Does Computer Use Increase Educational Achievements?

Student-level Evidence from PISA

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Abstract

The aim of this paper is to assess whether the use of ICT has an impact on student performances as measured in the OECD Programme for International Student Assessment (PISA) 2006. After controlling for observable students' characteristics and self-selection, we did find a positive and significant effect of the frequency of computer use on science scores. In most countries, however, this effect seems larger when computer is used at home rather than at school. This finding questions the effectiveness of educational policies aimed at promoting computer use at school as a tool for learning.

1. Introduction

In recent years the role of Information and Communication Technologies (ICTs) as a tool to raise educational achievements has attracted growing attention from both policy makers and academic researchers. While the former tend to be enthusiastic about the use of ICT in teaching and learning, the latter have found little evidence to support such an enthusiasm.

The question is far from academic. Although the value of ICT public investments in school is not known with certainty, there are clear indications that they have been substantial. In OECD countries, the average numbers of computer per student in school doubled in only three years, from 1 to 10 in 2000 to 1 to 5 in 2003. Similarly, while less than a third of OECD secondary schools had Internet access in 1995, access was virtually universal by 2001. This is currently the case for broadband connectivity in a growing number of OECD countries (OECD, 2010).

In more recent time the diffusion of ICTs in education has lost its status as a policy priority, but investments have not ceased. As the OECD observes (2010) <<education systems keep investing in technology in the belief that, sooner or later, schools and teachers will adopt it and benefit from it>>. Therefore, the question is: are ICT public investments in schools paying back?

Assessing the impact of computer use on student performances raises the same methodological issues as any program evaluation. A comparison between those who use the computer (*treated*) and those who do not (*control group*) would be legitimate only if the students in these two groups had similar characteristics. Unfortunately, there are two major reasons to expect that this is not the case.

First, the factors that affect computer use, e.g.: family background, also have an impact on student performances. Therefore, a positive correlation between computer use and student performance may simply capture the effects of a better family background (*spurious correlation*).

Second, while some of the above factors can be measured, others can be only measured with an error, eg: skills and interests, or are not observable at all, eg: attitudes. Observed differences in computer use, therefore, may reflect unobservable differences in students' characteristics. In these circumstances, the *treatment* (computer use) becomes *endogenous* because different students *self-select* into different frequencies of computer use.

One further complication in the present context is that our *treatment* (computer use) is not of the type "*treated-untreated*" (use/no use) but it may have different intensities, from high computer use to no use.

The paper deals with *spurious correlations* and *endogeneity* within a non-dichotomous "endogenous treatment model" (Vella, 1998), where the treatment consists of a discrete number of frequencies of computer use. Such a model permits to predict the frequency of computer use based on observable students' characteristics (*selection*) and to estimate the effects on student performances associated to each frequency of use (*outcome*).

The paper is organised as follows. Section 2 reviews previous studies about the relationship between ICT use and student performance. Section 3 introduces the econometric model used in this study to address these issues and its application to the PISA 2006 data. Section 4 looks at the factors that affect the frequency of computer use by students while Section 5 identifies the factors that influence student performances. Section 6 focuses on the returns from computer use at home and at school. Finally, Section 7 discusses the main policy implications of the paper.

2. Findings from previous studies

The role of ICTs in classrooms and their impact on students' performances have been the focus of an extensive literature over the last two decades. Earlier contributions have explored the effects of computer uses, while more recent studies have focused on the impact of online activities: Internet, educative online platforms, digital devices, blogs and wikis, etc.

This body of literature shows mixed results. Some studies found no significant effect of ICTs on education outcomes while others point out to a sizeable impact of ICTs on students' achievement. Both theoretical and empirical arguments may explain these mixed results.

On the theoretical ground, ICTs can be regarded as a more "productive" input in the student learning process. They can help students to acquire information for schooling purposes and to access a wider range of educational resources at home at any time of the day.

However, ICTs use in the classroom may also displace more effective teaching techniques, Some ICT applications, such as chat rooms or online games, can distract from learning at home. In addition, ICT-based applications could restrict the creativity of the learner as ICTs only allow for a pre-defined set of interactions.

The educational benefits from ICTs also depend on the capability of schools to change their organisation and teaching methods in a way that it is complementary to ICT use. Indeed, the economic literature on the "productivity paradox" (Brynjolfsson and Hitt, 2000) suggests that organisational change may be the key to unleash the educational potentials of ICTs.

Thus, the theory suggests that the impact of ICTs on student learning strongly depends on their specific uses and on the environment in which they are used.

On the empirical side, the positive effects of ICT use are generally inferred from a positive correlation between ICT and student performance (see Kirkpatrick and Cuban 1998, for example). However, to the extent the use of computer and teaching software are correlated with other inputs to education - eg: social background, parents' education, etc. - better student performance may well be a result of the latter rather than the effect of ICT use (*spurious correlation*).

Fuchs and Woessman (2004), for example, find a positive and significant correlation between the availability of computers at school and school performance in PISA; however, the correlation becomes small and insignificant when other school characteristics are taken into account.

A second issue arises from the fact that different choices about the frequencies of ICT use may reflect unobservable differences in students' characteristics, such as skills, attitudes or interests. As a consequence, one cannot compare student performance between ICT users (*treated*) and non-users (*control group*) because the two groups are not comparable. In these circumstances, the treatment becomes *endogenous* as different students *self-select* into different frequencies of computer use.

Some studies have tried to control for the endogeneity of ICT use, either using *experimental data* (Coates *et al.,* 2004; Rouse *et al*., 2004; Anstine and Skidmore, 2005; Banerjee *et al*., 2004) or exploiting *changes in policy* (Angrist and Lavy, 2002; Goolsbee and Guryan, 2002; Leuven et al. 2004; Machin *et al*., 2006).

Coates *et al.* (2004) compared student scores in face-to-face and online economics courses taught at three different institutions. After taking into account selection bias and differences in student characteristics, they report that the average scores are almost 15% higher for the face-to-face format than for the online format.

Rouse *et al*. (2004) present results from a randomized study of a popular instructional computer program designed to improve language and reading skills in the US. Their estimates suggest that while the use of computer programs may improve some aspects of students' language skills, these gains do not translate into a broader measure of language acquisition or into actual reading skills.

Anstine and Skidmore (2005) surveyed two matched pairs of on-campus and online courses, one in statistics, and the other in managerial economics. They report that after taking into account student characteristics and selection bias, students in the online format of the statistics class exam scored 14.1% less than in the traditional format, whereas, for the managerial economics class, the test scores within both formats were not significantly different.

Angrist and Lavy (2002) analyse the effects of a large-scale computerization policy in elementary and middle schools in Israele, based on a controlled comparison between schools that received funding and schools that did not receive them. They find no evidence that increased educational use of computers raised pupil test scores. In fact, they even find a negative and significant relationship between the programme-induced use of computers and the 4th grade Maths scores.

Goolsbee and Guryan (2002) found that an US program to subsidize schools' investment in Internet and communications led to an increase in Internet connections but had no impact on any measure of pupil achievement.

Leuven *et al.* (2004) find that the extra funds for computers and software in the Netherlands do not have a positive impact on pupils' achievement, and even seem to have a negative effect on language and Maths scores.

In general, those studies controlling for the *endogeneity* of ICT use tend to find no effect or even a negative effect of ICTs on student performances. There are, nonetheless, two noticeable exceptions.

Banerjee *et al*. (2004) present the results of a randomized policy evaluation carried out in two Indian States to improve the quality of education in urban slums. The authors found out that a computer assisted program, designed to reinforce mathematical skills, had a large and positive impact on math scores; however, the program did not produce positive spillovers to other subjects.

Machin *et al*. (2006) evaluated whether changes in ICT investment had any causal impact on changes in educational outcomes in English schools over the period from 1999 to 2003. Using an Instrumental Variable (IV) approach to control for endogeneity of ICT use, the authors found evidence for a positive causal impact of ICT investment on educational performance in primary schools.

The aim of the present paper is to contribute to this line of research by providing new evidence based on the OECD Programme for International Student Assessment (PISA). The approach and the data source are similar to those by Fuchs and Woessman (2004). Unlike their study, however, the present paper controls for the endogenity of computer use and provides results by country.

3. The econometric model

The OECD Programme for International Student Assessment (PISA) assesses the extent to which students near the end of compulsory education have acquired the knowledge and skills essential in everyday life. Students are tested in the domains of reading, mathematical and scientific literacy and complete a background questionnaire. In this study, we will focus on the student performance in science. Nonetheless, the scores of the three tests are highly correlated, so that the results presented for science can be generalized to math and reading as well.

Our aim is to assess whether computer use (IT^*) has an impact on PISA 2006 science scores (*Science*) after having controlled for other observable student characteristics (X):

$$Science_i = \beta' X_i + \delta(IT_i^*) + e_i \qquad (1)$$

where the subscript i *=1…….N* indicate the students, X denotes observable individual characteristics; e is an individual idiosyncratic error terms which influence the student's science scores; β denotes unknown parameters; and δ is an unknown function which generates increases science scores through additional computer use.

In the PISA 2006 survey we do not observe actual computer use IT* but only the variable IT (computer use frequency) with discrete values: 1 (never), 2 (once a month or less), 3 (a few times a month), 4 (once or twice a week) and 5 (almost every day). This means:

IT_i = 1 if $IT_i^* < \mu_1$; IT_i = 2 if $\mu_1 < IT_i^* \leq \mu_2$; IT_i = 3 if $\mu_2 < IT_i^* \leq \mu_3$; IT_i = 4 if $\mu_3 < IT_i^* \leq \mu_4$; IT_i = 5 if $\mu_4 < IT_i^*$.

We can write the observable computer use frequency as the following *j* dummy variables based on these discrete values:

$D_{ij} = 1 \; if \; IT_i = j$ and

$D_{ij} = 0 \; otherwise$

Therefore, equation (1) can be estimated through the following empirical model which comprises the reduced form representations of the student's science score and computer use:

$$Science_i = \beta' X_i + \sum_{j=1}^{5} \delta_j D_{ij} + e_i, \qquad i = 1 \ldots\ldots N \qquad (2)$$

$$IT_i^* = \lambda' Z_i + v_i, \qquad i = 1 \ldots\ldots N \qquad (3)$$

$$D_{ij} = 1 \; if \; IT_i = j; \quad D_{ij} = 0 \; otherwise \qquad i = 1 \ldots\ldots N; \; j = 1 \ldots\ldots 5 \qquad (4)$$

where X_i and Z_i continue to denote vectors of exogenous characteristics, possibly overlapping; e_i and v_i are jointly normally distributed error terms with zero means, variances σ_e^2 and σ_v^2 and covariance σ_{ev}; β, δ and λ are vectors of parameters and the effects of computer use are captured by the δ's.

The system of equations (2)-(4) is known as an "endogenous treatment model". The primary difficulty in consistently estimating the parameters from (2) is the endogeneity of the computer use dummy variables. This is due to the potential for students to choose their frequency of computer use (*self-selection*). In general, therefore, $\sigma_{ev} \neq 0$, which implies that computer use is not weakly exogenous to the science score.

Two estimation procedures are available to overcome the inconsistency in (2). The first procedure consists in estimating IT_i^* in (3) by Probit and then replacing IT_i with $\widehat{IT_i}$ in (4) to generate the dummies D_{ij}. The shortcoming of this procedure is that, if $X_i = Z_i$, D_{ij} and X_i likely to be strongly collinear through Z_i and the estimates of β and δ will have large standard errors. In general, the identification of (2) requires an instrumental variable, although there are frequently few candidates for simultaneous exclusion from X_i and inclusion in Z_i.

The second procedure consists in estimating the corresponding Probit residual in (3), $\widehat{v_i}$ and including both $\widehat{v_i}$ and D_{ij} in (2). The Probit residual is known as a *generalized residual* (Gourieroux *et al.*, 1987). By construction, the $\widehat{v_i}$ are uncorrelated with Z_i, over the whole sample. Therefore, the consequence of a high degree of collinearity between the generalized residual and the Z_i, which is a concern in the first procedure, does not arise. Therefore, this model is identified without exclusion restrictions due to the nonlinearity of the residual.

Equation (2) can be rewritten as:

$$Science_i = \beta' X_i + \sum_{j=1}^{5} \delta_j D_{ij} + \hat{v}_i, \qquad i = 1 \ldots\ldots N;\ j = 1 \ldots\ldots 5 \qquad (2')$$

and be estimated by least squares.

One shortcoming of equation 2' above is that the coefficients on X_i are constrained to be equal across all frequencies of computer use. Therefore, any differences in the coefficients will be captured by the dummies on the intercepts, ie: by the computer dummies. As a consequence, the estimated effects of computer use will be biased due to a misspecification of the functional form. To avoid this undesirable outcome, we will estimate the following equation:

$$Science_i = \sum_{j=1}^{5} \beta_j X_i + \sum_{j=1}^{5} \delta_j D_{ij} + \hat{v}_i, \qquad i = 1 \ldots\ldots N;\ j = 1 \ldots\ldots 5 \qquad (2'')$$

which allows for the coefficients of Xi to vary across frequencies of computer use.

Computer use by location

The PISA 2006 survey includes questions about the location of student computer use. The survey asks students to rate their frequency of computer use at three locations: home, school, and other places. We can test whether computer use has different effects at home and at school by rewriting equation (2'') as follows:

$$Science_i = \sum_{j=1}^{5} \beta_j X_i + \sum_{j=1}^{5} \delta_j^h D_{ij}^h + \sum_{j=1}^{5} \delta_j^s D_{ij}^s + \sum_{j=1}^{5} \delta_j D_{ij} + \hat{v}_i, \quad i = 1 \ldots\ldots N;\ j = 1 \ldots\ldots 5 \quad (2''')$$

where *s* and *h* denote at school and at home, respectively, the *D*'s are dummies for the frequency of computer use and the effects of computer use on science scores are captured by the δ's.

PISA plausible values

For each test and each student, PISA reports five plausible values. None of these values is the actual score of a student but they represent five random values drawn from the posterior distributions of the students' scores (OECD, 2005). This implies that, in order to obtain unbiased estimates, we had to run the same regression model five times, once for each plausible value of the science scores, and compute the unbiased estimates and their standard based on these five sets of estimates. However, the estimates generated by the five regressions and their standard errors turned out to be almost identical. For sake of simplicity, we have reported only the estimates for the first plausible value.

PISA replicate weights

As many international educational surveys, PISA 2006 uses a two-stage sample design. As a result, sampling variances have to be estimated through replication methods. These methods function by generating several subsamples, or replicate samples, from the whole sample. The statistic of interest is then estimated for each of these replicate samples and then compared to the whole sample estimate to provide an estimate of the sampling variance.

A replicate sample is formed simply through a transformation of the full sample weights according to an algorithm specific to the replication method. PISA 2006 uses the Fay's variant of the Balanced Repeated Replication with a Fay coefficient equal to 0.5 and 80 replicates. This means that each regression was run 81 times, first by weighting the data with the student final weights and then by weighting the data with each of the 80 replicates.

4. What explains ICT use?

The first step of our analysis is to estimate the frequency of computer use as a function of the observable characteristics of students (*selection*). The PISA 2006 surveys contain several variables that can be used as a proxy for the characteristics of the students, their families and their schools. We used these indicators to explain the determinants of computer use at home and at school. We did not consider computer use in other place both because it represents a fairly small percentage, particularly in OECD countries, and because the type of use is likely to be more diverse than at home and at school and less related to education.

We estimated the same econometric model (Ordered Probit, equation 3 in Section 3) in each of the 33 countries – 26 OECD and 7 partner countries - who filled out the ICT survey.

We begun with including all variables available in the PISA survey and that could be related to determinants of computer use based on previous studies: gender, immigration, computer possession, family wealth, educational attainments of the parents, etc. Then, we dropped variables that were not statistically significant one at the time, starting with the less significant one. The final results are reported in Table 1.

Table 1 about here

Three variables turn out to have a significant impact in a large majority of countries. The first variable is **gender**: male students use computers at home more frequently than female students in 24 countries. In the remaining countries, we found no difference in the frequency of computer use between males and females.

The second variable is the level of **family wealth**. This variable is measured by an index (WEALTH) based on the possession of cellular phones, televisions, cars, and other country specific items (Table 1). Previous studies have shown that household possessions are a more reliable indicator of family wealth than income.

In all countries, the wealth index has a positive sign: the higher the wealth of the student's family, the more he would tend to use computer at home. In most countries, however, this effect is not monotonic and tends to decrease for high income families (WEALTH squared has a negative sign). Only in Turkey and Chile the positive effect of wealth seems to be stronger for high income families.

The third factor explaining the frequency computer use is the level of **education and cultural resources available at home**. These variables are also measured by two indexes. The index of educational resources (HEDRES) is composed of various school items such as the availability of a room for studying, a calculator, books, a computer for school work and educational software (Table 3). The index of home possession (HOMEPOS) includes all items of the wealth index and the educational resources index (except for the item "school dedicated computer at home") plus further cultural resources, eg: books of poetry and classic literature, works of art. The sign of these two indexes is always positive: more educational and/or cultural resources tend to result in higher computer use.

Table 2 about here

Other factors turn out to have a positive effect on the frequency of computer use in a significant number of countries (the sign of the effect in brackets):

Parents' characteristics

- their highest level of education(+);
- whether one of the parents has a science related degree (+);
- whether one of the parents is a white collar (+);

Student's characteristics

- whether s/he is first or second generation immigrant (+);

School characteristics

- the number of teachers per student (+);
- the quality of educational resources (+);
- the size of the school (+);

ICT access in school

- the number of computers per student at school (+).

5. What explains student performance?

The second step of the analysis is to estimate the returns from computer use (*outcomes*), controlling for observable and unobservable student's characteristics. Observable characteristics are proxied by a set of PISA variables measuring household wealth, parents' education, school characteristics and student's skills and attitudes. Unobserved students' characteristics are controlled for through the generalized residuals estimated from the selection equation (see Section 3 above for more details).

As discusses, we will focus on the student performance in science. Nonetheless, the scores of all PISA tests are highly correlated, so that the results presented for science provide information also about math and reading.

We estimated the same statistical model (OLS, equation 2'' in Section 3) to explain science scores in each of the 33 countries – 26 OECD and 7 partner countries – that filled out both the general PISA survey and the ICT module. We begun with including all variables available in PISA and that, based on previous studies, could be related to determinants of science performance. In addition, we included the frequency of computer use and the measure of unobserved students' characteristics (generalised residuals) estimated in the previous section. We also allowed for the estimated coefficients to vary across computer use frequencies (see Section 3 for more details).

In additional to students' characteristics, the educational literature stresses the importance of peer and contextual effects. These are commonly proxied by school-average of students' performances. In the econometric analysis, however, these variables raise an issue of endogeneity: to the extent students or their parents can choose their school, one would expect better students/wealthier parents to choose a school with higher average performances. Unfortunately, a selection model that tried to address the endogeneity of both school and ICT use would become unmanageable. In order to minimize the endogeneity issue due to potential school selection, our analysis include a set of school-level variables which are not computed based on students' performances and are less likely to be endogenous: school size, principal evaluation, and the number of teacher per student.

The final results are reported in Table 3, while the estimated coefficients on the computer use dummies are reported in Table 4. In most countries, the variables that affect PISA science scores are the following:

Students' characteristics

- Gender;
- Immigration status;
- Interest in science;
- Motivation to continue learning about science.

Parents' characteristics

- Science-related carrier;
- Educational attainments;
- Occupation.

Household characteristics

- Home possession;
- Educational resources;
- Number of books at home.

School characteristics

- Size of the school;
- Quality of educational resources.

Frequency of computer use

- Frequency of computer use in any location;
- Frequency of computer use at school and at home.

Table 3 about here

The first set of factors is related to students' characteristics. The variable **gender** measures the difference in science scores between males and females. The variable has a positive sign, showing that males tend to have higher scores than females, when controlling for all other differences. The difference in science scores between males and females ranges between 18 points in Chili and 6 points Norway. Iceland is the only country where science scores are higher for female students (9 points).

The variable **immigration** measures the difference in science scores between "immigrants" and native. Its sign is negative in most countries and indicates that first and second generation immigrants tend to have lower science scores than natives. Immigration appears as one of the main determinants of the observed differences in science scores. It explains over 90 points in Finland, 70 points in Austria and Iceland, 60 points in Belgium and Thailand, and about 50 points in Denmark, Germany, the Netherlands, Sweden and Switzerland. In most of the remaining countries, the effect of this variable is between 20 and 30 points. The differences due to immigration are the lowest in Australia (about 10 points) while Macao (China) and Serbia are the only countries where immigrants have higher science scores than native (13 and 12 points, respectively).

The 2006 PISA dataset has nine science indexes related to students' attitudes and perceptions of science. Two of these indexes were significant and positive: the first measures students' **interest in science** (INTSCIE); the second students' motivation to continue learning about science or pursuing a **science-related career** in the future (*SCIEFUT)*[1]. In most countries, 1-point increase in both indexes accounts for between 20 and 30 points of the observed differences in science scores. Therefore, students with a stronger interest in science will tend to have better scores in science.

The second set of variables is related to the characteristics of parents. **Parental education** is often used in the analysis of educational outcomes. It is measured by the highest number of year in education of either parent (PARED)[2]. Our findings show that longer the time parent spent in education, the higher the expected science scores of their children. The effect is the largest in

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[1] The typical range of variation is between -3.5 and 3.5 for INTSCIE and -2.5 and 2.5 for SCIETFUT.

[2] The index PARED varies between 0 and 18 years of education.

Japan, where one additional year of either parent's education increase the science scores by over 8 points; Poland (7 points) and Hungary (6 points). It is the smallest in Canada and Macao, China (about 1 point).

Parents' occupations are classified according to the level and specialization of the skills they required. The index (HISEI) is based on the International Standard Classification of Occupations (ISCO-88) and ranges between 16 and 90. We found out that the higher the skills content of the occupation of either patent, the higher the science scores of his/her children. The effect on science scores can be as large as 145 points in the Czech Republic, 108 points in the Netherlands and New Zealand, and over 100 points in Portugal and Sweden.

Finally, the index PARSCI measures whether either **parent has a science-related career**. Its positive sign indicates that students have better science scores if one of their parents has a science-related career. Its effect ranges between 6 points in Norway and Belgium and 27 points in Thailand.

The third set of variables measures household characteristics. Educational literature points out the important role of family wealth on students' performances. The effects of wealth, however, are ambiguous. On the one hand, higher wealth may provide for more educational and cultural resources, which have a positive impact on students' score. On the others, higher wealth may weaken students' incentives to learn and may reduce the cost of leisure relative to education.

In our model, these two opposite effects are captured by two variables. The first variable is the level of **family wealth**. This variable is measured by an index (WEALTH) based on the possession of cellular phones, televisions, cars, and other country specific items (Table 2). Previous studies have shown that household possessions are a more reliable indicator of family wealth than income.

The second variable is the index of **home possession** (HOMEPOS), which includes all items of the wealth index, a set of educational resources, eg: the availability of a room for studying, a calculator, books, educational software; and a set of cultural resources, eg: books of poetry and classic literature, works of art.

Therefore, a higher level of wealth would result into a higher value of both the wealth index and the home possession index. On the contrary, a higher level of educational or cultural resources would increase the home possession index but they would not affect the wealth index.

Our regression results show that the effect of family wealth is significant and negative while the effect of home possession is significant and positive. As discussed above, these results need to be interpreted together.

The negative sign the wealth index captures the negative effect of wealth on the students' incentives to learn while the positive impact of the home possession index captures the positive effect of educational and cultural resources on students' performance.

The effects of cultural and educational resources at home on sciences score tend to be large. In Bulgaria, 1-point increase in home possession would result into a 50-point increase in science scores. The increase is over 45 points in Hungary and Lithuania, no less than 35 points in Greece, Poland, Serbia and the Slovak Republic and just below 30 points in the Czech Republic, Denmark, Italy, Japan, Macao (China) and Slovenia[3].

PISA 2006 also reports interesting information about the **number of books** in a household. We found that students from households with a large number of books (over 100) tend to achieve better scores in science. The role of this factor appears even stronger when one considers that the number of book also enter the home possession index.

The last set of variable looks at the characteristics of the school. The **size of school** (SCHSIZE) turned out to have a significant and positive impact on science scores in most countries. A positive effect may be an indication that large schools are proportionally better endowed with physical and human resources – eg: schools in urban versus rural areas – or it may be due to some “economy of scale” in the use of educational resources: as not all students use libraries, laboratory, tutors, etc. at the same time, students in larger schools would benefit more of a same stock of educational resources per capita.

This effect is fairly large: an increase in the school size by 100 students would result into an increase in science scores by 8 points in Slovenia, 7 in Bulgaria, and over 4 in Austria, Germany and Portugal. A negative impact of the size of school was found only in Iceland.

The **quality of educational resources** (SCMATEDU) is based on the self-evaluation of the school principal and provides a further measure of educational resources at school[4]. It has a positive and significant effect: 1-point increase in the index of educational resources would increase science scores by 10 points in Chile and Macao (China) and by over 7 points in Greece, Ireland, Switzerland and Lithuania.

6. Does ICT use improve student performance?

The final set of variables consists of dummies for the frequency of computer use. We first ask whether higher frequencies of computer use are associated to higher science scores, independently of whether the computer is used at school, at home or in both locations. We then consider whether the effects of computer use differ across locations.

Table 4 shows that higher frequency of computer use is associated to higher science scores in all countries. In a large majority of them, this effect becomes significant when the computer is used “once or twice a week” or “almost every day”. Spain and Croatia are the only countries where using a computer “a few times a month” seems to have a significant effect on science scores.

The educational returns from using a computer “once or twice times a week” appears the largest in the Czech Republic and Norway: the science scores of students using a computer “once or twice week” are 40 points higher than those of students with a lower frequency of computer use. In Hungary and Croatia this effect is 30 points while in most of the remaining countries is

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[3] Both WEALTH and HOMEPOS have an OECD average of zero and an OECD standard deviation of one.

[4] SCMATEDU typically ranges between -3.5 and 3.5.

about 20 points. Thailand and the Slovak Republic show the lowest increase from using a computer "once or twice a week" (7 and 9 points, respectively).

The educational returns from using a computer "almost every day" turns out to the largest in the Czech Republic and Chile: the science scores of students using a computer "almost every day" are, respectively, 70 and 51 points higher than those of students using a computer "once or twice a week". The difference is about 40 points in Hungary, Norway, Portugal, Croatia and Macao (China) and no less than 35 points in Australia, Belgium, Italy, the Netherlands, Spain, and Lithuania. The lowest effect is found in New Zealand (7 points), Ireland (9 points) and Poland (10 points).

In brief, our results suggest that computer use does have a positive and significant effect on science scores.

One related question is whether the effects of ICT on student performance are different when ICT is used at home or at school. On the one hand, we may expect ICT use at school to be accompanied by some ICT training, to be more closely related to educational activities and to benefit from the expertise of a teacher (Wenglinsky, 2002). On the contrary, ICT use at home may be more related to leisure activities and does not benefit from any formal training (Fuchs and Woessmann, 2004).

On the other hand, students using computer at home are likely to be more interested in ICTs, have more scope for experiment and self-learning and can search and discover the resources – both in terms of software and web content - that are best suited to their needs (Ravitz, Mergendoller and Rush, 2002; Valentine *et al.*, 2005; OECD, 2006).

We can further develop our analysis to explore this question. We have found that higher frequency in computer use is associated with higher science scores. We can now distinguish whether computer use occurs at school or at home and test whether the effects on science scores vary with location.

As a same student may use computer both at home and at school, the location of computer use is defined according to the location of the highest frequency of use. For example, if a student uses the computer once a week at home and almost every day at school, he would be considered as using the computer at school.

There are cases, however, when a student uses a computer at home and at schools with the same frequency. In such circumstances it is not possible to make a distinction between home and school: the effects would depend on whether the use is closer to the "school use" or the "home use".

Table 5 shows the estimated increase in average science scores associated to computer use at home and at school. Two results are worth to be highlighted. First, in a large majority of countries, computer use at school has no significant effect on science score. Therefore, the above findings that computer use is associated to higher science scores seems to be entirely driven by computer use at home only. This is notably the case of Belgium, Finland, Germany, Greece, New Zealand, Poland, Switzerland, Bulgaria, Croatia and Latvia.

Second, when computer use at school does have an effect on science scores, this is smaller than the effect of computer use at home. In a number of countries this differential is very large. In Chile, Italy and Thailand, the increase in science scores is about 25 points higher when a computer is used "almost every day" at home rather than at school. This differential is 19 points in Spain, 16 Points in Lithuania and 15 points in the Netherlands.

No significant differences between computer use at home and at school were found in the Czech Republic, Slovenia, Sweden and Macao, China. Austria is the only country where computer use at school has a larger effect on science scores than at home (3 points).

As for the effect of computer use "at home and at school", in most countries this seems smaller than the effect of computer use at home only. This suggests that the use of computer "at home and at school" is closer to the use at school than the use at home. There are, however, a few interesting exceptions where the effects on science scores are larger when computer is used both at home and at school. This is the case of Australia and, even more, Austria, where the effect of computer use "at home and at school" is significantly larger that the effect of computer use "at home" or "at school" separately.

To sum up, computer use seems to have a positive effect on science scores. However, this effect is manly driven by the use of computer at home rather than at school.

7. Implications for educational policy

Our analysis has shown that computer use does increase student performance (science scores) in PISA. This result has been obtained after having controlled for observable (*spurious correlation*) and unobservable (*selection*) differences among students, their families and their schools. The estimated increase in science scores, however, seems to be due mainly to the use of computer at home whereas the effects of computer use at school seem smaller or none.

This finding questions the effectiveness of educational policies aimed at promoting computer use at school as a tool for learning. Traditionally, these policies have focused on promoting ICT access and use at school but they have tended to neglect ICT access and use at home. If ICTs turn out to be more effective for educational purposes when they are used at home, educational policies should shift the mix of ICT access and use from school to home. Two measures appear suitable to achieve this objective.

The first is to promote ICT access at home, eg: by providing students and their families with financial support for the purchase of a computer or for the subscription to the Internet. The second measure is to ensure closer complementarities between the use of computer at home and at school. In particular, to make sure that the self-learning and exploration which is characteristic of ICT use at home becomes integrated in the use of ICT at school. By this way, the potential opened up by ICT use at home may be fully exploited in the formal learning environment offered in school.

Whether these measures may deliver the expected results, it is a question that the forthcoming PISA surveys may want to take aboard.

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TABLES AND FIGURES

Table 1. Determinants of computer use

	WEALTH	WEALTH2	HOMEPOS	HEDRES	PARED	HISEI	PARSCI	WHITEBLUE	IMMIGRATION	GENDER	SCHSIZE* 100	SCMATEDU	RATCOMP	F	Nr. of observations	Population size
Australia	**0.223**		**0.323**			**0.005**			**0.316**		**0.018**			**76.40**	12362	207458
	0.038		0.045			0.001			0.043		0.005					
Austria	**0.096**		**0.266**		**0.023**	**0.006**			**0.636**	**0.199**			*0.388*	**33.51**	4287	78227
	0.055		0.057		0.010	0.002			0.092	0.067			0.149			
Belgium	**0.499**	**-0.104**		**0.204**						**0.192**	**0.001**		**-0.043**	**127.01**	7513	102189
	0.035	0.021		0.024						0.040	0.000		0.004			
Canada	**0.431**			**0.161**	**0.031**	**0.004**			**0.319**	**0.177**			**0.972**	**38.57**	16802	271805
	0.040			0.024	0.010	0.001			0.060	0.038			0.172			
Chile	**0.638**	**0.096**	**0.305**		***0.020***								**3.260**	**272.73**	3511	154553
	0.079	0.025	0.061		0.009								1.040			
Czech Republic	**0.392**			**0.413**			**0.182**			**0.450**				**89.42**	4695	96765
	0.042			0.034			0.075			0.057						
Denmark																
Finland	**0.392**			**0.167**						**0.357**	***0.031***			**52.70**	4163	54046
	0.034			0.027						0.048	0.015					
Germany	**0.431**			**0.191**		*0.004*		***0.163***	**0.359**	**0.481**		*0.045*		**65.26**	3738	687142
	0.037			0.026		0.002		0.074	0.068	0.045		0.026				
Greece	**0.381**	***-0.048***	0.107						**0.231**	**0.489**			***0.511***	**83.60**	4129	80691
	0.052	0.023	0.049						0.065	0.042			0.261			
Hungary	**0.205**		**0.325**					***0.128***		**0.301**			**0.722**	**81.66**	3955	92655
	0.063		0.059					0.051		0.051			0.150			
Ireland	**0.243**		**0.232**			**0.006**								**102.85**	2967	35390
	0.059		0.052			0.001										
Iceland	**0.277**									**0.429**	***-0.047***			**19.98**	3367	4103
	0.048									0.068	0.000					

	WEALTH	WEALTH2	HOMEPOS	HEDRES	PARED	HISEI	PARSCI	WHITEBLUE	IMMIGRATION	GENDER	SCHSIZE* 100	SCMATEDU	RATCOMP	F	Nr. of observations	Population size
Italy	***0.112***	**-0.078**	**0.237**							**0.407**				**139.42**	18133	422440
	0.051	0.020	0.046							0.035						
Japan			**0.114**	**0.182**	**0.034**					***0.100***				**300.40**	4272	794391
			0.027	0.020	0.010					0.043						
Netherlands	**0.504**	**-0.168**						***0.193***			***0.013***			**20.74**	4102	159459
	0.078	0.046						0.096			0.006					
New Zealand	**0.347**			**0.139**				***0.140***	**0.312**	**0.129**				**37.14**	3708	41272
	0.032			0.031				0.069	0.065	0.047						
Norway	**0.235**	***-0.059***	***0.135***					***0.245***		**0.304**			**0.911**	**20.48**	3554	44618
	0.073	0.029	0.060					0.096		0.060			0.345			
Poland	**0.232**		**0.485**		***0.031***			*0.088*		**0.410**			**-0.492**	**171.46**	4772	441308
	0.061		0.053		0.013			0.049		0.039						
Portugal	**0.290**	**-0.084**	**0.244**							**0.211**	**0.016**		***1.269***	**100.34**	4374	77248
	0.064	0.024	0.058							0.050	0.005		0.582			
Slovak Republic	**0.207**		**0.318**					**0.119**		**0.436**				**104.8**	4190	66979
	0.059		0.056					0.050		0.048						
Slovenia	0.406	-0.103				0.007			0.486	0.339						
	0.035	0.023				0.002			0.104	0.046						
Spain	**0.442**			**0.327**						**0.185**	**0.232**	**0.053**		**166.08**	16134	313251
	0.024			0.019						0.041	0.009	0.019				
Sweden	**0.385**	**-0.105**		**0.136**						**0.397**				**42.85**	3457	99169
	0.056	0.035		0.046						0.064						
Switzerland	**0.448**	**-0.067**		**0.101**				**0.151**	**0.320**	**0.181**				**82.24**	10197	73057
	0.025	0.023		0.020				0.049	0.061	0.036						
Turkey	**0.932**	**0.154**	***0.099***						**0.823**	*0.123*			**3.043**	**61.97**	2833	376773
	0.092	0.022	0.048						0.237	0.067			1.138			

	WEALTH	WEALTH2	HOMEPOS	HEDRES	PARED	HISEI	PARSCI	WHITEBLUE	IMMIGRATION	GENDER	SCHSIZE* 100	SCMATEDU	RATCOMP	F	Nr. of observations	Population size
Bulgaria	**0.484**		**0.338**	**0.025**		**0.006**				**0.225**	**0.023**			**80.93**	3529	57394
	0.071		0.059	0.011		0.002				0.058	0.009					
Croatia			**0.441**							**0.422**			**1.783**	**127.96**	4162	37112
			0.031							0.049			0.704			
Latvia	**0.447**		**0.305**								**0.037**	**0.109**		**115.79**	3956	24308
	0.090		0.083								0.010	0.040				
Lituania	**0.572**		**0.168**			**0.007**				**0.400**	**0.027**		**1.989**	**101.46**	4130	44047
	0.075		0.063			0.002				0.049	0.009		0.754			
Macao, China	**0.234**		**0.175**							**0.309**				**69.33**	4206	5641
	0.061		0.059							0.052						
Serbia	**0.363**		**0.241**			**0.009**				**0.312**				**163.16**	4018	61788
	0.066		0.054			0.001				0.042						
Thailand	**0.202**		**0.264**		**0.023**	**0.006**				**0.114**			**1.352**	**56.14**	4984	509641
	0.045		0.051		0.006	0.002				0.049			0.476			

Note: Standard errors below (white rows). All estimates significant at 1% except: ***significant at 5%***; *significant at 10%*; <blank>: *non significant.*

Table 2. Items included in PISA indexes: WEALTH, HEDRES and HOMEPOS

		Item is used to measure index		
		WEALTH	*HEDRES*	*HOMEPOS*
Q13	In your home, do you have			
ST13Q01	A desk to study at		X	X
ST13Q02	A room of your own	X		X
ST13Q03	A quiet place to study		X	X
ST13Q04	A computer you can use for school work		X	
ST13Q05	Educational software		X	X
ST13Q06	A link to the Internet	X		X
ST13Q07	Your own calculator		X	X
ST13Q08	Classic literature (e.g., <Shakespeare>)			X
ST13Q09	Books of poetry			X
ST13Q10	Works of art (e.g., paintings)			X
ST13Q11	Books to help with your school work		X	X
ST13Q12	A dictionary		X	X
ST13Q13	A dishwasher (country-specific)	X		X
ST13Q14	A <DVD or VCR> player (country-specific)	X		X
ST13Q15	<Country-specific wealth item 1>	X		X
ST13Q16	<Country-specific wealth item 2>	X		X
ST13Q17	<Country-specific wealth item 3>	X		X
Q14	How many of these are there at your home?			
ST14Q01	Cellular phones	X		X
ST14Q02	Televisions	X		X
ST14Q03	Computers	X		X
ST14Q04	Cars	X		X
Q15	How many books are there in your home			X

Table 3. Determinants of science scores

	GENDER	IMMIGRATION	WEALTH	HOMEPOS	HISEI	WHITEBLUE	PARED	PARSCI	INTSCIE	SCIEFUT	BOOKS	SCHSIZE * 100	SCMATEDU	SLOPE DUMMIES	F	R2	NR. OF OBSERVATIONS	POPULATION SIZE
Australia		**-9.79**	**-23.24**	**16.53**	**0.86**	***7.74***	**2.91**		**10.62**	**18.03**	**29.48**	**0.96**	**6.12**	no	**267.10**	0.26	12226	205258
		3.47	2.74	2.08	0.08	3.64	0.54		1.16	1.13	2.03	0.37	1.58					
Austria	**9.50**	**-74.52**	**-17.94**	**16.20**	**0.74**				**14.91**	**7.42**	**36.93**	**4.44**		no	**81.92**	0.35	4269	77888
	3.80	7.94	3.72	3.79	0.10				2.13	2.03	3.74	0.98						
Belgium		**-61.36**	**-20.27**	**20.69**	**1.04**			***6.08***	**13.99**	**13.59**	**16.10**	**-0.07**		**yes**	**137.83**	0.31	7405	100696
		5.47	3.42	3.87	0.09			2.58	2.04	1.44	2.72	0.02						
Canada	**8.87**	**-21.43**	**-15.31**	**7.31**	**0.98**		***1.30***	**7.35**	**9.80**	**16.33**	**30.86**	**0.98**		no	**126.28**	0.21	16698	270319
	1.84	3.60	3.07	2.85	0.07		0.55	2.67	1.48	1.15	2.60	0.30						
Chile	**18.40**	***-32.63***	**-24.85**	**16.48**	**0.78**		**2.46**	***11.16***	**4.49**	**5.94**	**20.88**		**10.30**	no	**38.35**	0.26	3446	151631
	3.36	15.79	4.94	3.86	0.13		0.50	5.02	1.60	1.67	4.71		3.52					
Czech Republic	**10.23**	**-38.48**	**-34.46**	**28.34**	**1.62**				**14.10**		**29.33**	**3.47**		no	**68.20**	0.24	4652	95716
	3.75	11.40	5.47	5.61	0.14				1.82		4.44	0.00						
Denmark	**11.05**	**-54.59**	**-19.18**	**28.95**	**0.80**		**2.39**			**19.15**				no	**68.93**	0.22	2754	34211
	2.93	8.80	2.23	2.46	0.12		0.81			1.66								
Finland	**8.14**	**-90.90**	**-13.71**	**9.55**	**0.55**		**1.79**		**17.68**	**16.10**	**26.60**			**yes**	**114.84**	0.24	4122	53503
	2.69	16.87	3.60	3.95	0.09		0.55		1.83	1.75	2.81							
Germany	**8.03**	**-52.96**	**-15.96**	**15.29**	**0.71**		**2.75**	**11.78**	**16.28**	**7.64**	**27.96**	**4.07**		no	**80.18**	0.32	3690	677466
	2.70	6.18	4.77	3.67	0.09		0.47	3.05	2.11	1.56	3.18	0.83						
Greece		**-32.60**	**-36.29**	**34.50**	**0.79**		**3.15**	***8.67***	**19.08**				***7.02***	**yes**	**49.18**	0.26	4112	80342
		8.40	4.41	4.56	0.12		0.58	3.56	1.80				3.06					
Hungary	**15.59**		**-50.32**	**45.22**	**0.78**		**6.36**	***6.58***	**13.13**		**16.83**			no	**76.66**	0.32	3947	92467
	2.60		4.53	4.60	0.13		0.71	2.98	1.99		3.37							
Ireland	**11.86**		**-22.89**	**15.88**	**0.75**		***1.70***		**12.67**	**15.44**	**31.02**		***7.63***	no	**68.79**	0.26	2950	35177
	3.73		3.94	4.08	0.11		0.71		1.89	1.93	4.07		3.32					
Iceland	**-8.74**	**-72.19**	**-34.02**	**18.19**	**0.68**		**3.53**		**13.18**	**17.32**	**22.31**	**-4.33**	**3.68**	no	**94.88**	0.26	3323	4050
	2.66	12.76	4.35	4.12	0.10		0.53		1.97	2.29	3.54	0.74	1.46					
Italy		**-29.11**	**-37.71**	**29.90**	**0.91**				**15.22**		**22.79**	**2.40**		***yes***	**65.26**	0.19	17712	412609
		5.85	3.85	4.27	0.08				1.30		2.82	0.49						

	GENDER	IMMIGRATION	WEALTH	HOMEPOS	HISEI	WHITEBLUE	PARED	PARSCI	INTSCIE	SCIEFUT	BOOKS	SCHSIZE * 100	SCMATEDU	SLOPE DUMMIES	F	R2	NR. OF OBSERVATIONS	POPULATION SIZE
Japan			**-31.14**	**29.21**			**8.07**		**19.90**	**12.99**		**3.76**			**354.79**	0.24	4272	794391
			4.60	3.93			0.85		1.69	2.00		0.76						
Netherlands	**8.72**	**-47.26**	**-24.29**	**21.30**	**1.20**			**9.36**	**14.76**	**8.67**	**20.05**	**3.17**		no	**130.43**	0.33	3978	154597
	2.92	6.80	3.82	3.56	0.11			3.02	1.79	1.83	3.50	0.64						
New Zealand		**-23.94**		**8.62**	**1.19**		**2.68**		**12.26**	**18.19**	**38.37**	**0.92**	***4.77***	no	**150.44**	0.27	3686	41060
		4.35		2.15	0.11		0.79		1.97	2.03	3.76	0.26	2.21					
Norway	*5.65*	**-33.47**	**-25.35**	**15.94**	**0.92**			***6.08***	**20.37**	***4.82***	**26.90**			no	**95.31**	0.22	3499	43927
	3.14	7.57	3.82	3.76	0.10			2.78	1.57	2.02	3.98							
Poland	**5.87**		**-38.86**	**35.49**	**0.62**		**7.36**		**12.83**		**16.21**	***0.20***		no	**72.04**	0.20	4751	439445
	2.33		3.51	3.25	0.11		0.89		1.76		3.01	0.09						
Portugal	**6.54**	**-36.27**	**-22.04**	**25.53**	**1.15**			**12.71**	**7.82**	**16.39**	***7.75***	**4.02**		***yes***	**93.97**	0.29	4320	76219
	2.39	7.22	3.74	4.09	0.09			3.95	2.14	1.55	3.48	0.65						
Slovak Republic	***6.21***		**-41.41**	**37.01**	**0.86**	**14.08**	**3.64**	**10.62**	**13.28**	**20.32**	**2.37**			no	**49.32**	0.25	4178	66785
	3.16		4.45	4.64	0.13	4.01	0.81	3.64	1.55	3.18	1.14							
Slovenia	**9.42**	**-30.33**	**-35.94**	**30.08**	**0.92**		**3.69**		**11.67**	**9.11**	**19.49**	**8.25**		no	**130.98**	0.34	5535	18114
	2.34	4.96	3.50	3.30	0.12		0.77		1.86	1.57	3.87	0.43						
Spain	**10.40**	**-34.28**	**-34.85**	**22.89**	**0.80**		**1.82**		**10.52**	**12.26**	**22.56**			no	**174.07**	0.25	15931	308851
	2.17	5.80	2.84	3.29	0.08		0.35		1.19	1.23	2.50							
Sweden		**-48.83**			**1.15**				**20.03**		**33.29**	***2.52***		***yes***	**104.08**	0.27	3407	97845
		4.67			0.08				2.06		3.38	1.19						
Switzerland	**7.01**	**-56.14**	**-16.71**	**11.02**	**0.85**		**2.89**		**20.97**	**9.75**	**28.48**	**1.66**	**7.97**	no	**160.95**	0.36	10124	72522
	2.28	3.16	3.02	3.27	0.09		0.49		1.55	1.43	2.85	0.50	2.16					
Turkey			**-26.27**	**33.34**	**0.84**		**3.99**		**14.91**					no	**17.97**	0.26	2893	384596
			4.92	4.48	0.14		0.73		1.71									

	GENDER	IMMIGRATION	WEALTH	HOMEPOS	HISEI	WHITEBLUE	PARED	PARSCI	INTSCIE	SCIEFUT	BOOKS	SCHSIZE * 100	SCMATEDU	SLOPE DUMMIES	F	R2	NR. OF OBSERVATIONS	POPULATION SIZE
Bulgaria	***9.19***		**-52.67**	**50.28**			**2.10**	***9.89***	**7.66**		**19.26**	**7.16**		no	**33.31**	0.33	3514	57077
	3.83		4.52	5.38			0.81	4.23	1.77		4.08	1.11						
Croatia	***6.93***		**-38.68**		**0.88**	**10.93**		**8.94**			**13.03**	**3.22**		no	**52.28**	0.22	4144	36950
	3.09		3.39		0.11	3.55		2.93			3.69	0.01						
Latvia			**-38.59**		**0.93**						**16.67**			no	**71.69**	0.15	3940	24218
			4.50		0.13						3.21							
Lithuania			**-45.28**	**46.04**	**0.81**			**8.33**	**16.77**		**18.73**		***7.04***	no	**50.28**	0.23	4109	43825
			4.90	4.45	0.10			3.39	1.99		2.98		3.40					
Macao, China		**13.11**	**-33.97**	**28.96**	**0.39**		***1.03***		**19.65**			**-0.39**	**9.79**	no	**60.47**	0.16	4148	5558
		2.66	3.52	3.21	0.11		0.49		1.65			0.10	1.42					
Serbia		**11.91**	**-37.67**	**39.24**	**0.95**	**10.59**		**10.34**	**7.96**		**12.39**	*1.24*		no	**38.50**	0.18	3932	60462
		4.41	3.96	3.81	0.11	3.80		3.52	1.78		3.56	0.01						
Thailand		**-61.58**	***-7.00***		**0.47**			**26.84**	**16.21**		***8.21***	**1.12**	**6.60**	no	**97.74**	0.26	4830	494153
		22.46	3.09		0.10			6.83	1.70		3.57	0.27	2.23					

Note: Standard errors below (white rows). All estimates significant at 1% except: ***significant at 5%***; *significant at 10%*; <blank>: *non significant.*

Table 4. Increase in science scores from computer use

	Never	Once a month or less	A few times a month	Once or twice a week	Almost every day	Selection
Australia	**389.51**			**18.45**	**35.94**	No
	10.36			7.46	7.16	
Austria	**356.77**				**19.13**	No
	11.11				3.21	
Belgium	**368.91**			**27.36**	**35.02**	No
	9.56			6.46	5.52	
Canada	**398.85**			**16.91**	**23.33**	No
	9.59			5.82	5.17	
Chile	**319.17**				**50.64**	**Yes**
	17.03				11.07	
Czech Republic	**301.03**			**41.54**	**69.80**	**yes**
	22.50			8.90	15.10	
Denmark	**378.41**					no
	11.52					
Finland	**402.29**					no
	16.08					
Germany	**354.74**				**12.80**	no
	11.62				2.69	
Greece	**349.56**					no
	12.04					
Hungary	**273.61**			**30.81**	**39.20**	no
	16.32			11.14	10.53	
Ireland	**389.93**				**9.00**	no
	18.20				3.29	
Iceland	**347.66**				**17.14**	
	15.43				4.62	
Italy	**363.01**			*15.94*	**36.65**	**yes**
	9.32			9.33	8.33	
Japan	**411.85**				**11.24**	**no**
	11.88				3.67	
Korea						
Netherlands	**372.20**			*23.93*	**34.70**	*yes*
	19.06			14.23	13.65	
New Zealand	**392.09**				***7.15***	no
	12.77				3.68	
Norway	**366.19**			**40.28**	**41.25**	no
	10.22			9.93	8.39	
Poland	**337.17**				**10.75**	no
	10.81				3.27	
Portugal	**318.17**			**22.70**	**39.30**	no
	10.62			7.10	8.40	
Slovak Republic	**331.17**			***9.05***	**25.03**	no
	12.97			4.54	4.83	
Slovenia	**326.25**			*12.51*	**20.52**	no
	11.47			7.60	7.43	

	Never	Once a month or less	A few times a month	Once or twice a week	Almost every day	Selection
Spain	**353.84**		***12.84***	**25.73**	**38.11**	no
	7.50		5.78	5.02	5.23	
Sweden	**381.17**				**24.54**	**yes**
	11.82				7.99	
Switzerland	**349.44**			***14.25***	**17.85**	no
	10.10			6.21	6.16	
Turkey	**338.06**					no
	13.77					
Bulgaria	**305.90**				**16.59**	no
	13.19				4.40	
Croatia	**376.67**		**28.81**	**30.54**	**43.09**	**no**
	10.71		8.98	7.73	7.42	
Latvia	**396.72**			**19.25**	**26.29**	no
	8.14			5.59	5.43	
Lithuania	**395.55**			**22.97**	**35.96**	no
	8.15			5.11	5.20	
Macao, China	**401.92**			***20.88***	**39.88**	no
	13.12			11.92	11.97	
Serbia	**360.92**			***22.47***	**31.69**	no
	13.16			9.29	8.61	
Thailand	**310.02**			*7.96*	**12.51**	no
	23.29			4.73	4.91	

Note: Standard errors below (white rows). All estimates significant at 1% except: ***significant at 5%***; *significant at 10%*; <blank>: *non significant.*

Table 5. Increase in science scores from computer use at home and at school

		A few times a month			Once or twice a week			Almost every day			
	Never	**School & home**	**School**	**Home**	**School & home**	**School**	**Home**	**School & home**	**School**	**Home**	**Selection**
Australia	**388.79**				**20.40**		**27.17**	**39.71**	**26.43**	**38.23**	no
	8.11				5.33		5.31	4.79	5.74	4.34	
Austria	**355.68**							**32.44**	**19.38**	**16.17**	no
	10.93							5.63	7.24	3.34	
Belgium	**383.42**				**20.35**					**42.26**	**yes**
	7.01				4.53					5.25	
Canada	**405.37**						**18.68**	**15.43**		**20.25**	
	9.64						5.53	4.51		3.73	
Chile	**319.32**								***24.45***	**50.54**	**yes**
	17.21								11.75	7.95	
Czech Republic	**301.03**				**41.54**	**41.54**	**41.54**	**69.80**	**69.80**	**69.80**	**yes**
	22.50				8.90	8.90	8.90	15.10	15.10	15.10	
Denmark										**7.81**	no
										3.77	
Finland	**402.29**						**15.82**			**18.37**	no
	16.08						5.57			4.41	
Germany	**353.35**									**15.52**	no
	11.77									3.09	
Greece	**349.56**						**26.01**			**34.25**	
	12.04						4.45			5.00	
Hungary	**273.91**				**36.80**	***23.75***	**34.83**	***27.89***	**34.22**	**41.57**	No
	16.24				11.80	11.37	12.59	12.13	12.39	10.64	
Ireland	**391.22**						***7.73***				no
	18.21						3.19				
Iceland	**349.51**							**17.33**			no
	14.72							3.79			
Italy	**364.57**				**23.32**	**4.37**	**23.32**	**37.53**	**13.78**	**37.53**	**yes**
	9.29				9.12	1.05	9.12	8.25	3.09	8.25	
Japan	**412.85**									**13.70**	no
	11.92									3.76	
Korea											
Netherlands	**367.03**				***30.65***		**43.86**	***29.47***	***31.28***	**46.45**	***yes***
	17.00				13.67		14.63	12.52	15.44	12.16	
New Zealand	**391.93**						***10.27***			**13.37**	no
	12.52						4.99			3.27	
Norway	**366.79**				***30.55***	***34.88***	**45.26**	**29.92**	**39.83**	**43.44**	no
	10.28				14.40	15.71	10.10	9.03	13.94	8.55	
Poland	**334.95**									**15.77**	no
	10.62									3.15	
Portugal	**326.78**				**21.37**		**20.55**	**19.85**		**34.39**	no
	10.22				6.25		7.33	7.57		6.53	
Slovak Republic	**331.75**				**17.00**		***13.81***	*21.32*		**27.43**	no
	11.71				5.15		5.95	11.94		3.31	
Slovenia	**326.25**				*12.51*	*12.51*	*12.51*	**20.52**	**20.52**	**20.52**	no
	11.47				7.60	7.60	7.60	7.43	7.43	7.43	

		A few times a month			Once or twice a week			Almost every day			
	Never	**School & home**	**School**	**Home**	**School & home**	**School**	**Home**	**School & home**	**School**	**Home**	**Selection**
Spain	**353.30**			***12.96***	**20.83**	**20.83**	**31.12**	***20.49***	***20.49***	**39.13**	no
	7.39			5.77	5.58	5.58	11.36	9.56	9.56	15.29	
Sweden	**381.17**							**24.54**	**24.54**	**24.54**	**yes**
	11.82							7.99	7.99	7.99	
Switzerland	**356.91**						*8.65*			**11.47**	no
	7.67						4.79			3.33	
Turkey	**338.06**							**-27.14**	**-27.14**	**2.87**	no
	13.77							6.67	6.67	0.66	
Bulgaria	**305.56**									**25.46**	no
	13.21									4.15	
Croatia	**391.67**	***26.77***		***22.62***	**21.96**		**22.28**			**30.13**	no
	9.51	12.50		10.23	5.18		7.29			4.17	
Latvia	**400.61**				**21.24**	***9.14***	**21.24**			**25.53**	no
	9.11				6.07	4.59	6.07			5.32	
Lithuania	**393.82**				**36.67**	**16.35**	**36.84**		***24.66***	**41.02**	No
	7.34				7.67	5.62	7.77		10.24	4.45	
Macao, China	**400.89**				**25.42**	**9.94**	**25.42**	**40.27**	**40.27**	**40.27**	No
	13.10				11.78	3.61	11.78	11.93	11.93	11.93	
Serbia	**363.95**				**39.45**	**25.68**	**41.76**			**44.09**	No
	10.43				8.41	7.26	11.74			6.48	
Thailand	**299.72**				**27.79**	**5.26**	**27.79**	**26.27**	**-2.70**	**26.27**	No
	22.69				5.78	1.05	5.78	4.92	-0.41	4.92	

Note: Standard errors below (white rows). All estimates significant at 1% except: ***significant at 5%***; *significant at 10%*; <blank>: *non significant.*