The effect of ICTs access in households on learning achievements: a comparison pre-pandemic and post-pandemic in Argentina

María Marta Formichella and María Verónica Alderete[1]

Abstract: This article examines the association between primary students' academic performance and household access to computers with internet connectivity in Argentina, extending the empirical literature in the context of the COVID-19 pandemic. We investigate whether information and communication technologies (ICTs) affect educational outcomes and whether their impact differs before and after the pandemic. We estimate propensity score matching models using Aprender 2021 data for students in the final year of primary school, disaggregated by geographical regions. The results indicate that household access to computers with internet connectivity is associated with higher language arts and mathematics test scores. The estimated effect varies across regions. In addition, the performance gap between students with and without ICT access is, on average, 2.33% larger than the estimated pre-pandemic gap, suggesting that ICT access became more salient during school closures. Overall, this study contributes to the evidence on ICT-related educational inequalities at the primary level during the pandemic.

Keywords: household ICT access; digital divide; academic achievement; learning outcomes; propensity score matching.

JEL Classification: I21, I28, O33, C21, D83.

Preliminar

El efecto del acceso a las TIC en los hogares sobre los logros de aprendizaje: una comparación pre-pandemia y pos-pandemia en Argentina

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Resumen: Este artículo examina la relación entre el rendimiento académico de los estudiantes y el acceso a computadoras con conectividad a Internet en sus hogares, sumándose a la investigación empírica existente a la luz de la pandemia COVID-19. El objetivo es investigar cómo las tecnologías de la información y la comunicación (TIC) influyen en los resultados educativos entre los estudiantes de primaria. Además, comparar el impacto de las TIC en la educación antes y después de la pandemia. Se estima un modelo de emparejamiento por puntaje de propensión con datos de Aprender 2021 que corresponde a estudiantes del último año de primaria en Argentina en diferentes regiones geográficas. Los resultados confirman que el acceso a ordenadores con conexión a Internet en los hogares mejora la puntuación obtenida en lengua y matemáticas. El efecto del acceso a las TIC sobre los resultados educativos difiere entre las regiones de Argentina. Además, la diferencia de desempeño entre quienes tienen acceso a las TIC y quienes no, es en promedio un 2,33% mayor que la evidencia previa a la pandemia. Este artículo contribuye a la literatura empírica sobre la evaluación del impacto de las TIC durante la pandemia en el nivel primario.
Palabras clave: TIC en el hogar, acceso a las TIC, desempeño educativo, técnica de emparejamiento.

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L'effet de l'accès aux TIC à domicile sur les résultats scolaires : une comparaison entre la période pré-pandémique et post-pandémique en Argentine

Résumé : Cet article examine la relation entre les résultats scolaires des élèves et l'accès à des ordinateurs connectés à Internet à leur domicile, s'ajoutant ainsi aux recherches empiriques existantes à la lumière de la pandémie de COVID-19. L'objectif est d'étudier comment les technologies de l'information et de la communication (TIC) influencent les résultats scolaires des élèves du primaire. Il s'agit également de comparer l'impact des TIC sur l'éducation avant et après la pandémie. Un modèle d'appariement par score de propension est estimé à partir des données d'Aprender 2021 correspondant aux élèves de dernière année du primaire en Argentine dans différentes régions géographiques. Les résultats confirment que l'accès à des ordinateurs connectés à Internet à domicile améliore les scores obtenus en langue et en mathématiques. L'effet de l'accès aux TIC sur les résultats scolaires diffère selon les régions d'Argentine. En outre, la différence de performance entre ceux qui ont accès aux TIC et ceux qui n'y ont pas accès est en moyenne de

2,33 % supérieure à celle observée avant la pandémie. Cet article contribue à la littérature empirique sur l'évaluation de l'impact des TIC pendant la pandémie au niveau primaire.
Mots clés : TIC à domicile, accès aux TIC, performances scolaires, technique d'appariement.

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Introduction

In recent decades, Information and Communication Technologies (ICTs) have acquired greater significance as one of the critical factors of educational outcomes (Daoud et al., 2020; Formichella & Alderete, 2020; González-Betancor et al., 2021; Harwitz & Schmidt, 2009; Qaddumi et al., 2021). In 2015, the United Nations Educational, Scientific and Cultural Organization (UNESCO, 2015) had already indicated that these tools are a priority in the school environment. ICTs promote inclusion and the possibility of learning and teaching and, at the same time, make the education system governance/administration more efficient. Therefore, disparities in household access to ICT among students and/or their schools can lead to variations in their academic achievements. Besides, because of the isolation during the COVID-19 pandemic, this topic has become particularly relevant due to the suspension of in-person classes in 2020 and part of 2021. This generated a shift of schooling to home-based schooling (Dussel, 2020) and the necessary use of ICT to continue education. During this period, inequalities in student and family access became clearer.

During the pandemic, access and use of devices with educational purposes was very unequal in Argentina. Whereas 12.5% of public primary school students only use laptops, PCs, or tablets; 24% combine the use of different devices (including cell phones) and a vast majority (58.8%) were only able to use cell phones (Ziegler et al., 2020). This complicates the learning process considering that adults are usually the owners of those cell phones and were absent from the home to share them with their children for educational purposes (Moreno Fernández et al., 2022). In addition, and even more serious, Ziegler et al. (2020) estimated that 3.9% of students at this educational level did not have any kind of device during the pandemic. Therefore, almost 4% had serious communication issues and most likely abandoned their educational paths. Thus, the role of ICTs as determinants of educational performance has become more relevant in recent years and, especially since 2020, with the outbreak of the COVID-19 pandemic. However, there are several other elements influencing school performance, such as individual, family, and school factors (Alderete & Formichella, 2016; Wang & Chen, 2021). Among them, it is worth noting the geographical location of schools. This is particularly true in Argentina because of the decentralization of the educational system, which implies that each province administers the schooling of its inhabitants (Formichella et al., 2009).

Geographical location turns into a key factor of the determinants of school performance (Fernández-Gutiérrez et al., 2020). The geographical issue is closely related to the population distribution between the rural and urban sectors. In the former, there is a greater incidence of poverty due to unsatisfied basic needs (CEPAL, 2016), which limit access to ICTs, thus feeding the existent digital divide. There are also existing discrepancies within the urban sector. According to the Permanent Household Survey (EPH, as per its initials in Spanish), in the first quarter of 2021, Internet access in households ranged from 88% in the Northeast to 92.5% in Patagonia. Moreover, the possession of a computer went from 56.6% in the Northeast to 70.6% in Patagonia. Therefore, these regions have the least and greatest access to ICTs, respectively. Likewise, within each region there are gaps, especially among income quintiles (CEPAL 2016). In that sense, regional differences can be observed in relation to the educational policies connected to ICTs. To summarize, on the one hand, it is public knowledge that there has been immense technological progress in the use of the Internet and in broadband and, particularly, mobile broadband. On the other hand, an improvement has not yet been achieved in issues related to quality and equality in access to these technologies.

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Within this framework, the aim of this article is to analyze the effect of access to ICTs in students' households on educational outcomes. We are interested in determining whether the impact of such effect was modified during the isolation due to the COVID-19 pandemic. This goal is carried out by comparing the results found from *Aprender 2021*, conducted during the pandemic, with those obtained in a previous study from *Aprender* 2018 (Alderete & Formichella, 2023).

The analysis focused on the primary school level. Although some studies have examined the impact of ICTs on school results at the secondary level in Argentina (Alderete & Formichella, 2016a; Formichella et al., 2020; Llach & Cornejo, 2018), research at the primary one is scarce (Alderete & Formichella, 2023). Since these analyses have acquired special relevance due to the pandemic, this article contributes to the empirical literature on ICT impact assessment. Furthermore, the study used a significant and representative sampling, *Aprender* 2021, which comprises data at the national level differentiated by geographical regions. The survey covers the subjects of language arts and mathematics in primary school.

In this context, the hypothesis proposed is that access to ICTs in households improves school performance, while the lack of access (because of the isolation due to the pandemic) increases the discrepancies and gaps in educational outcomes. The methodology used is similar to Alderete & Formichella (2023), that uses data from *Aprender* 2018. Therefore, the main contribution of this article is the comparison of the educational outcomes before and after the pandemic by using updated and comparable data from Argentina. In this way, we can suggest the value of ICT access in households in such scenario.

This article is structured as follows. Section I presents the background on the matter. Next, the methodology, data, and variables used are detailed in Section II. Then, Section III provides the results obtained and their comparison with those of the previous study mentioned. Lastly, the final considerations of the work are developed in the Conclusion Section.

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I. Theoretical framework

Information and communication technologies (ICTs) play a central role in contemporary societies. Access to ICTs and basic digital skills has become essential for individuals to participate effectively in social, economic, and educational activities. This literature is particularly concerned with the effects of ICTs on students' educational trajectories and with the role of educational and technological policies aimed at fostering early and equitable access. Currently, various educational policies and technological interventions on children have been effective (Hurwitz, 2019).

Policymakers promote early access to technology as a first step on the educational path (United States Education Department, 2017).

Hargittai (2003, p. 823) characterizes the digital divide as the disparity between individuals who have access to digital technologies and those who do not, or alternatively, between those who make use of these technologies and those who don't—typically framed in binary terms that separate the wealthy from the disadvantaged. More recent research has expanded this notion by identifying three distinct dimensions of the digital divide (Song et al., 2020; Van Laar et al., 2017; Van Dijk, 2012): a) The first-level digital divide, which concerns access to or availability of ICT infrastructure; b) The second-level digital divide, which involves differences in ICT usage skills or capabilities; and c) The third-level digital divide, which relates to the tangible outcomes or benefits derived from using ICT, including access to digital content.

Although several studies have been published on the impact of ICTs on education, research at the primary school level is scarce, not only in Argentina but also in the rest of the world. Some exceptions are found in Taiwan, South Africa, South Korea, China, Crete, and Palestine (Arvanitaki & Zaranis, 2020; Kim et al., 2014; Meelissen, 2008; Qaddumi et al., 2021; Wang & Chen, 2021). At the same time, very few investigations have focused on the effect of ICTs in households (for a review on the topic, see Daoud et al., 2020). Moreover, the literature does not find consensus regarding the impact of ICTs in households, on educational outcomes. A first group of authors evidenced a positive and significant impact (Hurwitz & Schmidt, 2020; Kim et al., 2014; Waimer et al., 2015; Wang & Chen, 2021; Wong et al., 2015). Another group observed a negative effect (Cristia et al., 2017; De Melo et al., 2013; Malamud et al., 2018). There is even a third group, who detected an ambiguous impact, since they found a significant effect on some ICTs variables or on some school disciplines (Fernández-Gutierrez et al., 2020; Ryu, 2014; Saez Lopez, 2012). According to the second group of authors, ICTs have a negative effect, especially on children with limited digital capabilities, as they distract from the learning process or, even worse, discourage children's participation in the activity. The impact on educational outcomes will depend on the digital capabilities that children can acquire through the Internet (Hurwitz & Schmidt, 2020).

In Argentina, there are few studies that have assessed the consequences of the digital gap in the learning achievements at the primary level of education; and most of them focus on a qualitative perspective (Anderete Schwal, 2020; Benitez Largui, 2020). Anderete Schwal (2020) shows that educational segregation during the pandemic have increased due to the digital divide and inequalities in Argentine familie's cultural and economic capital. Benitez Largui (2020)

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observes that connectivity is undoubtedly the main structural barrier to achieve distance education, together with other subjective, organizational, and communicational obstacles.

Other studies at national level obtained diverse results. Based on data from Aprender 2016, Cortelezzi et al. (2018) estimated a multilevel regression model and identified a positive effect of Internet access in households, which was not significant in the case of cell phones. Likewise, and with the same data, Llach & Cornejo (2018) studied the factors associated with school performance and found comparable results. Finally, Roman & Murillo (2014) used UNESCO's Second Regional Comparative and Explanatory Study (SERCE, as per its initials in Spanish) and concluded that the availability of computers in households positively affects educational outcomes.

School performance is explained by a set of individual variables linked to demographics, family characteristics, and school-related factors. Regarding the first variable, some authors who analyzed the effect of ICTs indicated that gender and family income are closely related to school performance (Hurwitz & Schmidtt, 2020; Wang & Chen, 2021). Particularly, women show a higher level in relation to Internet use and digital capabilities than men. However, other researchers affirm the opposite (Cristia et al., 2017; Dúo-Terrón et al., 2022; Meelisen, 2008). In Argentina, studies carried out at the secondary school level found that the results depend on the subject. Men perform better in mathematics and science, whereas women do in language arts (Alderete & Formichella, 2016). On the other hand, attending school at the primary (pre-school) level is correlated with better school performance in subsequent years. Conversely, repeating a grade is associated with worse results (Formichella et al., 2020; Alderete & Formichella, 2016).

There is consensus about the significance of variables at the family level, such as parents' educational level, to account for the development of digital capabilities at an early age (Hurwitz & Schmidt, 2020; Saçkes et al., 2011) and their incidence on school performance. In fact, Halpern et al. (2021) analyzed students between the ages of 12 and 18 in Chile and determined that parental mediation at home has a greater effect on the use of technologies and school performance than mediation carried out in schools. In the same way, Moreno-Fernandez et al. (2022) stated that a considerable number of families were unable to adequately attend their children's school homework during the pandemic, which would translate into inequalities in the educational environment.

Regarding the role of socioeconomic (SEL) and cultural level of the household, various articles identified a positive association with access to ICTs in this context (Gonzalez Betancor et al., 2021; Kim et al., 2014). The better the educational climate and employment status of parents,

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the better the school results at the primary and secondary school levels (Alves et al., 2017; Lusquiños, 2020; Meelissen, 2008). On the contrary, other articles did not find a significant relationship between these variables (De Melo, 2013). In the same way, the availability of books or libraries and/or other educational supplies in households improve school performance (Gustafsson et al., 2018; Sayans-Jiménez et al., 2018; Serio, 2018). Moreover, access to drinking water (De Melo, 2013; Diaz-Gines et al., 2019; Middel & Kameshwara, 2021) and the number of people per room (overcrowding) (Llach & Cornejo, 2018; Pierse et al., 2016; Tuñon & Poy, 2019) also affect the results obtained. Finally, child labor causes the opposite effect if it is considered a proxy variable of SEL (Llach & Cornejo, 2018). On the other hand, the type of school that children attend matters by virtue of the availability or not of educational resources and their SEL (Machin et al., 2006). It is worth mentioning the positive relationship between access to ICTs at school and school results (Alderete & Formichella, 2016; Formichella et al., 2020). However, there is no consensus on the role of the type of management as there are no significant results (Calero & Escardibul, 2007; Formichella, 2011; Formichella y Krüger, 2013) as significant correlations (Cornejo & Llach, 2018; Kruger, 2018).

Finally, it should be highlighted the relevance of the geographical region and area in school performance. Evidence shows that educational performance is positively linked to school attendance in the urban sector (Formichella & Krüger, 2013; Formichella & Ibañez Martín, 2014). In Argentina, Cervini (2010), Cervini & Dari (2009), Cornerjo & Llach (2018), and Santos & Escudero (2018) examined the geographical issue in education. The regions with the greatest proportion of rural population are in the north (NOA - Northwestern Argentina and NOE - Northeastern Argentina). Moreover, there is an enormous gap among the socioeconomic indicators of the different provinces in Argentina (Buchbinder et al., 2019). Several authors found evidence with respect to the existence of a digital divide, which accompanies the disparities in school performance among territories and regions (Cornejo & Llach, 2018; Lusquiños, 2020; Reggi & Gil-García, 2021; Toudert, 2015). Public programs that seek to provide schools with technological resources have an impact on minimizing the digital divide between the rural and urban sectors (Moral Pérez et al., 2014), with a greater incidence in the context of the recent COVID-19 pandemic (Sosa Díaz, 2021). In this sense, Garcia Diaz (2021) mentioned that a resilient answer to future crises requires modernizing educational systems.

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II. Methodology

To assess whether household access to ICTs improves the educational performance of students in their final year of primary school, this study adopts a quasi-experimental research design based on propensity score matching (PSM). This method provides a solution to the lack of randomness of the variable ICT access at home since students with ICT access at home could be qualitatively different from the rest. At the same time, this qualitative difference would be correlated with the educational outcomes. As a result, the relationship between household ICT access and educational outcomes is subject to endogeneity concerns.

The matching technique known as Propensity Score Matching (PSM), originally proposed by Rosembaum & Robin (1983) is used to confront the adverse selection problem. PSM estimates the effect of access to ICT at home by comparing the educational outcome of students with ICT access at home and that of other students without access but with similar observable characteristics. The PSM method can be summarized in four phases. First, the probabilistic or logistic model (Probit/logit) is estimated, or the probability that the treatment (having ICTs at home) is assigned to a student is calculated. Second, the propensity score (PS) is determined. Third, the sampling is divided into two sub-samples: the treated group (those that receive treatment) and the control group (those who do not receive it), and the common support region is selected. Finally, cases are matched under a non-parametric form. In summary, each individual is assigned a control with a similar PS and, in this way, pairs of individuals are constructed (the same control can be a pair with more than one treated individual). The technique is appropriate for controlling the process of assigning individuals to a group (treated group: with access to ICTs in their households) and estimating the causal effects of the treatment (Schneider et al., 2007). For individuals belonging to the control group, the lost potential value is imputed based on comparing data from similar groups (Guo & Fraser, 2015; Rosenbaum & Rubin, 1983).

This paper estimated the average treatment effect on educational outcomes. Based on Austin (2011), this average treatment effect captures the impact of displacing or moving an entire population from untreated to a treated condition at the population level. Then, this article intends to examine the educational outcome of students who have access to ICT in their households would have been if these technologies had not been available. Once the assumptions are validated, the estimates are developed using different matching methods (Nearest Neighbor, Kernel, and Radius), which allows contrasting and analyzing the significance of the differences between them

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(Bernal & Peña, 2016). Through these methods, the difference in the educational result of each pair of students (treated/control) is calculated to then estimate the average difference in the entire sample. This is known as the Average Treatment Effect or Average Treatment Effect (ATE). To test the null hypothesis (there is no difference between treated and controls, ATE=0), a significance test is obtained from the standard error of the difference between each pair. Then, it is concluded that the treatment has a significant effect on educational outcomes if the null hypothesis is rejected.

The analytical solution to the problem begins with the estimate of the average effect on the outcome of a binary treatment. Given a student *i*, i=1, …, N., it is determined that the pair (Yi(0), Yi(1)) represents the potential results of both types. The first type indicates the educational result if the student does not receive the treatment (does not have access to ICT in the household), and the second type represents the educational outcome if the student receives the treatment. If both states and types were simultaneously observable, the effect of ICT access in the household for student i would simply be represented by the difference Yi(1)-Yi(0). But this calculation is not possible since only one of the states is observable (it is a quasi-experiment)

$$Yi=Yi(Di)=\{Yi(0) \text{ if } Di=0; \quad Yi(1) \text{ if } Di=1\} \quad (1)$$

Where Di is a variable that indicates whether the student has access or not to ICT in the household. It is assumed that the educational outcomes reach the following values considering the models of Quandt (1972) and Rubin (1974). Where X are the explanatory and regressive variables, observable random variables, and U are the residuals or non-observable random variables.

The average causal effect obtained by comparing different educational outcomes and under the condition of accessing ICTs in households can be expressed as follows:

The average difference observed in the educational outcomes ATE: E (Yi|Di=I) – E (Yi|Di= 0) is equal to the sum of the average effect of accessing ICTs in households on the treated groups ATT: E (Y1i|Di=1) – E(Y0i|Di=1) in addition to the selection Bias E(Y0i|Di=1)-E(Y0i|Di=0).

The problem stems from the Average Treatment on the Treated (ATT), since it is not possible to observe the cases with a school result Y0 for those students who have access to ICTs in their households (D=1), and this explains the presence of selection bias (Heckman, 1990). The PSM method offers a response to this bias by substituting randomness for conditioning in the regressors (through a probabilistic regression model). Then, the omission of relevant variables in the estimation must be avoided or minimized. According to Chen & Kaplan (2015), the PSM method

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allows us to achieve this goal. For this, the PSM was calculated with the STATA 14 software and the *psmatch2* command.

The data used are from the *Aprender* 2018 survey from the Ministry of Education of Argentina, which are publicly and freely accessible. This is the only database that allows analysis of educational differences among regions. The results of the last year (6th grade) of primary school were studied both for all of Argentina as well as by geographical region (Pampean, Cuyo, Northeast, Northwest, Patagonia, and the Autonomous City of Buenos Aires [CABA, as per its initials in Spanish]). The scores obtained by students in different subjects (mathematics and language arts) represent school performance. For each student, a PS was estimated, which is the probability of access to ICTs in households and the dependent variable by virtue of a set of observable variables. Regarding the control variables, those related to students, households and the educational institution were used (Lazear, 2001).

Dependent Variable: it represents the school result; the score obtained in the different tests of language arts and mathematics. It consists of a numeric variable that takes values between 0 and 800.

Treatment variable:

- Access to ICTs in households: It is the availability of desktop or laptop computers in households with Internet access. This variable takes value one if students have a desktop and/or laptop computer with Internet access in their household and zero otherwise.

The treatment pretends to identify the digital divide in terms of unequal access to ICT (first digital divide). ICT use (digital skills) or ICT appropriation is not utilized as a treatment in this model, firstly, because of the availability of data. In the student questionnaire, there are no clear questions specifically addressing ICT use. Only a few items refer to attending virtual classes during the pandemic, watching recorded classes or videos online, or receiving assignments via email, virtual classroom platforms, or WhatsApp. In the director's questionnaire, there are more questions, but it focuses on ICT at school, instead of ICT at home as in this study. Secondly, to avoid endogeneity problems between the treatment and the result. In the case of ICT use, there could be many non-observable variables to control for, for instance, preferences for the technology, ease of use (how user-friendly is the technology for the student), perception of usefulness, and others that are not completely covered by the survey.

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Control variables:

- Male: it represents a variable that takes value one if the student is male and zero if female.
- Repetition: it is a variable that takes value one if the student has ever repeated any grade in primary school and zero otherwise.
- Initial Kindergarten: it is a binary variable that takes value one if the student attends the initial level of kindergarten (nursery and/or 3-year-olds class) before the level corresponding to 4-year-olds, and zero otherwise.
- Parents' education: it represents a binary variable that indicates the highest educational level reached by the parents, with value one if at least one of the parents finished secondary school and zero if none did.
- Child labor: it is a binary variable that indicates if students work for a third party outside the household, if they have helped their parents or relatives with jobs outside the household, and/or performed housework such as caring for siblings, working on the farm/ranch/vegetable patch, or house chores. If housework or caring for someone is carried out sporadically to cooperate in the home, it is not considered child labor. However, jobs done every day or from Monday to Friday regularly involve child labor. Therefore, the variable takes value one if students work outside or inside their home on a regular basis, and zero otherwise.
- Persons per room: it is a numeric variable that represents the level of overcrowding in households. It is estimated as the quotient between the number of people living in the household and the number of rooms or bedrooms available.
- Drinking water: it indicates the presence or absence of drinking water in households. The variable takes value one if households have drinking water, and zero otherwise.
- Number of books: it is a quantitative variable that represents the availability of books in households.
- Rural area: it is a variable that takes the value one if the school in which the student is enrolled is in a rural area and zero if this school is in an urban area.
- Public management: it represents a binary variable that takes value one if the school the student attends is of public management or administration and zero otherwise.

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In the Aprender 2018 program, unlike the one of 2016, there is no data available on the school vulnerability quartile, despite it being an important sociodemographic factor to explain not only the probability of access to ICTs in households but also the school results of students (Formichella & Alderete, 2020). On the other hand, it is not possible to use the SEL index provided by Aprender, since it was constructed with ICT indicators, and they cannot be in the treatment and in other explanatory variables at the same time. For such reasons, the type of school management and the urban or rural area were included in the regression as proxy variables of SEL. Students with the greatest vulnerabilities are expected to correspond to public and rural schools and, therefore, have lower probability of access to ICTs than the rest, as well as lower performance. In the same way, as explained in Section 2, students whose parents have less than complete secondary education are expected to be less likely to have access to ICTs and show lower school results. The same is expected of students from overcrowded households, without drinking water, with few or no books, who have not attended nursery at the initial level, do child labor, or have repeated a grade.

III. Results

This section presents the main results of the study. Table 1 reports descriptive statistics for the treatment variable (ICT access), outcome variables (language arts and mathematics scores), and control variables.: those of the treatment (ICT), those of the results (scores on language arts and mathematics), and those that act as controls. Most of them are binary, although the result variables, persons per room, and number of books are continuous.

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Table 1. *Descriptive Statistics*

Variable	Observations	Media	SD	Min	Max
ICT	587475	.641469	.4795695	0	1
Language	612528	471.4558	94.00476	199	723
Mathematics	597961	486.4022	97.00365	206	776
Repetitions	572023	.0907289	.2872234	0	1
Parents education	533780	.8081344	.3937683	0	1
Boy	557617	.4791927	.4995673	0	1
Persons per room	583218	1.77887	1.110275	.1	11
Drinking water	580773	.8410704	.3656107	0	1
Number of books	580773	.6164267	.4862563	0	1
Child labor	514954	.1370412	.4564372	0	1

kindergarten	568260	.5919104	.4914803	0	1
Public school	635515	.7333957	.442184	0	1
Rural	635515	.0965249	.2953099	0	1

Note: / *Sig.1%.

Source: Own elaboration based on Aprender (2021).

As can be seen in Table 2, before carrying out the matching process, access to a computer and the Internet in households (ICT Treatment) has an impact on the average educational outcomes. Table 2 shows a statistically significant difference in the average performance in favor of those who have ICTs, both in language arts and mathematics.

Table 2. *Average difference of the results outcomes by ICT access condition*

Variables	Treatment	N	Media	Media Difference (absolute)	Media Difference (percentage)
Language	Without ICT	199975	434.3032	-61.82702*	14.23%
	ICT	367049	496.1303		
Mathematics	Without ICT	194977	455.4057	-50.93777*	11.19%
	ICT	361240	506.3435		

Note: / *Sig.1%.

Source: Own elaboration based on Aprender (2021).

In the same way, upon comparing the medians of the explanatory variables and the conditioning factors of the matching between those students who have ICTs availability in their households and those who do not (again, prior to carrying out the matching), significant statistical differences are observed (Table 3).

Table 3. *Differences in the means of the explanatory variables according to Access to ICT*

Variables	Treatment	N	Media	Average difference
Repetition	Without ITC	198365	0.164	0.114*
	ICT	366309	0.050	
Parents' education	Without ICT	175991	0.691	-0.159*
	ICT	311338	0.850	

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Boy	Without ICT	190692	0.488	0.015*
	ICT	359980	0.473	
Persons per room	Without ICT	204608	2,088	0.003*
	ICT	371682	1,611	
Drinking water	Without ICT	203926	0.723	-0.182
	ICT	376847	0.905	
Number of books	Without ICT	203926	0.402	-0.331*
	ICT	376847	0.733	
Child labor	Without ICT	175491	0.837	0.001*
	ICT	333151	0.633	
Kindergarten	Without ICT	196461	0.523	-0.107*
	ICT	364494	0.630	
Public school	Without ICT	210628	0.898	0.278*
	ICT	376847	0.620	
Rural	Without ICT	210628	0.165	0.107*
	ICT	376847	0.057	

Note: / * p < 0.01.

Source: Own elaboration based on Aprender (2021).

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After describing the variables and the differences between the treated and the non-treated students, the results of the probabilistic model (PROBIT) are presented below. This model was estimated to assess the probability that a student has access to ICTs at home and, thus, be part of the treatment. In other words, the PSM was calculated. Table 4 provides the results obtained. All variables are statistically significant, except for male. This finding is contrary to previous evidence showing better educational outcomes for women in language arts and for men in mathematics (Author and Author, 2016).

The type of link between the variables and the probability that a student belongs to the treated group and, at the same time, obtains better school results corresponds to the background of the topic (Author, 2016). On the one hand, the variables of repetition, child labor, persons per room, and rural areas present a negative association. On the other hand, parents' education, drinking water, number of books, and private school are positively related to the likelihood of accessing ICTs and achieving better school results.

Table 4. *Estimation of the PROBIT model for Language and Maths, whole country*

Variables	coefficient	p-value	coefficient	p-value
Repetition	-.4689902	0	-.4726907	0
Parents' education	.2798609	0	.2798609	0
Boy	-.0037545	0.444	-.0017546	0.723
Persons per room	-.1223889	0	-.1227241	0
Drinking water	.4749875	0	.4767695	0
Number of books	.5870368	0	.5887831	0
Child labor	-.3674425	0	-.3661028	0
kindergarten	.1020562	0	.1006572	0
Public school	-.564853	0	-.5618152	0
Rural	-.4618673	0	-.4643834	0
_cons	.465449	0	.4611984	0

Source: Own elaboration based on Aprender (2021).

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On this occasion, based on the PSM calculation, the sampling divided into two groups is presented: those treated and those that are not (controls) (Table 5). Moreover, the so-called common support region is defined in this way. It varies according to the geographical area (the whole country and each region) and the result variable used, as can be seen below.

Table 5. *Common support region. Sample size with PSM based on the result variable and region*

Region	Subject	Treated	Controls	Total
Patagonia	Language	11 717	4 093	15 810
	Maths	11 521	3 989	15 510
Northwest NOA	Language	25 513	21 633	47 823
	Maths	25 813	21 191	47 004
Northeast NEA	Language	17 948	18 423	36 371
	Maths	17 668	17 953	35 621
CUYO	Language	17 010	8 805	25 815
	Maths	16 776	8 628	25 404
CABA	Language	17 199	2 133	19 332
	Maths	16 991	2 087	19 078
Pampeana	Language	152 938	55 442	208 380
	Maths	150 916	54 205	205 121
Total country	Language	243 002	110 529	353 531
	Maths	239 685	108 053	347 738

Source: Own elaboration based on Aprender (2021).

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Later, the matching of the individuals was carried out in a parametric manner. This means that the pairs were matched by choosing a control case with a similar score (PSM) for each treated case. It is worth noting that the same individual can act as a control for more than one treated individual. The results obtained according to three different matching methods are presented below.

By means of applying the Kernel method, Table 6 shows that the ATT on the scores in language arts and mathematics is higher in the treated group than in the control one, both for the whole country and each one of the regions. Such a statistically significant difference is considered relevant. In the table, the column difference refers to the discrepancy in absolute terms between the scores; the next column presents a percentage gap, which is calculated as the absolute difference in relation to the average result of those who participate in the treatment.

Based on the results reported, it is concluded that students who have ICTs in their households have a higher average performance in the two subjects analyzed. For the whole country, the superiority in the scores of language arts ranges between 5.73% (Kernel) and 4.27% (Nearest neighbor), while in mathematics this number ranges between 4.2% and 3.6%, evincing a greater gap due to not having access to ICTs in the former subject. Radius Caliper always shows an intermediate difference between the other methods.

Furthermore, based on the Kernel and Nearest Neighbor methods, it is observed that the regions with the greatest percentage difference between the treated and control groups are Cuyo in language arts and Pampean in mathematics. Conversely, CABA and the Northwest present the smallest discrepancy. On the contrary, the Radius Caliper method shows that the greatest relative impact of the treatment on school achievements occurs in the Northwest, both in mathematics and language arts. In addition, the least effect in mathematics is observed in the Northeast region, and that in language arts, in Patagonia.

Table 6. *Results of the treatment on the educational outcomes by PSM method*

Region	Variable	Sample	Kernel			Radius			Nearest Neighbor		
			Difference	Difference in %	T-stat	Difference	Difference in %	T-stat	Difference	Difference in %	T-stat
Patagonia	Language	Unmatched	56.303	11.28	34.78	56.30	11.28	34.78	56.30	11.28	34.78
		ATT	28.82	5.78	13.69	28.82	5.75	13.69	22.11	4.43	5.52
	Maths	Unmatched	49.00	9.74	29.86	49.00	9.74	29.86	49.00	9.74	29.86
		ATT	25.94	5.16	11.98	26.60	5.29	12.4	22.23	4.42	5.5
Northwest NOA	Language	Unmatched	56.74	11.52	69.59	56.74	11.52	69.59	56.74	11.52	69.59
		ATT	28.40	5.77	23.71	28.40	5.77	23.71	26.71	5.42	9.19
	Maths	Unmatched	37.69	7.51	42.73	37.69	7.51	42.73	37.69	7.51	42.73
		ATT	19.744	3.93	14.63	20.11	4.01	15.09	27.42	5.46	8.61
Northeast	Language	Unmatched	50.42	10.4	53.79	50.42	10.4	53.79	50.42	10.4	53.79
		ATT	27.51	5.68	19.98	27.51	5.68	19.98	23.08	4.76	7.41
	Maths	Unmatched	32.47	6.63	31.71	32.47	6.63	31.71	32.47	6.63	31.71
		ATT	19.81	4.05	12.69	19.932	4.07	12.87	15.49	3.16	4.43
Cuyo	Language	Unmatched	59.22	11.98	50.73	59.22	11.98	50.73	59.22	11.98	50.73
		ATT	30.12	6.09	18.68	30.65	6.2	19.29	25.60	5.18	8.21
	Maths	Unmatched	49.15	9.65	40.02	49.15	9.65	40.02	49.15	9.65	40.02

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		ATT	24.78	4.87	14.13	25.52	5.01	14.77	20.84	4.09	6.13
CABA	Language	Unmatched	61.45	11.57	29.29	61.45	11.57	29.29	61.45	11.57	29.29
		ATT	24.66	4.64	8.9	24.66	4.64	8.9	28.36	5.34	4.95
	Maths	Unmatched	57.58	10.61	26.62	57.58	10.61	26.62	57.58	10.61	26.62
		ATT	27.92	5.14	9.74	29.32	5.4	10.33	28.58	5.27	4.88
Pampeana	Language	Unmatched	64.50	12.83	144.08	64.50	12.83	144.08	64.50	12.83	144.08
		ATT	28.51	5.67	43.35	29.77	5.92	45.8	25.08	4.99	7.59
	Maths	Unmatched	56.39	10.99	119.69	56.39	10.99	119.69	56.39	10.99	119.69
		ATT	27.42	5.35	38.55	28.37	5.53	40.36	26.21	5.11	7.23
Total country	Language	Unmatched	63.90	12.74	195.03	63.90	12.74	195.03	63.90	12.74	195.03
		ATT	28.72	5.73	57.51	29.73	5.93	60.22	21.40	4.27	6.74
	MS	Unmatched	47.05	9.22	48.44	52.50	10.26	151.42	52.50	10.26	151.42
		ATT	24.27	4.76	16.95	27.32	5.34	50.5	25.08	3.6	6.70

Source: Own elaboration based on Aprender (2021).

The results exhibited here should be compared with those found in Alderete & Formichella (2023), who used a data source prior to the COVID-19 pandemic (*Aprender* 2018). Table 7 shows how the impact of access to ICTs on school results increased in the two subjects studied and in accordance with the methods considered between 2018 and 2021. In this way, it is possible to assert that access to ICTs became more relevant during the time of isolation, which is reflected in the school achievements quantified after the most critical moment of the pandemic. Similarly, the treatment being more significant, the disadvantage of those who are not treated results in more evident.

Table 7. *Comparison of the relative ATT, before and after the pandemic, according to the matching method. Total country*

Matching method	Subject	ATT difference (%) Aprender 2018	ATT difference (%) Aprender 2021	Change in the effect (%)
Kernel	Language	2.64%	5.73%	3.09
	Maths	3.21%	4.76%	1.55
Radius Caliper	Language	2.74%	5.93%	3.19
	Maths	3.33%	5.34%	2.01
	Language	2.09%	4.27%	2.18

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Nearest neighbou	Maths	1.70%	3.66%	1.96

Fuente: Own elaboration based on Author and Author (2023) and Aprender 2021

IV. Discussion

The results provide evidence that students with access to a computer and internet connectivity at home achieve higher scores in both language arts and mathematics, both nationwide and across regions. In other words, These findings are consistent with the empirical evidence in favor of access to ICTs on learning achievements at the primary school level (Alderete & Formichella, 2023; Arvanitaki & Zaranis, 2020; Balanskat et al., 2006; Choque-Larrauri, 2011; Machin et al., 2006; Qaddumi et al., 2021; Wang & Chen, 2021). Cristia et al. (2017), Wainer et al. (2015) and Roman and Murillo (2014) also find positive effects of access to ICT on academic performance, especially in primary school.

Moreover, since the treatment refers to the student ICT at home and not to the school's, the findings are similar to Daoud et al. (2020) and Hurwitz & Schmitt (2020), highlighting the importance of the home environment in capitalizing on the educational benefits of the internet. Besides, Wong et al. (2015) and González-Betancor et al. (2021) address how household socioeconomic conditions amplify or mitigate these effects.

The estimates indicate substantial regional heterogeneity in the magnitude of the treatment effect. Therefore, results agree with evidence in Argentina of a regional disparity on education, such as Alderete & Formichella (2023); Author (2019); Santos & Escudero (2018); Cornejo & Llach (2018); Cervini (2010) and Cervini & Dari (2009). However, this paper goes a step further by quantifying post-pandemic regional differences with recent data (Aprender 2021), while many previous studies work with pre-COVID data or without regional disaggregation. Two of the PSM methods show that the greatest impact of access to ICTs is in Cuyo in language arts and in the Pampean region in mathematics. These regional disparities in Argentina are also observed in the international empirical evidence (Fernández Gutiérrez et al., 2020).

Besides, this paper finds that gender is not a significant variable to explain the probability of accessing ICT at home. A possible explanation is that gender digital gaps in access to technologies tend to be more pronounced in rural contexts, in adolescents, or in adult women (González-Betancor et al., 2021; Wong et al., 2015;), while in childhood —especially in primary education — these differences are less evident, which coincides with the results of the present study. Family decisions regarding the provision of technology tend not to discriminate between sons and

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daughters in compulsory education contexts (such as primary), where access to digital educational resources is perceived as a generalized need rather than a gender-differentiated investment (Halpern et al., 2021). On the other hand, the digital inclusion policies promoted in Argentina during the last decade, such as the Conectar Igualdad Plan, although focused on the secondary level (Alderete & Formichella, 2016b), have contributed to generating a culture of transversal equipment, without explicit gender bias (Benítez Larghi, 2020).

Moreover, the evidence obtained suggests the usefulness of ICT for primary education. ICT has acquired a greater incidence in the context of the recent COVID-19 pandemic, as mentioned in other studies (Anderete Schwal, 2020; Moreno-Fernandez et al., 2022; Sosa Díaz, 2021). Those families without technology at home were incapable of attending their children's school homework properly during the pandemic. As a result, inequalities in ICT access translate into inequalities in educational performance. In Argentina, as well as in other developing countries, the educational segregation during the pandemic has heightened due to the digital divide and disparities in cultural and economic capital among families. In this sense, this paper quantifies the change in the educational gap before and after the pandemic, which is not present in many previous works. Therefore, as Benitez Largui (2020) states, connectivity represents the primary structural barrier to achieving distance education.

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Conclusions

The widespread diffusion of ICTs has profoundly transformed social and educational practices over recent decades. However, their relevance has increased exponentially due to social isolation because of the COVID-19 pandemic. The school environment has also been profoundly reshaped by this new reality. ICTs began to play a crucial role, especially after the virtual education experience to which educational systems all over the world were thrown into at a time when isolation became the main way to prevent the spread of COVID-19.

Thus, the objective of this work was to study the impact of the availability of computers and the Internet in students' households in Argentina on primary school achievements. The analysis was conducted in the whole country and for each of its regions. The findings obtained support the hypothesis proposed in the introduction: students who have access to ICTs achieve, ceteris paribus, better scores in tests of language arts and mathematics. However, there is also evidence in favor of the fact that the effect of access to ICTs on school results differs among regions in Argentina.

Furthermore, the results indicate that the impact increased after the pandemic, which is an indicator of the relevance that ICTs acquired during the isolation period. It is worth noting that, although access to ICTs does not guarantee their proper use (Formichella &Alderete, 2020), the fact that their availability makes a difference in educational outcomes (and by controlling for endogeneity) suggests that a good use is made of it.

Finally, from this work arises the need to implement policies aimed at expanding access to ICTs in households of primary school students, such as the one-to-one computing initiative (one computer delivered to one student) or those related to the subsidy of the Internet service. Again, access is a necessary but not sufficient condition for the efficient use of ICTs. Therefore, some other type of action in this regard should complement the policies. Inequalities at the ICT access level can only promote inequalities at the educational level.

Explaining the sources of these regional differences falls beyond the scope of this article. For future research, we expect to estimate other types of models, specifically multilevel ones, to include a level linked to geographical regions or provinces and the variables that characterize them. Thus, it would be possible to determine which of these are related to school results and their discrepancies by region.

Ethics Statement

This study did not involve human subjects directly and relied exclusively on secondary data; therefore, ethical committee approval was not required.

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