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The impact of Homework on Student Achievement:
Evidence from 57 countries

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by

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Abstract

This paper examines the effect of homework on student achievement using data from 57 countries that participated in PISA 2006. For that, we use a within-student identification strategy that allows us to account for most confounding influences at the country, school and student level. We find that homework has a positive and highly statistically significant effect on student test scores. The heterogeneity analysis provides evidence of an uneven distribution of the homework effect among different subsamples. Specifically, we can conclude that there is a larger homework effect for boys than for girls, for private schools than for public schools, and for developing countries than for their developed counterparts.

Keywords: Homework, Test Scores, Study Time, Heterogeneity Analyses

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1. Introduction

The importance of education is currently one of the most debated topics on governmental level since it is expected that higher education level increases the supply of human resources for a country and improves productivity in the long run (Hanushek & Woessmann, 2012). In theory, there are various channels through which the quality of education may be improved. These include increasing teacher salaries, reducing class size or investing in school infrastructure. However, most of them are very costly to implement and there is no guarantee that these school-devoted resources would result in an improved education level that translate into corresponding student achievements (see Hoxby, 1999; Hoxby, 2000; Hanushek, 2003, Häkkinen, Kirjavainen & Uusitalo, 2003). There is therefore a growing interest in studying the effect of homework on student achievement because changing the amount of homework is relatively easy to implement and almost costless to a government (Grodner & Rupp, 2013). Even though the history of homework research is quite rich, most studies have been conducted using US data only (see Cooper, 1989; Betts, 1997; Aksoy & Link, 2000, Caudill & Long, 2009). To the best of our knowledge, there are only a few exceptions, for example, studies from Germany and Denmark done by Trautwein (2007) and Rønning (2011), respectively. In addition, there are two more papers that adopt a multi-country approach. One comes from Falch & Rønning (2012) who used data for 16 OECD countries, and the other from Dettmers, Trautwein & Ludtke (2009) who considered the effect of homework in 40 countries.

In this paper we use data from the 2006 wave of the Programme for International Student Assessment (PISA) to study the effect of homework on school achievement in a sample of 398,750 students in 14,360 schools in 57 countries. This dataset, which includes information on time spent on homework and standardised test scores for the three subjects for each student, allows us to use a within-student estimation approach. The main advantage of this approach is the ability to control for unobserved *subject-invariant* factors that may be correlated with homework, such as an individual's ability, parental background, genes and so on. Thus, this estimation method deals with a large source of omitted variable bias that would otherwise result in endogeneity and inconsistent estimation in the main regression. However, this empirical method cannot account for *subject-specific* factors that, again, may introduce bias into the results. Therefore, we use available control variables to partly account for this source of endogeneity. We also conduct a heterogeneity analysis using different subsamples and check for any non-linearities in our effects.

We find a positive and highly significant effect of homework on student achievement. Specifically, one additional hour of homework increases test scores by, approximately, 2 percent. However, the heterogeneity analysis reveals a non-homogenous distribution of the results across different subpopulations. Namely, we can conclude that there is a larger effect of homework for boys than for girls, while homework in public schools has relatively smaller effect on student achievement if compared to private schools. Finally, by analysing developing and developed countries we can see that the effect of homework on achievement is stronger in developing countries.

This study makes two main contributions over the available research on the effects of homework. First, as far as we know, there are no other papers, studying the homework effect, conducted on such a large-scale analysis, which includes 57 countries accounting for almost 90% of the world economy. Second, our paper can act as a complement to the well-known paper by Lavy (2015), who uses the same data source, namely PISA 2006, to investigate the effect of instructional time on student outcomes. To explain, generally, studying in high school can be divided into two parts. One part refers to the time spent in class, which is covered in the Lavy (2015) study, while the other part corresponds to outside school activities. The latter is exactly what we consider as the casual variable of interest in our paper, namely, the time spent on homework and studying. What we are trying to convey is that the results found by Lavy (2015) cannot be generalized into final conclusions about the study process as a whole, because the “picture” is not complete. Therefore, by having almost identical study samples with Lavy (2015), we are able to argue that the combination of our results can account for the whole study process. Moreover, as mentioned previously, the explanatory variable we use provides a measure for both homework and study time, covering more time dimensions that constitute an educational process. Consequently, we are able to provide more extensive knowledge on the high school learning production function.

The rest of the paper is organized as the following. Section 2 reviews the literature on the homework topic. Section 3 describes the data. Section 4 explains the empirical approach. Section 5 reports the main results as well as the results of the robustness checks and the heterogeneity analysis. Section 6 offers concluding remarks.

2. Previous research

Most research that study the effect of homework is concentrated in other disciplines rather than economics (e.g. Cooper & Lindsay, 1998; Cooper et al. 2006; Patall et al. 2008). However, there are some that do come from economics (e.g. Trautwein, 2007; Dettmers et al. 2009; Rønning, 2011; Falch & Rønning, 2012). Even though almost all of them find a positive effect of homework on student achievement, homework remains a disputed topic among researchers (Trautwein & Köller, 2003). Additionally, as it was mentioned in the introduction part, the majority of papers on homework topic within economics are US-based (e.g. Betts, 1996; Aksoy & Link, 2000; Grove & Wasserman, 2006; McMullen & Busscher, 2009; Eren & Henderson, 2008; Eren & Henderson, 2011; Emerson & Mencken, 2011; Grodner & Rupp, 2013) . We start by reviewing some exceptions, i.e. studies that do not focus primarily on the United States.

Rønning (2011) uses a difference-in-difference approach and applies it to data on elementary school pupils in Denmark to investigate the heterogenous effects of homework on student achievement. She concluded that assigning homework has greater effect on pupils from advantaged family background, who also get more help from their parents, compared to children from lower part of socioeconomic status. Using student and teacher fixed effects and thus addressing potential biases, Falch & Rønning (2012) find a positive and statistically significant effect of homework on nine-year-old pupils' school achievement. Their sample includes 16 OECD countries that participated in Trends in International Mathematics and Science Study (TIMMS) 2007. The observed effect, however, seems to be non-uniformly distributed across population, being larger for girls than for boys. Trautwein (2007) uses data from secondary schools for testing the relevance of the widely accepted belief that there is a positive association between time spent on homework and study outcomes. He concludes that, indeed, there is a positive relationship between homework and achievement on both student and class level. So far, we have only discussed papers that use data from a particular country. Dettmers et al. (2009) are one of the first who conduct a multilevel analysis of homework effect using 40 countries which participated in the Programme for International Student Assessment (PISA) 2003. The result indicates that an increase in the time spent on mathematics homework improves student achievement. This finding is consistent for almost all countries in their sample.

On the other hand, we review some US-based studies. Eren & Henderson (2008) use parametric and nonparametric techniques to study the impact of math homework on corresponding achievement using data from the National Educational Longitudinal Study of 1988 (NELS:88). They find that math homework has a positive and statistically significant effect on the corresponding math test scores. Interestingly, Eren & Henderson (2011) include English, history and science test scores, in addition to math, as dependent variables to investigate the effect of homework. As the authors explain, math homework itself explains little about homework in other important subjects and it would not be fully correct to make general conclusions about homework and its effects. Importantly, this time the authors use within-student and within-teacher estimates to control for unobserved subject-invariant factors of both students and teachers that may be correlated with homework variable. Once again, they find a large positive and statistically significant effect of math homework on math test scores. However, this effect is little or non-existent in the other disciplines. In addition, the heterogeneity analysis reveals larger effects of math and science homework for White and Hispanic students, respectively. Finally, it is more beneficial for children from more educated families to receive additional math homework than for children whose parents do not have a high school diploma.

Interestingly, there are some studies from the United States that use the field experiment approach to answer the similar question of how homework impacts learning outcomes. One example would be the research conducted by Grodner & Rupp (2013) who consider 423 students from a microeconomics course, where the treatment group is required to do the homework while the control group is not. The results indicate that the treatment group performs much better in terms of retention rates and test scores. Similarly, Emerson & Mencken (2011) investigate a sample of 145 microeconomics students to figure out whether those assigned to do homework via special online automated graded homework system, that is treatment group, perform better compared to students who still have access to homework but its completion is not a requirement for them. The results indicate higher achievements on course-specific tasks for the treatment group. However, no benefits are revealed if achievement is measured by scores on standardised test, namely, on the Test of Understanding in College Economics (TUCE).

We want to stress the fact that there are many more studies that estimate the effect of homework since, as we said, the literature on this topic is quite abundant. However, our intention is to provide a general intuition on what has been done before, and to show that almost all of these studies are focused primarily on a single country, be it U.S or some European country. Yet less is known about the aggregate homework effect among these countries. Thus, we contribute to the existing literature by conducting a multilevel analysis that captures 57 countries and provides a causal relationship between homework and achievement from a cross-cultural perspective.

3. Data

3.1.Background on PISA

The data we are using for this research comes from the Programme for International Student Assessment, commonly known as PISA. The main objective of the PISA survey is to analyse different education systems across different countries by measuring the competences of students in three main subjects: language, mathematics and science literature. This survey started in 2000 and it has been continuously held every three years, the last one being in 2018. In this paper, we focus on the 2006 wave, which provides the most detailed information on homework. The sample is composed of 398,750 students in 14,360 schools from 57 countries. In each country, 15-16-year-old students are sampled in a way such the sample is representative of the corresponding population.

The main part of each PISA wave is the assessment of student competences using standardised test scores. In the scientific literacy domain, student abilities are tested based on the engagement in science-related issues. For that, competences in scientific phenomena explanation, scientific enquiry design, evaluation and data interpretation are required. The reading literacy domain attempts to capture students' capacity to engage, understand and reflect on written texts in order to achieve their study goals. Finally, the mathematical literacy domain evaluates the capacity of students to formulate, employ and interpret mathematics in different contexts (OECD, 2006). Additionally, these tests are composed of both multiple choice and open questions. Apart from student skills and knowledge, information about students' background is also collected. For example, questions about their parent's education, family wealth or home educational resources are included. Moreover, school principals and teachers are also required to fill additional questionnaires in order to determine how schools are managed, as well as to provide information on teachers' background.

3.2.Main variable of interest

The main variable of interest is "student time spent on homework and studying out of school by themselves" which provides information *about each of the three subjects*. Therefore, since every student is observed three times in the dataset, that is once per each subject, this is similar to a panel. For the sake of simplicity, we often replace our main variable with homework time, homework effect, the effect of homework time and so on. For example, when we write homework effect, we actually mean the effect of time spent on homework and studying. Besides, it is very important to clarify that when we talk about the time students spend on homework and studying, we refer to student time spent on homework and studying at home, and without any external help. That is, the time students spend on homework and study does not include, for example, lectures time at school or the time they spend with private teachers. Students report homework time by answering to the following question: "How much time do you typically spend per week studying the following subjects?". The answer is reflected in a scale as no time, less than 2 hours a week, from 2 or more but less than 4 hours a week, from 4 or more but less than 6 hours a week and 6 or more hours a week. Furthermore, the average homework time is constructed by assigning the value of 0,1,3,5 and 7 hours of homework a week to each of the categories in the scale, respectively. That way, we can calculate the average homework time by computing the sample mean.

Regarding the main variable, we cannot analyse the direct effect of homework on student achievement. This is due to the fact that, once again, the variable of interest is defined as "the time students spend studying or doing homework out of school by themselves". It means that we are not dealing solely with homework time, but with additional study time. On the other hand, as it was mentioned in the introductory part, this variable captures more dimensions of time that constitutes an educational process, and eventually, allows us to provide a more profound knowledge about the study process in high schools for 2006. Another concern is that, as the time spent in studying and doing homework is reported by students, there might be some measurement errors that should be accounted for. In order to solve this potential issue, we take the average time of studying and doing homework by school. Therefore, if there are only a few students per school who present measurement errors, then misleading survey responses cannot considerably affect the school-average result. By doing this we are able to control for the potential measurement errors arising from student self-reporting.

Results from PISA exams are reported using scales, which represent the proficiency degree in a particular domain. At first, the OECD average for all the subjects was 500 with a standard deviation of 100, implying that for scores ranging from 400 to 600 around 66.66% of the students should fall inside. However, over the years, the average of the OECD score has changed and varied around 500 points. For the analyses in this paper test scores are standardised to have a mean of 0 and standard deviation of 1.

3.3. Descriptive Statistics

Table 1 reports the proportion of students divided in samples according to the time they spent studying and doing homework by themselves. From that table, we can differentiate five different categories: no time, less than 2 hours a week, 2 or more but less than 4 hours a week, 4 or more but less than 6 hours a week, and 6 or more hours a week.

Table 1:

Mean Value of Hours per Week Spent Studying and Doing Homework

		Proportion of students by weekly spent time				
Subject	Mean	No Time	< 2 hours	[2 – 4) hours	[4 – 6) hours	6 hours +
Panel (a): Whole Sample						
Science	1.63	21.42	48.10	21.42	6.40	2.67
Mathematics	1.95	12.90	48.83	26.21	8.44	3.62
Reading	1.80	13.88	52.30	23.66	7.24	2.91
Panel (b): 35 Developed Countries						
Science	1.39	24.24	51.45	18.29	4.54	1.49
Mathematics	1.78	14.45	51.10	24.98	7.04	2.44
Reading	1.63	15.84	54.41	22.05	5.83	1.86
Panel (c): 22 Developing countries						
Science	1.93	17.51	44.79	24.68	8.72	4.30
Mathematics	2.12	11.55	46.98	26.37	9.89	5.21
Reading	1.94	11.79	51.49	24.57	8.20	3.95

Notes: The sample in panel (a) includes the following countries: Azerbaijan, Argentina, Australia, Austria, Belgium, Brazil, Bulgaria, Canada, Chile, Chinese Taipei, Colombia, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hong Kong-China, Hungary, Iceland, Indonesia, Ireland, Israel, Italy, Japan, Jordan, Korea, Kyrgyzstan, Latvia, Liechtenstein, Lithuania, Luxembourg, Macao-China, Mexico, Montenegro, Netherlands, New Zealand, Norway, Poland, Portugal, Qatar, Romania, Russian Federation, Serbia, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Thailand, Tunisia, Turkey, United Kingdom, United States and Uruguay. Panel (b) includes 35 countries from Developed Economies: Australia, Austria, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Luxembourg, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, United Kingdom and United States. Panel (c) includes 23 developing countries: Azerbaijan, Argentina, Brazil, Chile, Chinese Taipei, Colombia, Hong Kong-China, Indonesia, Israel, Jordan, Korea, Kyrgyzstan, Macao-China, Mexico, Montenegro, Qatar, Russian Federation, Serbia, Thailand, Tunisia, Turkey and Uruguay.

By looking at the different panels, we can find that there are substantial differences in the time students spend on homework. From the panel that includes the whole sample, we see that the average time spent on homework is 1.95 hours per week for mathematics, 1.63 for science and 1.80 for reading. Meaning that, students spend more time working on mathematics than on reading or science. In the developed countries sample the same pattern can be observed. From the three courses, mathematics is the subject students spend most time working on followed by reading and science. Besides, the average time students in developed countries spend on mathematics, science and reading are 1.78, 1.39 and 1.63 hours per week respectively. Finally, in the developing countries sample, the average time spent on each subject is 2.12, 1.93 and 1.94 hours per week for mathematics, science and reading, respectively. Here, again, the subject where students spend more time on homework and studying corresponds to mathematics.

The time students spend on homework varies greatly across countries, and within each country for different schools, individuals and subjects. This variation is partly explained by the data since, for example, we observe that the difference in homework time by subject can be explained by the instruction time per week. According to the data, there is a positive correlation between the time spent on homework in each subject and the time students spend on lectures per week in that subject. For example, some countries dedicate more lecture time to certain subjects which in turn may affect student homework time on that subject. In addition, the same can happen at the school level. Some schools may dedicate more lecture time to some subjects that directly affects the student time spent on homework and studying it. This makes sense, since the more material students cover in lectures the more time they need to dedicate to homework and studying that subject. At the individual level, some students might be more efficient than others by dedicating the same amount of time. For example, more efficient students may dedicate less time to homework because they might learn the school material much faster than the students that are not so productive and vice versa.

4. Empirical approach

We define the educational production function as

$$(1)\quad TS_{iskc} = \beta_1 HW_{iskc} + \beta_2 X_{isc} + \beta_3 S_{sc} + \beta_4 C_{skc} + \mu_i + \alpha_s + \delta_k + \eta_c + \varepsilon_{iskc}$$

Where TS_{iskc} is the achievement test score of student i in school s in subject k in country c, and HW_{iskc} denotes the number of hours student i in school s in subject k in country c spent on homework and studying per week. X_{isc} is a vector of observable characteristics of student i in school s in country c, such as individual and family background characteristics. In our model, S_{sc} is a vector of observable characteristics of school s in country c and C_{skc} is a vector of observable characteristics of subject k in school s in country c. These two vectors can be defined as school specific and subject specific characteristics. On the contrary, μ_i, α_s, δ_k and η_c represent all the unobserved characteristics at the individual, school, subject and country level respectively. For example, μ_i includes the endowed ability, motivation and other constant non-cognitive skills of student i. Finally, ε_{iskc} represents the remaining unobserved error term.

When estimating the impact of homework on test scores the main empirical challenge is the possible correlation of homework time with other observed and unobserved factors that explain student achievements. This would invalidate the crucial assumption of an exogenous error term in the absence of which results are not reliable. Let's consider one example to build up the intuition. Parental education may be one such factor that correlates with the causal variable of interest. Indeed, it was found that children from more educated families get more help with homework since the education is highly valued in such families (Guryan et al., 2008; Rønning, 2011). Therefore, if for some reason we cannot control for parental background then an endogeneity problem would arise which would lead to biased and inconsistent estimators. There are other possible factors that, if not controlled for, would result in endogeneity such as genes, unobserved ability and so on.

One way to deal with this problem is to use a common approach in the literature, namely within-student estimation (see Dee, 2005; Dee, 2007; Eren & Henderson, 2011; Falch & Rønning, 2012; Lavy, 2015). This identification strategy largely eliminates both observed and unobserved student traits. To explain, by using the within-student estimation we can partly isolate the effect of homework on student achievement since all other students-specific characteristics affecting the test scores are controlled for. Moreover, this method automatically accounts for school unobserved characteristics, since these are the same for all three subjects. In other words, the student fixed effects fully absorb the school fixed effects, meaning that one cannot control for student-specific characteristics without at the same time implicitly controlling for the school-specific factors. To this end, we follow the within-student estimator procedure. One should also note that this method can be only used because of specific data outset, where we can observe test scores in multiple subjects for each student while also having relatively large variation in time spent on homework for these subjects. Thus, by subtracting the individual specific average over subject from equation (1) we get:

$$(2)\quad TS_{iskc} - \overline{TS}_{isc} = \beta_1(HW_{iskc} - \overline{HW}_{isc}) + \beta_2(X_{isc} - \bar{X}_{isc}) + \beta_3(S_{sc} - \bar{S}_{sc}) + \beta_4(C_{skc} - \bar{C}_{sc}) + (\mu_i - \bar{\mu}_i) + (\alpha_s - \bar{\alpha}_s) + (\eta_c - \bar{\eta}_c) + (\delta_k - \bar{\delta}) + (\varepsilon_{iskc} - \bar{\varepsilon}_{iskc}),$$

where $X_{isc} = \bar{X}_{isc}$, $S_{sc} = \bar{S}_{sc}$, $\mu_i = \bar{\mu}_i$, $\alpha_s = \bar{\alpha}_s$ and $\eta_c = \bar{\eta}_c$.

OLS estimate of equation (2) will provide a consistent estimator of β_1 as long as the time spent on homework and studying is uncorrelated with subject-specific unobserved factors included in the error term. Therefore, again, within-student estimator allows us to control for potential bias arising from student, school and country unobservable characteristics.

Nevertheless, we still have only a partial effect of homework because there are also subject-specific factors that vary from subject to subject such as the experience of teacher, instructional time, method of teaching and so on. Furthermore, unobserved peer characteristics can also bias our estimates. For example, more talented students may be gathered in the same classes with better and more ambitious teachers who assign a lot of homework. This would bias our estimator of interest downward. The bias would have an opposite sign if less skilled classes get more homework. Unfortunately, we are not able to fully control for all mentioned sources of endogeneity for two main reasons. First, as it was already mentioned, student fixed effects method does not account for subject-variant factors. Second, the data on such factors is scarce. The only two variables that we find in PISA 2006 to control for the subject differences are instructional time by subject and teacher's shortage, where the latter provides information if there is any lack of qualified teachers in math, science or language. Importantly, by adding these controls in fixed effects regression we can see almost no effect on the coefficient of interest, meaning that there is no self-selection bias where more qualified teachers lead more talented classes or vice versa. Putt in a different way, students in our sample are as good as randomly assigned to teachers and different instructional times.

Before interpreting the results of our model, two main assumptions must be stated. First, following Lavy (2015) the effect of homework and studying time per week should be the same for all the subjects. This means that, for example, the effect of studying mathematics and doing math homework should affect student achievement in the same way science and reading do. As Lavy (2015) mentioned, this assumption can be easily violated if the production function of knowledge varies from subject to subject. For example, it could be the case that, if compared to reading, the effect of homework in mathematics yields the highest return in achievement when students are older. Second, regarding the peer traits, we have to assume that these are subject-invariant. This assumption, however, is believable since we are analysing the sample of high-school students who usually have the same lessons, and thus classmates, in different subjects.

To sum up, the identification strategy we use deals with several potential sources of endogeneity that come from unobserved student and school characteristics where both are subject-invariant. However, it does not consider subject-variant traits, such as teachers and class characteristics or instructional time. As we said, to control for any possible teacher and instructional time differences we include available control variables that fortunately do not significantly change the coefficient of interest. While unobserved peer characteristics are assumed to be fixed across different subjects and therefore would be automatically controlled for by within-student estimation method.

5. Results

Our baseline results are presented in Tables 2-7. Table 2 reports simple OLS regression where we run homework and studying time on student test scores in math, science and reading separately. We also have four sets of control variables, which are country dummies and individual-, school- and subject-specific characteristics. These sets of controls are included in the OLS regression one-by-one in order to see the magnitude of a change in the coefficient of interest. Importantly, the OLS specification includes a great amount of endogeneity issues and therefore cannot be trusted. Nevertheless, a common way in literature is to start from simple ordinary least squares (e.g. Rønning, 2011; Falch & Rønning, 2012; Lavy, 2015). On the other hand, Table 3 shows the pooled effect of homework and studying time. Fixed effects estimators are included here to reveal the homework-achievement causal relationship, and to be compared to the OLS estimators. Table 4 reports the regression of homework and study time on standardised achievement scores using school-level means in order to account for possible measurement errors and to validate our results. Tables 5-7 provide a heterogeneity analysis by gender, school type and country income respectively.

Starting from Table 2, in panel *(a)* we show that generally homework time has a positive correlation with student achievement in mathematics and science with and without controls. The only exception appears in the column (5), when all sets of controls are included in the regression, where the association between the time spent on science homework and corresponding test scores is found to be negative although not statistically different from zero. On the other hand, the results for reading homework behave in an unpredictable way, oscillating in terms of the coefficient sign and significance level. However, column (15), with all control variables included, shows negative correlation of homework with test scores in reading. Panel *(b)* indicates that the highest marginal effect of homework in all three subjects occurs when the time period spent on homework approximates to one hour per week. Beyond that, the marginal effect of studying and doing homework starts to decrease. To explain, for example, the coefficient in column (5) is 0.134, which suggests that if one studies and does homework in science for approximately one hour per week, then the corresponding test score should increase by 0.134 of a standard deviation of the distribution of the test scores.

Table 2:

OLS regression of Homework and Study time on Standardised Achievement Scores by Subjects

	Science					Mathematics					Reading				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Panel (a): Continuous hours															
Hours	0.0342***	0.0708***	0.0432***	0.0425***	-0.00173	0.0513***	0.0589***	0.0377***	0.0374***	0.00554***	-0.00615*	0.0194***	-0.00153	-0.00134	-0.0215***
	(0.00356)	(0.00296)	(0.00238)	(0.00236)	(0.00241)	(0.00324)	(0.00256)	(0.00209)	(0.00208)	(0.00207)	(0.00334)	(0.00284)	(0.00221)	(0.00220)	(0.00211)
Panel (b): Categorical hours															
Less than 2 hours	0.198***	0.343***	0.247***	0.243***	0.134***	0.214***	0.316***	0.232***	0.228***	0.143***	0.172***	0.339***	0.211***	0.207***	0.150***
	(0.0147)	(0.0119)	(0.00967)	(0.00964)	(0.00935)	(0.0142)	(0.0119)	(0.00999)	(0.00990)	(0.00934)	(0.0155)	(0.0125)	(0.0106)	(0.0105)	(0.0106)
From 2 up to 4 hours	0.259***	0.463***	0.307***	0.302***	0.110***	0.404***	0.484***	0.341***	0.336***	0.176***	0.197***	0.371***	0.197***	0.195***	0.0874***
	(0.0179)	(0.0136)	(0.0113)	(0.0113)	(0.0112)	(0.0172)	(0.0142)	(0.0119)	(0.0118)	(0.0111)	(0.0185)	(0.0151)	(0.0123)	(0.0122)	(0.0118)
From 4 up to 6 hours	0.250***	0.490***	0.312***	0.306***	0.0557***	0.326***	0.438***	0.299***	0.295***	0.100***	0.0813***	0.290***	0.120***	0.119***	-0.00462
	(0.0234)	(0.0189)	(0.0152)	(0.0151)	(0.0150)	(0.0206)	(0.0174)	(0.0142)	(0.0142)	(0.0137)	(0.0231)	(0.0187)	(0.0155)	(0.0155)	(0.0149)
6 or more hours	0.208***	0.471***	0.324***	0.318***	0.0416**	0.317***	0.427***	0.293***	0.290***	0.0819***	-0.137***	0.155***	0.0274	0.0264	-0.0915***
	(0.0304)	(0.0245)	(0.0209)	(0.0208)	(0.0203)	(0.0307)	(0.0244)	(0.0205)	(0.0204)	(0.0201)	(0.0336)	(0.0280)	(0.0244)	(0.0243)	(0.0235)
Country Dummies	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Individual Characteristics	No	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes
School Characteristics	No	No	No	Yes	Yes	No	No	No	Yes	Yes	No	No	No	Yes	Yes
Subject Characteristics	No	No	No	No	Yes	No	No	No	No	Yes	No	No	No	No	Yes
Observations	384,213	384,213	384,213	384,213	384,213	384,847	384,847	384,847	384,847	384,847	379,681	379,681	379,681	379,681	379,681

The table shows OLS regression of students z-scores on hours of homework and study time spent per week in a particular subject. Scores are standardised to have a mean of 0 and a standard deviation of 1. The omitted category is no time. Robust standard errors are clustered at school level and are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1

However, if a student spends approximately three hours per week on studying science, then in order to get the marginal effect of one-hour study we need to divide the estimated coefficient by three. We, therefore, get an approximate marginal effect of 0.037 [=(0.110 points/3 hours)]. This means that the marginal effect of one-hour study is larger when students spend less than two hours per week doing science homework if compared to the situation where the study time ranges between two and four hours. The same logic applies to other disciplines. However, as we said, we cannot rely on the OLS specifications even when a rich set of control variables are included, since they are not able to fully remove endogeneity that comes from unobservable factors contained in the error term that may be correlated with homework variable.

Moving on to Table 3, from panel *(a)* we can see that by using OLS to estimate the pooled effect of homework time on student achievement we find a positive association between these two variables. The result is robust to the inclusion of control variables since the estimated coefficient changes only slightly.

Columns (6) and (7) provide estimates for the student fixed effects which we consider our main specifications. As one can observe, when using the within-student estimation method and thus accounting for all subject-invariant observed and unobserved factors, there is still a positive but less strong effect of homework if compared to the naïve OLS estimators which seem to be overestimated. Interestingly, the inclusion of control variables in the OLS regressions generally decreases the estimated coefficient of interest. By conditioning on student unobserved factors, the coefficient of homework variable decreases even more, although remaining positive, supporting the general decreasing trend in the estimated coefficients with additional controls. Moreover, by adding subject-specific controls to the within-student estimation in column (7), we are controlling for a larger number of potential sources of endogeneity and thus reinforcing the validity of our estimates. Consequently, we can observe an additional reduction in the magnitude of the homework effect, but a minor one, going from 0.0267 to 0.0222. Therefore, we can conclude robust result in fixed effects estimates.

Summing up table 3 and panel *(a)*, with both naïve OLS estimators and fixed effects estimators included, we can conclude that the former ones overestimate the effect of pooled homework time on student achievement, while the latter show a more precise effect of interest, which is positive and highly statistically significant. Specifically, one additional hour of homework raises test scores in mathematics, science or language by, on average, 0.0222 of a standard

Table 3:

Estimated effect of Homework and Study time on Standardised Achievement Scores

	Pooled OLS					Student FE	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel (a): Continuous hours							
Hours	0.0256***	0.0528***	0.0323***	0.0320***	-0.000270	0.0267***	0.0222***
	(0.00278)	(0.00222)	(0.00171)	(0.00170)	(0.00163)	(0.00108)	(0.000996)
Panel (b): Categorical hours							
Less than 2 hours	0.169***	0.326***	0.235***	0.2308***	0.144***	0.0270***	0.0221***
	(0.0118)	(0.00868)	(0.00752)	(0.00745)	(0.00724)	(0.00385)	(0.00388)
From 2 up to 4 hours	0.252***	0.431***	0.293***	0.2883***	0.135***	0.0861***	0.0720***
	(0.0144)	(0.0108)	(0.00872)	(0.00863)	(0.00828)	(0.00478)	(0.00465)
From 4 up to 6 hours	0.193***	0.414***	0.270***	0.2660***	0.0762***	0.132***	0.110***
	(0.0180)	(0.0136)	(0.0108)	(0.01071)	(0.0103)	(0.00622)	(0.00606)
6 or more hours	0.148***	0.392***	0.269***	0.2648***	0.0533***	0.181***	0.149***
	(0.0238)	(0.0178)	(0.0149)	(0.01484)	(0.0142)	(0.00938)	(0.00911)
Country Dummies	No	Yes	Yes	Yes	Yes		
Individual Characteristics	No	No	Yes	Yes	Yes		
School Characteristics	No	No	No	Yes	Yes		
Subject specific Characteristics	No	No	No	No	Yes	No	Yes
Observations	1,122,198	1,122,198	1,122,198	1,122,198	1,122,198	1,122,198	1,122,198
Number of Students						374,066	374,066

The table shows OLS and FE[2] regression of students z-scores on hours of homework and study time spent per week in a particular subject. Scores are standardised to have a mean of 0 and a standard deviation of 1. The omitted category is no time. Robust standard errors are clustered at school level and are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1

[2] Note that FE regression refers to the OLS estimate of equation (2), that is, where all subject-invariant characteristics are controlled for.

deviation of the test score distribution. We consider this effect to be modest to large given that the scores are standardised to have a mean of 0 and a standard deviation of 1. On the other hand, by looking at panel *(b)* we can see that, again, for the OLS specifications, the pooled marginal effect of homework time is the largest for the time-range between zero and two hours per week. This panel also shows that in fixed effect estimates, the effect monotonically increases with hours spent on homework.

5.1.Robustness Check

One of the main concerns mentioned in our paper is the possibility of having measurement errors in the variable of interest. As explained in the data section, when performing the PISA test, students are required to fill the variable “Homework and Study time per week” for each of the three subjects. Therefore, the self-reported answers may contain measurement errors if the survey is not completed carefully by students. Consequently, we may get biased and inconsistent results. Therefore, in order to check for validity of the student-reported homework time, we estimate the same model, but by using school-level average homework and study time. That way, we can attempt to correct for possible measurement errors, since it is more difficult to affect an average result with a few individual-specific measurement errors. In other words, if there are only a few students per school who present measurement errors, then misleading survey responses of such pupils cannot considerably affect the school-average result. In short, this robustness check is based on a school sample rather than on an individual sample.

The results of our robustness check are presented in Table 4. In order to control for all unobservable and subject-invariant characteristics, we regress the fixed effects model presented in equation 2. The estimated results can be seen in columns (6) and (7). We can clearly see that the coefficient presented in column (7), with subject-specific controls included, closely relates to the corresponding coefficient in Table 3. Specifically, the school-level estimator is only 9.45% higher than the student-level one, meaning that the difference between these two estimators is quite insignificant. Therefore, as both samples, student-level and school-level, provide consistent and very similar coefficients we can conclude that we do not find any evidence for possible measurement errors, which supports the causal interpretation of our finding.

Table 4:

Regression of Homework and Study time on Standardised Achievement Scores using School-Level Means

	Pooled OLS					Student FE	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Continuous hours							
Hours	0.0312***	0.113***	0.0801***	0.0793***	0.0411***	0.0325***	0.0243***
	(0.00982)	(0.00882)	(0.00652)	(0.00648)	(0.00621)	(0.00362)	(0.00354)
Country Dummies	No	Yes	Yes	Yes	Yes		
Individual Characteristics	No	No	Yes	Yes	Yes		
School Characteristics	No	No	No	Yes	Yes		
Subject specific Characteristics	No	No	No	No	Yes	No	Yes
Observations	1,122,198	1,122,198	1,122,198	1,122,198	1,122,198	1,122,198	1,122,198
Number of Students						374,066	374,066

The table shows OLS and FE regression of students z-scores on hours of homework and study time spent per week in a particular subject at school level data. Scores are standardised to have a mean of 0 and a standard deviation of 1. Robust standard errors are clustered at school level and are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1

5.2.Heterogeneous effects

In order to gain further insights into the effect of homework time, we conduct a heterogeneity analysis by gender, school type and country income. Importantly, note that Tables 5-7 provide coefficients that have been calculated directly by using the fixed effect model with subject-specific control variables.

We start by presenting the heterogeneity analysis by gender, namely, male students versus female students. The estimates are presented in table 5. As one can see, both coefficients are positive and significant at 1 % significance level. Nevertheless, boys are found to be more affected by homework time than girls. Indeed, the coefficient for boys is more than twice as large as the coefficient for girls, and this difference is significantly different from zero. Interestingly, Falch & Rønning (2012) get completely opposite results, being more than twice as large homework effect for girls than for boys. However, even though both, Falch & Rønning (2012) and us, use almost the same study years, namely 2007 and 2006 respectively, the data sources and number of countries included in the analysis differs substantially. If precisely, Falch & Rønning (2012) use data from 16 OECD countries that participated in Trends in International Mathematics and Science Study (TIMMS) 2007. While our paper, as already discussed, deals with 57 countries that conducted a survey for PISA 2006. Therefore, generally, the results we get are not comparable.

Table 5:

Estimated effect of Homework and Study Time on Standardised Achievement Scores by Gender

	Student FE	
	Boys	Girls
	(1)	(2)
Hours of Studying	0.0305***	0.0140***
	(0.00150)	(0.00117)
Observations	551,949	570,240
Number of Students	183,983	190,080

The table shows FE regression of students z-scores on hours of homework and study time spent per week in a particular subject. Scores are standardised to have a mean of 0 and a standard deviation of 1. Robust standard errors are clustered at school level and are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 6 reports differences in the estimators by school type. In this table we can differentiate between two different school types, namely, private and public. Besides, private schools are divided into other two main branches, private but government dependent, that are charter schools, and government independent. This differentiation can give us a deeper insight about the effect of homework time, that students have in these different types of schools, on the corresponding test scores. From Table 6, we can first spot that all types of schools provide positive and highly significant coefficients. Secondly, the difference between these estimates is relatively small, although statistically significant. Finally, we see that private schools still show a higher homework effect than public ones. Importantly, this heterogeneity analysis includes the sample of all countries under study, namely, both developed and developing ones. However, we expect public and private schools to provide a different quality of education in developed and developing countries. Therefore, it is difficult for us to provide a feasible reason for such a difference between the homework effect in these two types of school at the moment. Nevertheless, we will elaborate more on that in later section of the result part in table 7, which provides separate estimates for developing and developed countries respectively.

Table 6:

Estimated effect of Homework and Study Time on Standardised Achievement Scores by School Type

	Student FE		
	Private Schools		Public Schools
	Independent	Government Dependent	
	(1)	(2)	(3)
Hours of Studying	0.0239***	0.0269***	0.0217***
	(0.00621)	(0.00221)	(0.00111)
Observations	29,592	80,820	918,417
Number of Students	9,864	26,940	306,139

The table shows FE regression of students z-scores on hours of homework and study time spent per week in a particular subject. Scores are standardised to have a mean of 0 and a standard deviation of 1. Robust standard errors are clustered at school level and are presented in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

5.3.Evidence for Developing and Developed countries

Table 7 analyses the effect of homework and study time by country income, that is, between developed and developing countries. In the first column we present the results using the whole sample, whereas in columns (2) to (5) we look at different subpopulations. That way we are able to conduct more profound and detailed homework heterogeneity examination, that divides existing subsamples into additional subgroups.

Note that panel *(a)* in Table 7, presents results based on a sample of 35 developed countries (High-income countries): Australia, Austria, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Luxembourg, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, United Kingdom and United States. On the other hand, panel *(b)* presents estimates based on 23 developing countries (Middle-Low income countries): Azerbaijan, Argentina, Brazil, Chile, Chinese Taipei, Colombia, Hong Kong-China, Indonesia, Israel, Jordan, Korea, Kyrgyzstan, Macao-China, Mexico, Montenegro, Qatar, Russian Federation, Serbia, Thailand, Tunisia, Turkey and Uruguay.

We start by looking at the effect of the whole sample. One can observe that the productivity of time spent on doing homework is higher for developing countries than for their developed counterparts. Importantly, although this difference is small, it is statistically different from zero. Again, at the moment we are not able to provide an exact reason for such result. Since, in this paper, we do not conduct any statistical analysis on the underlying reasons for the observed between-subsamples differences. However, we are still able to presume that it could be the case that students in developing countries get a higher return from their homework time because of a relatively lower quality of the education level these countries have. To explain, students in developed countries may already have a higher test score by going to better schools, so studying further at home will not have a high overall marginal increase. On the other hand, in developing countries, the score-gain from being in school may be smaller, therefore studying at home will have a higher marginal effect. The reason for that may lie in different study environments between developing and developed countries. For example, it is more likely the case that developed countries may afford to have more advanced computer labs, more qualified teachers and more equipped study facilities in general. Therefore, all these mentioned factors may already have a great contribution to the student test scores, dampening the impact of homework and outside-school study. While the opposite may happen for the developing countries, namely, the effect of homework time may be larger when coming from poor study setting.

From panel *(a)* and columns (2) to (5), we conclude that developed countries present the same heterogenous result by gender and school type if compared to the whole sample in tables 5 and 6. Namely, we can still observe higher homework effect for boys and private schools than for girls and public schools respectively. However, by looking at panel *(b)* for developing countries, one can notice that we get the opposite results in columns (4) and (5). Specifically, the effect of homework is found to be larger for public schools here. The possible reason for that may be that the difference between public and private schools is larger in developing countries than in developed ones. It means that, perhaps, only children from wealthy families can afford to go to private schools which are usually get funded by the high-status parents. Therefore, again, private schools in poor countries may have a better study environment than public schools do. Eventually, this lowers the impact of homework on corresponding student test scores for private schools, where existing school infrastructure, better teachers or more individual-oriented class tasks already largely decide the future exam points.

As mentioned before, from panel *(a)*, columns (4) and (5), we find that the effect of homework turned out to be larger for private schools than for public schools in developed countries. One may expect that the difference in education standards between both types of schools in developed countries is smaller than in the developing countries. From that, we could provide a possible explanation for higher homework effect for private schools in developed countries. To explain, it may be the case that private schools in rich countries are still more focused on their students, while teachers prepare homework that is based specifically on their needs. In other words, since the difference between both types of schools is less in the developed countries, the higher homework effect for private schools may be the result of, for example, more student-oriented homework tasks that is, perhaps, prepared more carefully by the teachers. We can only assume that the reason why this is not the case for the developing countries, is that the difference in education standards that these two types of schools provide is much larger. Therefore, even though one may argue that private schools in poor countries may also be more student-oriented, this is perhaps not enough to outweigh the marginal gains that public school students can get when doing their homework. Since, again, the quality of education of public schools in poorer countries may not be that good, so that by studying at home, these students can gain relatively more benefit.

Table 7:

Heterogeneous effect of Homework and Study Time on Standardised Achievement Scores

	Student FE				
	All	Gender		Type of School	
		Boys	Girls	Public	Private
	(1)	(2)	(3)	(4)	(5)
Panel (a): Developed Countries					
Continuous hours	0.0185***	0.02989***	0.00725***	0.0166***	0.0212***
	(0.00131)	(0.00188)	(0.00158)	(0.00165)	(0.00212)
Observations	499,320	249,783	249,537	391,671	107,649
Number of Students	166,440	83,261	83,179	130,557	35,883
Panel (b): Developing Countries					
Continuous hours	0.0222***	0.02912***	0.01594***	0.0223***	0.0153**
	(0.00139)	(0.00212)	(0.00165)	(0.00141)	(0.00628)
Observations	395,799	189,876	205,914	368,586	27,213
Number of Students	131,933	63,292	68,638	122,862	9,071

The table shows FE regression of students z-scores on hours of homework and study time spent per week in a particular subject for two samples. The first sample is composed of 35 developed countries and the second sample of 23 developing countries. Scores are standardised to have a mean of 0 and a standard deviation of 1. Robust standard errors are clustered at school level and are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1

6. Conclusion

This paper attempts to find the effect of homework and study time on student achievement level by using a within-student estimation method that conditions out student and school characteristics from the model. Following Lavy (2015), we use PISA 2006 as our main data source for this paper. The estimated sample gathers 398,750 students from 14,360 schools in 57 countries. Importantly, the age of students that participated in PISA 2006 survey ranges between 15- and 16-years old, meaning that we are dealing with high-school students in general.

The results suggest that when using simple OLS regression for estimating the effect of homework, the coefficient of interest tends to be overestimated. This happens because this method does not account for unobserved student and school traits, which eventually results in an endogenous error term. On the other hand, the student fixed effects approach largely removes both observed and unobserved subject-invariant specific factors such as, parental education, unobserved abilities and talents or genes. To control for specific subject-variant characteristics, we use an available set of control variables that provide information whether there is a lack of qualified teachers in addition to the instructional time in different schools and subjects. Thus, by using the within-student estimation method we get a positive and highly significant effect of homework time on student test scores. The result is robust to the inclusion of subject-varying unobserved student characteristics. It means that we find no evidence for selection bias that would otherwise invalidate our results.

Importantly, since our explanatory variable, that is, homework time, is self-reported by students one should expect possible measurement errors. To account for that we use the same technique that Lavy (2015) uses in his paper, that is, transform the student-level data to the respective school-level means and estimating the latter one. Fortunately, this robustness check reveals no presence of student measurement errors that may bias our result. We also conduct heterogeneity analysis which identified larger homework effect for boys than for girls. While public schools have shown to be less affected by homework and study time than private schools. Finally, we analyse if there is any heterogeneity in the results between developed and developing countries. We conclude a greater homework effect for the latter.

One limitation of this paper is the inability to also condition on teacher fixed effects. This happens because we use a sample of high school students who have different teachers for different disciplines. Therefore, the within-student estimation itself cannot account for unobserved teacher characteristics. This would not be the case if instead of high school students, students from elementary school were to be used as a study sample, since such pupils usually have the same teacher across different subjects. Even though we include the available control variables to control for possible differences between teachers, we still think it may be insufficient to fully remove endogeneity issues coming from unobserved teacher characteristics.

Additionally, it is conceivable to argue that the results may not be applicable today. To explain, since we are using data from 2006, it is hard to believe that the study environment has not changed since that time. New methods of teaching, more advanced gadgets, improved internet connection, different social medias connecting students worldwide are only a few things that have changed since 2006. Thus, we expect the homework time to, perhaps, have less effect on the student achievement nowadays. Recall, the heterogeneity analyses revealed a greater effect of homework for the developing countries. As it was said, the possible explanation is that the study environment in developing countries are worse than in their developed counterparts. Thus, additional homework time may have relatively larger effect in countries that have worse study circumstances. This is what we are trying to convey, namely, that the effect of homework time may have less impact in today's world among the countries under study, since most of them did improve in terms of study features since 2006. We consider this as an interesting topic to shed light on and leave it as a ground for future research.

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Appendix

Table A 1:

Summary Statistics

	Observations	Mean	Std. Dev.	Minimum	Maximum
Dependent variables:					
Science Score	398,750	-0.2430686	1.026044	-4.81369	4.128361
Mathematics Score	398,750	-0.284096	1.024504	-4.924365	3.952251
Reading Score	393,139	-0.3679534	1.058852	-4.989802	5.788879
Treatment variables:					
Continuous:					
Science Homework Time	384,213	1.630179	1.630212	0	7
Mathematics Homework Time	384,847	1.950102	1.711422	0	7
Reading Homework Time	385,115	1.798852	1.62912	0	7
Categorical:					
Science Homework Time					
No time	382,630	0.2142723	0..4103171	0	1
Less than 2 hours	382,630	0.4810261	0.4996405	0	1
2 up to 4 hours	382,630	0.2141311	0.4102188	0	1
4 up to 6 hours	382,630	0.0639286	0.244626	0	1
6 or more hours	382,630	0.0266419	0.1610348	0	1
Mathematics Homework Time					
No time	383,255	0.1290159	0.335218	0	1
Less than 2 hours	383,255	0.4883876	0.4998658	0	1
2 up to 4 hours	383,255	0.2620057	0.4397263	0	1
4 up to 6 hours	383,255	0.0844059	0.277996	0	1
6 or more hours	383,255	0.0361848	0.1867499	0	1
Reading Homework Time					
No time	383,526	0.1388433	0.3457833	0	1
Less than 2 hours	383,526	0.5231171	0.499466	0	1
2 up to 4 hours	383,526	0.2365654	0.4249738	0	1
4 up to 6 hours	383,526	0.0724436	0.2592213	0	1
6 or more hours	383,526	0 .0290306	0.1678926	0	1
Independent variables:					
Student characteristics:					
Mother’s education:					
None	385,947	0.054251	0.2265126	0	1
Primary education	385,947	0.085675	0.2798839	0	1
Lower secondary	385,947	0.149264	0.356349	0	1
Upper secondary	385,947	0.092365	0.2895409	0	1

	Observations	Mean	Std. Dev.	Minimum	Maximum
Post-secondary	385,947	0.2857335	0.4517637	0	1
Short-cycle tertiary education	385,947	0.1370136	0.3438622	0	1
Bachelor, Master or PhD	385,947	0.1956979	0.3967375	0	1
Father's education:					
None	376,021	0.0495478	0.217009	0	1
Primary education	376,021	0.0821709	0.2746253	0	1
Lower secondary	376,021	0.1463216	0.3534288	0	1
Upper secondary	376,021	0.1027735	0.3036632	0	1
Post-secondary	376,021	0.2761521	0.4470936	0	1
Short-cycle tertiary education	376,021	0.1274663	0.333495	0	1
Bachelor, Master or PhD	376,021	0.2155677	0.4112162	0	1
Books at home					
0-10 books	389,162	0.1566648	0.3634849	0	1
11-25 books	389,162	0.1910978	0.3931664	0	1
26-100 books	389,162	0.2979967	0.4573786	0	1
101-200 books	389,162	0.1628859	0.369262	0	1
201-500 books	389,162	0.1206798	0.3257552	0	1
500 books or more	389,162	0.0706749	0.2562814	0	1
Student age	397,086	15.7793	0.2915263	15.17	16.33
Gender					
Male	398,746	0.494721	0.4999728	0	1
Female	398,746	0.505279	0.4999728	0	1
Home resources	393,355	-0.2328861	1.086751	-4.8441	1.6534
Internet					
Yes	386,752	0.6501401	0.4769261	0	1
No	386,752	0.3498599	0.4769261	0	1
TVs					
None	391,639	0.0144521	0.1193451	0	1
One	391,639	0.224209	0.4170609	0	1
Two	391,639	0.344672	0.4752618	0	1
Three or more	391,639	0.4166669	0.4930073	0	1
School characteristics					
School type					
Private independent	364,316	0.0284231	0.1661786	0	1
Private government-dependent	364,316	0.0769277	0.2664771	0	1
Public	364,316	0. 8946492	0.3070054	0	1
Ratio of computers	377,844	0.1314361	0.1048029	0	1.915
Girls proportion	382,837	0.5174785	0.162316	0	1
Town size					
Village	378,484	0.1693916	0.3750979	0	1
Small town	378,484	0.2494214	0.4326787	0	1
Town	378,484	0.2256476	0.4180086	0	1
City	378,484	0.2873596	0.4525313	0	1
Large city	378,484	0.0681799	0.2520547	0	1
Use of computers					
Almost every day	248,939	0.0933683	0.2909484	0	1

	Observations	Mean	Std. Dev.	Minimum	Maximum
Once or twice a week	248,939	0.4989375	0.4999999	0	1
Few times a month	248,939	0.1714436	0.3768969	0	1
Once a month or less	248,939	0.1197562	0.3246769	0	1
Never	248,939	0.1164944	0.3208175	0	1
Shortage library material					
Not at all	376,907	0.1866004	0.3895909	0	1
Very little	376,907	0.2953089	0.4561821	0	1
To some extent	376,907	0.3606619	0.4801932	0	1
A lot	376,907	0.1574288	0.364205	0	1
Subject-specific characteristics:					
Regular science lessons					
No time	381,005	0.1119618	0.3153198	0	1
Less than 2 hours	381,005	0.2376058	0.4256169	0	1
2 up to 4 hours	381,005	0.347313	0.4761169	0	1
4 up to 6 hours	381,005	0.1939397	0.3953827	0	1
6 or more hours	381,005	0.1091797	0.3118649	0	1
Regular mathematics lessons					
No time	381,933	0.0337127	0.1804889	0	1
Less than 2 hours	381,933	0.1435435	0.3506267	0	1
2 up to 4 hours	381,933	0.3395936	0.4735719	0	1
4 up to 6 hours	381,933	0.3677608	0.4821964	0	1
6 or more hours	381,933	0.1153893	0.3194916	0	1
Regular reading lessons					
No time	382,312	0.0334936	0.1799218	0	1
Less than 2 hours	382,312	0.1578266	0.3645788	0	1
2 up to 4 hours	382,312	0.3583356	0.479512	0	1
4 up to 6 hours	382,312	0.3396101	0.4735775	0	1
6 or more hours	382,312	0.1107342	0.3138031	0	1
Shortage of science teachers					
No at all	376,845	0.6088365	0.4880115	0	1
Very little	376,845	0.1697913	0.3754498	0	1
To some extent	376,845	0.1608354	0.3673795	0	1
A lot	376,845	0.0605368	0.2384791	0	1
Shortage of mathematics teachers					
No at all	376,853	0.6000138	0.4898958	0	1
Very little	376,853	0.2519046	0.4341073	0	1
To some extent	376,853	0.0726331	0.2595336	0	1
A lot	376,853	0.0754485	0.264114	0	1
Shortage of reading teachers					
No at all	376,841	0.6458666	0.4782505	0	1
Very little	376,841	0.2198726	0.4141607	0	1
To some extent	376,841	0.1102322	0.3131793	0	1
A lot	376,841	0.0240287	0.1531385	0	1