The effect of digital technologies on disadvantaged students' learning outcome: An analysis of PISA 2015

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Abstract

The use of digital technologies for learning is high on the policy agenda and, despite the lack of empirical evidence, is believed to benefit especially disadvantaged groups of students. This paper uses PISA 2015 data to shed light on whether digital technologies are associated with students' achievement and whether this association is different depending on students' socio-economic status. Within-school estimates do not reveal substantial differences in how ICT use affects disadvantaged and other students. We find that school characteristics do play a role in shaping the above mentioned relations. For instance, using ICT at home for schoolwork is associated with higher science literacy for disadvantaged students, but the association is stronger in non-public schools and in schools with higher number of computers per student.

Keywords: ICT, digital learning, socio-economic background, PISA

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1. Introduction

The use of digital technologies for teaching and learning has been high on the policy agenda for the past few years and, given the rapid evolution of technologies, it is foreseen to keep being a central topic in education policy. Policymakers and stakeholders across Member States consider that digital technologies provide a unique opportunity to increase efficiency and equity in education (European Commission, 2013). The importance of digital technologies in the education realm is further accentuated by the fact that education systems are required to provide citizens with the digital competences needed in the 21st century economy and society (European Commission, 2016), and therefore to reverse the current digital skills gap (European Commission, 2016a).

Most countries in Europe have high rates of computer access in school (European Commission, 2013) and initiatives of 1:1 devices have also been spreading (Bocconi et al., 2013). Nevertheless, there is consensus among stakeholders that digital technologies have not been fully exploited in education and trainings systems across Europe and the evidence on their effect on student achievement is, at best, mixed (Falck et al., 2015). In fact, while there is some evidence that digital technologies might improve student outcomes, some experts counterargument that the same impact could be achieved by implementing other well-managed non-technology supported interventions (Underwood et al., 2009). Still, even if indeed that seems to be the case, it is undeniable that the digital skills that may arise from these interventions are crucial to face the expansion of the digital society and economy (ICF, 2015).

The mixed causal evidence on how digital technologies impact learning outcomes could mask important heterogeneous effects for different sub-groups of students (Bulman and Fairlie, 2016). Indeed, the use of digital technologies for learning is believed to benefit especially disadvantaged groups of students (European Commission, 2013), because it broadens access to education and enables the provision of more flexible and individualized learning approaches (Redecker et al., 2011). Furthermore, the wider use of technology and open educational resources can contribute to alleviate costs for educational institutions and students (Inamorato dos Santos et al., 2016).

However, little is known about how the use of digital technologies for learning impacts the learning outcomes of disadvantaged groups of students. Given the lack of evidence in this area, we use PISA 2015 data to shed light on whether digital technologies are associated with students' achievement and whether this association is different depending on students' socio-economic status.

The structure of the report is as follows. The next section reviews the literature for both the general student population, but in more detail, for the disadvantaged group of students. Section 3 describes the data used in the report and the sample, as well as the definition of disadvantaged students used in the empirical analysis. Section 4 presents descriptive statistics on the age when students started using digital devices, on the access to and use of ICT, highlighting differences between students from different socio-economic statuses. In Section 5 we examine whether ICT use is associated with students' achievement as measured in PISA. Section 6 concludes.

2. Literature review

Digital technologies and general student population

Policy makers, educators and researchers believe in the potential of digital technologies to improve learning outcomes (European Commission, 2013) because they have the potential to give access to additional learning resources and facilitate pedagogical strategies that could be beneficial to the students. For instance, instruction can be individualized in terms of content and pace, game-based and cooperative learning are enabled, pre-teaching and re-teaching practices are facilitated, which may free-up teachers' time to other targeted teacher actions (European Commission, 2016; Bulman and Fairlie, 2016; and Falch and Mang, 2015). These expectations led to increased investments in digital technologies in schools and to the provision of computer for use at home. On the other side of the debate, critics are less enthusiastic and more sceptical about the use of technology for learning. According to them, digital technologies are seen as potentially distracting students, as they can be used for social networking, games, displacing time from schoolwork. In addition, the effect of digital technologies at school depends, ultimately, on whether schools are choosing the optimal levels of technology relative to traditional inputs (Bulman and Fairlie (2016).

The empirical literature examining the causal effects of digital technology reaches inconclusive or, at best, mixed findings (Bulman and Fairlie, 2016). A group of meta-analyses concludes that learning processes supported by digital technologies are as effective as those without technology (Hattie 2009; Tamim et al. 2011; Higgins et al. 2012; Means et al. 2010). On the positive side, Sung et al. (2016) suggest that learning with mobile devices is significantly more effective than traditional teaching methods. Several authors have claimed that this mixed evidence may be due to the purpose for which digital technologies are used (Falck et a. 2015; and Biagi and Loi 2013) and to other factors of the technology intervention rather than the technology per se (Archer et al. 2014; and Sung et al. 2016).

Digital technologies and disadvantaged students

Theoretical considerations

Whether introducing digital technologies may benefit more some groups of students than others has also been subject to debate. European Commission (2013) ascertains that some of the expected benefits brought about by digital technologies could be more relevant for disadvantaged groups.

An immediate issue is the one of access: given that disadvantaged groups of students tend to have less access to digital technologies, providing them the opportunity to access and use them may yield higher effects than for their more advantaged counterparts, decreasing therefore the digital divide. It is well established, though, that providing access is not enough as this is only one of the digital problems of disadvantaged groups. In fact, inequalities in access to ICT seem to have been weakened and students from disadvantaged groups have caught up when it comes to access to technology in education (European Commission, 2013a). However, even in this case second digital divide persists in how students from different socio-economic background use technology (OECD, 2016). Isomaki and Kuronen (2013) even describe further dimensions of digital inequalities - in equipment, autonomy of use, skills, social support, motivation, engagement and attitudes - suggesting that a more comprehensive approach must be undertaken if the goal is to increase learning outcomes with the use of digital technologies. Centeno et al. (2012) also highlight the existence of a dual exclusion problem faced by youth at risk: socio-economic factors drive complex forms of digital exclusion and digital exclusion in turn reinforces and deepens existing socio-economic disadvantages.

On the one hand, there is the expectation that digital technologies may benefit especially disadvantaged groups of students. Barley et al. (2002) argue that the potential brought by technologies to change from a teacher-centred model to a more student-centred instruction approach may benefit especially students at risk. Indeed, the use of computers might make it easier to adjust the level of difficulty and learning speed to the capabilities of disadvantaged students (Falck et al, 2015; ICF, 2015). Barley et al. (2002) add that computer-assisted instruction is seen as motivational and can connect classroom learning to real-life situations through the use of images, videos and sounds. Other important characteristics are that it is non-judgmental, gives frequent feedback, can individualize learning, allows for more autonomy and provides multi-sensory learning environments increasing the chances of student engagement. Considering specifically the migrant population, the European Commission (2016b) argues that the possibility to access and explore learning materials in their own language may increase motivation for learning. Open and flexible distance education is seen as particularly suitable for highly mobile students, such as newly arrived migrants and refugees (Colucci et al., 2016; Dahya, 2016; EADTU-EU Summit, 2016; World Bank, 2016).

On the other hand, some advocate that digital technologies may broaden the gap between the engaged and disengaged youth and create further divides (Cranmer, 2010). Along these lines, Warschauer and Matuchniak (2010) suggests that technology does not itself lead to positive effects but it is rather an "intellectual and social amplifier", which can help make good schools better but increase problems at less successful schools. Falck et al. (2015) argue that the use of computers might require complementary skills such as basic cognitive knowledge or critical thinking, as well as proactivity, self-discipline, and autonomy which might be less pronounced among disadvantaged students.

Discussing the case of dropouts or those at risk of dropping out, Kozma and Wagner (2006) put forward the idea that ICT by itself will not make any difference, but its capabilities can be used to supplement, support, reinforce and extend ICT-based programmes. They advocate that effective environments for the disadvantaged are those addressing a comprehensive set of needs: i) academic needs by: engaging students in challenging tasks; focusing on individual learners' skills and needs; providing students with structure and support; presenting frequent assessment and feedback; ii) social needs by: creating a supportive learning community; connecting with the outside community and resources; and iii) linguistic needs by: building on current languages skills and developing new ones. The authors argue that ICT should be used in group situations to support social engagement with learning. Centeno et al. (2012) emphasize the role of ICT in promoting inclusion by supporting youth resilience or protective factors, such as improve the set of skills, and promote entrepreneurship, creativity and participation in civic life.

In the opposite spectrum, some approaches, such as distance learning, may even be detrimental due to the lack of provision of social support disadvantaged learners need to maintain their engagement in learning. Inappropriate use of ICT can isolate disadvantaged learners from teachers, fellow students and community members that could otherwise support their learning and success. Cullen et al. (2011) also support the "learning for inclusion" approach, where learning is used as a facilitator to break the cycle of social exclusion. They argue that the "success" in using ICTs to support at risk young people depends on contextual factors, and whether right tools in the right context are put forward.

Falck et al. (2015) therefore conclude that, while they do expect the effects of using computers to be different depending on students' characteristics, whether it is beneficial or harmful is not completely clear from theoretical grounds and that this issue must be addressed by empirical analyses.

Empirical Considerations

Little attention has been given in the empirical literature to examine the effects of digital technologies on disadvantaged learners (ICF, 2015), which is likely due to the finding of no effect in many studies (Bulman and Fairlie, 2016). The large majority of the findings come from developing countries and from the U.S., which may be of limited interest in the European context.

We start by resuming the evidence available from reviews and meta-analyses, after which the conclusions from specific papers conducted in European countries is presented. As only a few papers targeting disadvantaged students were found in Europe, we search for heterogeneous effects in documents focusing on the general student population to complement those.

Reviews and meta-analyses

The three meta-analyses/literature reviews found that focus specifically on disadvantaged groups cover mainly evidence from the U.S. Even though the results can thus not be directly interpreted in the European context, it is still informative to summarize their findings here.

Barley et al. (2002) look at the effect of computer-assisted instruction on low-achievers from grades 1 to 12 and find a pooled effect size of 0.37. They also report that effects are found across all the grades, but that higher effects show up in mathematics (rather than literacy) and in combined practices (drill + practice and problem solving) rather than in one of the practices alone. Cheung and Slavin (2012) focus on struggling readers and carry out a meta-analysis of 20 studies that have analysed educational technology applications in elementary schools. While digital technologies produce a positive but modest effect on the reading skills of struggling readers (effect size 0.14), the effect sizes were the smallest in randomized experiments (0.04), which casts doubt about the overall impact. Among four types of applications, small-group tutorial applications that were integrated in the curriculum produced the largest effects sized (0.32). Surprisingly, the supplemental programs generated a smaller effect (0.18).

Also U.S. based, Zielezinski and Darling-Hammon (2014) review 53 studies of grades 6 to 12 underserved students - labelled as minority, low-achievers, under-credited or not on the track to graduate. Although the studies included in that review did not aim to identify causal effects and therefore were not of high evaluation quality, the insights brought about by the authors are worth reporting. They find indicative evidence that underserved students benefit from opportunities to learn that include one-to-one access to devices and benefit from digital technologies designed to promote high levels of interactivity and emphasize discovery and opportunities to represent thinking in multiple forms. Furthermore, successful digital learning is characterized by the right blend of teachers and technologies and in settings with real-time digital feedback.

European papers focusing on disadvantaged students/schools

Three European papers were identified that focus on disadvantaged groups of students and that carry out high-quality evaluation designs. Two of them point to negligible effects of digital technologies, while one other is more optimistic on the effect of digital storybooks on disadvantaged migrant young children.

In a randomized experiment, Verhallen and Bus (2010) compare the effect of digital storybooks in the second language vocabulary of children from immigrant and low-income backgrounds in the Netherlands. Children exposed to digital books significantly improved their vocabulary knowledge. Among the digital technologies used – static versus video, the video format resulted in better knowledge about the words. The authors conclude that using video storybooks might be an important additional practice in classrooms with many second language learners from low socio-economic backgrounds.

Another paper is Leuven et al. (2007), who exploit a policy in the Netherlands providing additional funding for computers and software to schools with more than seventy percent disadvantaged students. They find that, while students do spend more time on a computer in school, the test scores outcomes are negatively and insignificantly affected.

Finally, Malamud and Pop-Eleches (2011) look at the effect of providing home computers to low-income students from grades 1 to 12 or university. The authors explore a voucher government program in Romania that subsidized the purchase of home computers for low-income students enrolled in public schools. The families that applied to such voucher were ranked by income per capita and the number of vouchers available where given to the poorest ones. For evaluation purposes, they compared families just below and above the attribution threshold and found interesting results. First, students that received the voucher used computers about 3-4 hours a week more than their counterparts who did not receive the voucher, which however did not translate into increased computer use for doing homework of for using educational software. Actually, children receiving the voucher were 14 percentage points more likely to use a computer for games on a daily basis. Furthermore, while self-reported measures of computer-fluency were higher in the former group, they performed worse in Mathematics, English and Romanian.

Searching for heterogeneous effects

Some papers look into the general student population and, in addition, investigate the existence of heterogeneous effects according to the students' characteristics, i.e. examine whether the effect in specific groups of students is different (higher or lower) than that found in the general population. We summarize both the general and the heterogeneous effects here.

In line with the previous summarized literature, the results are mixed. Some studies report that, among the broader student population, disadvantaged students were actually the only ones benefiting from digital technologies.

One example is Chechhi et al. (2015) who look at a governmental intervention in Italy whereby 156 6^{th} grade classes were given additional resources to purchase ICT equipment – about 1500€ per student. The evaluation results show very modest increases in literacy (not numeracy), but that is confined for children from low-educated parents and in the lower-part of the scores distribution. Further qualitative analysis carried out by an external classroom observer report that the observed degree of cooperation between students in the treated classes is much stronger than in traditional classes. The authors consider that this extended cooperation is likely to result in a net gain for the weakest part of the class. The teachers perceptions were also very positive, especially in schools located in deprived areas and when applied to disabled and foreign students. There was a general agreement by teachers that the available ICT was an extremely powerful tool to enhance the effectiveness of traditional way of teaching, as it allows creating a stable reservoir of resources easily and readily available to all students. Again, the weakest part of the class is likely to benefit most from this, since better students would be able to find their way to learning even in the standard scenario.

Penszko and Zielonka (2015) carry out an ex-post evaluation study of the digital school project implemented in Poland in the academic year 2012/2013 in primary schools. This project entailed a comprehensive public intervention, with funds to buy ICT equipment, interactive white boards, visualizers and other devices, and with the provision of teacher training and development of e-textbooks. More than 3500 schools applied to the pilot phase, of which 399 were randomly selected. Interestingly, they estimate the effect on the test score distribution, beyond the usual comparison of means. They find that the only significant result was a small effect in the lower part of the distribution of reasoning scores. However, this effect was only present in 2013 (3 to 5 months after the ICT equipment was delivered) and no longer in 2014, which lead the authors to conclude that it was due to the novelty effect. Using Turkish PISA 2012 data, Bellibas (2016) finds that ICT availability at home is only significant for the achievement of low socio-economic status (SES), not for the high-SES or for the general student population. This is an example of how a null effect at the pooled level can be masking significant effects in different groups of students.

Other studies instead, find mixed or negative results for disadvantaged students. Looking at TIMSS data, Falck et al. (2015), examine the effect of different uses of ICT on achievement of 4th and 8th grade students. At the pooled level they have found that using the computer to look for ideas and information improves student achievement, while using them to practice skills reduces student achievement. When differentiating between socio-economic backgrounds, they find the same results for both low- and high-SES students, but the effects tend to be smaller for the low-SES ones - positive effects are less positive and negative effects less negative. Gui et al. (2014) find no difference in the effect of using internet at home for schoolwork on the learnings outcomes of advantaged and disadvantaged students.

Discussion

The empirical literature examining the causal effect of digital technologies on students' learning outcomes show mixed findings and, whether digital technologies impacts disadvantaged students differently, is also unclear. However, the (scarce) evidence does not seem to point to a negative effect of digital technologies on disadvantaged students. It should be highlighted that the evidence for the general student population is thorough and it has been summarized in several and extensive meta-analyses. In contrast, the evidence for the disadvantaged groups of students is relatively scarce and, for European countries, arises from a few and isolated papers. There is therefore the need to carry out more research in this area in order to have critical mass of evidence on which to ground more definite conclusions.

We contribute to this goal by analysing the recently released PISA 2015 data. This is a promising exercise because, in fact, the PISA data has been little explored to analyse the impact of digital technologies on disadvantaged students. OECD (2011) briefly mentions the issue to conclude that the relationship between the index of computer use, both at school and at home, and performance in digital reading does not differ greatly between socio-economically disadvantaged and advantaged students across OECD countries, although it does in a few countries. In the most recent report, OECD (2015) stresses that one of the most disappointing findings is that technology is of little help in bridging the skills divide between disadvantaged and disadvantaged students. This deduction is reached by comparing results from PISA 2009 and 2012 and realizing that access to computers has become universal in between these years, but that this change did not contribute to decrease the skills gap between students from different socio-economic background.

Given that the PISA data contain the most uniform measure of computer access and use across all countries and cover all of the Member States, in the second part of the research project we contribute to the discussion and bring new and the most up to date insights to the literature and to the policy debate.

3. Data and sample

The Programme for International Student Assessment (PISA) is an international large survey that aims at assessing 15 years old students' performance mainly in the domains of reading, mathematics and science. In addition to gathering data on student achievement, PISA collects extensive information on student's and school's characteristics. Furthermore, since the first wave a separate questionnaire on students' familiarity with digital devices has been given as optional for participating countries. In this questionnaire, students are asked about their access to digital technologies at home and at school, if and with how intensity they use them and for what activities.

In this report, we explore the PISA 2015 data from the ICT familiarity questionnaire for students, the student main questionnaire and the school questionnaire. The main domain assessed in 2015 was science which means that a higher share of assessment time was dedicate to it. For this reason, when examining the association between students' ICT use and achievement we focus more on science, while still presenting results for the other two domains.

In 2015, the majority of the European Member States administered the ICT Familiarity Questionnaire. Only Cyprus, Malta, Romania and one entire region of the UK did not, and therefore are not included in the report. Therefore, the working sample is composed of 25 European Member States. Because the items on the age when digital devices were used for the first time and the items on access to ICT were completely missing for Germany, this country is not included in the correspondent descriptive statistics.

For the descriptive statistics part in Section 4, we use the maximum number of observations in each of the items in order to give the most complete picture possible. For the econometric analysis in Section 5 though, all the observations with missing values in the relevant variables are dropped and the working sample is constituted of 109,967 students from 5,847 schools of 25 countries. More details about the reduced sample will be given later on.

Definition of disadvantaged students

We divide students into three groups according to their socio-economic status. Following OECD's work, we make use of the OECD Index of economic, social and cultural status (ESCS) that is provided directly in the PISA dataset. This index summarizes information on home possession, parental highest education and occupational status. We define three groups of students relying on within-country distribution of this index as follows[1]:

- Disadvantaged students: those with ESCS lying below one standard-deviation from the country's ESCS mean.
- Medium socio-economic status: those students with ESCS lying between one standard-deviation below the country's ESCS mean and one standard-deviation above the country's ESCS mean.
- Advantaged students: with ESCS lying above one standard deviation from the country's ESCS mean.

At the pooled level, this categorization leads to a total of 17% of disadvantaged students, 19% of advantaged students and 64% of students with medium socio-economic background.

4. Descriptive statistics on access to and use of digital technologies

This section presents descriptive statistics on the access to and use of digital technologies by all the students and differences observed depending on students' socio-economic statuses. We look into the age at which students started to use digital technologies, into the access to digital devices at the moment of the survey (age 15) both at home and at school and into the different activities in which they use digital devices. For each of these three topics we start by giving their definition, followed by descriptive statistics at pooled level.

4.1 Age when students started to use digital technologies

Definition

[1] The students' weights are taken into account when performing this exercise.

One of the items in the ICT familiarity questionnaire asks students how old were they when first used a digital device, such as "desktop computers, portable laptops, notebooks, smartphones, tablet computers, cell phones without internet access, game consoles, or internet-connect television".

Descriptive statistics

Less than one percent of the students in the sample (excluding Germany) report "never have used so far". On average, 34% of student have used digital devices for the first time before age 6 and 39% between ages 7 and 9. Only 25% have started using them after age 10. Examining the differences according to socio-economic background reveals that disadvantaged students start using them later in life when compared to their counterparts. In fact, only 27% of disadvantaged students have used them before age 6, compared to 34% of medium socio-economic students and 40% of students from more advantaged backgrounds. In contrast, more than 30% of disadvantaged students report having used digital devices for the first time after age 10, while only 18% of the advantaged do so.

Table 1 – Age when students reported to have used digital devices for the first time (pooled data), all students and by socio-economic status

	6 years old or younger (%)	**7-9 years old (%)**	**10 years old or older (%)**	**Never used so far (%)**
All students	34.5	39.8	25.3	0.5
By socio-economic status:				
Disadvantaged	27.6	37.9	33.63	0.9
Medium	34.4***	40.3***	24.9***	0.4***
Advantaged	40.7***	39.9***	18.9***	0.4***

Source: Own computations using PISA 2015 data.
Note: Weighted averages at pooled level (24 countries). All students answering question IC002 are included. Germany does not report this variable and is not included in this table. Asterisks indicate whether the share is statistically different from the share of disadvantaged group of students. *** p<0.001.

4.2 Access to digital technologies at home and at school

Definition

In the ICT Familiarity questionnaire, students are asked whether they have access to an array of digital devices for their use at home and at school. The OECD provides a variable for access to ICT at home and at school (ICTHOME and ICTSCH, respectively), which is the sum of all of the items in the correspondent question. However, we define access to ICT in a different way by referring to the original questions (IC001 and IC009) and focusing on devices that allow accessing and using digital resources[2].

The definitions of access to digital devices in this report are as follows:

- Access to devices at home- Access to internet connection and one computer, or cell phone, or table or ebook-reader.
- Access to devices at school- Access to computer, laptop, tablet and internet connection[3].
- Access to devices in the classroom- access to data projector or interactive whiteboards.

Descriptive Statistics

At the age of the survey – on average 15 years old – almost all students report having access to digital devices at home (98%) and at school (99%). The access at school seems indeed to be uniform since basically 100% of students from all socio-economic statuses report so. However, at home, disadvantaged students do have less access to digital devices. Even though the difference is statistically significant, its magnitude is small, with gaps of around 5-6 percentage points, suggesting that the first digital divide has almost closed up.

Table 2 – Access to ICT at home and at school (pooled level), all students and by socio-economic status

	Access ICT at school (%)	**Access ICT at home (%)**	**School has data projector or interactive whiteboard (%)**
All students	99.9	98.1	99.6
By socio-economic status:			
Disadvantaged	99.9	94.0	99.3

[2] For instance, one of the questions used in the index ICTHOME but that we disregard asks students whether they have access to USB memory sticks at school or a portable music player at home.
[3] We find substantial variation in the answers of students from the same school and therefore take the mode answer within each school.

Medium	99.9	98.7***	99.7***
Advantaged	99.9	99.5***	99.9***

Source: Own computations using PISA 2015 data.
Note: Weighted averages at pooled level (24 countries). All students answering question IC001 or IC009 are included. Germany does not report access to digital devices and is not included in this table. Asterisks indicate whether the share is statistically different from the share of disadvantaged group of students. *** p<0.001.

4.3 Use of digital technologies at school and outside of school

Definition of types of ICT use

In the ICT Familiarity questionnaire, the students are asked how often they use digital devices for several activities outside of school (not necessarily at home) and at school. Many of the activities refer to similar types of ICT uses and therefore we group them together. Following the relevant literature, we consider it is important to distinguish the place of ICT use – at home/outside of school or at school – and the purpose of ICT use – if it is used for educational or more general purposes. The following describes each of the groups formed and the activities that compose them:

- **H_schoolwork** - Use of digital devices outside of school to do schoolwork:
  - Browsing the internet for school work (e.g. preparing an essay or presentation)
  - Browsing the internet to follow up lessons (e.g. for finding explanations)
  - Downloading, uploading or browsing material from the school's website
  - Doing homework on a computer
  - Doing homework on a mobile device
- **H_communication** - Use of digital devices outside of school to communicate with colleagues and/or teachers about schoolwork:
  - Using email for communication with other students about schoolwork
  - Using email for communication with teachers and submission of homework or other schoolwork
  - Using social networks for communication with other students about schoolwork
  - Using social networks for communication with teachers
- **H_general** - Use of digital devices outside of school for non-educational purposes:
  - Playing one-player game; Playing collaborative online games; Playing online games via social networks
  - Using email
  - Chatting online

- Participating with social networks
- Browsing the internet for fun
- Reading news in the internet
- Obtaining practical information from the internet (e.g., locations, dates of events)
- Uploading own created contents for sharing (e.g., music, videos, poetry, computer programs)
- Downloading music, films, games or software from the internet

- **S_educational** - Use of digital devices at school for educational purposes:
    - Browsing the internet for schoolwork
    - Downloading, uploading or browsing material from the school's website
    - Posting my work on the school's website
    - Playing simulations at school
    - Practicing and drilling, such as for foreign language learning or mathematics
    - Doing homework on a school computer
- **S_general** - Use of digital devices at school for non-educational purposes:
    - Chatting online at school
    - Using email at school

Descriptive Statistics

To the question on how often they used digital devices for each of the activities, students answered in the scale: 1- never or hardly never; 2- once or twice a month; 3- once or twice a week; 4- almost every day; 5- every day. For descriptive purposes, we examine the percentage of students that report using ICT for at least one of the activities forming each of the groups with the intensity of at least once per week.

The large majority of the students use ICT for most of the types of activities at least once per week: almost all of them use ICT for general purposes outside of the school – 98% -, while to a lesser extent at the school – 44.1%. Concerning educational purposes, 78% of students report using ICT to do schoolwork outside of school, and 70% to communicate with colleagues and teachers about schoolwork. Surprisingly, using ICT for educational purposes at school is reported to happen at least once per week by 58% of the students.

When disaggregating by socio-economic status, we find that a lower share of students from disadvantaged backgrounds report using ICT for all of the purposes when compared to their counterparts, except for educational purposes at school.

Table 3 – Share of students reporting using ICT at least once per week in at least one of the activities composing the index (pooled level), all students and by socio-economic status

	H_schoolwork	H_commun	H_general	S_education	S_general
All students	77.9	69.9	97.5	58.5	44.1
By socio-economic status:					
Disadvantaged	71.8	64.5	95.8	57.0	42.2
Medium	78.6***	74.5***	97.6***	59.4**	44.8***
Advantaged	81.5***	77.9***	98.6***	57.4	43.6*

Source: Own computations using PISA 2015 data.
Note: Weighted averages at pooled level (25 countries). All students answering question IC001 or IC009 are included. Germany is included. Asterisks indicate whether the share is statistically different from the share of disadvantaged group of students. *** p<0.001; ** p<0.01; * p<0.1.

5. Use of digital technologies and students' achievement

5.1 Sample

In the section, we study whether the intensity of ICT use is related to students' learning outcomes. The idea is therefore to carry out an econometric analysis where these two factors are related to each other, while holding constant other relevant characteristics at the individual and school levels.

For this purpose, we reduce the working sample to the observations that do not have missing information in any of the variables used in the analysis[4]. This implies that results presented from now onwards are produced with a total of 109,967 students from 5847 schools in 25 European Member States. Table 4 shows some figures of the working sample by country.

[4] This meant a reduction of the original sample of around 30% (nearly 50,000 students), from all the 25 countries. Of those dropped, 20% were from disadvantaged socio-economic status, 64% from medium and 16% from more advantaged backgrounds. These shares are in line with the share of each of the groups in the original sample, which reassures that the eliminated observations do not belong mainly to one of the socio-economic groups.

Table 4 – Descriptive statistics for reduced sample, by country

Country	Students		Schools		Socio-economic status	
	Number	% of sample	Number	% of sample	% disadvantaged	% advantaged
AT	4,893	4.5	254	4.3	13.9	20.4
BG	3,480	3.2	175	3.0	13.2	21.9
BE	6,359	5.8	267	4.6	15.0	19.9
CZ	4,935	4.5	331	5.7	13.6	20.6
DE	3,900	3.5	244	4.2	14.8	22.1
DK	4,662	4.2	327	5.6	17.1	15.2
ES	4,786	4.4	201	3.4	17.5	21.0
EE	4,177	3.8	205	3.5	18.3	19.3
FI	4,463	4.1	161	2.8	15.9	18.8
FR	4,007	3.6	250	4.3	13.9	21.4
UK	3,815	3.5	234	4.0	16.8	19.3
GR	3,856	3.5	208	3.6	16.3	22.0
HR	3,913	3.6	160	2.7	12.8	21.3
HU	4,009	3.6	236	4.0	14.4	22.4
IE	4,005	3.6	167	2.9	16.8	19.9
IT	7,927	7.2	461	7.9	17.4	20.0
LT	4,675	4.3	308	5.3	19.8	18.6
LU	3,372	3.1	44	0.8	15.8	20.7
LV	3,635	3.3	248	4.2	19.4	19.7
NL	4,108	3.7	181	3.1	15.0	18.6
PL	3,379	3.1	167	2.9	13.7	19.7
PT	5,496	4.9	244	4.2	17.6	22.3
SK	4,231	3.8	277	4.7	7.6	20.2
SI	4,347	3.9	296	5.1	18.8	20.5
SE	3,537	3.2	201	3.4	15.7	16.5
Pooled	109,967	100	5,847	100	15.7	20.1

Source: Own computations using PISA 2015 data.

It is clear that some countries are over-represented in the working sample. To avoid having the results driven by the countries that have higher number of observations, we impose that each country contributes to the econometric results in a similar way. This implies that the results should not be interpreted as the results for the population but for the average of the countries.

For this part of the report, the variables related with students' achievement and ICT use are recoded to make the interpretation of the results more informative. In particular, students' achievement in each of the domains is normalized in order to have mean zero and standard deviation one. As for ICT use, indices for the intensity of ICT use for the different purposes are computed. We do so by adding the answers of students to each of the activities forming the type and location of ICT use. Furthermore, in order to be able to directly compare movements in the distribution of usage intensity in the different types of uses, those indices are normalized to have mean zero and standard deviation one[5].

5.2 Descriptive relation

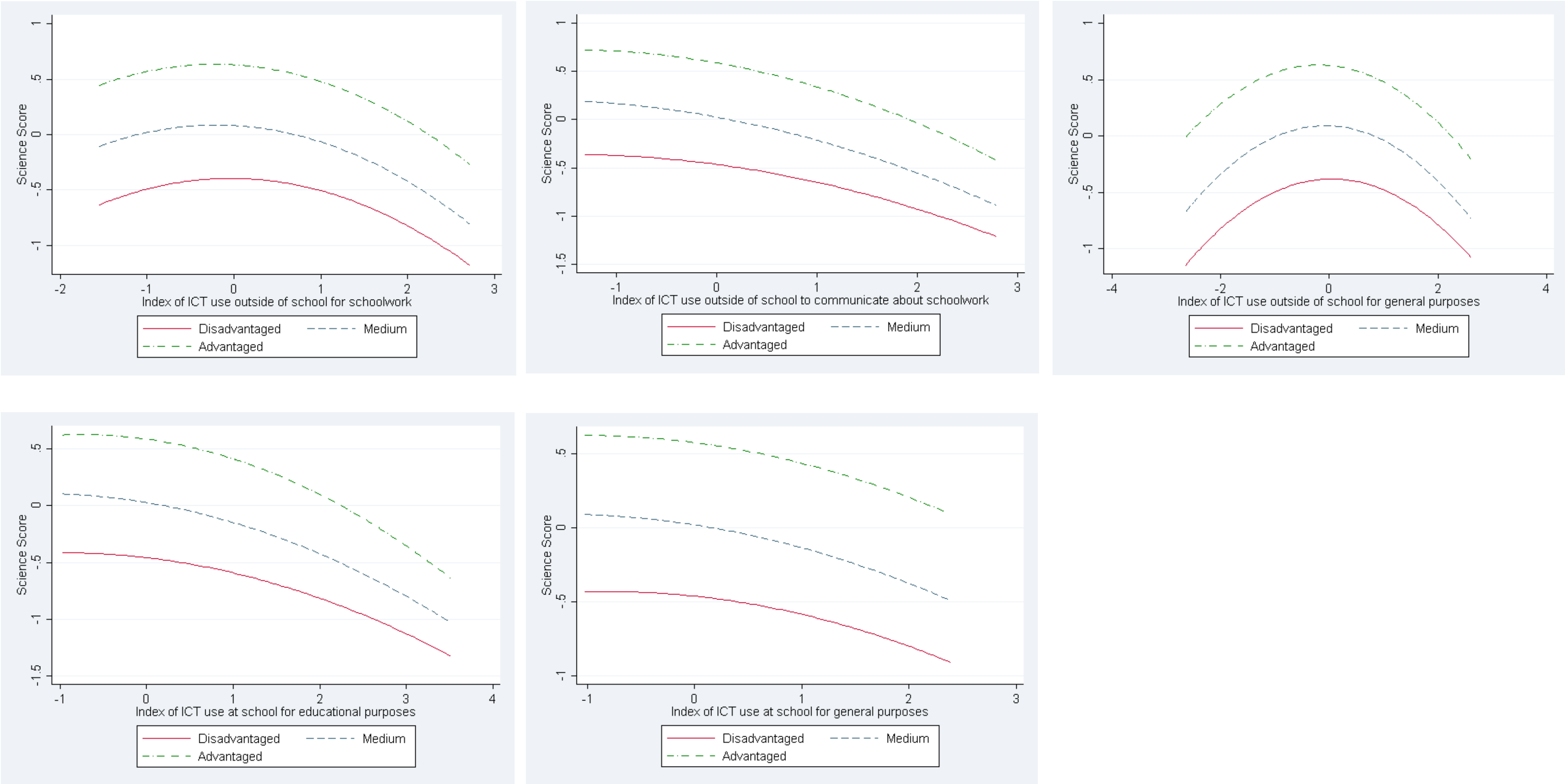
Figure 1 plots the quadratic fit between student's achievement in science and each of the indices capturing intensity of ICT use. Common to all graphs in the figure, is the fact that students from more advantaged background score higher than their counterparts, followed by those from medium and more disadvantaged socio-economic statuses. However, the pertinent piece to interpret is the shape and the slopes of the curves for each group.

The figure shows that the curves for using ICT for communication at home and at school for any of the two purposes – educational and general ones – has a negative slope for all the groups of students. This suggests that higher intensity of ICT use for these purposes is negatively associated with students' science performance. The only difference across groups of students is that the negative slope seems to be less steep for disadvantaged students, indicating that the relation between ICT use and achievement is not as pronounced as for the other groups of students.

In contrast, the relation between students' achievement and intensity of CT use at home for schoolwork and general purposes looks like an inverted U-shaped. This points to a positive relation confined to lower levels of intensity of use. Also in these two graphs, the negative part of the curve seems to be less steep for disadvantaged students.

[5] The students' weights are used to perform this standardization.

Figure 1 – Association between students' achievement in science and each of the intensity of ICT use indices (pooled level), by socio-economic status



Source: Own computations using PISA 2015 data.

Note: Each graph plots the quadratic fit of science score to each of the five indices of intensity of ICT use. Pooled data for 25 countries used. Students' weights used.

5.3 Econometric specification

The descriptive evidence just shown is a simple correlation between the two variables and completely ignores that there could be other factors driving these relations. If indeed, there are other factors simultaneously related with students' achievement and intensity of ICT use, we are attributing to ICT use the effect that is due to those other factors. This is what is typically referred to as omitted variable bias – the relation between two variables is biased because other factors are omitted from the relation of interest. In order to mitigate this issue, we run an econometric specification relating the students' achievement in the PISA tests – the dependent variable – with the different intensity of ICT uses, while controlling for several variables that can be thought of to be simultaneously related to the dependent and independent variables.

Our main specification is as follows:

$$PISA\ score_{is} = \alpha + \beta Intensity\ of\ ICT\ uses_{is} + \gamma X_{is} + \delta_s + \varepsilon_{is},$$

where the PISA score of student *i* in school *s* is related to the different intensity of ICT uses, individual demographic characteristics and school fixed effects[6]. β is therefore the main vector of interest. It is worthwhile to discuss in detail a couple of features of this specification.

The first relates to the fact that it includes all the five indices capturing intensity of ICT use. We consider it is important to control for all the indices of intensity of ICT use because all of them all positively related to each other[7]. This means that, on average, students that use more digital devices more intensively for one purpose also tend to use them more intensively for the other purposes. If only one of the indices is included in the econometric specification, it would be capturing not only its effect but also the effect of the other indices. By controlling for all of them, the betas are interpreted as an increase in the intensity of using ICT for one specific purpose while holding fixed all the other types of ICT use, favouring therefore the isolation of the relation between each type of ICT use and students' score.

[6] Notice that by including school fixed effects we are automatically including country fixed effects as well.
[7] The correlation matrix between the indices is as follows:

	H_schoolwork	H_Commun.	H_general	S_education
H_commun.	0.71	1		
H_general	0.43	0.43	1	
S_education	0.57	0.51	0.34	1
S_general	0.34	0.36	0.35	0.59

Second, the set of control variables X_{is} includes the age, gender and migration status of the student, whether he/she has repeated a grade and his/her socio-economic index provided by PISA (ESCS). We hypothesize that also schools' characteristics are likely to influence both the intensity of ICT use and students' achievement; if these are not taken into account in the econometric analysis, the effect of intensity of ICT use could be partly explained by school characteristics. In order to avoid this problem, and because we do not know exactly which school's characteristics are relevant, we only run within-school estimates which effectively hold constant any factors that are common to all students attending the same school (δ_s). We acknowledge that by doing so we may be overlooking important school factors that influence how ICT use relates to achievement. In order to give some insight on this matter, in a second stage we divide schools into different groups to check if the associations found before are driven by schools with specific characteristics or show up regardless of school's characteristics.

Third, and despite our efforts described in the two above paragraphs, it is important to highlight that this econometric analysis still has non-negligible shortcomings. In fact, it may still suffer from omitted variable bias if other non-observable factors are associated both with ICT use and students' achievement. Standard examples of such factor are student's motivation and/or innate ability. In addition, the specification could suffer from reverse causality, which in this case occurs if ICT use is actually affected by students' achievement and not the other way around, as hypothesized by the model. Due to these two reasons, it must be acknowledged that the estimates presented are not causal relations between intensity of ICT use and students' achievement. Accordingly, we will only interpret the sign and significance of the coefficient rather than their magnitude, even though the former are likely to suffer from the same problems.

Finally, given that both the dependent and main independent variables are normalized, the coefficients are interpreted as the increase in students' achievement, relative to one standard deviation, associated with a one standard deviation increase in the intensity of ICT use index.

5.4 Results

Table 5 presents the first results from the econometric analysis in two panels: in Panel A results are shown for the general student population, whereas Panel B shows results for each of the three groups defined based on socio-economic status.

The results from the econometric analysis in the Panel A of Table 5 show a positive association between student's achievement and intensity of ICT use at home for schoolwork and for general purposes. This means that a higher intensity of ICT use at home for these purposes is associated, on average, with higher scores in the science test. In contrast, a negative association is found between achievement and the other types of ICT use intensity, i.e. using ICT at home to communicate with students or teachers about school work and using ICT at school both for educational and general purposes. The association that is higher in magnitude is the one on communication which could be due to several reasons. One is a composition effect, whereby students that do this type of activity more intensively may be systematically different from the ones that use it less. For instance, they could miss school more or pay less attention in the classroom, so that they feel the need to contact colleagues or teachers to get information they missed at class. Another explanation could be that this activity distracts them from schoolwork and is relatively unproductive.

In Panel B, we disaggregate students into the three groups according to their socio-economic status. The results are in line to the ones of Panel A and there does not seem to exist substantial differences between the coefficients of the disadvantaged groups of students and those of their counterparts. This difference arises mainly in communication with students and teachers about schoolwork that is significantly less negative for disadvantaged students. In addition, using more intensively ICT use at school for educational purposes is negative for all groups of students, but especially so to students from medium socio-economic background.

Table 5 – Results from the econometric specification (pooled data), all students and by socio-economic status. Dependent variable: Achievement in science

	PANEL A Without distinguishing students	**PANEL B** Separating students into 3 groups according to socio-economic status	
H_schoolwork	0.048***	Disadvantaged	0.049***
		Medium	0.048***
		Advantaged	0.057***
H_commun.	-0.182***	Disadvantaged	-0.137***
		Medium	-0.184***
		Advantaged	-0.212***
H_general	0.082***	Disadvantaged	0.084***
		Medium	0.084***
		Advantaged	0.079***
S_education	-0.085***	Disadvantaged	-0.070***
		Medium	-0.089***
		Advantaged	-0.083***
S_general	-0.045***	Disadvantaged	-0.055***
		Medium	-0.041***
		Advantaged	-0.045***
Observations	109,967		109,967
R-squared	0.474		0.471

Source: Own computations from PISA 2015 data.
Notes: Within-school estimates and controlling for individual covariates. Standard-errors (not shown) clustered at the school level. Shaded cells: significantly different from the effect for disadvantaged. *** p<0.001.

These results are similar for the other domains tested in PISA – reading and mathematics (Table 6). The only point worthwhile mentioning is that the coefficients of the maths specification are slightly lower than the ones for science and reading. This may indicate that achievement in math is, on average, less affected by intensity of ICT use.

Table 6 – Results from the econometric specification for the several domains (pooled data), by socio-economic status.

	Dependent variable:	Science literacy	Reading literacy	Maths literacy
H_schoolwork	Disadvantaged	0.049***	0.053***	0.035***
	Medium	0.048***	0.044***	0.034***
	Advantaged	0.057***	0.041***	0.036***
H_commun.	Disadvantaged	-0.137***	-0.134***	-0.103***
	Medium	-0.184***	-0.164***	-0.150***
	Advantaged	-0.212***	-0.188***	-0.179***
H_general	Disadvantaged	0.084***	0.077***	0.072***
	Medium	0.084***	0.076***	0.062***
	Advantaged	0.079***	0.074***	0.071***
S_Education	Disadvantaged	-0.070***	-0.110***	-0.053***
	Medium	-0.089***	-0.122***	-0.084***
	Advantaged	-0.083***	-0.109***	-0.073***
S_General	Disadvantaged	-0.055***	-0.029***	-0.049***
	Medium	-0.041***	-0.017***	-0.026***
	Advantaged	-0.045***	-0.025***	-0.035***
	Observations	109,967	109,967	109,967
	R-squared	0.471	0.480	0.465

Source: Own computations from PISA 2015 data.
Notes: Within-school estimates and controlling for individual covariates. Standard-errors (not shown) clustered at the school level. Shaded cells: significantly different from the effect for disadvantaged. *** p<0.001.

By school type

By doing a within-school analysis we may overlook school characteristics that may influence how the use of ICT is associated with students' achievement. Therefore, in the remaining part of the report we look at different types of schools to examine if the results found so far are driven by specific types of schools or if, in contrast, arise regardless of school type.

In particular, we look at four characteristics of schools and for each of the characteristics we divide schools in two types:

- Computers available per student: schools lower than the median and schools higher than the median;
- Average ESCS at school: schools lower than the median and schools higher than the median;

- Urban and rural schools;
- Public and non-public schools.

In this exercise, we run the full specification but only interpret the coefficients of disadvantaged students.

We find that, indeed, results depend on school characteristics (Table 7). First, using ICT at home for schoolwork is associated with higher achievement in science for disadvantaged students, but this association is stronger:

- In schools with higher number of computers per student. The reason for this could be that disadvantaged students may need to have access to more computers at school and to actually use them to be able to use digital devices at home effectively.
- In schools with above median ESCS.
- In non-public schools. The reason for this could be that private schools meet several necessary conditions that enable disadvantaged students to use ICT at home more effectively. For instance, non-private schools may implement digital devices in the learning process more effectively (e.g., provide teacher training, use specific pedagogical practices, etc).

Second, using ICT at school for educational purposes is associated with lower science literacy for disadvantaged only in public schools, not in non-public schools. This finding reinforces the argument put forward before.

Table 7 – Results from the econometric specification (pooled data) by school characteristics. Dependent variable: Achievement in science

	Computers per student at school			Average ESCS in the school		
	Below median	Above median	Diff.	Below median	Above median	Diff.
H_schoolwork & Disadvantaged	0.029*	0.081***	***	0.036***	0.124***	***
H_commun. & Disadvantaged	-0.101***	-0.168***	***	-0.149***	-0.168***	
H_general & Disadvantaged	0.077***	0.084***		0.109***	0.031*	***
S_Education & Disadvantaged	-0.075***	-0.078***		-0.082***	-0.081***	
S_general & Disadvantaged	-0.043***	-0.061***		-0.038***	-0.107***	***
Observations	48,138	47,415		54,992	54,975	
R-squared	0.471	0.458		0.421	0.366	
	Urban school			Public school		
	Yes	No	Diff.	Yes	No	Diff.
H_schoolwork & Disadvantaged	0.024	0.051***		0.034***	0.101***	*
H_commun. & Disadvantaged	-0.119***	-0.142***		-0.136***	-0.129***	
H_general & Disadvantaged	0.073***	0.095***		0.093***	0.069***	
S_education & Disadvantaged	-0.087***	-0.070***		-0.078***	-0.015	*
S_general & Disadvantaged	-0.024	-0.054***		-0.044***	-0.120***	**
Observations	29,134	69,645		80,703	12,026	
R-squared	0.483	0.470		0.473	0.453	

Source: Own computations from PISA 2015 data.

Notes: Within-school estimates and controlling for individual covariates. Standard-errors (not shown) clustered at the school level. *** p<0.001, ** p<0.05, * p<0.1. Columns named "Diff." show whether the difference between the coefficients from the two types of schools is statistically different from zero.

6. Conclusion

The use of digital technologies for learning is high on the policy agenda and is believed to benefit especially disadvantaged groups of students. This paper starts by reviewing the existent evidence of the effect of digital technologies for learning on the learning outcomes of disadvantageous students. The overall consensus emerging from this literature is that the causal effect of digital technologies is mixed. It is also unclear whether they affect disadvantaged students differently, but the available evidence does not suggest that digital technologies contribute to further disparities in students' learning outcomes.

Given the lack of evidence in this area, we use PISA 2015 data to shed light on whether digital technologies are associated with students' achievement and whether this association is different depending on students' socio-economic status. We report several descriptive statistics showing that, compared to their counterparts, disadvantaged students start using digital devices later in life, have only slightly less access to ICT at home and tend to use less ICT for both educational and general purposes.

Within-school estimates do not reveal substantial differences in how ICT use affect disadvantaged and other students. For all of the groups, we find a positive association between a higher intensity of ICT use at home for schoolwork and for general purposes. In contrast, a negative association is revealed between learning outcomes and a higher intensity of ICT use at school, for both educational and general purposes, and at home to communicate about schoolwork.

We find that school characteristics play a role in shaping the above mentioned relations. For instance, using ICT at home for schoolwork is associated with higher science literacy for disadvantaged students, but the association is stronger: i) in schools with higher number of computers per student; ii) in schools with above median ESCS; and iii) in non-public schools. Furthermore, using ICT at school for educational purposes is associated with lower science literacy for disadvantaged only in public schools, not in non-public schools.

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