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DOES COMPUTER-ASSISTED LEARNING ENHANCE MATHEMATICS PERFORMANCE? EVIDENCE FOR SPAIN

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Abstract

This paper analyses whether the Programme School 2.0 introduced in 2009 has improved the mathematics performance of the students affected by it using data from PISA 2009 and PISA 2012. It does not appear that the extraordinary investment in computer equipment carried out in schools in the study period (2009-2012) has led to improved academic performance. In fact, the number of computers per student in 2012 has a significant and negative effect on Mathematics scores for all students (non-repeaters: -114.17 points, 1-year repeaters: -42.22 points, and 2-year repeaters: -88.56 points, respectively): -88.56 points, respectively). The results of the assessment in Mathematics using computer procedures (CBA module) reveal that participation in School 2.0 has not managed to increase the Mathematics-CBA score (-3.15 points among non-repeating students who use the computer to do homework 1-2 times/week and -48.35 among those who have a computer/tablet at the school). In this sense, the use of school computers should be examined in greater depth. As a positive and encouraging note, the Programme School 20. may have led to the development of other social or even 'solidarity' skills, as evidenced by a greater propensity to comment on aspects of the Mathematics subject or to help other classmates and friends with Mathematics.

Keywords

Mathematics, ICT, Spain, Academic Performance, PISA, Spillovers

1. Introduction

The analysis of Information and Communication Technologies (ICT) implementation in schools has been the subject of a large body of literature in the last decade. As mentioned by Angrist and Lavy (2002), the use of ICT in schools can be approached from two points of view: computer skills development and computer-based learning. While the advantages of being familiar with new technologies are undeniable in the 21st century, the evidence on the use of computer-based learning as a complementary or substitute methodology to traditional teaching is more controversial.

When analyzing the use of ICT and computer-based instruction, it should be borne in mind that both variables may be correlated with other (unobservable or imperfectly measured) educational inputs which simultaneously affect educational performance. This problem is well illustrated in the work of Fuchs and Woessman (2004). Using PISA (2000) data for 32 countries, they found that there was a positive and significant relationship between performance and computer availability, which, however, became non-significant when other school characteristics were taken into account. This result suggests that in order to test whether there is a cause-effect relationship between ICT and academic performance, experimental or quasi-experimental data is needed to differentiate between a 'treatment group' and a 'control group'. So far, the few studies that have specifically addressed the issue of endogeneity have not found that the introduction of ICT leads to an improvement in the results in mathematics or language subjects, and it has even been suggested that they are less favourable than previous teaching systems.

Some studies have corroborated a substantial improvement in academic performance as a result of the introduction of ICT in the usual teaching methodology. For example, Machin et al. (2007) analysed the change in computer provision and ICT use in UK schools over the period 1999-2003. Using an instrumental variables approach to control for the potential endogeneity problem of ICT use, they concluded that there was a positive causal relationship of ICT investment on performance in primary education. Focusing on the case of repeaters or below-average achievers, Banerjee et al. (2004) studied the introduction of a computer-based programme for slum students in two Indian states. The programme achieved a substantial improvement in mathematics performance, but no significant benefits were found in other subjects. In recent years, a stream of research has used randomised experiments to evaluate the success of ICT implementation. In this regard, Barrow et al. (2009) in the

United States and Carrillo et al. (2010) in Canada found a positive effect of ICT on academic outcomes. More recently, Muralidharan et al. (2017) studied the impact of a computer-assisted instruction programme in urban India, in which students received after-school training. They randomly provided a voucher for access to these additional classes and observed a marked improvement in Mathematics and Hindi subjects, with the most notable improvement in students starting from lower levels. The underlying reasons explaining this success are in line with the research of Kaur (2016) and Lessani et al. (2017) who have shown that methods based on problem-solving in which the student is the main actor in the learning process enhance creativity and the ability to face new challenges.

However, other studies have not found a statistically significant relationship between ICT use and educational achievement. Golsbee and Guryan (2002) studied a programme in the United States whereby schools were given grants to increase the number of computers and Internet access and concluded that after these investments were made, there was no improvement in educational performance. Rouse et al. (2004) presented the results of a randomised study of a computer programme designed to improve reading comprehension and vocabulary in the United States and found no evidence that the programme substantially improved students' reading skills. Spencer-Smith and Hardman (2014) analyzed the assessment of the Senior Certificate for mathematics subject, comparing the use of ICT by different schools in Cape Town during the academic year, but found no improvement in the schools which implemented ICT. Cristia et al. (2014) analysed a public programme implemented in secondary schools in Peru, which provided better computer equipment and internet connectivity, but did not observe positive results on student performance.

Some studies have even concluded that the introduction of ICT has led to a decline in educational achievement. Angrist and Levy (2002) compared academic performance in primary and secondary schools in Israel, using as a differential variable the fact that not all schools had received funding to increase the provision of computers in classrooms. They found no evidence that the use of computers for educational purposes resulted in improved academic performance. On the contrary, they found a negative association between the use of ICT in classrooms and the mathematics performance of 4th-grade students. In the same vein, Leuven et al. (2004) concluded that educational investments to increase the number of computers in schools in the Netherlands did not lead to an improvement in performance, but had a negative effect on Language and Mathematics.

There are theoretical and empirical arguments that may help to explain this disparity in results. On one hand, ICT can be seen as an additional input to the student's learning function, as it allows access to more educational resources at school (and at home at any time of the day). On the other hand, the benefits of ICT depend on the ability of schools to modify their teaching methods so that they become complementary. What is known as the productivity paradox, that is, insufficient organisational or teaching changes may act as a drag on the educational benefits of ICT (Brynjolfsson and Hitt, 2000). On the other hand, the use of ICT in the classroom should not be overlooked. Kubiatko and Vickova (2010) evaluated PISA 2006 for the Czech Republic and found that for ICT use to result in improved academic performance, it should be properly oriented towards the realisation of learning activities. In the same vein, Aypay (2010) and Güzeller and Ayça (2014) suggest that the minimal positive results observed for students using ICT in Turkey were due to inadequate ICT integration in schools.

The main objective of this paper is the short-term analysis of the effect of the Programme School 2.0 on the Mathematics performance of Spanish students studying in public schools based on data from Pisa 2012 and 2009. The implementation of this computer-based-learning model was intended to turn the traditionally implemented models for teaching mathematics, based on lectures by the teacher. Specifically, we set out to answer the following questions. Firstly, what has been the evolution of the Mathematics performance of students in public schools between 2009 and 2012? Secondly, has the School 2.0 programme had a significant impact on students' performance in Mathematics in 2012, compared to the baseline situation in 2009, and distinguishing between the repeater and non-repeater students? Third, we question whether the School 2.0 programme has generated any positive externalities among students in terms of sharing information about the subject of mathematics or help with mathematics homework.

2. The Programme School 2.0

In July 2009, the Sectorial Conference of Education approved an investment of 98,182,419 € to carry out the Programme School 2.0. The purpose of these funds was to co-finance the following activities on a 50/50 basis with the Autonomous Communities:

1. The transformation into digital classrooms of all 5th and 6th-grade Primary Education and 1st and 2nd year Compulsory Secondary Education classrooms in public schools.
2. The provision of computers for the personal use of all students in the aforementioned courses, enrolled in publicly funded schools, in a 1:1 ratio.

3. The implementation of teacher training actions to guarantee the effective use of the programme's resources.
4. The development of digital content that could be used by teachers.

According to the CEAPA Report (2010), the participation of by the Autonomous Communities (regions) in the Programme School 2.0 has not been homogeneous:

1. Communities with full participation in all public centres: Andalusia, Aragon, Cantabria, Castilla León, Castilla La Mancha, Catalonia, Extremadura, Galicia, Navarre, the Basque Country, La Rioja, Ceuta and Melilla.
2. Communities with partial participation (only in some public centres): Asturias, the Balearic Islands, and the Canary Islands.
3. Non-participating Communities: Madrid, Murcia and Comunidad Valenciana. As they have not participated in the School 2.0 programme, they do not appear in Table 1.

With regard to the investment made in Programme School 2.0, Table 1 shows the distribution allocated to the finance programme. The total investment amounts to 302 million euros. Almost 50% of the expenditure has been made in three Communities (Andalusia, Catalonia, and Madrid). Although Madrid, Murcia, and Comunidad Valenciana have received 54.2 million euros to develop the Programme School 2.0, it has not been implemented.

Table 1: *Budget of the Programme School 2.0*

	Total Budget.	Resolution 3-8-2009	Resolution 27-1-2010	Resolution 22-4-2010	Resolution 27-12-2010	Resolution 3-6-2011
Andalucía	70.081.420	21.863.049	1.351.264	19.724.774	1.704.244	25.438.089
Aragón	9.832.459	2.944.061	182.009	2.923.499	231.712	3.551.178
Asturias	6.383.629	1.935.006	119.685	1.828.332	144.872	2.355.734
Baleares	7.718.435	2.262.589	139.879	2.275.768	180.774	2.859.425
Canarias	16.983.532	5.102.630	315.506	4.915.225	389.617	6.260.554
Cantabria	3.987.342	1.228.515	75.989	1.128.569	89.481	1.464.788
Castilla y León	18.148.363	5.655.585	349.769	5.215.975	413.325	6.513.709
Castilla La Mancha	18.928.362	5.900.357	364.769	5.348.040	461.207	6.853.989
Cataluña	53.191.112	15.419.839	953.471	15.526.156	1.232.958	20.058.688
C. Valenciana	22.919.873	11.164.050	690.083	11.065.740	-	-
Extremadura	10.202.075	3.253.566	201.190	2.870.992	247.420	3.628.907

Galicia	18.026.168	5.701.300	352.657	5.052.538	435.485	6.484.188
Madrid	23.022.965	11.162.504	689.861	11.170.600	-	-
Murcia	8.273.915	3.905.017	241.389	3.824.080	303.429	-
Navarra	5.065.906	-	-	-	-	5.065.906
País Vasco	5.665.355	-	-	-	-	-
Rioja	2.315.613	684.351	42.301	674.671	53.586	860.704
Ceuta y Melilla	1.383.066	-	-	-	-	-
Total	302.129.589	98.182.419	6.069.822	93.544.959	5.888.110	91.395.859

Source: *Own Work using Information from the Official State Bulletin*

With the information of total expenditure per Autonomous Community and the number of students who have received a computer, we obtain the ratio of investment per student (Table 2). This ratio should be understood in a broad sense since it includes not only the value of the equipment received by the student but also the corresponding imputation of expenditure on classroom digitalization and teacher training. On average, the programme School 2.0 has involved an investment of 476.1 euros per student, with a maximum of 1,840.81 in Navarre and 1,201.74 in Galicia, and a minimum of 142.25 in the Basque Country. To appreciate the magnitude of this figure, it has been compared with the expenditure per ESO student in public schools in 2010.

On average, students in the programme School 2.0 have received an investment that represents 5 percent of that of an ESO student in a public school, with a maximum of 20 percent in Navarre and a minimum of 1.6 percent in the Basque Country. Although Andalusia has received the highest amount of funds (70 million euros), the expenditure per student is half the national average and only 2.7 percent of the expenditure per ESO student in a public school.

However, these results should be treated with caution since, as mentioned above, the figure of 476.1 euros per student encompasses three concepts (digitalization of classrooms, teacher training, and the provision of a computer for each student).

Finally, the following circumstances need to be taken into consideration: (i) the computer that the student receives can be used for more than one academic year (by the same student or by others in successive promotions), (ii) once the classroom has been digitized, the maintenance cost is lower, (iii) and that teachers who have received a training course will apply this knowledge over several promotions. Therefore, the cost of 476.1 €/student can be considered as an upper bound.

Table 2: *Estimated Expenditure per Student of the Programme School 2.0 and Comparison with the Average Expenditure per Student in Compulsory Secondary Education and Public Schools.*

	Budget in Programme School 2.0 (1)	Equipment for students (2)	Investment per student (3)=(1)/(2)	Investment per student of the Programme School 2.0 in relation to public expenditure per public student
Andalucía	70.081.420	282.082	248,4	0,027
Aragón	9.832.459	17.006	578,2	0,064
Asturias	6.383.629	14.568	438,2	0,048
Baleares	7.718.435	27.050	285,3	0,032
Canarias	16.983.532	26.139	649,7	0,072
Cantabria	3.987.342	4.390	908,3	0,100
Castilla y León	18.148.363	19.275	941,5	0,104
Castilla La Mancha	18.928.362	43.250	437,6	0,048
Cataluña	53.191.112	100.209	530,8	0,059
C. Valenciana	22.919.873	-	-	
Extremadura	10.202.075	22.047	462,7	0,051
Galicia	18.026.168	15.000	1201,7	0,133
Madrid	23.022.965	-	-	---
Murcia	8.273.915	12.307	672,3	0,074
Navarra	5.065.906	2.752	1840,8	0,203
País Vasco	5.665.355 (*)	39.826	142,3	0,016
Rioja	2.315.613	4.103	564,4	0,062
Ceuta y Melilla	1.383.066 (**)	4.545	304,3	0,034
Total	**302.129.589**	**634.549**	**476,1**	**0,053**

Source: *Own work using annual public expenditure per public student in secondary education (2010). (Facts and Figures. The school year 2013/2014. Ministry of Education, Culture, and Sport; p. 11)*

3. Data, Sample Design, and Econometric Model

The data sources used in this paper are the fourth and fifth waves of PISA (Programme for International Student Assessment) for 2009 and 2012. PISA is a cross-sectional study conducted every three years since 2000 on 15-year-old students with the aim of assessing their performance in the areas of mathematics, reading, and science, as well as cross-curricular problem-solving skills. PISA does not consider students' knowledge in these areas in isolation, but in relation to their ability to apply it to real-world situations.

This work focuses on the assessment of mathematics achievement, i.e. '*the ability to identify and understand the role of mathematics in the world, to make informed judgments and to use mathematics to solve life problems constructively*' (OECD, 1999). In addition, PISA (2009) introduced a module to assess digital reading skills called PISA-ERA (Electronic Reading Assessment). In PISA (2012), a module to assess skills using computer-based tests called PISA-CBA (Computer Based Assessment) was introduced, as opposed to the traditional paper-and-pencil format.

In terms of sample selection, PISA uses a two-stage stratified procedure. First, schools where 15-year-old students are in school are selected with probability proportional to the number of students. Second, within each school, students are selected at random.

As the objective of the paper is the determination of the success level of the program School 2.0, we need to compare Mathematic scores in 2009 and in 2012 to evaluate to which extend this program has contributed to the change in Mathematics performance. For this purpose, we incorporate in our analysis 11,049 observations for PISA 2009, 15,375 for PISA 2012, 1,897 for PISA-ERA-2009 and 5,579 for PISA-CBA 2012.

To determine if the program School 2.0 has had a different influence over Mathematics achievement using pen-and-paper formats or using computers, we will compare the results of the general modules of PISA 2009 with PISA 2012 and also PISA-ERA2009 with PISA-CBA 2012. A distinction is also made according to the repetition of academic years. For PISA 2009 and 2012 In relation to grade repetition, we define the variable REP(x,y) where 'x'{0,1} indicates whether or not the student has repeated a year of Primary Education and 'y' '{0,1,2} refers to the number of years of Secondary Education that the student has repeated. Therefore, students with REP(0,0) are non-repeaters and are in the grade that corresponds to their age.

For PISA-ERA and PISA-CBA, the lower number of observations obliges us to define broader repeater categories. The group of '1-year repeaters' includes students who have repeated one year of Primary Education or one year of ESO. In the group of '2-year repeaters' are students who have repeated one year of Primary and one year of ESO, or who have repeated 2 years of ESO. (By law, it is not possible to repeat one more year in Primary Education).

Average Mathematics scores in 2009 and 2012 are shown in Table 3, distinguished by the level of participation in the Programme School 2.0 and grade repetition. In 2009, the Mathematics score of the Communities that later participated (fully) in School 2.0 was higher than the score of the Communities that later did not participate in School 2.0 for total students and for students who had repeated an academic year. Also, in 2009, the Mathematics score of the Communities that subsequently did not participate in School 2.0 was higher than those that subsequently participated partially in School 2.0 for all students, non-repeaters, and repeaters of one year. In 2012, the same situations are repeated.

In the comparison between PISA-ERA (2009) and PISA-CBA (2012), we highlight the following results. In PISA-ERA (2009), non-participating Communities achieved a higher score for non-repeating students compared to the other two types of Communities. The Communities with partial participation were in last place for total, non-repeaters, and 1-year repeaters.

In PISA-CBA (2012), there are no significant differences between fully participating and non-participating regions for total students and non-repeating students. As in 2009, the regions with partial participation are significantly behind. Among students who have repeated a grade of secondary education (REP (0,1)), the score in non-participating regions is higher than in regions with full participation.

Finally, when comparing PISA (2009) with PISA-ERA (2009) for non-repeating students, there is an increase in the module of 13 points in the e-reading module for non-participating regions and similar scores in regions with full participation. When comparing PISA (2012) with PISA-CBA (2012) for non-repeating students, there is a significant reduction in the CBA module: 17 points in non-participating Communities and 15 points in Communities with full participation.

Table 3: *Mean and Standard Deviations of Mathematics Scores for Public Schools*

		Has participated in School 2.0?			Test for equal means		
		Yes, partially	No vs. Yes	No. Vs. Yes (partially)	Yes vs. Yes (partially)	No vs. Sí (parcial)	Sí vs. Sí (parcial)
PISA 2012. Mathematics scores for general module							
Total	Mean	470,92	477,24	446,01	0,0001	0,0000	0,0000
	Std. Dev	88,58	86,33	83,51			
	N	2.220	11.031	2.124			
REP (0,0)	Mean	512,16	510,46	490,42	0,3584	0,0000	0,0000
	Std. Dev	75,83	76,42	74,28			

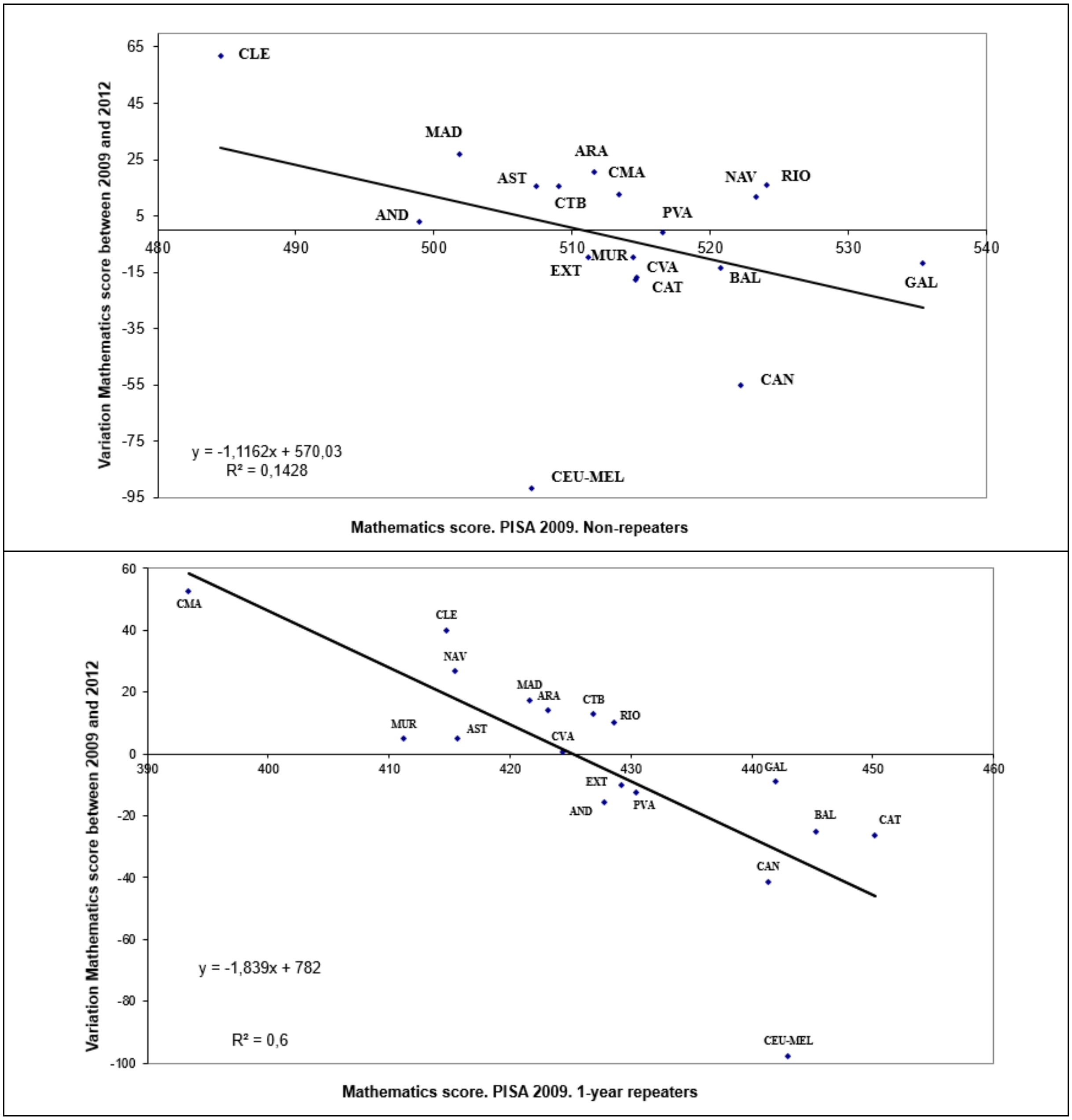
	N	1.353	7.468	1.400			
REP (0,1)	Mean	437,63	433,43	410,76	0,1210	0,0000	0,0000
	Std. Dev	65,95	63,45	61,79			
	N	473	2.074	356			
REP (1,0)	Mean	391,34	405,02	403,55	0,0153	0,0730	0,7729
	Std. Dev	68,40	65,54	51,48			
	N	135	595	181			
REP (1,1)	Mean	379,14	376,89	365,08	0,6257	0,0619	0,0285
	Std. Dev	67,19	63,11	64,30			
	N	194	676	153			
REP (0,2)	Mean	385,72	412,11	397,59	0,0004	0,4476	0,2072
	Std. Dev	61,05	60,99	54,23			
	N	65	218	34			
PISA 2012. Mathematics scores for Computer Based Assessment							
Total	Mean	465,78	466,54	454,81	0.7590	0.0436	0.0010
	Std. Dev	77,78	83,71	76,59			
	N	752	4546	281			
REP (0,0)	Mean	495,61	495,33	487,62	0.9180	0.1892	0.0470
	Std. Dev	68,60	74,54	69,16			
	N	457	3264	182			
REP (0,1)	Mean	444,91	430,86	433,95	0.0037	0.3518	0.7176
	Std. Dev	66,07	69,59	55,84			
	N	175	747	36			
REP (1,0)	Mean	408,95	394,68	396,44	0.1402	0.3937	0.8430
	Std. Dev	70,97	72,74	44,37			
	N	33	260	33			
REP (1,1)	Mean	385,41	382,79	375,92	0.7659	0.5578	0.5390
	Std. Dev	67,75	68,64	66,20			
	N	56	208	24			
REP (0,2)	Mean	411,24	393,56	444,30	0.2237	0.2809	0.0498
	Std. Dev	68,36	72,63	35,96			
	N	31	67	6			
PISA 2009. Mathematics scores for general module							
Total	Mean	456,11	467,39	471,08	0,0000	0,0000	0,0925
	Std. Dev	88,55	87,59	85,97			

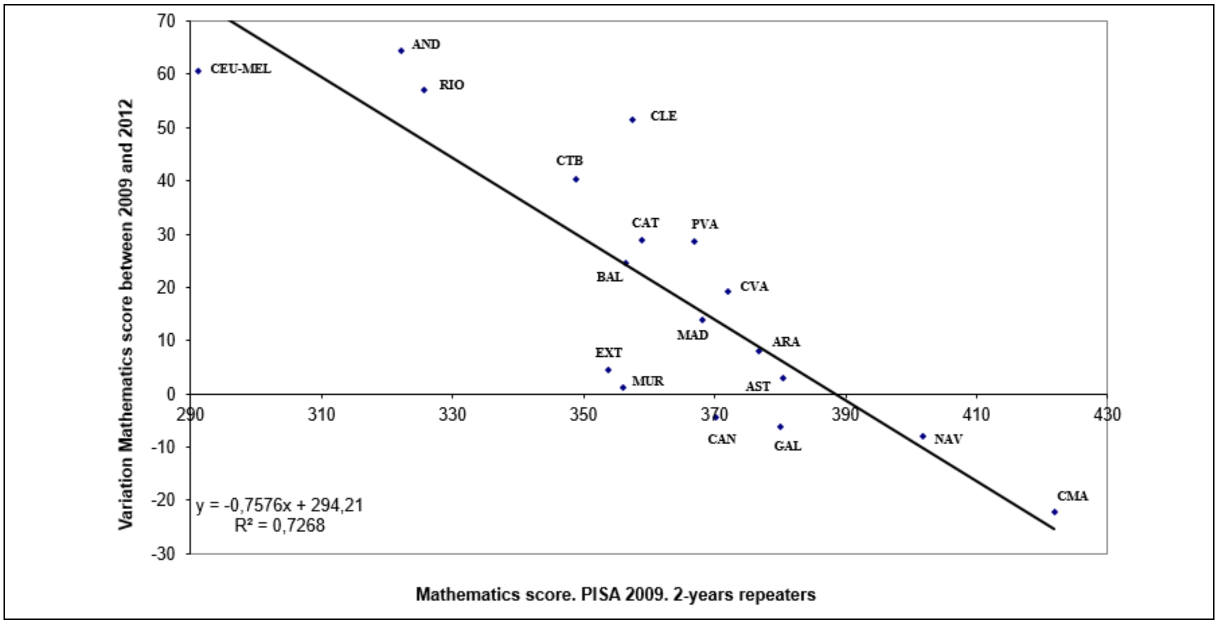
	N	1571	7242	2236			
No repeater	Mean	510,06	513,65	517,49	0,1586	0,0105	0,0943
	Std. Dev	70,58	72,20	69,24			
	N	927	4452	1415			
REP-1 year	Mean	417,66	427,78	435,85	0,0020	0,0000	0,0110
	Std. Dev	69,81	69,53	69,36			
	N	520	2305	660			
REP-2 years	Mean	362,91	362,25	369,15	0,9235	0,4403	0,2845
	Std. Dev	70,74	74,63	65,62			
	N	124	485	161			
PISA 2009. Mathematics scores for Electronic Reading Assessment							
Total	Mean	491,91	482,94	432,33	0,0328	0,0000	0,0000
	Std. Dev	85,71	86,45	93,94			
	N	763	980	154			
No repeater	Mean	523,47	512,60	494,21	0,0117	0,0018	0,0555
	Std. Dev	74,70	73,05	78,78			
	N	541	671	84			
REP-1 year	Mean	445,75	441,77	400,36	0,5877	0,0001	0,0015
	Std. Dev	65,28	76,01	78,85			
	N	170	224	43			
REP-2 years	Mean	386,76	379,61	360,94	0,5806	0,1160	0,2540
	Std. Dev	69,31	77,05	64,33			
	N	52	85	27			

Source: *Own work using PISA (2009) and PISA (2012). Using sample weights.*

Fig. 1 to 3 shows the relationship between the Mathematics score in PISA 2009 and its growth rate between 2009 and 2012 by Autonomous Communities and the number of repeated grades. We appreciate a negative evolution between 2009 and 2012 for both repeater and non-repeater students (negative slope of the regression lines for the three figures). Communities who attained the best results in PISA 2009 have experienced the most acute decrease in Mathematics scores. The highest slope of the regression line corresponds to 1-year repeater students.

We also appreciate a rather different evolution among Communities. For example, Castilla-León attained the lowest score for non-repeater students in PISA 2009, but it has achieved the highest increase between 2009 and 2012. On the contrary, Ceuta and Melilla obtained a medium-level score, but they have suffered a serious step back between 2009 and 2012.


Variation Mathematics score between 2009 and 2012
65
45
25
5
-15
-35
-55
-75
-95
480
490
500
510
520
530
540
CLE
MAD
ARA
AST
CMA
NAV
RIO
CTB
AND
PVA
MUR
CVA
EXT
BAL
CAT
GAL
CAN
CEU-MEL
y = -1,1162x + 570,03
R² = 0,1428
Mathematics score. PISA 2009. Non-repeaters
Variation Mathematics score between 2009 and 2012
60
40
20
0
-20
-40
-60
-80
-100
390
400
410
420
430
440
450
460
CMA
CLE
NAV
MAD
ARA
CTB
RIO
MUR
AST
CVA
GAL
EXT
AND
PVA
BAL
CAT
CAN
y = -1,839x + 782
R² = 0,6
CEU-MEL
Mathematics score. PISA 2009. 1-year repeaters



Figures 1 to 3: *Relationship between PISA 2009 (Mathematics) and score growth rate between PISA 2009 and PISA 2012. Public Schools*

AND: Andalucía; ARA: Aragón; AST: Asturias; BAL: Baleares; CAN: Canarias; CAT: Cataluña; CLE: Castilla-León; CMA: Castilla La Mancha; CTB: Cantabria: CVA: Comunidad Valenciana; CEU_MEL: Ceuta and Melilla; EXT: Extremadura; GAL: Galicia: MAD: Madrid; MUR: Murcia, NAV: Navarra; RIO: Rioja; PVA: País Vasco.

4. Model

Regarding the analytical framework, we propose to estimate a 'difference-in-difference' model. This model allows us to catch the effect of participation in School 2.0 over Mathematics achievement. The dependent variable is the Mathematics score of student *i* belonging to school *j* ($Math_{ij}$):

$$Math_{ijt} = \alpha_0 + \alpha_1 X_{it} + \alpha_2 X_{jt} + \alpha_3 Year_{2012} + \alpha_4 Part_{jt} + \alpha_3 Year_{2012} \cdot Part_{jt} + \alpha_4 GDPpc_{ct} + \alpha_3 Notebook_{\mathrm{ijt}} \cdot Part_{jt} + \alpha_3 Comp_{2012} \cdot Part_{jt} + \alpha_3 CompGR_{\mathrm{j}} \cdot Part_{jt} + +\alpha_3 GDPpc_{\mathrm{ct}} \cdot Part_{jt} + \varepsilon_{it} + \mu_{jt} + \upsilon_{ijt}$$

where X_{it} refers to observable characteristics of the student *I* and his/her family in year *t* (nationality of the student, age at arrival in Spain, language spoken at home, foreign father and/or mother, lives with only one parent, more than 100 books at home, educational level of parents, occupation of parents, the student has notebook/digital pad at school), X_{jt} refers to characteristics of the school j in year t (endowment of computers per student in 2012, the growth rate of computers' endowment between 2009 and 2012, class size, size of municipality of residence, the proportion of immigrant students and immigrant students).

$Part_{jt}$ is a binary variable that takes the value 1 if the Community has participated in the program School 2.0 in t=2012, $Year_{2012}$ is a binary variable that takes the value 1 in 2012, $GDPpc_{ct}$ is the regional GDP per capita (in real terms) in region c and year t.

We also include interactions between participation in Program School 2.0 and having a notebook/digital pad at school j and year t ($Notebook_{\mathrm{ijt}}$), computer's endowment at school in 2012 ($Comp_{2012}$), computer's endowment growth rate between 2009-2012 for each school ($CompGR_{\mathrm{j}}$) and GDP per capita to gather some potential effects linked to the economic recession.

Finally, ε_{it} denotes unobservable student characteristics, μ_{jt} denotes unobservable characteristics of the school, and finally, v_{ijt} is a random error term.

PISA gives 5 plausible values for the Mathematics score of each student. For the estimation of the model, we have followed the methodology proposed by OECD (2009). As usual, the error term v_{ijt} is assumed to be normally distributed with a mean of zero is clustered by Community to control for the possibility of within-group correlation among schools located in the same region.

5. Model

This section discusses the results of the estimation of the difference-in-differences model. For reasons of space, only the results relating to the comparison between fully-participant Communities and non-participant Communities will be discussed. First, we compare the results using PISA 2009 and 2012 data. Secondly, the results using PISA-ERA-2009 and PISA-CBA-2012.

5.1 Comparison between Fully- Participant Communities and Non-Participant Communities in School 2.0

Results shown in Table 4 indicate that the number of computers per pupil in 2012 has a significant and negative effect on the Mathematics grade for all students (non-repeaters: -114.17 points, repeaters of 1 year: -42.22 points and repeaters of 2 years: -88.56 points, respectively). For repeaters, the availability of a laptop/tablet decreases the Mathematics score by 16.78 points (repeaters of 1 year) and 21.91 points (repeaters of 2 years).

For students who have repeated one or two years, we appreciate that the ratio of computers per student has a negative and significant influence over Mathematics performance (-42.22 and -88.56 points, respectively).

The availability of a laptop/tablet decreases the Mathematics score by7.96 points for non-repeaters, 16.78 points (repeaters 1 year), and 21.91 points (repeaters 2 years). However, the interaction with School 2.0 is not significant for repeater students, although it has a small and negative effect for non-repeaters (-6.66).

The interaction between School 2.0 and GDP per capita is significant, but its coefficient is very small so that an increase of 1,000 euros per capita only increases the score for non-repeating students by 0.4. Therefore, the economic differences between regions with higher GDP per capita (Basque Country: 30,043€) and lower GDP per capita (Extremadura: 15,129 €) are not relevant to explain the variation in results between the participating regions.

Table 4: *Difference-in-Difference Regression Comparing Fully-Participant and No -Participant Communities (PISA 2009 and PISA 2012). All public Schools*

	No repeater		Repeated 1 year		Repeated 2 years	
	Coef	**t**	**Coef**	**t**	**Coef**	**t**
Computers per student (PISA 2012)	-114.17	-5.19	-42.22	7.78	-88.56	-1.60
Growth rate of computers per student 2009-2012	1.56	3.12	0.64	1.06	0.96	0.96
Has notebook/digital pad in school	-7.96	-3.42	-16.78	-6.91	-21.91	-4.63
Has participated in School 2.0	-5.36	-1.49	4.82	0.92	0.24	0.04
Year 2012	-14.58	-1.73	-1.87	-0.18	43.90	3.66
Interaction with participation in School 2.0:						
Computers per student (PISA 2012)	112.93	5.02	43.87	1.21	80.36	1.44
Notebook/digital pad in school	-6.66	-2.44	4.84	1.28	10.89	1.66
Year 2012	-5.78	-0.58	-34.65	-3.68	-26.95	-1.65
Growth rate of computers per student 2009-2012	-1.63	-3.25	-0.53	-0.88	-0.59	-0.58
GDP per capita	0.0004	1.80	0.0011	4.01	0.0007	1.39
Constant	452.60	64.93	394.26	31.42	299.86	20.32
N	14,200		6,102		1,762	
R^2	0.5434		0.5927		0.5571	

Estimated coefficients are the average of the obtained coefficients for the 5 plausible values and using sample weights.

The results in Table 4 have shown a negative effect of the School 2.0 Programme on repeating students. These results are worrying, and we wonder whether it is possible that the effect was not homogeneous, but that the time of exposure to School 2.0 may have generated different effects. To this end, among the subsample of repeating students, we differentiate between those who started participating in School 2.0 in 2009 and those who started in 2010. Results of this new estimation are shown in Table 5.

The interaction effect between the starting year of the School 2.0 programme and the year 2012 is significant and negative for 1-year repeaters. However, in absolute value, the effect is slightly higher for those who entered later in the programme, in 2010. This result could indicate that there is a 'habituation effect' to the new methodology.

In the case of students who have repeated 2 years, the interaction effect is significant and positive for those who entered the programme in 2009, but not significant in 2010.

For both years, there is a sharp drop in the score from 1-year repeaters to 2-year repeaters (from 32.16 to -58.38 for 2009; from 26.61 to -37.90 for 2010). In this case, it should be analysed whether the change in teaching methodology has made it more difficult for students who had already repeated a year, or whether it was the trigger for some students having to repeat a year between 2009-10 and the completion of PISA (2012).

Table 5: *Difference-in-Difference regression comparing fully-participant and no-participant Communities (PISA 2009 and PISA 2012). All public schools*

	Repeater 1 year		Repeater 2 years	
	Coef	**t**	**Coef**	**t**
Computers per student (PISA 2012)	-43.34	-1.24	-85.59	-1.55
Growth rate of computers per student 2009-2012	0.66	1.09	0.91	0.90
Has notebook/digital pad in school	-16.53	-6.89	-21.54	-4.46
Has participated in School 2.0	-25.61	-1.49	41.17	2.59
Year 2012	-2.71	-0.27	45.37	3.82
Interaction with participation in School 2.0:				
Computers per student (PISA 2012)	54.97	1.51	90.80	1.68
Notebook/digital pad in school	4.78	1.36	11.34	1.73
Year 2012	-64.11	-3.66	7.47	0.32
Growth rate of computers per student 2009-2012	-0.73	-1.20	-0.84	-0.86
GDP per capita	0.0018	5.98	0.0014	2.08
Started in 2009	32.16	1.90	-58.38	-4.51
Interaction with year 2012	-59.82	-3.46	43.53	2.29
Started in 2010	26.61	1.60	-37.90	-2.22
Interaction with year 2012	-64.11	-3.66	7.47	0.32
Constant	396.92	31.52	297.97	21.45
N	6,102		1,762	
R^2	0.5993		0.6707	

Estimated coefficients are the average of the obtained coefficients for the 5 plausible values and using sample weights.

As a robustness analysis, we propose to estimate the difference-in-differences model but restrict the sample to schools that participated in both PISA 2009 and PISA 2012. Results are shown in Table 6.

The number of computers per pupil in 2012 has a significant and negative effect on non-repeating and repeating students (-355.69 points and -278.44 points, respectively). In fully-participant the interaction effect is significant and positive, leading to a net result of +68.66 for non-repeating students and -29.83 for one-year repeaters.

The interaction between the variable 'the year 2012' and participation is negative and significant for repeaters of 1 year (-91.06 points) and repeaters of 2 years (-118.77 points).

In fully-participant Communities, the availability of a laptop/tablet decreased the score by 20.72 points for non-repeating students.

Table 6: *Difference-in-Difference regression comparing fully-participant and no -participant Communities (PISA 2009 and PISA 2012). Public schools participating in PISA 2009 and 2012.*

	No repeater		Repeated 1 year		Repeated 2 years	
	Coef	**t**	**Coef**	**t**	**Coef**	**t**
Computers per student (PISA 2012)	-355.69	-5.53	-278.44	-3.26	152.99	0.56
Growth rate of computers per student 2009-2012	3.89	5.94	2.51	2.34	-2.46	-0.71
Has notebook/digital pad in school	-3.58	-0.97	-22.23	-4.06	-16.86	-1.49
Has participated in School 2.0	-28.88	-3.93	-24.02	-2.10	58.53	1.48
Year 2012	-22.33	-2.72	8.57	0.63	90.52	2.34
Interaction with participation in School 2.0:						
Computers per student (PISA 2012)	424.35	6.39	248.61	2.75	-240.21	-0.89
Notebook/digital pad in school	-20.72	-4.33	3.84	0.42	-2.99	-0.17
Year 2012	-24.63	-1.68	-91.06	-3.86	-118.77	-3.03
Growth rate of computers per student 2009-2012	-5.12	-6.81	-1.77	-1.59	3.86	1.11
GDP per capita	0.0014	2.87	0.0029	3.18	0.0032	3.60
Constant	483.90	20.04	366.09	13.14	207.01	3.64
N	5,084		2,091		544	
R^2	0.5380		0.5170		0.6876	

Estimated coefficients are the average of the obtained coefficients for the 5 plausible values and using sample weights.

5.2. Comparison of Mathematics performance using PISA-ERA and PISA-CBA between fully-Participant and Non-Participant Communities

The advantage of using PISA-ERA and PISA-CBA is that it provides information on the frequency of using ICT for homework at home. Three binary variables are introduced for '1-2 times/month', '1-2 times a week', 'almost every day' (with 'every day' is the omitted category). Interactions between these variables and participation in School 2.0 are also introduced. Estimation results are shown in Table 7.

We appreciate that Participation in School 2.0 did not favour a higher score in the CBA module. Among non-repeating students, the use of the computer for homework (1-2 times/week) had a negative effect in fully-participant Communities (-3.15), but a positive effect in non-participants (55.62). For non-repeating students, the availability of a laptop/tablet decreases the score in Mathematics-CBA (-48.35 points in participating Communities versus -23.36 points in non-participating). For students who have repeated two years, a reduction is observed in all the ACs (-54.68 in non-participants, and -74.73 in participants).

Table 7: *Difference-in-difference Regression Comparing Fully-Participant and No-Participant Communities (PISA-ERA 2009 and PISA-CBA 2012). All public schools.*

	No repeater		Repeated 1 year		Repeated 2 years	
	Coef	**t**	**Coef**	**t**	**Coef**	**t**
Computers per student (PISA 2012)	0.00	-0.04	0.01	0.60	-0.01	-0.16
Growth rate of computers per student 2009-2012	-0.33	-0.96	-0.96	-2.74	-0.11	-0.13
Has notebook/digital pad in school	-23.36	-1.72	3.59	0.18	-27.77	-1.25
Uses ICT for doing homework						
1-2 times per month	7.20	0.48	21.83	1.35	-12.91	-0.88
1-2 times per week	55.62	4.66	-0.19	-0.01	-54.68	-3.40
Almost all days	5.67	0.36	0.15	0.01	-20.42	-1.09
Has participated in School 2.0	-58.77	-2.45	-15.45	-0.60	-124.83	-4.14
Year 2012	-90.23	-4.52	-24.37	-1.06	-151.42	-3.19
Interaction with participation in School 2.0:						
Computers per student (PISA 2012)	21.55	1.02	1.54	0.12	13.42	0.72
Notebook/digital pad in school	33.78	1.78	-30.54	-1.63	35.78	1.59
Year 2012	81.00	1.72	-6.67	-0.20	136.24	1.57

Growth rate of computers per student 2009-2012	0.36	0.67	0.86	2.12	0.27	0.27
ICT fo;r homework: 1-2 times/month	33.74	2.48	24.65	1.37	31.51	1.44
ICT for homework: 1-2 times/week	-14.20	-1.19	7.79	0.37	104.78	5.15
ICT for homework: almost all days	34.84	1.65	19.14	0.85	56.33	1.72
GDP per capita	-0.0030	-2.09	-0.001	-0.98	-0.0026	-1.04
Constant	505.76	13.66	414.98	10.23	535.49	9.69
N	4,458		1,521		459	
R^2	0.7700		0.8092		0.7334	

Estimated coefficients are the average of the obtained coefficients for the 5 plausible values and using sample weights.

5.3. Positive Spillovers

Apart from the effect of the program School 2.0 over academic results, we are also concerned with other types of effects, such as spillover effects. It is interesting to determine if this program has affected the ways in which students interact among them (talk about Mathematics, join together to solve problems, exchange information regarding different issues of the subject). For this purpose, we have analysed the variables ‘talks about mathematics with peers/friends’ and ‘helps other peers/friends with mathematics’. Since both are ordinal coded (1: ‘always or almost always’, 2: ‘often’; 3: ‘sometimes’, 4: ‘never or almost never’), ordered probit models were estimated. Table 8 shows the predicted probabilities for both events as a function of the number of repeated grades and the ratio between the predicted probability for fully-participant Communities and non-participant Communities in School 2.0. [Results of the estimation of the ordered probit are omitted due to space constraints, but are available upon request]

We find that, for non-repeating students, the probability of talking about mathematics ‘always or almost always’ or ‘often’ is 17% or 10% higher for students in fully-participating Communities than for students in non-participant Communities. The probability of helping a classmate with mathematics ‘always or almost always’ or ‘often’ is 21% or 11% higher for students in fully-participating Communities than for non-participating Communities.

On the other hand, we find that for students who have repeated a grade, the probability of helping a classmate with mathematics ‘always or almost always’ or ‘often’ is 9% or 5% higher among students in fully-participating Communities than for non-participating Communities.

Finally, for students who have repeated two grades, the most striking result of all is that the probability of helping a classmate with mathematics ‘always or almost always’ or ‘often’ is 46% or

27% higher among students in fully-participating Communities than in non-participating Communities.

Table 8: *Predicted Probabilities for Positive Spillovers related to Mathematics*

	Talks about Mathematics with friends/classmates			
	Always or almost always	Often	Sometimes	Never or almost never
Predicted probability				
No repeater	0.027	0.118	0.369	0.485
Rep. 1 year	0.041	0.119	0.292	0.548
Rep. 2 years	0.064	0.105	0.269	0.563
Ratio of predicted probabilities between fully-participant and non-participant Communities				
No repeater	1.17	1.10	1.03	0.95
Rep. 1 year	0.98	1.01	1.02	0.99
Rep. 2 years	0.94	1.03	1.06	0.97
	Helps other Friends/classmates with Mathematics			
	Always or almost always	Often	Sometimes	Never or almost never
Predicted probability				
No repeater	0.039	0.185	0.495	0.281
Rep. 1 year	0.046	0.147	0.414	0.393
Rep. 2 years	0.047	0.132	0.363	0.458
Ratio of predicted probabilities between fully-participant and non-participant Communities				
No repeater	1.21	1.11	1.01	0.90
Rep. 1 year	1.09	1.05	1.01	0.97
Rep. 2 years	1.46	1.27	1.09	0.85

6. Conclusions

In this paper, we have carried out an evaluation of the Spanish experience of introducing digitisation in primary and secondary classrooms by comparing the results obtained in the subject of Mathematics between communities participating and not participating in this digitisation process and at a stage before and after the project.

The results are in line with those obtained previously by Rouse et al. (2004), Spencer-Smith and Hardman (2014), and Cristia et al. (2014) in the sense that no clearly favourable evolution is observed among students participating in School 2.0. However, generalisations are never a good thing, and some clarifications are necessary. Firstly, as Kubiatko and Vickova (2010) suggest, it is not enough to digitise classrooms and provide students with devices. They also need to be used in the right way, which requires training for teachers and appropriate materials. For this reason, a future line of research is to carry out an in-depth analysis of how new technologies have been implemented in classrooms. For example: for what kind of activities (geometry, algebra, fractions, etc.) have they been used and how often?

Secondly, the results concerning repeating students are very striking. Although in principle, the evolution is not favourable, it cannot be ruled out that there is a learning effect or a time lag necessary to move from traditional methodologies based on book-paper to the new ICT. In relation to this point, a call for attention should be made to the support teachers who exist in all the centres so that they assess how the new technologies can help to solve the learning difficulties carried over from previous years, instead of becoming an additional difficulty. assessed in PISA who started their participation in the Program School 2.0 earlier.

Third, we would like to highlight that just as Kaur (2016) and Lessani et al. (2017) have emphasised that problem-based methods help students to be more creative and to better cope with new challenges, in this article we have found that ICTs bring about new forms of relationships among students. Since mobile phones and video games are part of students' everyday lives, learning mathematics through ICT is likely to make them feel that the subject is closer to them, and stimulate cooperation and mutual help.

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