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Choose the school, choose the performance. New evidence on determinants of students' performance in eight European countries

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Abstract

This study aims to identify the main determinants of students' performances in reading and math across eight European Union countries (i.e., Austria, Croatia, Germany, Hungary, Italy, Portugal, Slovakia, and Slovenia). Based on student level data from the OECD-PISA 2018 survey and by means of the application of efficient algorithms, we highlight that the number of books at home or a variable combining the type and location of school represent the most important predictors of the students' performance in all the analyzed countries, while other school characteristics are rarely relevant. Econometric results show that students attending vocational schools perform significantly worse than those in general schools. Looking at differences between students attending schools in big cities and those in small cities, they are never statistically significant except in Portugal. Through the Gelbach decomposition method, which allows to measure the relative importance of observable characteristics to explain a gap, we show that the differences in test scores between big and small cities depend on the schools' characteristics, while the differences between general and vocational schools are mainly explained by the families' social status. Results appear robust to the hierarchical model approach.

Keywords: Gelbach Decomposition, Education inequalities, Machine learning, PISA, Schooling tracking, Student performance, hierarchical models.

JEL Classification: I21, I24, J24.

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Choose the school, choose the performance. New evidence on determinants of students' performance in eight European countries

Abstract

This study aims to identify the main determinants of students' performances in reading and math across eight European Union countries (i.e., Austria, Croatia, Germany, Hungary, Italy, Portugal, Slovakia, and Slovenia). Based on student level data from the OECD-PISA 2018 survey and by means of the application of efficient algorithms, we highlight that the number of books at home or a variable combining the type and location of school represent the most important predictors of the students' performance in all the analyzed countries, while other school characteristics are rarely relevant. Econometric results show that students attending vocational schools perform significantly worse than those in general schools. Looking at differences between students attending schools in big cities and those in small cities, they are never statistically significant except in Portugal. Through the Gelbach decomposition method, which allows to measure the relative importance of observable characteristics to explain a gap, we show that the differences in test scores between big and small cities depend on the schools' characteristics, while the differences between general and vocational schools are mainly explained by the families' social status. Results appear robust to the hierarchical model approach.

1. Introduction

Students' academic performance is one of the key features in education, it determines the success, or the failure of an academic institution and it has a direct impact on the socio-economic development of a country (Farooq et al. 2011). Low academic performance may result in students' disengagement, and consequent dropping out from the education system. Young people without an upper secondary qualification tend to face severe difficulties entering – and remaining – in the labor market, and this has economic and social consequences for individuals and society alike. Improving educational outcomes is prominently for many OECD countries as a way of enhancing micro and macroeconomic outcomes as well as addressing inequalities (OECD 2019b).

Researchers have long been interested in exploring variables affecting quality of performance of students. These variables are inside and outside the school and they may be termed as student factors, family factors, school factors and peer factors (Crosnoe et al. 2004). Students' factors may include immigration status, age/grade, but also intelligence, attitude, motivation, interests, and attitude and study habits (Nisar et al. 2017). Family factors relate to socio-economic status including parents' qualifications and occupation, family size, income and social standing in society and home environment. Moreover, these factors affect student performance through the community context. If a school is located in a city, students may enjoy additional resources nearby, such as public libraries and museums, which support learning and may be less accessible to students attending a rural school. Finally, school factors include ownership, resources, student–teacher ratio, or size of the class, and the type of school, while peer factors refer to the interactions between individuals with similar age, fairly close friends, sharing the same activities.

This study aims to identify the main determinants of reading and math performances of students living in the European Union. To do that, we use data from the OECD-PISA 2018 Survey which reports internationally comparable information on students, their own households, and the characteristics of attended schools. Specifically, we focus on Austria, Croatia, Germany, Hungary, Italy, Portugal, Slovakia, and Slovenia, as these countries begin the school tracking when students are 15 years old or before.

The novelty of this paper to the existing literature on the topic is threefold. First, we identify the main determinants of students' performance for each country by means of the application of the efficient

computational procedures proposed by Furnival and Wilson (1974). Second, in a comparative perspective across the eight European Union countries, we deeply explore the role played by two specific determinants: the type of school (general vs vocational) and its localization (big vs small city). Third, in addition to OLS and the hierarchical linear models generally used in literature on education (Goldstein 1995; Blanco-Blanco et al. 2014; Martinez-Abad et al. 2020), we implement the decomposition analysis proposed by Gelbach (2016) to assess the underlying mechanisms behind the average gaps in cognitive test scores among students attending schools which are different in type or location.

Our main findings highlight that the number of books at home or a variable combining the type and location of school represent the most important predictors of the students' performance in all the analyzed countries, while other school characteristics are rarely relevant. Econometric results show that students attending vocational schools perform significantly worse than those in general schools, and that those attending a vocational school in a big city tend to perform worse than the ones in a small city. Furthermore, the decomposition analysis shows that the variables explaining the gap between types of schools are overall similar across the countries: we find that the families' socio-economic characteristics are the main underlying reason of the differences between general and vocational schools, while the quality of the school represents the main explanation between big and small cities.

The remainder of the paper is structured as follows. Section 2 reviews the main empirical literature related to the determinants of students' performances, Section 3 introduces data used in the analysis and some descriptive statistics. Section 4 presents the algorithms performed to identify the best model specifications. Section 5 shows and discusses empirical results, while Section 6 concludes.

2. Literature review

The quality of education plays a key role in students' opportunities and affects the economic growth of countries by improving productivity and social development. (Hanushek and Woessmann 2007; Raitano and Vona 2013). The importance of education for social and economic policies highlights the need to monitor students' performance (Giambona and Porcu 2015). The literature is very rich and explore different channels to develop policy implication with the aim to improve educational quality. For the estimation of the education production function relevant factors are generally considered: the student's background; the ways in which teaching is organized and delivered in classes; the human and financial resources available to schools; and institutional structures of the educational system.

Fuchs and Woessmann (2007), using the PISA database, show a strong relationship between family background and students' achievement in standardized reading, mathematical and science exams across a range of countries. These findings are confirmed by other analyses conducted both at country level (see e.g., Lee and Barro 2001) and at student level (Woessmann 2003). Factors such as socioeconomic status, immigration status, age/grade, are highly related to student' performance (Karakolidis et al. 2016). Gender is a special case within this category, since its influence can favor male or female students depending on the competence under study (generally boys outperform girls in math and science, and the opposite is true for reading), also with varying degrees of intensity (Gamazo et al. 2018). Regarding to the immigration background, Giannelli and Rapallini (2016) show that immigrant students have a significantly lower score gap in math and Tonello (2016) finds a weak negative impact of the share of immigrant students on the language scores of native peers. Concerning the age of students, if students were enrolled a year before they achieve better than other students, while, as discussed by Agasisti and Vittadini (2012) if students were not admitted to the next grade during their past career its achievement worsen. The role of ICT availability, recently studied by the literature, is not clear (Banerjee et al. 2007). Wittwer and Senkbeil (2008) show that the use of computers, or other technological tools, can exert a positive, neutral or even negative impact on students' achievement: searching more information on internet can stimulate and increase students' skills, but playing videogames can be detrimental in terms of their education, as can be spending too much time online (OECD 2015). International studies have demonstrated that the different ICT-access at home can make the disparities

in education between poor and rich worse, if different home use is associated to different outcomes (Agasisti et al. 2020). Finally, some articles point out that there is difference to have ICT at home or at school (Escueta et al. 2020).

At school level, factors like ownership, student–teacher ratio, or size, have produced diverse results. There are studies that find positive relationships and others no significant relationship or contradictory results (Kim and Law 2012; Acosta and Hsu 2014). For the class size, there is no consensus on what the best ratio of students to teachers is, although the ‘conventional wisdom’ is that students need more time and interaction with teachers for quality education. Some studies find a small positive impact of reduced class size on long-term outcomes such as overall educational attainment (Bingley et al. 2005; Browning and Heinesen 2007). Differently, Denny and Oppedisano (2013), analyzing PISA data for the UK and USA, suggest that bigger classes lead to better results. Two other school’s elements relevant for students’ achievements are: the presence of career guidance or counselling services, and the competition between schools located in the same area. Potential benefits from the presence of guidance assisting students in planning for their scholastic career could result from people being better able to manage their choices of learning and work, thereby maximizing their potential (te Wierik et al. 2015). Several researches indeed suggest that attending to students’ career development positively contribute to academic achievement (Evans and Burck 1992; Kenny et al. 2006). Regarding to the second factor, when there are more schools in an area, there is more competition, and competition may improve students’ outcomes by enhancing students' motivation, effort, and interest if it allows them to enroll at a school that better suits their preferences. Moreover, school competition may improve a school's productivity, leading to better teacher selection. Overall, education systems should be more efficient, likely leading to more positive outcomes (Belfied and Levin 2002).

Three institutional features mainly influence the performance of students: how much autonomy individual schools have; how they are held accountable; and whether, and how much competition there is between the publicly and privately operated schools. School autonomy in terms of process and personnel decisions is associated with better educational outcomes (Smidova 2019). Because of a principal-agent problem, according to which local decision makers can act opportunistically, the autonomy works in an environment where schools are accountable for their students’ achievement (Hanushek and Woessmann 2011). The mix of public-private funding seems important. The highest tests scores of 2003 PISA math test scores were found in countries with both a high share of privately operated schools and high average share of government funding (Woessmann et al. 2013). Woessman (2016), focusing on the math score in PISA from 2003, finds that resource inputs such as expenditure per student appear to have limited effects on student performance. The opposite result arises taking into consideration the number of books at home, as proxy for the educational, social, and economic background of the students’ families.

An additional determinant of students’ performances is the type of school attended (general vs vocational schools). Creating homogeneous group of students might help teachers to be more effective and some students might benefit from more practical, vocational training that prepares them for the labour market. However, other students in these tracks might lose more than they gain – from lower expectations from their teachers to more disengaged classmates. OECD (2016), in a PISA report, shows that the share of low performers is twice as large among students enrolled in a vocational track than among students enrolled in a general track. On average across OECD countries, 41% of students pursuing a vocational education were low performers in mathematics in 2012, whereas 21% of students in a general track were. Brunello and Rocco (2015) suggest that students with a vocational education do not perform as well as those with a general education both in labour market outcomes and in the level of basic skills, including literacy and numeracy. Looking at the Italian context, Bratti et al. (2007) confirms these findings highlighting that academic and technical schools perform better than vocational.

Finally, the literature offers evidence about the effects of the location of school. Rural areas have long been associated with inferior opportunities, one of which being the provision of education (Arnold et al. 2005). Evidence suggests that rural schools and their students are educationally at a disadvantage in comparison to their urban counterparts in terms of their academic achievement. On average across OECD countries, students

who attend schools in big cities perform better in PISA than students who attend schools in villages, rural areas, or small towns (OECD 2010). The size of the gaps differs across countries, reflecting differences in the resources and learning opportunities available in rural and urban areas, as well as differences in population density or distribution of labour markets. For example, in Italy, Slovak Republic, and Romania, the performance gap between students in city schools and those in rural schools is more than 45 score points, after accounting for student's socio-economic background (OECD 2010). OECD (2019a), analyzing PISA 2015 data, confirms these results but shows also that in Belgium, the United Kingdom and the United States, students in rural school outperform those in city schools. Despite the challenges facing rural schools, some studies argue that small and rural schools can be particularly beneficial to socio-economically disadvantaged students (Semke and Sheridan 2012). Nonetheless, PISA 2015 data reveal that the share of resilient students is somewhat higher in city than in rural schools, on average across OECD countries.

To the best of our knowledge, none of the studies mentioned in this section combined different factors. This paper tries to fill this gap jointly analyzing the effect of the type and the location of schools on students' performance.

3. Data and descriptive statistics

The analysis relies on data from the PISA survey for the year 2018. PISA is a standardized international project implemented every three years by the Organization for Economic Cooperation and Development (OECD) that measures the cognitive abilities in reading, mathematics and science skills of all students between the age of 15 years and 3 months and 16 years and 2 months. Each PISA wave concentrates on one particular subject and provides a more detailed information regarding it. PISA 2018 focuses on reading. In each test subject, the results are scaled to fit approximately normal distributions, with means for OECD countries around 500 score points and standard deviations around 100 score points. The students' scores considered, both in reading and mathematics, are calculated as the average of the ten plausible values.¹ Other than data on skills and knowledge of students, PISA collects interesting information on students, their own families, and on schools' characteristics. The sample follows a stratified two-stage sample design: in the first stage, schools having 15-year-old students are randomly selected in each country. In the second stage, students are randomly selected with equal probability within schools. In our analysis, we focus on 8 European countries, Austria, Croatia, Germany, Hungary, Italy, Portugal, Slovakia, and Slovenia, which begin the school tracking when students are 15 years old or before.² As usual in empirical studies using PISA survey data, all descriptive statistics and estimates take into account individual sample weights provided.

In what follows, the dependent variables of our analysis are students' scores in mathematics and reading and our main variable of interest combines the type of institution attended (i.e., general and vocational) and the municipality size in which the school is placed. If a school is located in a municipality with more than 15,000 inhabitants, then we consider it as placed in a big city, otherwise in a small city. Therefore, we create a categorical variable that distinguishes four types of schools: i) General - Big City; ii) General – Small City; iii) Vocational - Big City; iv) Vocational – Small City.

Overall, once dropped observations with missing values on the variables used in this analysis, our sample counts 45,285 students enrolled in over 2,068 schools in the eight countries. Table 1 indicates that number of students observed and the average score in reading and mathematics for each considered country. Italy represents the largest sub-sample as it counts more than 10,388 students. Other than this case, the other countries range between 3,739, in the case of Germany, and 5,994, in the case of Croatia. Table 1 also points out that students in Germany, Austria, and Slovenia present the highest mean scores in our sample (which are

¹ For more details see: <https://www.oecd.org/pisa/>.

² Starting by the sample containing all the European Union countries, we have excluded those countries where school systems establish that the tracking begins after 15 years old (source: https://eacea.ec.europa.eu/national-policies/eurydice/national-description_en) and those in which the math or the reading performance of students still in lower secondary level is statistically different to the ones reported by those already in an upper secondary school.

also higher than the average of OECD countries) both in mathematics and in reading. The mean scores in Portugal are almost equal to 500 and are slightly higher than Hungary. Finally, the lowest averages are showed by Croatia, Italy, and Slovakia. We also note that countries' rankings in reading and mathematics are not equal to each other.

Table 1. Number of sample observations, and students' performance scores by country

Country	Acronym	Observations	Read score	Math score
Germany	DE	3,739	511.3	511.3
Croatia	HR	5,994	484.3	468.6
Italy	IT	10,388	481.7	491.3
Hungary	HU	4,431	489.5	494.8
Austria	AT	5,299	507.4	519.5
Portugal	PT	5,254	496.5	497.0
Slovenia	SI	5,285	503.6	517.3
Slovakia	SK	4,895	465.5	492.9
Total		45,285	495.8	500.8

Source: Elaborations of the authors on PISA 2018 data.

3.1. Some descriptive statistics

Table 2 shows the distribution of students distinguishing, for each country, among the categories of the type of school above explained: general school in a big city (G-BC), general school in a small city (G-SC), vocational school in a big city (V-BC), and vocational school in a small city (V-SC). Across countries, we point out a heterogeneity in the distribution of students. Three-fifths of children are enrolled in a general school located in a big city in Portugal and Germany. The share decreases to little more than two-fifths in Slovakia, Hungary, and Italy, while the percentage is about 20–30 percent in Slovenia, Austria, and Croatia. Students attending a general school in a small city are about a tenth in each country, with the exception of Germany and Portugal, where the proportion of students is little more than 20 percent, and Hungary and Croatia, where the percentage is about 4–6 percent. The shares of vocational students in big and small cities are similar in Italy, Hungary, and Slovenia (respectively, 40–46 percent and 8–14 percent), as well as in Germany and Portugal (respectively, 9–10 percent and 7–9 percent). In Croatia, more than half of students attend a vocational school in a big city and 14 percent frequents a vocational school in a small city. In Austria and Slovakia, vocational students are overall equally distributed in big and small cities (respectively, 32–35 percent in Austria and 20–26 percent in Slovakia).

Table 2. Share of students by type of school by country

Country	General - Big City (%) (G-BC)	General- Small City (%) (G-SC)	Vocational - Big City (%) (V-BC)	Vocational - Small City (%) (V-SC)
Germany	60.58	22.21	8.64	8.57
Croatia	27.65	6.44	52.20	13.70
Italy	41.92	9.60	40.73	7.76
Hungary	44.26	4.44	41.85	9.45
Austria	20.21	12.89	32.75	34.15
Portugal	61.66	21.48	9.95	6.91
Slovenia	29.98	9.87	46.06	14.09
Slovakia	45.47	8.56	20.94	25.03
Total	49.41	15.14	25.40	10.05

Source: Elaborations of the authors on PISA 2018 data.

4. Selection of good fitting models

One aim of this paper is to identify, for each country analysed, the best set of predictors of students' performance in reading and math. In this situation, even considering the usual information limitations of a survey dataset, the number of potential predictors is large, but the inclusion of all of them in the model specification may affect the estimate efficiency. A solution generally adopted to avoid this issue consists of limiting the model specification to the relevant covariates only, but this procedure has an important issue as well: it may suffer of arbitrariness.

An alternative approach, more and more spread in applied economic studies (Bloise and Tancioni 2021; Chernozhukov et al. 2022), suggests the use of algorithms and machine learning techniques to select the best set of regression variables. Among the number of existing methodologies, in this analysis, we adopt the efficient computational procedures proposed by Furnival and Wilson (1974). This methodology relies on a branch and bound algorithm and uses sequences of sweep operations to carry out the computations (Lawless and Singhal 1978). The aim of these efficient algorithms is to determine the best fitting models, for each possible number of covariates k , using tests on residual sums of squares to compare the 2^k possible submodels.³ Once selected all the best fitted models for each quantity of predictors, the best model specification of a specific country is identified among them as the one reporting the lowest Bayesian information criterion (BIC) value.⁴ All estimates are based on linear regression models where standard errors are clustered by the school identification number.

We develop these procedures considering two different dependent variables: the logarithmic transformation of the students' reading and math score. The basket of predictors from which we select the best models is composed by the following thirteen variables: gender (i.e., female or male), language spoken at home (i.e., local or foreign), age (both year and months), highest parental occupational status (i.e., high, average, and low occupational level on the basis of the ISEI classification),⁵ number of books at home (i.e., 11 books or fewer, 11-25 books, 26-100 books, 101-200 books, 201-500 books, 500 or more books),⁶ presence of a e-book reader, a tablet or other similar device at home, presence of a computer at home, the variable combining type of school and municipality size (see Section 3), the class size (i.e., 15 students or fewer, 16-20 students, 21-25 students, 26 or more students), public school dummy, the school IT supply (proxied through the number of computers per student), presence of career guidance services at school, and the presence of other schools in the area.⁷ Main descriptive statistics of these variables for the total sample of students are provided in Table A.1.

Figure 1 shows the outcome of Furnival and Wilson (1974)'s algorithms with respect to the students' performance in reading for each country and for the pooled sample of students (labelled as 'Total'). This figure provides three different information: i) how many predictors compose the best model specification; ii) which predictors are included in the best model; iii) the selection order of predictors in the best model. The latter is obtained looking at variable additions into the best fitted models when the quantity of predictors increases. For instance, referring to Germany, the best one-predictor model is the one containing the variable about the number of books at home, while the best two-predictors model adds the class size variable to the former, the

³ To be clear, the selection of variables does not depend on the magnitude of their coefficients but on the relative importance they have in explaining the heterogeneity of the dependent variable.

⁴ To perform the best subsets variable selection, we used the `gvselect` Stata command created by Charles Lindsey and Simon Sheather.

⁵ The highest parental occupational status is measured by the HISEI variable. For a deeper explanation of its construction see: <https://www.oecd-ilibrary.org/sites/0a428b07-en/index.html?itemId=/content/component/0a428b07-en>.

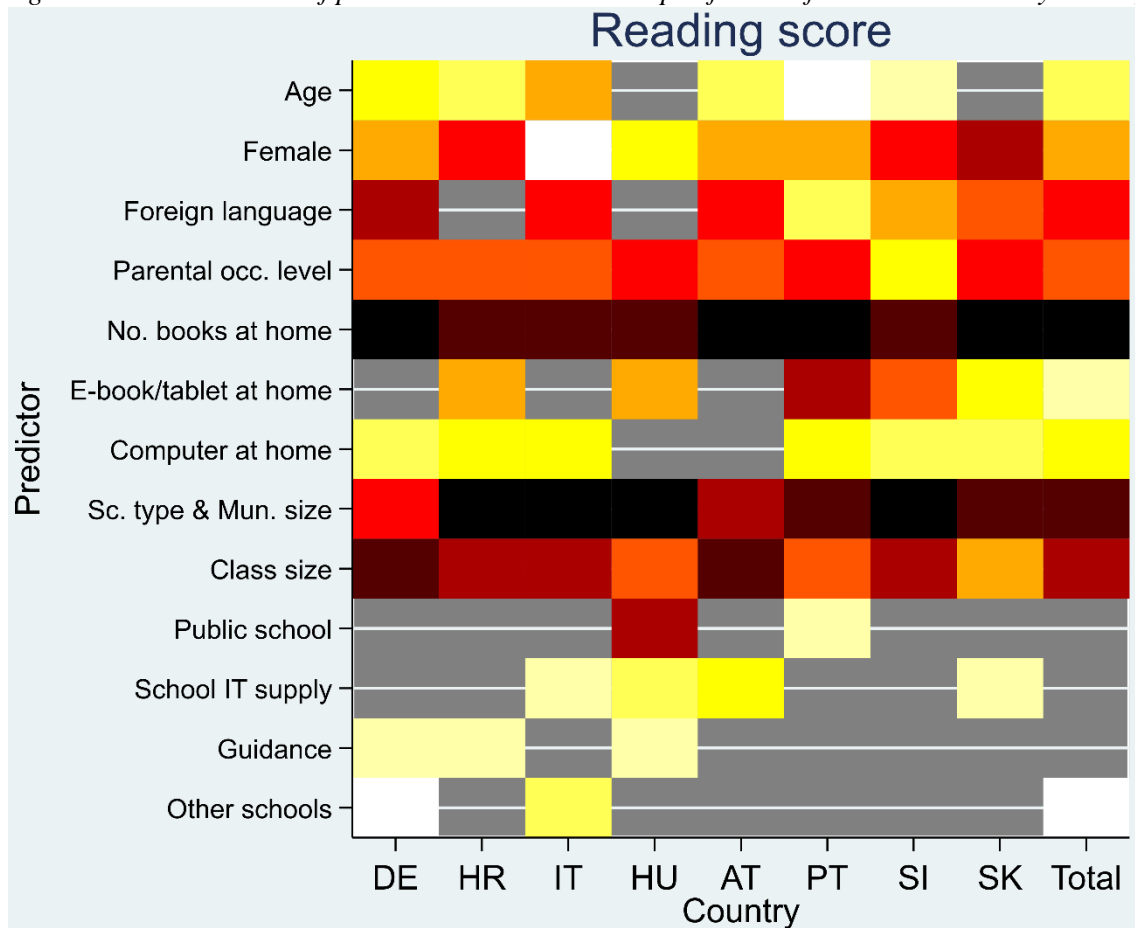
⁶ The PISA survey dataset also provides a composite index which gives a synthetic information on all items owned by a household. Among the others, the number of books at home represents one of the items composing this index, thus the correlation existing between these two variables is strong. Moreover, once this composite index is included in the basket of predictors, results of efficient algorithms of predictors selection report it in best fitted models in one country only (Italy), while the number of books at home is preferred in all other cases. More details available upon request to the authors.

⁷ From the variables provided by the PISA survey dataset and somewhat related to the students' performance, we exclude here having repeated almost a school year, the percentage of full professors, the percentage of qualified professors, the percentage of government expenditure, and the percentage of student fees because of their large extent of missing values.

best three-predictors model adds the dummy for foreign language spoken at home to the former, and so on. Somehow, we may then argue that the number of books at home is the most important predictor of students' read score in Germany, followed by the class size, the language spoken at home, and the other variables observed.⁸

As illustrated in Figure 1, Italy, Germany, and Portugal (and the total sample) count ten predictors in their best model specifications, Croatia, Hungary, Slovenia, and Slovakia count nine predictors, whereas Austria has eight predictors in its best models. The combination of predictors differs across countries as well. The public school dummy is included only in the Hungarian and Portuguese best model specification. The school IT supply is selected in best models for Italy, Hungary, Austria, and Slovakia only. The variable related to the guidance services is included in best models reported by Germany, Croatia, and Hungary, while the presence of other schools in the area is selected in the German and Italian best models, as well as in the pooled sample one. At the opposite, variables regarding students' gender and parental occupational status, the number of books at home, the variable mixing type of school and municipality size, and the class size are included in all best models.

Figure 1. Selection order of predictors and best model specification for the read score by country



Notes: The lighter is the cell, the later the predictor was selected in the best fitted model. The Total model refers to the pooled sample of students and also includes country dummies. Source: Elaborations of the authors on PISA 2018 data.

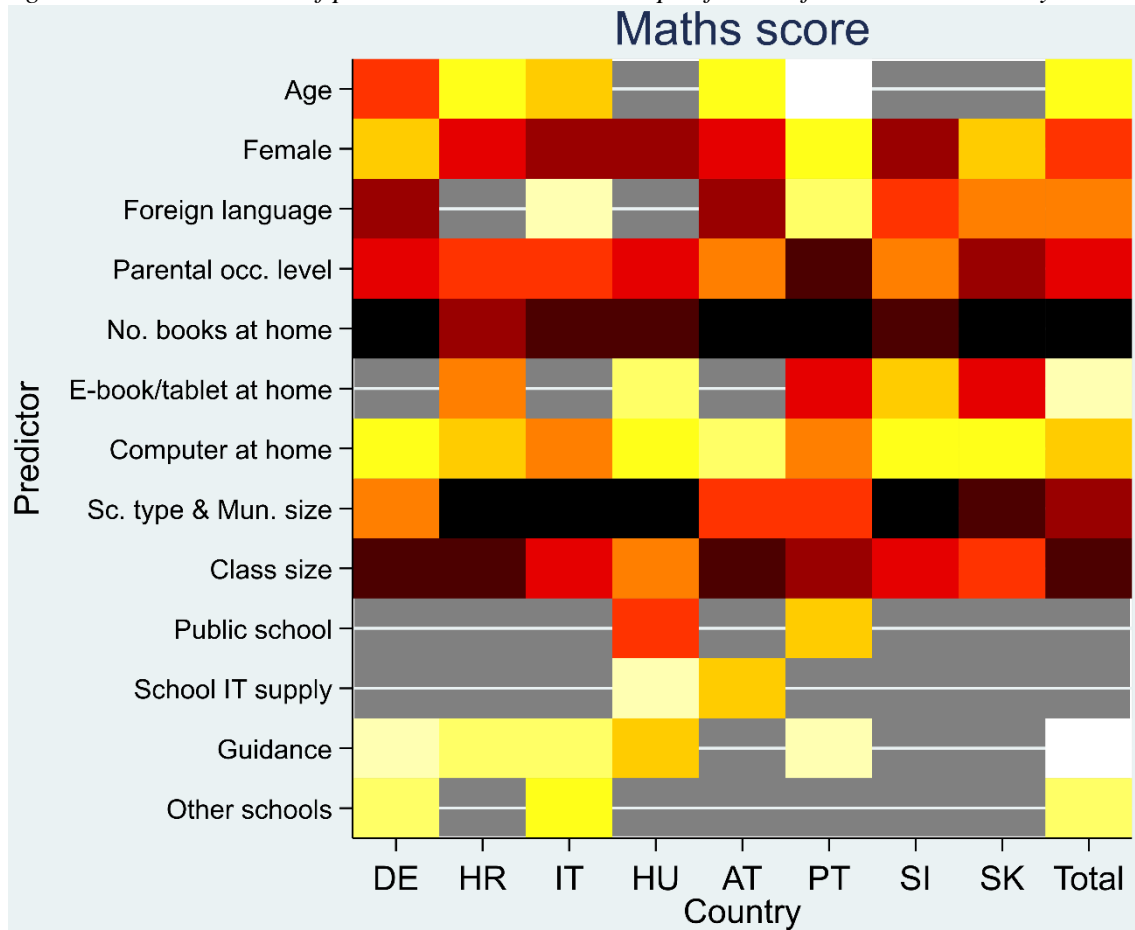
Regarding the selection order of predictors, one variable between the number of books at home and the set of dummies reflecting the type of school and the municipality size always represents the most important predictor of students' read score in the analysed countries. These two variables are followed, in terms of importance, by

⁸ To be noted, while in this application of the adopted methodology all best fitted models appear nested when the quantity of predictors increases, the same situation may not necessarily stand in other applications.

the class size except for the Slovakian case and the Portuguese one. When included, the students' age and the last four school-level variables tend to be among the less important predictors. The only exception here is represented by the public school dummy which is among the three most relevant variables in Hungary.

When we replicate this analysis on the students' math score some interesting differences occur with respect to the results presented above (Figure 2).

Figure 2. Selection order of predictors and best model specification for the math score by country



Notes: The lighter is the cell the later the predictor was selected in the best fitted model. The Total model refers to the pooled sample of students and also includes country dummies. Source: Elaborations of the authors on PISA 2018 data.

First, Slovenia and Slovakia now report as best a model specification with one predictor less, while the Hungarian, Austrian, and Portuguese best models (and the total sample one) have one more. Second, students' gender is here much more important in the Italian best model, as it is third in this case, while the opposite occurs for speaking a foreign language. This difference represents an interesting corroboration regarding the size of the gender gap in math score in Italy. As many previous papers found (Contini et al. 2017; Granato 2020), Italy is among the countries displaying the largest differential between boys and girls in STEM disciplines. The relevance of the gender variable to explain the math score rather than the reading score confirms from a new perspective the urgency of which this country suffers. Finally, the categorical variable pointing the type of school and municipality size is less relevant in different countries, namely in Germany, Austria, Portugal, and even in the pooled sample. In almost the same cases the class size or the parental occupational status are of greater importance both on the reading and math score.

5. Results

5.1. Estimation of the effects on students' performance

Once the best models are identified for all countries analysed, this section presents the results of OLS estimations to provide the effects of selected determinants on the reading and math performance of students.

In line with the evidence illustrated in Figure 1, the number of books at home (somehow a proxy of parents' education level and the household well-being level in general), the variable combining type of school and municipality size, and the class size have overall the greater effects – *ceteris paribus* – on the reading score of students (Table 3).

Table 3. Estimated effects on the reading score of students

Variables	DE	HR	IT	HU	AT	PT	SI	SK	Total
Age	0.056***	0.025***	0.034***		0.040***	0.029***	0.024***		0.039***
Female	0.035***	0.041***	0.012*	0.027***	0.028***	0.042***	0.042***	0.057***	0.030***
Foreign speaking	-0.103***		-0.041***		-0.074***	-0.066***	-0.045***	-0.093***	-0.075***
Average occupational level	0.028***	0.031***	0.035***	0.040***	0.027***	0.037***	0.005	0.051***	0.036***
High occupational level	0.062***	0.047***	0.036***	0.058***	0.039***	0.075***	0.032***	0.063***	0.059***
11-25 books	0.060***	0.033***	0.056***	0.071***	0.065***	0.034***	0.058***	0.094***	0.060***
26-100 books	0.120***	0.056***	0.103***	0.105***	0.100***	0.093***	0.082***	0.147***	0.111***
101-200 books	0.155***	0.082***	0.110***	0.136***	0.123***	0.126***	0.107***	0.197***	0.138***
201-500 books	0.185***	0.085***	0.122***	0.164***	0.162***	0.147***	0.119***	0.242***	0.165***
500 books or more	0.191***	0.040***	0.121***	0.165***	0.150***	0.137***	0.109***	0.186***	0.166***
E-book/tablet at home		-0.064***		-0.040***		-0.099***	-0.059***	-0.058***	-0.019***
Computer at home	0.104***	0.064***	0.041***			0.072***	0.131***	0.043**	0.069***
General - Big city	0.007	-0.011	-0.008	0.013	0.007	0.033***	-0.017	-0.021	0.008
Vocational - Big city	-0.092***	-0.135***	-0.130***	-0.135***	-0.081***	-0.017	-0.154***	-0.051***	-0.091***
Vocational - Small city	-0.049**	-0.165***	-0.124***	-0.144***	-0.081***	-0.101***	-0.164***	-0.113***	-0.081***
16-20 students	0.031	0.019	0.048	0.030	0.069***	-0.006	-0.007	0.015	0.029
21-25 students	0.105***	0.073***	0.114***	0.029	0.119***	0.040	0.016	0.020	0.088***
26 students or more	0.160***	0.111***	0.124***	0.062***	0.141***	0.089***	0.065***	0.063***	0.127***
Public school				0.064***		-0.036***			
School IT supply			-0.017	0.033**	0.012**			-0.013*	
Guidance	-0.107***	0.013		0.030					
Other schools	0.027		0.016						0.017**
Constant	5.037***	5.651***	5.440***	5.944***	5.376***	5.502***	5.652***	5.930***	5.290***
Country fixed effects	No	No	No	No	No	No	No	No	Yes
Observations	3,739	5,994	10,388	4,431	5,299	5,254	5,285	4,895	45,285
R-squared	0.373	0.358	0.289	0.430	0.315	0.321	0.386	0.389	0.331

Notes: Standard errors are clustered at the school level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Source: Elaborations of the authors on PISA 2018 data.

Specifically, we observe an increasing effect according to the number of books owned (at least until 500 books) and the number of students within the same classroom. To be noted, as the number of books at home is self-reported by the students, it is possible that some of those who report owning more than 500 books overestimate the real number of books when guessing the answer. As for the type of school and the size of the municipality where the school is located, results show that students attending vocational schools perform significantly worse than those in general schools. Among both general and vocational school students, no differences related to the municipality size in performances arise, except for Portugal, where students in big cities perform significantly better (Figure A.1), everything else equal, than those in small cities. Finally, in line with Denny and Oppedisano (2013), results suggest that bigger classes lead to better results.

Looking at the demographic characteristics of students, female students always report – *ceteris paribus* – higher reading scores than male ones, but this effect is very small and slightly significant in Italy. When included in the best models, the age of students appears positively relevant in explaining the students' performances (especially in Germany), while students speaking a foreign language at home have a significantly lower score (especially in Slovakia and Germany). Also, the parental occupational status plays an important and positive role on the reading score of students, and its effects are pretty stable across European countries.

Interestingly however, in most cases, results report a significant difference in performances only between students having parents with a low occupational level and the others, and no significant differences between the ‘average occupational level’ and the ‘high occupational level’ groups. Another interesting outcome arises from the analysis of variables related to the presence of digital devices at home. In particular, we observe that the presence of a computer at home tends to have a positive effect on reading scores of students, while an opposite effect is engendered – *ceteris paribus* – by the presence of a tablet or similar device at home. As discussed by OECD (2016), this ambiguous result is probably related to the fact that these two variables capture different dimensions of the digital nature of reading, as well as the use of digital devices at the student’s home.⁹

As for the school-level variables (other than the one mixing the school type and localization), Table 3 highlights that attending a public school gives opposite effects in the two countries in which it is considered: it increases the students’ performance in Hungary while it decreases them in Portugal. The same occurs for the school IT supply as a higher number of computers per student engenders significantly greater scores in Hungary and Austria, while the effect is negative in Slovakia. Finally, the presence of career guidance services significantly reduces the students’ reading scores in Germany,¹⁰ while the presence of other schools in the area engenders a significant and positive effect on the dependent variable when we look at the pooled sample (Hoxby 2000; Belfield and Levin 2002).

As regards the effects on the math score, results illustrated in Table 4 overall confirm what seen for the reading score with some important exceptions. First, female students now report – *ceteris paribus* – significantly lower performances than males, especially in Italy. Second, students attending a general school in a big city do not have any more a better performance than those attending the same school in a small city in Portugal, while this ‘urban-rural’ gap still remains significant in the same country (see Figure A.2 in Appendix). Third, a greater school IT supply always engenders a positive effect on the students’ math score. Fourth, the presence of career guidance services now presents a positive effect on the students’ performances in Hungary and Portugal, while the coefficient related to the presence of other schools in the area is now significant (and positive) in Germany and Italy.

In Appendix B, we summarize some robustness checks of the main results presented in this section.

⁹ It has to be considered however that the two variables related to the presence of digital devices at home are expected to be somewhat correlated. For this reason, as an additional analysis, we replicated the econometric analysis showed in Tables 3 and 4 including in the model specification an interaction term between the ‘E-book/tablet at home’ variable and the ‘Computer at home’ one. Table A.2 in Appendix shows that the coefficient of the ‘E-book/tablet at home’ variable is not biased due to the correlation with the ‘Computer at home’ variable, but the former stops to be significant in most cases once the interaction term is included. The co-presence of a computer and a tablet (or similar) at home appears having a significant and positive effect on students’ scores in Slovenia (reading) and Hungary (mathematics) only.

¹⁰ The effect of the ‘guidance’ variable appears here counterintuitive as this kind of services should improve rather than worsen the students’ performances. Nonetheless, it is possible that these services are activated just in those schools where the students’ performances are known to be low. This common policy strategy would help explaining (at least partially) why students’ performances are lower on average in presence of guidance services.

Table 4. Estimated effects on the math score of students

Variables	DE	HR	IT	HU	AT	PT	SI	SK	Total
Age	0.062***	0.033***	0.034***		0.031***	0.025***			0.040***
Female	-0.033***	-0.050***	-0.068***	-0.047***	-0.056***	-0.030***	-0.047***	-0.026***	-0.045***
Foreign speaking	-0.078***		-0.016**		-0.082***	-0.058**	-0.065***	-0.059***	-0.051***
Average occupational level	0.029***	0.032***	0.037***	0.033***	0.026***	0.041***	0.007	0.063***	0.038***
High occupational level	0.068***	0.054***	0.042***	0.051***	0.035***	0.081***	0.038***	0.082***	0.065***
11-25 books	0.055***	0.028***	0.032***	0.043***	0.053***	0.041***	0.042***	0.109***	0.049***
26-100 books	0.103***	0.051***	0.082***	0.087***	0.088***	0.114***	0.063***	0.157***	0.098***
101-200 books	0.138***	0.071***	0.104***	0.115***	0.104***	0.139***	0.090***	0.202***	0.129***
201-500 books	0.160***	0.077***	0.105***	0.144***	0.133***	0.160***	0.108***	0.240***	0.147***
500 books or more	0.166***	0.037***	0.100***	0.148***	0.142***	0.141***	0.087***	0.199***	0.148***
E-book/tablet at home		-0.054***		-0.022***		-0.080***	-0.046***	-0.056***	-0.016***
Computer at home	0.095***	0.080***	0.069***	0.051***	0.074**	0.102***	0.090***	0.060***	0.084***
General - Big city	-0.011	-0.009	-0.012	0.009	0.000	0.020	-0.019	-0.029	-0.006
Vocational - Big city	-0.071***	-0.141***	-0.103***	-0.121***	-0.066***	-0.035**	-0.153***	-0.049***	-0.077***
Vocational - Small city	-0.047**	-0.166***	-0.092***	-0.131***	-0.068***	-0.099***	-0.154***	-0.094***	-0.070***
16-20 students	0.066	0.009	0.060	0.021	0.057**	-0.027	0.012	0.003	0.040*
21-25 students	0.130***	0.067***	0.126***	0.018	0.104***	0.015	0.032	0.019	0.097***
26 students or more	0.175***	0.101***	0.137***	0.048**	0.126***	0.063***	0.074***	0.052***	0.130***
Public school				0.053***		-0.053***			
School IT supply				0.021*	0.014***				
Guidance	-0.072*	0.015	-0.021	0.029*		0.045**			-0.013
Other schools	0.034**		0.021*						0.024***
Constant	4.942***	5.534***	5.460***	5.991***	5.542***	5.564***	6.143***	5.992***	5.307***
Country fixed effects	No	No	No	No	No	No	No	No	Yes
Observations	3,739	5,994	10,388	4,431	5,299	5,254	5,285	4,895	45,285
R-squared	0.365	0.384	0.283	0.477	0.347	0.341	0.425	0.381	0.325

Notes: Standard errors are clustered at the school level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Source: Elaborations of the authors on PISA 2018 data.

5.2. An application of the Gelbach decomposition method

In order to assess the underlying mechanisms behind the differences in cognitive test scores among the types of school, we implement the well-known decomposition analysis proposed by Gelbach (2016). This method allows us to decompose the contribution of each covariate (selected through the procedure explained in Section 4) in the change of our coefficients of interest from the base to the full regressions. In other words, we identify the main dimensions explaining the cognitive gap between types of schools in each country pointed out in the base analysis. The main positive feature of this method is that results are independent from the order in which the variables are included into the regression.

Table 5 presents the results keeping the general schools in small cities as reference category. In columns “Base ols” and “Full ols” we report the coefficients of interest obtained by, respectively, the baseline analysis and the full analysis showed in the previous section. The column “Total explained” displays the difference between the base and full estimates. The following columns display the contribution, in percentage terms, of each selected covariate in composing the “Total explained”. The relevance of the characteristics in explaining the gap among the types of school is always heterogeneous also within the same country.

As regards to the analysis of reading scores, we point out that in almost all the countries, with the exception of Hungary and Austria, the “Total explained” coefficient of general schools in big cities is positive and significant. This result is due in particular to the class size, suggesting that the difference between small-big cities in these countries seems to be explained by the quality of schools, even if in Portugal and Slovakia also the parental occupation status and the number of books matter.

Table 5. Decomposition of the linkage between the type of school and the reading score by country

Country	Type of school	Base OLS	Full OLS	Total explained	Age	Female	Foreign speaking	Parental occ. status	No. books at home	Ebook/tablet at home	Computer at home	Class size	Public school	School IT supply	Guidance	Other schools
DE	L-BC	0.037	0.007	0.029*	0.00%	3.45%	-27.59%	17.24%	24.14%		0.00%	75.86%			3.45%	3.45%
	V-BC	-0.154***	-0.092***	-0.062***	-6.45%	3.23%	20.97%	14.52%	40.32%		4.84%	35.48%			-6.45%	-6.45%
	V-SC	-0.093***	-0.049**	-0.044**	0.00%	-2.27%	0.00%	11.36%	25.00%		-2.27%	65.91%			0.00%	-2.27%
HR	L-BC	0.043***	-0.011	0.055***	-1.82%	-1.82%		12.73%	10.91%	0.00%	0.00%	83.64%			-1.82%	
	V-BC	-0.146***	-0.135***	-0.006												
	V-SC	-0.207***	-0.165***	-0.040***	-2.50%	22.50%		32.50%	42.50%	0.00%	0.00%	0.00%			0.00%	
IT	L-BC	0.030	-0.008	0.037***	-2.70%	0.00%	0.00%	10.81%	16.22%		0.00%	67.57%		2.70%		5.41%
	V-BC	-0.160***	-0.130***	-0.030**	6.67%	10.00%	20.00%	23.33%	66.67%		3.33%	-33.33%		3.33%		3.33%
	V-SC	-0.140***	-0.124***	-0.016												
HU	L-BC	0.025	0.013	0.012												
	V-BC	-0.173***	-0.135***	-0.035												
	V-SC	-0.218***	-0.144***	-0.071***		9.86%		21.13%	50.70%	0.00%		23.94%	-30.99%	14.08%	12.68%	
AT	L-BC	-0.003	0.007	-0.011												
	V-BC	-0.131***	-0.081***	-0.051***	-3.92%	5.88%	19.61%	17.65%	58.82%			3.92%			-1.96%	
	V-SC	-0.125***	-0.081***	-0.044***	-4.55%	2.27%	4.55%	22.73%	63.64%			22.73%			-11.36%	
PT	L-BC	0.083***	0.033***	0.053***	3.77%	1.89%	-1.89%	26.42%	28.30%	1.89%	1.89%	35.85%	1.89%			
	V-BC	-0.019	-0.017	0.008												
	V-SC	-0.112***	-0.101***	0.002												
SI	L-BC	0.000	-0.017	0.017*	5.88%	0.00%	0.00%	11.76%	0.00%	-5.88%	0.00%	100.00%				
	V-BC	-0.188***	-0.154***	-0.032***	-3.13%	25.00%	9.38%	25.00%	78.13%	0.00%	0.00%	-34.38%				
	V-SC	-0.218***	-0.164***	-0.053***	0.00%	15.09%	3.77%	16.98%	50.94%	0.00%	0.00%	11.32%				
SK	L-BC	0.006	-0.021	0.028*		3.57%	17.86%	21.43%	32.14%	0.00%	3.57%	17.86%		10.00%		
	V-BC	-0.065**	-0.051***	-0.013												
	V-SC	-0.180***	-0.113***	-0.065***		9.23%	10.77%	12.31%	38.46%	1.54%	1.54%	21.54%		5.97%		

Notes: Standard errors are clustered at the school level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Source: Elaborations of the authors on PISA 2018 data.

In Germany, Italy, Austria and Slovenia, the “Total explained” coefficients of vocational schools in big cities are negative and significant. In particular, they are due to the social background (i.e., the number of books at home, be foreigner, and the parents’ occupation status). A partial exception is represented by Germany, in which the class size matter for more than a third of the explained gap. It is also interesting to note that the average size of the classes in Italy and in Slovenia would advantage the vocational schools in big cities rather than general schools in small cities.

Finally, the gaps of vocational schools in small cities are significant for all the analysed countries except to Italy and Portugal. In Germany, which confirms to be a peculiar case, this gap is mainly due to the class size. Other than this country, in the rest of the cases the coefficients are explained by the social background. In Croatia, Hungary, Slovenia, and Slovakia also the gender variable matters, suggesting that in these countries females (which have typically better performance in the reading tests) are grouped in general schools rather than in vocational schools. Table A.3 in Appendix provides results of the Gelbach decomposition on the math score, which overall confirms what observed for reading scores.

To sum up, our results point out that the gap score, both in reading and mathematics, on the basis of the city’s dimension seems to depend relatively more on the quality of the school, in particular by the class size, while the differences between general and vocational schools appears to be explained, above all, by the families’ social status.

6. Conclusions

In this study we used PISA 2018 data from eight European countries to identify the main determinants of the students’ math and reading scores. We focus on the role played by two specific determinants: the type of secondary school and its localization. The results in all the steps are slightly homogeneous among the countries, pointing out common issues in education systems across Europe. First, the most important predictors resulting by the computational procedure are the number of books at home, the type and the location of the school. These characteristics have also the greater effect on students’ performance. More specifically, the type of schools presents results rather as expected, as students attending general schools perform better than those in vocational schools. Otherwise, everything else equal, the location of schools does not show many significant differences. The clearest exception is represented by Portugal. In this country, the gap between big and small cities, both between general and vocational schools, is always significant in favour of big cities. Finally, we implement the Gelbach decomposition in order to catch the main drivers at the basis of the above-explained differences. Also in this analysis, results are homogeneous each other and are very interesting in terms of policy implications aimed at improving the education systems. The analysis clearly points out that the families’ socio-economic characteristics are the main causes of the gap between general and vocational schools, and the quality of the school represents the main explanation of the difference in terms of scores between big and small cities.

These results are relevant because researchers have to go in-depth into the mechanisms behind the inequalities characterizing students’ performances. Students’ lower performances, both in reading and mathematics, in vocational schools, may imply their worse adaptability to changing economic conditions (Hanushek et al. 2017). Moreover, it is known that a low level of education may engender a higher inclination towards populist ideas (Goodwin and Heath 2016). At the same time, however, vocational schools are expected to provide specific skills and competences in line with what needed in the local labour market. In terms of policy suggestions, keeping this potential but relevant trade-off in mid, policymakers then need to understand towards which kind of factors public aid and support should be directed. This is particularly important because lower educated families tend to underestimate the child’s education career and they do not support their children’s study (Heckman 2006). Consequently, students coming from households with a low socio-economic background are pushed to schools more focused on providing job skills than pursuing tertiary education (Schizzerotto and Barone 2006; Mocetti 2012). Another critical aspect is related to the distribution of public resources between urban and rural areas. Schools in small cities and rural areas tend to receive relatively less

public resources than those in big cities and metropolitan areas, so that the former are not equally able to invest in both the structure and necessary tools (Mathis 2003). These pieces of evidence, along with the ones provided by our analysis, could of course engender an increase of performance inequality among students, as well as future levels of income and wealth inequality. Azzolini and Vergolini (2014) argue that reforms aiming at reducing curricula differences between tracks could be pursued to solve (or at least alleviate) this issue.

It would be important to invest in order to guarantee that all students develop a common set of core competences and learning contents for at least the first few years of the upper secondary school. The urban–rural achievement gaps can best be addressed through initiatives or reforms at school level to consider differences in compositions of students.

Declarations and ethics statements

Ethical approval:

Not applicable.

Informed consent from participants:

Not applicable.

Data availability statement for Basic Data Sharing Policy:

Data are freely available here: <https://www.oecd.org/pisa/>.

Clinical trial registration:

Not applicable.

Consent to publish statement / form:

Not applicable.

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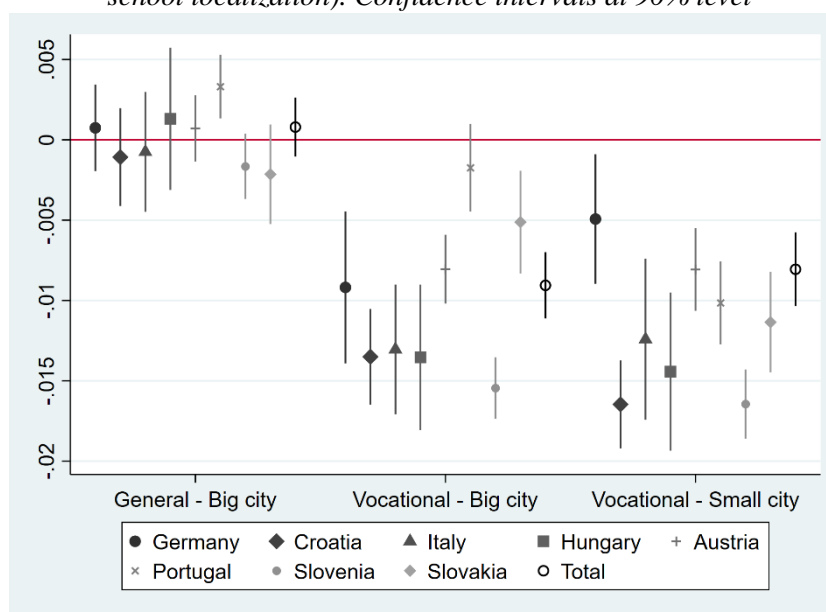
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Online Appendix A – Additional descriptive statistics and econometric results

Table A.1. Variables description

Variable	Definition	Mean	Std. Dev.	Min	Max
<i>Dependent variables</i>					
Log(Read score)	Continuous variable representing the logarithmic transformation of the students' score in reading.	6.186	0.206	5.167	6.672
Log(Math score)	Continuous variable representing the logarithmic transformation of the students' score in mathematics.	6.200	0.184	5.257	6.635
<i>Control variables</i>					
Age	Continuous variable representing the students' age at the time of interview (months included as decimal).	15.796	0.288	15.250	16.330
Female	Binary variable taking value 1 for female, 0 for male.	0.492	0.500	0.000	1.000
Foreign speaking	Binary variable taking value 1 for those speaking a foreign language at home, and 0 otherwise.	0.141	0.348	0.000	1.000
Low occupational level	Binary variables representing the highest parental occupational status. Based on the ISEI classification of occupations, the occupational level is High if at least one parent attained an occupation coded between 70 (Senior government official) and 89 (Medical doctor), Middle if the highest occupation attained ranges between 40 (Pharmaceutical technician and assistant) and 69 (Chief executive, senior official and legislator), and Low for occupations in lower levels.	0.392	0.488	0.000	1.000
Average occupational level		0.359	0.480	0.000	1.000
High occupational level		0.248	0.432	0.000	1.000
11 books or fewer	Binary variables representing the number of books at home.	0.116	0.321	0.000	1.000
11-25 books		0.158	0.365	0.000	1.000
26-100 books		0.293	0.455	0.000	1.000
101-200 books		0.191	0.393	0.000	1.000
201-500 books		0.153	0.360	0.000	1.000
500 books or more		0.089	0.284	0.000	1.000
Ebook/tablet at home	Binary variable taking value 1 for those having an E-book reader, a table, or an iPad at home, and 0 otherwise.	0.247	0.431	0.000	1.000
Computer at home	Binary variable taking value 1 for those having a desktop computer, a portable laptop, or a notebook at home, and 0 otherwise.	0.970	0.170	0.000	1.000
General - Big city	Binary variables combining the type of school and the size of the municipality where the school is located. A municipality is considered as Big city if it has more than 15,000 inhabitants, and as Small city otherwise.	0.494	0.500	0.000	1.000
General - Small city		0.151	0.358	0.000	1.000
Vocational - Big city		0.254	0.435	0.000	1.000
Vocational - Small city		0.100	0.301	0.000	1.000
15 students or fewer	Binary variables representing the class size of interviewed student.	0.027	0.162	0.000	1.000
16-20 students		0.158	0.365	0.000	1.000
21-25 students		0.427	0.495	0.000	1.000
26 students or more		0.388	0.487	0.000	1.000
Public school	Binary variable taking value 1 if the interviewed student attends a public school, and 0 otherwise.	0.937	0.242	0.000	1.000
School IT supply	Continuous variable representing the number of computers per student in the school attended by the interviewed student.	0.599	0.754	0.000	14.667
Guidance	Binary variable taking value 1 if the teachers (or other staff) provide a career guidance to students, and 0 otherwise.	0.849	0.358	0.000	1.000
Other schools	Binary variable taking value 1 if there are other schools in the area, and 0 otherwise.	0.742	0.437	0.000	1.000

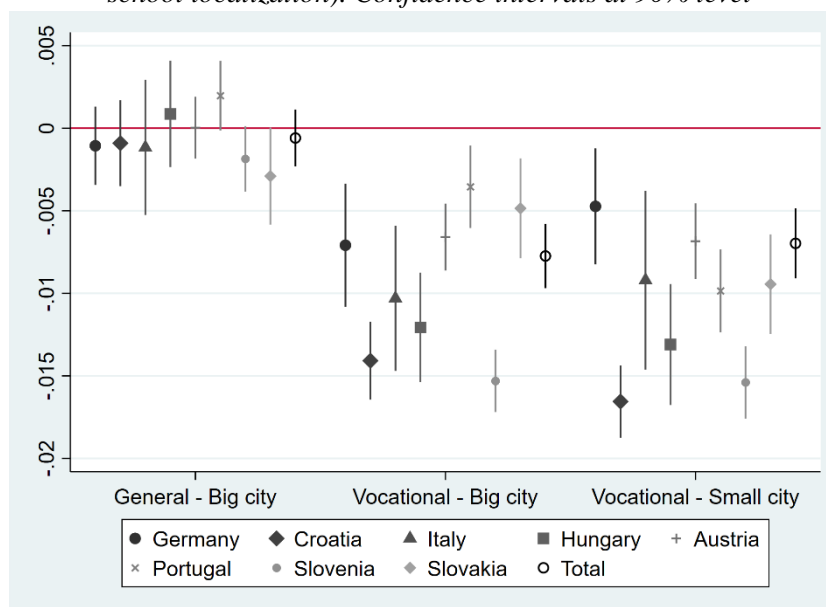
Figure A.1. Estimated effects on the reading score of students (focus on effects of school type and school localization). Confidence intervals at 90% level



Notes: Standard errors are clustered at the school level. Each country regression is estimated considering the best model specification identified in Section 4. The dependent variable is the average of the ten plausible values in reading (in logarithm). Full estimates are provided in Table 3.

Source: Elaborations of the authors on PISA 2018 data.

Figure A.2. Estimated effects on the math score of students (focus on effects of school type and school localization). Confidence intervals at 90% level



Notes: Standard errors are clustered at the school level. Each country regression is estimated considering the best model specification identified in Section 4. The dependent variable is the average of the ten plausible values in reading (in logarithm). Full estimates are provided in Table 4.

Source: Elaborations of the authors on PISA 2018 data.

Table A.2. Estimated effects on the reading score and math score of students (with the interaction term of digital devices variables)

Variables	Reading score					Math score					
	HR	PT	SI	SK	Total	HR	HU	PT	SI	SK	Total
Age	0.025***	0.029***	0.024***		0.039***	0.034***		0.025***			0.040***
Female	0.041***	0.042***	0.042***	0.057***	0.030***	-0.050***	-0.047***	-0.030***	-0.047***	-0.026***	-0.045***
Foreign speaking		-0.066***	-0.045***	-0.093***	-0.075***			-0.057**	-0.065***	-0.059***	-0.051***
Average occupational level	0.031***	0.037***	0.005	0.051***	0.036***	0.032***	0.033***	0.041***	0.007	0.063***	0.038***
High occupational level	0.047***	0.075***	0.032***	0.063***	0.059***	0.054***	0.051***	0.080***	0.038***	0.082***	0.065***
11-25 books	0.033***	0.034***	0.058***	0.094***	0.060***	0.028***	0.043***	0.041***	0.042***	0.109***	0.049***
26-100 books	0.056***	0.093***	0.082***	0.147***	0.111***	0.051***	0.087***	0.114***	0.063***	0.157***	0.098***
101-200 books	0.082***	0.126***	0.107***	0.197***	0.138***	0.071***	0.115***	0.139***	0.090***	0.202***	0.129***
201-500 books	0.085***	0.147***	0.119***	0.242***	0.165***	0.077***	0.144***	0.160***	0.108***	0.240***	0.147***
500 books or more	0.040***	0.137***	0.109***	0.186***	0.166***	0.037***	0.148***	0.141***	0.087***	0.199***	0.148***
E-book/tablet at home	-0.118	-0.104***	-0.233***	-0.035	-0.035	-0.158	-0.140***	-0.174**	-0.104	-0.053	-0.018
Computer at home	0.063***	0.071***	0.121***	0.046**	0.068***	0.078***	0.044***	0.099***	0.087***	0.060***	0.084***
Interaction term	0.055	0.005	0.175**	-0.024	0.016	0.104	0.119***	0.095	0.059	-0.004	0.002
General - Big city	-0.011	0.033***	-0.017	-0.021	0.008	-0.009	0.009	0.020	-0.019	-0.029	-0.006
Vocational - Big city	-0.135***	-0.017	-0.154***	-0.051***	-0.091***	-0.141***	-0.121***	-0.035**	-0.153***	-0.049***	-0.077***
Vocational - Small city	-0.165***	-0.101***	-0.164***	-0.114***	-0.081***	-0.166***	-0.132***	-0.099***	-0.154***	-0.094***	-0.070***
16-20 students	0.019	-0.006	-0.007	0.015	0.029	0.009	0.021	-0.026	0.012	0.003	0.040*
21-25 students	0.073***	0.040	0.016	0.020	0.088***	0.067***	0.018	0.016	0.032	0.019	0.097***
26 students or more	0.111***	0.089***	0.065***	0.063***	0.127***	0.101***	0.048**	0.064***	0.074***	0.052***	0.130***
Public school		-0.036***					0.053***	-0.053***			
School IT supply				-0.013*			0.021*				
Guidance	0.013					0.015	0.030*	0.045**			-0.013
Other schools					0.017**						0.024***
Constant	5.652***	5.502***	5.661***	5.927***	5.291***	5.535***	5.998***	5.570***	6.147***	5.992***	5.307***
Country fixed effects	No	No	No	No	Yes	No	No	No	No	No	Yes
Observations	5,994	5,254	5,285	4,895	45,285	5,994	4,431	5,254	5,285	4,895	45,285
R-squared	0.358	0.321	0.387	0.389	0.331	0.384	0.478	0.341	0.425	0.381	0.325

Notes: Standard errors are clustered at the school level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Each country regression is estimated considering the best model specification identified in Section 4. The dependent variables are the average of the ten plausible values in reading and mathematics (in logarithm). The 'interaction term' variable represents the interaction between the 'E-book/tablet at home' variable and the 'Computer at home' one. Source: Elaborations of the authors on PISA 2018 data.

Table A.3. Decomposition of the linkage between the type of school and the mathematics score by country

Country	Type of school	Base OLS	Full OLS	Total explained	Age	Female	Foreign speaking	Parental occ. status	No. books at home	Ebook/tablet at home	Computer at home	Class size	Public school	School IT supply	Guidance	Other schools
DE	L-BC	0.014	-0.011	0.025*	0.00%	-4.00%	-24.00%	24.00%	24.00%		0.00%	80.00%			4.00%	4.00%
	V-BC	-0.120***	-0.071***	-0.055***	-8.16%	-4.08%	20.41%	18.37%	44.90%		4.08%	38.78%			-6.12%	-10.20%
	V-SC	-0.090***	-0.047**	-0.046**	0.00%	2.33%	0.00%	13.95%	23.26%		0.00%	65.12%			0.00%	-2.33%
HR	L-BC	0.047***	-0.009	0.058***	-1.75%	3.51%		12.28%	10.53%	0.00%	1.75%	78.95%			-1.75%	
	V-BC	-0.133***	-0.141***	0.015												
	V-SC	-0.188***	-0.166***	-0.022**	-5.26%	-57.89%		73.68%	78.95%	0.00%	0.00%	5.26%			0.00%	
IT	L-BC	0.024	-0.012	0.035***	-2.78%	-2.78%	0.00%	11.11%	13.89%		0.00%	69.44%			0.00%	8.33%
	V-BC	-0.122***	-0.103***	-0.008												
	V-SC	-0.104***	-0.092***	0.000												
HU	L-BC	0.027	0.009	0.020												
	V-BC	-0.145***	-0.121***	-0.023												
	V-SC	-0.179***	-0.131***	-0.042**		-26.09%		28.26%	71.74%	0.00%	4.35%	30.43%	-41.30%	13.04%	19.57%	
AT	L-BC	-0.010	0.000	-0.009												
	V-BC	-0.105***	-0.066***	-0.037***	-2.56%	-15.38%	28.21%	20.51%	66.67%		2.56%	2.56%		-5.13%		
	V-SC	-0.103***	-0.068***	-0.032***	-5.88%	-8.82%	5.88%	26.47%	70.59%		0.00%	23.53%		-14.71%		
PT	L-BC	0.072***	0.020	0.050***	1.82%	-1.82%	-1.82%	27.27%	29.09%	1.82%	3.64%	34.55%	3.64%		1.82%	
	V-BC	-0.028	-0.035**	0.002												
	V-SC	-0.108***	-0.099***	0.002												
SI	L-BC	-0.002	-0.019	0.019**		0.00%	-5.88%	11.76%	5.88%	0.00%	0.00%	94.12%				
	V-BC	-0.173***	-0.153***	-0.018**		-42.11%	26.32%	52.63%	115.79%	0.00%	0.00%	-52.63%				
	V-SC	-0.190***	-0.154***	-0.035***		-25.00%	8.33%	30.56%	69.44%	0.00%	0.00%	16.67%				
SK	L-BC	-0.006	-0.029	0.023*		-4.35%	13.04%	34.78%	39.13%	-8.70%	4.35%	21.74%				
	V-BC	-0.051**	-0.049***	0.000												
	V-SC	-0.149***	-0.094***	-0.057***		-5.66%	9.43%	18.87%	47.17%	1.89%	1.89%	24.53%				

Notes: Standard errors are clustered at the school level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Each country regression is estimated considering the best model specification identified in Section 4. The dependent variable is the average of the ten plausible values in mathematics (in logarithm). All results are weighted. The decomposition method is based on Gelbach (2016). Source: Elaborations of the authors on PISA 2018 data.

Online Appendix B – Robustness checks

In this Appendix, we first propose a replication of the efficient algorithm’s application (see Section 4) presented in Section 5.1 considering the full set of the thirteen variables composing the ‘basket of predictors’. The aim of this robustness check consists of verifying that the selection of best models made by the efficient algorithms does not leave anything relevant apart, and of course that our main results hold when we include additional covariates. Table B.1 shows the estimated effects on the students’ reading score and Table B.2 shows the ones on the students’ math score. As expected, additional covariates tend to be insignificant in almost cases and this is the reason why they were rejected by the algorithm when selecting the best models. More importantly, nonetheless, main considerations made in Section 5.1 remain exactly the same.

Table B.1. Estimated effects on the reading score of students (all variables included)

Variables	DE	HR	IT	HU	AT	PT	SI	SK	Total
Age	0.056***	0.024***	0.034***	0.011	0.041***	0.029***	0.024***	-0.013	0.039***
Female	0.035***	0.041***	0.012*	0.028***	0.028***	0.042***	0.040***	0.057***	0.030***
Foreign speaking	-0.104***	-0.023*	-0.042***	-0.046**	-0.073***	-0.065***	-0.045***	-0.093***	-0.075***
Average occupational level	0.029***	0.030***	0.035***	0.039***	0.026***	0.037***	0.005	0.050***	0.036***
High occupational level	0.064***	0.047***	0.037***	0.057***	0.039***	0.075***	0.031***	0.061***	0.059***
11-25 books	0.060***	0.033***	0.056***	0.070***	0.064***	0.035***	0.058***	0.094***	0.060***
26-100 books	0.121***	0.055***	0.103***	0.103***	0.098***	0.094***	0.082***	0.146***	0.111***
101-200 books	0.156***	0.082***	0.111***	0.133***	0.120***	0.127***	0.106***	0.195***	0.138***
201-500 books	0.188***	0.085***	0.123***	0.162***	0.159***	0.148***	0.118***	0.239***	0.165***
500 books or more	0.194***	0.039***	0.123***	0.164***	0.148***	0.138***	0.108***	0.183***	0.166***
E-book/tablet at home	-0.012*	-0.063***	-0.011**	-0.039***	0.003	-0.099***	-0.058***	-0.059***	-0.019***
Computer at home	0.105***	0.063***	0.042***	0.034***	0.064*	0.072***	0.130***	0.043**	0.069***
General - Big city	0.007	-0.006	-0.008	0.012	0.007	0.028**	-0.017	-0.021	0.008
Vocational - Big city	-0.092***	-0.133***	-0.125***	-0.135***	-0.077***	-0.022	-0.157***	-0.055***	-0.089***
Vocational - Small city	-0.051**	-0.165***	-0.118***	-0.144***	-0.077***	-0.095***	-0.165***	-0.114***	-0.080***
16-20 students	0.030	0.021	0.046	0.029	0.061***	-0.015	-0.005	0.015	0.030
21-25 students	0.104***	0.075***	0.113***	0.029	0.110***	0.029	0.014	0.019	0.088***
26 students or more	0.159***	0.113***	0.121***	0.063***	0.131***	0.079***	0.061***	0.065***	0.128***
Public school	0.014	0.028**	-0.002	0.063***	-0.002	-0.037***	-0.006	-0.021	0.007
School IT supply	-0.001	0.007	-0.015	0.031**	0.012**	0.000	-0.004	-0.015*	-0.002
Guidance	-0.105***	0.014	-0.012	0.029	0.012	0.033	-0.007	0.026	-0.008
Other schools	0.028*	-0.004	0.017	0.006	0.001	0.008	-0.009	0.011	0.018**
Constant	5.030***	5.635***	5.459***	5.732***	5.302***	5.480***	5.679***	6.121***	5.291***
Country fixed effects	No	No	No	No	No	No	No	No	Yes
Observations	3,739	5,994	10,388	4,431	5,299	5,254	5,285	4,895	45,285
R-squared	0.374	0.359	0.290	0.432	0.317	0.322	0.387	0.391	0.331

*Notes: Standard errors are clustered at the school level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The dependent variable is the average of the ten plausible values in reading (in logarithm). Source: Elaborations of the authors on PISA 2018 data.*

Table B.2. Estimated effects on the math score of students (all variables included)

Variables	DE	HR	IT	HU	AT	PT	SI	SK	Total
Age	0.062***	0.033***	0.034***	0.003	0.031***	0.025***	0.011	-0.013	0.040***
Female	-0.033***	-0.050***	-0.067***	-0.047***	-0.056***	-0.030***	-0.048***	-0.026***	-0.045***
Foreign speaking	-0.079***	-0.019	-0.016**	-0.033**	-0.082***	-0.058**	-0.066***	-0.059***	-0.051***
Average occupational level	0.030***	0.032***	0.038***	0.033***	0.026***	0.041***	0.007	0.063***	0.038***
High occupational level	0.070***	0.054***	0.043***	0.051***	0.035***	0.080***	0.038***	0.081***	0.065***
11-25 books	0.055***	0.027***	0.032***	0.043***	0.053***	0.042***	0.042***	0.109***	0.049***
26-100 books	0.104***	0.050***	0.082***	0.087***	0.087***	0.115***	0.063***	0.156***	0.098***
101-200 books	0.140***	0.071***	0.105***	0.115***	0.103***	0.140***	0.090***	0.201***	0.129***
201-500 books	0.162***	0.077***	0.107***	0.143***	0.132***	0.161***	0.107***	0.238***	0.147***
500 books or more	0.168***	0.036***	0.102***	0.149***	0.141***	0.142***	0.087***	0.197***	0.148***
E-book/tablet at home	-0.012**	-0.054***	-0.010*	-0.021***	0.003	-0.081***	-0.045***	-0.057***	-0.017***
Computer at home	0.095***	0.080***	0.070***	0.050***	0.073**	0.102***	0.088***	0.059***	0.084***
General - Big city	-0.010	-0.005	-0.012	0.005	-0.000	0.012	-0.018	-0.029	-0.006
Vocational - Big city	-0.072***	-0.139***	-0.103***	-0.121***	-0.064***	-0.041**	-0.154***	-0.052***	-0.078***
Vocational - Small city	-0.048**	-0.165***	-0.092***	-0.133***	-0.066***	-0.100***	-0.154***	-0.094***	-0.070***
16-20 students	0.065	0.013	0.059	0.021	0.053**	-0.030	0.013	0.003	0.040*
21-25 students	0.130***	0.070***	0.125***	0.018	0.099***	0.009	0.032	0.017	0.097***
26 students or more	0.175***	0.105***	0.136***	0.050**	0.120***	0.057***	0.073***	0.051***	0.131***
Public school	-0.009	0.019	-0.003	0.053***	0.002	-0.052***	-0.003	-0.012	-0.002
School IT supply	0.001	0.009	-0.003	0.019	0.013***	-0.004	-0.001	-0.006	0.002
Guidance	-0.072*	0.016	-0.021	0.028	0.008	0.048**	0.001	0.009	-0.013
Other schools	0.033**	-0.004	0.022*	0.013	0.001	0.015	-0.010	0.009	0.024***
Constant	4.966***	5.521***	5.470***	5.939***	5.531***	5.559***	5.993***	6.194***	5.311***
Country fixed effects	No	No	No	No	No	No	No	No	Yes
Observations	3,739	5,994	10,388	4,431	5,299	5,254	5,285	4,895	45,285
R-squared	0.366	0.385	0.283	0.479	0.348	0.341	0.426	0.382	0.325

Notes: Standard errors are clustered at the school level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The dependent variable is the average of the ten plausible values in mathematics (in logarithm). Source: Elaborations of the authors on PISA 2018 data.

Second, in line with part of the literature on the topic (Goldstein 1995; Chapman et al. 2016), we provide a sensitivity analysis where we replicate the main econometric analysis performing a multilevel mixed-effects linear regression model (also known as ‘hierarchical model’) rather than the standard OLS model. The hierarchical models, proposed among others by Searle et al. (1992) and Raudenbush and Bryk (2002), allow to better recognize hierarchical structures in regression models where the set of covariates includes variables at individual (i.e. student) level and others at higher (i.e. school) level. In the case here analysed, failing to recognize hierarchical structures, the adopted OLS estimates may then lead to an overstatement of statistical significance of regression coefficients for school-level variables (i.e. dummy variables for school type and school localization, public school dummy, school IT supply variable, presence of career guidance services at school, and the presence of other schools in the area). Tables B.3 and B.4 report estimates of hierarchical models for all countries (and the pooled sample) on the students’ reading score and students’ math score respectively.

Table B.3. Estimated effects on the reading score of students (hierarchical regression models)

Variables	DE	HR	IT	HU	AT	PT	SI	SK	Total
Age	0.054***	0.036***	0.031***		0.058***	0.014	0.019**		0.037***
Female	0.026***	0.029***	0.032***	0.017***	0.031***	0.034***	0.031***	0.045***	0.029***
Foreign speaking	-0.076***		-0.044***		-0.069***	-0.030*	-0.047***	-0.075***	-0.060***
Average occupational level	0.009	0.015***	0.015***	0.016***	0.007	0.034***	-0.007	0.029***	0.015***
High occupational level	0.018**	0.025***	0.013*	0.020***	0.012**	0.059***	0.007	0.022***	0.022***
11-25 books	0.036***	0.022***	0.032***	0.044***	0.043***	0.027***	0.036***	0.064***	0.035***
26-100 books	0.075***	0.042***	0.060***	0.063***	0.066***	0.074***	0.050***	0.106***	0.068***
101-200 books	0.090***	0.059***	0.059***	0.085***	0.083***	0.103***	0.070***	0.136***	0.080***
201-500 books	0.115***	0.060***	0.066***	0.099***	0.113***	0.125***	0.079***	0.156***	0.098***
500 books or more	0.122***	0.025**	0.069***	0.098***	0.107***	0.120***	0.072***	0.115***	0.101***
E-book/tablet at home		-0.054***		-0.037***		-0.085***	-0.046***	-0.052***	-0.016***
Computer at home	0.052**	0.045***	0.021*			0.033**	0.086**	0.040**	0.033***
General - Big city	-0.006	-0.001	0.008	-0.014	0.007	0.050***	-0.018*	0.006	0.005
Vocational - Big city	-0.096***	-0.134***	-0.145***	-0.181***	-0.098***	-0.017	-0.209***	-0.005	-0.096***
Vocational - Small city	-0.042***	-0.170***	-0.140***	-0.200***	-0.098***	-0.075***	-0.216***	-0.059***	-0.104***
16-20 students	0.083*	0.027	0.061**	0.051*	0.078***	0.018	-0.006	0.040*	0.036***
21-25 students	0.173***	0.069***	0.083***	0.056**	0.152***	0.060	0.013	0.066***	0.071***
26 students or more	0.249***	0.113***	0.089***	0.088***	0.160***	0.121**	0.042***	0.121***	0.124***
Public school				0.051***		-0.031			
School IT supply			0.011	0.021	0.013***			-0.016	
Guidance	-0.124**	0.014		0.036					
Other schools	0.029		0.007						0.020***
Constant	5.124***	5.522***	5.567***	6.031***	5.111***	5.733***	5.841***	5.922***	5.397***
Country fixed effects	No	No	No	No	No	No	No	No	Yes
Observations	3,739	5,994	10,388	4,431	5,299	5,254	5,285	4,895	45,285
Number of groups	183	170	477	158	197	265	269	349	2,068

Notes: Standard errors are clustered at the school level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Each country regression is estimated considering the best model specification identified in Section 4. The dependent variable is the average of the ten plausible values in reading (in logarithm). Source: Elaborations of the authors on PISA 2018 data.

Table B.4. Estimated effects on the math score of students (hierarchical regression models)

Variables	DE	HR	IT	HU	AT	PT	SI	SK	Total
Age	0.061***	0.042***	0.029***		0.045***	0.011			0.038***
Female	-0.039***	-0.052***	-0.043***	-0.052***	-0.039***	-0.037***	-0.042***	-0.032***	-0.041***
Foreign speaking	-0.054***		-0.018***		-0.070***	-0.013	-0.063***	-0.041***	-0.037***
Average occupational level	0.011*	0.018***	0.015***	0.013***	0.011**	0.037***	-0.006	0.042***	0.016***
High occupational level	0.026***	0.032***	0.016***	0.018***	0.014***	0.065***	0.013***	0.044***	0.027***
11-25 books	0.030***	0.017***	0.009	0.025***	0.031***	0.033***	0.021***	0.078***	0.024***
26-100 books	0.056***	0.037***	0.039***	0.054***	0.055***	0.096***	0.035***	0.115***	0.055***
101-200 books	0.075***	0.046***	0.049***	0.074***	0.065***	0.117***	0.058***	0.142***	0.070***
201-500 books	0.094***	0.054***	0.047***	0.091***	0.086***	0.138***	0.071***	0.158***	0.082***
500 books or more	0.097***	0.021**	0.046***	0.091***	0.098***	0.120***	0.053***	0.133***	0.083***
E-book/tablet at home		-0.047***		-0.021***		-0.069***	-0.035***	-0.047***	-0.014***
Computer at home	0.041**	0.062***	0.044***	0.026**	0.037	0.058***	0.037	0.040**	0.044***
General - Big city	-0.012	-0.005	0.003	-0.005	0.004	0.037***	-0.024**	-0.007	-0.004
Vocational - Big city	-0.058***	-0.142***	-0.119***	-0.145***	-0.078***	-0.030**	-0.203***	-0.002	-0.093***
Vocational - Small city	-0.000	-0.174***	-0.102***	-0.159***	-0.077***	-0.077***	-0.196***	-0.045***	-0.094***
16-20 students	0.149***	0.013	0.037	0.040*	0.058**	-0.021	0.018	0.033	0.035***
21-25 students	0.222***	0.064***	0.060*	0.036	0.129***	0.024	0.040**	0.069***	0.072***
26 students or more	0.292***	0.105***	0.067**	0.070***	0.140***	0.080***	0.075***	0.117***	0.121***
Public school				0.046***		-0.043**			
School IT supply				0.013	0.014***				
Guidance	-0.053	0.015	-0.004	0.044**		0.036			0.021***
Other schools	0.037*		0.012						0.007
Constant	4.951***	5.438***	5.667***	6.063***	5.375***	5.816***	6.233***	5.990***	5.419***
Country fixed effects	No	No	No	No	No	No	No	No	Yes
Observations	3,739	5,994	10,388	4,431	5,299	5,254	5,285	4,895	45,285
Number of groups	183	170	477	158	197	265	269	349	2,068

Notes: Standard errors are clustered at the school level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Each country regression is estimated considering the best model specification identified in Section 4. The dependent variable is the average of the ten plausible values in mathematics (in logarithm). Source: Elaborations of the authors on PISA 2018 data.

Results of this check confirm the robustness of the main considerations made in Section 5.1, showing that regression coefficients remain overall the same with few exceptions (e.g. the variable ‘Vocational - Small city’ is not significant anymore on math score in Germany, the variable ‘Vocational - Big city’ is not significant anymore in Slovakia).¹ To be considered, it is likely that results of hierarchical models are so similar to the ones reported in the main analysis (Tables 3 and 4), because the latter already took into account the potential heteroskedasticity related to the school-level variables: all regressions in Section 5 indeed have standard errors clustered at the school level. For this reason, despite results of hierarchical models may be able to capture some residual heteroskedasticity, as results are overall the same, we finally preferred considering them as robustness check only (and then leaving the OLS models one in the main analysis), because this econometric method does not allow performing the Gelbach decomposition, which represents an important novel of this study.

¹ To be noted, regression coefficients reported in Tables B.3 and B.4 are not fully comparable with those in Tables 3 and 4 because they are estimated with a different methodology. Specifically, the hierarchical model coefficients are obtained through a maximum likelihood estimation, while the ones reported in the main analysis are calculated through of an OLS estimation.