Academic loss due to the access to ICT resources

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Introduction

The purpose of this report is to examine the inequalities in the education system due to the access to ICT resources. The question got more spotlight with the Coronavirus pandemic of 2020 which forced students to adapt to distance learning almost overnight and continue their studies using their own electronic devices. My hypothesis is that even before the pandemic those who had limited access to computers or internet suffered considerable academic loss. Using 2018 PISA data from Hungary my goal is to gauge the link between the access to ICT resources at home and the students' PISA test scores and to estimate the magnitude of the academic loss due to the lack of such resources.

Data

The PISA survey is an international educational assessment implemented by the OECD which measures the 15-year-old students' mathematics, reading and science literacy every three years. The test scores of the students are supplemented by a student survey and a school survey. The student survey asks questions about the socio-economic background of the students as well the households' situation regarding the possession of computers or access to internet. The school survey provides additional information about the schools where the students continue their studies including their financing scheme and staff information.

In order to test the hypothesis about the pattern between the ICT resources and test scores, I will assume that two groups of predictors impact the students' academic performance: the background characteristics of the students and the characteristics of the students' school. The specification of the theoretical model is the following:

$$Test\ \ score_i = \alpha + \beta_1 No\ \ computer_i + \sum_k \gamma_k\ \ Student\ \ characteristics_{k,i} + \sum_l \rho_l\ \ School\ \ characteristics_{l,i}$$

Where the outcome $Test\ \ score$ is the plausible test score value of mathematics, reading or science, $No\ \ computer$ is a dummy showing if the students' household do not own any computers, $Student_{k,i}$ is a vector with the students' characteristics and family background variables and finally, $School_{l,i}$ contains the the attributes of the students' school. In this analysis I will only consider the students' background variables as controls and ignore the school effect despite we know that schools have considerable contribution to students' academic success. From the students' predictors the following variables will be considered: the students' index of socio-economic status "SES" (ESCS), the household's access to internet, the students' gender, education of parents, possession of an own room or own desk and the approximate number of books in the household. If there is academic loss due to the lack of access to ICT resources, then we expect to have significant negative estimate of the $No\ \ computer$ even after controlling for the students individual and family background variables. I will present the detailed results in the main text using the maths score as the outcome variable. Results for the reading score can be found in the **Appendix**.

Descriptive statistics

The below table summarizes the most important features of the outcome and explanatory variables. The distributions of the variables presented in the table can be found in **Appendix A2 Table 2**.

Table 1: Descriptive statistics

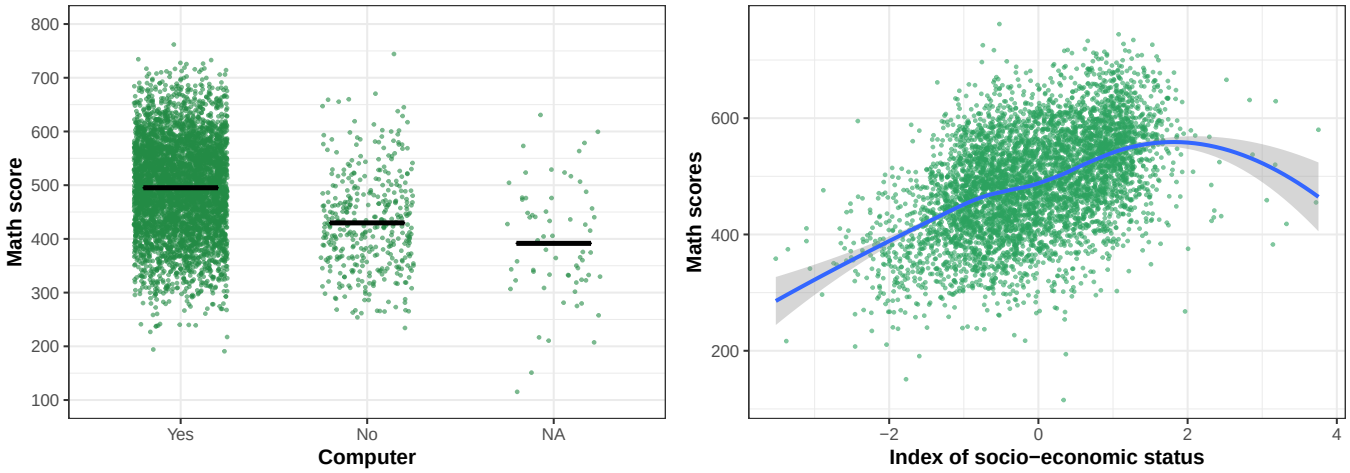
	N	Missing	Mean	SD	Min	Max	Range	P05	Median	P95
Math	5132	0.00	489.03	88.93	115.27	761.88	646.61	339.20	489.81	630.23
Computer	5067	65.00	0.08	0.26	0.00	1.00	1.00	0.00	0.00	1.00
Internet	5080	52.00	0.01	0.11	0.00	1.00	1.00	0.00	0.00	0.00
Female	5132	0.00	0.51	0.50	0.00	1.00	1.00	0.00	1.00	1.00
ESCS	5083	49.00	−0.06	0.92	−3.52	3.75	7.27	−1.55	−0.09	1.30
Own room	5077	55.00	0.08	0.28	0.00	1.00	1.00	0.00	0.00	1.00
Desk	5076	56.00	0.03	0.17	0.00	1.00	1.00	0.00	0.00	0.00

The average test score in math is 489 with a difference of 646 scores between the best and the worst test results. Binary variables were included in the summary table in order to explore the frequency of each group. If we look at the variable of our interest then we can see that the proportion of students without a computer at home is about 8 percent, while Internet connection is absent in the homes of 1 percent of students. The numbers are about the same if we look at the own room and own desk variables which shows that 8 and 3 percent of the students in the sample lack these at their homes. The SES index of a student is expected to be the most influential predictor of the students' performance. If we look at its distribution in the **Appendix A.2.** we can see that it has a distribution close to normal and lack extreme values. Note that in case of the parents' education three education categories were created from the ISCED codes: Pre-primary, primary and lower secondary education were grouped together (8 years of education), upper secondary education without secondary school leaving examination (10.5 years of education) and upper secondary education with secondary school leaving examination (12 years of education).

Relationship with test scores

In order to determine which are the potentially strong predictors of the test scores, the association between the math results and the explanatory variables needs to be examined. **Fig.1** shows the relationship of the math scores with the access to computers as well as with the students' SES index.

Fig1.: Relationship between (1) computers in the household / (2) ESCS and math test scores



Note: Horizontal lines in (1) show the average math test scores.

First, let's take a look at the variable of our interest. The first panel shows the average test scores among students who have and do not have computers in their households. As expected, students without access to computers in their homes have lower performance, on average. The average test score disadvantage of students without their own computers is 64 points in test scores. The figures imply considerable academic loss due to the lack of ICT resources, however we cannot yet draw conclusions as there are several other factors that determine the academic performance of the students.

It is also worth to take a look at the pattern of association between the outcome and the controlling variables. The second panel shows the scatter plot of our key control variable, the SES index against the math test scores together with the lowess smoother. It seems that the relationship is positive and linear just as we assumed, but after about the SES index of 2 it sharply decreases. It would imply that higher socio-economic status contributes to the academic performance until a certain level, but the performance of the students with the highest socio-economic status declines. In order to capture the potential non-linearity in the relationship, we can try to fit a piecewise linear spline and test if the negative association matters at all.

For all the predictors **Appendix A.3.** contains the corresponding visualizations of the joint distributions. The rest of our controls are either binary or ordinal. In this case we can take a look at the average test scores by each value of the variables to have an idea which can be the potentially strong predictors of the test results. The average math test scores do not seem to differ much by the gender of the students, by the own room and an own desk flags. However, test scores monotonically increase with the parents' education and with the number of the books owned in the household. It implies that the latter two predictors should be also in the focus of the regression analysis.

Model

The purpose of the regression analysis is to uncover and quantify the extent of the academic loss due to the access to the ICT resources while we also consider other characteristics of the students. The detailed model building steps can be found in the **Appendix A.4.** while in this section only some of the selected model specifications are presented.

Table 2: Regression output

	Dependent variable : Math scores			
Variable	(1)	(2)	(3)	(4)
Intercept	495.24***	494.70***	394.17***	396.16***
	(1.26)	(1.13)	(5.80)	(5.79)
Computer	-65.40***	-23.69***	-19.30***	-18.95***
	(4.69)	(4.47)	(4.54)	(4.54)
SES		43.34***	15.11***	
		(1.27)	(1.83)	
Internet			4.99	5.35
			(10.53)	(10.53)
Parents' education: 10.5 years			37.93***	37.16***
			(5.38)	(5.39)
Parents' education: 12 years			54.37***	52.93***
			(5.73)	(5.73)
Gender			-13.47***	-13.55***
			(2.17)	(2.17)
Socio-economic status <2				16.34***
				(1.81)
Socio-economic status >= 2				-61.85**
				(23.38)
Own room + Own desk			Y	Y
Books owned			Y	Y
Num.Obs.	5067	5051	4972	4972
R2	0.039	0.225	0.334	0.336
R2 Adj.	0.038	0.225	0.328	0.329
Student weights	Y	Y	Y	Y

* p <0.05, ** p <0.01, *** p <0.001

The results imply that the academic disadvantage of students without ICT resources at home is 65 test scores without controlling for the students' observable characteristics. However, the explanatory power of the first model is quite poor with only explaining about 4 percent of the overall variation of the math scores. When we include the SES index of the students in our second model the ICT gap decreases to 23 scores as well as the the R^2 increases to 22 percent. It suggests that, as we expected, the socio-economic background is the strongest predictor of the academic performance. In the third regression, more background variables of the students were added, including the education of the parents, the students' gender, the approximate number of books in the household and whether the students own a desk or a room and if the household has Internet connection. From the detailed regression output in **Appendix A.4.** it can be seen that the level of education of the parents and the number of books owned are both positively associated with the test performance. Female students have, on average, lower performance in the math test and owning a desk does not seems to influence the test scores. Moreover, the Internet connection is statistically not significant in the model which can be due to the low number of observations and its strong association with the computer field. Overall, after including all the available characteristics of the students the academic loss due to the lack of ICT resources is 17 scores in the math test. In regression four, piecewise linear spline was included to capture the negative pattern at the high level of the SES index. It seems that the more complicated pattern does not change much on the explanatory power of the model, hence we can use the third model to make robustness checks.

Generalization and external validity

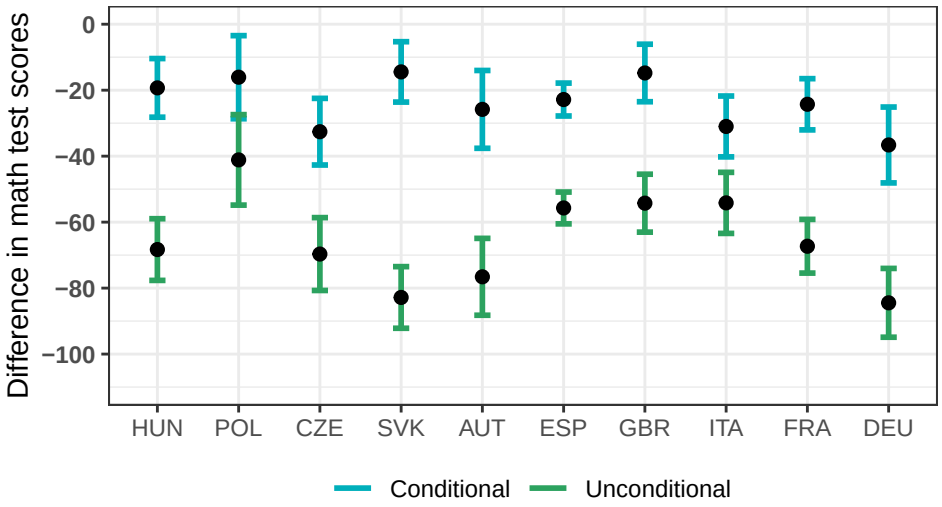
Now that we have examined the relationship between the access to ICT resources and the math scores in Hungary in 2018, let's make some robustness checks whether we can find similar patterns in case of the test scores in other subjects, in other countries and in other years when the test took place.

Firstly, let's take a look at at the ICT gap using the reading and science test scores as outcome variables. **Appendix A.5.** contains the results of the regressions of the unconditional and conditional ICT gap. The figures imply very similar academic disadvantages to what we saw using the math scores as dependent variable. The test score disadvantage is about 21 scores in case of reading and 19 test scores in case of science for those without computers at their homes.

Another interesting question is whether we can see the same pattern in other countries. In order to test the similarity in the pattern across countries, the same model was applied on the PISA survey results of the three other V4 countries

and on six Western European countries. **Appendix A.6.** contains the detailed results of the regressions, while in the main text only the estimated parameters of owning a computer are presented.

Fig.2: Academic loss due to ICT gap in European countries



Note: Markers show the estimated parameters of owning a computer and error bars show the 95% CI. The unconditional estimates shows the gap without control variables and the conditional estimates shows the results from the full model with the student background control variables.

The unconditional ICT gap seems to be the strongest in Slovakia and Germany, where students without ICT resources suffer more than 80 points loss in math test scores, on average. When all student background attributes are controlled for, some part of this disadvantage diminishes in all the examined countries, just like we have seen from the regression analysis of Hungary. If we compare the conditional gap with other countries, Hungary seems to have the smallest negative gap together with Slovakia, Poland and Great Britain. It can either mean that the disadvantage in academic loss due to the lack of ICT devices is moderate in Hungary compared to other European countries or that the students' performance is strongly related to the other background variables, such as the SES index or the education of parents. If we look at **Table 5** in **Appendix A.6.** it seems that the parents' education adds the most to the performance of the student in Hungary among the examined countries.

Finally, we can make another stability check by comparing different PISA survey results in Hungary. The evolution of the ICT gap over the past three PISA math tests in Hungary is shown in **Appendix A.7.**. It seems that the academic loss due to the ICT gap, both conditional and unconditional, slightly decreased over the examined three years. After controlling for the characteristics of the students we can observe that the ICT gap seems to be fairly stable over the three assessments with 23 to 18 test score disadvantage of the students without computers in their homes.

Conclusion

To sum up, our analysis suggested that even before the Coronavirus pandemic secondary school students without computers at their homes suffered loss in their academic performance. Using data from the PISA survey on fifteen-year-old students, we measured the links between students' scores in maths and their possibilities of accessing computers in their homes (hence attending remote learning). We found that in Hungary the lack of such resources are associated with about 60 points lower scores in the math test in the 2018 assessment. When we controlled for the background characteristics of the students the academic loss decreased to about 20 scores disadvantage, which seemed to be stable over the past three PISA assessments in Hungary. When we compared the results found in the Hungarian data to other European countries it also supported the conclusion that the lack of ICT resources are negatively correlated with cognitive outcomes. Finally, it is important to emphasize the limitations of this study. We did not consider the attributes of the schools where students continue their studies, such as the size of the school, the type (whether it is private of public school) and the student-teacher ratio of the institution, as additional control variables. We can expect that involving the school effect into our analysis would further decrease the ICT gap.

Appendix

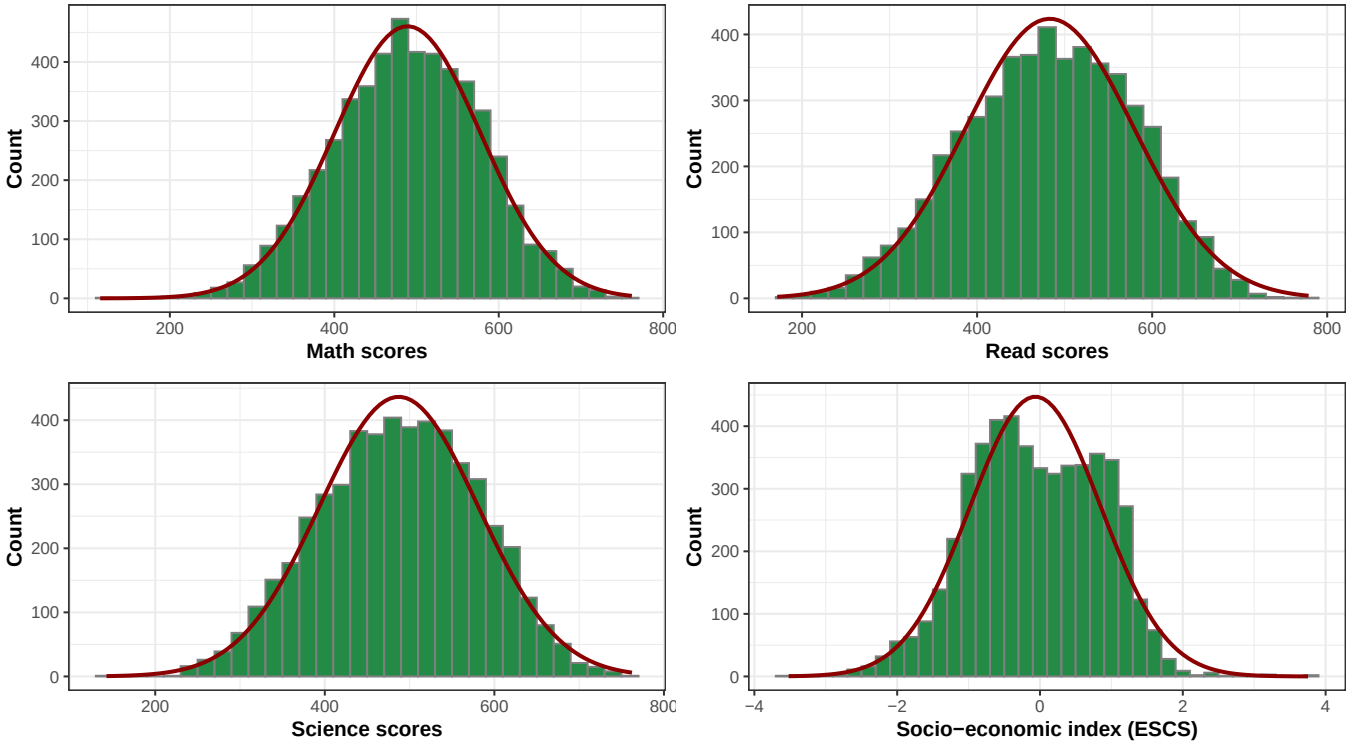
A1. Detailed descriptive statistics

Table 2: Descriptive statistics by access to computer

Computer	Variable	N	Missing	Mean	SD	Min	Max	P05	Median	P95
Without computer	Math	384	0.00	429.84	88.71	234.16	744.23	293.11	423.33	588.19
	Read	384	0.00	424.02	100.79	171.62	752.14	266.20	416.68	603.53
	Computer	384	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00
	Internet	383	1.00	0.08	0.28	0.00	1.00	0.00	0.00	1.00
	Female	384	0.00	0.57	0.50	0.00	1.00	0.00	1.00	1.00
	ESCS	381	3.00	−0.97	0.89	−3.52	1.08	−2.35	−0.98	0.60
	Own room	384	0.00	0.20	0.40	0.00	1.00	0.00	0.00	1.00
	Desk	383	1.00	0.12	0.33	0.00	1.00	0.00	0.00	1.00
With computer	Math	4683	0.00	495.24	86.10	190.76	761.88	350.70	495.67	632.61
	Read	4683	0.00	489.07	94.02	198.74	778.73	331.18	491.06	637.78
	Computer	4683	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Internet	4678	5.00	0.01	0.08	0.00	1.00	0.00	0.00	0.00
	Female	4683	0.00	0.50	0.50	0.00	1.00	0.00	1.00	1.00
	ESCS	4670	13.00	0.02	0.87	−3.36	3.75	−1.35	−0.01	1.32
	Own room	4672	11.00	0.07	0.26	0.00	1.00	0.00	0.00	1.00
	Desk	4670	13.00	0.02	0.15	0.00	1.00	0.00	0.00	0.00

A2. Single factor analysis - Histograms of explanatory variables

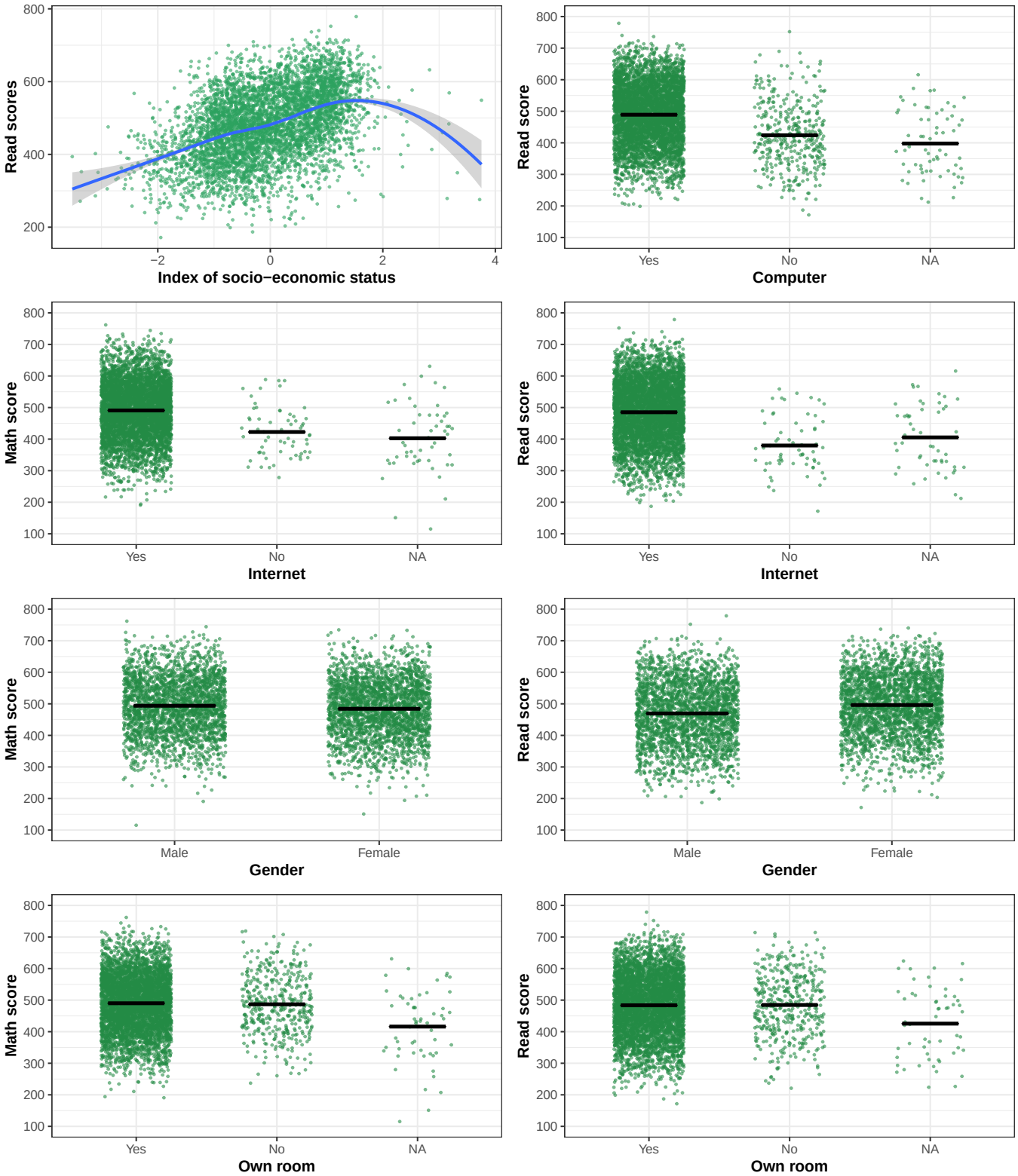
Fig3.: Histograms of the test scores and ESCS



Note: Normal curve was added to the chart.

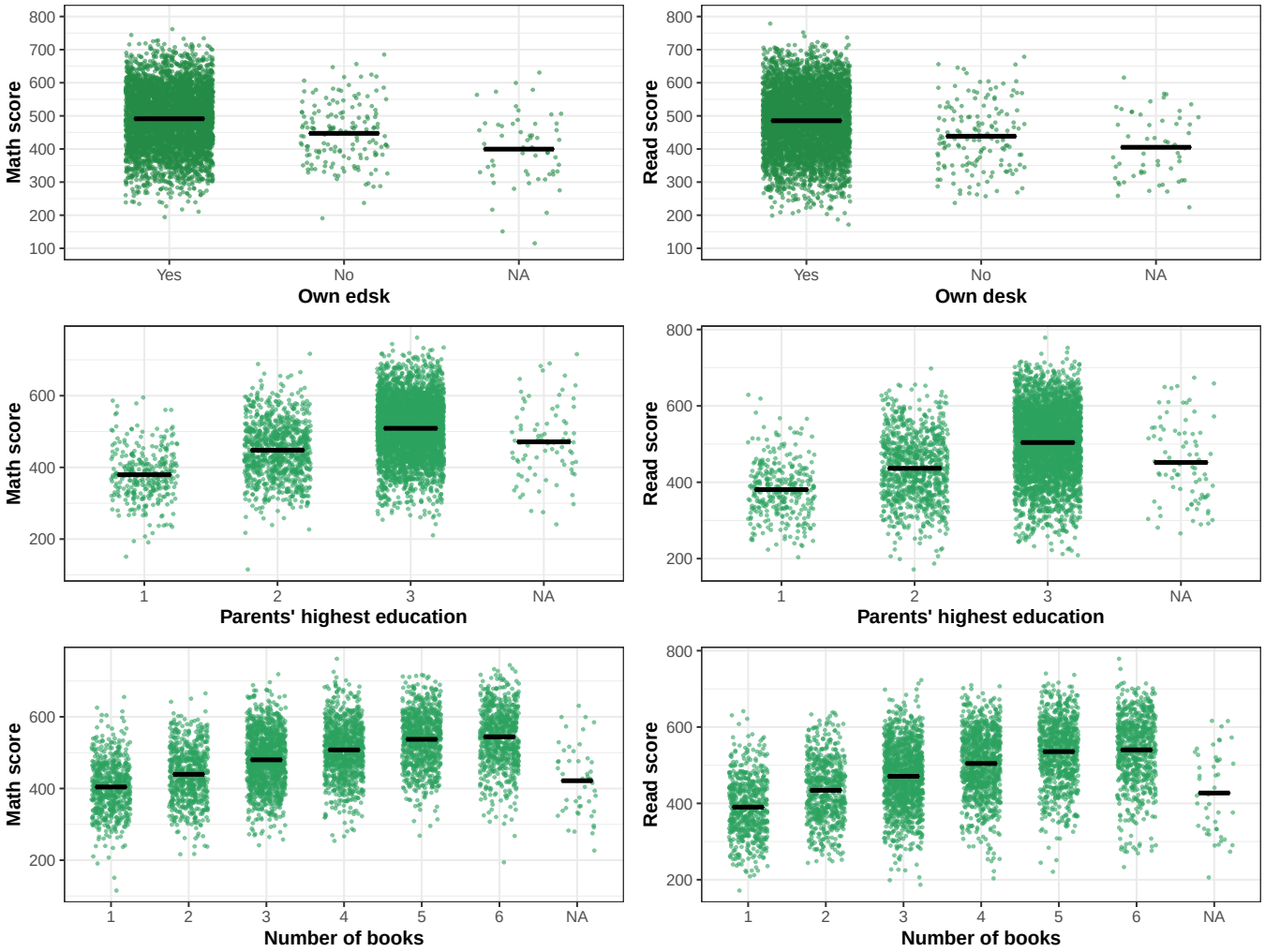
A3. Relatinship with outcome variables (mat and read scores)

Fig4.: Relationship with math test scores



Note: Note: Horizontal lines in (1) show the average math test scores.

Fig5.: Relationship with math test scores (cont'd)



Note: Note: Horizontal lines in (1) show the average math test scores.

A.4. Regression results - Building steps

Table 3: Dependent variable: Math score

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Intercept	495.24***	494.70***	434.79***	389.56***	395.20***	394.35***	394.84***	394.17***	396.16***
	(1.26)	(1.13)	(5.28)	(5.62)	(5.68)	(5.68)	(5.72)	(5.80)	(5.79)
Computer	−65.40***	−23.69***	−21.65***	−18.25***	−17.35***	−18.48***	−17.71***	−19.30***	−18.95***
	(4.69)	(4.47)	(4.72)	(4.53)	(4.51)	(4.54)	(4.54)	(4.54)	(4.54)
SES		43.34***	31.67***	14.90***	14.32***	14.70***	14.56***	15.11***	
		(1.27)	(1.67)	(1.81)	(1.81)	(1.82)	(1.82)	(1.83)	
Parents' education: 10.5 years			37.55***	37.27***	36.78***	36.82***	37.67***	37.93***	37.16***
			(5.33)	(5.32)	(5.30)	(5.29)	(5.32)	(5.38)	(5.39)
Parents' education: 12 years			64.54***	53.42***	53.43***	53.53***	53.96***	54.37***	52.93***
			(5.59)	(5.65)	(5.64)	(5.65)	(5.66)	(5.73)	(5.73)
Books: 11-25				16.33***	16.65***	16.80***	16.76***	16.46***	16.26***
				(4.36)	(4.32)	(4.34)	(4.34)	(4.36)	(4.36)
Books: 26-100				46.78***	47.48***	47.88***	47.33***	47.33***	46.92***
				(3.95)	(3.92)	(3.93)	(3.94)	(3.94)	(3.94)
Books: 101-200				64.21***	65.58***	65.74***	65.23***	64.99***	64.23***
				(4.40)	(4.39)	(4.41)	(4.41)	(4.42)	(4.41)
Books: 201-500				87.05***	89.20***	89.22***	88.80***	88.29***	87.32***
				(4.79)	(4.77)	(4.79)	(4.78)	(4.79)	(4.79)
Books: 500+				86.23***	87.76***	87.99***	87.28***	86.91***	86.77***
				(5.26)	(5.24)	(5.27)	(5.26)	(5.26)	(5.26)
Gender					−13.27***	−13.58***	−13.12***	−13.47***	−13.55***
					(2.17)	(2.17)	(2.17)	(2.17)	(2.17)
Own room						10.74**		10.77**	10.84**
						(4.04)		(4.04)	(4.03)
Own desk							3.93	3.40	3.59
							(6.35)	(6.49)	(6.51)
Internet								4.99	5.35
								(10.53)	(10.53)
Socio-economic status < 2									16.34***
									(1.81)
Socio-economic status >= 2									−61.85**
									(23.38)
Num.Obs.	5067	5051	5013	4999	4999	4989	4987	4972	4972
R2	0.039	0.225	0.259	0.328	0.333	0.335	0.332	0.334	0.336
R2 Adj.	0.038	0.225	0.258	0.326	0.332	0.334	0.330	0.332	0.334

A.5. Robustness checks - Read and Science scores

A.6. Robustness checks - Other countries

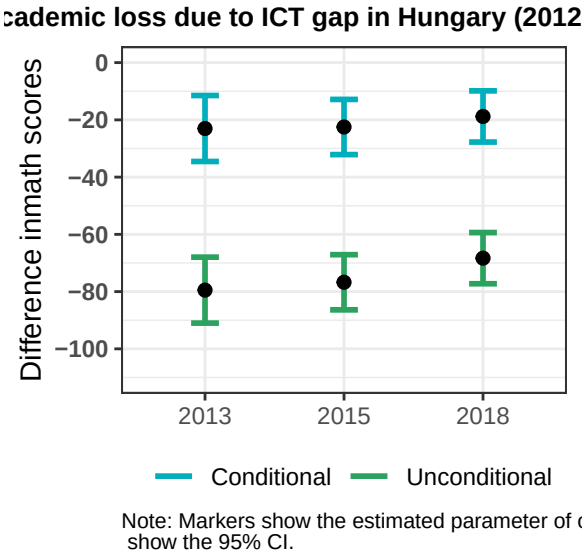
Table 4: Dependent variable: Math score

	Read	Read	Science	Science
Intercept	483.34***	368.32***	487.54***	383.80***
	(1.43)	(6.27)	(1.41)	(5.88)
Computer	−68.69***	−19.07***	−68.80***	−17.46***
	(5.64)	(5.23)	(5.21)	(4.82)
Internet		−40.07**		−33.31**
		(14.12)		(12.81)
SES		12.45***		12.53***
		(2.07)		(1.96)
Parents' education: 10.5 years		28.12***		30.06***
		(5.63)		(5.21)
Parents' education: 12 years		48.63***		56.47***
		(6.03)		(5.66)
Gender		21.35***		−7.70***
		(2.36)		(2.28)
Own room		14.54**		14.79***
		(4.50)		(4.37)
Books: 11-25		27.36***		19.15***
		(4.61)		(4.50)
Books: 26-100		53.02***		53.38***
		(4.34)		(4.14)
Books: 101-200		75.57***		68.25***
		(4.84)		(4.68)
Books: 201-500		99.73***		96.48***
		(5.20)		(4.92)
Books: 500+		98.82***		95.46***
		(5.69)		(5.42)
Own desk		0.94		9.31
		(7.15)		(6.21)
Num.Obs.	5067	4972	5067	4972
R2	0.039	0.316	0.042	0.329
R2 Adj.	0.039	0.315	0.041	0.327

Table 5: Dependent variable: Math score

	HUN	POL	CZE	SVK	AUT	ESP	GBR	ITA	FRA	DEU
Intercept	394.17***	462.55***	454.87***	406.56***	428.26***	434.78***	460.39***	443.05***	445.03***	456.31***
	(5.80)	(7.27)	(5.76)	(6.94)	(7.07)	(2.88)	(7.21)	(5.55)	(5.59)	(5.24)
Computer	−19.30***	−16.06*	−32.58***	−14.45**	−25.82***	−22.84***	−14.78***	−30.99***	−24.27***	−36.61***
	(4.54)	(6.42)	(5.15)	(4.67)	(6.02)	(2.55)	(4.45)	(4.71)	(3.96)	(5.87)
Internet	4.99	−30.08+	−21.45	−2.02	−49.85***	−2.88	−88.10***	−17.87*	−1.90	−32.55***
	(10.53)	(16.98)	(13.85)	(10.55)	(10.11)	(4.94)	(16.69)	(8.17)	(9.03)	(9.55)
SES	15.11***	22.53***	25.96***	18.19***	10.92***	10.73***	6.92***	11.42***	17.61***	13.04***
	(1.83)	(1.85)	(1.97)	(1.84)	(2.04)	(0.98)	(1.76)	(2.01)	(1.79)	(2.03)
Parents' education: 10.5 years	37.93***	10.26	5.22	10.64	24.42***	5.68*	7.20	10.95*	4.79	15.38**
	(5.38)	(6.91)	(4.96)	(6.84)	(6.09)	(2.28)	(6.91)	(4.81)	(4.82)	(4.93)
Parents' education: 12 years	54.37***	20.54**	16.41***	49.65***	31.98***	18.46***	31.49***	22.08***	26.72***	21.59***
	(5.73)	(6.51)	(4.82)	(6.63)	(6.58)	(2.12)	(7.25)	(4.01)	(5.06)	(3.62)
Gender	−13.47***	−6.57**	−14.49***	−13.45***	−20.55***	−12.00***	−17.63***	−20.20***	−13.98***	−17.04***
	(2.17)	(2.38)	(2.24)	(2.25)	(2.29)	(1.25)	(2.22)	(2.46)	(2.07)	(2.60)
Own room	10.77**	−2.43	10.56***	14.78***	−18.07***	−3.27+	−11.65**	6.92**	−11.99***	−17.36**
	(4.04)	(3.76)	(2.64)	(2.85)	(4.17)	(1.95)	(4.25)	(2.64)	(3.42)	(5.39)
Books: 11-25	16.46***	19.77***	22.64***	32.51***	30.45***	21.94***	12.28**	19.46***	28.84***	26.46***
	(4.36)	(4.33)	(4.49)	(4.20)	(4.49)	(2.63)	(3.98)	(4.84)	(3.79)	(5.41)
Books: 26-100	47.33***	42.69***	44.60***	58.22***	62.27***	46.42***	37.45***	44.77***	46.69***	52.76***
	(3.94)	(3.93)	(4.03)	(4.03)	(4.27)	(2.41)	(3.69)	(4.54)	(3.51)	(5.17)
Books: 101-200	64.99***	56.26***	59.09***	77.18***	71.77***	63.52***	60.05***	61.11***	62.58***	72.13***
	(4.42)	(4.48)	(4.50)	(4.60)	(4.73)	(2.66)	(4.26)	(5.18)	(4.01)	(5.60)
Books: 201-500	88.29***	77.63***	74.90***	96.54***	100.93***	74.72***	67.10***	70.72***	80.94***	80.69***
	(4.79)	(4.85)	(4.79)	(5.17)	(4.85)	(2.88)	(4.52)	(5.50)	(4.36)	(5.98)
Books: 500+	86.91***	72.25***	62.45***	60.60***	99.74***	73.21***	67.37***	58.66***	80.49***	85.97***
	(5.26)	(6.14)	(5.98)	(7.06)	(6.13)	(3.49)	(5.71)	(6.47)	(5.18)	(6.87)
Own desk	3.40	12.14+	−3.91	−16.04***	−21.42**	6.93+	−17.77***	−3.39	−28.32***	−14.07*
	(6.49)	(6.26)	(7.51)	(4.66)	(6.97)	(4.14)	(3.68)	(6.55)	(6.13)	(6.94)
Num.Obs.	4972	5461	6719	5740	6490	34 435	11 899	11 293	5976	4341
R2	0.334	0.198	0.232	0.311	0.257	0.189	0.192	0.170	0.292	0.265
R2 Adj.	0.332	0.196	0.231	0.309	0.255	0.189	0.191	0.169	0.290	0.263

A.7. Robustness checks - Other years



Note: Markers show the estimated parameter of
show the 95% CI.

Table 6: Dependent variable: Math score

	2012 - HUN	2012 - HUN	2015 - HUN	2015 - HUN	2018 - HUN	2018 - HUN
Intercept	483.82***	409.46***	483.13***	390.56***	489.65***	394.00***
	(1.51)	(5.89)	(1.39)	(5.50)	(1.35)	(5.71)
Computer	−79.48***	−23.02***	−76.74***	−22.49***	−68.31***	−18.81***
	(6.39)	(5.88)	(5.27)	(4.92)	(4.77)	(4.56)
SES		18.74***		11.39***		14.94***
		(2.02)		(1.72)		(1.83)
Parents' education: 10.5 years		11.66*		23.19***		37.70***
		(4.98)		(4.99)		(5.31)
Parents' education: 12 years		22.02***		48.59***		54.06***
		(5.54)		(5.36)		(5.66)
Gender		−14.97***		−15.48***		−13.43***
		(2.51)		(2.16)		(2.17)
Own room		11.98**		4.99		10.86**
		(3.87)		(4.02)		(4.05)
Books: 11-25		26.93***		20.17***		16.92***
		(4.98)		(4.39)		(4.36)
Books: 26-100		59.93***		51.12***		47.71***
		(4.73)		(4.03)		(3.95)
Books: 101-200		78.44***		79.08***		65.36***
		(5.30)		(4.41)		(4.43)
Books: 201-500		92.91***		103.14***		88.79***
		(5.39)		(4.54)		(4.81)
Books: 500+		115.39***		102.72***		87.49***
		(5.89)		(5.03)		(5.28)
Own desk		5.12		−17.38*		3.28
		(10.29)		(7.16)		(6.36)
Num.Obs.	4745	4581	5547	5417	5067	4977
R2	0.041	0.339	0.043	0.360	0.046	0.334
R2 Adj.	0.041	0.338	0.043	0.358	0.046	0.332