	-0.04	53.15	0.06	313.96	0.10	332.74	0.28	52.16	0.10	54.50	0.18
Male	318.36	0.16	318.06	0.05	53.83	0.24	53.67	0.11	328.41	0.31	327.27	0.19	55.83	0.40	55.12	0.24
Gender schools																
Female in mixed schools	300.44	-0.10	317.18	0.04	49.25	-0.13	52.10	-0.04	307.45	0.01	325.01	0.16	50.81	-0.01	53.27	0.07
Female in female schools	348.16	0.60	362.99	0.74	58.42	0.61	59.59	0.66	353.46	0.68	367.69	0.81	58.53	0.62	59.65	0.67
Male in mixed schools	313.03	0.09	311.62	-0.05	52.93	0.17	52.81	0.03	323.01	0.23	320.97	0.09	54.67	0.31	54.05	0.14
Male in male schools	331.25	0.35	340.16	0.39	55.13	0.34	55.35	0.26	342.41	0.52	350.47	0.55	57.59	0.54	57.47	0.46

Source: Author's calculations, based on ICFES information.

Table 3: Balance of covariates

	Pre			Post		
	Control	**Treated**		**Control**	**Treated**	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Treatment 1 - ICTs						
Age	15.34	15.18	***	17.33	17.17	***
Official school	0.97	0.90	***	0.96	0.88	***
Rural school	0.40	0.19	***	0.37	0.14	***
Mixed school	0.99	0.98	***	0.99	0.98	***
Mother with more than high school	0.08	0.19	***	0.07	0.20	***
Observations						
All	72,715	6,587		72,715	6,587	
Female	41,96	3,837		41,96	3,837	
Male	30,755	2,750		30,755	2,750	
Panel B: Treatment 2 - Computer						
Age	15.33	15.21	***	17.33	17.20	***
Official school	0.97	0.97		0.96	0.96	
Rural school	0.38	0.36	***	0.35	0.33	***
Mixed school	0.99	0.99	**	0.99	0.99	
Mother with more than high school	0.09	0.12	***	0.08	0.12	***
Observations						
All	73,513	5,789		73,513	5,789	
Female	42,49	3,307		42,49	3,307	
Male	31,023	2,482		31,023	2,482	
Panel C: Treatment 3 - Internet						
Age	15.33	15.31		17.32	17.31	
Official school	0.97	0.95	***	0.96	0.93	***
Rural school	0.40	0.23	***	0.37	0.19	***
Mixed school	0.99	0.99	***	0.99	0.99	**
Mother with more than high school	0.09	0.13	***	0.08	0.13	***
Observations						
All	70,659	8,643		70,659	8,643	
Female	40,84	4,957		40,84	4,957	
Male	29,819	3,686		29,819	3,686	

Source: Author's calculations, based on ICFES information. Column (3) and (6) indicate whether there is a significant difference between the controls and the treated according to the significance levels: *** p<0.01, ** p<0.05, * p<0.1

Table 4: Effects of ICTs access on learning outcomes

	High School Exit Exam Scores											
	Standardized math score						Standardized reading score					
	All		**Male**		**Female**		**All**		**Male**		**Female**	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
***Panel A**: ICTs*												
Treatment	0.075***	0.068***	0.062***	0.057***	0.086***	0.079***	0.015	0.009	0.006	0.002	0.023*	0.017
	(0.010)	(0.010)	(0.017)	(0.017)	(0.014)	(0.013)	(0.010)	(0.010)	(0.017)	(0.017)	(0.013)	(0.013)
Observations	157,890	157,890	66,683	66,683	90,272	90,272	157,890	157,890	66,683	66,683	90,272	90,272
School fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Baseline controls	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
***Panel B**: Computer*												
Treatment	-0.000	-0.002	-0.024	-0.026	0.020	0.019	-0.001	-0.004	0.018	0.016	-0.018	-0.021
	(0.010)	(0.010)	(0.017)	(0.017)	(0.014)	(0.014)	(0.010)	(0.010)	(0.016)	(0.016)	(0.014)	(0.014)
Observations	157,890	157,890	66,683	66,683	90,272	90,272	157,890	157,890	66,683	66,683	90,272	90,272
School fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Baseline controls	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
***Panel C**: Internet*												
Treatment	0.040***	0.038***	0.047***	0.045***	0.032***	0.028**	0.026***	0.024***	0.038***	0.038***	0.015	0.011
	(0.009)	(0.009)	(0.014)	(0.014)	(0.012)	(0.012)	(0.009)	(0.009)	(0.014)	(0.014)	(0.012)	(0.012)
Observations	157,890	157,890	66,683	66,683	90,272	90,272	157,890	157,890	66,683	66,683	90,272	90,272
School fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Baseline controls	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Mean dep. variable	0,023	0,023	0,14	0,14	-0,078	-0,078	0,016	0,016	0,002	0,002	0,032	0,032
Mean of Y in control group	-0,227	-0,227	-0,105	-0,105	-0,317	-0,317	-0,293	-0,293	-0,322	-0,322	-0,271	-0,271

Notes: The even columns present estimates controlling for the age of the students, mother schooling, the location of the school, the number of people in the household and whether the student was part of the controlled sample in Saber 9 and school fixed effects. The results are powerfully standardized. The treatment of panel A indicates that the student had access to computer and internet in Saber 11, the treatment of panel B indicates that the student had access to computer in Saber 11 and the treatment of panel C indicates that the student had access to the internet in Saber 11. Standard errors are grouped at the individual level in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 5: Effects of ICTs access on learning outcomes (**Sample 1**)

	High School Exit Exam Scores											
	Standardized math score						Standardized reading score					
	All		**Male**		**Female**		**All**		**Male**		**Female**	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
***Panel A**: ICTs*												
Treatment	0.079***	0.072***	0.061***	0.056***	0.091***	0.083***	0.020*	0.013	0.005	-0.001	0.030**	0.023*
	(0.010)	(0.010)	(0.017)	(0.017)	(0.014)	(0.014)	(0.010)	(0.010)	(0.017)	(0.017)	(0.014)	(0.014)
Observations	146,650	146,650	61,764	61,764	83,959	83,959	146,650	146,650	61,764	61,764	83,959	83,959
School fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Baseline controls	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
***Panel B**: Computer*												
Treatment	0.009	0.007	-0.021	-0.023	0.035**	0.033**	-0.001	-0.004	0.018	0.016	-0.016	-0.019
	(0.010)	(0.010)	(0.017)	(0.017)	(0.014)	(0.014)	(0.011)	(0.011)	(0.017)	(0.017)	(0.014)	(0.014)
Observations	146,650	146,650	61,764	61,764	83,959	83,959	146,650	146,650	61,764	61,764	83,959	83,959
School fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Baseline controls	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
***Panel C**: Internet*												
Treatment	0.038***	0.036***	0.050***	0.049***	0.027**	0.024*	0.025***	0.023**	0.042***	0.042***	0.011	0.007
	(0.009)	(0.009)	(0.014)	(0.014)	(0.012)	(0.012)	(0.009)	(0.009)	(0.015)	(0.015)	(0.012)	(0.012)
Observations	146,650	146,650	61,764	61,764	83,959	83,959	146,650	146,650	61,764	61,764	83,959	83,959
School fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Baseline controls	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Mean dep. variable	0,023	0,023	0,14	0,14	-0,078	-0,078	0,016	0,016	0,002	0,002	0,032	0,032
Mean of Y in control group	-0,227	-0,227	-0,105	-0,105	-0,317	-0,317	-0,293	-0,293	-0,322	-0,322	-0,271	-0,271

Notes: The even columns present estimates controlling for the age of the students, mother schooling, the location of the school, the number of people in the household and whether the student was part of the controlled sample in Saber 9 and school fixed effects. The results are powerfully standardized. The treatment of panel A indicates that the student had access to computer and internet in Saber 11, the treatment of panel B indicates that the student had access to computer in Saber 11 and the treatment of panel C indicates that the student had access to the internet in Saber 11. Standard errors are grouped at the individual level in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

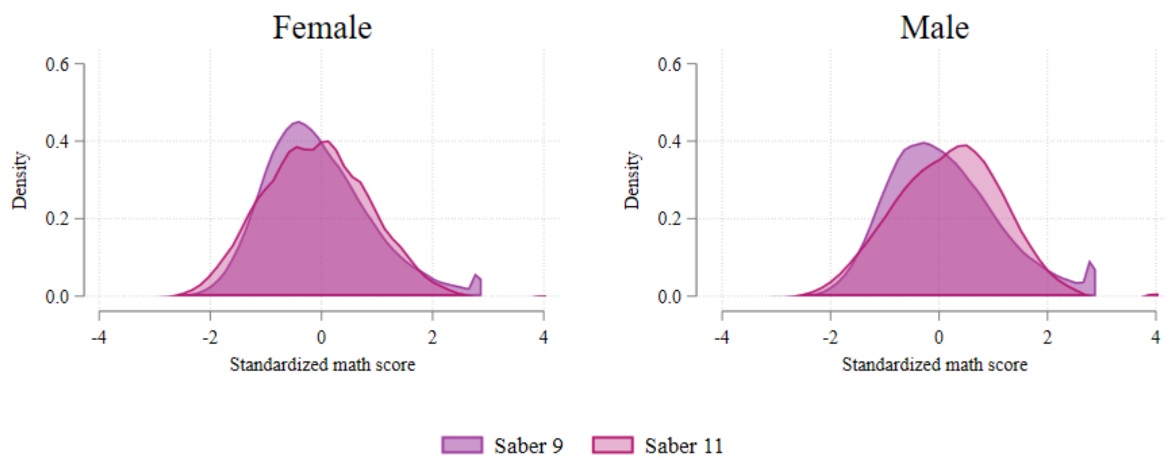
Table 6: Effects of ICTs access on learning outcomes (**IPW**)

	High School Exit Exam Scores											
	Standardized math score						Standardized reading score					
	All		**Male**		**Female**		**All**		**Male**		**Female**	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
***Panel A**: ICTs*												
Treatment	0.066***	0.058***	0.044**	0.039**	0.081***	0.071***	0.008	-0.000	-0.012	-0.018	0.020	0.012
	(0.011)	(0.011)	(0.018)	(0.018)	(0.014)	(0.014)	(0.011)	(0.011)	(0.018)	(0.018)	(0.014)	(0.014)
Observations	157,890	157,890	66,683	66,683	90,272	90,272	157,890	157,890	66,683	66,683	90,272	90,272
School fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Baseline controls	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
***Panel B**: Computer*												
Treatment	-0.001	-0.003	-0.022	-0.025	0.020	0.018	-0.005	-0.008	0.017	0.014	-0.021	-0.025*
	(0.011)	(0.011)	(0.018)	(0.018)	(0.015)	(0.015)	(0.011)	(0.011)	(0.017)	(0.017)	(0.015)	(0.014)
Observations	157,890	157,890	66,683	66,683	90,272	90,272	157,890	157,890	66,683	66,683	90,272	90,272
School fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Baseline controls	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
***Panel C**: Internet*												
Treatment	0.039***	0.037***	0.047***	0.046***	0.030**	0.026**	0.024***	0.022**	0.035**	0.036**	0.014	0.010
	(0.009)	(0.009)	(0.015)	(0.015)	(0.012)	(0.012)	(0.009)	(0.009)	(0.014)	(0.014)	(0.012)	(0.012)
Observations	157,890	157,890	66,683	66,683	90,272	90,272	157,890	157,890	66,683	66,683	90,272	90,272
School fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Baseline controls	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Mean dep. variable	0,023	0,023	0,14	0,14	-0,078	-0,078	0,016	0,016	0,002	0,002	0,032	0,032
Mean of Y in control group	-0,227	-0,227	-0,105	-0,105	-0,317	-0,317	-0,293	-0,293	-0,322	-0,322	-0,271	-0,271

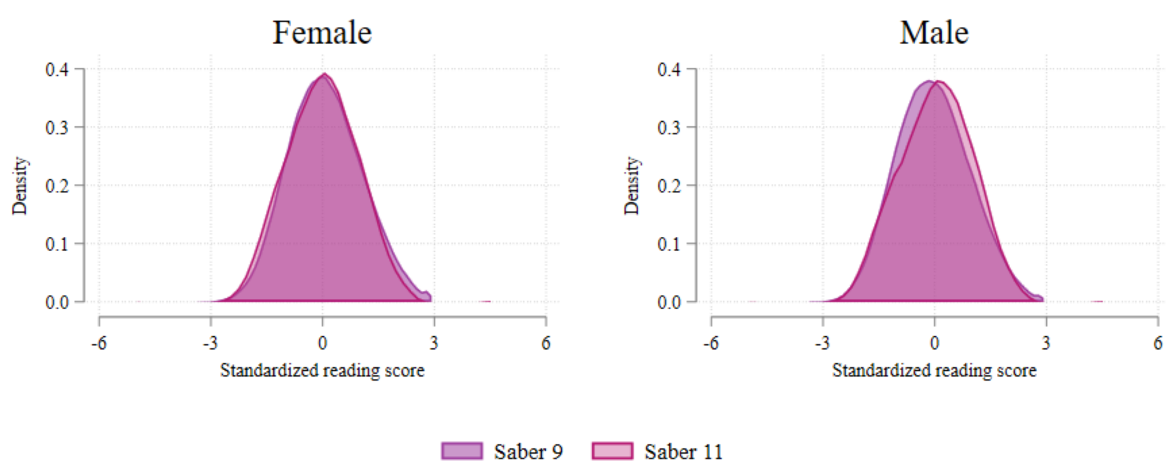
Notes: The even columns present estimates controlling for the age of the students, mother schooling, the location of the school, the number of people in the household and whether the student was part of the controlled sample in Saber 9 and school fixed effects. The results are powerfully standardized. The treatment of panel A indicates that the student had access to computer and internet in Saber 11, the treatment of panel B indicates that the student had access to computer in Saber 11 and the treatment of panel C indicates that the student had access to the internet in Saber 11. Standard errors are grouped at the individual level in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Figures

Figure 1: Densities of Math and Reading in Saber 9 and 11 by gender.



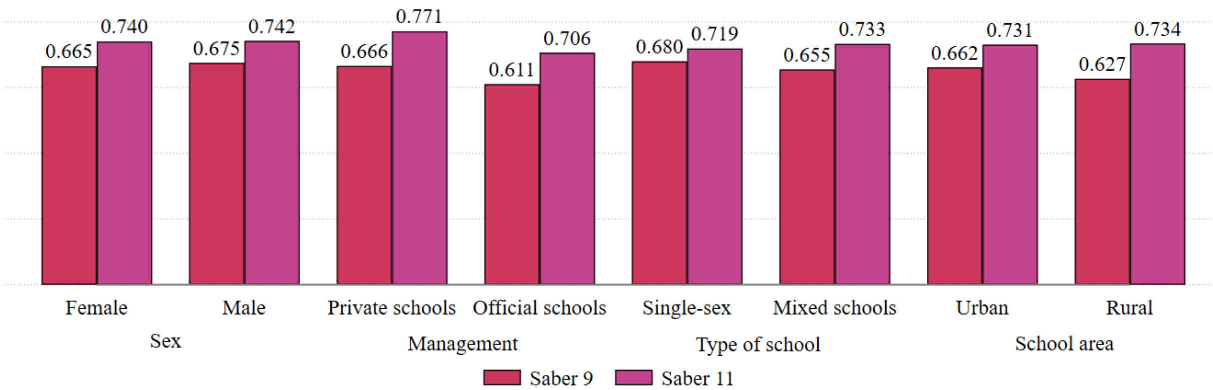
A. Math



B. Reading

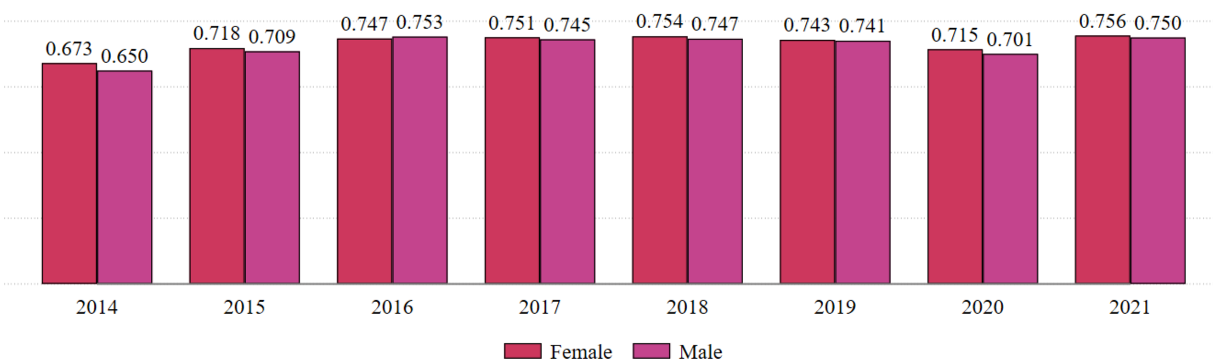
Note: Source ICFES

Figure 2: Correlation of reading scores with math by category in Saber 11 and Saber 9



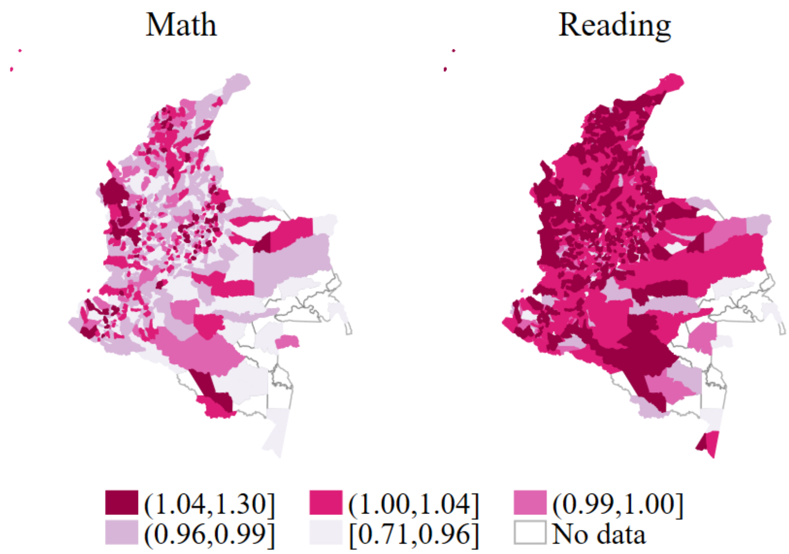
Note: All the correlations exhibit differences statistically significant.

Figure 3: Correlation of reading scores with math by gender in Saber 11 2014 – 2021

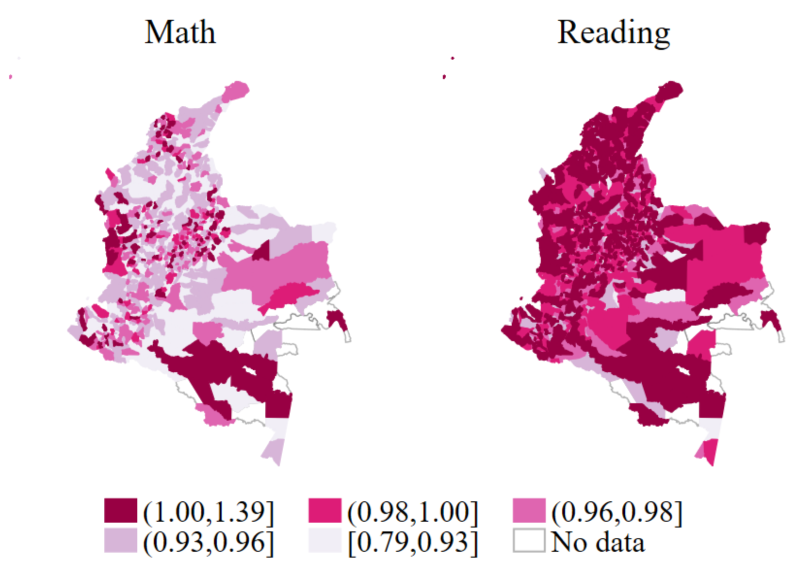


Note: All the correlations exhibit differences statistically significant with the exception of 2019 and 2021.

Figure 4: Ratio of women's scores to men's scores for math and reading



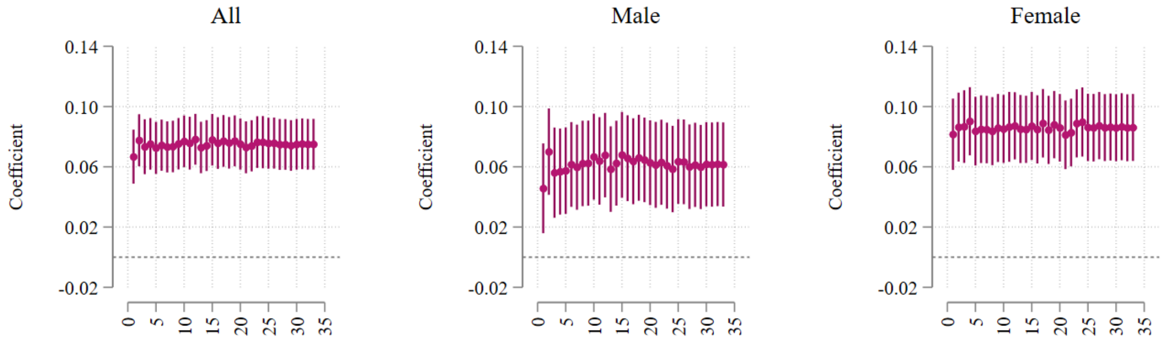
A. Saber 9 – 2017



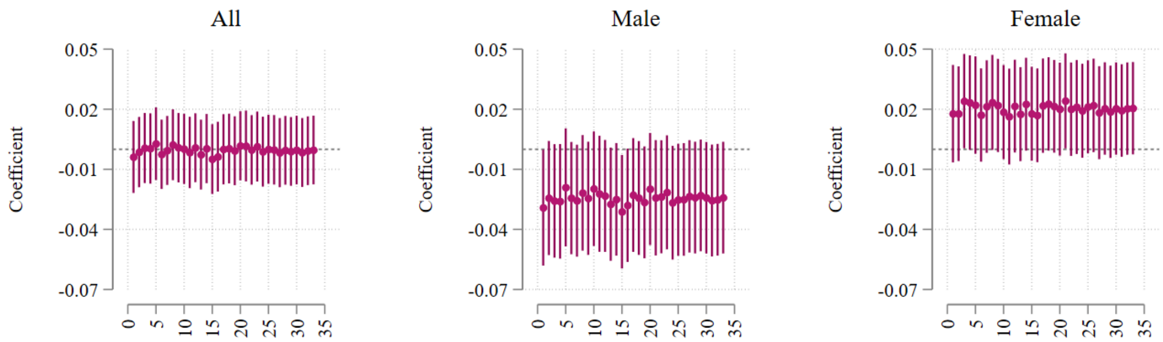
B. Saber 11 – 2019

Note: Calculus of the authors using Saber database (ICFES).

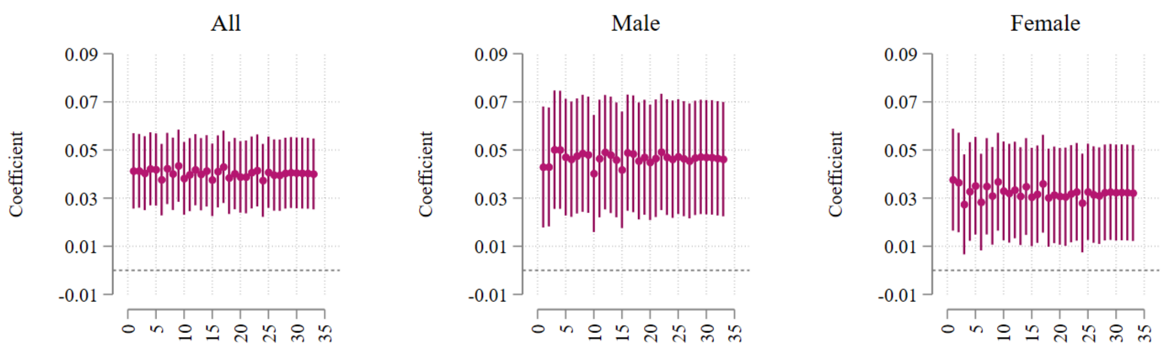
Figure 5: Estimated effects by excluding one department each time



A. Effect of access to ICTs on the standardized math score



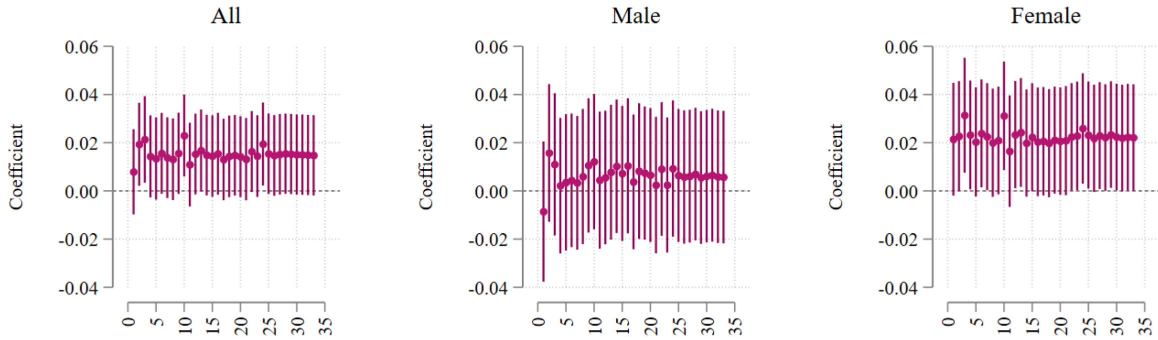
B. Effect of access to computer on the standardized math score



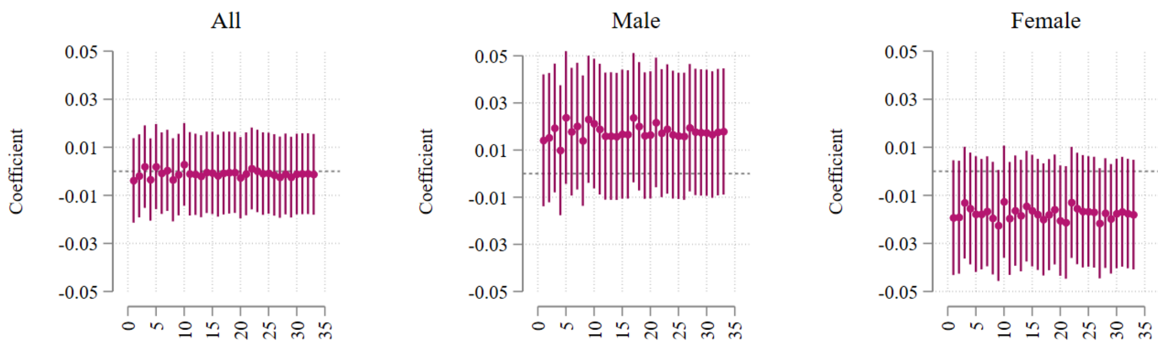
C. Effect of access to Internet on the standardized math score

Note: This figure presents the results of our main specification in equation (1) but excluding one department at each estimation. We present the point estimates of the regression and the confidence of interval at the 95%

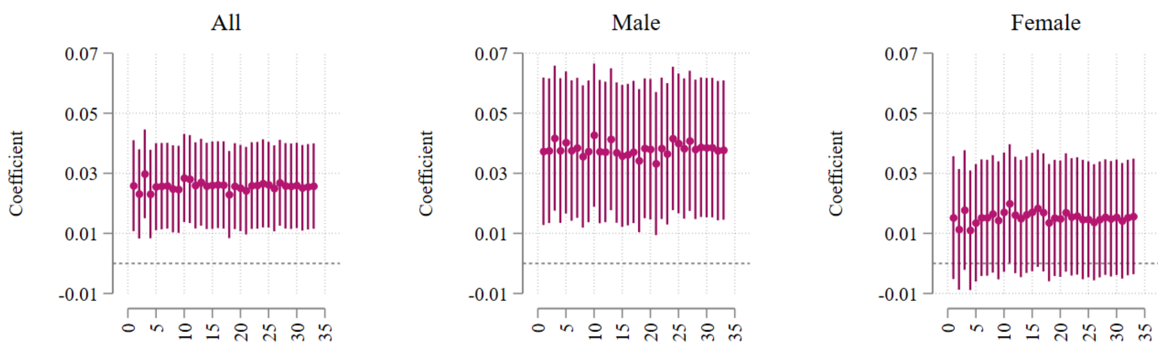
Figure 6: Estimated effects by excluding one department each time



A. Effect of access to ICTs on the standardized reading score



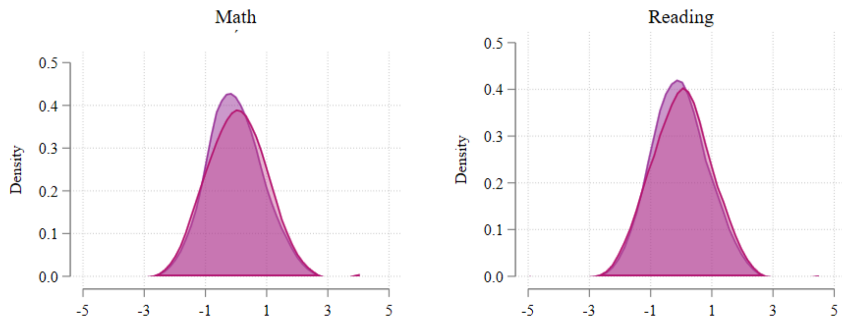
B. Effect of access to computer on the standardized reading score



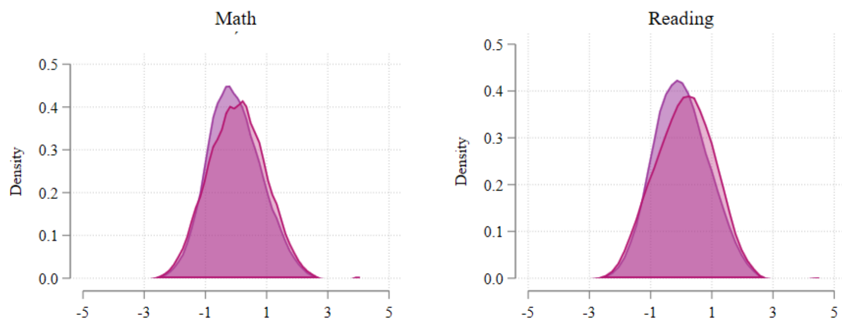
C. Effect of access to Internet on the standardized reading score

Note: This figure presents the results of our main specification in equation (1) but excluding one department at each estimation. We present the point estimates of the regression and the confidence of interval at the 95%.

Figure 7: Distribution of scores in Saber 11 with and without the predictions of those absent in Saber 11 who were in Saber 9.



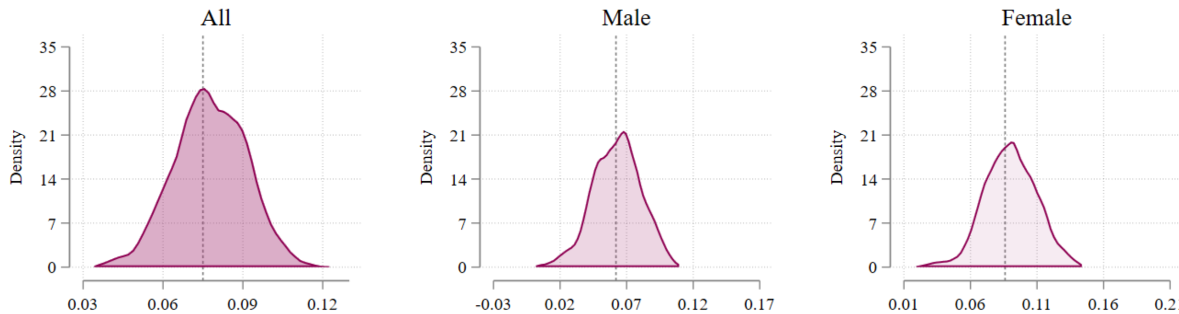
A. All



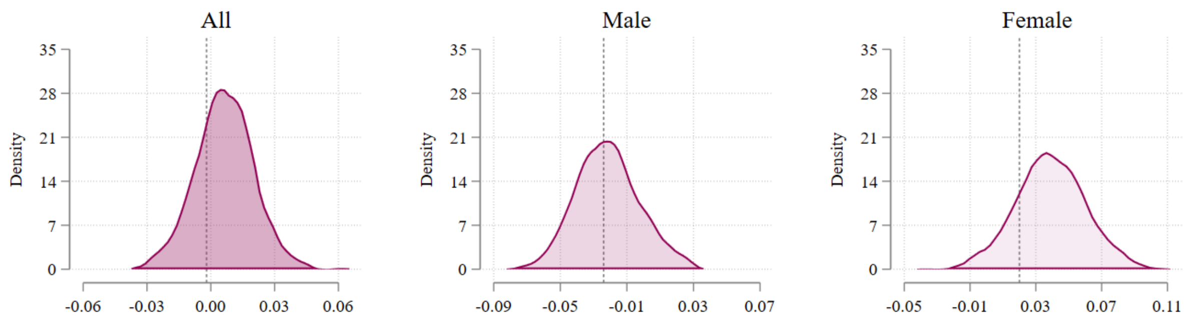
B. Female

Note: Calculus of the authors using Saber database (ICFES).

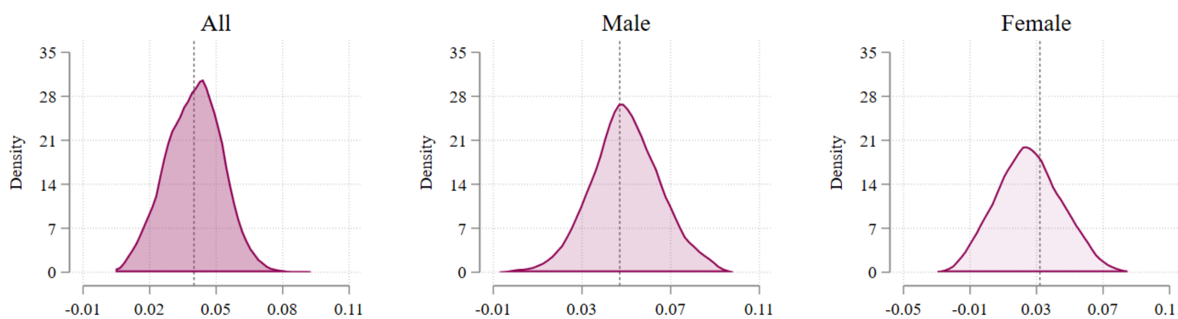
Figure 8: Distribution of treatment effect for gender-balanced random samples on math score



A. ICTs



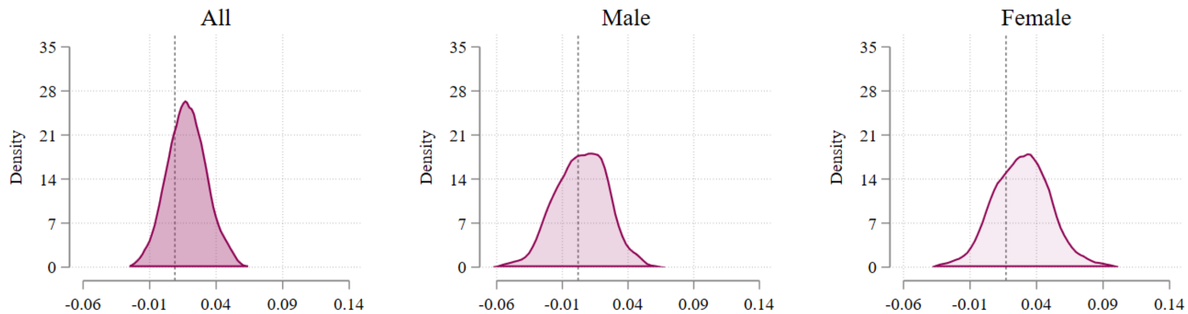
B. Computer



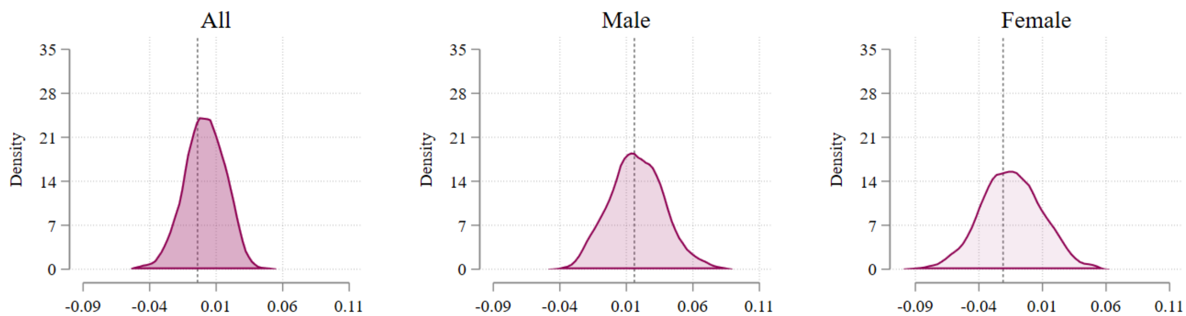
C. Internet

Note: Calculus of the authors using Saber database (ICFES). The sample is balanced and takes 40,000 observations for each gender. 500 iterations of the model are performed to obtain the distribution of the effect.

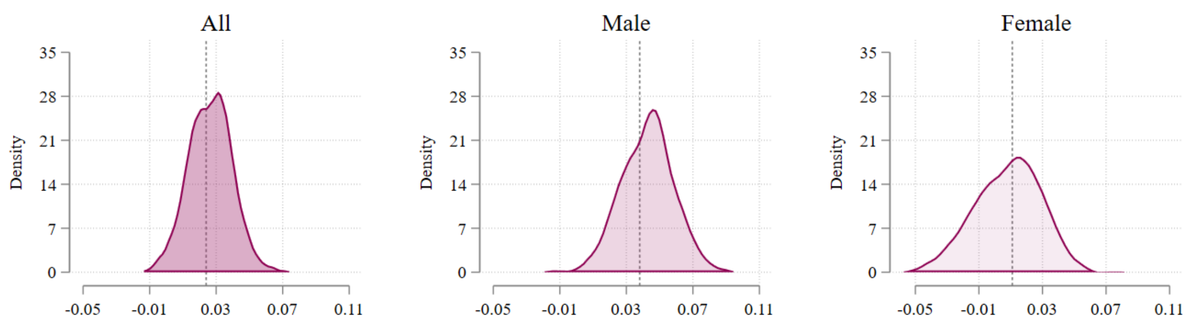
Figure 9: Distribution of treatment effect for gender-balanced random samples on reading score.



A. ICTs



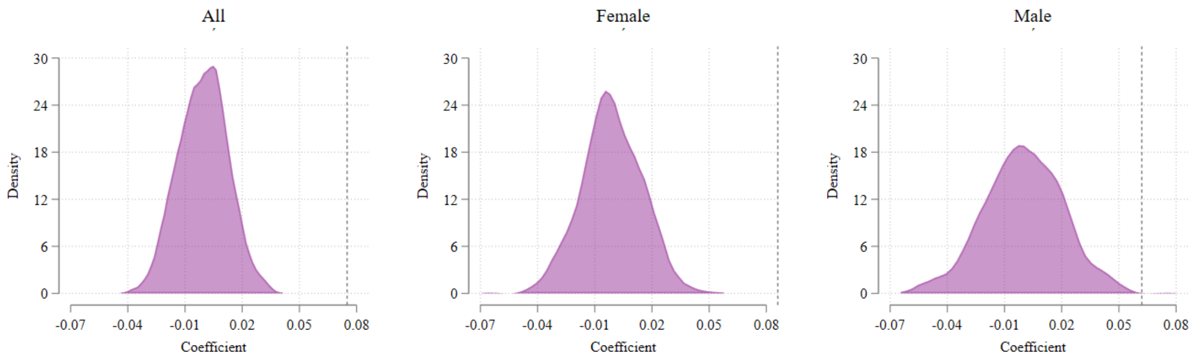
B. Computer



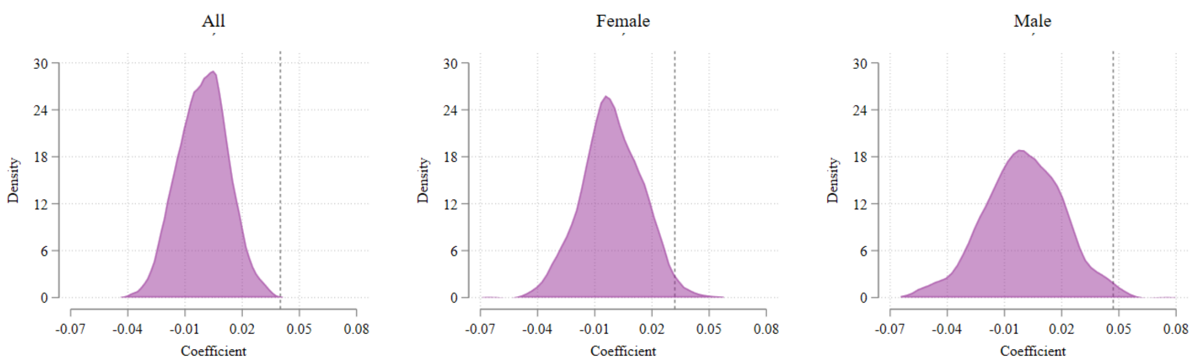
C. Internet

Note: Calculus of the authors using Saber database (ICFES). The sample is balanced and takes 40,000 observations for each gender. 500 iterations of the model are performed to obtain the distribution of the effect.

Figure 10: Distribution of placebo treatments



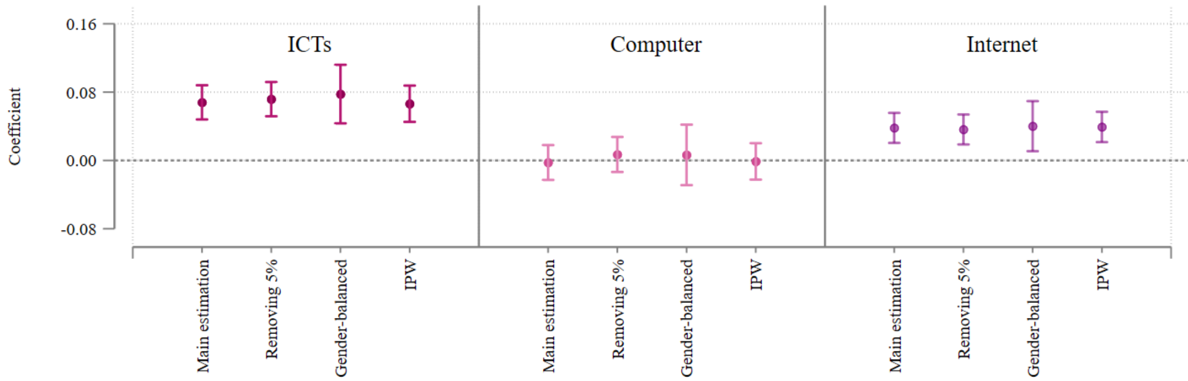
A. ICTs



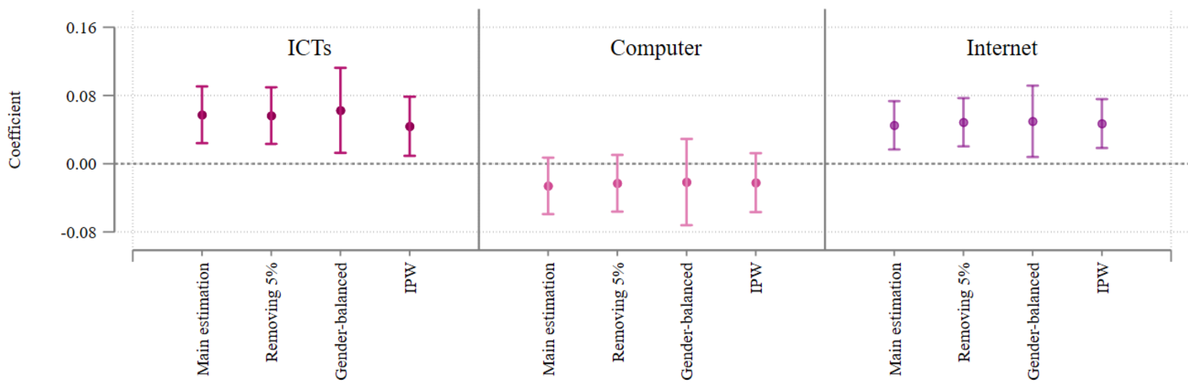
B. Internet

Note: Calculus of the authors using Saber database (ICFES). This figure presents the distribution of placebo treatments. Panels A and B carry out the same treatment randomization exercise, only panel A shows the p value, that is, the number of cases in which the placebo effect shows a greater effect than the first treatment (ICTs) and the Panel B shows the p-value for the second third (Internet).

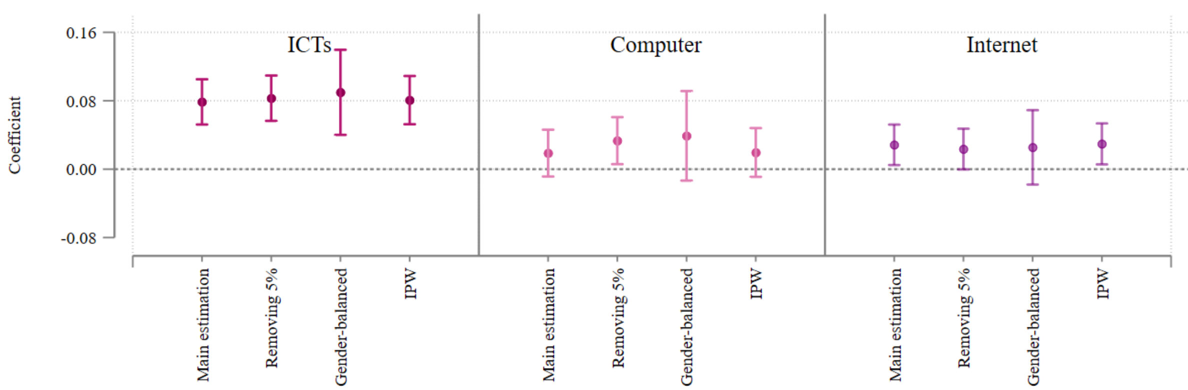
Figure 11: Estimated effects in math score with different specifications



A. All



B. Male



C. Female

Note: Calculus of the authors.

Appendix

Table A: Difference of means of control variables by gender.

	Matched in Saber 11						Sample					
	Saber 9/17			Saber 11/19			Saber 9/17			Saber 11/19		
	Male	Female		Male	Female		Male	Female		Male	Female	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Panel A: *Student characteristics*												
Age	15.24	15.05	***	17.24	17.05	***	15.48	15.21	***	17.48	17.20	***
Panel B: *Schools characteristics*												
Official school	0.76	0.78	***	0.75	0.78	***	0.97	0.97	*	0.95	0.96	***
Rural school	0.18	0.17	***	0.17	0.16	***	0.40	0.36	***	0.37	0.33	***
Mixed school	0.98	0.94	***	0.98	0.94	***	1.00	0.98	***	1.00	0.98	***
Panel C: *Household characteristics*												
Mother with more than high school	0.34	0.32	***	0.28	0.28		0.09	0.09		0.08	0.09	***
Internet and computer	0.58	0.55	***	0.54	0.51	***	0.00	0.00		0.08	0.08	
Computer	0.70	0.67	***	0.62	0.59	***	0.00	0.00		0.16	0.16	
Internet	0.65	0.63	***	0.66	0.63	***	0.00	0.00		0.19	0.19	
Without internet nor computer	0.23	0.25	***	0.26	0.29	***	1.00	1.00		0.73	0.74	
Observations												
By gender	162.904	194.156		162.904	194.156		33.505	45.797		33.505	45.797	
All	357.060			357.060			79.302			79.302		

Source: Author's calculations, based on ICFES information. *** p<0.01, ** p<0.05, * p<0.1

Table B: Effects of ICTs access on learning outcomes

	High School Exit Exam Scores					
	Standardized math score			Standardized reading score		
	All	Male	Female	All	Male	Female
	(1)	(2)	(3)	(4)	(5)	(6)
***Panel A:** ICTs*						
Treatment	0.069***	0.057***	0.080***	0.010	0.001	0.019
	(0.010)	(0.017)	(0.014)	(0.010)	(0.017)	(0.014)
Observations	156,134	66,468	88,745	156,134	66,468	88,745
School fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Baseline controls	Yes	Yes	Yes	Yes	Yes	Yes
Dedication to the internet (without academic activities)	Yes	Yes	Yes	Yes	Yes	Yes
***Panel B:** Computer*						
Treatment	-0.003	-0.026	0.017	-0.006	0.015	-0.025*
	(0.010)	(0.017)	(0.014)	(0.010)	(0.016)	(0.014)
Observations	156,134	66,468	88,745	156,134	66,468	88,745
School fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Baseline controls	Yes	Yes	Yes	Yes	Yes	Yes
Dedication to the internet (without academic activities)	Yes	Yes	Yes	Yes	Yes	Yes
***Panel C:** Internet*						
Treatment	0.039***	0.047***	0.029**	0.025***	0.040***	0.012
	(0.009)	(0.014)	(0.012)	(0.009)	(0.014)	(0.012)
Observations	156,134	66,468	88,745	156,134	66,468	88,745
School fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Baseline controls	Yes	Yes	Yes	Yes	Yes	Yes
Dedication to the internet (without academic activities)	Yes	Yes	Yes	Yes	Yes	Yes

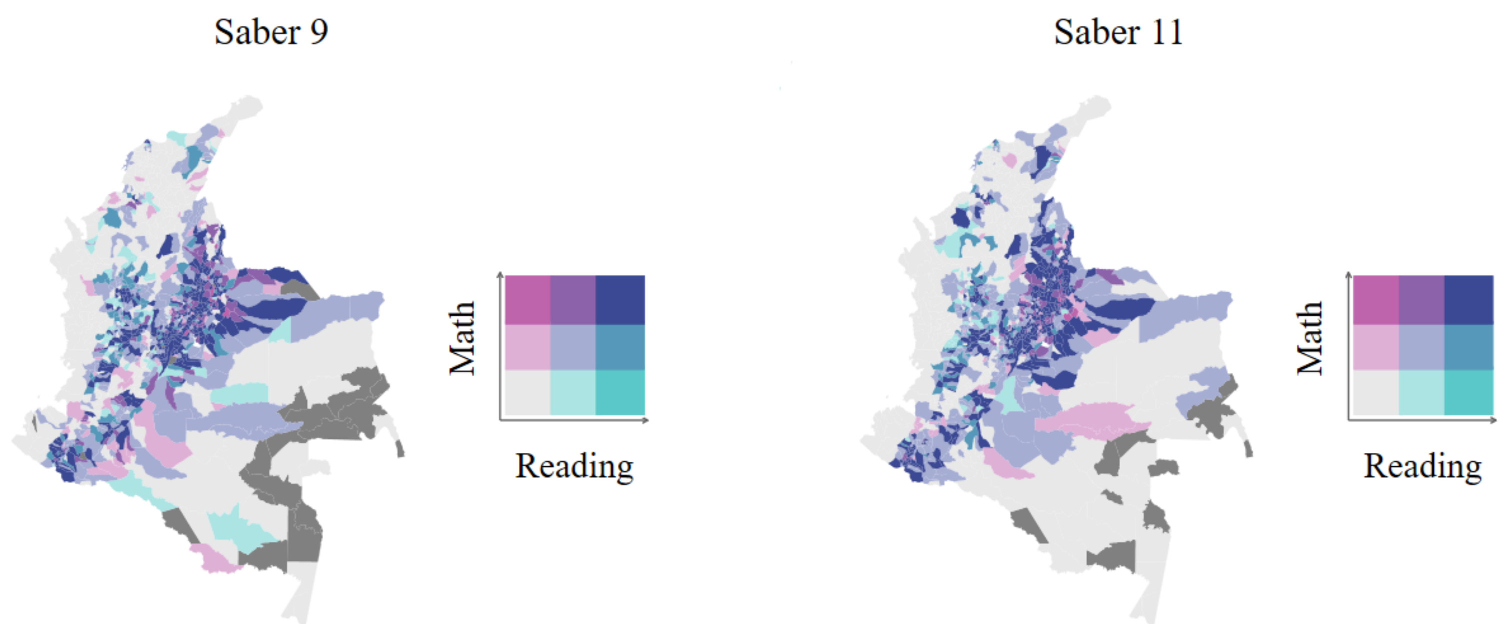
Note: Standard errors are grouped at the individual level in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table C: Effects of ICTs access on learning outcomes by quintiles of the dependent variable

	Standardized math score														
	All					Male					Female				
	Q1	Q2	Q3	Q4	Q5	Q1	Q2	Q3	Q4	Q5	Q1	Q2	Q3	Q4	Q5
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Panel A: *ICTs*															
Treatment	0.127***	0.161***	0.133***	0.122***	0.112***	0.180***	0.144***	0.110***	0.127***	0.094***	0.103***	0.159***	0.145***	0.116***	0.131***
	(0.026)	(0.024)	(0.023)	(0.020)	(0.020)	(0.049)	(0.044)	(0.039)	(0.033)	(0.029)	(0.034)	(0.030)	(0.030)	(0.027)	(0.030)
Observations	31,439	31,549	30,107	30,932	30,733	11,584	11,989	11,981	13,273	15,147	19,232	18,913	17,406	16,917	14,833
School fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Baseline controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Panel B: *Computer*															
Treatment	0.000	0.001	0.062**	0.054**	0.062***	-0.039	-0.026	-0.014	0.033	0.033	0.024	0.028	0.113***	0.066**	0.106***
	(0.025)	(0.025)	(0.024)	(0.022)	(0.020)	(0.043)	(0.045)	(0.044)	(0.036)	(0.028)	(0.033)	(0.031)	(0.032)	(0.029)	(0.030)
Observations	31,439	31,549	30,107	30,932	30,733	11,584	11,989	11,981	13,273	15,147	19,232	18,913	17,406	16,917	14,833
School fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Baseline controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Panel C: *Internet*															
Treatment	0.051**	0.048**	0.077***	0.066***	0.015	0.077**	0.087**	0.129***	0.076**	0.013	0.041	0.024	0.041	0.056**	0.004
	(0.020)	(0.019)	(0.020)	(0.019)	(0.019)	(0.037)	(0.034)	(0.033)	(0.029)	(0.027)	(0.025)	(0.025)	(0.026)	(0.027)	(0.031)
Observations	31,439	31,549	30,107	30,932	30,733	11,584	11,989	11,981	13,273	15,147	19,232	18,913	17,406	16,917	14,833
School fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Baseline controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

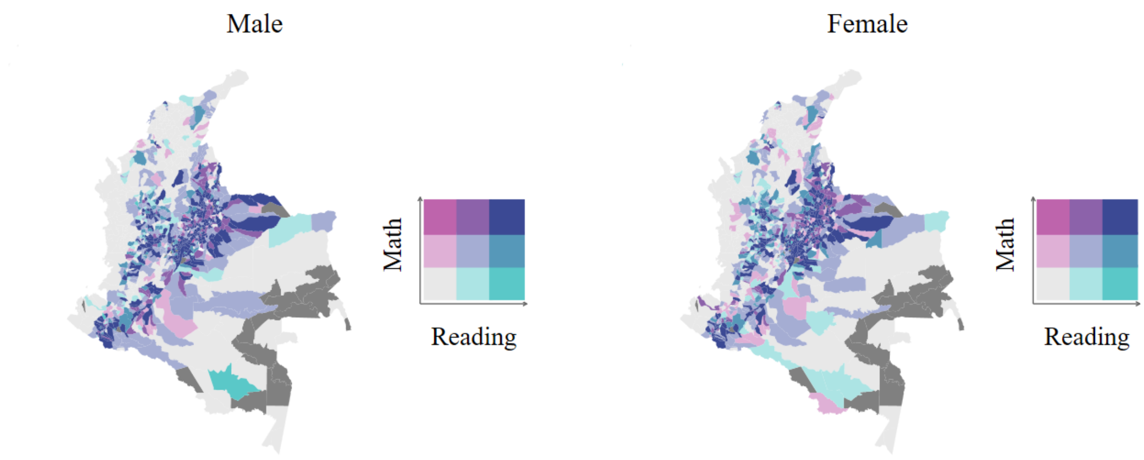
Note: Standard errors are grouped at the individual level in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Figure A: Bivariate map of Colombia between reading and math scores for Saber 9 and Saber 11.

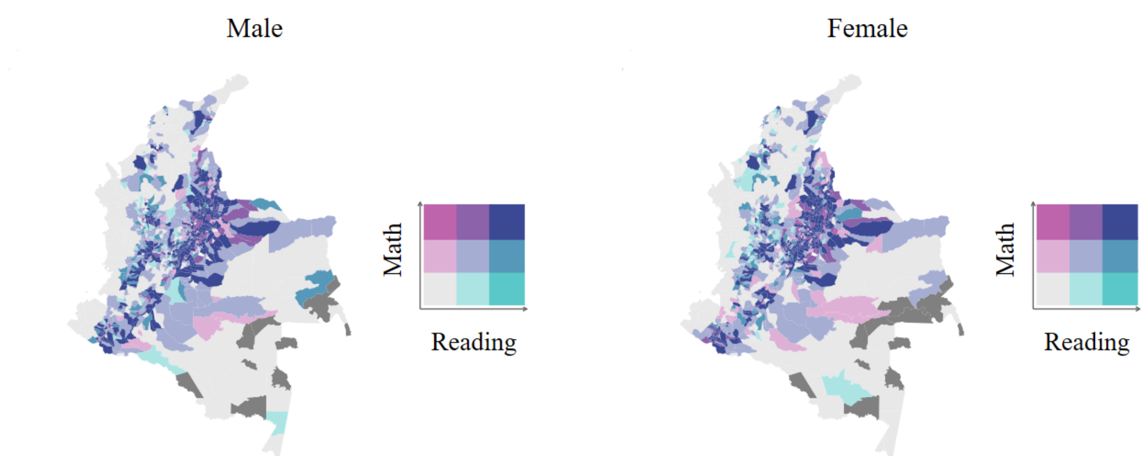


Note: Calculus of the authors using Saber database (ICFES).

Figure B: Bivariate map of Colombia between reading and math scores by gender for Saber 9 and Saber 11.



A. Saber 9



B. Saber 11

Note: Calculus of the authors using Saber database (ICFES).