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Homework assignment and student achievement in OECD countries∨

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Homework assignment and student achievement in OECD countries*

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Abstract

By using data from 16 OECD countries who participated in TIMSS 2007, this paper analyzes the effect of assigning homework on student achievement. The identification rests on within-student variation in homework across subjects in a sample of students who have the same teacher in both mathematics and science. Unobserved teacher and student characteristics are conditioned out of the model by applying a difference-in-difference approach. We find a modest, but statistically significant effect of homework.

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1 Introduction

Homework is the main intersection between home and school. It is a widespread belief among school leaders, teachers and parents that homework is a valuable educational tool. Assigning homework can be seen as an instrument to rise student effort. The UK government white paper “Excellence in schools” from 1997 advocates the use of homework, and national standards were developed afterwards. Official papers in relation to the US “No child left behind” reform support the recommendations from the National Parent Teacher Association that the amount of homework increases yearly by 10 minutes per night in K-12 education.

The literature on education production functions focuses on inputs such as financial resources and teacher quality. As Betts (1996) points out, this approach has the drawback of treating students simply as intermediate inputs to whom value is ‘added’. However, homework can also be used in order to compensate for low progress, either for the whole class or for a subsample of the students.

Cooper et al. (2006) summarize the US education literature on homework in primary and secondary education, and conclude that homework is positively related to academic achievement, with larger effects at the secondary level than at the primary level. They also conclude that none of the studies reviewed had a well-designed approach. The empirical evidence on the causal effect of homework on student achievement is mainly concentrated to students enrolled in universities in the US (Grove and Wasserman, 2006; Emerson and Mencken, 2010; Grodner and Rupp, 2011).

Assigning homework is a teacher policy. Any study of teacher policies that does not rely on policy interventions might have endogeneity biases. The main challenge is that observed teacher policy is likely to be correlated with unobserved characteristics and the behavior of teachers and students. The present paper attempts to reduce this problem by using an estimation strategy that condition on all teacher and student characteristics that have the same effect on two related subjects; mathematics and science. Moreover, this is also one of the first papers that addresses the causal effect of homework on the achievement of primary school children.[1]

We use data from the Trends in International Mathematics and Science Study (TIMSS) in 2007 for 9 years old students from 16 OECD countries. We exploit that students have the same teacher in mathematics and science, but are assigned different amount of homework in these two subjects. The estimating strategy relies on random relative homework assignment in mathematics and science at the teacher level, given teacher and student characteristics. We investigate the robustness of this assumption in several ways.

It is commonly recognized that homework can have negative effects (Cooper et al., 2006). For example, it can have a negative influence on attitudes toward school. We will estimate average effects, masking negative and positive elements. We also investigate whether the effect of homework is heterogeneous. It is well documented in the literature that better educated parents spend more time helping their children with homework than less educated parents (Guryan et al., 2008; Rønning, 2011). If homework is a substitute for in-school learning, it is particularly likely that the home environment influences the return to homework. To the extent that the home environment is important for whether the homework is completed and perceived or not, children of better educated parents may benefit more from homework than children of less educated parents.

The next section reviews the literature. Section 3 describes the data, Section 4 discusses the empirical approach, while the results are presented in Section 5. Section 6 concludes.

2 Existing literature

Cooper (1989) reviews nearly 120 US educational studies of the effect of homework on student achievement. Studies comparing the achievement of students given homework with the achievement of students without homework tend to find no association in primary education and a positive association in high school. In a follow-up paper, Cooper et al.

[1]Only McMullen and Busscher (2009) look at children in primary school. However, our study differ from their study in the sense that they only condition on student fixed effects and ignore that assigning homework is a teacher policy.

(2006) review US studies from the period 1987-2003. Some studies have investigated the effect of exogenous introduction of homework, but Cooper et al. argue that all these studies suffer from non-random assignments. Most of the cross-sectional analyses rely on student reported time on homework, which is vulnerably to a spurious relationship with achievement. The reported time may be related to unobserved variation in student ability and motivation. In addition, the cross-sectional analyses may be biased due to unobserved characteristics of students and teachers.

The review of the literature by Trautwein and Köller (2003) argues that there is an important distinction between homework assignment by teachers and student effort/time used on homework. One of few papers using non-US data is Trautwein (2007), who find for Germany that homework frequency is more important than the time students use on mathematics homework in a cross-section framework. Using data from TIMSS 2003, Baker et al. (2005) find that teachers in countries with low average student achievement assign more homework than teachers in countries with high achievement, see also Dettmers et al. (2009). Baker et al. (2005) are especially concerned that teachers in the US to a larger degree than teachers in other countries seem to correct the homework and give feedback. Dettmers et al. (2009) use another international comparable achievement test, and find in most countries a positive association between achievement in mathematics and average homework time at the class level as reported by the students.

The small literature in economics which addresses the causal effect of homework is mainly concentrated to students at the university level. Grodner and Rupp (2010) present evidence from a field experiment in which a treatment group of students was required to do homework. They find that the treatment group got significantly better learning outcomes. The novelty of Grodner and Rupp's paper is that they are able to separate between the effect of being assigned homework and the effect of completing homework. By exploiting natural experiments which randomly divided students into different study groups, both Grove and Wasserman (2006) and Emerson and Mencken (2010) find that students in groups with graded homework increased their achievement.

At lower levels, problems related to endogeneity have been addressed by either estimating value-added models or models with student fixed effects. In an unpublished paper, Betts (1996) extends the traditional value-added education production function with hours of homework as reported by teachers using representative US data for students in seventh to eleventh grade. He finds a sizable positive effect of homework. Some studies use data from the US survey National Educational Longitudinal Study of 1988 (NELS) which included 8 graders in the base year, with follow-ups in 1990 and 1992. Eren and Henderson (2008) use data for the tenth grade level in a value-added model. They find that homework assigned by teachers is most effective for high and low achievers.

As Todd and Wolpin (2003) point out, there is a severe potential endogeneity problem in value-added models. Alternative approaches include models with student fixed effects or credible instruments for homework. Aksoy and Link (2000) use a student fixed effects approach on the NELS data, and find strong effects of the time the students report doing homework. McMullen (2010) employ IV estimations using NELS data within a model with student fixed effects. As instruments for student reported homework time he uses the amount of homework assigned by the student's teacher and the student's "locus of control". The latter variable is a composite of answers on statements like "good luck is more important than hard work for success in life". One may wonder whether such opinions also influence how hard the student work in-school. McMullen finds that the IV estimate is almost 20 times larger than the fixed effects estimate.

McMullen and Busscher (2009) study younger students, and is thus more comparable to our study. They use data for students in first to fifth grade from the US survey Early Childhood Longitudinal Study and find no relationship between homework and achievement in pooled regressions. However, in models with student fixed effects, both the time teachers expect their students to spend on homework and the number of times per week the parents report their children worked on homework have positive effects on mathematics and reading achievement.

In a recent paper, Eren and Henderson (2011) exploit that eight grade students in

NELS are tested in two different subjects. They argue that it is possible to include both student fixed effects and teacher fixed effects in the model. It turns out that the effect of assigned homework, given student fixed effects, is extremely sensitive to the inclusion of teacher fixed effects. The results are driven by a large homework effect in mathematics.

There are some attempts to estimate heterogeneous effects of homework in the literature. Both Rønning (2011) and Eren and Henderson (2011) find that only students from higher educated parents benefit from homework. Rønning (2011) also shows that higher educated parents help more with homework than lower educated parents, and suggests that assigning homework can amplify existing inequalities through complementarities with home inputs.

Assigning homework can be interpreted as an attempt to increase student effort. The few explicit analyses of student effort that exist is therefore relevant for the interpretation of the findings in the homework literature, see for example Krohn and O'Connor (2005). However, the results in this literature for K-12 education is mixed, and suffer from the same methodological problems as the homework literature. The few studies that exists with an experimental framework with random assignment seems to be on college students. Stinebrickner and Stinebrickner (2008) exploit that assignment of roommates at Berea College is random, and use whether the roommate has a videogame as an instrument for study effort. They find that the return to effort is large.

Since assigning homework is a teacher policy, this paper is also related to the literature on effective teaching practices. Using NELS, Goldhaber and Brewer (1997) find several variables describing teacher behavior in the classroom to influence student achievement. Machin and McNally (2008) study a highly structured literacy hour that was introduced in English primary schools in the 1990s, and find that the change in teaching method significantly increased literacy skills. Schwerdt and Wuppermann (2009) exploit between-subject variation in lecturing style at eighth grade. They find that traditional lecture type teaching yields higher student achievement than in-class teaching time used for problem solving.

We are not aware of any other paper that use the same identification strategy as in the present paper. Several papers include student fixed effects, but the endogenous respond in teacher behavior is addressed to a smaller extend. When we rely on data where the student has the same teacher in two subjects, we can difference out of the model not only unobserved factors of students and teachers that has a common effect in the two subjects, but also every interaction between the student, the teachers, and the peer group.

3 Data

This paper uses data from the TIMSS (Trends in International Mathematics and Science Study) 2007 database. TIMSS is an international survey conducted by the International Association for the Evaluation of Educational Achievement (IEA). TIMSS samples students enrolled in the two adjacent grades that contain the largest proportion of 9 year olds (3rd/4th graders in most countries) and students enrolled in the two adjacent grades that contain the largest proportion of 13 year olds (7th/8th graders in most countries). The database contains information on student achievement in mathematics and science, as well as background information on the students, teachers, and schools. The student's parents did not participate in the TIMSS survey.

Due to lack of variation in homework for 7th/8th graders we focus on 3rd/4th graders. We also restrict the sample to OECD countries. These are Australia, Austria, Czech Republic, Denmark, England, Germany, Hungary, Italy, Japan, Netherlands, New Zealand, Norway, Scotland, Slovak, Sweden, and USA (in total 16 countries).

In the empirical analysis we drop students with missing information on homework (approximately 30 percent of the sample). As we exploit that a majority of the students in the sample have the same teacher in both mathematics and science, we also drop students who have different teachers in these two subjects and students who are being taught by more than one teacher per subject (additional four percent of the students).[2]

[2]The number of students excluded from the analysis by this procedure varies somewhat across countries. The highest number of students dropped are for the Unites States (55 percent), while no students are dropped in Italy.

Homework

All teachers who participated in TIMSS were asked how often they give homework. By merging the teacher data to the student data, we can identify the students who are assigned homework. Summary statistics are provided in Table 1.

In all countries, almost all students get at least some homework in mathematics. The only exception is the Netherlands where a majority of the students (63.6 percent) never get homework, and those who get homework only get it in some lessons. At the other extreme, in Germany and Hungary more than 90 percent of the students get homework in math in every or almost every lesson. In Australia, New Zealand, Sweden, England and Scotland, assigning homework in some lessons seem to be most common.

There is less cross country-variation in homework in science. Apart from Hungary and Italy, a majority of the students either get homework in some lessons or no lessons.

Student achievement

TIMSS 2007 summarizes student achievement by using Item Response Theory (IRT). The IRT scaling approach makes use of "plausible value" or multiple imputation methodology to obtain proficiency scores in mathematics and science for all the students who participated in the survey. According to the TIMSS 2007 user guide, plausible values are the best available measures of student achievement, and should be used to measure outcomes in studies of student achievement. The plausible values are predictions based on limited information, and are contaminated by some errors. In order to incorporate these errors, the TIMSS database provides five separate plausible values. The correlation between the plausible values range between 0.85 and 0.88. In this paper we use the average of all the plausible values as our measure of student achievement. Regressing homework on each of the five plausible values separately, and then calculating the average of these coefficients (with bootstrapped standard errors) give similar results.

A descriptive overview of the test scores, separately for country and subject, is given in Table 2. The test scores in TIMSS have an international mean of 500 and a stan-

Table 1: Fraction of students who get homework in mathematics and science.

Country	Every or almost every lesson	About half the lessons	Some lessons	Homework not given
		MATHEMATICS		
Australia	16.35	18.63	51.77	13.24
Austria	81.94	15.95	2.11	0.00
Czech Rep	20.75	57.92	21.34	0.00
Denmark	64.59	30.76	4.65	0.00
Germany	92.37	6.50	1.13	0.00
Hungary	93.03	3.47	1.94	1.55
Italy	57.11	17.34	23.42	2.13
Japan	60.56	22.05	15.78	1.62
Netherlands	0.49	2.47	33.43	63.62
New Zealand	14.45	9.62	57.61	18.31
Norway	39.81	39.81	20.22	0.15
Slovak Republic	64.50	23.05	11.70	0.74
Sweden	4.04	12.86	80.98	2.12
United States	75.47	9.94	10.53	4.06
England	1.97	13.91	80.91	3.21
Scotland	8.29	28.38	62.10	1.23
		SCIENCE		
Australia	0.00	0.06	33.79	66.15
Austria	0.60	5.97	93.43	0.00
Czech Rep	2.36	11.46	74.38	11.80
Denmark	0.00	8.22	26.76	65.03
Germany	6.76	30.08	53.02	10.13
Hungary	61.91	24.43	12.63	1.03
Italy	50.85	13.94	24.83	10.38
Japan	0.00	1.11	65.75	33.14
Netherlands	1.98	3.93	27.03	67.06
New Zealand	0.65	1.15	36.66	61.54
Norway	2.19	7.26	43.98	46.56
Slovak Republic	14.79	14.41	57.59	13.22
Sweden	0.82	0.00	52.71	46.47
United States	9.74	15.21	38.33	36.72
England	1.16	4.23	53.55	41.06
Scotland	0.00	1.97	50.61	47.42

Note: Information on homework comes from the teacher questionnaire.

Table 2: Student achievement. Average test scores with standard deviations in parentheses.

	mathematics	science	mathematics-science	Observations
Pooled	514.74	525.39	-10.66	498259
	(76.37)	(75.24)	(38.69)	
Australia	508.79	521.36	-12.57	3247
	(80.92)	(77.30)	(36.02)	
Austria	508.01	526.90	-18.89	2176
	(63.44)	(72.77)	(35.05)	
Czech Republic	487.76	516.79	-29.03	3220
	(66.35)	(70.35)	(31.46)	
Denmark	521.66	515.28	6.38	1850
	(67.46)	(71.51)	(37.45)	
Germany	527.53	529.85	-2.32	2646
	(62.00)	(71.77)	(34.87)	
Hungary	519.26	544.58	-25.32	3602
	(86.15)	(78.60)	(34.88)	
Italy	506.15	534.63	-28.48	4470
	(73.18)	(76.34)	(41.17)	
Japan	571.96	551.19	20.77	3334
	(71.42)	(63.91)	(36.36)	
Netherlands	535.22	523.95	11.26	2878
	(57.54)	(54.63)	(32.12)	
New Zealand	491.74	503.47	-11.74	3211
	(81.75)	(84.10)	(37.98)	
Norway	477.08	479.86	-2.78	3333
	(71.92)	(71.12)	(34.07)	
Slovak Republic	506.50	539.32	-32.82	3110
	(73.53)	(72.37)	(34.28)	
Sweden	510.82	532.49	-21.68	2550
	(60.76)	(65.96)	(34.53)	
United States	527.88	534.30	-6.43	3551
	(72.10)	(79.45)	(36.44)	
England	537.19	537.04	0.15	3804
	(81.97)	(75.71)	(35.54)	
Scotland	497.02	503.28	-6.26	2847
	(75.06)	(71.85)	(33.60)	

dard deviation of 100. Since we exclude non-OECD countries from the analysis, average achievement is slightly larger than the international mean in our sample, and the standard deviation is about 75 in both subjects.

Japan has the highest test score in both mathematics (572) and science (551), whereas Norway has the lowest score in both mathematics (477) and science (480). In most countries, the test score is higher in science than in mathematics, which reflects that non-OECD countries perform better in mathematics than in science relative to the OECD countries. The difference is largest for Slovak Republic, Czech Republic, and Italy.

Control variables

Since parents did not participate in the data collection, information on parental education and income is lacking in the TIMSS database. We will therefore use "number of books at home" and "how often the test language is spoken at home" as measures of students' socio-economic family background. These two variables come from the student questionnaire. As highlighted by among others Ammermueller and Pischke (2009), the number of books at home is highly correlated with parental education and income. In addition, the model includes gender and birth year.

From the teacher questionnaire we have information on teachers' gender, age and education as well as an indicator for class size. Summary statistics are given in Appendix Table A1. The table shows that the mean values of the variables are very similar in our sample (column (1)) as in the whole sample of students in TIMSS (column (2)). The exception is that missing values of teachers are common in the whole sample, but almost non-existent in our regression sample.

4 Empirical approach

This section presents our identification strategy. The following education production function is a useful starting point:

$$y_{injc} = X_{ijc}\beta^x + Z_{jc}\beta^z + hwa_{njc}\beta^A + hwh_{njc}\beta^H + hws_{njc}\beta^S + \beta_n^C C_c + \lambda_i + \eta_j + sw_{njc} + \epsilon_{injc} \quad (1)$$

y_{injc} is achievement of student i in subject n ($n = 1, 2$, where $1 = mathematics$ and $2 = science$) with teacher j in country c. Since it is impossible to separate between the class and the teacher in the TIMSS dataset, subscript j denotes both teacher and class. X_{ijc} is a vector of student characteristics, Z_{jc} is a vector of observed characteristics of the teacher and class, hwa_{njc} is a dummy variable taking the value one if the teacher assigns homework in subject n in all lessons, hwh_{njc} is dummy variable taking the value one if the teacher assigns homework in half of the lessons, hws_{njc} is a dummy variable taking the value one if the teacher assigns homework in some lessons. λ_i represents student fixed effect, η_j represents teacher fixed effect, and C is a vector of dummy variables for each country which are assumed to have different impact across subjects. Finally, the equation includes classwork (in-class learning) in subject n (sw_{njc}). ε_{inj} is a random error term.

Since homework is assigned by the teachers, one would in particular be concerned that homework assignment is related to teacher quality. Poor teachers may assign relatively much homework to compensate for lack of learning in class, which in a model without teacher quality included, would underestimate the effect of homework. It is also possible that high-skilled teachers use homework to achieve ambitious goals, which would overestimate the effect of homework. Equation (1) take such potential biases into account by including teacher fixed effects, and thus arguable represents causal effects.

Another concern is that the amount of homework is related to the ability of the students. Since homework is measured at the class level, the relevant question is whether homework assignment is related to some peer characteristics. To the extent that the ability of students is correlated with the amount of homework, this is taken into account by the student fixed effects in our model. In the data, the student has the same teacher in both mathematics and science. Differencing the model by subtracting y_{i2} from y_{i1} thus effectively condition on both student and teacher fixed effects.

$$y_{i1jc} - y_{i2jc} = \Delta y_{ijc} = \beta^A \triangle hwa^*_{jc} + \beta^H \triangle hwh^*_{jc} + \beta^S \triangle hws^*_{jc} + \beta^C C_c + \triangle sw_{jc} + \triangle \epsilon_{ijc} \quad (2)$$

As there is no information on classwork in the TIMSS data, it is not possible to separate between classwork (sw) and homework (hw) empirically.[3] In our estimations, the error term is $\triangle sw_{jc} + \triangle \epsilon_{ijc}$. If a teacher with poor teaching skills in one of the subject uses homework in a compensatory way, we would underestimate the effect of homework if relative teacher quality is not included in the model. On the other hand, a teacher that find science more interesting than mathematics can both put in relatively more effort in the science class and assign more homework in science, which would imply that we would overestimate the effect of homework.

An important question is thus why teachers vary their relative amount of homework assigned. Our identification assumes that the assignment is random, conditional on the elements in Equation (1). However, the teachers' homework policy may depend on teacher and student characteristics. To the extent that the relevant characteristics are observable, we can condition on them by including X_{ijc} and Z_{jc} in Equation (2). If the estimated effect of homework is sensitive to the inclusion of these characteristics, one would be concerned that the estimates are biased due to other omitted variables.

Biases in the estimated effects of homework in Equation (2) require correlation between omitted variables and homework. An indication for the relevance of such biases is the correlation between the observed student and teacher characteristics and the amount of homework. To investigate this issue we have estimated the following equations: $\Delta hwa_{jc} = X_{ijc}a^x + Z_{jc}a^z + \mathbf{a}^C C_c + \triangle e_{ijc}$, $\Delta hwh_{jc} = X_{ijc}a^x + Z_{jc}a^z + \mathbf{a}^C C_c + \triangle e_{ijc}$ and $\Delta hws_{jc} = X_{ijc}a^x + Z_{jc}a^z + \mathbf{a}^C C_c + \triangle e_{ijc}$.

[3] At the same time we assume that $corr(sw_{j1}, hw_{j2}) = 0$ and $corr(sw_{j2}, hw_{j1}) = 0$ which is not an unreasonable assumption.

The results for the model where $\triangle hwa_{jc}$ is the dependent variable are reported in the first column of Appendix Table A2. Table 3 reports p-values for F-tests on the coefficients a^z and a^x. Regarding the pooled sample for all countries, we cannot reject joint insignificance for all three dummy variables of homework assignment, neither for teacher characteristics nor student characteristics. For the country specific tests, however, the null of no effects is rejected at 5 percent level in about 50 percent of the cases. This implies that one must interpret country specific regressions on the effect of homework on student achievement with care. Notice, however, that there is typically no systematic relationship between homework assignment and student and teacher characteristics. In the US, for example, the significant joint effect of teacher characteristics is solely related to missing teacher information for about 1 percent of the sample.

We will also estimate models with a cardinal measure of homework. At the outset "yes-or-no" answers on surveys are ordinal since there is no explicit scaling. However, in our case, it is fair to assume that "Homework in half of the lessons" involves half as much homework as "Homework in every or almost every lesson". In order to impose a cardinal scale we must also allocate the amount of homework associated with "Homework in some lessons". Since this is less than half of the lessons and more than no lessons, and clearly is assumed to be significantly different from those alternatives, we will impose homework in each fourth lesson. Thus, we create a linear variable for homework (*homework*) which takes the value 1 when homework is assigned in all lessons, 0.5 if homework is assigned in half of the lessons, 0.25 if homework is assigned in some lessons, and 0 if homework is not given.

The relationship between the difference in the cardinal measure of homework between mathematics and science and teacher and student characteristics (i.e the following equation: $\triangle homework_{jc} = X_{ijc}b^x + Z_{jc}b^z + a^C C_c + \triangle e_{ijc}$) is reported in column (2) of Appendix Table A2, whereas the last column of Table 3 reports the p-values for F-test on the coefficients $b^x$and b^z. In the sample including all countries, the p-value on the tests for joint significance is similar for this linear variable as for the dummy variables of

Table 3: F-test of teacher and student characteristics on relative homework assignment

	Every or almost every lesson	About half of the lessons	Some lessons	Linear measure of homework
		Teacher characteristics		
All countries, pooled	0.101	0.529	0.114	0.091
Australia	0.047	0.049	0.070	0.016
Austria	<0.001	0.004	0.110	<0.001
Czech Rep	<0.001	<0.001	<0.001	<0.001
Denmark	0.277	0.659	<0.001	0.097
Germany	0.003	<0.001	<0.001	<0.001
Hungary	<0.001	<0.001	<0.001	<0.001
Italy	0.025	0.217	0.657	0.035
Japan	0.045	0.043	0.246	0.143
Netherlands	0.936	0.342	0.739	0.224
New Zealand	<0.001	0.041	<0.001	<0.001
Norway	<0.001	<0.001	<0.001	<0.001
Slovak Republic	<0.001	<0.001	<0.001	<0.001
Sweden	0.520	0.058	<0.001	<0.001
United States	<0.001	<0.001	<0.001	<0.001
England	0.643	0.070	0.062	0.144
Scotland	0.308	<0.001	<0.001	0.125
		Student characteristics		
All countries, pooled	0.126	0.220	0.941	0.002
Australia	0.270	0.518	0.138	0.002
Austria	0.065	0.054	0.395	0.045
Czech Rep	0.048	<0.001	0.001	0.837
Denmark	0.888	0.674	0.622	0.798
Germany	0.690	0.789	0.696	0.628
Hungary	<0.001	0.001	0.071	<0.001
Italy	0.294	0.270	0.031	0.263
Japan	0.005	0.032	0.001	0.048
Netherlands	0.992	0.740	0.248	0.031
New Zealand	0.008	0.364	0.360	0.113
Norway	0.975	0.033	0.018	0.993
Slovak Republic	<0.001	0.075	<0.001	<0.001
Sweden	0.666	0.125	0.546	0.311
United States	<0.001	0.227	0.678	<0.001
England	0.744	0.082	0.217	0.170
Scotland	0.436	0.002	0.020	0.193

Note: Information on homework comes from the teacher questionnaire.

homework. The student characteristics are, however, jointly significant in this case. As is clear from column (2) of Appendix Table A2, this is due to a highly significant effect of one of the dummy variables for number of books and year of birth.

5 Results

This section starts out by discussing OLS results and compare them with our preferred difference-in-difference estimates. Finally we present some heterogeneity analyses.

5.1 OLS

Results from estimating Equation (1) with OLS, pooling all countries, are presented in Table 4. The point estimates for homework are positive and similar for both mathematics (column 1) and science (column 2), but only statistically significant for science. Students who get homework in all lessons have on average 5-6 test score points higher performance than students who never get homework, that is 7-8 percent of a standard deviation. The last column of Table 4 stacks the data and presents average effects across the two subjects. Student achievement is highest in classes with homework in half of the lessons and lowest in classes which never have homework. The stronger effect of the dummy variable for homework in half of the lessons than on the dummy variable for homework in all lessons indicates that these estimates cannot be given a causal interpretation.

The model includes several measures of student and teacher characteristics. Regarding student characteristics, the results are as expected and in line with the previous literature. Regarding teacher characteristics, student achievement is highest for teachers 40-59 years of age, while teacher gender and teacher education has little impact. The model also includes an indicator for non-small class size. The results show that student achievement is higher in classes with at least 20 students than in smaller classes.

Interestingly, the effects of all control variables are very similar for the two subjects. This indicates that assuming similar responses, as done in the simple difference-in-difference approach, is a reasonable assumption. The variable with clearly different

Table 4: Results from estimating the relation between student achievement and homework by OLS

	Math		Sci		Math and sci	
Homework (no lessons = ref)						
-All lessons	5.4	(3.9)	5.8	(3.0)*	7.7	(2.3)***
-Half of the lessons	5.8	(3.9)	10.0	(2.6)***	9.0	(2.0)***
-Some lessons	1.2	(3.4)	5.9	(1.4)***	5.0	(1.4)***
Math					-16.3	(1.3)***
STUDENT/FAMILY CHARACTERISTICS						
Boy	9.7	(0.6)***	7.5	(0.6)***	8.6	(0.6)***
No of books (one bookcase=ref)						
-No or very few books	-56.6	(1.4)***	-57.3	(1.3)***	-57.0	(1.3)***
-One bookshelf	-24.8	(0.8)***	-24.5	(0.8)***	-24.6	(0.8)***
-Two bookcases	17.3	(0.9)***	17.9	(0.9)***	17.6	(0.9)***
-Three or more bookcases	17.4	(1.2)***	23.2	(1.1)***	20.3	(1.1)***
Test-language spoken at home (always = ref)						
-Almost always	6.2	(1.1)***	0.5	(1.0)	38.7	(1.7)***
-Sometimes or never	-26.9	(1.8)***	-43.9	(1.8)***	-35.4	(1.7)***
Birth year (1996=ref)						
-1995	-47.0	(2.6)***	-42.0	(2.7)***	-44.5	(2.6)***
-1997	-3.6	(0.9)***	-4.7	(0.8)***	-4.1	(0.8)***
-1998	-13.0	(3.2)***	-19.4	(3.2)***	-16.2	(3.1)***
TEACHER/CLASS CHARACTERISTICS						
Female teacher	1.8	(1.7)	2.0	(1.6)	1.9	(1.6)
Teacher's age (25-29=ref)						
-30-39	2.2	(2.1)	1.5	(2.0)	1.9	(2.0)
-40-49	6.3	(2.1)***	6.0	(2.0)***	6.1	(2.0)***
-50-59	7.7	(2.1)***	7.2	(2.0)***	7.4	(2.1)***
-60 or older	3.5	(4.1)	1.8	(3.9)	2.8	(4.0)
Class size (1-19 =ref)						
-20-33+	5.5	(1.6)***	4.2	(1.6)***	4.9	(1.6)***
Teacher's ed (Tert ed. (long), low level=ref)						
-<=Upper secondary	-5.3	(3.2)*	-6.3	(3.1)**	-5.8	(3.1)*
-Tert ed. (short)	-2.8	(2.6)	-2.0	(2.7)	-2.4	(2.6)
-Tert ed. (long), high level	-2.1	(2.3)	-2.5	(2.1)	-2.3	(2.2)
R-square	0.220		0.216		0.221	
Observations	49829		49829		99658	

Note: In addition to reported variables, all model specifications include subject times country specific effects and dummy variables for missing information on control variables. Standard errors are heteroskedasticity robust and clustered at the teacher level . */**/*** denotes statistically significance at the 10/5/1 percent level.

effects is the indicator for test-language spoken only sometimes or never at home. Being a language minority is more detrimental for achievement in science than in mathematics.

As already discussed, the decision to assign homework may be correlated with unobserved variables which also affect student achievement. In order to come closer to the causal effect of homework more elaborated identification strategies must be applied.

5.2 Difference-in-difference approach

In this paper the identification strategy is to eliminate the unobserved student and teacher characteristics by applying the difference-in-difference method as described in Equation (2). To the extent that these characteristics have the same effects on mathematics and science, they are differenced out of the model.

Table 5 starts out by only including teacher fixed effects (column (1)). In addition to dummy variables for homework and country specific effects, this model also includes student characteristics. The results show that assigning more homework in mathematics than in science increases the achievement in mathematics relative to science. Homework in all lessons increases student test scores by 3.2, that is 4.4 percent of a standard deviations. This effect is larger in relative terms since the standard deviation in student achievement in mathematics relative to science is only about 39. Thus, assigning homework in all lessons in mathematics and no lessons in science increases the relative score in mathematics by 8.2 percent of a standard deviation of the difference in test score.

The effect of assigning homework in half of the lessons and in some lessons are smaller as expected, but statistically significant at 1 percent level. If the effect of homework is linear, we would expect to find that the effect of homework in half of the lessons was 50 percent of the effect of homework in all lessons. Our results indicate that the difference is 65 percent, but not significantly larger than 50 percent. Thus, the relative effects of the dummy variables for homework seem reasonable, in contrast to the OLS results in Table 4. The effects estimated are smaller than the OLS results, which indicates than the OLS results are biased upwards by omitted characteristics of the teachers.

Table 5: The effect of assigned homework on student achievement; the difference-in-difference approach

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Homework all lessons	3.2	3.3	2.8				
	(0.8)***	(0.8)***	(0.7)***				
Homework half of the lessons	2.1	2.1	2.0				
	(0.7)***	(0.7)***	(0.7)***				
Homework some lessons	1.3	1.3	1.2				
	(0.5)***	(0.5)***	(0.5)**				
Homework				3.0	3.0	2.5	2.3
				(0.7)***	(0.7)***	(0.7)***	(0.7)***
Homework*No books							1.8
							(1.6)
Teacher fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Student fixed effects	No	Yes	Yes	No	Yes	Yes	Yes
Student characteristics	Yes	No	Yes	Yes	No	Yes	Yes
Teacher characteristics	No	No	Yes	No	No	Yes	Yes
F-test for joint significance, p-value							
- Teacher characteristics	-	-	0.3007	-	-	0.3131	0.3179
- Student characteristics	-	-	<0.001	-	-	<0.001	<0.001
- Country fixed effects	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
R-square	0.1221	0.154	0.173	0.1221	0.154	0.173	0.1726
N	99658	49829	49829	99658	49829	49829	49829

Note: Country fixed effects are also included in all specifications. Standard errors are heteroskedasticity robust and corrected for teacher-level clustering. */**/*** denotes statistically significance at the 10/5/1 percent level.

The model in column (2) also includes student fixed effects. This is the model in Equation (2) above. The results are almost identical to the model with only teacher fixed effects in column (1), which indicate that biased estimates are mainly related to unobserved teacher behavior.[4]

If the approach differences out all relevant factors at the student and teacher level, the estimated effect of homework should not be sensitive to the inclusion of such variables in the first-difference model. In column (3) we allow student and teacher characteristics to have different effects on achievement in mathematics and science. With this change in model formulation, the estimated effects of homework do not change much. The effect of homework in all lessons compared to never homework declines from 3.3 to 2.8, that is 60 percent of the standard error in column (1). The decline is solely due to the inclusion of student characteristics. A model only including teacher characteristics does not change the effect of homework at all.

The lower part of Table 5 presents results for F-tests of joint significance of the control variables. The null hypothesis of no joint effect of teacher characteristics (including class size) can clearly not be rejected. The full model results for the model specification in column (3) are presented in Appendix Table A3. In fact, all teacher characteristics are insignificant at 10 percent level. However, the F-statistics for student characteristics is significant. This indicates that the assumption in Equation (2) that all student characteristics have the same effect on achievement in mathematics and science does not hold in reality. As shown in Appendix Table A3, boys and students from language minorities perform better in mathematics than in science

The final part of Table 5 presents results using our cardinal measure of homework, $\triangle homework_{jc}$. We estimate the following equation:

$$\triangle y_{ijc} = \beta^{hw} \triangle homework_{jc} + \alpha^{C} C_c + e_{ijc} \quad (3)$$

[4]Notice that with the data structure on our sample, it is not possible to include student fixed effects without at the same time implicitly including teacher fixed effects. Since all students have the same teacher in both subjects, differencing across subjects at the student level implies that all teacher effects which are similar in the two subjects also are differenced out of the model.

Equation (3) is clearly a testable simplification of Equation (2). The effect of homework for this model specification are presented in columns (4)-(6) in Table 5. In all cases the simplification is not rejected at 10 percent level.[5] By this approach, the effect of homework is 3.0 in the model without control variables and 2.5 in the model with control variables. The correlations between the control variables and student achievement (measured as the difference between the scores in math and science) resemble the results from specification (3) in Table 5 and Appendix Table A3, and are therefore not reported.

5.3 Heterogeneous effects

Column (7) in Table 5 includes interaction terms between homework and the indicator for whether the family has no or very few books at home. This is the group of students with lowest achievement as is clear from Table 4. The interaction term is positive, indicating that students with the most disadvantage family background gains the most from homework, but the effect is clearly insignificant.

In Table 6 we present results from country-specific estimations. The table only uses the cardinal measure of homework in order to simplify the comparison across countries. The first column presents results for the difference-in-difference model without control variables, the same model specification as in column (5) in Table 5. The effect of homework is positive in 12 of the 16 countries, and the effect is significant at 1 percent level in Australia, Austria, and the US. In the latter countries, the effect of homework is about 11-15 test score points, that is 14-21 percent of a standard deviation in these countries. For most other countries, the estimated effect is in line with the average effect in Table 5. Sweden turns up as an outlier with a negative effect that is significant at 5 percent level.

The model in column (2) in Table 6 includes student and teacher characteristics. This change in specification leaves the estimated effect of homework almost unaltered in all countries. Although the multivariate correlation with homework varies across countries as shown in Table 3, the change in the point estimate is small in every country. The

[5]The p-value on whether the model in column (5) is an allowable simplification of the model in column (2) is 0.42, and the p-value on whether the model in column (6) is an allowable simplification of the model in column (3) is 0.34.

Table 6: Homework and student achievement. Country specific estimates.

	Homework		With interaction terms	
			Homework	Homework*No books
	(1)	(2)	(3)	
Australia	11.3	9.6	9.2	5.4
	(3.4)***	(2.8)***	(3.0)***	(7.4)
Austria	12.9	13.2	12.6	4.4
	(4.9)***	(4.1)***	(4.2)***	(11.4)
Czech Rep	2.9	3.0	3.3	-5.7
	(2.5)	(2.5)	(2.5)	(9.4)
Denmark	5.0	6.1	6.8	-7.6
	(4.4)	(4.5)	(4.7)	(9.5)
Germany	2.9	1.4	2.5	-16.2
	(3.3)	(3.0)	(3.0)	(12.3)
Hungary	-4.2	-2.7	-2.2	-5.5
	(3.4)	(2.8)	(2.8)	(7.5)
Italy	-1.0	-1.1	-0.9	-1.7
	(1.5)	(1.5)	(1.5)	(3.8)
Japan	4.1	3.7	3.1	4.6
	(2.2)*	(2.3)	(2.4)	(4.9)
Netherlands	5.7	4.9	4.5	6.4
	(3.6)	(3.5)	(3.7)	(9.2)
New Zealand	2.2	1.7	0.6	10.5
	(2.7)	(2.5)	(2.7)	(7.0)
Norway	1.8	2.1	2.7	-9.0
	(1.9)	(1.9)	(2.0)	(7.2)
Slovak	-0.4	-0.9	-1.1	3.0
	(2.4)	(2.6)	(2.6)	(5.5)
Sweden	-10.4	-8.7	-9.2	11.5
	(4.4)**	(4.2)**	(4.3)**	(24.7)
United States	15.2	11.8	11.6	1.3
	(2.7)***	(2.4)***	(2.3)***	(5.7)
England	2.8	2.6	3.6	-8.8
	(4.0)	(3.5)	(3.7)	(7.1)
Scotland	5.1	4.8	4.3	5.1
	(3.5)	(3.4)	(3.7)	(10.3)
Controlling for				
-student/fam char	No	Yes	Yes	Yes
-Teacher/class char	No	Yes	Yes	Yes

Note: Results from country specific regressions. The models in column (1), (2) and (3) have the same specification as the models in column (5), (6) and (7) in Table 5, respectively. Standard errors are heteroskedasticity robust and corrected for teacher-level clustering. */**/*** denotes statistically significance at the 10/5/1 percent level.

largest change is for the US, for the which the estimate of homework in all versus none lessons is reduced from 15.2 to 11.8 score points.

The last columns in Table 6 (model (3)) present country specific results for the model which allows the effect of homework to differ between students with no or very few books at home and other students. The interaction effect is positive in nine countries and negative in seven countries. Students in Germany, Norway and England, whose parents have few books, seem to be those who are most hurt by getting homework, whereas students from the same background in Sweden and New Zealand seem to benefit the most from homework. However, in all 16 countries the interaction term is insignificant at 10 percent level.

The existing literature on homework is mainly form the US. To make a more throughout comparison with that literature, Table 7 presents results from different model specifications on the sample of students in the US.

The OLS results are very different for mathematics and science. Whereas homework seems to be negatively related to achievement in mathematics (column (1)), the pattern is less clear for science (column (2)). Only the relation between achievement in science and assigning homework in half of the lessons is statistically significant (and positive). In column (3) which presents average effects across the two subjects, homework is positively correlated with achievement. Also in this case the point estimate of homework in half of the lessons is higher than the point estimate of homework in all lessons (cf. Table 4). These results resemble the previous findings for the US that homework is not significantly related to higher achievement in primary education.

When conditioning on teacher fixed effects, the point estimate of assigning homework becomes larger and statistically significant at one percent level (column (4) and (6)), which is more in line with the existing findings for the secondary level (seventh to eleventh grade) for the US. This suggests a negative correlation between the amount of homework assigned and teacher quality. This result differs from other countries where we found that OLS overestimates the effect of homework. In contrast to other countries, it seems like

Table 7: Results from estimating Equation (1), (2) and (3) for US

	OLS			Diff-in-diff				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Math	Sci	Math and sci					
Homework	-15.3	-0.1	5.8	17.9	13.6			
all lessons	(8.5)*	(9.4)	(6.9)	(2.7)***	(2.4)***			
Homework	-17.2	21.2	13.6	10.7	7.8			
half of the lessons	(9.4)*	(9.9)**	(7.6)*	(2.9)***	(2.5)***			
Homework	-19.7	7.2	5.8	10.0	7.0			
some of the lessons	(11.3)*	(6.5)	(5.2)	(2.0)***	(1.7)***			
Homework						15.3	11.8	11.6
						(2.7)***	(2.4)***	(2.3)***
Homework*No books								1.3
								(5.7)
Controlling for:								
-Teacher fixed effects	No	No	No	Yes	Yes	Yes	Yes	Yes
-Student fixed effects	No	No	No	No	Yes	No	Yes	Yes

Note: N = 3,551 students. Included in all specifications are student and teacher characteristics. Standard errors are heteroskedasticity robust and corrected for class/teacher-level clustering. */**/*** statistically significance at the 10/5/1 percent level.

weak teachers assign more homework in order to compensate for poor teaching skills in the US. On the other hand, in line with the results for all countries, the relative effects of the three dummy variables of homework are meaningful in the difference-in-difference specification in contrast to the OLS specification. The effect of the amount of homework seems reasonable linear.

Finally, columns (5) and (7) in Table 7 include student fixed effects. Including student fixed effects reduces the effect of homework somewhat (about 1.5 standard errors), but the effect of homework is still highly significant and larger than the international average effect. Finally, there seems to be no evidence that pupils with few books at home perform better or worse when homework is assigned in the US.

6 Discussion and concluding remarks

By using data on 3rd/4th graders from 16 OECD countries which participated in TIMSS 2007, this paper analyzes the effect of homework on student achievement. The identification rests on within-student variation in homework in a sample of students who have the same teacher in both mathematics and science. Unobserved teacher and student characteristics are conditioned out of the model by applying a difference-in-difference approach.

Our findings indicate that models which do not take unobserved teacher characteristics into account tend to overestimate the effect of homework. When conditioning on unobserved characteristics of the teachers which are constant across mathematics and science, we find that assigning homework in all lessons compared to never assigning homework increases student test scores by 3.2 points, which is 4.4 percent of a standard deviation. This estimate is not sensitive to the inclusion of student fixed effects. The effect of assigning homework is largest in the US, Austria and Australia where it amounts to about 14-21 percent of a standard deviation. For most other countries we find an effect of homework of about the same magnitude as the average effect. It may be the case that the effect of homework depends on educational institutions. Why the effect of homework seems to vary across countries will be an interesting research avenue.

With survey data, it is not possible to distinguish between the importance of homework and classwork. To the extent that homework is correlated with unobserved classwork, it will be a part of the effect of homework estimated. Teachers assigning relatively more homework in mathematics than in science may also have different degrees of classwork in the two subjects. We cannot rule out that teachers who assign relatively much homework in mathematics also are able to pursue efficient in-class learning, although it seems most likely that the correlation between homework and classwork is negative. In that case we underestimate the pure effect of homework. One obvious fruitful avenue of further research is field experiments with random assignment of homework. However, also in that case it will be a challenge to keep classwork constant in a credible way.

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Appendix

Table A1: Control variables, summary statistics. Reported are percentages

	(1)	(2)
	Our sample	Full sample
PUPIL/FAMILY CHARACTERISTICS		
Number of books at home		
- *No or very few books*	9.43	9.52
- *One bookshelf*	22.94	22.82
- *One bookcase*	34.40	34.40
- *Two bookcases*	16.78	16.67
- *Three or more bookcases*	13.85	13.80
- *Missing information*	2.60	2.79
How often test language is spoken at home		
- *Always*	78.03	76.54
- *Almost always*	12.96	13.51
- *Sometimes or never*	7.21	7.99
- *Missing information*	1.80	1.97
Birth year		
- *<=1995*	2.47	2.82
- *1996*	43.69	45.92
- *1997*	52.39	50.05
- *>=1998*	1.44	1.21
- *Missing information*	0.01	0.01
Gender		
- *Girl*	49.05	48.98
- *Boy*	49.64	49.60
- *Missing information*	1.31	1.42
TEACHER/CLASS CHARACTERISTICS		
Teachers' gender		
- *Female*	81.77	78.03
- *Male*	17.94	17.29
- *Missing information*	0.29	3.68
Teacher's age		
- *25-29*	14.82	13.82
- *30-39*	24.42	24.00
- *40-49*	27.92	26.77
- *50-59*	28.48	27.66
- *60 or older*	3.90	3.93
- *Missing information*	0.45	3.84
Teacher's education (based on isced codes)		
- *Upper secondary or less*	9.26	6.88
- *Tertiary education, short**	10.37	12.01
- *Tertiary education (long), lower level***	47.62	46.30
- *Tertiary education (long), higher level****	23.75	24.31
- *Missing information*	9.00	10.50
Class size		
Math		
- *1-19 pupils*	19.02	15.87
- *20-33+ pupils*	77.65	61.38
- *Missing information*	3.32	22.75
Science		
- *1-19 pupils*	18.40	15.87
- *20-33+ pupils*	78.56	61.38
- *Missing information*	3.04	22.75
N pupils	49,829	73,103

Note: The data on family background comes from the pupil questionnaire, whereas the information on

Table A2: The relation between differences in homework assignment across subjects and student and teacher characteristics.$\triangle hwa_{jc}$ $\triangle homework_{jc}$

Dependent variable	$\triangle hwa_{jc}$		$\triangle homework_{jc}$	
	Coeff	St.error	Coeff	St.error
	(1)		(2)	
TEACHER/CLASS CHARACTERISTICS				
Female teacher	-0.003	(0.022)	-0.005	(0.017)
Teacher's age (25-29=ref)				
-30-39	0.007	(0.026)	-0.012	(0.020)
-40-49	-0.026	(0.027)	-0.024	(0.020)
-50-59	-0.036	(0.027)	-0.040	(0.021)*
-60 or older	0.074	(0.047)	0.036	(0.037)
Class size (1-19 =ref)				
-20-33+	0.024	(0.020)	0.017	(0.015)
Teacher's ed (Tert ed (long), low level=ref)				
-Upper sec or less	0.042	(0.054)	0.031	(0.040)
-Tert ed (short)	-0.059	(0.030)**	-0.048	(0.024)**
-Tert ed (long), high level	-0.015	(0.023)	-0.008	(0.019)
PUPIL/FAMILY CHARACTERISTICS				
Boy	-0.003	(0.004)	-0.005	(0.003)*
No of books (one bookcase=ref)				
-No or very few books	0.000	(0.009)	0.008	(0.007)
-One bookshelf	0.003	(0.006)	0.002	(0.005)
-Two bookcases	-0.009	(0.006)	-0.014	(0.005)***
-Three or more bookcases	-0.009	(0.008)	-0.005	(0.006)
Test-language spoken at home (always = ref)				
-Almost always	-0.018	(0.012)	-0.017	(0.009)*
-Sometimes or never	0.032	(0.013)**	0.025	(0.010)**
Birth year (1996=ref)				
-1995	-0.018	(0.017)	-0.019	(0.011)*
-1997	0.012	(0.006)*	0.013	(0.005)***
-1998	0.080	(0.035)**	0.050	(0.027)*
R-square	0.2980		0.3039	

Note: N = 49,829. A constant term, country fixed effects and dummy variables for missing information on control variables are included in all specifications. Standard errors are heteroscedasticity robust and corrected for teacher-level clustering. */**/*** statistically significance at the 10/5/1 percent level.

Table A3: Table 5 con't. The relation between observed student and teacher characteristics.

	(3)	
STUDENT/FAMILY CHARACTERISTICS		
Boy	2.2	(0.3)***
No of books (one bookcase=ref)		
-No or very few books	0.8	(0.7)
-One bookshelf	-0.2	(0.4)
-Two bookcases	-0.7	(0.5)
-Three or more bookcases	-5.8	(0.5)***
Test-language spoken at home (always = ref)		
-Almost always	-11.3	(0.8)***
-Sometimes or never	17.0	(0.8)***
Birth year (1996=ref)		
-1995	-5.2	(1.1)***
-1997	1.2	(0.4)***
-1998	6.7	(1.5)***
TEACHER/CLASS CHARACTERISTICS		
Female teacher	-0.2	(0.6)
Teacher's age (25-29=ref)		
-30-39	0.5	(0.7)
-40-49	0.3	(0.7)
-50-59	0.5	(0.7)
-60 or older	1.8	(1.1)
Class size (1-19 =ref)		
-20-33+	0.8	(0.5)
Teacher's ed (Tert ed. (long), low level=ref)		
-<=Upper secondary	1.0	(1.0)
-Tert ed. (short)	-1.0	(0.8)
-Tert ed. (long), high level	0.5	(0.7)