IEB Institut d'Economia de Barcelona

IEB Working Paper 2018/20

DO INFORMATION AND COMMUNICATION TECHNOLOGIES (ICT) IMPROVE EDUCATIONAL OUTCOMES? EVIDENCE FOR SPAIN IN PISA 2015

Nerea Gómez-Fernández, Mauro Mediavilla

Human Capital

IEB Working Paper

IEB Working Paper 2018/20

DO INFORMATION AND COMMUNICATION TECHNOLOGIES (ICT) IMPROVE EDUCATIONAL OUTCOMES? EVIDENCE FOR SPAIN IN PISA 2015

Nerea Gómez-Fernández, Mauro Mediavilla

Postal Address:
Institut d'Economia de Barcelona
Facultat d'Economia i Empresa
Universitat de Barcelona
C/ John M. Keynes, 1-11
(08034) Barcelona, Spain
Tel.: + 34 93 403 46 46
ieb@ub.edu
http://www.ieb.ub.edu

IEB Working Paper 2018/20

DO INFORMATION AND COMMUNICATION TECHNOLOGIES (ICT) IMPROVE EDUCATIONAL OUTCOMES? EVIDENCE FOR SPAIN IN PISA 2015

Nerea Gómez-Fernández, Mauro Mediavilla

ABSTRACT: With the world becoming increasingly digitalized, determining the relationship between the use of ICT in the learning process and educational outcomes takes on special relevance for guiding educational policy decisions in a reasoned way. The objective of this study is to evaluate the effect on academic performance of the use and availability of Information and Communication Technologies (ICT) at school and at home. For this purpose, we apply a hierarchical lineal regression model approach with data from the Programme for International Student assessment survey (PISA) 2015. PISA 2015 contains a brief but specific questionnaire for ICT that is completed voluntarily in some of the countries participating in the survey, as is the case in Spain. The results show differences in the sign of the impact according to the ICT variable used. The positive impact of ICT use is associated with its use for entertainment at home and with the students' interest in ICT. However, the use of ICT for schoolwork at home and the general use of ICT by students in schools have negative effects on the learning process. Another significant result is the magnitude of the coefficient for the relation between the starting age for using ICT on the scores in the three competences. The higher the age, the lower the score achieved. The results of the regressions by tertiles of performance show that ICT can also play an important role in improving the academic performance of the students with the worst results. Finally, some control variables related to students, home and location are also relevant in our models.

JEL Codes: I20, I21, O33
Keywords: Education, PISA 2015, ICT, Spain, Academic Performance

Nerea Gómez-Fernández
Universitat Politècnica de València
Email: negofer@upv.es

Mauro Mediavilla
Universitat de València &
Institut d'Economia de Barcelona (IEB)
Email: Mauro.Mediavilla@uv.es

1. Introduction

The intense digitalization that current society is experiencing calls for analysis of the role of Information and Communication Technologies (ICT) in the educational context in order to offer appropriate guidance in educational policy decision making.

The incorporation of ICT into the educational process offers numerous advantages. The use of ICT is associated with greater student motivation thanks to the use of more attractive, entertaining and fun tools (Bullock, 2001; Tüzün et al., 2009). Likewise, new Information and Communication Technologies allow a greater interactivity in learning, greater possibilities for cooperation and an improvement in communication between teachers and students (Schulz et al., 2002). The ICT also stimulates initiative and creativity (Allegra et al., 2001; Wheeler et al., 2002) and enables individualization and flexibilization of education (Abell, 2006). All these advantages, among others, should lead to an improvement in academic performance and the acquisition of competences by the students.

However, the use of ICT by students is also frequently associated with problems. The possible distraction of students when consulting resources that do not contribute to learning (Lee et al., 2014) and addiction to ICT (Carbonell et al., 2012; Türel & Toraman, 2015) are examples of potential disadvantages. In addition, the excess of information on the internet can lead to significant losses of time and use of resources of poor reliability. All these disadvantages can have negative consequences on the personal and social development of students as well as on their academic performance and acquisition of skills.

The coexistence of potential advantages and disadvantages has led to an important debate about how ICT should be implemented to enable an improvement in the learning process. The previous literature has evaluated the effects of various ICT modalities on academic performance but the results obtained are not conclusive, that is, there is no consensus about the incidence (positive, negative or neutral) of ICT in the acquisition of competences. Some of the more prominent studies to date are analysed in detail in the next section of this article.

The objective of this study is to estimate the effect of the use and availability of Information and Communication Technologies (ICT) at school and at home on academic performance of Spanish students based on the results of the Program for International Student Assessment (PISA) in 2015. Specifically, the hypothesis to be tested is the positive impact of ICT on academic performance. The analysis of a number of variables related to the use of ICT of students and schools allows analysis and evaluation of the effectiveness of factors that potentially affect the quality of education. This would help to identify successful educational policies and interventions for Spain.

The approach of this analysis lies in the use of PISA 2015 microdata, recently published in December 2016 by the Organization for Economic Cooperation and Development (OECD), and the inclusion of variables not explored in the previous literature (students' interest in ICT and importance of ICT as a topic in Social Interaction). Furthermore, the analysis of the latest published data is especially relevant as it coincides with a period characterized by the intensification of the use of ICT in homes and in Spanish schools. In 2013, the Digital School Culture Plan (Ministry of Education, Culture and Sports) was launched and, at the same time, the different Autonomous Communities carried out their own programs. The final goal of all these measures is to improve the connectivity between schools and the quality of educational ICTs, and to develop the digital skills of teachers.

Results suggest a positive impact on academic performance from using ICT at home for entertainment purposes and students' interest in ICT. However, using ICT at home for schoolwork, the availability and use of ICT at school and the importance of ICT as a topic in social interaction are associated with negative effects on learning for the set of evaluated skills. Additionally, the higher the starting age for using ICT and the greater the importance of ICT as a topic in social interaction, the lower the students' results in PISA.

Our regressions by tertiles of performance show two main results: (i) ICTs have a higher impact on academic achievement of low performance students, and (ii) the use of ICT at home for schoolwork, the availability of ICT at school and a higher starting age for using ICT are associated with lower scores independently of the competence and the tertile of performance of the student.

The paper is structured as follows. Section 2 presents a review of previous studies that have investigated the effect of ICT on academic performance. Then, section 3 describes the data and variables used in the analysis and the methodological approach and section 4 presents the results of the empirical analysis. Lastly, section 5 concludes with the final considerations.

2. Literature Review

The report by Coleman et al. (1966) was the first analysis of the determinants of educational performance and initiated a line of research in the area of the Economics of Education focused on the study of personal, school and family factors that affect educational quality. The subsequent emergence of ICT in schools and homes led to the need to include this quality factor in the analysis of the determinants of academic performance, as evidenced in the literature review carried out by Cox et al. (2004), Condie and Munro (2006) and Claro (2010).

The empirical evidence on the effect of ICT on learning and academic performance is not conclusive. The results of the different investigations carried out differ in the conclusions reached. Articles that show a positive impact of ICT on academic performance coexist alongside other research that clarifies the absence of significant effects or that affirms a negative impact. One of the factors that may explain this lack of consensus is the use of very varied analysis methodologies and models. In addition, the inconsistency of results can be attributed to variations in the object of study (subjects, countries), which only allow extraction of limited information on the effect of ICT on academic performance. Added to this is the difference between the PISA databases during its last six editions. In comparison to PISA 2000, subsequent editions have added more and more detailed information on the use of ICTs. In addition, the ICTs themselves have been developed at a considerable rate, which also significantly alters the results between years.

Next, we present the main results achieved by some of the most relevant studies carried out so far. These investigations can be divided into two major methodological groups. On the one hand, there are studies focused on the analysis of the evaluation of concrete policies through experimental or quasi-experimental designs. Alternatively, there are articles that study the effects of ICT by analysing correlations based on international assessment tests, such as PISA.

Availability and use of ICT at school

The use of computer programs for educational purposes in schools has been widely evaluated in the literature. Barrow et al. (2009) evaluate the impact of the introduction of a computer program for the teaching of algebra in schools in the United States. Their results indicate that the students who used the computer program reached higher scores than those who were exposed to the traditional teaching method. Similarly, Carrillo et al. (2011) evaluate a municipal computer-aided instruction program for teaching mathematics and languages in elementary schools in Ecuador and determine a statistically significant positive impact on the scores obtained in mathematics. The impact is heterogeneous among students, being higher for those who are at the top of the performance distribution. These results are in line with those obtained by Banerjee et al. (2007) for India, who study the effects of a computer-assisted learning program for the reinforcement of mathematics instruction. Their results suggest a high effectiveness of the program, observing positive effects on academic performance in the subject of mathematics that persist even after the cessation of the program. The case of India is also analysed by Linden (2008), who also highlights that the effectiveness of computer-aided teaching programs depends on whether they are complements or substitutes for the traditional teacher. The author suggests that the effects on performance in mathematics are positive when the computer is a complement to traditional teaching methods. On the other hand, when the computer replaces traditional teaching, negative effects are observed.

More recently, Muralidharan et al. (2017) study the impact of a computer-assisted after-school instruction program in urban areas of India. Specifically, they evaluate the effects of the random provision of a voucher to cover program expenses and observe an increase in the marks obtained in the evaluation tests of the mathematics and Hindi subjects, with the higher gain for students with lower starting scores.

Furthermore, there are studies that suggest the lack of a relevant impact of educational software on the academic performance of schoolchildren. Rouse and Krueger (2004) evaluate the impact of the "Fast for World" computer program, implemented in schools in the United States to improve reading and linguistic skills, and observe a limited improvement in the language skills of students, with no clear impact on academic performance.

Another group of authors has focused on the analysis of investment in ICT, especially in the availability of computers in schools. In this line, Machin et al. (2010) find in England a positive effect on academic performance because of the greater investment in ICT, especially in the subjects of English and sciences. However, numerous studies indicate the absence of significant effects of the installation of computers in schools on academic performance. In Israel, Angrist and Lavy (2002) analyse the effect of the installation of computers in public schools. The authors conclude that there is no evidence of the existence of educational benefits, that is, the greater use of computers does not have a positive effect on the scores of the standardized tests. This result is also in line with that obtained by Goolsbee and Guryan (2006) when analysing the effect of the "E-Rate" subsidy promulgated by the United States government to facilitate investment in ICT in schools. The results indicate a significant increase in investment in ICT because of the implementation of the subsidy but no significant effects are observed in the academic performance of the students. Barrera-Osorio and Linden (2009) evaluate the introduction of computers in schools in Peru and conclude that it had a zero impact on academic performance in mathematics and language, suggesting that this could be explained by the lack of incorporation of computers by teachers in the curriculum of the subjects. Similarly, Cristia et al. (2014) analyse a public program implemented in secondary public schools in Peru to improve access to computers and the internet and do not observe significant effects on the academic performance of students.

Some previous studies that have evaluated specific policies have found negative effects of the investment in ICT on academic performance. This is the case in Leuven et al. (2007), who evaluate the implementation of a subsidy to finance computers and software for disadvantaged students in the Netherlands. Similarly, Belo et al. (2016) investigate whether the installation of broadband in schools in Portugal affects academic performance. The results suggest negative effects of significant magnitude in the grades obtained. The introduction of broadband allows new resources for learning but it is also a distraction opportunity for students, showing that schools that restrict access to pages of distraction obtain better results than those that do not.

Several studies specifically analyse the implementation of the 1:1 computer model in schools using experimental designs. This model consists of delivering to the educational institutions individual electronic devices for each student, that is, each student has their own device that allows access to the internet, course materials and textbooks in digital format. The implementation of the Plan Ceibal in Uruguay – which provides a portable computer to each child of school age and to each teacher of the public school - is noteworthy. De Melo et al. (2013) suggest that Plan Ceibal would not have had an impact on mathematics and reading. This could be explained by the fact that laptops are used in class mainly to search for information on the internet. Authors' findings confirm that the technology alone cannot have an impact on learning. However, Ferrando et al. (2011) find a positive impact of Plan Ceibal on the performance of children in mathematics. There was no impact on reading, but only when the analysis is restricted to children in the sixth grade.

In the same line of research, Grimes and Warschauer (2008) evaluate the effect in three schools in California. The results show improvements in academic performance in the subjects of English and mathematics from the second year of use of the device. Suhr et al. (2010) also evaluate the program in the United States and obtain a similar result. Students who participate in the program obtain higher scores in the subject of English at the end of two years of their participation. Similarly, Lai et al. (2015) study the effects of the establishment of the model in certain schools for immigrants from Beijing and find evidence of improvements in academic performance in the subject of mathematics. The maximum positive effect is achieved around two months after beginning the program and is greater in students whose parents have lower educational levels. More recently, Mora et al. (2018) analyse the impact of a One Laptop per Child program introduced by the Catalan government in Spain. Their results indicate that the program had a negative impact on student performance in Catalan, Spanish, English and mathematics, being this effect stronger among boys than girls.

Based on the analysis of the PISA database, several authors find positive effects in the scores achieved in the tests due to the use of ICT in the learning process. Fuchs and Woessman (2005) analyse the data of all the countries participating in PISA 2000 and show positive effects of the use of a computer in the educational process. Similarly, Kubiatko and Vlckova (2010) evaluate PISA 2006 data for the Czech Republic and find that students who use ICT in the educational process obtain higher scores than students whose use of ICT is not linked to the educational process. Similarly, the recent study by Alderete and Formichella (2016) analyses the effects of the "Connect Equality" Program implemented in Argentina and consists of the delivery of three and a half million laptops for students and teachers of public high schools, special education and teacher training. Using PISA data, the authors obtain statistically significant differences in educational performance, such that students who participate in the program show a higher academic performance as a result of the use of laptops. Güzeller and Ayça (2014) also find positive effects in Turkey but of very little significance, suggesting the existence of a lack of adequate integration of ICT in schools.

However, other studies do not find clear evidence that there is a relationship between ICT and academic performance in PISA in certain subjects. Aypay (2010) analyses the PISA 2006 data for Turkish students. The author suggests that there is no significant relationship between the use of computers and academic performance in mathematics, science and reading.

In the previous literature, there are also works related to the use of ICT. Biagi and Loi (2013) determine that the extent of use of computers - as opposed to the intensity of use of an activity - has positive effects on the results of the PISA exams. Specifically, the authors determine that the use of computers for gaming activities increases scores, while the intensity of use for activities related to the study plan decreases performance. More recently, Falck et al. (2018) using international database Trends in International Mathematics and Science Study (TIMSS) for basic education conclude that using computers to look up information has a positive effect on students' results, while using computers to practise skills has negative effects. Authors suggest that these two effects compensate, resulting in overall null effects of classroom computers on student achievement.

Availability and use of ICT at home

There are studies that evaluate the effects of computer use at home. Fairlie and Robinson (2013) analyse the measures implemented in California schools for the free provision of computers at home. The results suggest the absence of effects of computer use at home in the educational process. In Peru, Beuermann et al. (2015) evaluate an experiment in the provision of portable computers for the home and do not find evidence of improvements in academic performance. It is suggested that students who received computers show a greater probability of making less effort in school, and cognitive skills only improve for students who are below the median level of academic achievement. However, Malamud and Pop-Eleches (2010) study the government bonds offered in Romania in 2008 for the purchase of a personal computer and find that the children of households that benefited from a computer improve their skills test computer scores but get lower results in math, English and Romanian tests. This indicates that providing computers at home to low-income households in Romania caused a drop in academic performance, but improved the computer and cognitive skills of the students. More recently, Fairlie (2016) investigates the effects by gender of the provision of free personal computers for the home for low-income students in US schools. The author concludes, based on an empirical analysis, that boys are more likely than girls to use computers for games rather than for schoolwork. Based on this evidence, Fairlie (2016) analyses the effect of the free provision of computers on academic performance by gender. There is no evidence of negative effects of the use of the computer at home on academic performance for boys compared to girls.

Using PISA, a series of investigations have focused on analysing the effects of the use of the computer at home, several studies showing a positive correlation between the possession of a computer at home and the educational result in PISA (Schmitt and Wadsworth, 2006; Fairlie, et al., 2010; Notten and Kraaykamp, 2009). Similarly, Spiezia (2010) shows that the positive effect is greater when the computer is used at home than when it is used in school. However, Agasisti et al. (2017) carry out a more detailed analysis of the use of ICT at home and show that in most OECD countries there is an association between using computers intensely at home for homework and achieving lower test scores across all subjects.

The familiarization of students with the use of ICT also seems to be a key factor for the effects on educational performance. Kubiatko and Vlckova (2010) conclude that students more familiar with the use of ICT obtain better academic results in science, especially if the use is related to the educational process. The analysis of international tests also allows the study of the so-called "knowledge gap" (Donohue at al., 1975) between social strata in the educational area. Gui et al. (2014) analyse the case of Italy and find evidence that the use of the internet for completing homework does not have different impacts on learning according to their social background.

In summary, the empirical evidence found in previous international studies is not conclusive, that is, there is no clear effect of ICT on the acquisition of competencies.

Spanish Case

In the case of Spain, the previous literature does not provide clear evidence of the impact of ICT on educational performance.

Choi and Calero (2013) find evidence that having a computer at home reduces the chances of obtaining results lower than level two of PISA. The authors also clarify that those students who most frequently use a computer at home are more likely to reach level two of PISA. With respect to the computer in the classroom, the proportion of computers with internet connection and the number of computers does not show statistically significant effects on academic performance. The authors point out, based on their results of a multilevel logistic model, the ineffectiveness of increasing the volume of computers in schools to reduce school failure. Contrary to these results, Cordero et al. (2015) and Cabras and Tena (2013) - through a multilevel regression and a Bart model, respectively - show a positive effect of having computers in schools for educational purposes, especially in more unfavourable socio-economic groups. However, the authors emphasize the need to equip the centres with computers, but only with the accompaniment of a strategy that encourages use for teaching purposes. Cordero et al. (2015) also find a significant positive relationship between owning a home computer and performance for students with the lowest scores.

More recently, Mediavilla and Escardíbul (2015) conclude that a longer time of use of ICT to perform school tasks has negative effects on the academic performance of the subjects evaluated in PISA, while the greater use of computers as entertainment and the earlier use of ICT leads to improvements in the acquisition of skills. However, these results are different by gender, obtaining greater incidence in the performance of women with respect to age of onset and time of use. Escardíbul and Mediavilla (2016) also find a higher impact of ICT on academic performance in mathematics than in science and reading. More specifically, they find a positive impact of attitudinal variables towards computers and the starting age for using ICT but a negative impact of ICT´s excessive use. The authors also control these impacts according to ownership of the school but find no statistically significant differences.

On the other hand, Vilaplana (2016) analyses the specific impact of the Escuela 2.0 program implemented in Spanish schools with the aim of favouring the introduction of new technologies. The author finds a positive net effect of the provision of ICT, albeit minor, deferring the effects between repeating and non-repeating students. With regard to computer use at home on completion of homework, a positive effect on reading comprehension scores is observed. This last result contradicts that obtained by Mediavilla and Escardíbul (2015), calling for further research on the possible causes of this discrepancy. One of the explanations by the authors of the negative effect of the use of ICT on the performance of school tasks could be the reverse causality, that is, students with lower performance require more frequent use of ICT for the completion of tasks. Likewise, less familiarity with ICTs can lead to a greater dedication of time to learning to work with the tool, to the detriment of the time dedicated to learning itself. On the other hand, the positive impact obtained by Vilaplana (2016) can be explained by the disappearance of this last cause, thanks to the effects of familiarization and mastery of ICT that entails the introduction of a 1: 1 computer program such as Escuela 2.0.

3. Data and Methodological Approach

3.1 Data: PISA 2015

The Program for International Student Assessment (PISA) is a study carried out by the Organization for Economic Cooperation and Development (OECD) every three years. The objective is to evaluate educational systems by assessing the skills and knowledge of 15-year-old students, regardless of their academic year. The purpose of the report is to enable the comparison of data between countries and thus improve educational policies and student outcomes.

The first application of the PISA study was carried out in the year 2000 and it was subsequently edited in 2003, 2006, 2009, 2012 and 2015. Throughout this research, we work with the latest data available from December 2016, corresponding to the study conducted in 2015. The PISA microdata bases are central to the objective of the analysis of this research since they include variables that approximate the performance in basic competences.

More than half a million students participated in PISA 2015, with 72 countries represented. The test carried out by the students lasts two hours and includes standardized tests for all the countries that evaluate the areas of science, mathematics, reading comprehension, collaborative problem solving and financial education. The selection technique of the sample consists of a two-stage sampling: (1) selection of educational centres with a minimum of 150 per country, and (2) election of approximately 35 students of 15 years in each centre. The total number of students evaluated in each country must exceed 4,500. In the case of Spain in PISA 2015, 980 schools and 32.330 students participated.

In addition to the test, students must complete a questionnaire of approximately one hour in which they are asked information about their background, study habits, perception of their learning environment and their commitment and motivation. Likewise, PISA also conducts a questionnaire for schools. In this survey, information is requested on aspects such as demographic characteristics or the evaluation of the quality of learning. The questionnaire for schools includes specific questions about ICTs that are used in this paper. Finally, there is a brief but specific questionnaire for ICT that is done voluntarily in some of the participating countries in PISA. In this questionnaire, the students gives more details about the availability of ICT, what they use it for, how familiar they are with ICT and their general attitude towards the use of computers. This questionnaire provides very specific information. In this paper we have merged the microdata bases for Spain of the student test, the questionnaire for schools and the specific questionnaire on ICT.

Working with the PISA database requires making a series of adjustments prior to the econometric analysis specified in the PISA manual (see OECD, 2009). The use of PISA microdata requires working with plausible values from the results of the evaluations. The plausible values refer to random values that are calculated based on the distributions of the scores obtained by the students. This happens because, in PISA, not all students respond to the complete test and it is necessary to estimate how they would have answered the total number of items. In fact, PISA 2015 includes ten plausible values instead of only five as in its previous versions. The OECD (2009) explains that the population statistics and the parameters of the regression models have to be estimated using the plausible values separately, while the value of the population statistic must be calculated as the average of the statistics obtained with each of these. All these considerations have been taken into account in our analysis.

3.2 Descriptive Analysis

Based on the PISA 2015 microdata database, the variables that have been considered for the econometric analysis are detailed in this section. Specifically, a multilevel model has been developed at two levels (school and student) to investigate the relationship between the use of ICT by schoolchildren and academic performance in the case of Spain. Three separate models have been developed for each of the dependent variables: the score in mathematics, the score in science and the score in reading comprehension.

These dependent variables are defined by the three competences that are evaluated in PISA-2015. Mathematical competence analyses the student's ability to identify and understand the role of mathematics in the world, to make informed judgments and to use and be involved in mathematics in a way that satisfies vital needs as a citizen. The competence in reading comprehension assesses the student's ability to understand, use and analyse critical texts in order to achieve their own goals, develop their possibilities and knowledge and participate in society. Finally, the competence in science reflects the degree of scientific knowledge of the student and how it is used for the identification of questions, acquisition of new knowledge, explanation of scientific phenomena and extraction of conclusions based on evidence of topics related to science. Table 1 shows the main descriptive statistics of the dependent and independent variables of our analysis.

[Table 1 around here]

Next, a detailed description of the explanatory variables used in the analysis is presented.

In relation to the use of ICT, we have selected the following eight variables from the ICT questionnaire: ICT available at School Index, ICT available at Home Index, ICT use outside of school for schoolwork, ICT use outside of school for leisure, use of ICT at school in general, students' ICT Interest, the degree to which ICT is a part of their daily social life and starting age for using ICT. ICT in the centre has also been measured with the index of availability of computers obtained from the school questionnaire, which represents the ratio of computers available to 15-year olds for educational purposes to the total number of students in the modal grade for 15-year olds. Table A.1 of the Annex presents the exact definition of each of them.

Regarding the interpretation of the variables' values, the ICT variables at student level that we have chosen – except for ICT available at School Index, ICT available at Home Index and the starting age for using ICT - were scaled using the Item Response Theory (IRT) model. Weighted likelihood Estimates (WLE) for the latent dimensions were transformed to scales with a mean of zero and a standard deviation of one across OECD countries. Therefore, the scores of these indices must be interpreted by comparing them to the OECD mean. Negative values on the index indicate that students responded less positively than the average student did across OECD countries. Likewise, students with positive scores are those who responded more positively than the average student in OECD countries.

The variables regarding students' ICT Interest and students' ICT as a topic in Social Interaction have been introduced for the first time in PISA 2015, so its analysis becomes novel and especially relevant. The variables Index of perceived competence in ICT and Index of autonomy in ICT are also new in PISA 2015. Nevertheless, we have decided not to include these two variables in our analysis since we consider that they present a bias of subjectivity. Students may overestimate or underestimate their competence or autonomy in the use of ICT and therefore, if these variables were used, it may lead us to extract wrong conclusions.

As control variables at student level, we consider the gender, the index of immigration status, the age of arrival of immigrant students in the country, the repetition of grade at ISCED 1 and ISCED 2, school truancy and the start age of ISCED 0. At family level, we consider the language at home, the highest occupational status of parents (HISEI), the *index* of highest educational level of parents (HISCED) and the total number of books in the home.

Table A.2 of the Annex specifies the definition of categorical control variables. Regarding the Index of highest occupational status of parents (HISEI), note that this indicator can take values from 11 to 89 and higher HISEI indicates higher levels of occupational status. Table A.3 of the Annex presents the most relevant descriptive statistics of the control variables.

According to the information provided by the school directors, we have used control variables related to the characteristics of schools. The school factors included in the analysis as control variables are: school ownership (private or public), location (number of inhabitants), index of school autonomy, number of students per classroom, school size (total enrolment at school), number of students per teacher (total number of enrolled students divided by total number of teachers) and the index proportion of all teachers fully certified (fully certified teachers divided by the total number of teachers).

Regarding the index of school autonomy, this reflects the responsibility of the school for allocating resources to schools (appointing and dismissing teachers; determining teachers' starting salaries and salary increases; formulating school budgets and allocating them within the school; establishing student-assessment policies; choosing textbooks; and determining which courses are offered and the content of those courses). The index of autonomy takes value from zero to one and higher scores indicate a higher degree of autonomy.

In addition to the school questionnaire, PISA 2015 also includes a teachers' questionnaire. However, we should point out as a limitation of this research that the database we use for Spain subdivided into Autonomous Communities does not contain information about the teachers' training in ICT. Therefore, in this research we are not able to include in our analysis the relation between teachers' ICT skills and the academic performance of students.

Autonomous Communities of Spain

We have also used as explanatory variables seventeen dummies created from the string variable SUBNATIO and that represent the different Autonomous Communities of Spain. The reference category is "Comunidad Valenciana". Including these variables enables potential regional variations to be identified.

3.3 Missing- data imputation

Regarding the missing values, table A.3 of the annex shows that there are six control variables with a percentage of missing values higher than 5% and whose imputation enables the sample of the final estimates to be increased. The initial sample for the three models estimated in this research - prior to the imputation - is of 17,853 students, this being the total of observations of 32,330 students from the original PISA database for Spain.

In order to impute the missing values, we first explore the pattern of the missing values. It should be noted that in our database there are no observations with missing values in the dependent variables (student scores), and we have not imputed values for the ICT variables directly of interest in our research. The analysis of the pattern confirms the suitability of the imputation of the six control variables with values of missing values higher than 5%: (1) age at start of ISCED 0 (7%); (2) highest occupational status of parents (HISEI) (5.64%); (3) school ownership (5.91%); (4) school size (8.80%); (5) student-teacher ratio (9.89%); and (6) index proportion of all teachers fully certified (15.21%).

Once the imputation of these six variables has been decided, the dichotomous correlation test is carried out between the variables to be imputed - with zero value for the missing values and value one for the valid values - and the rest of the original variables, as recommended by Carpenter et al. (2007). The results confirm the randomness (MAR - Missing At Random -, Rubin, 1976). Based on this, it is appropriate to proceed with the imputation.

In line with the previous literature, the imputation is carried out using an iterative imputation method that imputes multiple variables by using chained equations (van

Buuren et al., 1999)[1]. The imputation through this technique involves a sequence of univariate imputation methods with fully conditional specifications of prediction equations (Royston and White, 2011). Specifically, in our case, we follow the recommendations of Rubin (1996) and Acock (2005) and we use all the variables available in the models. After considering the characteristics of each variable, we estimate the missing values from three different empirical approaches: ordered logistic regression for ordinal variables, multinomial logistic regression for nominal variables and linear regression for continuous variables. For each missing value, 16 imputed observations have been generated (m = 16), considering that the variable "index proportion of all teachers fully certified" presents a maximum percentage of missing values of 15.21%.

After the variables are imputed, a post-estimation analysis is carried out. The differences in means between the original and the imputed variables are tested, finding a non-significant difference in all cases. A graphical analysis is also carried out to analyse the differences in the kernel density distribution function of the imputed variables and the original ones.[2] It is shown that the distribution of the imputed variables replicates that of the original ones. Therefore, it can be concluded that the imputation does not affect the distribution of the variables.

The result of the imputation of the missing values is a gain of 3.976 observations on average, which implies an increase of the sample of around a 22%. That is, thanks to the imputation of the missing values, the total number of observations in the estimates has increased from 17,853 to a mean of 21,829 observations.

3.4 Methodological approach

In the PISA test, the population is selected in stages. First, the participating schools are chosen and subsequently students are selected within each school. There is therefore a hierarchical multilevel structure that implies dependence on observations within each set (Hox, 1995). Due to this structure, it is convenient to examine PISA data using multilevel regression models (Thorpe, 2006, Calero et al., 2009, Formichella, 2011, Song and Kang, 2012, Mediavilla and Escardíbul, 2015). OECD (2009) states that using a multilevel analysis implies incorporating the consideration of the dependence of the observations inside each group, since the fact that the observations of the students are grouped into larger units - the schools- is taken into account

The use of linear hierarchical regression models has made it possible to overcome the limitations of methodologies traditionally applied in research on academic performance. Since the principle of independence is not met in PISA - the observations of students from

---

[1] It is also possible to impute using multivariate normal regression options. However, due to the non-normal distribution of some variables to be imputed, the use of this technique is not adequate.
[2] These results are available upon request.

the same school have similar characteristics - it is not appropriate to make Ordinary Least Squares (OLS) estimates. Employing OLS means forgetting the context of the students, producing what is called in the literature an atomistic fallacy (Alker, 1969). The atomization makes reference to the fact that the variance-covariance matrix of the results does not consider the homogeneity within each group (schools).

Three different models are developed, one for each dependent variable: mathematics score, reading comprehension score and science score. Additionally, we run regressions by tertiles of academic performance in order to test the existent of differential effects. In the models developed in this paper there are two levels: schools and students. There are variables that characterize schools (level 2) and others that are specific to each individual (level 1). While the first variables are the same for all students of the same school, the second ones respond to specific characteristics of each student.

Once the previous considerations are applied, the multilevel analysis model presented in equations (1) to (3) is estimated following Snijders (2011):

Level 1 equation

$$\mathrm{Y_{ij}} = \beta_{0j} + \sum_{k=1}^{K} \beta_{kj}\mathrm{X_{kij}} + \mathrm{r_{ij}} \qquad r_{ij} \sim N(0, \sigma^2) \qquad (1)$$

Level 2 equation

$$\beta_{kj} = \gamma_{k0} + \sum_{q=1}^{Q} \gamma_{kq}\mathrm{W_{qj}} + \mathrm{u_{kj}} \qquad \mathrm{u_{kj}} \sim N(0, \tau_1) \qquad (2)$$

Where $\mathrm{Y_{ij}}$refers to the score obtained by student "i" at school "j"; X is a set of "k" characteristics of student "i" in school "j" (variables of level 1); β_{0j} and β_{kj} are level 1 estimated coefficients and $\mathrm{r_{ij}}$ are the level 1 random effects. Each of the level 1 coefficients turns into a dependent variable in the level 2 equation. $\mathrm{W_{qj}}$ is a vector of "q" characteristics of school "j"; γ_{k0} and γ_{kq} are level 2 coefficients and $\mathrm{u_{kj}}$ are the random effects at level 2.

Equation (3) has been obtained by substituting in equation 1 (student level) the coefficients by equations 2 and 3 (school level). In this way, a series of effects can be distinguished fixed ($\gamma_{00} + \sum_{q=1}^{Q} \gamma_{0q}\mathrm{W_{qj}} + \sum_{k=1}^{n} \beta_{kj}\mathrm{X_{kij}}$) of the random effects (u_{0j} + $\mathrm{r_{ij}}$).

$$Y_{ij} = \gamma_{00} + \sum_{q=1}^{Q} \gamma_{0q}\mathrm{W_{qj}} + \sum_{k=1}^{n} \beta_{kj}\mathrm{X_{kij}} + \mathrm{r_{ij}} + u_{0j} \qquad (3)$$

All the estimations are made with the statistical program Stata, which allows us to estimate the parameters of the previous equations by iterative methods that maximize a function of maximum likelihood.

4. Results

The results of the incidence of the variables related to ICT in the acquisition of the three competences evaluated at PISA 2015 are presented in table 2.

Regarding the related personal variables one result that stands out is the magnitude of the impact of the starting age for using ICT on the scores in mathematics, science and reading. The higher the age, the lower the score achieved, as also suggested by Mediavilla and Escardíbul (2015) and Escardíbul and Mediavilla (2016). Moreover, it is important to highlight the result obtained for the variables introduced for the first time in PISA 2015: "interest in use by ICT of the students "and "ICT as a topic in Social Interaction". Students' interest in ICT is positively related with the scores achieved in our three models, while the importance of ICT as a topic in social interaction shows a negative effect for all the competences.

As for the use of ICT at home, the availability of ICT at home is the only factor that shows opposing effects depending on the competence evaluated. For mathematics, results suggest that having more ICT available at home involves a higher academic performance. Nevertheless, the direction of this effect is reversed and becomes negative for reading comprehension. For its part, the use of ICT at home for schoolwork shows in the three models a negative relation with academic performance. This negative impact can be explained by two reasons: (1) those with worse academic results need more time to perform computer tasks, that is, there is an inverse causality; and (2) students less familiar with ICT may require more time of use to control the use of the devices and may spend less time learning themselves. Nevertheless, the use of ICT at home for leisure is associated with higher values of scores in the three competences. These results are in line with that obtained in previous studies (Biagi and Loi, 2013, Mediavilla and Escardíbul, 2015, Agasisti et al., 2017). This positive effect can be explained, among other reasons, by the improvement of attitude and familiarization with computers as a result of their leisure use resulting in better performance. Results indicate a significant magnitude of this home variable effect in comparison with the rest of ICT variables analysed.

[Table 2 around here]

Results for the availability of ICT at school indicate a negative effect on academic performance, independently of the competence evaluated. The general use of ICT at school is also associated with lower scores in the three competences. These negative effects should be analysed in depth to identify their causes and be able to put in place educational policies to overcome these problems. A possible explanation for the negative impact of these variables is the inadequate use of resources or the lack of familiarization of the teaching staff, as found by Cruz el al. (2018). The lack of familiarization of teachers with devices such as digital whiteboards or computers can lead to limitations in the teaching process that negatively affect the content of the subject taught and therefore academic performance, since strong teacher skills seem to have positive effects on student achievement (Meroni et al., 2015). Therefore, as suggested by Mediavilla (2018), we should ask ourselves whether we have our teachers adequately trained to develop new pedagogical methodologies that allow the effective use of ICT. In other words, the resources must be adapted in order to adequately complement the traditional teaching method. Regarding the number of computers per students, results show that it has no influence on any of the three competences.

Next, we would like to highlight some of the results obtained for the control variables used in our models. These results can be found in the appendix (table A.4).

At student level, results show a better performance of boys than girls in mathematics and science. However, girls perform better at reading. The index of immigrant status suggests that native students get better scores than immigrants in all the competences, but especially in reading. Moreover, the higher the age of arrival in the country for immigrant students, the worse the academic performance. Concerning repetition of grades and school truancy, both negatively affect the students' scores. Finally, the start age of ISCED 0 is only statistical significant for mathematics, indicating that a higher start age leads to a worse academic performance in this area.

At home and family level, we observe that speaking a language different to Spanish at home is negatively associated with the performance in science and reading, but has no effect on mathematics. The occupational status of parents and the number of books at home are positively related to scores in all the competences, but the education status of parents is not statistically significant in any of the areas evaluated.

At school level, most of the variables are not statistically significant. Only the school autonomy seems to be relevant and affect scores achieved in mathematics.

Finally, we have detected regional variations. One of the most notable results is that Castilla y León and Madrid show a better performance in all the competences than the Comunidad Valenciana (Autonomous Communities of reference in the three models). In contrast, Andalucía is the only region that shows a worse performance for the three areas. It would be of great interest to study in depth these regional variations in future research in order to draw accurate conclusions and guide educational policy decisions.

Additionally to the estimations presented in this results' section, a special section at the end of this paper has been dedicated to carrying out a comparative analysis between PISA 2012 and PISA 2015 in order to verify the robustness of the results, as well as to investigate if the effects of the different ICT variables have been maintained over time. The results show that most of the variables maintain their behavior over time.

Regression models by tertiles of performance

We have run separately linear hierarchical regression models by using tertiles of performance in the three competences[3] in order to study if there are significant variations on the relation between ICT on academic performance depending on the tertile of performance of the students. For this purpose, we have split the sample for Spain in each competence into three groups: high achieving students (highest tertile of performance in the corresponding competence), middle achieving students (second tertile) and low achieving students (lowest tertile). Table 3 shows the descriptive statistics of the score achieved by students in each of the tertiles of the different competences. Table 4 shows the sign of the coefficients of our regressions[4]. If there is no sign, it means the coefficient is not statistically significant.

[Table 3 around here]

[Table 4 around here]

The most notable result of the models by tertiles of performance is found in the statistical significance of the different variables. As observed in the previous tables, most of the ICT variables are statistically significant in the estimates for the low achieving students, but become not statistically significant for the scores of those students in the middle and top tertile of academic achievement. This result has substantial implications for public policy recommendations, as it suggests that ICT can be an important tool to improve the academic performance of the students with the worse results as also advocated by Muralidharan et al. (2017).

The results by tertiles confirm the negative relation between the use of ICT at home for homework, the availability of ICT at school and a higher starting age for using ICT, and the scores of the students. However, the relation between the rest of ICT variables and the

[3] This split method has been decided given the distribution of academic performance variables (see graph A.1 in appendix).

[4] The complete results of these regressions are in tables A.5, A.6 and A.7 (Annex).

academic achievement of students varies depending on the competence and tertile analysed.

Therefore, our regressions by tertiles of performance show two main results: (i) ICT has a higher impact on academic achievement of low performance students, and (ii) the use of ICT at home for schoolwork, the availability of ICT at school and a higher age of beginning in the use of ICT, are associated with lower scores independently of the competence and the tertile of performance of the student.

5. Final Considerations

The analysis of PISA 2015 microdata through a two-level linear hierarchical model reveals a correlation between the use of ICT at the personal and school level and the academic performance of Spanish students in mathematics, science and reading comprehension.

We have obtained several results that deserve special attention. The sign of the association with academic performance differs between the diverse ICT variables used. This fact shows the importance of properly implementing ICT in the learning process, with the aim of making the most of the advantages of Information and Communication Technologies. In this regard, it is striking that the positive association between academic achievement and the use of ICT at home is related with the use of ICT for entertainment purposes and not for homework (negative impact). This result is in line with that obtained in previous studies (Biagi and Loi, 2013, Mediavilla and Escardíbul, 2015, Agasisti et al., 2017). As already mentioned in the description of the results, the negative effect of using ICT at home for schoolwork can be explained by the existence of inverse causality and the lack of familiarization of students with electronic devices. Moreover, it is also important to train teachers to correctly integrate ICT when assigning homework.

However, the positive relation between the use of ICT for entertainment and the academic performance can be explained by the fact that, thanks to playing with ICT, students become more motivated and more familiar with using these tools, which can have a positive effect when they use them for educational purposes.

On the other hand, it is also noteworthy that the index of general use of ICT in schools by students is associated with negative effects. This result indicates an inadequate use of ICT at schools and thus should be analysed in depth in order to identify its causes and overcome them. One reason could be insufficient teacher training in the use of ICT, as suggested by Cruz el al. (2018) who conclude that teachers still do not have the digital skills needed to work with ICT in schools.

At the student level, one significant result is the magnitude of the coefficient for the relation between the starting age for using ICT on the scores in mathematics, science and reading. The higher the age, the lower the score achieved. Moreover, it is important to highlight the result obtained for the variables introduced for the first time in PISA 2015: "interest in use by ICT of the students “and “ICT as a topic in Social Interaction”. Students’ interest in ICT is positively related with the scores achieved in our three models while the importance of ICT as a topic in social interaction shows a negative effect for all the competences.

On the other hand, the use of control variables for Autonomous Communities determines some significant regional variations that should be analysed in more detail in order to draw accurate conclusions. A possible future line of research would be to investigate, with different models for each Autonomous Community, the potential differences in the incidence of ICT in academic performance. It would also be interesting to make comparisons of the results of the national set with other countries. These comparative analyses would allow the contextualization of the results and recommended policies.

The results obtained have substantial implications for educational policies in Spain, especially due to the fact that the main conclusions reached in this research were also observed in PISA 2012, as shown in our comparative analysis section. According to our results, it would be advisable to explore the use of ICT in schools. New technologies must adapt to the curriculum of the subjects and be conveniently applied in the learning process. At the same time, teachers must receive sufficient training to be competent in digital uses and be able to take advantage of ICT in the classroom. Likewise, the interest in ICT of students should be strengthened. Moreover, as observed in the results of the regressions by tertiles of performance, ICT can also play an important role in improving the academic performance of those students with the worse results.

The structure of the education system must be reorganized and adapted to the new needs of an intensely digitized world in order to convert ICT into a quality factor that leads to an improvement in the academic performance of school students.

6. References

Abell, M. (2006). Individualizing learning using intelligent technology and universally designed curriculum. *The journal of Technology, Learning and Assessment*, *5(3):5-10.*

Acock, A. (2005). Working with missing values. *Journal of Marriage and family*, *67*(4), 1012-1028.

Agasisti, T., Gil-Izquierdo, M. & Han, S. (2017). ICT use at home for school-related tasks: What is the effect on a student's achievement? Empirical evidence from OECD PISA data. *Munich Personal RePEc Archive (MPRA) Paper*, no. 81343

Alderete, M., & Formichella, M. (2016). Efecto de las TIC en el rendimiento educativo: el Programa Conectar Igualdad en la Argentina. *Revista CEPAL,* (119), 89-107. Retrieved from http://www.econis.eu/PPNSET?PPN=873793161.

Alker, H. (1969). A typology of ecological fallacies. *Quantitative Ecological Analysis in the Social Sciences*, 1969. pp. 69–86.

Allegra, M., Chifari, A. & Ottaviano, S. (2001). ICT to train students towards creative thinking. *Educational Technology & Society*, *4*(2), 48-53.

Alonso, C., Guitert, M. & Romeu, T. (2014). Los entornos 1x1 en Cataluña. *Educar*, *50*(1), 41-64.

Angrist, J. & Lavy, V. (2002). New evidence on classroom computers and pupil learning. *The Economic Journal*, *112*(482), 735-765.

Aypay, A. (2010). Information and communication technology (ICT) usage and achievement of Turkish students in PISA 2006. *TOJET: The Turkish Online Journal of Educational Technology*, *9(2), 116-124.*

Banerjee, A., Cole, S., Duflo, E. & Linden, L. (2007). Remedying education: Evidence from two randomized experiments in India. *The Quarterly Journal of Economics*, *122*(3), 1235-1264.

Barrera-Osorio, F. & Linden, L. (2009). The use and misuse of computers in education: Evidence from a randomized experiment in Colombia. Washington: The World Bank.

Barrow, L., Markman, L. & Rouse, C. (2009). Technology's edge: The educational benefits of computer-aided instruction. *American Economic Journal: Economic Policy*, *1*(1), 52-74.

Belo, R., Ferreira, P. & Telang, R. (2016). Spillovers from Wiring Schools with Broadband: The Critical Role of Children. *Management Science*, *62*(12), 3450-3471.

Beuermann, D., Cristia, J., Cueto, S., Malamud, O. & Cruz-Aguayo, Y. (2015). One laptop per child at home: Short-term impacts from a randomized experiment in Peru. *American Economic Journal: Applied Economics, 7*(2), 53-80.

Biagi, F. & Loi, M. (2013). Measuring ICT use and learning outcomes: Evidence from recent econometric studies. *European Journal of Education*, *48*(1), 28-42.

Bullock, J. (2001). Evaluating the impact of using ICT upon student motivation and attainment in English. *Available: HYPERLINK http://www. educ. cam. ac. uk/research/projects/tips/bullock. pdf*.

Cabras, S. & Tena, J. (2013). Estimación del efecto causal del uso de ordenadores en los resultados de los estudiantes en la prueba PISA 2012. *PISA 2012, Informe Español*, *67-87.*

Calero, J., Choi, Á. & Waisgrais, S. (2009). Determinantes del rendimiento educativo del alumnado de origen nacional e inmigrante en PISA-2006. *Cuadernos económicos de ICE*, (78), 281-310.

Carbonell, X., Chamarro, A., Griffiths, M., Oberst, U., Cladellas, R. & Talarn, A. (2012). Problematic Internet and cell phone use in Spanish teenagers and young students. *Anales de Psicología/Annals of Psychology*, *28*(3), 789-796.

Carillo, P., Onofa, M. & Ponce, J. (2011). Information technology and student achievement: evidence from a randomized experiment in Ecuador. Working Paper IDB-WP-223. Washington, DC: Inter-American Development Bank.

Carpenter, J., Kenward, M. & White, I. (2007). Sensitivity analysis after multiple imputation under missing at random: a weighting approach. *Statistical Methods in Medical Research*, *16*(3), 259-275.

Choi, A. & Calero, J. (2013). Determinantes del riesgo de fracaso escolar en España en PISA 2009 y propuestas de reforma. *Revista de Educación*, 362, 562-593.

Claro, M. (2010). *Impacto de las TIC en los aprendizajes de los estudiantes. Estado del arte.* Santiago de Chile: CEPAL

Coleman, J. (1966). *Equality of educational opportunity* (Vol. 2). Washington, DC: US Department of Health, Education, and Welfare, Office of Education.

Condie, R. and Munro, B. (2006). The impact of ICT in schools—a landscape review, Coventry: Becta.

Cordero, J., Pedraja, F. & Simancas, R. (2015) Factores del éxito escolar en condiciones socioeconómicas desfavorables. *Revista de Educación*, (370), p. 172- 187. DOI: 10.4438/1988- 592X-RE-2015-370-302.

Cox, M., Webb, M., Abbott, C., Blakely, B., Beauchamp, T. & Rhodes, V. (2004). ICT and pedagogy : a review of the research literature : a report to the DfES (ISBN: 1844781356). Unknown Publisher.

Cristia, J., Czerwonko, A. & Garofalo, P. (2014). Does technology in schools affect repetition, dropout and enrollment? Evidence from Peru. *Journal of Applied Economics*, *17*(1), 89-111.

Cruz, F., Díaz, M. & Mantilla, J. (2018). El proceso de integración y uso pedagógico de las TIC en los centros educativos madrileños. *Educación XX1*, 21(2, 395-416

De Melo, G., Machado, A., Miranda, A. & Viera, M. (2013). Impacto del Plan Ceibal en el aprendizaje: Evidencia de la mayor experiencia OLPC. *Serie Documentos de Trabajo/FCEA-IE; DT13/13*.

Donohue, G., Tichenor, P. & Olien, C. (1975). Mass media and the knowledge gap a hypothesis reconsidered. *Communication Research*, *2*(1), 3-23.

Escardíbul, J. & Mediavilla, M. (2016). El efecto de las TIC en la adquisición de competencias. Un análisis por tipo de centro educativo. *Revista Española de Pedagogía*, Vol. 74, No. 264. pp. 317-335

Fairlie, R. (2016). Do boys and girls use computers differently, and does it contribute to why boys do worse in school than girls? *B. E. Journal of Economic Analysis and Policy, 16*(1), 59-96. Retrieved from https://search.proquest.com/docview/1786124120?accountid=1719.

Fairlie, R. & Robinson, J. (2013). Experimental evidence on the effects of home computers on academic achievement among schoolchildren. *American Economic Journal: Applied Economics*, *5*(3), 211-240.

Fairlie, R., Beltran, D. & Das, K. (2010). Home computers and educational outcomes: evidence from the NLSY97 and CPS. *Economic Inquiry*, *48*(3), 771-792.

Falck, O., Mang, C. & Woessmann, L. (2018). Virtually No Effect? Different Uses of Classroom Computers and their Effect on Student Achievement. *Oxford Bulletin of Economics and Statistics*, *80*(1), 1-38.

Ferrando, M., Machado, A., Perazzo, I. & Vernengo, A. (2011). Aprendiendo con las XO: El Impacto del Plan Ceibal en el aprendizaje. Documentos de Trabajo (working papers) 11-03, Instituto de Economía – IECON.

Formichella, M. (2011). ¿Se debe el mayor rendimiento de las escuelas de gestión privada en la Argentina al tipo de administración? *Revista de la Cepal, N° 10*5, 151-166.

Fuchs, T. & Wößmann, L. (2005). *Computers and Student Learning: Bivariate and Multivariate Evidence on the Availability and Use of Computers at Home and at School* (No. Ifo Working Paper No. 8). Ifo Institute-Leibniz Institute for Economic Research at the University of Munich.

Goolsbee, A. & Guryan, J. (2006). The impact of Internet subsidies in public schools. *The Review of Economics and Statistics*, *88* (2), 336-347.

Grimes, D. & Warschauer, M. (2008). Learning with laptops: A multi-method case study. *Journal of Educational Computing Research*, *38* (3), 305-332.

Gui, M., Micheli, M. & Fiore, B. (2014). Is the Internet creating a 'learning gap' among students? Evidence from the Italian PISA data. *Italian Journal of Sociology of Education*, *6*(1), 1-24.

Güzeller, C. & Ayça, A. (2014). Relationship between ICT variables and mathematics achievement based on PISA 2006 database: International evidence. *TOJET: The Turkish Online Journal of Educational Technology*, *13* (1), 184-192.

Hox, J. (1995). *Applied multilevel analysis*. Ámsterdam: TT-publikaties.

Kubiatko, M. & Vlckova, K. (2010). The relationship between ICT use and science knowledge for Czech students: A secondary analysis of PISA 2006. *International Journal of Science and Mathematics Education*, *8* (3), 523-543.

Lai, F., Luo, R., Zhang, L., Huang, X. & Rozelle, S. (2015). Does computer-assisted learning improve learning outcomes? Evidence from a randomized experiment in migrant schools in Beijing. *Economics of Education Review, 47*, 34-48. DOI: http://dx.doi.org/10.1016/j.econedurev.2015.03.005

Lee, Y., Atkinson, C., Hritsko, D. & Acquaah, K. (2014). *The Effects of Cell Phone Distraction on Cognitive Tasks* (pp. 1-42). Working paper.

Leuven, E., Lindahl, M., Oosterbeek, H. & Webbink, D. (2007). The effect of extra funding for disadvantaged pupils on achievement. *The Review of Economics and* Statistics, *89* (4), 721-736.

Linden, L. (2008). *Complement or substitute? The effect of technology on student achievement in India*. Mimeo Columbia University.

Machin, S., McNally, S. & Meghir, C. (2010). Resources and standards in urban schools. *Journal of Human Capital*, *4* (4), 365-393.

Malamud, O. & Pop-Eleches, C. (2011). Home computer use and the development of human capital. *The Quarterly Journal of Economics*, *126*(2), 987–1027.

MediavIlla, M. & Escardíbul, J. (2015). ¿Son las TIC un factor clave en la adquisición de competencias? Un análisis con evaluaciones por ordenador. *Hacienda Pública Española*, (212), num. 1, p. 67-96.

Mediavilla, M. (2018). "De cuando la innovación tecnológica no implica innovación educativa: el caso de las políticas TIC en España". *Indicadores comentados sobre el estado del Sistema Educativo Español*, pp. 100-103. Fundación Ramón Areces – Fundación Europea Sociedad y Educación.

Meroni, E., Vera-Toscano, E. & Costa, P. (2015). Can low skill teachers make good students? Empirical evidence from PIAAC and PISA. *Journal of Policy Modeling*, (37), Issue 2, p. 308-323.

Mora, T., Escardíbul, J. O., & Di Pietro, G. (2018). Computers and students' achievement: An analysis of the One Laptop per Child program in Catalonia. *International Journal of Educational Research*.

Muralidharan, K., Singh, A. & Ganimian, A. (2016). Disrupting education? experimental evidence on technology-aided instruction in India. Technical report, National Bureau of Economic Research.

Notten, N. & Kraaykamp, G. (2009). Home media and science performance: A cross national study. *Educational Research and Evaluation*, *15*(4), 367-384.

OECD. Publishing. (2009). *PISA Data Analysis Manual: SAS*. OECD.

OECD. Publishing (2015). Technical Report. OECD.

Rouse, C. & Krueger, A. (2004). Putting computerized instruction to the test: a randomized evaluation of a "scientifically based" reading program. *Economics of Education Review*, *23* (4), 323-338.

Royston, P. & White, I. (2011). Multiple imputation by chained equations (MICE): implementation in Stata. *Journal of Statistical Software*, *45*(4), 1-20.

Rubin, D. (1976). Inference and missing data. *Biometrika*, *63*(3), 581-592.

Rubin, D. (1996). Multiple imputation after 18+ years. *Journal of the American statistical Association*, *91*(434), 473-489.

Schmitt, J. & Wadsworth, J. (2006). Is there an impact of household computer ownership on children's educational attainment in Britain? *Economics of Education Review*, *25* (6), 659-673.

Schulz-Zander, R., Büchter, A. & Dalmer, R. (2002). The role of ICT as a promoter of students' cooperation. *Journal of Computer Assisted Learning*, *18*(4), 438-448.

Snijders, T. (2011). Multilevel analysis. In: *International Encyclopedia of Statistical Science* (pp. 879-882). Springer Berlin Heidelberg.

Song, H. & Kang, T. (2012). Evaluating the Impacts of ICT Use: A Multi-Level Analysis with Hierarchical Linear Modeling. *Turkish Online Journal of Educational Technology-TOJET*, *11* (4), 132-140.

Spiezia, V. (2010). Does computer use increase educational achievements? Student-level evidence from PISA. *OECD Journal: Economic Studies*, (1), 1-22.

Suhr, K., Hernandez, D., Grimes, D. & Warschauer, M. (2010). Laptops and fourth grade literacy: Assisting the jump over the fourth-grade slump. *The Journal of Technology, Learning and Assessment*, *9* (5), 1-46.

Thorpe, G. (2006). Multilevel analysis of PISA 2000 reading results for the United Kingdom using pupil scale variables. *School Effectiveness and School Improvement*, *17* (1), 33-62.

Türel, Y. & Toraman, M. (2015). The relationship between Internet addiction and academic success of secondary school students. *Anthropologist*, *20(1,2), 280-288.*

Tüzün, H., Yılmaz-Soylu, M., Karakuş, T., İnal, Y. & Kızılkaya, G. (2009). The effects of computer games on primary school students’ achievement and motivation in geography learning. *Computers & Education*, *52*(1), 68-77.

Van Buuren, S. & Oudshoorn, K. (1999). Flexible multivariate imputation by MICE. *Leiden, The Netherlands: TNO Prevention Center*.

Vilaplana, C. (2016). Evaluation of reading achievement of the program school 2.0 in Spain using PISA 2012. In A. Pareja-Lora, C. Calle-Martínez & P. Rodríguez-Arancón (Eds), New perspectives on teaching and working with languages in the digital era (pp. 63-72). Dublin: Research-publishing.net. DOI: 10.14705.

Wheeler, S., Waite, S. & Bromfield, C. (2002). Promoting creative thinking through the use of ICT. *Journal of Computer Assisted Learning*, *18*(3), 367-378.

Table 1: Descriptive statistics of the ICT variables and dependent variables used in the analysis

Variable	***N***	***% Missing Values***	***Mean***	***Std. Dev.***	***Min***	***Max***
ICT available at Home Index	29.433	8.96	8,803	1,697	0,000	11,000
ICT use outside of school for schoolwork	30.724	4.97	-0,090	0,870	-2,691	3,604
ICT use outside of school for leisure	31.259	3.31	-0,086	0,834	-3,710	4,848
ICT available at School Index	29.106	9.97	6,015	2,051	0,000	10,000
Use of ICT at school in general	30.888	4.46	-0,043	0,868	-1,668	3,629
Students' ICT interest	30.688	5.08	0,173	0,981	-2,995	2,720
Students' ICT as a topic in Social interaction	30.177	6.67	0,103	0,943	-2,136	2,428
Starting age for using ICT	31.699	1.95	1,896	0,852	1,000	5,000
Computer / Students ratio	29.181	9.74	0,798	0,726	0,000	8,654
Mean Mathematics	32.330	0.00	492,979	76,128	221,876	736,249
Mean Reading	32.330	0.00	501,576	80,336	204,008	755,13
Mean Science	32.330	0.00	499,347	83,086	198,269	745,844

Source: compiled by the authors based on microdata from PISA 2015

Table 2. Effect of ICT on the academic performance in mathematics, science and reading[5].

VARIABLES	(1) Mathematics	(2) Science	(3) Reading
ICT available at Home Index	**0.719**	**-0.622**	**-1.091**
	(0.003)	(0.024)	(0.000)
ICT use outside of school for schoolwork	**-8.398**	**-10.301**	**-11.001**
	(0.000)	(0.000)	(0.000)
ICT use outside of school for leisure	**1.696**	**4.188**	**4.318**
	(0.002)	(0.000)	(0.000)
ICT available at School Index	**-2.419**	**-2.856**	**-2.160**
	(0.000)	(0.000)	(0.000)
Use of ICT at school in general	**-0.995**	**-2.807**	**-3.162**
	(0.049)	(0.000)	(0.000)
Students' ICT interest	**2.968**	**3.986**	**5.370**
	(0.000)	(0.000)	(0.000)
Students' ICT as a topic in Social interaction	**-1.140**	**-1.367**	**-3.587**
	(0.011)	(0.007)	(0.000)
Starting Age for using ICT	**-10.679**	**-12.403**	**-9.886**
	(0.000)	(0.000)	(0.000)
Computer / Students ratio	1.092	1.302	0.840
	(0.121)	(0.119)	(0.280)

[5] The full results of the estimates can be found in the table A.4. in the Annex.

Constant and student, family, school and location (Autonomous Communities) control variables included	Yes	Yes	Yes
Observations (min-max) $^{\alpha}$	21,785-21,887	21,785-21,887	21,785-21,887
Number of schools	864	864	864

**P-values in parentheses. Statistically significant values up to 5% level included appear in bold.*

**The coefficients and the p-values are the result of calculating the average of the 16 estimates made for the different 16 values of each imputed variable.*

$^{\alpha}$ *Total number of observations varies according to the estimate as a consequence of the manual elimination of outliers presented by some imputed variables*.

Table 3: Descriptive statistics of the dependent variable (mean) by tertiles of performance in the three competences (mathematics, science and reading)

	N	Mean	Std. Dev.	Min	Max
			Mathematics		
Bottom	10,777	407.286	40.363	221.876	461.061
Middle	10,777	495.956	19.568	461.092	529.812
Top	10,776	575.703	34.334	529.817	736.249
			Science		
Bottom	10,777	405.243	43.064	198.269	463.598
Middle	10,777	502.990	21.850	463.608	540.425
Top	10,776	589.817	36.385	540.427	745.844
			Reading		
Bottom	10,777	409.983	47.471	204.008	471.470
Middle	10,778	508.180	20.355	471.485	542.516
Top	10,775	586.581	32.178	542.524	755.130

Table 4: Sign of the effect of ICT on the academic performance in mathematics, reading and science by tertiles of performance

	Mathematics			Science			Reading		
VARIABLES	Bottom	Middle	Top	Bottom	Middle	Top	Bottom	Middle	Top
ICT available at Home Index			pos				neg		
ICT use outside of school for schoolwork	neg	neg	neg	neg	neg	neg	neg	neg	neg
ICT use outside of school for leisure	pos			pos			pos		
ICT available at School Index	neg	neg	neg	neg		neg	neg	neg	neg
Use of ICT at school in general				neg			neg		
Students' ICT interest	pos			pos			pos	pos	
Students' ICT as a topic in Social interaction	neg							neg	neg
Starting Age for using ICT	neg	neg	neg	neg	neg	neg	neg	neg	neg
Computer / Students ratio						pos			
Constant and student, family, school and location (Autonomous Communities) control variables included	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations (min-max) $^{\alpha}$	6,147-6,193	7,512-7,550	8,086-8,161	6,077-6,120	7,532-7,580	8,133-8,207	6,021-6,069	7,588-7,620	8,138-8,211
Number of schools $^{\alpha}$	850-853	860	848-850	852-856	860-862	852-854	850-853	861-862	850-852

**P-values in parentheses. Statistically significant values up to 5% level included appear in bold.*

**The coefficients and the p-values are the result of calculating the average of the 16 estimates made for the different 16 values of each imputed variable.*

$^{\alpha}$ *Total number of observations and schools varies according to the estimate as a consequence of the manual elimination of outliers presented by some imputed variables.*

Appendix

Table A.1. Definition of ICT variables used in the empirical analysis

Variable	***Definition***
ICT use outside of school for schoolwork (WLE)	Frequency of use of digital devices (never or hardly ever, once or twice a month, once or twice a week, almost every day, every day) to perform the following activities at school: use email or Social Networks for communication with other students or teachers about schoolwork; browse the internet to complete school assignments or follow up lessons; download/upload/browsing school materials from the school's intranet; check the schools website for announcements; do homework on computer or on a mobile device; download learning apps on a mobile device.
ICT use outside of school for leisure (WLE)	Frequency of use of digital devices (never or hardly ever, once or twice a month, once or twice a week, almost every day, every day) to perform the following activities at home: games (one-player or collaborative); email; chat; social networks; online games; fun videos; read the news; get practical information; download music, films, games or software from the Internet; upload own created content for sharing; download new applications on a mobile device.
Use of ICT at school in general (WLE)	Frequency of use of digital devices (never or hardly ever, once or twice a month, once or twice a week, almost every day, every day) to perform the following activities at school: chat online; use e-mail; browse the Internet for schoolwork; download/upload/browse school webs; post the work on the schools website; play simulations at school; practice and drill, foreign language learning or math; do homework on a school computer; use school computers for group work and communication with other students.
Students' ICT interest (WLE)	Degree of agreement (strongly disagree, disagree, agree, strongly agree) with the following statements: "I forget about time when I'm using digital devices"; "The Internet is a great resource for obtaining information I am interested in"; "It is very useful to have Social Networks on the Internet"; "I am really excited discovering new digital devices or applications"; "I really feel bad if no Internet Connection is possible"; "I like using digital devices".

Students' ICT as a topic in Social interaction (WLE)	Degree of agreement (strongly disagree, disagree, agree, strongly agree) with the following statements: "To learn something new about digital devices, I like to talk about them with my friends"; "I like to exchange solutions to problems with digital devices with others on the Internet"; "I like to meet friends and play computer and video games with them"; "I like to share information about digital devices with my friends"; "I learn a lot about digital media by discussing with my friends and relatives".
ICT available at School Index (Sum)	Sum of the following items: desktop computer; laptop or notebook; tablet; internet connected school computers; internet connection via wireless network; storage space for school-related data; ;USB stick; eBook reader; Data Projector; Interactive Whiteboard.
ICT available at Home Index (Sum)	Sum of the following items: desktop computer; laptop or notebook; tablet; internet connection; video games console; cell phone (with and without internet access); portable music player; printer; USB stick; eBook reader.
Starting age for using ICT (Categorical)	1 = 6 years old or younger 2 = 7-9 years old 3 = 10-12 years old 4 = 12 years old or older 5 = I have never used a digital device until today
Computer / Students ratio	Total number of computers per student at the school

Source: compiled by the authors based on OECD codebook for microdata from PISA 2015.

Table A.2: Definition of categorical control variables

Student Level	
Female	0 = Male 1 = Female
Index Immigration Status (IMMIG)	0= Native 1 = Second-generation 2 = First-generation
Age of Arrival of Immigrant Students	0 = Native 1 = age 0-2 2 = age 3-5 3 = age 6-7 4 = age 8-9 5 = age 10-11 6 = 12 years or older
Repetition of grade	0 = Did not repeat a grade 1 = Repeated a grade
School truancy (number of whole school days skipped in the last two full weeks prior to the test)	1= None 2 = One or two times 3 = Three or four times 4 = Five or more times
Starting age of ISCED 0	1 = 2 years or younger 2 = 3 years 3 = 4 years or older 4 = Did not attend ISCED 0
Family Level	
Language at home	0 = Language of test 1 = Other language
Highest educational level of parents (HISCED)	1 = None or ISCED 1 2 = ISCED 2 3= ISCED 3B, 3C, 3A, 4 4 = ISCED 5B, 5A, 6
Number of books at home	1.= 0-10 books 2 = 11-25 books 3 = 26-100 books 4 = 101-200 books 5 = 201-500 books 6 = More than 500 books

School Level	
School Ownership	1 = Private Independent 2 = Private Government-Dependent 3 = Public
Location (Community in which the school is located)	1 = A village, hamlet or rural area (fewer than 3 000 people) 2 = A small town (3 000 to about 15 000 people) 3 = A town (15 000 to about 100 000 people) 4 = A city (100 000 to about 1 000 000 people) 5 = A large city (with over 1 000 000 people)
Class Size (Average size of classes in the national modal grade for 15-year-olds in the school)	1 = 15 students or fewer 2 = 16-20 students 3 = 21-25 students 4 = 26-30 students 5 = 31-35 students 6 = 36-40 students 7 = 41-45 students 8 = 46-50 students 9 = More than 50 students

Source: compiled by the authors based on microdata from PISA 2015

Table A.3: Descriptive statistics control variables

Variable	*N*	*% Missing Values*	*Mean*	*Std. Dev.*	*Min*	*Max*
	Student Level					
Female	32.330	0.00	0,494	0,500	0	1
Index Immigration Status (Immig)	31.640	2.13	0,201	0,588	0	2
Age of Arrival of Immigrant Students	32.309	0.00	0,318	1,060	0	6
Repetition of Grande	32.130	0.00	0,285	0,451	0	1
School Truancy	31.840	1.51	1,277	0,585	1	4
Starting age of ISCED 0	30.065	7.00	1,827	0,610	1	4
Family Level						
Language at home	32.119	0.00	0,171	0,376	0	1
Highest occupational status of parents (HISEI)	30.507	5.64	48,519	23,166	11	89
Highest educational level of parents (HISCED)	31.698	1.95	3,289	0,950	1	4
Number of books at home	32.038	0.00	3,493	1,374	1	6
School Level						
School Ownership	30.418	5.91	2,609	0,587	1	3
Location	31.140	3.68	3,019	1,002	1	5
School Autonomy	31.228	3.40	0,562	0,186	0	1
Class Size	30.971	4.20	3,826	1,809	1	9
School Size	29.484	8.80	744,506	435,693	23	4034
Student-Teacher ratio	29.133	9.89	12,527	4,420	1	50,476
Index proportion of all teachers fully certified	27.410	15.21	0,887	0,280	0	1

Source: compiled by the authors based on microdata from PISA 2015.

Table A.4: Complete models

VARIABLES	(1) Mathematics	(2) Science	(3) Reading
ICT available at Home Index	**0.719**	**-0.622**	**-1.091**
	(0.003)	(0.024)	(0.000)
ICT use outside of school for schoolwork	**-8.398**	**-10.301**	**-11.001**
	(0.000)	(0.000)	(0.000)
ICT use outside of school for leisure	**1.696**	**4.188**	**4.318**
	(0.002)	(0.000)	(0.000)
ICT available at School Index	**-2.419**	**-2.856**	**-2.160**
	(0.000)	(0.000)	(0.000)
Use of ICT at school in general	**-0.995**	**-2.807**	**-3.162**
	(0.049)	(0.000)	(0.000)
Students' ICT interest	**2.968**	**3.986**	**5.370**
	(0.000)	(0.000)	(0.000)
Students' ICT as a topic in Social interaction	**-1.140**	**-1.367**	**-3.587**
	(0.011)	(0.007)	(0.000)
Starting age for using ICT	**-10.679**	**-12.403**	**-9.886**
	(0.000)	(0.000)	(0.000)
Computer / Students ratio	1.092	1.302	0.840
	(0.121)	(0.119)	(0.280)
Female	**-19.156**	**-15.514**	**8.626**
	(0.000)	(0.000)	(0.000)
Index Immigration Status	**2.554**	**7.036**	**10.793**
	(0.018)	(0.000)	(0.000)
Age of arrival of immigrant students	**-3.939**	**-4.813**	**-5.438**
	(0.000)	(0.000)	(0.000)
Repetition of grade	**-72.119**	**-73.394**	**-74.083**
	(0.000)	(0.000)	(0.000)
School Truancy	**-10.324**	**-10.573**	**-9.288**
	(0.000)	(0.000)	(0.000)
Starting age of ISCED 0	**-2.652**	-1.178	-0.546
	(0.000)	(0.125)	(0.439)
Language at home	-1.624	**-8.309**	**-8.480**
	(0.259)	(0.000)	(0.000)
Highest occupational status of parents	**0.259**	**0.266**	**0.230**
(HISEI)	(0.000)	(0.000)	(0.000)
Highest educational level of parents (HISCED)	-0.256	0.008	0.192
	(0.584)	(0.883)	(0.698)
Number of books at home	**10.959**	**12.440**	**11.891**
	(0.000)	(0.000)	(0.000)
School Ownership	1.200	1.931	-1.655
	(0.356)	(0.208)	(0.247)
Location	-0.090	0.788	0.828
	(0.873)	(0.266)	(0.209)
School Autonomy	**8.007**	7.090	3.748
	(0.035)	(0.115)	(0.372)
Class Size	0.528	0.439	0.312
	(0.068)	(0.202)	(0.330)

School Size	0.001	0.000	0.001
	(0.612)	(0.821)	(0.728)
Student-Teacher ratio	-0.046	0.065	0.270
	(0.768)	(0.726)	(0.118)
Index proportion all teachers fully certified	2.710	3.347	3.758
	(0.128)	(0.113)	(0.056)
Andalucía	**-10.476**	**-11.498**	**-11.544**
	(0.000)	(0.001)	(0.000)
Aragón	**10.875**	**8.632**	1.662
	(0.000)	(0.015)	(0.616)
Asturias	2.216	2.574	**-7.478**
	(0.465)	(0.474)	(0.026)
Baleares	2.104	3.696	-2.989
	(0.473)	(0.287)	(0.356)
Canarias	**-16.039**	0.142	0.795
	(0.000)	(0.931)	(0.807)
Cantabria	**7.906**	-1.062	-2.498
	(0.007)	(0.758)	(0.438)
Castilla León	**15.122**	**16.437**	**12.075**
	(0.000)	(0.000)	(0.000)
Castilla La Mancha	4.908	**6.993**	1.682
	(0.086)	(0.039)	(0.595)
Cataluña	**10.183**	**8.672**	-2.801
	(0.001)	(0.018)	(0.412)
Extremadura	-3.687	**-11.137**	**-15.994**
	(0.213)	(0.002)	(0.000)
Galicia	1.457	**12.601**	4.300
	(0.619)	(0.000)	(0.185)
La Rioja	**20.749**	3.938	**-10.757**
	(0.000)	(0.287)	(0.002)
Madrid	**8.672**	**9.629**	**6.105**
	(0.004)	(0.007)	(0.065)
Murcia	-5.641	-1.516	-6.172
	(0.053)	(0.660)	(0.054)
Navarra	**20.907**	**6.221**	2.245
	(0.000)	(0.076)	(0.493)
País Vasco	-3.487	**-18.258**	**-14.781**
	(0.205)	(0.000)	(0.000)
Comunidad Valenciana	Omitted	Omitted	Omitted
Constant	**507.929**	**521.401**	**519.553**
	(0.000)	(0.000)	(0.000)
Observations (min-max) $^{\alpha}$	21,785-21,887	21,785-21,887	21,785-21,887
Number of schools	756	756	756

**P-values in parentheses. Statistically significant values up to 5% level included appear in bold.*

**The coefficients and the p-values are the result of calculating the average of the 16 estimates made for the different 16 values of each imputed variable.*

α Total number of observations varies according to the estimate as a consequence of the manual elimination of outliers presented by some imputed variables.

Table A.5: Effect of ICT on the academic performance in mathematics by tertiles of performance[6]

VARIABLES	Bottom	Middle	Top
ICT available at Home Index	-0.035	-0.039	**0.898**
	(0.868)	(0.776)	(0.001)
ICT use outside of school for schoolwork	**-2.474**	**-1.595**	**-2.550**
	(0.000)	(0.000)	(0.000)
ICT use outside of school for leisure	**1.359**	0.246	-0.358
	(0.008)	(0.480)	(0.607)
ICT available at School Index	**-0.740**	**-0.339**	**-1.136**
	(0.000)	(0.006)	(0.000)
Use of ICT at school in general	-0.583	0.043	0.469
	(0.251)	(0.869)	(0.406)
Students' ICT interest	**2.401**	0.434	0.637
	(0.000)	(0.100)	(0.206)
Students' ICT as a topic in Social interaction	**-1.066**	-0.077	-0.417
	(0.033)	(0.778)	(0.387)
Starting age for using ICT	**-3.742**	**-1.269**	**-5.035**
	(0.000)	(0.000)	(0.000)
Computer / Students ratio	0.452	-0.074	0.510
	(0.429)	(0.831)	(0.411)
Constant and student, family, school and location (Autonomous Communities) control variables included	Yes	Yes	Yes
Observations (min-max) $^{\alpha}$	6,147-6,193	7,512-7,550	8,086-8,161
Number of schools $^{\alpha}$	850-853	860	848-850

**P-values in parentheses. Statistically significant values up to 5% level included appear in bold.*
**The coefficients and the p-values are the result of calculating the average of the 16 estimates made for the different 16 values of each imputed variable.*
$^{\alpha}$ *Total number of observations and schools varies according to the estimate as a consequence of the manual elimination of outliers presented by some imputed variables*.

[6] Complete results upon request

Table A.6: Effect of ICT on the academic performance in science by tertiles of performance[7]

VARIABLES	Bottom	Middle	Top
ICT available at Home Index	-0.482	-0.176	0.385
	(0.071)	(0.301)	(0.177)
ICT use outside of school for schoolwork	**-2.691**	**-1.468**	**-3.159**
	(0.000)	(0.000)	(0.000)
ICT use outside of school for leisure	**2.810**	-0.090	-0.522
	(0.000)	(0.815)	(0.480)
ICT available at School Index	**-1.000**	-0.207	**-1.057**
	(0.000)	(0.1134)	(0.000)
Use of ICT at school in general	**-1.666**	-0.298	-0.312
	(0.002)	(0.382)	(0.605)
Students' ICT interest	**3.201**	0.324	0.279
	(0.000)	(0.276)	(0.603)
Students' ICT as a topic in Social interaction	-0.839	-0.206	-0.423
	(0.111)	(0.509)	(0.409)
Starting age for using ICT	**-3.155**	**-1.397**	**-5.664**
	(0.000)	(0.000)	(0.000)
Computer / Students ratio	0.875	0.147	**1.314**
	(0.177)	(0.705)	(0.050)
Constant and student, family, school and location (Autonomous Communities) control variables included	Yes	Yes	Yes
Observations (min-max) $^{\alpha}$	6,077-6,120	7,532-7,580	8,133-8,207
Number of schools $^{\alpha}$	852-856	860-862	852-854

**P-values in parentheses. Statistically significant values up to 5% level included appear in bold.*
**The coefficients and the p-values are the result of calculating the average of the 16 estimates made for the different 16 values of each imputed variable.*
$^{\alpha}$ *Total number of observations and schools varies according to the estimate as a consequence of the manual elimination of outliers presented by some imputed variables.*

[7] Complete results upon request

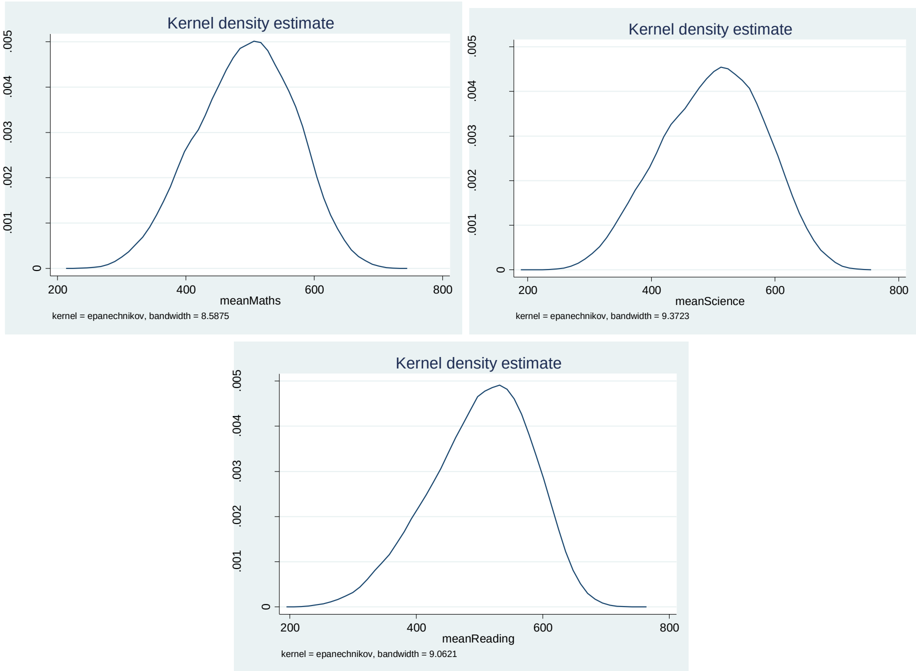
Table A.7: Effect of ICT on the academic performance in reading by tertiles of performance[8]

VARIABLES	Bottom	Middle	Top
ICT available at Home Index	**-0.944**	-0.284	-0.014
	(0.001)	(0.065)	(0.875)
ICT use outside of school for schoolwork	**-3.198**	**-1.441**	**-1.906**
	(0.000)	(0.000)	(0.004)
ICT use outside of school for leisure	**2.860**	0.144	-0.288
	(0.000)	(0.685)	(0.678)
ICT available at School Index	**-1.111**	**-0.367**	**-1.160**
	(0.000)	(0.004)	(0.000)
Use of ICT at school in general	**-3.250**	0.247	-0.063
	(0.000)	(0.437)	(0.896)
Students' ICT interest	**4.178**	**0.961**	0.419
	(0.000)	(0.000)	(0.385)
Students' ICT as a topic in Social interaction	-0.328	**-0.622**	**-1.129**
	(0.567)	(0.028)	(0.015)
Starting age for using ICT	**-3.016**	**-0.897**	**-3.759**
	(0.000)	(0.002)	(0.000)
Computer / Students ratio	0.626	0.073	0.532
	(0.342)	(0.837)	(0.363)
Constant and student, family, school and location (Autonomous Communities) control variables included	Yes	Yes	Yes
Observations (min-max) $^{\alpha}$	6,021-6,069	7,588-7,620	8,138-8,211
Number of schools $^{\alpha}$	850-853	861-862	850-852

**P-values in parentheses. Statistically significant values up to 5% level included appear in bold.*
**The coefficients and the p-values are the result of calculating the average of the 16 estimates made for the different 16 values of each imputed variable.*
$^{\alpha}$ *Total number of observations and schools varies according to the estimate as a consequence of the manual elimination of outliers presented by some imputed variables*.

[8] Complete results upon request

Graph A.1: Kernel Density Estimation of the dependent variables



Comparative Analysis: PISA 2012 and PISA 2015

In order to verify the robustness of the results as well as to investigate if the effects of the different ICT variables have been maintained over time, we have conducted a comparative analysis between the databases of PISA 2012 and PISA 2015 for the case of Spain.

We have estimated models as similar as possible to the ones presented previously in the main text in order to assess whether the relation between ICT and academic performance has changed from 2012 to 2015. Regrettably, it has not been possible to perform an exact replication, given that PISA 2015 contains new variables that are not included in PISA 2012 or that, although included, are not exactly identical and therefore not directly comparable: Students' ICT interest, Students' ICT as a topic in Social interaction, Starting age for using ICT, Age of arrival of immigrant students, Language at home, Index proportion all teachers fully certified and the seventeen Autonomous Communities. The rest of ICT and control variables have been included in the estimates for both databases, these being defined in the same way in both years and presenting the same categories in the case of categorical variables. Therefore, the only difference that exists in the estimates presented in this section between 2012 and 2015 is that in 2015 we have carried out an imputation of missing values, while in 2012 we have not. The total number of observations for PISA 2012 is 25,313 and in our estimates we account for 17,716 observations so, when interpreting our results, we have to take into account that we lose 30% of the sample.

Table A.8 shows the results of the comparative analysis. First of all, we should state that some of the results of our main research changed when not including the ICT variables and control variables previously enumerated, since they do not exist in PISA 2012. However, these variations are minor: (1) the coefficients for the availability of ICT at home for reading and science become not statistically significant, while being negative in the main text; (2) the coefficient for the general use of ICT at school in mathematics also becomes not statistically significant, while being also negative for the estimate of our main text; and (3) the coefficient for the computer/students ratio becomes positive and statistically significant in mathematics. These are the only three variations that the results for 2015 present when deleting some of the ICT and control variables due to comparative reasons.

As for the comparison of the coefficients between PISA 2012 and PISA 2015, we can conclude that the following results do not change over time: (1) the negative association between the use of ICT at school for schoolwork, the general use of ICT at school and academic performance endures; (2) similarly, the positive association between the use of ICT at home for entertainment and academic achievement persists over time; and (3) the positive association between the Computer / Students ratio and mathematics scores also endures, while the association remains not statistically significant for science and reading. However, some of the variables show a slightly different behaviour depending on the year evaluated: (4) the availability of ICT at home was negatively associated with academic achievement in 2012, while in 2015 seems to have no effect (science and reading) or to have a positive effect (mathematics); and (5), the general use of ICT at school, results show that the negative association with scores remains over time except for the competence of mathematics (becomes statistically not significant). Nevertheless, if we take into account the results for PISA 2015 shown in the main text (in principle more robust since they include more control variables) and compare them with the PISA 2012 results in this section, most of these differences disappear, since the coefficients for mathematics regarding the general use of ICT at school, as well as the coefficients for the availability of ICT at home in science and reading, are negative and statistically significant. The only difference then - if comparing the main text results and the results for PISA 2012 carried out in this section - would be a change in the association of the availability of ICT at home and the academic performance in mathematics, which was negative in 2012, but becomes positive in 2015.

Therefore, according to our results, we find that this comparative analysis supports the main conclusions obtained in our research and shows that the sign of the association between academic performance and the different ICT variables remains over time for most of the variables.

Table A.8. Effect of ICT on the academic performance in mathematics, science and reading. Comparison between PISA 2012 and PISA 2015.

	PISA 2012			PISA 2015		
VARIABLES	(1) Mathematics	(2) Science	(3) Reading	(1) Mathematics	(2) Science	(3) Reading
ICT available at Home Index	**-1.830**	**-3.512**	**-3.580**	**1.431**	0.171	-0.409
	(0.002)	(0.000)	(0.0000	(0.000)	(0.527)	(0.104)
ICT use outside of school for schoolwork	**-5.595**	**-7.189**	**-6.679**	**-9.560**	**-11.729**	**-12.618**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ICT use outside of school for leisure	**4.753**	**7.517**	**8.020**	**4.170**	**7.538**	**7.238**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ICT available at School Index	**-2.526**	**-2.555**	**-3.249**	**-2.487**	**-2.988**	**-2.359**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Use of ICT at school in general	**-5.137**	**-5.362**	**-6.545**	-0.630	**-2.369**	**-2.863**
	(0.000)	(0.000)	(0.000)	(0.206)	(0.000)	(0.000)
Computer / Students ratio	**4.505**	2.564	2.649	**2.112**	1.142	-0.084
	(0.006)	(0.137)	(0.145)	(0.010)	(0.222)	(0.921)
Constant and student, family and school control variables included	Yes	Yes	Yes	Yes	Yes	Yes
Observations (min-max) $^{\alpha}$	17,716	17,716	17,716	22,886-22,905	22,886-22,905	22,886-22,905

**P-values in parentheses. Statistically significant values up to 5% level included appear in bold.*

**The coefficients and the p-values are the result of calculating the average of the 16 estimates made for the different 16 values of each imputed variable.*

$^{\alpha}$ *Total number of observations – in PISA 2015 – varies according to the estimate as a consequence of the manual elimination of outliers presented by some imputed variables.*

2013

2013/1, Sánchez-Vidal, M.; González-Val, R.; Viladecans-Marsal, E.: "Sequential city growth in the US: does age matter?"
2013/2, Hortas Rico, M.: "Sprawl, blight and the role of urban containment policies. Evidence from US cities"
2013/3, Lampón, J.F.; Cabanelas-Lorenzo, P-; Lago-Peñas, S.: "Why firms relocate their production overseas? The answer lies inside: corporate, logistic and technological determinants"
2013/4, Montolio, D.; Planells, S.: "Does tourism boost criminal activity? Evidence from a top touristic country"
2013/5, Garcia-López, M.A.; Holl, A.; Viladecans-Marsal, E.: "Suburbanization and highways: when the Romans, the Bourbons and the first cars still shape Spanish cities"
2013/6, Bosch, N.; Espasa, M.; Montolio, D.: "Should large Spanish municipalities be financially compensated? Costs and benefits of being a capital/central municipality"
2013/7, Escardíbul, J.O.; Mora, T.: "Teacher gender and student performance in mathematics. Evidence from Catalonia"
2013/8, Arqué-Castells, P.; Viladecans-Marsal, E.: "Banking towards development: evidence from the Spanish banking expansion plan"
2013/9, Asensio, J.; Gómez-Lobo, A.; Matas, A.: "How effective are policies to reduce gasoline consumption? Evaluating a quasi-natural experiment in Spain"
2013/10, Jofre-Monseny, J.: "The effects of unemployment benefits on migration in lagging regions"
2013/11, Segarra, A.; García-Quevedo, J.; Teruel, M.: "Financial constraints and the failure of innovation projects"
2013/12, Jerrim, J.; Choi, A.: "The mathematics skills of school children: How does England compare to the high performing East Asian jurisdictions?"
2013/13, González-Val, R.; Tirado-Fabregat, D.A.; Viladecans-Marsal, E.: "Market potential and city growth: Spain 1860-1960"
2013/14, Lundqvist, H.: "Is it worth it? On the returns to holding political office"
2013/15, Ahlfeldt, G.M.; Maennig, W.: "Homevoters vs. leasevoters: a spatial analysis of airport effects"
2013/16, Lampón, J.F.; Lago-Peñas, S.: "Factors behind international relocation and changes in production geography in the European automobile components industry"
2013/17, Guío, J.M.; Choi, A.: "Evolution of the school failure risk during the 2000 decade in Spain: analysis of Pisa results with a two-level logistic mode"
2013/18, Dahlby, B.; Rodden, J.: "A political economy model of the vertical fiscal gap and vertical fiscal imbalances in a federation"
2013/19, Acacia, F.; Cubel, M.: "Strategic voting and happiness"
2013/20, Hellerstein, J.K.; Kutzbach, M.J.; Neumark, D.: "Do labor market networks have an important spatial dimension?"
2013/21, Pellegrino, G.; Savona, M.: "Is money all? Financing versus knowledge and demand constraints to innovation"
2013/22, Lin, J.: "Regional resilience"
2013/23, Costa-Campi, M.T.; Duch-Brown, N.; García-Quevedo, J.: "R&D drivers and obstacles to innovation in the energy industry"
2013/24, Huisman, R.; Stradnic, V.; Westgaard, S.: "Renewable energy and electricity prices: indirect empirical evidence from hydro power"
2013/25, Dargaud, E.; Mantovani, A.; Reggiani, C.: "The fight against cartels: a transatlantic perspective"
2013/26, Lambertini, L.; Mantovani, A.: "Feedback equilibria in a dynamic renewable resource oligopoly: pre-emption, voracity and exhaustion"
2013/27, Feld, L.P.; Kalb, A.; Moessinger, M.D.; Osterloh, S.: "Sovereign bond market reactions to fiscal rules and no-bailout clauses – the Swiss experience"
2013/28, Hilber, C.A.L.; Vermeulen, W.: "The impact of supply constraints on house prices in England"
2013/29, Revelli, F.: "Tax limits and local democracy"
2013/30, Wang, R.; Wang, W.: "Dress-up contest: a dark side of fiscal decentralization"
2013/31, Dargaud, E.; Mantovani, A.; Reggiani, C.: "The fight against cartels: a transatlantic perspective"
2013/32, Saarimaa, T.; Tukiainen, J.: "Local representation and strategic voting: evidence from electoral boundary reforms"
2013/33, Agasisti, T.; Murtinu, S.: "Are we wasting public money? No! The effects of grants on Italian university students' performances"
2013/34, Flacher, D.; Harari-Kermadec, H.; Moulin, L.: "Financing higher education: a contributory scheme"
2013/35, Carozzi, F.; Repetto, L.: "Sending the pork home: birth town bias in transfers to Italian municipalities"
2013/36, Coad, A.; Frankish, J.S.; Roberts, R.G.; Storey, D.J.: "New venture survival and growth: Does the fog lift?"
2013/37, Giulietti, M.; Grossi, L.; Waterson, M.: "Revenues from storage in a competitive electricity market: Empirical evidence from Great Britain"

2014

2014/1, Montolio, D.; Planells-Struse, S.: "When police patrols matter. The effect of police proximity on citizens' crime risk perception"
2014/2, Garcia-López, M.A.; Solé-Ollé, A.; Viladecans-Marsal, E.: "Do land use policies follow road construction?"
2014/3, Piolatto, A.; Rablen, M.D.: "Prospect theory and tax evasion: a reconsideration of the Yitzhaki puzzle"
2014/4, Cuberes, D.; González-Val, R.: "The effect of the Spanish Reconquest on Iberian Cities"
2014/5, Durán-Cabré, J.M.; Esteller-Moré, E.: "Tax professionals' view of the Spanish tax system: efficiency, equity and tax planning"
2014/6, Cubel, M.; Sanchez-Pages, S.: "Difference-form group contests"
2014/7, Del Rey, E.; Racionero, M.: "Choosing the type of income-contingent loan: risk-sharing versus risk-pooling"
2014/8, Torregrosa Hetland, S.: "A fiscal revolution? Progressivity in the Spanish tax system, 1960-1990"
2014/9, Piolatto, A.: "Itemised deductions: a device to reduce tax evasion"
2014/10, Costa, M.T.; García-Quevedo, J.; Segarra, A.: "Energy efficiency determinants: an empirical analysis of Spanish innovative firms"
2014/11, García-Quevedo, J.; Pellegrino, G.; Savona, M.: "Reviving demand-pull perspectives: the effect of demand uncertainty and stagnancy on R&D strategy"
2014/12, Calero, J.; Escardíbul, J.O.: "Barriers to non-formal professional training in Spain in periods of economic growth and crisis. An analysis with special attention to the effect of the previous human capital of workers"
2014/13, Cubel, M.; Sanchez-Pages, S.: "Gender differences and stereotypes in the beauty"
2014/14, Piolatto, A.; Schuett, F.: "Media competition and electoral politics"
2014/15, Montolio, D.; Trillas, F.; Trujillo-Baute, E.: "Regulatory environment and firm performance in EU telecommunications services"
2014/16, Lopez-Rodriguez, J.; Martinez, D.: "Beyond the R&D effects on innovation: the contribution of non-R&D activities to TFP growth in the EU"
2014/17, González-Val, R.: "Cross-sectional growth in US cities from 1990 to 2000"
2014/18, Vona, F.; Nicolli, F.: "Energy market liberalization and renewable energy policies in OECD countries"
2014/19, Curto-Grau, M.: "Voters' responsiveness to public employment policies"
2014/20, Duro, J.A.; Teixidó-Figueras, J.; Padilla, E.: "The causal factors of international inequality in co2 emissions per capita: a regression-based inequality decomposition analysis"
2014/21, Fleten, S.E.; Huisman, R.; Kilic, M.; Pennings, E.; Westgaard, S.: "Electricity futures prices: time varying sensitivity to fundamentals"
2014/22, Afcha, S.; García-Quevedo, J,: "The impact of R&D subsidies on R&D employment composition"
2014/23, Mir-Artigues, P.; del Río, P.: "Combining tariffs, investment subsidies and soft loans in a renewable electricity deployment policy"
2014/24, Romero-Jordán, D.; del Río, P.; Peñasco, C.: "Household electricity demand in Spanish regions. Public policy implications"
2014/25, Salinas, P.: "The effect of decentralization on educational outcomes: real autonomy matters!"
2014/26, Solé-Ollé, A.; Sorribas-Navarro, P.: "Does corruption erode trust in government? Evidence from a recent surge of local scandals in Spain"
2014/27, Costas-Pérez, E.: "Political corruption and voter turnout: mobilization or disaffection?"
2014/28, Cubel, M.; Nuevo-Chiquero, A.; Sanchez-Pages, S.; Vidal-Fernandez, M.: "Do personality traits affect productivity? Evidence from the LAB"
2014/29, Teresa Costa, M.T.; Trujillo-Baute, E.: "Retail price effects of feed-in tariff regulation"
2014/30, Kilic, M.; Trujillo-Baute, E.: "The stabilizing effect of hydro reservoir levels on intraday power prices under wind forecast errors"
2014/31, Costa-Campi, M.T.; Duch-Brown, N.: "The diffusion of patented oil and gas technology with environmental uses: a forward patent citation analysis"
2014/32, Ramos, R.; Sanromá, E.; Simón, H.: "Public-private sector wage differentials by type of contract: evidence from Spain"
2014/33, Backus, P.; Esteller-Moré, A.: "Is income redistribution a form of insurance, a public good or both?"
2014/34, Huisman, R.; Trujillo-Baute, E.: "Costs of power supply flexibility: the indirect impact of a Spanish policy change"
2014/35, Jerrim, J.; Choi, A.; Simancas Rodríguez, R.: "Two-sample two-stage least squares (TSTSLS) estimates of earnings mobility: how consistent are they?"
2014/36, Mantovani, A.; Tarola, O.; Vergari, C.: "Hedonic quality, social norms, and environmental campaigns"
2014/37, Ferraresi, M.; Galmarini, U.; Rizzo, L.: "Local infrastructures and externalities: Does the size matter?"
2014/38, Ferraresi, M.; Rizzo, L.; Zanardi, A.: "Policy outcomes of single and double-ballot elections"

2015

2015/1, Foremny, D.; Freier, R.; Moessinger, M-D.; Yeter, M.: "Overlapping political budget cycles in the legislative and the executive"
2015/2, Colombo, L.; Galmarini, U.: "Optimality and distortionary lobbying: regulating tobacco consumption"
2015/3, Pellegrino, G.: "Barriers to innovation: Can firm age help lower them?"
2015/4, Hémet, C.: "Diversity and employment prospects: neighbors matter!"
2015/5, Cubel, M.; Sanchez-Pages, S.: "An axiomatization of difference-form contest success functions"
2015/6, Choi, A.; Jerrim, J.: "The use (and misuse) of Pisa in guiding policy reform: the case of Spain"
2015/7, Durán-Cabré, J.M.; Esteller-Moré, A.; Salvadori, L.: "Empirical evidence on tax cooperation between sub-central administrations"
2015/8, Batalla-Bejerano, J.; Trujillo-Baute, E.: "Analysing the sensitivity of electricity system operational costs to deviations in supply and demand"
2015/9, Salvadori, L.: "Does tax enforcement counteract the negative effects of terrorism? A case study of the Basque Country"
2015/10, Montolio, D.; Planells-Struse, S.: "How time shapes crime: the temporal impacts of football matches on crime"
2015/11, Piolatto, A.: "Online booking and information: competition and welfare consequences of review aggregators"
2015/12, Boffa, F.; Pingali, V.; Sala, F.: "Strategic investment in merchant transmission: the impact of capacity utilization rules"
2015/13, Slemrod, J.: "Tax administration and tax systems"
2015/14, Arqué-Castells, P.; Cartaxo, R.M.; García-Quevedo, J.; Mira Godinho, M.: "How inventor royalty shares affect patenting and income in Portugal and Spain"
2015/15, Montolio, D.; Planells-Struse, S.: "Measuring the negative externalities of a private leisure activity: hooligans and pickpockets around the stadium"
2015/16, Batalla-Bejerano, J.; Costa-Campi, M.T.; Trujillo-Baute, E.: "Unexpected consequences of liberalisation: metering, losses, load profiles and cost settlement in Spain's electricity system"
2015/17, Batalla-Bejerano, J.; Trujillo-Baute, E.: "Impacts of intermittent renewable generation on electricity system costs"
2015/18, Costa-Campi, M.T.; Paniagua, J.; Trujillo-Baute, E.: "Are energy market integrations a green light for FDI?"
2015/19, Jofre-Monseny, J.; Sánchez-Vidal, M.; Viladecans-Marsal, E.: "Big plant closures and agglomeration economies"
2015/20, Garcia-López, M.A.; Hémet, C.; Viladecans-Marsal, E.: "How does transportation shape intrametropolitan growth? An answer from the regional express rail"
2015/21, Esteller-Moré, A.; Galmarini, U.; Rizzo, L.: "Fiscal equalization under political pressures"
2015/22, Escardíbul, J.O.; Afcha, S.: "Determinants of doctorate holders' job satisfaction. An analysis by employment sector and type of satisfaction in Spain"
2015/23, Aidt, T.; Asatryan, Z.; Badalyan, L.; Heinemann, F.: "Vote buying or (political) business (cycles) as usual?"
2015/24, Albæk, K.: "A test of the 'lose it or use it' hypothesis in labour markets around the world"
2015/25, Angelucci, C.; Russo, A.: "Petty corruption and citizen feedback"
2015/26, Moriconi, S.; Picard, P.M.; Zanaj, S.: "Commodity taxation and regulatory competition"
2015/27, Brekke, K.R.; Garcia Pires, A.J.; Schindler, D.; Schjelderup, G.: "Capital taxation and imperfect competition: ACE vs. CBIT"
2015/28, Redonda, A.: "Market structure, the functional form of demand and the sensitivity of the vertical reaction function"
2015/29, Ramos, R.; Sanromá, E.; Simón, H.: "An analysis of wage differentials between full-and part-time workers in Spain"
2015/30, Garcia-López, M.A.; Pasidis, I.; Viladecans-Marsal, E.: "Express delivery to the suburbs the effects of transportation in Europe's heterogeneous cities"
2015/31, Torregrosa, S.: "Bypassing progressive taxation: fraud and base erosion in the Spanish income tax (1970-2001)"
2015/32, Choi, H.; Choi, A.: "When one door closes: the impact of the hagwon curfew on the consumption of private tutoring in the republic of Korea"
2015/33, Escardíbul, J.O.; Helmy, N.: "Decentralisation and school autonomy impact on the quality of education: the case of two MENA countries"
2015/34, González-Val, R.; Marcén, M.: "Divorce and the business cycle: a cross-country analysis"

2015/35, Calero, J.; Choi, A.: "The distribution of skills among the European adult population and unemployment: a comparative approach"
2015/36, Mediavilla, M.; Zancajo, A.: "Is there real freedom of school choice? An analysis from Chile"
2015/37, Daniele, G.: "Strike one to educate one hundred: organized crime, political selection and politicians' ability"
2015/38, González-Val, R.; Marcén, M.: "Regional unemployment, marriage, and divorce"
2015/39, Foremny, D.; Jofre-Monseny, J.; Solé-Ollé, A.: "'Hold that ghost': using notches to identify manipulation of population-based grants"
2015/40, Mancebón, M.J.; Ximénez-de-Embún, D.P.; Mediavilla, M.; Gómez-Sancho, J.M.: "Does educational management model matter? New evidence for Spain by a quasiexperimental approach"
2015/41, Daniele, G.; Geys, B.: "Exposing politicians' ties to criminal organizations: the effects of local government dissolutions on electoral outcomes in Southern Italian municipalities"
2015/42, Ooghe, E.: "Wage policies, employment, and redistributive efficiency"

2016

2016/1, Galletta, S.: "Law enforcement, municipal budgets and spillover effects: evidence from a quasi-experiment in Italy"
2016/2, Flatley, L.; Giulietti, M.; Grossi, L.; Trujillo-Baute, E.; Waterson, M.: "Analysing the potential economic value of energy storage"
2016/3, Calero, J.; Murillo Huertas, I.P.; Raymond Bara, J.L.: "Education, age and skills: an analysis using the PIAAC survey"
2016/4, Costa-Campi, M.T.; Daví-Arderius, D.; Trujillo-Baute, E.: "The economic impact of electricity losses"
2016/5, Falck, O.; Heimisch, A.; Wiederhold, S.: "Returns to ICT skills"
2016/6, Halmenschlager, C.; Mantovani, A.: "On the private and social desirability of mixed bundling in complementary markets with cost savings"
2016/7, Choi, A.; Gil, M.; Mediavilla, M.; Valbuena, J.: "Double toil and trouble: grade retention and academic performance"
2016/8, González-Val, R.: "Historical urban growth in Europe (1300–1800)"
2016/9, Guio, J.; Choi, A.; Escardíbul, J.O.: "Labor markets, academic performance and the risk of school dropout: evidence for Spain"
2016/10, Bianchini, S.; Pellegrino, G.; Tamagni, F.: "Innovation strategies and firm growth"
2016/11, Jofre-Monseny, J.; Silva, J.I.; Vázquez-Grenno, J.: "Local labor market effects of public employment"
2016/12, Sanchez-Vidal, M.: "Small shops for sale! The effects of big-box openings on grocery stores"
2016/13, Costa-Campi, M.T.; García-Quevedo, J.; Martínez-Ros, E.: "What are the determinants of investment in environmental R&D?"
2016/14, **García-López, M.A; Hémet, C.; Viladecans-Marsal, E.:** "Next train to the polycentric city: The effect of railroads on subcenter formation"
2016/15, Matas, A.; Raymond, J.L.; Dominguez, A.: "Changes in fuel economy: An analysis of the Spanish car market"
2016/16, Leme, A.; Escardíbul, J.O.: "The effect of a specialized versus a general upper secondary school curriculum on students' performance and inequality. A difference-in-differences cross country comparison"
2016/17, **Scandurra, R.I.; Calero, J.**: "Modelling adult skills in OECD countries"
2016/18, **Fernández-Gutiérrez, M.; Calero, J.**: "Leisure and education: insights from a time-use analysis"
2016/19, Del Rio, P.; Mir-Artigues, P.; Trujillo-Baute, E.: "Analysing the impact of renewable energy regulation on retail electricity prices"
2016/20, Taltavull de la Paz, P.; Juárez, F.; Monllor, P.: "Fuel Poverty: Evidence from housing perspective"
2016/21, Ferraresi, M.; Galmarini, U.; Rizzo, L.; Zanardi, A.: "Switch towards tax centralization in Italy: A wake up for the local political budget cycle"
2016/22, Ferraresi, M.; Migali, G.; Nordi, F.; Rizzo, L.: "Spatial interaction in local expenditures among Italian municipalities: evidence from Italy 2001-2011"
2016/23, Daví-Arderius, D.; Sanin, M.E.; Trujillo-Baute, E.: "CO2 content of electricity losses"
2016/24, Arqué-Castells, P.; Viladecans-Marsal, E.: "Banking the unbanked: Evidence from the Spanish banking expansion plan"
2016/25 Choi, Á.; Gil, M.; Mediavilla, M.; Valbuena, J.: "The evolution of educational inequalities in Spain: Dynamic evidence from repeated cross-sections"
2016/26, Brutti, Z.: "Cities drifting apart: Heterogeneous outcomes of decentralizing public education"
2016/27, Backus, P.; Cubel, M.; Guid, M.; Sánchez-Pages, S.; Lopez Manas, E.: "Gender, competition and performance: evidence from real tournaments"
2016/28, Costa-Campi, M.T.; Duch-Brown, N.; García-Quevedo, J.: "Innovation strategies of energy firms"
2016/29, Daniele, G.; Dipoppa, G.: "Mafia, elections and violence against politicians"

2016/30, Di Cosmo, V.; Malaguzzi Valeri, L.: “Wind, storage, interconnection and the cost of electricity”

2017

2017/1, González Pampillón, N.; Jofre-Monseny, J.; Viladecans-Marsal, E.: “Can urban renewal policies reverse neighborhood ethnic dynamics?”
2017/2, Gómez San Román, T.: “Integration of DERs on power systems: challenges and opportunities”
2017/3, Bianchini, S.; Pellegrino, G.: “Innovation persistence and employment dynamics”
2017/4, Curto-Grau, M.; Solé-Ollé, A.; Sorribas-Navarro, P.: “Does electoral competition curb party favoritism?”
2017/5, Solé-Ollé, A.; Viladecans-Marsal, E.: “Housing booms and busts and local fiscal policy”
2017/6, Esteller, A.; Piolatto, A.; Rablen, M.D.: “Taxing high-income earners: Tax avoidance and mobility”
2017/7, Combes, P.P.; Duranton, G.; Gobillon, L.: “The production function for housing: Evidence from France”
2017/8, Nepal, R.; Cram, L.; Jamasb, T.; Sen, A.: “Small systems, big targets: power sector reforms and renewable energy development in small electricity systems”
2017/9, Carozzi, F.; Repetto, L.: “Distributive politics inside the city? The political economy of Spain’s plan E”
2017/10, Neisser, C.: “The elasticity of taxable income: A meta-regression analysis”
2017/11, Baker, E.; Bosetti, V.; Salo, A.: “Finding common ground when experts disagree: robust portfolio decision analysis”
2017/12, Murillo, I.P; Raymond, J.L; Calero, J.: “Efficiency in the transformation of schooling into competences: A cross-country analysis using PIAAC data”
2017/13, **Ferrer-Esteban, G.; Mediavilla, M.:** “The more educated, the more engaged? An analysis of social capital and education”
2017/14, Sanchis-Guarner, R.: “Decomposing the impact of immigration on house prices”
2017/15, Schwab, T.; Todtenhaupt, M.: “Spillover from the haven: Cross-border externalities of patent box regimes within multinational firms”
2017/16, Chacón, M.; Jensen, J.: “The institutional determinants of Southern secession”
2017/17, Gancia, G.; Ponzetto, G.A.M.; Ventura, J.: “Globalization and political structure”
2017/18, González-Val, R.: “City size distribution and space”
2017/19, García-Quevedo, J.; Mas-Verdú, F.; Pellegrino, G.: “What firms don’t know can hurt them: Overcoming a lack of information on technology”
2017/20, Costa-Campi, M.T.; García-Quevedo, J.: “Why do manufacturing industries invest in energy R&D?”
2017/21, Costa-Campi, M.T.; García-Quevedo, J.; Trujillo-Baute, E.: “Electricity regulation and economic growth”

2018

2018/1, Boadway, R.; Pestieau, P.: “The tenuous case for an annual wealth tax”
2018/2, Garcia-López, M.À.: “All roads lead to Rome ... and to sprawl? Evidence from European cities”
2018/3, Daniele, G.; Galletta, S.; Geys, B.: “Abandon ship? Party brands and politicians’ responses to a political scandal”
2018/4, Cavalcanti, F.; Daniele, G.; Galletta, S.: “Popularity shocks and political selection”
2018/5, Naval, J.; Silva, J. I.; Vázquez-Grenno, J.: “Employment effects of on-the-job human capital acquisition”
2018/6, Agrawal, D. R.; Foremny, D.: “Relocation of the rich: migration in response to top tax rate changes from spanish reforms”
2018/7, García-Quevedo, J.; Kesidou, E.; Martínez-Ros, E.: “Inter-industry differences in organisational eco-innovation: a panel data study”
2018/8, Aastveit, K. A.; Anundsen, A. K.: “Asymmetric effects of monetary policy in regional housing markets”
2018/9, Curci, F.; Masera, F.: “Flight from urban blight: lead poisoning, crime and suburbanization”
2018/10, Grossi, L.; Nan, F.: “The influence of renewables on electricity price forecasting: a robust approach”
2018/11, Fleckinger, P.; Glachant, M.; Tamokoué Kamga, P.-H.: “Energy performance certificates and investments in building energy efficiency: a theoretical analysis”
2018/12, van den Bergh, J. C.J.M.; Angelsen, A.; Baranzini, A.; Botzen, W.J. W.; Carattini, S.; Drews, S.; Dunlop, T.; Galbraith, E.; Gsottbauer, E.; Howarth, R. B.; Padilla, E.; Roca, J.; Schmidt, R.: “Parallel tracks towards a global treaty on carbon pricing”
2018/13, Ayllón, S.; Nollenberger, N.: “The unequal opportunity for skills acquisition during the Great Recession in Europe”
2018/14, Firmino, J.: “Class composition effects and school welfare: evidence from Portugal using panel data”
2018/15, Durán-Cabré, J. M.; Esteller-Moré, A.; Mas-Montserrat, M.; Salvadori, L.: “La brecha fiscal: estudio y aplicación a los impuestos sobre la riqueza”

2018/16, Montolio, D.; Tur-Prats, A.: "Long-lasting social capital and its impact on economic development: the legacy of the commons"
2018/17, Garcia-López, M. À.; Moreno-Monroy, A. I.: "Income segregation in monocentric and polycentric cities: does urban form really matter?"
2018/18, Di Cosmo, V.; Trujillo-Baute, E.: "From forward to spot prices: producers, retailers and loss averse consumers in electricity markets"
2018/19, Brachowicz Quintanilla, N.; Vall Castelló, J.: "Is changing the minimum legal drinking age an effective policy tool?"

Institut d'Economia de Barcelona

UNIVERSITAT DE BARCELONA

ieb@ub.edu
www.ieb.edu

Human Capital

IEB Working Paper