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Digital technologies and learning outcomes of students from low socio-economic background: An Analysis of PISA 2015

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Title
Digital technologies and learning outcomes of students from low socio-economic background:
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Abstract
Results using PISA 2015 data suggest that the use of digital technologies is positively associated with students' achievement, but only for some purposes and if used with low-intensity. Students from low socio-economic backgrounds would particularly benefit to use digital technologies for general purposes.

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Note

This report is part of the EffectiveEDU Administrative Agreement agreed between DG EDUCATION AND CULTURE (EAC) and DG JOINT RESEARCH CENTRE (JRC).

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Foreword

JRC research on Learning and Skills for the Digital Era started in 2005. The aim was to provide evidence-based policy support to the European Commission on harnessing the potential of digital technologies to encourage innovation in education and training practices; improve access to lifelong learning; and impart the new (digital) skills and competences needed for employment, personal development and social inclusion. More than 20 major studies have been undertaken on these issues resulting in more than 120 different publications.

Recent work on capacity building for the digital transformation of education and learning, and for the changing requirements for skills and competences has focussed on the development of digital competence frameworks for citizens (DigComp), educators (DigCompEdu), educational organisations (DigCompOrg) and consumers (DigCompConsumers). A framework for opening-up Higher Education Institutions (OpenEdu) was also published in 2016, along with a competence framework for entrepreneurship (EntreComp). Some of these frameworks are accompanied by (self-) assessment instruments. Additional research has been undertaken on Learning Analytics, MOOCs (MOOCKnowledge, MOOCs4inclusion), Computational thinking (Computhink) and policies for the integration and innovative use of digital technologies in education (DigEduPol).

This report on "Digital technologies and learning outcomes of students from low socio-economic background: An Analysis of PISA 2015" was done on behalf of DG EAC. It suggest that the use of digital technologies is positively associated with students' achievement, but only for some purposes and if used with low-intensity. Students from low socio-economic backgrounds would particularly benefit to use digital technologies for general purposes.

More information on all our studies can be found on the JRC Science hub: https://ec.europa.eu/jrc/en/research-topic/learning-and-skills.

Yves Punie

Project Leader

DG JRC Unit Human Capital and Employment

European Commission

Executive summary

The use of digital technologies for learning is high on the policy agenda and is believed to benefit disadvantaged groups of students especially. This study assesses the extent to which the association between learning outcomes and the use of digital technologies differs systematically between students with different socio-economic statuses.

We start by summarizing the existing evidence on the causal effects of digital technologies on learning outcomes. We highlight the relative lack of evidence on the pedagogical use of digital technologies on disadvantaged students when compared to the general student population. The overall consensus emerging from the literature is that the causal effect of digital technologies is mixed. While it is unclear whether disadvantaged students are differently affected by them, the available evidence does not suggest that digital technologies contribute to further disparities in students' learning outcomes.

Using data from PISA 2015, we document that students from low socio-economic backgrounds start using digital devices later in life, have slightly less access to ICT at home and tend to use ICT less intensively especially in out-of-school activities than their counterparts. In the multivariate analysis, we find a positive association between disadvantaged students' achievement and the use of ICT for some purposes, but only among those students who use ICT less intensively. However, we find no evidence that this association is systematically different from that of students from higher socio-economic backgrounds. The exception is the use of ICT outside of school for general purposes by low-intensity users: in this case, disadvantaged students would particularly benefit from using ICT more intensively. Furthermore, we also find that - among low-intensity users of ICT - the probability of being a resilient student[1] is positively correlated with the use of ICT at school for educational purposes and at home for schoolwork and general purposes.

More generally, our research suggests that low-intensity users of ICT are likely to be using ICT sub-optimally, both at home and at school, and would benefit (in terms of PISA scores) from using ICT more intensively. However, the fact that medium and high-intensity users of ICT typically would not gain from additional ICT use is consistent with the hypothesis that the relationship between use of ICT and learning outcomes is inversely U-shaped.

[1] Defined by the OECD as a student who comes from a disadvantaged socio-economic background, but who also performs significantly better than would be expected based on her/his socio-economic background (OECD, 2009).

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, is expected to remain a central topic in education policy. Policymakers and stakeholders across the 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 education is further accentuated by the fact that education systems are required to provide citizens with the digital competences they need in the 21st century economy and society (European Commission, 2016), in order to reverse the current digital skills gap (European Commission, 2016a).

Most countries in Europe have high rates of computer access in schools (European Commission, 2013) and initiatives to provide 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 training systems across Europe and the evidence of their effects on student achievement is, at best, mixed (Falck et al., 2015). Though there is some evidence that digital technologies might improve student outcomes, some experts argue that the same impact could be achieved by implementing other well-managed, non-technology-supported interventions (Underwood et al., 2009). Still, even if that were indeed the case, it is undeniable that the digital skills that may arise from these interventions are crucial for dealing with 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 be of special benefit to 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 help to reduce 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 affects the learning outcomes of disadvantaged students, defined here as students from low socio-economic backgrounds. 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 affected by students' socio-economic status.

The structure of the report is as follows. The next section reviews the literature which looks into the relation between digital technologies and learning outcomes for the general student population and also, in more detail, for disadvantaged students. Section 3 describes the data used in the report and the sample, and the definition of disadvantaged students used in the empirical analysis. Section 4 presents descriptive statistics on the age when students start using digital devices, on their access to and use of ICT, highlighting differences between students from different socio-economic statuses. In Section 5, we look at whether ICT use is associated with students' achievement as measured in PISA. In Section 6, we offer our conclusions.

2. Literature review

2.1 Digital technologies and general student population

Policy makers, educators and researchers believe that digital technologies can improve learning outcomes (European Commission, 2013) because they enable access to additional learning resources and facilitate pedagogical strategies that could benefit 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 for other targeted teacher actions (European Commission, 2016; Bulman and Fairlie, 2016; and Falch and Mang, 2015). These expectations have led to increased investments in digital technologies in schools and to the provision of computers for use at home. There are, however, more critical standpoints that are less enthusiastic and more sceptical about the use of technology for learning. It has been argued that digital technologies can distract students, as they can be used for social networking, and games, thus displacing time from schoolwork. In addition, the effect of digital technologies at school depends, ultimately, on whether schools are choosing the optimal balance between technology and traditional inputs (Bulman and Fairlie, 2016).

The empirical literature examining the causal effects of digital technology is inconclusive or, at best, presents 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 surrounding the technology intervention rather than the technology per se. For instance, whether the intervention supplements or substitutes traditional learning in classrooms is crucial (Bulman and Fairlie, 2016). Tamim et al. (2011) suggest that other aspects of the interventions such as pedagogy, teacher effectiveness, subject domain and fidelity of implementation may have a greater impact, which is supported by Kampylis et al. (2013).

In order to assess these claims, researchers have looked into the role of moderating factors in meta-analyses. An example is Archer et al. (2014) who report that, in interventions where teacher training and support is mentioned, the size of the effect is much greater than in the others. More recently, Sung et al. (2016) carried out an impressive investigation of many interesting moderating factors worth reporting here. First, the size of the effect is greater for young children, followed by adults (university students, teachers and adults) and finally by secondary-schoolers. Second, with respect to hardware use, handhelds seem to deliver a greater effect than laptops. Third, using mobile devices in informal settings brings about greater effect sizes than using them in schools, which may be interpreted as a positive effect of supplemental rather than substitutive use. With respect to teaching methods, inquiry-oriented learning, mixed methods and computer-assisted testing had a greater effect; game-learning, lectures, self-directed learning had a moderate effect; and cooperative-learning had the smallest effect.

2.2 Digital technologies and disadvantaged students

Theoretical considerations

Whether introducing digital technologies may benefit some groups of students more than others has also been the subject of debate. The European Commission (2013) ascertained that some of the expected benefits brought about by digital technologies could be more relevant for disadvantaged groups, not only because they broaden access to education, but also because they could contribute to reducing educational costs.

An immediate issue is access: given that disadvantaged groups of students tend to have lower access to digital technologies (though inequalities in access to ICT in education have decreased; European Commission, 2013a), providing them with the opportunity to access and use them is the first step to reducing the digital divide. However, this is not enough because a second digital divide in how students from different socio-economic backgrounds use technology persists (OECD, 2016). Isomaki and Kuronen (2013) describe still more dimensions of digital inequalities - in equipment, autonomy of use, skills, social support, motivation, engagement and attitudes. This suggests that a more comprehensive approach must be taken 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.

If differences in access and use of digital technologies related to socio-economic status exist, it is possible that increased access and use of these technologies may benefit disadvantaged groups of students especially.

Barley et al. (2002) argue that the potential of technologies to change a teacher-centred model to a more student-centred instruction approach may be of special benefit to students at risk of dropping-out. Indeed, the use of computers offers the possibility of adjusting 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. It is non-judgmental, gives frequent feedback, can individualize learning, allows for more autonomy and provides multi-sensory learning environments which increase the chances of student engagement. 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 young people at risk depends on contextual factors, and whether the right tools in the right context are put forward.

As regards the migrant population, the European Commission (2016b) argues that if they can access and explore learning materials in their own language, this may increase their motivation to learn. 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).

However, some advocate that digital technologies may broaden the gap between engaged and disengaged youth and create further divides (Cranmer, 2010). Along these lines, Warschauer and Matuchniak (2010) suggest that technology does not in itself lead to positive effects but it is rather an "intellectual and social amplifier", reinforcing the gaps between more and less successful schools. Approaches such as distance learning may even be detrimental due to the lack of provision of social support, which disadvantaged learners need to maintain their engagement in learning. Inappropriate use of ICT can isolate disadvantaged learners from teachers, fellow students and community members who could otherwise support their learning and success. 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) argue that ICT alone will not make any difference, but it can be used to supplement, support, reinforce and extend ICT-based programmes. They advocate that effective environments for the disadvantaged are those that address 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 helping young people to be more resilient, or by protecting them by improving their skills sets, and by promoting entrepreneurship, creativity and participation in civic life.

Falck et al. (2015) therefore conclude that they expect the effects of using computers to be different depending on students' characteristics. However, they also, point out that from a theoretical point of view, it is not clear whether these effects are beneficial or harmful. They argue that this issue must be addressed by empirical analyses.

Empirical Studies

The empirical literature pays little attention to the analysis of the effects of digital technologies on disadvantaged learners (ICF, 2015). This is probably due to the general null effect found in many studies which look at the student population as a whole (Bulman and Fairlie, 2016). Most of the findings come from developing countries[2] and from the U.S., which may be of limited interest in the European context.

We start by summarising the evidence available from reviews and meta-analyses, and we then present the conclusions from specific papers written on European countries. As only a few papers that target disadvantaged students were found in Europe, we also looked at evidence on heterogeneous effects in studies that focus on the general student population.

Reviews and meta-analyses

The meta-analyses/literature reviews show that studies that focus on disadvantaged groups are mainly U.S.-based. Even though the results cannot 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 while

[2] For instance, Naik et al. (2016) look at a randomized experiment in India where satellite-terrestrial technology is used to telecast additional interactive classes. Results show that the intervention has a positive impact on student performance and that the impact is highest among the socially disadvantaged students.

effects are found across all the grades, these are greater 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 in a meta-analysis of 20 studies that 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 is smaller in randomized experiments (0.04), which casts doubt on the overall impact. Among four types of applications, small-group tutorial applications integrated in the curriculum produced the largest effects (0.32). Surprisingly, the supplemental programmes 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 – i.e. minority, low-achievers, under-credited or not on 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 authors' insights are worth reporting. They find indicative evidence that underserved students benefit from opportunities to learn that include one-to-one access to devices. They also benefit from digital technologies which are designed to promote high levels of interactivity, emphasize discovery and represent thinking in multiple forms. Furthermore, successful digital learning results from the right blend of teachers and technologies and in settings with real-time digital feedback.

European papers focusing on disadvantaged students/schools

We identified three European papers that focus on disadvantaged groups of students and that carry out high-quality evaluation designs. Two of them suggest that the effects of digital technologies are negligible, while the third is more optimistic about the effect of digital storybooks on disadvantaged migrant young children.

In a randomized experiment with 92 five-year-olds, 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. Among the digital technologies used (static or video digital technologies), the video format achieved more improvement in the children's vocabulary. 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 describe the implementation of a policy in the Netherlands that provided additional funding for computers and software to schools where more than 70% of the students were disadvantaged. The authors find that the computer subsidy was not used to invest in extra computers or replace the old ones, and infer that it was used to buy new software or invest in internet connections. The authors explore the threshold of the share of disadvantaged students set by the policy to identify the effect of the subsidy on students' achievement. They conclude that, while students do spend more time on computers at school, their test scores are either negatively or 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 government voucher programme in Romania that subsidized the purchase of home computers for low-income students enrolled in public schools. The families that applied to these vouchers were ranked by income per capita and the poorest ones were given the voucher. Data for the evaluation was collected from a survey of the participating families, to which more than 50% responded- a total of around 3,500 families. For evaluation purposes, they compared families just below and above the attribution threshold and found interesting results. First, students who received the vouchers used computers about 3-4 hours a week more than their counterparts who did not receive the vouchers. However, these extra hours were not spent on doing homework or 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 at the general student population and, in addition, investigate the existence of heterogeneous effects according to the students' characteristics, i.e. examine whether the effect of the use of digital technologies differs across groups of students, when compared to the general student population. As with the previous literature we have summarized, the results are mixed.

Some studies report that, of the student population as a whole, disadvantaged students were actually the only ones to benefit from digital technologies. Checchi et al. (2015) look at a government intervention in Italy in which 156 6th grade classes were given additional resources to purchase ICT equipment – about 1,500€ per student. The evaluation results show very modest increases in literacy (not numeracy). These increases were confined to children from low-educated parents and to the lower part of the scores distribution. Further qualitative analysis carried out by an external classroom observer reports 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 members of the class. The teachers' perceptions were also very positive, especially for disabled and foreign students and in schools located in deprived areas. There was a general agreement by teachers that the available ICT was an extremely powerful tool to enhance the effectiveness of traditional teaching methods, as it allows them to create a stable pool of resources easily and readily available to all students. Again, the weakest members of the class are 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 comprehensive public intervention allocated funds to buy ICT equipment, interactive white boards, visualizers and other devices, provided teacher training and developed e-textbooks. More than 3,500 schools applied to the pilot phase, of which 399 were randomly selected. Interestingly, the authors 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 on 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 was no longer visible in 2014, which led 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 has a positive and significant impact on the achievement of students with low socio-economic status (SES), but not for students with high-SES or for the general student population. This is an example of how a null effect at the pooled level can mask significant effects in different groups of students.

Other studies 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 found that using the computer to look for ideas and information improves students' achievement, while using them to practice skills does the opposite. 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 that examines the causal effect of digital technologies on students' learning outcomes presents mixed findings. Also, it is unclear whether digital technologies affect disadvantaged students differently. However, the (scarce) evidence does not seem to indicate that digital technologies have a negative effect on disadvantaged students.

It should be highlighted that the evidence for the effects of digital technologies on the general student population is considerable and has been summarized in several and extensive meta-analyses. In contrast, the evidence for disadvantaged students is relatively scarce and, for European countries, is presented in a few isolated papers. More research in this area is therefore needed, in order to have a critical mass of evidence on which to base 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 only partially explored to analyse the impact of digital technologies on disadvantaged students. The OECD (2011) briefly mentions the issue and concludes that the relationship between the intensity 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. 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 advantaged and disadvantaged students. This conclusion is reached after comparing results from PISA 2009 and 2012. During this time, access to computers became universal, but it did not contribute to the reduction of the skills gap between students from different socio-economic backgrounds.

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. We base these on PISA data which contain the most uniform measures of computer access and use across all countries, including all the Member States.

3. Data and sample

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

In this report, we explore the PISA 2015 data gathered by 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 dedicated to it. For this reason, when examining the association between students' ICT use and achievement we focus more on science, though we do also present 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 Scotland[3] did not, and therefore they are not included in the report. Hence, 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 corresponding descriptive statistics.

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

3.1 Definition of disadvantaged students

We divide students into three groups according to their socio-economic status. Researchers agree on a triple nature of SES which incorporates parental income, parental education, and parental occupation (Sirin, 2005). The OECD provides an index in the PISA dataset that has been widely used to capture students' socio-economic background. It summarizes information on home possessions, parental education and occupational status - Index of economic, social and cultural status (ESCS). We define three groups of students based on the within-country distribution of this index as follows[4]:

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

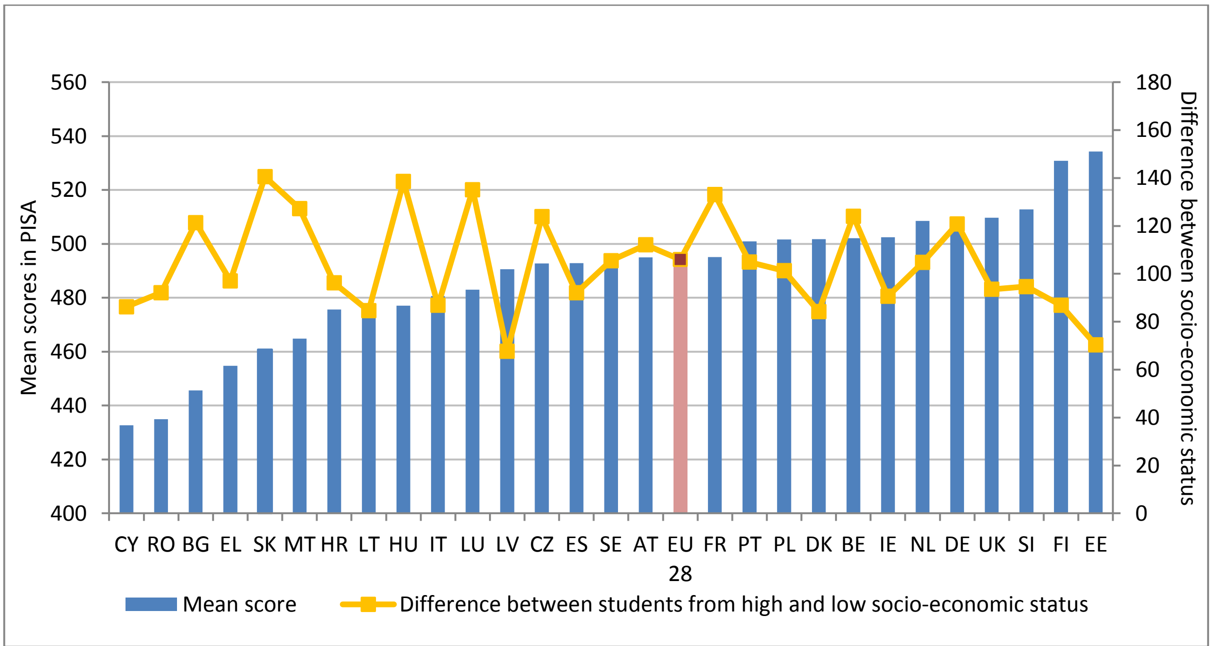
[3] Accordingly, the results presented in the report for UK refer only to England, Wales and Northern Ireland.
[4] The students' weights are taken into account when performing this exercise.

- Advantaged students: those with ESCS values above one standard deviation from the country's ESCS mean.

Of the total sample, 17% are disadvantaged students, 19% are advantaged students and 64% are students from medium socio-economic backgrounds.

Figure 1 shows the average score in science by country and the difference between students from high and low socio-economic statuses. At European level, the performance gap between students with high and low socio-economic status is larger than 100 points: on average, advantaged students score 551 points in science and disadvantaged students only 445. The difference between socio-economic status groups varies across Member States, but it is always above 60 points. The countries where the gap is smaller are Latvia and Estonia. In contrast, the Slovak Republic, Hungary, Luxembourg and France have performance gaps larger than 130 points.

Figure 1 - Performance in science for all students and difference between students from high and low socio-economic statuses



Source: Own computations using PISA 2015 data.
Notes: Countries ranked by ascending order of mean score. See Table A.1 in the annex for the correspondent complete set of descriptive statistics, including for reading and mathematics.

These figures highlight the need to find effective ways to reduce the gap in science performance between students from high and low socio-economic backgrounds. In this report, we look at the role ICTs could play in pursuing this goal.

4. Students and digital technologies: descriptive statistics

This section presents descriptive statistics on the several questions related to digital technologies. We consider the age at which students started to use digital technologies, their access to digital devices at the moment of the survey (age 15) both at home and at school, the different activities for which they use digital devices and their perceptions of their own ICT competence. For each of these, we start by providing a definition, followed by descriptive statistics for the general student population and the difference between students from high and low socio-economic statuses, both at European and country levels.

4.1 Age when students started to use digital technologies

One of the items in the ICT familiarity questionnaire asks students how old they were when they 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".

Table 1 shows the share of students reporting each of the following answers: 9 years old or younger, between 10 years old or older; never used until the time of the survey. Of the total sample, less than 1% reported "never have used so far". On average, 77% of students used digital devices for the first time at age 9 or younger and 23% when they were 10 years old or older. Examining the differences according to socio-economic backgrounds reveals that disadvantaged students started using them later in life than their counterparts. In fact, only 69% of disadvantaged students used them before the age of 10, compared to 77% of medium socio-economic students and 83% of students from more advantaged backgrounds. In contrast, 30% of disadvantaged students reported that they used digital devices for the first time at the age of 10 or older, while only 17% of the advantaged did so.

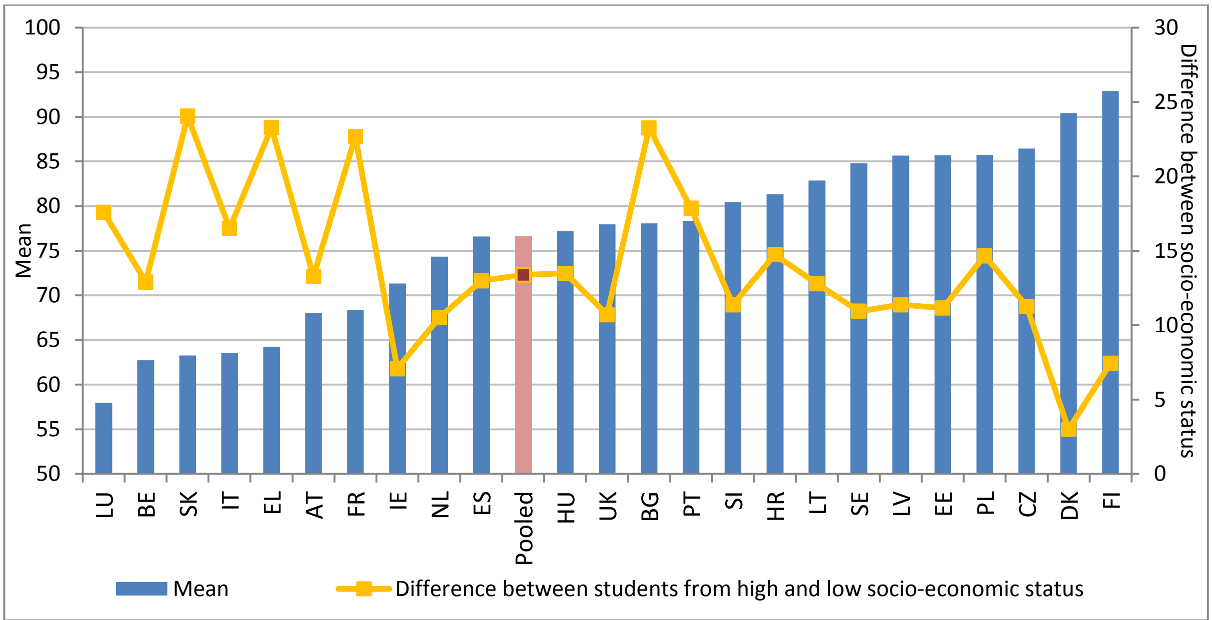
Table 1 - Age when students reported they had used digital devices for the first time (pooled data)

	9 years old or younger (%)	10 years old or older (%)	Never used so far (%)
All students	76.6	22.8	0.6
By socio-economic status			
Disadvantaged	69.3	29.8	0.9
Medium	76.9***	22.7***	0.5***
Advantaged	82.7***	16.9***	0.5***

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<0.01.

In terms of cross-country heterogeneity, we observe in Figure 2 that less than 70% of students started using digital devices before the age of 10 in Luxembourg, Belgium, the Slovak Republic, Italy, Greece, Austria and France, while in Denmark and Finland more than 90% of students did so. Denmark and Finland are also the countries, along with Ireland, where the gap between advantaged and disadvantaged students is the smallest. At the opposite end of the spectrum, the largest differences between socio-economic groups are revealed in countries such as the Slovak Republic, Greece, France and Bulgaria. In particular, the Slovak Republic and Greece have a relatively lower average together with a very large socio-economic-driven gap, which positions disadvantaged students in a particularly deprived situation. Indeed, only 50-55% of disadvantaged students report that they used digital devices before the age of 10 in these two countries. This is also the case in Luxembourg.

Figure 2 - Share of students who report using digital devices for the first time at age 9 or younger and difference between students from high and low socio-economic statuses



Source: Own computations using PISA 2015 data.
Notes: Pooled includes all the 24 countries shown, it does not include Germany. Countries ranked by ascending order of share of disadvantaged students using digital devices before age 10. See Table A.2 in the annex for the correspondent complete set of descriptive statistics.

4.2 Access to digital technologies at home and at school

In the ICT Familiarity questionnaire, students are asked whether they have access to a range 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 corresponding 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 access to and use of digital resources[5].

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

- Access to devices at home: access to internet connection and one computer, or cell phone, or tablet or ebook-reader.
- Access to devices at school: access to computer, laptop, tablet and internet connection[6].
- Access to devices in the classroom: access to data projector or interactive whiteboards.

Table 2 shows that, at the age at which students were surveyed – on average 15 years old – almost all of them report they had access to digital devices at home (98%) and at school (99%). The access at school seems indeed to be uniform since 100% of students from all socio-economic statuses report that this is 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)

	Access ICT at school (%)	Access ICT at home (%)	School has data projector or interactive whiteboard (%)
All students	99.9	98.2	99.6
By socio-economic status:			
Disadvantaged	99.9	94.4	99.2
Medium	99.9	98.8***	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<0.01.

Access to ICT at school is also widespread across countries – all countries have shares of at least 99% (see Table A.3 in the annex). Therefore, the only difference across countries worth exploring is access to ICT at home, which is shown in Figure 3.

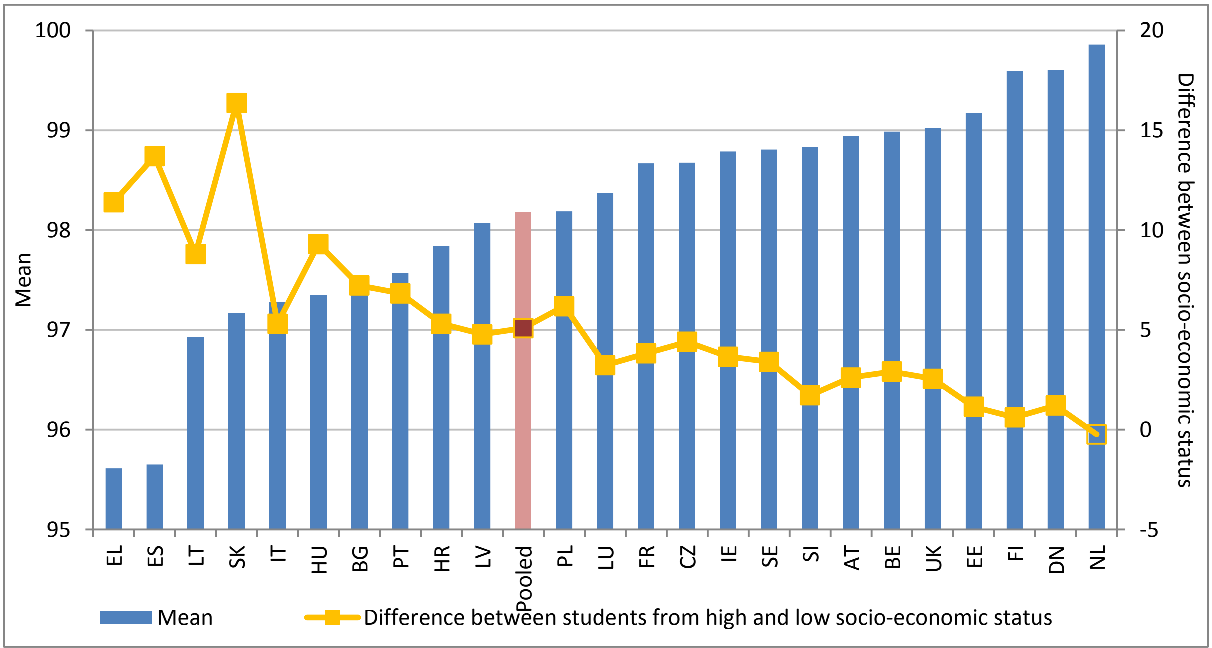
Data reveal that more than 95% of students have access to ICT at home in all countries. Still, Greece and Spain are the countries which have the lowest figures, whereas in

5 For instance, one of the questions used in the OECD indices but that we disregard asks students whether they have access to USB memory sticks at school or a portable music player at home.

6 We find substantial variation in the answers of students from the same school and therefore take the mode answer within each school.

Belgium, the UK, Estonia, Finland, Denmark and the Netherlands access is basically universal. In terms of socio-economic differences, the gap is necessarily smaller among the countries with averages close to 100. However, among the countries where fewer students have access to digital devices at home, the gap between advantaged and disadvantaged students is non-negligible: around 10 p.p. in Hungary, Lithuania, Spain, Greece, and more than 15 p.p. in the Slovak Republic. Slovakian students with low socio-economic status report the lowest access to ICT at home (82.7%) across the whole of Europe, showing that the first digital divide is still relevant there.

Figure 3 – Share of students who report they have access to digital devices at home, and the difference between students from high and low socio-economic statuses



Source: Own computations using PISA 2015 data.
Notes: Pooled includes all the 24 countries shown, it does not include Germany. Countries ranked by ascending order of share of disadvantaged students having access to digital devices at home. Unfilled markers mean that the difference between socio-economic groups is not statistically different from zero. See Table A.3 in the annex for the correspondent complete set of descriptive statistics.

4.3 Use of digital technologies at school and outside of school

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.[7]. Many of the activities refer to similar types of ICT uses and therefore we group them

[7] It should be highlighted that the items referring to the use of ICT at school are very general. In particular, it is unclear whether students are using ICT in the classroom during lessons or outside of the classroom for individual purposes. The question asked to students is: "How often do you use digital devices for the following activities at school?" Most of the items refer to outside of classroom activities (download, doing homework, posting work). Others activities may be taking place in the classroom, but the items do not refer that explicitly (practicing and drilling, playing simulations, browsing the internet for schoolwork). Because the different items do not refer to whether the activities take place in a classroom context or not, one should abstain from interpreting the results to be presented below as the effects of ICT at school in general.

together. 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 schools 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 ICT 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 ICT outside of school for general 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 on 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 programmes)
    - Downloading music, films, games or software from the internet

- **S_Education:** Use of ICT at school for educational purposes:
    - Browsing the internet for schoolwork
    - Downloading, uploading or browsing material from the school's website
    - Posting own work on the school's website
    - Playing simulations at school
    - Practicing and drilling, e.g. for foreign language learning or mathematics
    - Doing homework on a school computer
    - Using school computers for group work and communication with other students

- **S_General:** Use of ICT at school for general purposes:
    - Chatting online at school
    - Using email at school

To the question on how often they used digital devices for each of the activities, students answered according to the following scale: 1- never or hardly ever; 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 in at least one of the activities that are part of the groups, with an intensity of at least once per week.

Descriptive statistics for the sample as a whole are presented in Table 3. Most 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 school – 98%, and to a lesser extent at school – 51%. Concerning educational purposes, 78% of students report using ICT to do schoolwork outside of school, and 74% to communicate with colleagues and teachers about schoolwork. Surprisingly, only 59% of the students report that they use ICT for educational purposes at school at least once per week.

Table 3 – Share of students who report they use ICT at least once per week (pooled data)

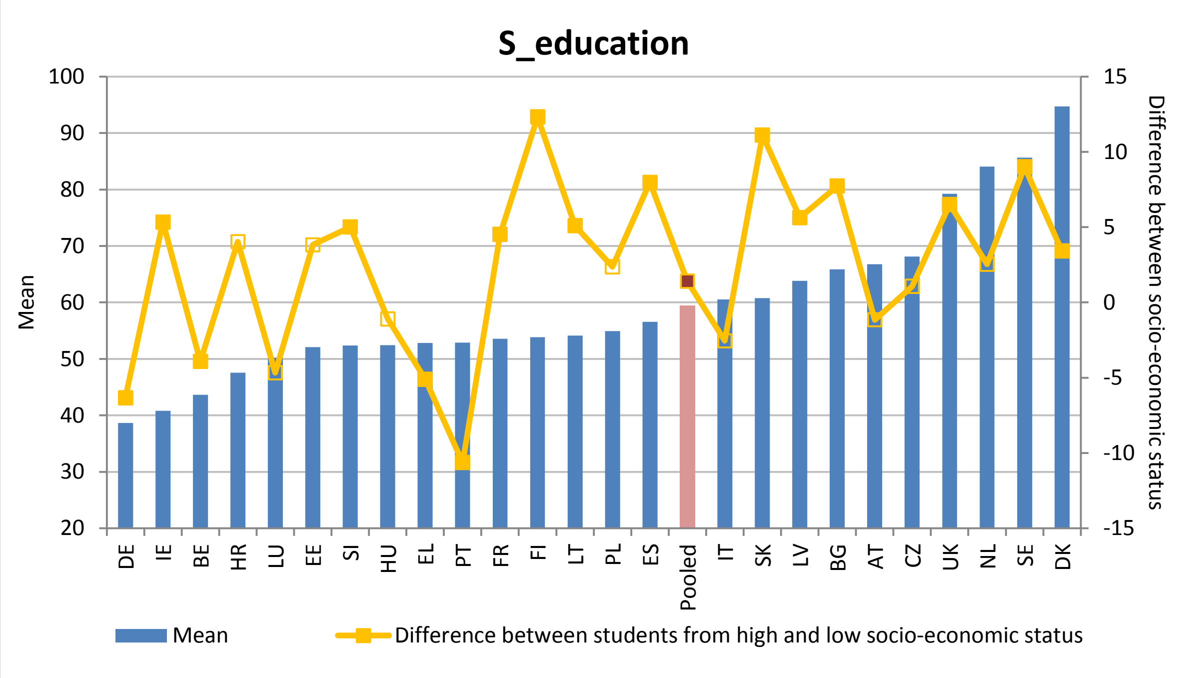
	H_schoolwork	H_commun.	H_general	S_education	S_general
All students	78.0	74.2	97.6	59.4	51.4
By socio-economic status:					
Disadvantage	71.8	69.0	95.9	57.5	49.2
Medium	78.4***	74.5***	97.7***	60.1***	51.9***
Advantaged	81.6***	78.0***	98.6***	58.9**	51.6***

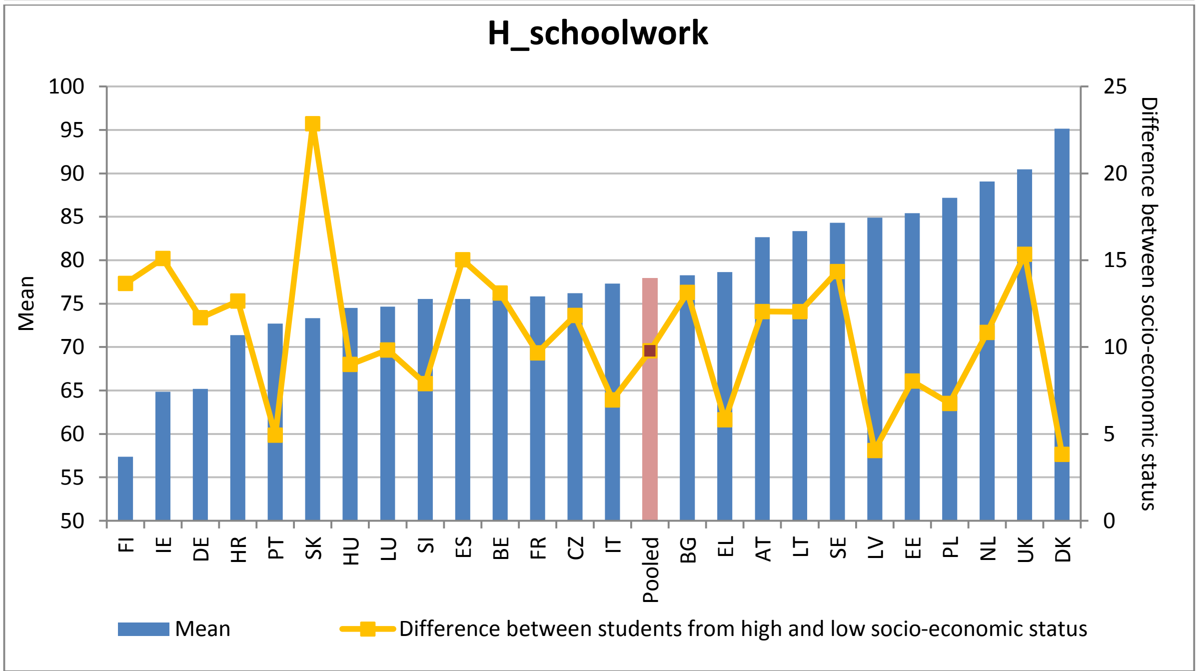
Source: Own computations using PISA 2015 data.
Note: Weighted averages at pooled level (25 countries, including Germany). All students answering questions IC008, IC010 and IC011 are included. Asterisks indicate whether the share is statistically different from the share of disadvantaged group of students. *** $p<0.01$; ** $p<0.05$; * $p<0.1$.

When disaggregating by socio-economic status, we find that fewer students from disadvantaged backgrounds report that they use ICT for all of the purposes than their counterparts. However, it should be highlighted that, even though they are statistically significant, some of the differences are small, in particular in the activities performed at school and for general purposes outside of school. This similar use of ICT in schools across socio-economic groups suggests that schools play a role in closing the existing gaps at home, both in terms of access to ICT and their use. However, this is not happening in the same way in all countries.

In fact, as evidenced in Figure 4, in Finland and in the Slovak Republic, students from high economic backgrounds are more likely to report using ICT at school for educational purposes, than disadvantaged students. In contrast, in other countries, disadvantaged students report that they use more ICT at school for that purpose - Germany, Belgium, Greece and Portugal. This may indicate that schools support the use of ICT by disadvantaged students in the classroom or that these students choose to use ICT at school rather than at home to do schoolwork.

Figure 4 – Share of students who report that they use ICT at least once per week in each location and for each purpose and the difference between students from high and low socio-economic statuses





Source: Own computations using PISA 2015 data.
Notes: Pooled includes all the 25 countries shown, it does include Germany. Countries ranked by ascending order of share of students reporting using ICT at least once per week for the correspondent use. Unfilled markers mean that the difference between socio-economic groups is not statistically different from zero. See Table A.4 in the annex for the correspondent complete set of descriptive statistics, including all types of ICT use.

As for the use of ICT at home for schoolwork, we also observe large cross-country differences. It should be highlighted though that these differences may also reflect different practices across countries in terms of the homework that students are asked to do. In Finland, Ireland and Germany a smaller share of students report using ICT at home for schoolwork at least once per week, whereas in the UK and Denmark, more than 90% report doing so. The difference between socio-economic groups is particular high in the Slovak Republic, where 79% of students from high socio-economic backgrounds use ICT outside of school for school work at least once per week, while only 56% of students from low socio-economic backgrounds do so. In contrast, this type of ICT use is relatively widespread in Denmark across all socio-economic groups.

4.4 Students' self-reported ICT competence level

In the ICT Familiarity questionnaire, students were asked a few questions about their level of competence in using ICT[8]. The OECD provides an index - the variable COMPICT- that combines all of these items and attempts to measure the students' perceived ICT competence.

Students from different socio-economic backgrounds appear to have different levels of perceived competences: values increase with socio-economic status. The differences between the groups of students are statistically significant. The difference between disadvantaged and advantaged students is high, and corresponds to more than 20% of the overall competence standard deviation.

Table 4 – Students' perceived ICT competence level (pooled level)

	Students' Perceived ICT competence (average)
All students	0.000 (by construction)
By socio-economic status:	
Disadvantaged	-0.115
Medium	0.006***
Advantaged	0.112***

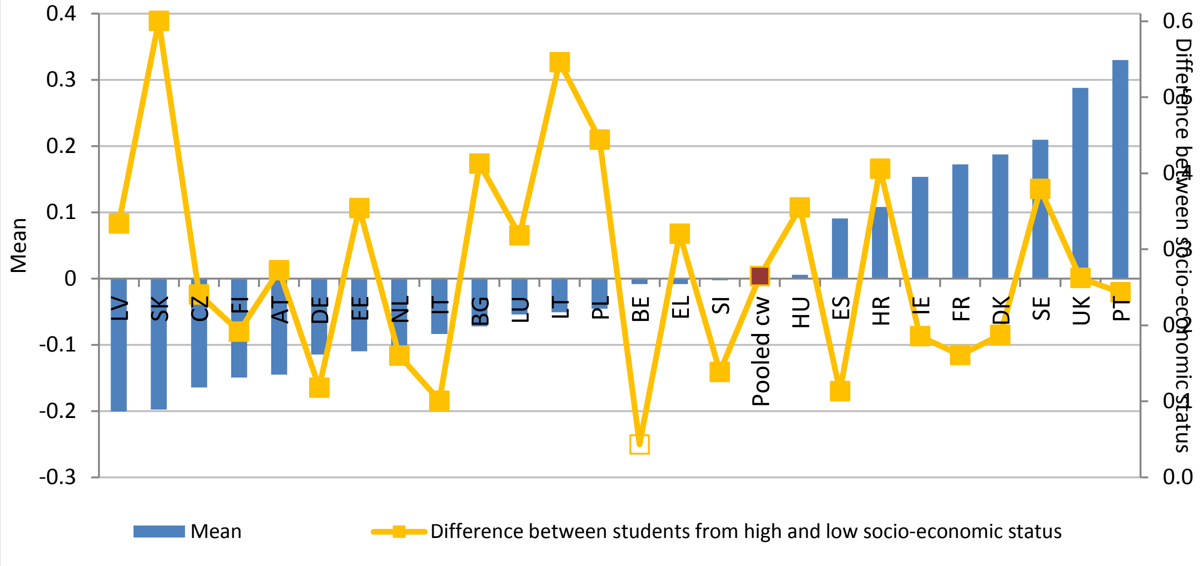
Source: Own computations using PISA 2015 data.
Note: Weighted averages at pooled level (25 countries, including Germany). Asterisks indicate whether the share is statistically different from the share of disadvantaged group of students. The students' perceived ICT competence has been computed such that, at pooled level, it has zero mean and standard deviation of one. *** p<0.01.

Figure 5 shows that the gap in ICT competence between students from high and low socio-economic statuses exists in all countries (except Belgium, where it is not statistically different from zero). It is particularly high in the Slovak Republic, Lithuania,

[8] Examples of such questions are: "I feel comfortable using digital devices that I am less familiar with" or "When I come across problems with digital devices, I think I can solve them". Students answer on a scale from "Strongly Disagree" to "Strongly Agree" (4 levels).

Poland and Bulgaria, where the difference amounts to more than 2 standard deviations from the overall mean.

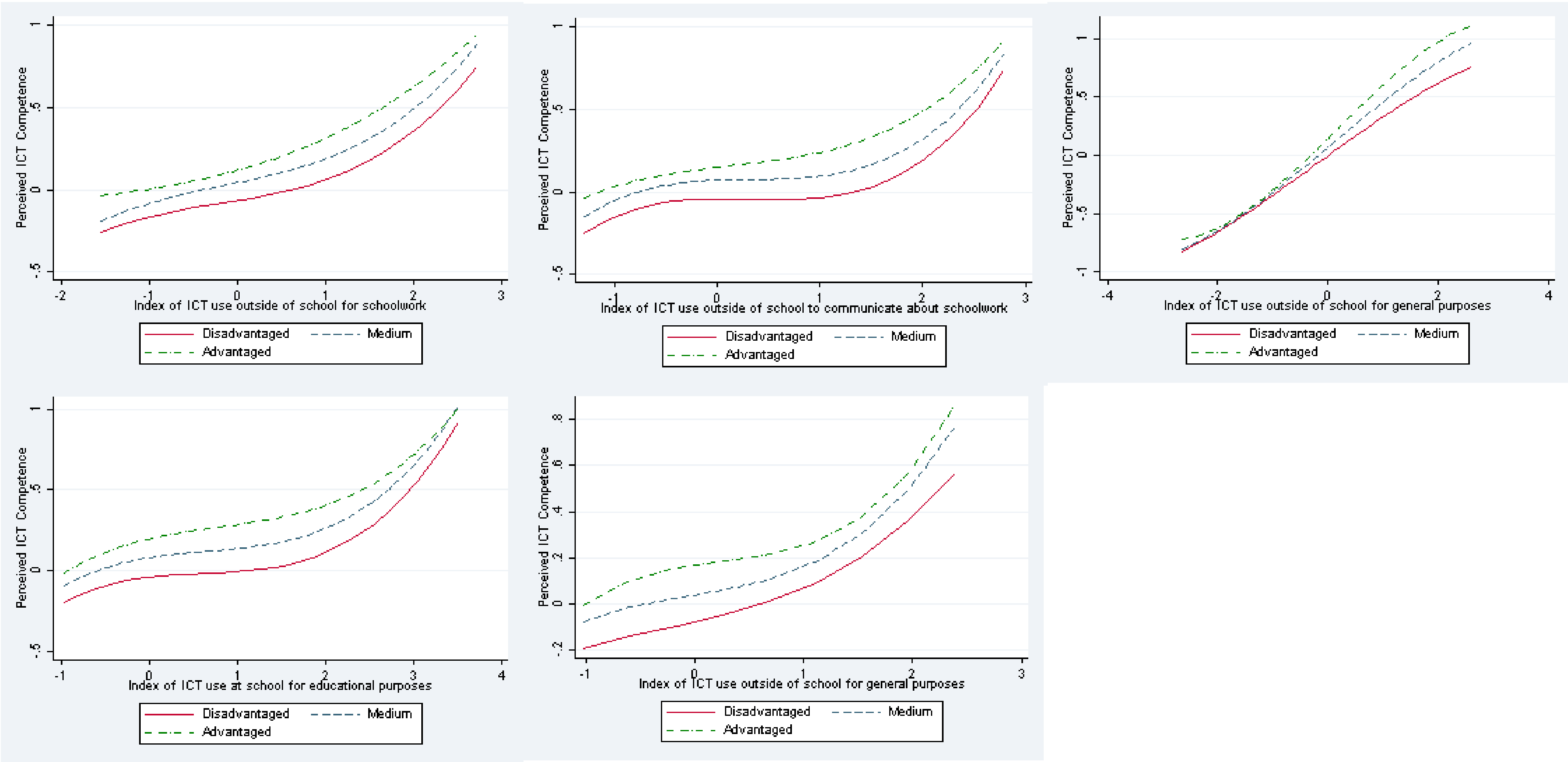
Figure 5 – Average level of students' perceived ICT competence and difference between students from high and low socio-economic statuses



Source: Own computations using PISA 2015 data.
Notes: Pooled includes all the 25 countries shown. Countries ranked by ascending order of mean perceived ICT competence. Unfilled markers mean that the difference between socio-economic groups is not statistically different from zero. See Table A.5 in the annex for the correspondent complete set of descriptive statistics, including all types of ICT use.

Figure 6 plots the relation between students' perceived ICT competences and each of the indices which capture intensity of ICT use (i.e., plotting bivariate relationships). The figure shows that higher intensities of ICT use are associated with higher levels of perceived ICT competence. It also shows that, for students from disadvantaged backgrounds, this relationship tends to lie below the ones for the other two groups. This indicates that, for an equal value of the "use of ICT" index (for each of the five types of uses), students from disadvantaged backgrounds have lower values of perceived ICT competences. This is likely to reflect the effect of other covariates and should not be interpreted in a causal way. However, it is interesting that the same level of ICT use is associated with different perceived abilities.

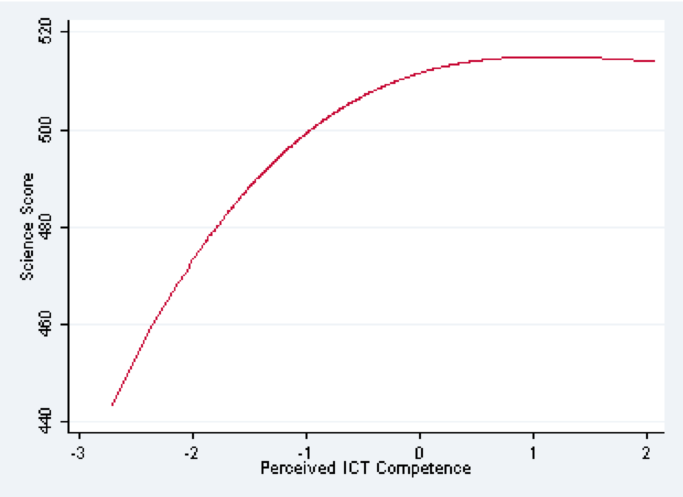
Figure 6 – Relation between students' perceived ICT competence level and each of the indices of ICT uses



Source: Own computations using PISA 2015 data.
Notes: Each graph plots the relation between perceived ICT competence and each of the five indices of intensity of ICT use, including 3rd order polynomials (cubic fit). Pooled data from 25 countries used.

Figure 7 plots the relation between students' achievement in science and the level of perceived ICT competence[9] revealing that this relationship is positive, but with a diminishing slope. The figure shows that higher levels of ICT competence are associated with better PISA scores, until the higher levels of perceived competences are reached, when the curve flattens out. The strong association between perceived ICT competences and PISA scores suggests that increasing the students' ICT competence might also improve performance in the domains of science, mathematics and reading. However, we cannot interpret it in a causal way and we cannot rule out issues of reverse causality or omitted variable bias. Moreover, we must remember that these are simple correlations between the variables, which fail to control for other factors. Potentially these could completely explain why they co-move (e.g. motivation, innate ability, etc.)[10].

Figure 7- Relation between students' perceived ICT competence level and PISA science scores



Source: Own computations using PISA 2015 data.
Notes: The graph plots the relation between science achievement and perceived ICT competence, including 3rd order polynomials (cubic fit). Pooled data from 25 countries used.

The messages from Figures 6 and 7 seem to indicate that students from disadvantaged backgrounds might benefit from improved use of ICT, since an improvement of this kind is associated with higher perceived ICT skills which, in turn, are positively associated with their PISA score. However, it is unclear whether they would benefit more than other socio-economic groups. The answer to the latter question can be addressed with multivariate regression analysis, where we control for other relevant covariates (hence satisfying the *ceteris paribus* condition).

9 For reading and mathematics the relation is very similar and, therefore, not shown here.

10 However, we also estimate the relation between perceived ICT competence and performance in PISA, while controlling for other potential confounding variables such as age, gender, grade repetition, migrant status and socio-economic status. The relation shown in the graph is still found in those more elaborate analyses. However, remaining unobserved differences between students still threaten the causal interpretation of the relationship.

5. Use of digital technologies and students' achievement

5.1 Sample

In Section 5, we study whether the intensity of ICT use is related to students' learning outcomes by carrying out an econometric analysis where these two factors are related to each other, while controlling for other relevant characteristics at the individual and school levels.

For this purpose, we exclude from the analysis the observations that have missing information in any of the variables used in the analysis[11]. This means that results presented in this section are produced with a total of 109,967 students from 5,847 schools in 25 European Member States. Table 5 shows some figures of the working sample by country.

Table 5 – Descriptive statistics for reduced sample, by country

Country	Students		Schools		Socio-economic status	
	Number	% of sample	Number	% of sample	% Disadv.	% Advant.
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.

[11] This implied 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.

It is clear that some countries are over-represented in the working sample. To avoid having the results driven by the countries that have a higher number of observations, we weight countries equally by using senate weights. This means that the results should be interpreted as representative of the average of the countries (as opposed to the whole population).

For this part of the report, indices for the intensity of ICT use for the different purposes are computed. We do so by summing up the students' answers to each of the activities which form the type and location of ICT use (see Section 4.3). Furthermore, in order to be able to directly compare changes in the distribution of usage intensity in the different types of uses, these indices are normalized to have mean zero and standard deviation one[12].

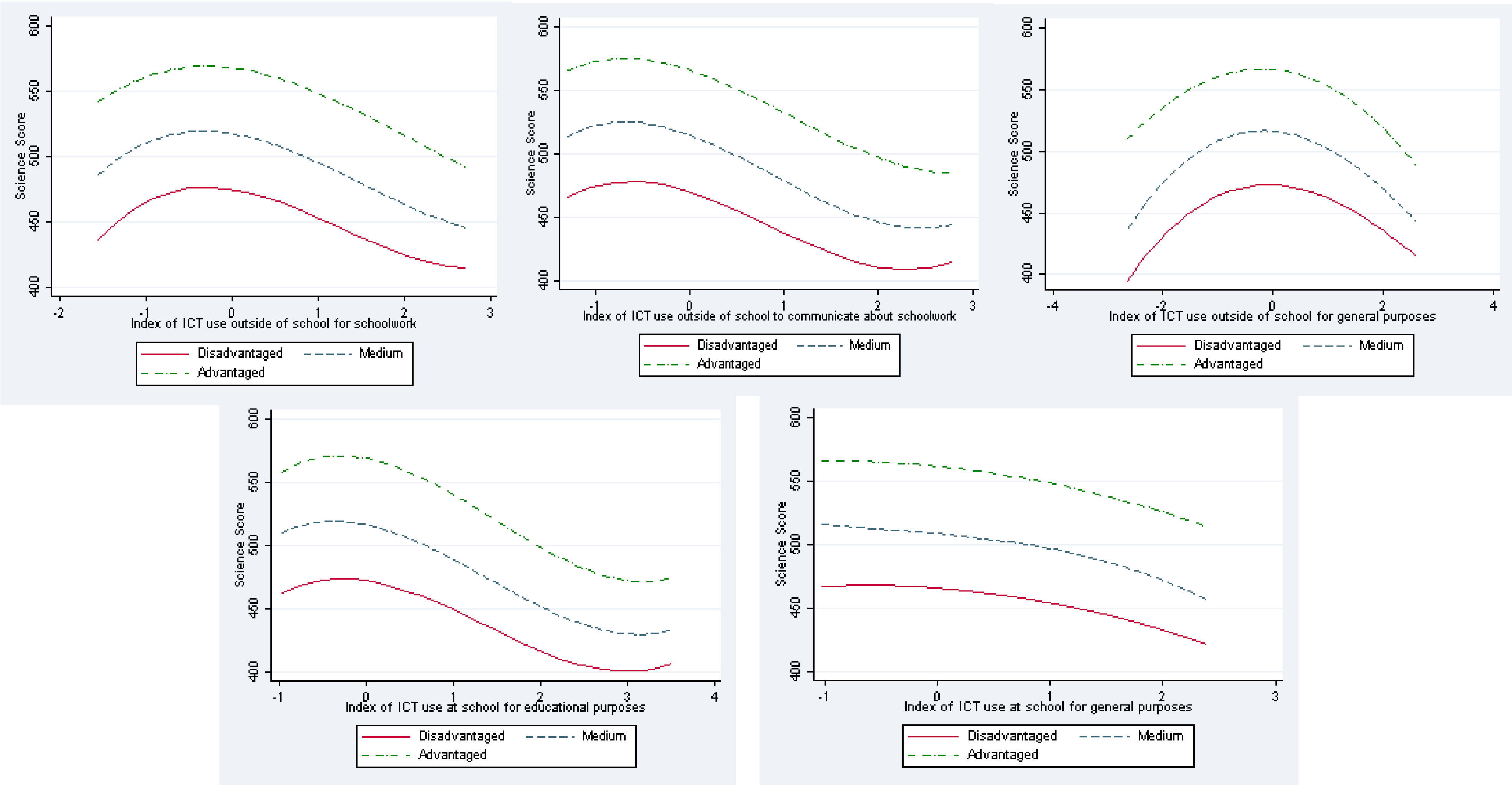
5.2 Descriptive relation

Figure 8 plots the relation between students' achievement in science and each of the indices which capture intensity of ICT use, i.e. for each group separately (i.e., plotting univariate relationships). Common to all graphs in the figure is the fact that, regardless of the level of ICT use, the average science scores of more advantaged students are always higher than those of students from medium socio-economic statuses, which, in turn, are higher than those of students with lower socio-economic status.

When we look at the shape of the curves for each of the ICT uses, we find two types of patterns. A clear negative relation is found between students' scores and use of ICT for general purposes at school (S_general), suggesting that higher intensity of this type of ICT use is always negatively associated with students' science performance. The other types of use present a (more or less perfect) inverted U-shaped relation with science scores, pointing to a positive relation that is confined to the lower levels of use intensity. However, a striking difference should be highlighted: the highest value of the (estimated) function for the use of ICT at home for general purposes (H_general) is reached for values of the latter variable that are close to the mean; for the other types of uses – H_schoolwork, H_communication and S_education – the highest value of the (estimated) function relating ICT use and PISA scores corresponds to very low levels of intensity, which suggests that it may be better to keep the intensity of ICT use at relatively lower levels.

[12] The students' weights are used to perform these standardizations.

Figure 8 - Relation between students' achievement in science and each of the indices of ICT use



Source: Own computations using PISA 2015 data.
Note: Each graph plots the relation between science score and each of the five indices of intensity of ICT use, including 3rd order polynomials (cubic fit). Pooled data for 25 countries used.

5.3 Econometric specification

The descriptive evidence just shown is a simple correlation between the variables and completely ignores other factors that may also drive these relations. If there are other factors simultaneously related to students' achievement and intensity of ICT use, we incur the risk of attributing to ICT use the effects that are 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 regressing the students' achievement in the PISA science test – the dependent variable – on the different intensities of ICT uses, while controlling for several variables that could 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 intensity in the different ICT uses, individual demographic characteristics (X_{is}) and school fixed effects (δ_s)[13]. β is therefore the main vector of interest. Some features of this specification are worth discussing in detail.

The first relates to the fact that we include all five indices which capture intensity of ICT use. We consider that controlling for all the indices of intensity of ICT use is important because all of them are positively related to each other[14]. This means that, on average, students who use digital devices more intensively for one purpose also tend to use them more intensively for other purposes. If only one of the indices is included in the econometric specification, it would be capturing not only its own effect but also the effect of the other indices. By controlling for all of them, the coefficients 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, hence the relation between each type of ICT use and students' scores can be captured.

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 also hypothesize that 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 partly capture the role of school characteristics. In order to avoid this problem, and because we do not know exactly which school characteristics are relevant, we introduce school fixed effects, running within-school estimates, and holding constant any factor that is common to all students attending the same school (δ_s). We acknowledge that by doing so, we

13 Notice that by including school fixed effects we are automatically including country fixed effects as well.

14 We tested for multicollinearity and it is not an issue in any of our specifications. 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

may be overlooking school factors[15] that influence how ICT use relates to achievement. In a second stage, we divide schools into different groups to check if the associations are driven by potentially relevant school-specific characteristics (e.g. private vs public).

Third, it is important to highlight that this econometric analysis still has non-negligible shortcomings despite our efforts described above. In fact, it may still suffer from omitted variable bias if other non-observable factors are associated with both ICT use and students' achievement. Standard examples are student motivation and/or innate ability. In addition, the specification could suffer from reverse causality, which would occur if ICT use were actually affected by students' achievement and not the other way around, as hypothesized by the model. For 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 coefficients rather than their magnitude, even though the former may suffer from the same problems.

Fourth, given that the main independent variables of interest – indices of ICT use intensity - are standardized, i.e. have mean zero and standard deviation of one, the associated coefficients should be read as the change in students' achievement (PISA points) associated with a one standard deviation increase in the intensity of ICT use index. Since all the indices of ICT use intensity are measured on the same scale, the coefficients can be compared.

Finally, PISA's complex survey design was taken into account in all estimations - all 10 plausible values of science scores were considered and standard errors are clustered at school level, which effectively takes into account the fact that students are nested within schools (Jerrim et al., 2017).

5.4 Results

5.4.1 Results for the general student population

Table 6 presents the first results from the econometric analysis. First, we introduce each of the ICT uses one by one (columns 1-5), and then (in column 6) we include all of them. The results prove the importance of controlling for all the ICT use measures. While all the coefficients in the first five columns are negative, in column 6 the coefficients for the use of ICT outside of school for schoolwork and for general purposes are positive. This difference is due to the fact that the uses of ICT are positively correlated among themselves and, hence, individual variables, if introduced in isolation, capture the effects of the excluded ones. For instance, in column 1, the coefficient on H_schoolwork is negative but, in column 6 -when holding constant other types of ICT uses- its estimate is positive. This happens because H_schoolwork is highly correlated with H_communication

[15] Potentially relevant school factors are the number of computers available for students, broad financial resources, attitudes towards technology and digital technologies in particular, teacher training, school autonomy, school size, school location etc. (e.g. see Perrotta, 2013). In Sections 5.4.1 and 5.4.2, the role of these school factors is disregarded because we introduce school fixed effects. However, in Section 5.4.3 we provide results distinguishing between private and public status of schools and between schools with low and high numbers of computers available for students.

which is strongly and negatively associated with science scores. If the latter is not properly controlled for, the former will capture this highly negative association.

Table 6 – Results from the econometric specification: Basic results

Dep. Variable: PISA science score	(1)	(2)	(3)	(4)	(5)	(6)
H_schoolwork	-9.8***					4.33***
H_communication		-15.7***				-16.56***
H_general			-1.62***			7.51***
S_education				-14.0***		-7.99***
S_general					-10.6***	-4.03***
Observations	109,967					

Source: Own computations from PISA 2015 data.
Notes: Each column presents coefficients from different regressions. Within-school estimates and controlling for individual covariates. Standard-errors (not shown) clustered at the school level. See Table A.6 in the annex for the full set of results, including for reading and mathematics. *** p<0.01.

The results in column 6 show a positive association between students' achievement in science and intensity of ICT use at home for schoolwork (H_schoolwork) and for general purposes (H_general). In contrast, a negative association is found between achievement in science and the other measures of ICT use intensity, i.e. using ICT at home to communicate with students or teachers about school work (H_communication) and using ICT at school both for educational and general purposes (S_education and S_general).

As previously mentioned, the coefficients on S_education should be interpreted with caution since it is not clear whether ICT at school refers to activities performed in a classroom context or not. Even if they are performed within the classroom, it should be kept in mind that the literature highlights that an effective use of ICT may depend on variables other than just the intensity of ICT use[16].

The association that is higher in magnitude is the one on communication and this highly negative correlation could be due to several reasons. It could reflect a composition effect, whereby students that perform this type of activity more intensively may be systematically different from the ones that perform it less frequently. For instance, if they miss school more often or pay less attention in the classroom, they may feel the need to contact colleagues or teachers to get the information they missed in class. Another explanation could be that this activity distracts them from schoolwork and is relatively unproductive.

These results arise from imposing a linear relation between intensity of ICT uses and science scores. This may be a strong assumption and, indeed, the descriptive statistics from Section 5.2 hinted at possible non-linear associations. To account for this possibility, we divide students into three groups according to their intensity of ICT use –

[16] The negative coefficient of S_education might be driven by only some of the items composing the index. To inspect this possibility, as an alternative specification, we introduced in the regression the 7 individual items that compose the index (see section 4.3). It results that only one of them has a positive coefficient – browsing the internet for schoolwork. Given that the large majority of the items enter with a negative coefficient, we have decided to continue to use the index.

low, medium and high[17] - in each of the five possible uses and examine the effect of increasing ICT use intensity within each of these groups[18]. This procedure allows for different coefficients in different parts of the various ICT use distributions, and it is relevant because we suspect that the relation between intensity of ICT use and student achievement may follow an inverted U-shaped curve. This would imply that students who are close to the bottom of the ICT use distribution may be constrained in their use. In these cases, increasing their ICT use would produce some improvements in their school performance, since these students are use-constrained to start with. On the other hand, increasing the use of ICT for those who are already in the upper part of the distribution is unlikely to generate any benefit in terms of school performance.

The results obtained in Table 7 seem to (partially) support this interpretation. In fact, we find evidence of a non-linear relation between (almost) all of the ICT uses and science scores. Among the low intensity users, increasing the use of ICT is associated with an increase in the science scores, whereas among the medium and high intensity users, a negative association arises. This is the case for all the types of ICT use except the use of ICT at school for general purposes (S_general), for which we only find negative coefficients.

Table 7 – Results from the econometric specification: Testing non-linearity

Dep. Variable: PISA science score		
Types of ICT use	Intensity of ICT use	Dep. Var. Science Score
H_schoolwork	Low	4.5***
	Medium	-0.8**
	High	-1.8***
H_coomunication	Low	1.4***
	Medium	-0.6
	High	-3.1***
H_general	Low	7.0***
	Medium	-0.2
	High	-6.4***
S_education	Low	3.7***
	Medium	-6.2***
	High	-9.5***
S_general	Low	-0.9**
	Medium	-1.7***
	High	-0.7

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. See Table A.7 in the annex for the full set of results, including for reading and mathematics. *** p<0.001, **p<0.05.

17 This division is done using the 33th and 66th percentiles of ICT use intensity in each of the five types of ICT use.

18 For each of the groups, the variables of intensity of ICT use are again standardized to have mean zero and standard deviation. This is advisable to be able to compare coefficients across groups of intensity of use. In fact, the coefficient of the model will inform about the change in PISA score resulting from an increase in the intensity of ICT use that is similar for all the three intensity groups.

The coefficients for the use of ICT at school for educational purposes are among the highest. They indicate that increasing the use of ICT at school for educational purposes among the medium and high-intensity users is associated with a decrease of 6 to 10 PISA points, suggesting that intensive use of ICT at school may be detrimental for students. In contrast, among the low-intensity users, a higher intensity of use is associated with an increase in the PISA science score, even though of a lower magnitude: 3-4 PISA points. This pattern suggests, that using ICT at school for educational purposes can be positively related to students' achievement, provided that the intensity of use is kept at lower levels.

The highest positive coefficient is the one on the use of ICT outside of school for general purposes (H_general) among low-intensity users, suggesting that low-intensity users may benefit from increasing the intensity of activities such as searching for information, gaming and entertainment/social ones. Increasing intensity of ICT use at home for schoolwork among the low-intensity users is also positively associated with achievement in science.

All the results described are qualitatively similar for reading and mathematics (see Table A.7).

5.4.2 Disadvantaged versus other groups of students

Next, we analyse whether the results and associations found above differ according to students' socio-economic groups – i.e. the three socio-economic status groups presented above: low, medium and high socio-economic status. Given the interesting insights from the previous section, we keep separate the three groups of ICT use intensity. Accordingly, we distinguish between 6 groups of students, combining the categorizations of socio-economic status and intensity of ICT use[19]. Following the logic of the findings from the last section, we are particularly interested in testing whether, among low-intensity ICT users (within each ICT use type), those who come from a disadvantaged socio-economic background would benefit more from increased ICT use (since they are more likely to be truly use-constrained).

Table 8 shows the same type of results as Table 7, but with the further disaggregation by socio-economic status. Analysing each of the columns, we conclude that, in general, the results are in line with the ones presented previously since a similar pattern can be found across the three socio-economic groups. This implies that increasing the intensity of ICT use is associated with higher PISA scores only in the case of the low users group, confirming the non-linearity (i.e. concavity) in the use of ICT.

When looking at the coefficients for different socio-economic statuses within each ICT-use group we find some variations[20]. However, more importantly, only in a few cases is

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[19] See Table A.8 in the Annex to see the tabulation between these two categorizations. The share of each of the socio-economic groups that are low, medium or high intensity users of ICT is substantial.

[20] These are the most significant across socio-economic group variation:

- H_schoolwork: The negative effect found overall for the medium and high intensity users seems to be driven mostly by students from medium socio-economic status.
- H_communication: Among the students that use ICT less intensively for communication, only students from high socio-economic status do not present a positive coefficient.
- S_education: The positive coefficient found before for low intensity users is not confirmed for disadvantaged students. This means that, regardless of their intensity of ICT use for this purpose,

this variation statistically significant across socio-economic statuses (these cases are highlighted in grey). In general, the coefficients for disadvantaged students tend to be higher than that of advantaged students, though most of the differences are not statistically different from zero. One of the few significant differences shows up in the general use of ICT at home among low intensity users (H_general, row 7): an increase in the intensity of this use is associated more strongly with science scores for disadvantaged than for advantaged students. The other significant difference arises in the use of ICT at school for educational purposes (S_education):

- Among low intensity users for this purpose, the association between an increase in the intensity of use and science score is significantly higher for students from medium socio-economic backgrounds than for disadvantaged ones;
- Among medium intensity users, an increase in the intensity of use is more strongly (and negatively) associated with science scores for disadvantaged students;
- Among high intensity users, advantaged students are the ones showing the most negative association with science scores.

Table 8 – Results from the econometric specification: Disadvantaged versus other groups of students

Dep. Variable: PISA science score				
Type of ICT use	Intensity of Use	Disadv.	Medium	Advant.
H_schoolwork	Low	5.03***	5.03***	3.06***
	Medium	-0.29	-1.02*	-0.81
	High	-1.04	-1.97**	-1.25
H_communication	Low	1.87	1.65***	0.87
	Medium	0.36	-0.65	-1.11
	High	-2.13	-2.72***	-4.10***
H_general	Low	8.04***	7.59***	4.52***
	Medium	-0.49	0.21	-0.95
	High	-4.41***	-6.86***	-5.73***
S_education	Low	1.74	4.11***	4.26***
	Medium	-8.87***	-5.78***	-5.57***
	High	-7.73***	-9.04***	-12.77***
S_general	Low	0.00	-1.23**	-0.70
	Medium	-0.99	-1.71**	-2.10*
	High	-1.80	-0.74	0.90

Source: Own computations from PISA 2015 data.
Notes: All estimates shown result from the same regression. Within-school estimates and controlling for individual covariates. Standard-errors (not shown) clustered at the school level. Shaded cells: significantly different from the coefficient for disadvantaged. See Table A.9 in the annex for the full set of results, including for reading and mathematics. *** p<0.001; ** p<0.05; * p<0.1.

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disadvantaged students do not show any positive relation between an increase in ICT use at school for educational purposes and science scores.

- S_general: The results found before seem to be mostly driven by students from medium socio-economic status.

Similar results are found for the other domains tested in PISA – reading and mathematics (see Table A.9 in the Annex).

To sum up, when looking at ICT uses at home, we find that low-intensity users would benefit from an increase in the intensity of use, medium users would be largely unaffected, while high users would actually be negatively affected. Within the group of low-intensity users, individuals from low and medium socio-economic backgrounds are those who tend to benefit more, particularly in the case of home use for general purposes (H_general). For other types of ICT use, the differences between socio-economic statuses are not statistically significant.

When considering the use of ICT at school, an increase in PISA score is associated only with additional use for educational purposes (and not for a general use) and only for the low-intensity users. However, within low users, the gains would be larger for students from medium and high socio-economic backgrounds, contrary to our initial expectations. Further research should be done to understand why this is the case.

5.4.3 The role of schools

By performing a within-school analysis, we overlook school characteristics that may influence the association of ICT use and students' achievement. Therefore, we now concentrate on students from disadvantaged backgrounds and examine whether the results change across both ICT use intensity and school type[21]. In particular, we look at public versus private schools (Table 9) and at schools with low versus high numbers of computers per student (Table 10)[22].

In both cases, we find differences regarding the use of ICT outside of school for schoolwork (H_schoolwork). For instance, we find that the association between this type of ICT use and PISA science scores is higher for disadvantaged students enrolled in private schools. In fact, for private schools, we find that, for both low and medium-intensity users, coefficients are positive and high. The reason for this could be that non-public schools meet several necessary conditions that enable disadvantaged students to use ICT at home more effectively. For instance, non-public schools may use digital devices in the learning process more effectively, e.g., by providing teacher training, by using specific pedagogical practices or by prescribing specific types of homework that are more suited to the use of ICT. Unfortunately, with the existing data we cannot test these hypotheses. An alternative explanation is that the frequency and the type of schoolwork students are asked to perform is systematically different across school types.

A similar difference is revealed between schools with lower and higher numbers of computers per student. In particular, the intensity of ICT use for schoolwork at home (H_schoolwork) among the low-intensity and disadvantaged users is more strongly associated with an increase in PISA achievement in schools with a higher number of computers per student. This suggests that disadvantaged students may benefit from higher access to computers at school as a way to compensate for the lower access/use at home. Moreover, higher access to technology at school can induce students from

[21] In this exercise, we run the full specification but, for simplicity, only compare the coefficients related to disadvantaged students and only comment those that are statistically different across school types.

[22] We divide schools according to the median of computers per student at the school.

disadvantaged backgrounds to also use ICT more effectively at home (provided ICT access is available).

We also find that an increase in the use of ICT for educational purposes at school (S_education) is positively associated with achievement only among low-intensity users from schools with fewer computers per student. This suggests that these schools are particularly under-using ICT for educational purposes and could be using it more intensively.

Table 9 – Results from the econometric specification: The role of type of school

Dep. Variable: PISA science score				
Types of ICT use	Intensity of ICT use	Disadv. & Public	Disadv. & Private	Difference between types of schools
H_schoolwork	Low	3.44***	11.73***	**
	Medium	-1.08	7.29*	**
	High	-1.01	-2.84	
H_communication	Low	1.77	0.67	
	Medium	1.48	-2.89	
	High	-1.75	-0.43	
H_general	Low	9.31***	5.29	
	Medium	-1.28	-2.52	
	High	-5.40***	-5.29	
S_education	Low	2.39*	-1.25	
	Medium	-9.56***	-4.15	
	High	-6.66***	-10.16**	
S_general	Low	0.56	-0.74	
	Medium	-1.80	1.40	
	High	-2.64*	3.23	

Source: Own computations from PISA 2015 data.
Notes: All estimates shown result from the same regression. Within-school estimates and controlling for individual covariates. Standard-errors (not shown) clustered at the school level. Shaded cells: significantly different from the coefficient of advantaged students. See Table A.10 in the annex for the full set of results, including for medium and high socio-economic students. The last column presents the p-value of testing the difference between the coefficients of the two types of schools. *** p<0.001; ** p<0.05; * p<0.1.

Table 10 – Results from the econometric specification: The role of the number computers at school

Dep. Variable: PISA science score				
Types of ICT use	Intensity of ICT use	Disadv. & Low computers	Disadv. & High computers	Difference between types of schools
H_schoolwork	Low	3.05*	6.98***	*
	Medium	-3.48*	1.96	**
	High	-1.19	-2.97	
H_communication	Low	4.98***	0.09	**
	Medium	-0.52	1.47	
	High	-5.06**	0.99	*
H_general	Low	9.23***	7.96***	
	Medium	-1.15	-0.56	
	High	-3.78*	-4.15**	
S_education	Low	3.94**	-0.38	*
	Medium	-10.1***	-5.91***	*
	High	-5.69**	-8.42***	
S_general	Low	0.28	0.56	
	Medium	-0.98	-1.09	
	High	0.99	-4.37**	**

Source: Own computations from PISA 2015 data.
Notes: All estimates shown result from the same regression. Within-school estimates and controlling for individual covariates. Standard-errors (not shown) clustered at the school level. Shaded cells: significantly different from the coefficient for disadvantaged. See Table A.11 in the annex for the full set of results, including for medium and high socio-economic students. The last column presents the p-value of testing the difference between the coefficients of the two types of schools. *** p<0.001; ** p<0.05; * p<0.1.

5.4.4 Heterogeneity across countries

We then look at the relationship between ICT use and PISA scores by groups of countries. The groups considered are the following:

- Southern: Spain, Portugal, Italy and Greece
- Nordic: Finland, Sweden and Denmark
- Central: France, Austria, Belgium, the Netherlands, Germany, Ireland, the UK, Luxembourg
- Eastern: Bulgaria, Estonia, the Czech Republic, Lithuania, Latvia, Slovenia, the Slovak Republic, Hungary, Croatia, Poland

Table 11 – Results from the econometric specification: Different groups of countries

Dependent variable: PISA science score					
Types of ICT use	Intensity of ICT use	Southern EU countries	Central EU countries	Nordic EU countries	Eastern EU countries
H_schoolwork	Low	-3.32	8.62***	10.59***	3.58
	Medium	-0.99	-0.77	-2.60	-0.32
	High	2.47	-3.96	-2.15	-1.78
H_communication	Low	0.64	4.62**	1.32	-4.12**
	Medium	-0.24	-5.46**	-7.66*	-7.01**
	High	-2.63	-9.91***	-13.73***	-0.24
H_general	Low	11.71***	4.37**	5.25	11.90***
	Medium	0.16	-2.24	3.53	-0.32
	High	-2.92	-2.56	5.79	-8.06***
S_education	Low	3.34	1.16	7.22*	3.78**
	Medium	-7.97***	-2.81	-6.04*	-11.70***
	High	-7.17**	-5.51**	-6.35	-6.50***
S_general	Low	-	-	-5.88	0.68
	Medium	-1.93	-4.08***	-6.35*	-3.30*
	High	-3.59	1.16	-2.74	-0.34

Source: Own computations from PISA 2015 data.
Notes: The estimates from each column result from the different regressions. Within-school estimates and controlling for individual covariates. Standard-errors (not shown) clustered at the school level. Shaded cells: significantly different from the coefficient for advantaged. See Table A.12 in the annex for the full set of results, including for medium and high socio-economic students. *** p<0.001; ** p<0.05; * p<0.1.

Table 11 presents results for the disadvantaged group of students only, but the full specification is used (i.e. students from medium and high socio-economic are included as well). Shaded cells signal that the coefficient for disadvantaged is significantly higher than that of advantaged students.

When we look at the significance of ICT use at home for disadvantaged students, we find positive and significant coefficients only for the group of low users (but not for all the countries: e.g. the coefficient on H_communication is negative in Eastern countries). However, the positive effects are not significant in all the countries: i) for use of ICT at home for school-related activities (H_schoolwork), the coefficient is significant only in Central and Northern countries; ii) for use of ICT at home for communication activities (H_communication) the coefficient is significant only in Central European countries, while it is negative in Eastern countries, iii) for the use of ICT for generic purposes (H_general) it is significant in all the countries with the exception of the Nordic countries.

When we compare these effects across students from different socio-economic groups, we find that they are higher for students from low socio-economic background (relative to students from a high socio-economic status) only in three cases: in Central European countries for H_schoolwork, and in Southern and Eastern European countries for H_general.

These results are broadly consistent with the evidence found in previous sections (the only exception being H_communication in Eastern countries) but they also show some relevant cross-country differences.

As for ICT use at school among disadvantaged students, the positive and significant coefficients are confined to low-intensity users of ICT for educational purposes in Nordic and Eastern countries. However, they are not significantly different from the coefficients of students from high socio-economic background. This indicates that, especially in the Nordic countries, for which the coefficient is particularly high (7.22), low-intensity users of ICT at school would particularly benefit from additional use for educational purposes – irrespective of their social status. One possible explanation for this result is that Nordic countries have been particularly successful in introducing digital technologies (including for learning), indicated by their high share of students who start to use ICT early in life and their high share of students who access ICT at home. In addition, the differences across socio-economic statuses are the lowest in these countries[23]. It hence appears that, in the Nordic countries, low-intensity ICT users –irrespective of their social status – tend to "fall behind" the rest of the student population (i.e. their digital gap is higher) and hence benefit (relatively) more from increased use intensity in terms of learning abilities and outcomes.

On the other hand, in Southern and Central European countries, the use of ICT at school does not appear to be significantly associated with improvements in the school performance of disadvantaged students.

5.4.5 ICT use and resilient students

As a final point, we explored whether ICT use at school or at home is related to the probability of being a resilient student, which, according to the OECD is defined as a student who comes from a disadvantaged socio-economic background, but who also performs significantly better than would be expected based on her/his socio-economic background (OECD, 2009). Again, we want to stress that we are not claiming any causality since, especially for the case of resilient students, the selection bias could be very large.

Table 12 shows the results of the regression where only disadvantaged students are included and where the dependent variable is a dummy variable which indicates whether disadvantaged students are resilient or not.

The results indicate that, among disadvantaged students, the probability of being resilient is indeed slightly associated with the use of ICT. Despite the low magnitude of the coefficients (1-2 percentage points), it is encouraging to find that the probability of being a resilient student is positively associated with an increase: a) in the intensity of ICT use at home for schoolwork (H_schoolwork) among low-intensity users; b) in the intensity of ICT use at home for general purposes (H_general) for low-intensity users; and c) in the intensity of ICT use at school for educational purposes (S_education) for low-intensity users. Positive and significant coefficients are only found among the low-intensity users, which corroborates our earlier findings. The fact that the coefficients of

[23] Sweden and Denmark also have a high share of students reporting the use of ICT at school for educational purposes at least once per week.

S_education for medium and high-intensity users are negative and significant is in line with the hypothesis that there is an optimal level of intensity of ICT use.

Table 12 – ICT use and students' resilience

Dependent variable: Resilient student indicator		
Types of ICT use	Intensity of ICT use	Dep. Variable: Resilient student
H_schoolwork	Low	0.016**
	Medium	-0.002
	High	-0.008
H_communication	Low	0.007
	Medium	-0.005
	High	-0.004
H_general	Low	0.027****
	Medium	0.002
	High	-0.026***
S_education	Low	0.013*
	Medium	-0.048***
	High	-0.033***
S_general	Low	0.005
	Medium	-0.005
	High	0.005

Source: Own computations from PISA 2015 data.
Notes: Only disadvantaged students included. All estimates shown result from the same regression. 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.

6. Conclusion

Students from low socio-economic backgrounds –relative to those from medium and high social statuses- tend to have fewer opportunities to access to education, fewer chances of completing education and lower educational outcomes, such as PISA scores. Digital technologies may, in theory, help to reduce this gap, by enabling access to additional learning resources and facilitating pedagogical strategies that could be beneficial to the students. This is especially true if schools compensate for the limited access to and utilization of digital technologies that disadvantaged students typically have at home. Digital technologies can support the move from a teacher-centred model to a more student-centred instruction approach. This may be of special benefit to students at risk of dropping-out. Moreover, the use of computers can help to adjust levels of difficulty and learning speed to the capabilities of disadvantaged students. In addition, computer-assisted instruction is seen as motivational and can connect classroom learning to real-life situations through the use of images, videos and sounds. Finally, digital learning can give access to frequent feedback, it can individualize learning, and it allows more autonomy and provides multi-sensory learning environments, thus increasing the chances of student engagement.

However, whether digital technologies can in practice contribute to breaking the cycle of social exclusion is an open question, which needs to be answered on empirical grounds.

In this study, we provide evidence of the relationship between learning outcomes and ICT utilization, both at home and at school, paying special attention to students from disadvantaged socio-economic backgrounds. Using data from the 2015 PISA survey, which focuses on science, we document that disadvantaged students start using digital devices later in life than their counterparts, and have slightly less access to ICT at home. We also construct indices of intensity of ICT use by students, distinguishing between 5 types of (location-dependent) ICT use: i) use of ICT outside school for schoolwork-related activities; ii) use of ICT outside school to communicate with teachers or classmates about schoolwork; iii) use of ICT outside school for general purposes; iv) use of ICT at school for educational purposes; v) use of ICT at school for general purposes. Students from low socio-economic backgrounds appear to use ICT less intensively than students from medium and high socio-economic statuses in all the five categories, but especially in those related to use of ICT outside of school.

In the multivariate regression analysis, we start by looking at the general student population. We find that achievement in PISA is positively associated with only two of the variables which capture ICT use - use of ICT outside school for schoolwork-related activities, and use of ICT outside school for general purposes. However, it is negatively associated with the other types of use. In particular, and contrary to our initial expectations, we find that the intensity of ICT use at school has a negative coefficient. However, these results were based on the assumption that the relationship between PISA scores and ICT uses is linear. To relax this assumption, we divide students according to their intensity of ICT use: low-intensity users, medium-intensity users and high-intensity users. The results indeed refute the linearity hypothesis since the association between PISA scores and ICT uses becomes positive for the low users for four out of five of the possible ICT uses (the only one for which it is not significant is ICT use at school for general purposes). As for medium and high-intensity users, the coefficient is always negative (but not always significantly different from zero). We take this as an indication that low-intensity users may be constrained in their use of ICT and may therefore benefit from additional use, especially at home.

In a second stage, the multivariate analysis looks at disadvantaged students more closely and assesses the extent to which the relation between ICT and achievement differs by socio-economic status. We do that by running the same regression, and allow for differences related to socio-economic statuses, while keeping the distinction between low, medium and high-intensity users for each category of ICT use. When looking at the three uses of ICT at home, we find that - within the group of low-intensity users- individuals from low and medium socio-economic backgrounds are those that tend to benefit more from increased intensity levels, particularly in the case of home use for schoolwork and for general purposes. However, when we consider the two uses of ICT at school by low-intensity users, the gains are larger for students from medium and high socio-economic backgrounds, contrary to our intuitions.

We also examine whether the results differ between private and public schools and between schools with low and high numbers of computers per student. In both cases, we find differences regarding the use of ICT outside of school for schoolwork among the low-intensity users. We conclude that the association between this type of ICT use and PISA science scores is greater for disadvantaged students enrolled in private schools and in schools where the numbers of computers available to students are larger. The latter suggests that disadvantaged students may benefit from greater access to computers at school as a way to compensate for the lower access/use at home, or it may be an incentive to use ICT more effectively at home.

To sum up, we find a positive association between disadvantaged students' achievements and the use of ICT for some purposes, but only among those students who use ICT less intensively. We find no evidence, though, that this association is systematically different from that of students from higher socio-economic backgrounds. The exception is the use of ICT outside of school for general purposes among low-intensity users: in this case, disadvantaged students are the group that would particularly benefit from using ICT more intensively.

Still, we find that the use of ICT has some, though limited, potential to help disadvantaged students break the cycle of social exclusion. In fact, among disadvantaged students who are also low ICT users, the increased use of ICT (for some purposes) is positively associated with the probability of being resilient.

More generally, though we stress that it is not possible to give a causal interpretation to our results, our research suggests that low-intensity users of ICT are likely to be using ICT sub-optimally, both at home and at school. Hence, they would benefit (in terms of PISA scores) from additional intensity of use. On the other hand, medium-intensity and high-intensity users of ICT (irrespective of their socio-economic status) typically would not gain from using ICT still more intensively. This suggests that the use of ICT by students can improve their learning outcomes only to a certain degree and that it is crucial to use ICT properly in order to reap their benefits.

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Annex

Descriptive Statistics

Table A.1 – Average scores in the three PISA domains, for all students and by socio-economic groups

	Science Mean Scores				Reading Mean Scores				Mathematics Mean Scores			
	All students	By socio-economic status			All students	By socio-economic status			All students	By socio-economic status		
		Disadv.	Medium	Advant.		Disadv.	Medium	Advant.		Disadv.	Medium	Advant.
AT	495	439	493	551	485	430	483	541	497	442	496	547
BE	502	442	503	566	499	442	500	559	507	451	508	568
BG	446	383	446	504	431	358	433	497	441	386	440	498
CY	433	392	432	479	443	403	443	484	437	393	437	483
CZ	493	433	491	556	487	421	488	550	493	431	492	555
DE	509	452	513	573	509	459	515	567	507	456	510	560
DK	502	463	504	547	500	464	503	543	511	474	515	549
EE	534	504	533	575	519	492	518	557	519	489	518	560
EL	455	409	452	506	467	416	464	521	454	414	451	500
ES	493	447	492	539	495	452	494	540	486	442	484	532
FI	531	489	530	576	526	486	525	570	511	471	510	553
FR	495	430	496	563	499	432	500	570	493	432	493	558
HR	476	435	469	531	487	446	480	540	464	426	456	519
HU	477	403	476	541	470	394	469	534	477	408	475	540
IE	502	460	501	551	521	479	521	567	504	463	502	549
IT	481	437	482	524	485	437	488	531	489	445	490	534
LT	476	437	477	521	473	432	475	518	478	441	479	522
LU	483	421	479	557	481	419	479	554	485	434	481	553
LV	491	458	491	525	488	452	489	524	482	446	484	515
MT	465	405	463	532	446	390	445	508	479	422	480	533
NL	509	461	507	566	503	461	500	559	513	473	510	563
PL	502	453	498	554	506	457	503	554	504	459	502	552
PT	501	453	495	558	498	452	494	551	492	445	486	551
RO	435	395	429	487	433	381	427	493	444	398	437	504
SE	493	446	496	551	500	454	505	552	494	450	496	547
SI	513	469	512	564	505	467	504	552	510	474	510	552
SK	461	379	460	519	453	361	453	513	475	394	476	528
UK	510	472	509	565	497	465	496	550	492	456	492	545
EU 28	495	445	494	551	494	445	494	549	493	445	492	545

Source: Own computations using PISA 2015 data.

Table A.2 - Share of students reporting starting to use digital devices at different age groups (%), for all students and by socio-economic groups

	9 years old or younger				10 years old or later				Never so far			
	All Students	By socio-economic status			All students	By socio-economic status			All students	By socio-economic status		
		Disadv.	Medium	Advant.		Disadv.	Medium	Advant.		Disadv.	Medium	Advant.
AT	68.0	61.5	67.7***	74.7***	31.6	38.0	31.9***	25.0***	0.4	0.5	0.4	0.3
BE	62.7	56.6	62.5***	69.5***	37.0	42.9	37.3***	30.2***	0.3	0.5	0.2	0.3
BG	78.0	62.8	79.6***	86.0***	20.4	33.7	19.1***	13.5***	1.5	3.5	1.4***	0.5***
CZ	86.5	79.1	87.1***	90.4***	13.2	20.6	12.6***	9.3***	0.3	0.2	0.3	0.4
DE	-	-	-	-	-	-	-	-	-	-	-	-
DK	90.4	88.1	90.9**	91.1*	9.4	11.7	8.9**	8.7*	0.2	0.2	0.2	0.2
EE	85.7	80.1	85.7***	91.2***	13.7	19.4	13.6***	8.4***	0.6	0.5	0.7	0.4
EL	64.3	52.9	63.5***	76.1***	34.5	45.8	35.4***	22.7***	1.2	1.3	1.1	1.2
ES	76.6	68.6	77.4***	81.6***	23.0	30.3	22.3***	18.3***	0.4	1.1	0.3**	0.1***
FI	92.9	87.7	93.6***	95.2***	6.6	11.4	6.0***	4.6***	0.5	0.8	0.5	0.2**
FR	68.4	55.6	68.7***	78.3***	31.1	43.0	30.9***	21.5***	0.5	1.4	0.4**	0.2***
HR	81.3	71.6	82.0***	86.3***	18.3	27.7	17.8***	13.4***	0.3	0.7	0.2	0.3
HU	77.2	69.9	77.1***	83.4***	22.2	29.5	22.2***	16.1***	0.7	0.7	0.7	0.5
IE	71.3	69.1	70.6	76.2***	28.5	30.4	29.3	23.7***	0.2	0.5	0.1	0.1
IT	63.5	55.0	63.5***	71.5***	36.0	44.4	36.2***	27.9***	0.4	0.6	0.3	0.6
LT	82.9	75.1	84.0***	87.9***	16.0	23.1	15.0***	11.2***	1.1	1.8	1.0*	0.9
LU	58.0	50.4	57.2***	68.0***	40.8	48.3	41.8***	30.5***	1.3	1.3	1.0	1.5
LV	85.7	77.9	87.0***	89.3***	14.3	22.1	13.0***	10.7***	0.0	0.0	0.0	0.0
NL	74.4	69.1	74.2***	79.6***	25.5	30.8	25.7***	20.2***	0.1	0.1	0.1	0.2
PL	85.7	75.8	86.5***	90.5***	13.9	23.4	13.2***	9.2***	0.3	0.8	0.3	0.3
PT	78.3	68.5	78.4***	86.4***	21.4	31.1	21.5***	13.3***	0.2	0.4	0.1	0.4
SE	84.8	78.5	85.5***	89.4***	14.4	20.2	13.9***	9.8***	0.8	1.3	0.6*	0.8
SI	80.5	75.6	80.0***	87.0***	19.0	24.0	19.5***	12.5***	0.5	0.4	0.6	0.6
SK	63.3	50.2	62.4***	74.3***	35.5	45.6	36.7***	24.9***	1.2	4.1	0.9***	0.8***
UK	78.0	71.2	78.8***	81.9***	21.6	28.3	20.8***	17.5***	0.5	0.5	0.4	0.7
Pooled	76.6	69.3	76.9***	82.7***	22.8	29.8	22.7***	16.9***	0.6	0.9	0.5***	0.5***

Source: Own computations using PISA 2015 data.
Notes: Pooled includes all the 24 countries shown, it does not include Germany. Asterisks indicate whether the share is statistically different from the share of disadvantaged group of students. *** p<0.01, ** p<0.05, * p<0.1.

Table A.3 – Share of students reporting to have access to digital technologies at home and at schools (%), for all students and by socio-economic groups

	Access to ICT at home				Access to ICT at school				School has data projector or interactive whiteboard			
	All students	By socio-economic status			All students	By socio-economic status			All students	By socio-economic status		
		Disadv.	Medium	Advant.		Disadv.	Medium	Advant.		Disadv.	Medium	Advant.
AT	98.9	97.2	99.1***	99.8***	99.9	100	99.8	99.8	100	100	100	100
BE	99.0	96.7	99.4***	99.7***	99.4	99.0	99.5	99.7**	99.3	98.8	99.4	99.7**
BG	97.5	91.8	98.4***	99.1***	100	100	100	100	98.0	94.5	98.6***	99.4***
CZ	98.7	95.5	99.1***	99.9***	100	100	100	100	100	100	100	100
DE	-	-	-	-	-	-	-	-	-	-	-	-
DK	99.6	98.8	99.7***	100***	100	100	100	100	100	100	100	100
EE	99.2	98.4	99.3	99.6**	99.3	99.8	99.1**	99.4	98.9	98.4	98.8	99.4
EL	95.6	87.8	96.7***	99.1***	99.9	99.6	100	100	99.8	99.0	100*	100*
ES	95.7	85.6	97.5***	99.3***	100	100	100	100	100	100	100	100
FI	99.6	99.1	99.7**	99.7*	100	100	100	100	100	100	100	100
FR	98.7	96.0	99.1***	99.8***	100	100	100	100	98.9	98.7	99.1	99.8***
HR	97.8	93.6	98.4***	98.9***	100	100	100	100	99.9	100	99.9*	100
HU	97.3	90.4	98.4***	99.7***	100	100	100	100	99.0	96.5	99.3***	100***
IE	98.8	96.2	99.2***	99.8***	100	100	100	100	99.9	99.9	99.9	100
IT	97.3	93.4	98.0***	98.7***	99.9	100	100	100	99.7	99.2	99.7**	100***
LT	96.9	91.0	98.1***	99.8***	100	100	100	100	100	100	100	100
LU	98.4	96.4	98.6***	99.7***	100	100	100	100	100	100	100	100
LV	98.1	94.6	98.9***	99.4***	100	100	100	100	99.8	99.6	99.7	100
NL	99.9	99.9	99.9	99.7	100	100	100	100	100	100	100	100
PL	98.2	93.3	98.9***	99.5***	99.6	99.4	99.6	99.7	100	100	100	100
PT	97.6	92.8	98.4***	99.6***	100	100	100	100	100	100	100	100*
SE	98.8	96.3	99.2***	99.7***	100	100	100	100	99.4	99.0	99.5	99.6
SI	98.8	97.7	99.0***	99.4***	99.7	99.9	99.7	99.7	98.5	98.4	98.3	99.4*
SK	97.2	82.7	98.6***	99.0***	99.9	99.5	99.9	100	99.6	98.3	99.8***	99.8***
UK	99.0	97.4	99.4***	100***	100	100	100	100	99.9	100	99.9**	99.9**
Pooled	98.2	94.4	98.8***	99.5***	99.9	99.9	99.9	99.9	99.6	99.2	99.7***	99.9***

Source: Own computations using PISA 2015 data.

Notes: Pooled includes all the 24 countries shown, it does not include Germany. Asterisks indicate whether the share is statistically different from the share of disadvantaged group of students. *** p<0.01, ** p<0.05, * p<0.1.

Table A.4 – Share of students that reported using ICT for each of the purposes and locations at least once per week (%), for all students and by socio-economic groups

	H_schoolwork				H_communication				H_general			
		By socio-economic status				By socio-economic status				By socio-economic status		
	All students	Disadv.	Medium	Advant.	All students	Disadv.	Medium	Advant.	All students	Disadv.	Medium	Advant.
AT	82.6	75.9	82.4***	88.0***	68.3	65.9	69.0	67.7	98.4	97.7	98.6	98.4
BE	75.7	67.7	75.9***	80.8***	80.2	70.9	80.0***	87.9***	98.6	97.3	98.6**	99.3***
BG	78.3	69.2	78.9***	82.3***	82.5	74.6	82.5***	87.7***	93.6	87.9	93.8***	96.8***
CZ	76.2	69.0	76.3***	80.8***	81.9	77.0	82.2**	84.1***	97.5	96.3	97.6	97.7
DE	65.2	57.0	66.2***	68.7***	57.3	50.0	58.3***	60.8***	94.0	90.1	94.4***	95.8***
DK	95.1	93.7	95.0	97.5***	79.4	73.5	80.5***	81.3***	99.0	98.7	99.2	98.8
EE	85.4	81.3	85.7**	89.3***	84.0	81.2	84.1	86.6**	98.4	96.9	98.7**	99.0**
EL	78.6	73.5	79.7***	79.3**	78.1	75.0	78.9*	77.9	96.8	94.8	96.8*	98.2***
ES	75.5	66.6	76.1***	81.6***	74.0	69.6	74.1**	77.6***	98.2	96.5	98.2**	99.4***
FI	57.4	50.8	56.8***	64.5***	42.0	37.3	41.6**	47.0***	98.6	98.0	98.6	99.1*
FR	75.8	69.7	76.2***	79.3***	63.4	58.8	63.2*	68.0***	98.1	97.0	97.9	99.5***
HR	71.4	62.3	72.0***	74.9***	86.0	78.9	86.7***	88.2***	95.9	92.7	96.1***	97.3***
HU	74.5	68.2	75.0***	77.2***	82.1	73.3	82.7***	86.5***	97.5	94.6	97.6**	99.1***
IE	64.8	56.9	64.8***	72.0***	62.4	56.1	62.5***	68.0***	99.3	98.8	99.3	99.6*
IT	77.3	72.6	77.9***	79.6***	71.9	68.4	71.5	76.3***	97.4	95.7	97.6**	98.4***
LT	83.4	75.9	84.6***	87.9***	75.8	67.7	76.8***	81.3***	96.6	94.1	96.9***	98.4***
LU	74.7	69.3	74.5**	79.1***	79.1	77.9	78.5	82.5**	97.7	96.3	97.6	99.1***
LV	84.9	82.2	85.5*	86.2*	77.3	77.7	77.5	76.5	98.0	96.7	98.1*	98.6**
NL	89.1	82.5	89.5***	93.3***	68.6	63.4	68.1**	74.4***	99.2	99.0	99.2	99.5
PL	87.2	81.4	88.1***	88.2***	81.7	77.1	82.4**	82.7**	97.9	95.0	98.2***	99.0***
PT	72.7	68.7	73.6**	73.7**	73.9	70.7	74.1*	76.0**	97.5	95.0	97.7***	98.9***
SE	84.3	76.6	84.6***	91.0***	66.8	62.3	67.1**	70.8***	98.5	98.5	98.4	98.9
SI	75.5	71.8	75.4*	79.7***	85.3	82.3	84.6	90.2***	97.7	96.5	97.6	99.2***
SK	73.3	55.9	73.6***	78.8***	81.7	68.6	82.0***	85.6***	95.6	87.4	96.0***	97.2***
UK	90.5	81.9	91.0***	97.2***	72.3	63.5	72.4***	81.5***	99.1	98.7	99.1	99.5
Pooled	78.0	71.8	78.4***	81.6***	74.2	69.0	74.5***	78.0***	97.6	95.9	97.7***	98.6***

Table A.4 – continued.

	S_education				S_general			
	All students	Disadv.	Medium	Advant.	All students	Disadv.	Medium	Advant.
AT	66.8	65.6	67.9	64.4	61.6	57.9	62.3*	62.8*
BE	43.6	45.5	43.9	41.5*	33.8	39.1	33.8***	29.8***
BG	65.8	61.0	65.9*	68.7*	64.6	58.2	65.8***	65.2**
CZ	68.2	68.6	67.6	69.6	67.9	67.3	67.1	70.6
DE	38.7	39.4	40.3	33.1**	22.1	19.7	23.2*	20.2
DK	94.7	93.3	94.7	96.7***	77.9	74.5	78.6**	78.3
EE	52.1	50.1	52.2	53.9	39.5	36.0	39.5	42.9**
EL	52.9	54.3	53.7	49.2*	40.4	43.6	40.8	36.8**
ES	56.6	51.7	57.0**	59.7***	39.9	38.1	39.8	41.7
FI	53.8	48.1	53.3**	60.4***	78.3	75.3	78.5*	80.3**
FR	53.6	51.3	53.4	55.8*	34.7	32.3	35.7	33.4
HR	47.5	42.0	49.1***	46.0	51.8	46.7	53.0**	51.0
HU	52.4	50.6	53.8	49.5	52.3	49.5	53.3	51.3
IE	40.8	38.5	40.5	43.9**	37.3	37.3	36.6	40.1
IT	60.6	60.9	61.2	58.3	49.1	51.1	48.6	48.9
LT	54.1	51.2	54.4	56.3	34.1	33.2	32.9	39.1**
LU	50.2	52.8	50.3	48.2	43.7	42.0	43.3	45.9
LV	63.8	60.6	64.1	66.2**	62.2	59.2	62.4	64.6*
NL	84.1	81.7	84.6*	84.2	69.3	64.4	70.3***	70.0**
PL	54.9	51.2	56.2**	53.5	32.9	29.4	34.0*	32.0
PT	52.9	55.9	54.9	45.3***	56.2	55.6	58.0	52.0
SE	85.7	80.9	85.7***	89.9***	66.2	66.3	65.7	69.1
SI	52.3	50.8	51.7	55.8*	54.5	56.8	53.6	55.6
SK	60.8	52.7	60.8***	63.9***	56.5	46.5	56.9***	59.3***
UK	79.2	75.1	80.0**	81.6**	57.8	49.8	58.2***	64.0***
Pooled	59.4	57.5	60.1***	58.9**	51.4	49.3	51.9***	51.6***

Source: Own computations using PISA 2015 data.
Notes: Pooled includes all the 25 countries shown, it does include Germany. Asterisks indicate whether the share is statistically different from the share of disadvantaged group of students. *** p<0.01, ** p<0.05, * p<0.1.

Table A.5 - Students' Perceived ICT competence, all students and by socio-economic groups

	Students' perceived ICT competence			
	All students	By socio-economic status		
		Disadv.	Medium	Advant.
AT	-0.145	-0.288	-0.147***	-0.016**
BE	-0.008	-0.035	-0.002	0.008
BG	-0.072	-0.311	-0.073***	0.102***
CZ	-0.164	-0.313	-0.157***	-0.073***
DE	-0.114	-0.190	-0.113*	-0.072**
DK	0.187	0.107	0.187**	0.294***
EE	-0.110	-0.308	-0.096***	0.047***
EL	-0.008	-0.186	-0.006***	0.134***
ES	0.091	0.028	0.093*	0.141***
FI	-0.149	-0.284	-0.129***	-0.093***
FR	0.172	0.053	0.190***	0.214***
UK	0.288	0.169	0.285***	0.431***
HR	0.108	-0.158	0.122***	0.248***
HU	0.006	-0.210	0.016***	0.145***
IE	0.153	0.045	0.162***	0.231***
IT	-0.084	-0.111	-0.100	-0.010**
LT	-0.051	-0.358	-0.016***	0.188***
LU	-0.054	-0.220	-0.058***	0.098***
LV	-0.201	-0.400	-0.182***	-0.066***
NL	-0.102	-0.184	-0.101**	-0.024***
PL	-0.045	-0.332	-0.030***	0.112***
PT	0.330	0.168	0.346***	0.411***
SE	0.210	0.020	0.211***	0.399***
SI	-0.003	-0.063	-0.010	0.076***
SK	-0.198	-0.621	-0.187***	-0.020***
Pooled	0.000	-0.152	0.006***	0.112***

Source: Own computations using PISA 2015 data.

Notes: Pooled includes all the 25 countries shown. By construction, the average at pooled level is zero. Asterisks indicate whether the average is statistically different from the average of disadvantaged group of students. *** p<0.01, ** p<0.05, * p<0.1.

Full results from the econometric specification

Table A.6 - Basic results

Type of ICT use	Science	Reading	Mathematics
H_schoolwork	4.33***	3.89***	2.98***
H_communication	-16.56***	-15.16***	-12.9***
H_general	7.51***	7.38***	5.41***
S_education	-7.99***	-10.71***	-6.46***
S_general	-4.03***	-1.95***	-2.87***

Source: Own computations using PISA 2015 data.
Notes: Each column presents coefficients from different regressions. Within-school estimates and controlling for individual covariates. Standard-errors (not shown) clustered at the school level. *** p<0.01.

Table A.7 - Testing non-linearity

Type of ICT use	Intensity of ICT use	Dep. Var.: Science score	Dep. Var.: Reading	Dep. Var.: Mathematics
H_schoolwork	Low	4.47***	4.28***	4.24***
	Medium	-0.86*	-0.81*	-0.99**
	High	-1.80***	-1.69***	-2.43***
H_communication	Low	1.38***	2.19***	2.01***
	Medium	-0.61	-0.52	-0.62
	High	-3.05***	-3.59***	-2.55***
H_general	Low	7.04***	8.38***	6.41***
	Medium	-0.23	-0.22	-0.51
	High	-6.38***	-6.94***	-5.61***
S_education	Low	3.72***	4.05***	3.40***
	Medium	-6.19***	-5.79***	-4.94***
	High	-9.53***	-11.10***	-7.64***
S_general	Low	-0.94**	-1.38***	-0.28
	Medium	-1.71***	-0.26	-1.26**
	High	-0.70	-0.88	-1.00*

Source: Own computations using PISA 2015 data.
Notes: Each column presents coefficients from different regressions. Within-school estimates and controlling for individual covariates. Standard-errors (not shown) clustered at the school level. *** p<0.01, ** p<0.05, * p<0.1.

Table A.8 – Tabulation between socio-economic status and levels of intensity of ICT intensity

Type of ICT use	Intensity of ICT use	Simple tabulation	Tabulation Share by row				Tabulation Share by column		
			Disadv.	Medium	Advant.		Disadv.	Medium	Advant.
H_schoolwork	Low	31.3	18.5	63.4	18.1	= 100	37.2	30.9	28.2
	Medium	40.3	14.4	64.5	21.1	= 100	37.3	40.4	42.3
	High	28.4	14.0	65.1	20.9	= 100	25.5	28.7	29.5
							= 100	= 100	= 100
H_communic.	Low	38.7	16.9	64	19	= 100	42.1	38.5	36.6
	Medium	31.7	14.2	64.2	21.5	= 100	28.9	31.6	33.9
	High	29.6	15.3	64.8	19.9	= 100	29.1	29.8	29.4
							= 100	= 100	= 100
H_general	Low	33.9	18.3	63.4	18.3	= 100	39.8	33.4	30.8
	Medium	34.6	14.2	64.7	21.1	= 100	31.6	34.8	36.3
	High	31.5	14.2	64.8	21	= 100	28.6	31.7	32.9
							= 100	= 100	= 100
S_education	Low	34.9	16.2	63.6	20.2	= 100	36.2	34.5	35.2
	Medium	36.4	14.9	64.2	20.8	= 100	34.8	36.4	37.8
	High	28.7	15.7	65.3	19	= 100	28.4	29.1	27
							= 100	= 100	= 100
S_general	Low	44.6	15.8	63.8	20.3	= 100	45.3	44.2	45.1
	Medium	23.3	15.9	64.4	19.6	= 100	23.8	23.4	22.8
	High	32.1	15	64.9	20.1	= 100	30.9	32.4	32.1
							= 100	= 100	= 100

Table A.9 –Disadvantaged versus other group of students

Table A.9.1 - Dependent variable: PISA science score

Type of ICT use	Intensity of ICT use	Disadvantaged	Medium	Advantaged
H_schoolwork	Low	5.03***	5.03***	3.06***
	Medium	-0.29	-1.02*	-0.81
	High	-1.04	-1.97***	-1.25
H_communication	Low	1.87	1.65***	0.87
	Medium	0.36	-0.65	-1.11
	High	-2.13	-2.72***	-4.10***
H_general	Low	8.04***	7.59***	4.52***
	Medium	-0.49	0.21	-0.95
	High	-4.41***	-6.86***	-5.73***
S_education	Low	1.74	4.11***	4.26***
	Medium	-8.77***	-5.78***	-5.57***
	High	-7.73***	-9.04***	-12.77***
S_general	Low	0.00	-1.23**	-0.70
	Medium	-0.99	-1.71***	-2.10*
	High	-1.80	-0.74	0.90

Table A.9.2 - Dependent variable: PISA reading score

Type of ICT use	Intensity of ICT use	Disadvantaged	Medium	Advantaged
H_schoolwork	Low	4.95***	4.91***	2.54**
	Medium	0.29	-1.00*	-0.99
	High	-0.93	-1.62*	-1.95
H_communication	Low	2.41**	2.60***	1.42
	Medium	0.23	-0.63	-0.65
	High	-2.64	-3.37***	-4.42***
H_general	Low	9.55***	8.77***	6.20***
	Medium	-0.25	0.13	-0.82
	High	-5.475***	-7.21***	-6.62***
S_education	Low	2.15*	4.53***	4.21***
	Medium	-7.94***	-5.39***	-5.41***
	High	-10.99***	-10.41***	-13.58***
S_general	Low	-1.08	-1.59***	-0.91
	Medium	1.29	-0.39	-0.86
	High	-1.66	-1.09	0.99

Table A.9.3 - Dependent variable: PISA mathematics score

Type of ICT use	Intensity of ICT use	Disadvantaged	Medium	Advantaged
H_schoolwork	Low	4.79***	4.68***	3.13***
	Medium	-0.60	-1.07*	-1.02
	High	-1.79	-2.55***	-2.00
H_communication	Low	2.44**	2.24***	1.68*
	Medium	0.02	-0.66	-0.89
	High	-1.62	-2.22***	-3.73***
H_general	Low	7.76***	6.65***	4.60***
	Medium	-1.22	-0.19	-0.62
	High	-4.00***	-5.92***	-5.29***
S_education	Low	2.02*	3.69***	3.74***
	Medium	-7.05***	-4.44***	-4.97***
	High	-5.79***	-7.44***	-9.83***
S_general	Low	0.60	-0.42	-0.52
	Medium	-1.01	-1.22*	-1.42
	High	-2.05	-1.07*	0.62

Source: Own computations using PISA 2015 data.
Notes: All the coefficients presented in each sub-table come from the same regression. Within-school estimates and controlling for individual covariates. Standard-errors (not shown) clustered at the school level. *** p<0.01, ** p<0.05, * p<0.1.

Table A.10 – The role of type of schools

Dep. Variable: PISA science score		Public			Private			Difference between school types		
Types of ICT use	Intensity of ICT use	Disadv.	Medium	Advant.	Disadv.	Medium	Advant.	Disadv.	Medium	Advant.
H_schoolwork	Low	3.44***	5.34***	3.50***	11.73***	3.95***	4.96*	**		
	Medium	-1.08	-1.74***	-1.38	7.29*	1.20	0.94	**	*	
	High	-1.01	-1.64*	-0.07	-2.84	1.50	-4.04			
H_communication	Low	1.77	1.73***	0.76	0.67	1.73	-2.15			
	Medium	1.48	-0.86	-1.45	-2.89	-0.46	-0.76			
	High	-1.75	-2.75***	-4.31***	-0.43	-5.93**	-7.49**			
H_general	Low	9.31***	8.20***	5.89***	5.29	4.10**	0.62		**	*
	Medium	-1.28	0.14	-0.89	-2.52	0.17	-0.81			
	High	-5.40***	-6.60***	-6.84***	-5.29	-7.51***	-0.75			**
S_education	Low	2.39*	4.45***	5.07***	-1.25	1.86	3.62			
	Medium	-9.56***	-6.48***	-6.54***	-4.15	-4.07***	-2.40			
	High	-6.66***	-7.97***	-11.72***	-10.16**	-7.29***	-10.88***			
S_general	Low	0.56	-1.38**	-1.36	-0.74	-2.20	-0.82			
	Medium	-1.80	-1.49*	-1.97	1.40	-3.77*	-2.30			
	High	-2.64*	-1.13	0.54	3.23	-3.48*	-0.30			

Source: Own computations using PISA 2015 data.
Notes: The coefficients for disadvantaged, medium and advantaged students come from the same regression. Within-school estimates and controlling for individual covariates. Standard-errors (not shown) clustered at the school level. *** p<0.01, ** p<0.05, * p<0.1.

Table A.11 – The role of the number of computers at school

Dep. Variable: PISA science score		Computers per student LOW			Computers per student HIGH			Difference between School types		
Types of ICT use	Intensity of ICT use	Disadv.	Medium	Advant.	Disadv.	Medium	Advant.	Disadv.	Medium	Advant.
H_schoolwork	Low	3.05*	5.10***	3.91**	6.98***	5.43***	3.53*	*		
	Medium	-3.48*	-1.56*	-0.79	1.96	-0.40	-0.84	**		
	High	-1.20	-1.86	-1.32	-2.97	-1.47	-1.08			
H_communication	Low	4.98***	1.29	-0.61	0.09	2.27***	1.81	**		
	Medium	-0.52	-0.14	-0.93	1.47	-1.20	-1.23			
	High	-5.06**	-1.53	-3.61*	1.00	-4.03***	-4.45*	*		
H_general	Low	9.23***	6.99***	5.55***	7.96***	8.43***	3.83**			
	Medium	-1.15	0.52	-1.03	-0.56	-0.03	-1.01			
	High	-3.78*	-7.07***	-6.39***	-4.15**	-7.21***	-5.71***			
S_education	Low	3.94**	3.68***	4.88***	-0.38	5.10***	4.49***	*		
	Medium	-10.07***	-6.79***	-7.39***	-5.91***	-5.08***	-3.87**	*		*
	High	-5.69**	-8.75***	-12.15***	-8.42***	-9.25***	-13.88***			
S_general	Low	0.28	-2.60***	-1.57	0.55	-0.18	0.70		**	
	Medium	-0.98	-1.61	-1.29	-1.09	-2.31**	-2.51			
	High	0.99	-1.51	0.36	-4.37**	0.27	0.82	**		

Source: Own computations using PISA 2015 data.
Notes: The coefficients for disadvantaged, medium and advantaged students come from the same regression. Within-school estimates and controlling for individual covariates. Standard-errors (not shown) clustered at the school level. *** p<0.01, ** p<0.05, * p<0.1.

Table A.12 – Different groups of countries

Table A.12.1 - **Southern European countries** (EL, ES, IT, PT)

Types of ICT use	Intensity of ICT use	Disadv.	Medium	Advant.
H_schoolwork	Low	-3.32	2.37*	2.02
	Medium	-0.99	-2.33	-2.31
	High	2.47	-0.86	-4.09
H_communication	Low	0.64	-0.19	0.63
	Medium	-0.24	-1.81	-0.04
	High	-2.63	-3.92**	-8.30***
H_general	Low	11.71***	8.39***	5.02*
	Medium	0.16	1.44	2.95
	High	-2.92	-6.15***	-2.47
S_education	Low	3.34	2.81**	4.99**
	Medium	-7.97***	-5.78***	-6.91***
	High	-7.17**	-6.51***	-6.21*
S_general	Low	-	-	-
	Medium	-1.93	-7.12***	-5.04***
	High	-3.59	-0.38	-0.23

Table A.12.2 - **Central European countries** (AT, BE, DE, FR, IE, LU, NL, UK,)

Types of ICT use	Intensity of ICT use	Disadv.	Medium	Advant.
H_schoolwork	Low	8.62***	5.77***	1.02
	Medium	-0.77	-0.38	-2.78*
	High	-3.96	1.01	-0.32
H_communication	Low	4.62**	2.78***	3.34
	Medium	-5.46**	-5.07***	-9.05***
	High	-9.91***	-9.61***	-11.07***
H_general	Low	4.37**	3.07***	3.41*
	Medium	-2.24	0.10	0.72
	High	-2.56	-5.12***	-3.00
S_education	Low	1.16	4.39***	2.08
	Medium	-2.81	-1.28	-2.44
	High	-5.51**	-10.59***	-14.08***
S_general	Low	-	-	-
	Medium	-4.08***	-2.82***	-2.14*
	High	1.16	0.43	2.03

Table A.12.3 - **Nordic European countries** (DK, FI, SE)

Types of ICT use	Intensity of ICT use	Disadv.	Medium	Advant.
H_schoolwork	Low	10.59***	10.50***	9.89**
	Medium	-2.60	-5.42***	-5.60*
	High	-2.15	-2.00	-2.55
H_communication	Low	1.32	2.98	4.60
	Medium	-7.66*	-10.88***	-6.49
	High	-13.73***	-15.59***	-11.44***
H_general	Low	5.25	10.43***	2.43
	Medium	3.53	0.14	-3.27
	High	5.79	-8.00***	-7.52*
S_education	Low	7.22*	7.27***	5.92*
	Medium	-6.04*	-2.47	1.89
	High	-6.35	-4.87**	-13.22***
S_general	Low	-5.88	-5.91***	-3.97
	Medium	-6.35*	-5.40***	-10.82***
	High	-2.74	-3.04	0.49

Table A.12.4 - **Eastern European countries** (BG, CZ, EE, HR, HU, LT, LV, PL, SK, SI)

Types of ICT use	Intensity of ICT use	Disadv.	Medium	Advant.
H_schoolwork	Low	3.58	4.58***	3.71*
	Medium	-0.32	-1.27	1.04
	High	-1.78	-4.77***	-4.98**
H_communication	Low	-4.12**	-4.33***	-3.85***
	Medium	-7.01**	-5.31***	-5.18***
	High	-0.24	-2.10	-0.47
H_general	Low	11.90***	9.76***	6.28***
	Medium	-0.32	0.57	-1.73
	High	-8.06***	-6.28***	-6.97***
S_education	Low	3.78**	3.87***	5.03***
	Medium	-11.70***	-6.87***	-9.22***
	High	-6.50***	-5.15***	-7.48***
S_general	Low	0.68	-0.74	-2.19
	Medium	-3.30*	-3.85***	-4.36***
	High	-0.34	-0.18	0.64

Source: Own computations using PISA 2015 data.
Notes: The coefficients for disadvantaged, medium and advantaged students come from the same regression. Within-school estimates and controlling for individual covariates. Standard-errors (not shown) clustered at the school level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

List of country codes and abbreviations

Country codes
AT - Austria
BE- Belgium
BG – Bulgaria
CY - Cyprus
CZ - Czech Republic
DE - Germany
DK- Denmark
EE - Estonia
EL - Greece
ES - Spain
FI - Finland
FR - France
HR - Croatia
HU - Hungary
IE - Ireland
IT - Italy
LT – Lithuania
LU – Luxembourg
LV - Latvia
MT - Malta
NL – The Netherlands
PL - Poland
PT - Portugal
RO - Romania
SE - Sweden
SI - Slovenia
SK – Slovak Republic
UK – The United Kingdom

U.S. – United States of America
EU – European Union

Abbreviations
OECD - Organisation for Economic Co-operation and Development
PISA - The Programme for International Student Assessment
SES - Socio-economic status

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