Study Time and Scholarly Achievement in PISA*

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Abstract

We take a different look at the PISA 2006 data set considering time input as the main ingredient for scholarly achievement. Across countries, absolute time spent studying is negatively related to scholarly achievement, while a larger fraction of total study time spent in the classroom is associated to better performance. However, at the country level more total study time (class time plus homework time) is associated to better performance. When considering different groups of students, this positive relationship between time input and scholarly achievement breaks down. In particular girls and students with a migratory background spend more time in class rooms and doing homework but perform worse. We estimate a non-linear production function for education which allows us to consider marginal rates of substitution among various input factors for the production of education: different time inputs, family characteristics, and aspects of school environment. We find that compensating for less class time or lower socio-economic background by individual study time, is enormously time-costly or even impossible for students in Spain, as well as for students in the three best and the three worst performing OECD countries. Our results also show that in particular additional hours of class time rather than more teachers or better-equipped schools can compensate for a less advantageous family background.

JEL classification: I21, I21, Z13
Keywords: PISA, time input, effort, scholarly achievement, family background, school environment, complements, substitutes

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1 Introduction

Various international programs for assessing educational systems (TIMMS - Trends in International Mathematics and Science Study, PISA -Programme for International Student Assessment, etc.) have shown that countries that spend similar amounts on education do very differently in terms of educating their young generations. This is important given that as Hanushek and Woessmann [2010] point out, there exists a positive relation between trend economic growth and trend in scholarly achievement. In this sense, Spain's performance gives reason to worry. Despite the fact that Spain's expenditure in primary and secondary education is very similar to the OECD average, the performance of Spanish students in all PISA studies has been below average (see OECD [2010], OECD [2007], OECD [2004a] y OECD [2004b]).[1] However, expenditure is just one of many possible ingredients into the production of education. This papers focuses on time spent studying as the main ingredient to learning and educational outcomes. We present an empirical cross-country study using data from the "Program for International Student Assessment" (PISA) that jointly analyzes students' study time, possible interdependencies with aspects of the students' school environment and family background, and their effects on scholarly achievement. For our analysis we focus on seven OECD countries, Spain, the three best performing countries (Finland, Canada, and Korea), and the three lowest ranked countries (Mexico, Greece, and Turkey). Considering descriptive statistics on time spent studying by students in these countries and different groups of students in particular we attempt to establish a relation between time input and scholarly achievement. In a second step we estimate a non-linear production function for education in order to be able to consider possible effects of substitution between time and other inputs to education. The current paper thus contributes to a better understanding of one of the key determinants for scholarly achievement: individual student effort measured as individual student study time. Our results allow us to address questions like: Does more study time always lead to better scholarly achievement or are there decreasing returns to scale in effort? Do better-off students, in terms of family background and/or school environment, exert more or less effort?; and Can students compensate for less advantageous school environments or socio-economic backgrounds by exerting more individual effort?.

Since the pioneering work of Schultz [1960], Becker [1962], and Ben-Porath [1967] who first formulated a production function of education with time as the central input factor, there have been important advances in the theory of the production of education.[2] Apart

[1] In 2008, Spain and all average OECD member countries spent 46.1% and 46.4% respectively of their GDP per capita per on each primary and secondary student, Worldbank [2011].

[2] While all three authors' main focus is on college education and the opportunity costs of studying in terms of forgone earnings, the notion of study time as a key input to the production of education is easily

from considering individual student effort as key to scholarly achievement these advances have suggested interdependencies of effort with aspects of family background and school environment. Considering the latter for instance, Correa and Gruver [1987] analyze the interplay between teachers and students in a game-theoretical framework. More recently, De Fraja and Landeras [2006] show that an increase in incentives and in the efficiency in competition among schools can result in a decrease in effort by students. On the other hand, on the relation between effort and family background, Lin and Lai [1996] propose a simple economic model and find that if leisure is a normal good and students are paid monetary rewards for their achievement, those from better-off family backgrounds exert less effort. Landeras [2010] shows that the way individual effort and family background interact, is related to the student's degree of risk aversion. In Albornoz et al [2011] effort exerted by students, parents, and teachers is increasing in the average ability in the class room.

However, while effort and time spent studying has been a centerpiece of many theoretical papers on education, a large part of the empirical literature has ignored the relationship between time input and achievement in education. Instead, the focus has been on the direct influence of aspects of school environment on scholarly achievement. Numerous studies have compared teacher-student ratios, the way schools are funded, competition among schools, different pedagogical methods, class size, etc. in order to explain differences in scholarly achievement. Evidence on the effects of most of these variables is mixed. Studying the relation between class size and scholarly achievement for instance, Bressoux et al [2004] and Angrist and Lavy [1999] find that larger class size affects educational outcomes clearly negatively while Woessmann and Fuchs [2008] or Anghel and Cabrales [2010] do not find any strong effects. Results in Rivkin et al [2005] seem to indicate the importance of teachers' quality rather than class size for educational outcomes. Gibbons et al [2008] on the other hand consider the effect of competition among schools on scholarly achievement and find it to be neglectably small, while Hoxby [2000] estimates it to be positive and significant. The fact that these and many other empirical studies do not take into account time input to studying is to a great extent due to data limitations. In the TIMSS study for instance, teachers instead of students report information about homework time, turning the variable homework time into an estimate by teachers of the time needed for homework assigned, rather than a measure of study time by students.[3]

extended to any type of education, by interpreting forgone leisure as opportunity cost (see Costrell [1994] for a model of education standards where the production function for education is a negative function of the student's utility).

[3]Eren and Henderson [2011] use such a measure and find a positive effect of amount of assigned maths homework on students' maths test scores.

As a result, there are only few empirical studies in the economics literature that measure effort and estimate its effect on aspects of scholarly achievement. Examples are Bonesrønning ([2004] who finds that for Norwegian secondary schools parental effort in education decreases as student's class size increase, making the two complementary inputs to education. Cooley [2010] estimates how peers' effort and achievement influence student's scholarly performance. The paper by De Fraja et al. [2010] provides a theoretical model of effort by students, parents and schools. The authors then test their model empirically for British data and find parents' effort to be more decisive for student's achievement than students' own effort or schools' effort. Stinebrickner and Stinebrickner [2008] consider data for college students and find that more study time can make up for lower ability, measured by scores in college entrance exams.[4]

The last part of the current paper that provides an estimation of a non-linear production function of education is closely related to Polacheck et al [1978] and Coates [2003] who take into account time spent studying and instructional time respectively. Both works provide estimations of non-linear production functions of education that allow for interactions among different input factors for education. Polacheck et al [1978] propose a production function for education of the CPES type ('constant partial elasticity of substitution') and estimating marginal rates of substitution between class time, individual study time, and ability for college students they find that less able students can compensate for their disadvantages by spending more time studying. Coates [2003] performs a similar exercise for public school students in Illinois and his results show that the magnitude of the positive effects of instructional time on educational outcomes are very much dependent on class size.[5]

Our paper is also related to the empirical literature that uses data from the "Progam for International Student Assessment" (PISA) to explain differences in educational outcomes. Using data from PISA 2000, Fuchs and Wößmann [2007] estimate a linear education production function for the sample of all participating countries and find that in particular institutional factors of a country's educational system can account for differences in a student's performance. Regarding the below-average performance in PISA of Spanish students, Ciccone and Garcia-Fontes [2008] find that while migration patterns

[4]In the sociology and education science literature these types of studies are more abundant. Examples here are Fan and Chen [2001] who analyze the role of parents' effort on scholarly achievement or Trautwein [2007] who finds a positive relationship between homework and scholarly achievement. The author points out that frequency and difficulty of homework are more important than mere time spent on homework.

[5]Others who provide estimations of non-linear production function of education and interaction effects among input factors are Figlio [1999] and Baker[2001].

have no explanatory power, average low parental education of Spanish students is partly responsible for this result. Among those that include the variable individual study time in country-regressions or cross-country studies, are de Bortoli and Cresswell [2004] who compare PISA 2000 results for Aborigines and Non-Aborigines students in Australia and find a positive relationship between time spent doing homework and scholarly achievement for both groups, with Aborigine students obtaining worse results that are partly due to fewer hours of homework. Another analysis of the PISA 2000 results for New Zealand points out the possibility of decreasing returns to scale for time spent doing homework, given similar outcomes for those spending a moderate amount of time doing homework and those spending a lot of time. However, as the study also states, this result could also be due to differences in unobserved ability among students (Ministry of Education, New Zealand [2002]). Looking at Canadian PISA data, Frempong and Ma [2006] confirm the positive relationship between time spent doing homework and scholarly achievement, while Looker and Thiessen [2004] establish a positive relationship between homework time and students' future aspirations. Findings by the OECD [2008] quantify the positive relationship between homework time and scholarly achievement at a 3.1 percentage points higher PISA score in science for students at schools with one extra hour of science homework per week. Among the few comparative analysis are Kotte et al [2005] who reject the hypothesis that differences in scholarly achievement between Spanish and German students can be explained by differences in time spent doing homework. Rindermann and Ceci [2009] analyze results of the first three PISA studies and find that across countries individual student effort is negatively related to scholarly achievement. The authors thus propose two distinct interpretations of student effort: i) on the individual level where homework time has a positive effect on cognitive growth, and ii) on the country level where a lot of homework time indicates low quality of educational institutions that instead of internalizing, delegate an important part of the learning process towards parents and students. Closely related to the current paper is Lavy [2010] who considers PISA 2006 data and focuses on time spent in class rooms to explain differences in educational outcomes across countries. Using information on instructional time per subject and PISA scores for each subject the author performs within-student estimations and finds the effect of one additional hour of class time to be significantly positive and to be larger in developed than in developing countries. Different from the current paper however, the author does not consider time spent studying outside the classroom.

Hence, to the best of our knowledge, the current paper is the first one to focus on students' individual effort as a central input factor to scholarly achievement and to employ PISA 2006 data to empirically test advances in the theoretical literature regarding the interdependencies of effort with aspects of family background and school environment. The remaining of the paper is organized as follows. We first present briefly the PISA

2006 data set and provide some descriptive statistics for the seven countries considered. Section 3 presents an analysis of students' individual effort and its interdependencies with various aspects of family background and school environment. In Section 4 we estimate a non-linear production function for education and marginal rates of substitution among different input factors for the production of education. Section 5 concludes.

2 Data: PISA 2006

For our analysis we use data from the "Progam for International Student Assessment" (PISA), administered by the OECD. PISA tests samples of around 4,000 to 30,0000 students of age 15 (independently of the grade they are in) in all OECD countries, as well as a couple of non-OECD countries. Up to now, PISA has been carried out four times, in 2000, 2003, 2006, and 2009. Test subjects are reading, maths, and science, with each PISA wave paying particular attention to one of these subjects. Thirteen different booklets containing different combinations of these three subjects are designed and assigned randomly to approximately 35 students in selected representative schools.[6] The test lasts for two hours. In addition, PISA administers individual student questionnaires, school questionnaires, and in some countries parent questionnaires gathering information not only on students' performance but also on their study habits, interests, family background, and school environment.

It is important to note that PISA scores are estimated values, so called, plausible values, that contain students' test scores as well as background information from questionnaires. These scores are meant to reflect the distribution of students' performance in a country rather than a student's individual performance.[7] Regarding the distribution of students' performance, PISA defines six levels of proficiency: low, moderate, strong and top, for each subject. These categories are thought to reflect a student's literacy in maths, science, and reading. While, the first three PISA reports (2000, 2003, and 2006) all include the variable time spent studying reported by students, in particular, PISA 2006 clearly differentiates between class time, individual study time (doing homework), and private lessons for each subject. That is why we focus on data from PISA 2006 for our analysis. We restrict our attention to results from seven of the fifty-six countries that carried out PISA 2006: Spain, as well as the three best (Korea, Finland, Canada) and the three worst per-

[6] Note that this implies that not all students are tested in all three subjects.

[7] For each student and each subject PISA reports five plausible values (PVs) which implies that any equation of interest has to be estimated five times and weighted means of coefficients have to be obtained (see OECD [2009a] for the exact description on the technical procedure involved).

forming OECD countries (Mexico, Greece, Turkey). Apart from time spent studying we also consider students' individual characteristics as gender and migrant status. As information on students' parental background we use highest parental occupation and PISA's index of economic, social, and cultural status (ESCS-Index) that combines information on parental occupation, education, wealth, educational resources, and possessions.[8] The school characteristics we take into account in our analysis are student-teacher ratios, computers per 100 students, and schools' ownership (private vs. public). In addition part of our analysis considers low and top achievers separately. Table 2.1 provides descriptive statistics from PISA 2006 for these variables for the seven countries considered as well as the number of students in the sample.[9]

More than two-hundred thousand students across 30 OECD countries participated in PISA 2006. In Finland, Korea, Turkey, and Greece around 4,000-5,000 students participated while Spain, Canada, and Mexico had around 20,000 to 30,000 students participating. Regarding the performance of students across these countries, Finish students did best in maths and science, while Korean students ranked first in reading and second in maths. Canadian students came second in maths and third in reading. Mexican students were ranked last in all subjects, while Turkey and Greece came in 29th and 28th respectively. The time that students spent studying, in class, at home, or in private lessons varied across countries. While Finish students spent around 14 hours per week in class, Korean students spent on average 3 hours more per week in a class room. Around half of all students in the samples of all seven countries considered were girls. On the other hand, the fraction of first or second generation immigrants among students varied strongly across countries. While in Canada, Greece, and Spain between 21% and 7-9% of students had a migratory background, in Finland, Turkey, Korea, and Mexico this was the case for less than 2% of students. Considering students' parental background, more students in Spain, Turkey, and Mexico had parents with blue collar occupations compared to students in Korea and Canada. This is also reflected in the value of the ESCS-index, positive in Korea and Canada while negative in all other countries. School environments also differ across countries, with private schools being more important in Spain, Korea and Mexico compared to Finland, Turkey, or Greece.

[8]The index contains information about parental occupation measured using the International Socio-Economic Index of Occupational Status (ISEI), highest level of education among parents measured in years of schooling, an index of family wealth, an index of educational resources at home as well as an index containing information "classical culture" possessions. The index is standardized such as to have mean zero and standard deviation one for all OECD countries combined.

[9]This number corresponds to the number of participating students less those excluded for non-eligibility, physical, mental, or linguistic reasons. For the countries considered here exclusion percentages are less than 1% in Turkey, Mexico, Korea, around 1.3% in Greece, 2.8% in Spain and Finland and 7.4% in Canada.

Table 2.1: Descriptive Statistics PISA 2006: Weighted Means

Countries:	Spain	Finland	Korea	Canada	Mean OECD	Mexico	Turkey	Greece
Number of Students	19,047	4,579	5,172	20,965	242,402*	30,922	4,941	4,808
Mean Score								
[Rank among 30 OECD countries]								
Maths	484 [24]	548 [1]	547 [2]	527 [5]	484	406 [30]	424 [29]	459 [28]
Science	488 [23]	563 [1]	522 [7]	534 [2]	491	410 [30]	424 [29]	473 [28]
Reading	461 [26]	547 [2]	556 [1]	527 [3]	484	410 [30]	447 [29]	460 [28]
Average Study Time								
Class	13.6	14.2	16.5	17.3	14.8	14.5	14.8	13.1
Homework		7.8	5.2	7.1	7.3	8.5	8.6	7.8
Private Lessons	3.0	1.8	6.2	3.5	3.8	4.5	7.2	7.8
Individual Characteristics								
Girls	0.49	0.50	0.49	0.50	0.50	0.52	0.45	0.50
Immigrants								
1st or 2nd generation	0.07	0.02	$\simeq 0$	0.21	0.09	0.02	0.01	0.08
Parental Background								
High White Collar	0.40	0.56	0.68	0.67	0.54	0.33	0.36	0.54
Low White Collar	0.26	0.27	0.18	0.22	0.25	0.22	0.16	0.19
High Blue Collar	0.23	0.11	0.09	0.06	0.13	0.24	0.36	0.17
Low Blue Collar	0.10	0.05	0.05	0.06	0.08	0.21	0.13	0.11
ESCS-Index	-0.31	0.26	-0.01	0.37	-0.10	-0.99	-1.28	-0.15
School Environment								
Private Schools	35.4%	3.0%	46.4%	7.3%	17.1%	15.0%	2.3%	5.2%
Student-Teacher Ratio	12.4	11.3	16.3	16.7	13.4	27.1	18.5	8.9
Computers per 100 students	10	15	19	18	15	7	5	8
Proficiency Levels								
Low achievers								
Maths	24.7%	5.9%	8.8%	10.8%	21.3%	56.5%	52.1%	32.3%
Science	19.6%	4.1%	10.0%	11.3%	19.3%	51%	46.6%	24.1%
Reading	55.3%	20.4%	28.9%	18.2%	43.8%	76.2%	63.4%	54.1%
Top achievers								
Maths	7.3%	24.4%	27.1%	18.0%	13.3%	0.9%	4.2%	5.1%
Science	4.8%	20.9%	10.3%	14.4%	9.0%	0.3%	0.9%	3.4%
Reading	1.8%	16.7%	21.7%	14.5%	8.6%	0.6%	2.1%	3.5%

*Total OECD.

The average student-teacher ratio was lowest in Greece with only 9 students per teacher, and highest in Mexico with an average of more than 27 students per teacher. Canadian and Korean schools tended to be best equipped with computers while schools in Turkey reported clearly fewer computers per student. Top and low achievers were distributed differently across countries and subjects, however their distribution was very much related to a country's average PISA score. Countries ranked highest tended to have a larger fraction of their students among the group of top achievers and only few students within the group of low achiever.

2.1 Time Input to Education

Citing Ben-Ponrath [1967] " It is hard to think of forms of human capital that the individual can acquire as final goods-he has to participate in the creation of his human capital." (p.352); How much time do 15 years old spend creating their human capital? For our analysis of students' individual time input we distinguish between time in class, time spent doing homework and private lessons and consider separately the effect each has on scholarly achievement. Table 2.2 contains country means of absolute values and fractions of weekly study time spent in class, doing homework, and receiving private lessons for each of the three subjects. Across countries, there does not seem to be a clear relationship between total study time and scholarly achievement. While in Spain students spend on average a total of around 6 hours and 25 minutes per week studying mathematics, in some countries with better scholarly achievement students spend more time studying (Korea and Canada) while in others (Finland) they spend less time. On the other hand, students in the three worst ranked OECD countries (Mexico, Turkey, and Greece) spend more time studying math, science, and reading than students from better performing countries.[10] When taking into account information on school weeks per year and thus considering average instruction times per year, the picture does not change. There is no clear relationship between instruction time per year and scholarly achievement across countries. Compared to Spanish students, students in Finland receive less hours of total class time, but do receive more science lessons in a year. On the other hand, Korean students spend more total time in class rooms, but receive less reading and maths classes compared to Spanish students, while students in worst ranked countries like Mexico and Greece receive more total instruction time, as well as more maths, science, and reading classes (see Table A-1.1 of the Appendix A-1).

[10]We also consider statistics for the average OECD. These are derived using national student weights and considering the OECD one big country; alternatively one could simply use an un-weighted mean across all countries, giving the same weight to each country independent of its size.

Table 2.2: Average Study Time

	Weekly hours dedicated to: (% of total study time):			
	Class	Homework	Private Lessons	Total
Mathematics				
Spain	3.42 (58%)	1.92 (30%)	0.99 (13%)	6.41
Finland	3.45 (71%)	1.20 (23%)	0.37 (6%)	5.02
Korea	4.70 (57%)	2.31 (22%)	2.28 (21%)	9.32
Canada	4.50 (63%)	1.97 (26%)	0.94 (11%)	7.45
Mean OECD	3.89 (57%)	1.97 (29%)	1.07 (16%)	6.83
Mexico	3.95 (55%)	2.26 (32%)	1.18 (14%)	7.35
Turkey	3.82 (51%)	2.31 (32%)	2.08 (27%)	8.17
Greece	3.45 (49%)	2.01 (25%)	2.23 (26%)	7.71
Science				
Spain	3.12 (59%)	1.74 (31%)	0.68 (11%)	5.56
Finland	3.13 (71%)	1.07 (23%)	0.32 (6%)	4.52
Korea	3.58 (67%)	1.22 (19%)	1.02 (14%)	5.84
Canada	4.00 (66%)	1.55 (26%)	0.55 (9%)	6.13
Mean OECD	3.21 (60%)	1.56 (29%)	0.70 (13%)	5.37
Mexico	3.16 (49%)	2.12 (37%)	1.01 (15%)	6.24
Turkey	2.86 (51%)	1.64 (28%)	1.35 (21%)	5.81
Greece	3.18 (48%)	1.85 (26%)	1.99 (26%)	7.02
Reading				
Spain	3.60 (61%)	1.89 (27%)	0.58 (12%)	6.10
Finland	3.13 (71%)	1.14 (23%)	0.36 (6%)	4.63
Korea	4.48 (66%)	1.40 (17%)	1.45 (17%)	7.34
Canada	4.43 (66%)	1.74 (24%)	0.87 (11%)	7.06
Mean OECD	3.84 (60%)	1.78 (28%)	0.92 (14%)	6.44
Mexico	3.73 (55%)	2.06 (31%)	1.10 (15%)	6.87
Turkey	3.99 (55%)	2.18(26%)	1.81 (20%)	7.96
Greece	3.18 (51%)	1.94 (28%)	1.63 (22%)	6.75

However, when instead we take a look at how students divide their total study time among class time, homework time, and private lessons, students in better performing countries seem to spend on average more of their total study time in the classroom and less doing homework or receiving private lessons. Among all OECD countries, students from countries ranked above average in all three subjects spend less total time studying, they receive fewer private lessons and spend less time doing homework. However, these students spend more time in the classroom and hence allocate a larger fraction of their study time to time in class and a smaller fraction of time to private lessons compared to students from other countries. Korea, one of the best-ranked countries according to PISA 2006, is an exception as Korean students spend a large amount of time in private lessons. Hence, our observation regarding less time spent doing homework by students in better ranked countries is in line with findings by Rindermann and Ceci [2009] who report a negative cross-country correlation of -.22 between average time spent doing homework and PISA test scores.

On the other hand, at the country level we observe a clear positive relationship between scholarly achievement and time input (see Table 2.3). This might be due to i) more hours studying leading to better achievement or ii) more able students being more productive studying and thus spending more time doing so. However, differentiating among the three types of time inputs reveals a negative relationship between hours of private lessons and achievement except for Korea and Greece, and for Turkey in maths and science.[11] This finding could be explained by the fact that in most countries students of low ability attend private lessons more frequently than high ability students. Class time and scholarly achievement and time spent doing homework and scholarly achievement are positively correlated in all countries, with correlations ranging from .09 to .43 and .01 to .26 respectively.

When grouping students at the country level into low, moderate, strong, and top achievers, we observe that top achievers spend more time studying (doing homework) than any other group of achievers.[12] Table 2.4 shows an increasing function of belonging to one of the four groups and spending time studying or being in class. However, there are some exceptions. In Canada strong achievers spend more time doing maths homework than top achievers and low achievers spend more time on their reading assignments than moderate achievers. In Finland moderate achievers instead of low achievers spend the least time on science and reading assignments.

[11] Among all remaining OECD countries correlations between hours of private lessons and achievement are negative with the only two exceptions being the Slovak Republic (positive for all subjects) and Japan (zero correlation for mathematics).

[12] We adopt the classification of students into these four groups from the PISA study, see OECD (2009) for the details.

Table 2.3: PISA 2006: Correlations between Study Time and PISA Scores

	Correlation PISA test score and weekly hours dedicated to:			
	Class	Homework	Private Lessons	Total time
Mathematics				
Spain	0.21	0.11	-0.16	0.10
Finland	0.15	0.02	-0.17	0.05
Korea	0.31	0.41	0.33	0.48
Canada	0.20	0.04	-0.18	0.08
Mean OECD	0.26	0.07	-0.11	0.13
Mexico	0.26	0.03	-0.12	0.14
Turkey	0.35	0.23	0.24	0.35
Greece	0.28	0.14	0.18	0.26
Science				
Spain	0.36	0.21	-0.13	0.27
Finland	0.30	0.09	-0.16	0.20
Korea	0.24	0.25	0.19	0.32
Canada	0.28	0.12	-0.12	0.20
Mean OECD	0.30	0.06	-0.13	0.17
Mexico	0.09	0.01	-0.17	0.03
Turkey	0.43	0.26	0.29	0.41
Greece	0.43	0.13	0.17	0.33
Reading				
Spain	0.23	0.10	-0.27	0.08
Finland	0.15	0.10	-0.16	0.08
Korea	0.26	0.22	0.20	0.33
Canada	0.20	0.08	-0.16	0.10
Mean OECD	-0.06	0.03	0.08	0.01
Mexico	0.20	0.01	-0.17	0.08
Turkey	0.23	-0.01	-0.03	0.09
Greece	0.29	0.08	0.04	0.19

Table 2.4: PISA 2006: Study Time and Proficiency Level

	Weekly hours dedicated to homework/class: according to type of achiever			
Mathematics	Low (< 420)	Moderate (420-544)	Strong(545-606)	Top(> 607)
Spain	1.67/2.97	2.02/3.48	2.13/3.70	2.14/ 3.79
Finland	1.17/2.83	1.17/3.33	1.23/3.55	1.24/3.67
Korea	1.01/3.45	1.71/4.50	2.50/4.97	3.42/ 5.11
Canada	1.77/3.51	1.96/4.39	2.08/4.75	2.01/4.98
Mean OECD	1.84/3.18	1.93/3.96	1.97/ 4.37	2.26/4.52
Mexico	2.20/3.49	2.33/4.44	2.40/4.94	2.48/5.15
Turkey	1.93/3.22	2.58/4.29	3.13/4.93	3.20/5.19
Greece	1.77/ 2.86	1.99/3.58	2.36/4.04	2.76/4.35
Science	Low (< 409)	Moderate (409-558)	Strong(559-632)	Top(> 632)
Spain	1.34/2.23	1.65/2.95	2.21/4.05	2.52/4.86
Finland	1.08/ 2.15	0.99/2.74	1.09/3.31	1.21/ 3.79
Korea	0.72/2.84	1.07/ 3.50	1.49/3.89	1.84/3.98
Canada	1.21/2.71	1.47/3.73	1.69/4.41	1.79/4.89
Mean OECD	1.45/ 2.35	1.52/3.13	1.67/3.87	1.79/4.32
Mexico	2.11/3.00	2.13/3.26	2.19/3.85	2.56/4.43
Turkey	1.25/1.94	1.81/3.33	3.04/5.53	3.05/6.03
Greece	1.63/1.99	1.79/3.29	2.25/ 4.22	2.70/4.77
Reading	Low (< 407)	Moderate (407-552)	Strong(553-625)	Top(> 625)
Spain	1.92/2.97	1.94/3.48	2.07/3.70	2.02/3.79
Finland	1.14/2.83	1.05/3.33	1.20/3.55	1.30/3.67
Korea	1.41/3.45	1.15/4.50	1.51/4.97	1.85/5.11
Canada	1.74/ 3.51	1.68/4.39	1.80/4.75	1.95/4.98
Mean OECD	1.78/ 3.89	1.74/3.97	1.74/4.22	1.86/3.76
Mexico	2.05/3.49	2.06/4.44	2.09/4.94	2.02/5.15
Turkey	2.20/3.22	2.30/4.29	1.94/4.93	1.45/ 5.19
Greece	1.98/2.86	1.99/3.58	2.10/ 4.04	2.10/4.35

For the subject of reading the same holds true for Korea and the OECD average, and in Spain, Mexico, Turkey, Greece, and for the OECD average, students who are strong achievers spend more time doing their reading assignments than top achievers. In all countries considered and across all three subjects (with the exception of the average OECD for reading) students in higher achievement groups are the ones who spend more time in the classroom. Numbers of Table 2.4 thus seem to suggest a clearly positive and almost monotonous relationship between scholarly achievement and time input

However, when considering fractions instead of absolute time spent being in class or doing homework the relationship between scholarly achievement and time input weakens (see Table A-1.2 of Appendix A-1 for fractions of weekly hours dedicated to class/homework time for the four groups of achievers). While in Spain, Mexico, and Greece belonging to a higher achievement group is associated to a larger fraction of time spent in class, in Korea the relationship is inverted. Regarding all subjects, Korean top achievers spend a smaller fraction of their study time in class than low achievers. And while Spanish students across all groups of achievers dedicate around 30% of their time to homework, in Korea the fraction of study time dedicated to homework is clearly increasing in the type of achiever. For all other countries considered as well as for the OECD average, the fraction of time spent in maths or science class is increasing in the type of achiever (with the exception of Turkey) whereas for reading no clear relationship between the fraction of study time spent in class and performance emerges.

3 Time Input, Family Background, and School Environment

In order to better analyze the effect of individual study time on scholarly achievement we consider the probability of belonging to one of the four groups of achievers as a function of students' effort in terms of homework time ($e_{i,}$), his family background (b_i) defined by the highest occupation among his parents, school characteristics, i.e. private or public school (a_i), and individual characteristics (z_i), namely gender and immigrant background. We thus formulate and estimate the following logit regression,

$$z_k = \beta_0 + \beta_1 e_i + \beta_2 ai + \beta_3 b_i + \beta_4 z_j, \tag{3.1}$$

with $k = 1, 2, 3, 4$, denoting the four different groups of achievers. The reference group in all countries is a male public school student without immigrant background whose par-

ents' occupation is of low white-collar type.[13]

A strong relationship between the probability of belonging to one of these different groups of achievers and certain aspects of a student's family background and school environment emerges. In particular, for mathematics being a girl reduces the probability of being a top achiever (or strong achiever in Mexico) across all countries considered. With the exception of Finland and Korea where the effect is not statistically significant, the same holds true for science. On the contrary, the probability of being a top or strong achiever in reading is positively related to being a girl. In Spain, Finland, and the average OECD being an immigrant of 1st or 2nd generation reduces the probability of being a strong or top achiever while it increases the probability of being a low achiever in maths and science. Considering aspects of the students' school environment, in Korea and Turkey, being a public or private school student has no effect on the probability of belonging to one of the different groups of achievers. In Finland however, private school students have a higher probability of being low achievers in maths and science and a lower probability of being low achievers in reading, but also a lower probability of being strong achievers in maths. On the other hand for the average OECD as well as for Spain, Canada, Mexico, and Greece private school attendance tends to be related to a higher probability of better scholarly achievement.

Furthermore a student's family background clearly affects the probability of belonging to a certain group of achiever. Having a parent whose occupation is classified as high white-collar increases the probability of being in the highest group of achiever in any of the three subjects while it decreases the probability of being a low achiever in maths and science. Surprisingly, the probability of being a low achiever in reading is higher for students whose parents are high white collar employees compared to those with parents whose occupation is classified as low white collar. Finally, the variable homework time for the corresponding subject tends to show the expected sign, increasing the probability of being a top or strong achiever while reducing the probability of being a low or moderate achiever. However, only in the case of Korea are coefficients for this variable significant across all subjects and across all groups of achievement. In general, the relationship between homework time and the probability of being a high achiever tends to be less significant for the subject of reading compared to maths or science. Given this strong relationship between scholarly achievement and aspects of a student's family background and school environment the question arises if scholarly achievement is mainly determined by time input or if differences in achievement arise because of other factors associated with different aspects of family background and school environment. Put differently: Do sons

[13]Tables A3 and A4 of the Appendix A-1 show the results of the logit regressions.

of non-migrant parents with white-collar occupations who attend private schools perform better because they spend more time studying or is their performance due to other factors that differentiate them from immigrant working class girls who attend public schools? In case difference in performance turn out to be due to differences in time inputs results of Table 2.4 could be confirmed. However, mean study time (class time and homework time) and average performance of different groups displayed in Tables 3.5 and 3.6 show that this is generally not the case. In particular girls clearly spend more time studying in class and at home but perform worse in math and science assignments. With the only exception of Greece where girls spend less time studying math but obtain better results, we observe the same pattern in all other countries considered as well as for the OECD average. While Finish girls outperform Finish boys in science they also do spend more time studying than boys.

Focusing on individual study time, i.e. homework time, we observe a similar phenomenon when comparing students according to their migratory background. Students who are 1st or 2nd generation immigrants tend to spend more time doing homework but perform worse. The only exception is Greece where immigrant students spend less time doing homework and perform worse and Turkey where 1st or 2nd generation migrants spend less time doing math or science homework but obtain better results than native students. However, different from the comparison between boys and girls, immigrant students tend to receive fewer classes, equating or even lowering their sum of class time and study time received, compared to native students. Hence, when grouping students according to different individual characteristics, the positive relationship between more individual study time (homework time) and better scholarly achievement cannot be confirmed. For the comparison between boys and girls even the positive relationship between the sum of class time and study time and scholarly achievement is generally rejected.

On the other hand, when grouping students according to their parents' occupation or the ownership of their schools, both the positive relationship between hours of study time (class time plus homework time) and better performance, as well as the positive relationship between individual study time (homework time) and scholarly achievement are maintained (see Table 3.6). Children whose parents have a white-collar occupation perform better in all countries, with the exception of Mexico for mathematics and science and Turkey for reading. Students whose parents are white-collar employees also spend more time doing homework and receive more classes compared to children of working class background. Considering the OECD average, working class children spend more time doing reading assignments than those whose parents have white-collar occupations, while there are no differences in time spent on science homework.

Table 3.5: PISA 2006: Study time and Individual Characteristics

		Weekly hours dedicated to homework/class (score): by group		
	Boys	Girls	Immigrants	Natives
Mathematics				
Spain	1.7/3.3 (484)	2.2/3.5 (476)	2.0/3.2(429)	2.0/3.4 (485)
Finland	1.1/3.3 (554)	1.3/3.6 (543)	1.4/3.1 (466)	1.2/3.5 (550)
Korea**	2.3/4.7 (552)	2.3/4.8 (543)		
Canada	1.7/4.4 (534)	2.2/4.7 (520)	2.5/4.5 (524)	1.8/4.5 (531)
Mean OECD*	1.8/3.8 (489)	2.1/4.0 (478)	2.1/3.7(458)	2.0/3.9(489)
Mexico	2.2/3.9(410)	2.3/4.0 (401)	2.4/2.9 (321)	2.3/4.0 (411)
Turkey	2.2/3.7 (427)	2.5/3.9 (421)	1.9/3.4 (456)	2.3/3.8 (425)
Greece	2.1/3.4 (461)	1.9/3.5 (457)	1.8/3.2 (424)	2.0/3.5 (463)
Science				
Spain	1.5/3.0 (491)	2.0/3.3 (486)	1.8/2.9 (434)	1.7/3.2 (494)
Finland	1.0/2.9 (562)	1.2/3.4 (565)	1.1/2.8 (472)	1.1/3.1(566)
Korea**	1.2/3.6 (521)	1.2/3.6 (523)		
Canada	1.4/3.8 (536)	1.8/4.2 (532)	2.1/4.0(524)	1.4/4.0(541)
Mean OECD	1.5/3.1 (492)	1.7/3.3 (490)	1.7/3.1(457)	1.5/3.2(497)
Mexico	2.1/3.1 (413)	2.2/3.2 (406)	2.2/3.0(319)	2.1/3.2 (415)
Turkey	1.6/2.9 (418)	1.8/2.9(430)	1.4/3.1 (440)	1.7/2.9 (425)
Greece	1.9/3.0 (468)	1.8/3.4 (479)	1.5/2.6 (433)	1.9/3.2 (478)
Reading				
Spain	1.6/3.5 (443)	2.1/3.8 (479)	1.9/3.2 (415)	1.9/3.6 (465)
Finland	1.0/3.0 (521)	1.3/3.3 (572)	1.2/2.9 (490)	1.1/3.1 (549)
Korea**	1.4/4.4 (539)	1.4/4.5 (574)		
Canada	1.5/4.2 (511)	2.0/4.6(543)	2.1/4.3 (523)	1.6/4.5 (532)
Mean OECD	1.6/3.7(466)	1.9/4.0(502)	1.9/3.6(455)	1.8/3.9 (488)
Mexico	2.0/3.7 (393)	2.1/3.8 (427)	2.2/2.8 (299)	2.1/3.8 (417)
Turkey	1.9/3.8 (427)	2.5/4.2 (471)	2.2/4.3 (437)	2.2/4.0 (448)
Greece	1.6/2.7 (432)	2.2/3.6 (488)	1.7/2.7 (431)	2.0/3.2 (464)

**For Korea, means for migrants and natives are not considered given that there is only one student in the PISA 2006 sample who is a 2nd generation migrant.

Table 3.6: PISA 2006: Study time, Parental Background and School Environment

	Weekly hours dedicated to homework/class (score): by group			
	bluecollar	whitecollar	public	private
Mathematics				
Spain	1.9/3.3 (457)	2.0/3.5 (495)	1.9/3.3 (466)	2.1/3.7(505)
Finland	1.2/3.4 (525)	1.2/3.5 (554)	1.2/3.5 (549)	1.6/3.3 (533)
Korea	2.0/4.6 (529)	2.4/4.7 (551)	2.2/4.6 (549)	2.4/4.8 (545)
Canada	1.8/4.3 (496)	2.0/4.6 (534)	2.0/4.5 (524)	2.4/4.5 (575)
Mean OECD	1.9/3.7 (438)	2.0/4.0(501)	2.0/3.9(476)	2.0/4.1 (518)
Mexico	2.3/3.8 (383)	2.3/4.1 (428)	2.3/3.9 (398)	2.1/4.3 (448)
Turkey	2.2/3.6(404)	2.4/4.1(446)	2.3/3.8 (423)	2.5/5.2 (444)
Greece	1.8/3.2(423)	2.1/3.6 (476)	2.0/3.4 (455)	2.1/4.2 (526)
Science				
Spain	1.6/2.8 (463)	1.8/3.3 (504)	1.6/2.8 (475)	1.9/3.6 (513)
Finland	1.0/3.0 (540)	1.1/3.2 (569)	1.1/3.1 (564)	1.3/3.5 (557)
Korea	1.1/3.5 (507)	1.3/3.6 (525)	1.3/3.7 (524)	1.2/3.4 (520)
Canada	1.4/3.6 (497)	1.6/4.1 (543)	1.6/4.0 (532)	1.7/4.0 (575)
Mean OECD	1.6/2.8(442)	1.6/3.3 (509)	1.6/3.2(485)	1.5/3.3(520)
Mexico	2.1/3.1 (388)	2.1/3.2 (432)	2.2/3.1 (402)	2.0/3.6 (450)
Turkey	1.6/2.6 (406)	1.8/3.2 (443)	1.6/2.9 (424)	1.6/2.7 (431)
Greece	1.6/2.6 (436)	1.9/3.4 (490)	1.8/3.1 (469)	2.1/4.6 (544)
Reading				
Spain	1.8/3.5 (438)	1.9/3.7 (475)	1.8/3.5 (446)	2.0/3.7 (488)
Finland	1.0/3.1 (523)	1.2/3.2 (553)	1.1/3.1 (547)	1.3/2.9 (540)
Korea	1.2/4.4 (543)	1.5/4.5 (559)	1.4/4.4 (554)	1.4/4.6 (558)
Canada	1.7/4.2 (489)	1.8/4.5 (536)	1.8/4.4 (524)	1.6/4.3 (573)
Mean OECD	1.9/3.7 (437)	1.7/3.9 (504)	1.8/3.8 (477)	1.5/4.0(510)
Mexico	2.0/3.7 (385)	2.1/3.8 (436)	2.1/3.7 (402)	1.9/4.0 (459)
Turkey	2.2/3.8 (427)	2.1/4.2 (468)	2.2/4.0 (447)	2.3/5.0 (441)
Greece	1.8/2.9 (419)	2.0/3.3 (478)	2.0/3.2 (455)	1.7/3.6 (542)

Regarding mathematics white-collar children spend more time on their homework than working class children. However, the sum of class time and homework time is always larger or at least equal for children whose parents hold a white-collar occupation, which might be the central reason why they always outperform children of blue-collar parents.

Similarly, private school students tend to spend more time doing homework and they receive more classes than those attending public schools with these additional hours of time input being associated to better achievement. In Mexico private school students spend less time doing math or science homework but given additional hours in class their total study time is larger and they perform better. On the other hand, in Finland those attending private schools do worse in science and math even though they spend more total time doing homework or being in a classroom. However, being in class represents a smaller fraction of total study time for Finish private school students compared to public school students. In Korea public school students do also better in maths and science, spending more time on science and less on maths than those attending private schools. However, in reading Korean private school students spend more time and perform better than those attending public schools.

4 Production Function of Education - Effort and other determinants of scholarly achievement in PISA

More individual effort in terms of time spent doing homework is not necessarily linked to better achievement, as descriptive statistics of Tables 3.5 and 3.6 have shown. Other factors such as parental background and school environment seem to play an important role in determining scholarly performance. We thus propose an analysis that simultaneously takes into account various factors of scholarly achievement, allowing us to determine the impact of each one of these factors and to estimate marginal rates of substitution among different factors. This latter step permits us to address questions like: How many more hours of homework time are necessary to offset the negative effect caused by fewer classes? Or can children from less advantageous family backgrounds compensate by more individual study time? Our approach follows Polacheck et al [1978] who propose a production function for education of the CPES type ('constant partial elasticity of substitution') and estimate marginal rates of substitution between class time, individual study time, and ability for college students.[14] This approach allows us to estimate marginal rates of substitution among different inputs for the production of education and to thus study the

[14]For their sample of college students, the authors find that less able students can compensate for their disadvantages by spending more time studying.

existence of complementarities between individual effort, family background, and school environment. We specify the following functional form for the production function of scholarly achievement

$$q = \gamma[\sum_{i=1}^{n} \delta_i X_i^{-\rho}]^{-\mu/\rho} + \epsilon_i, \tag{4.2}$$

with $i = 1, ...n$, being the number of explanatory variables and q the measure of scholarly achievement. We impose $\sum_{i=1}^{n} \delta_i = 1$, interpreting each coefficient as the share of the corresponding variable in the production of scholarly achievement. Marginal products of each input factor are given by:

$$MP_i = \frac{\partial q}{\partial X_i} = \frac{q^{\frac{\mu+\rho}{\mu}}}{X_i^{\rho+1}} \mu \delta_i \gamma^{-\rho/\mu}. \tag{4.3}$$

Given marginal products we can estimate the marginal rates of substitution of X_i for X_j, by

$$MRS_{ij} = \frac{\delta_i}{\delta_j} \frac{X_j}{X_i}^{\frac{1}{\sigma_{ij}}}$$

where $i \neq j$ and $\sigma_{ij} = \frac{1}{1+\rho}$.

For our analysis we estimate scholarly achievement q measured by the PISA test score, as a function of the students' effort in terms of homework time (X_1), class time (X_2), his family background (X_3) measured by an adjusted ESCS-index and characteristics of his school environment (X_4) and (X_5), in particular the number of computers per 100 students and the teacher-student ratio.[15] We interpret the computers to students ratio as an indicator for a school's funding and we include the teacher-student ratio in order to tests its highly disputed effects on scholarly achievement. The ESCS-index has been adjusted to a positive scale, adding a values of 10 in order to avoid negative values unsuitable for estimation of Equation 4.2.[16]

Figure 4.1 displays the results of the nonlinear least square estimation of Equation 4.2 for science and mathematics for the seven countries considered as well as for the OECD average.

[15] For a more intuitive interpretation we use the inverse of the student-teacher ratio, the teacher-student ratio as input factor to the production of education.

[16] Note that our estimation is clearly biased by the omission of the student's ability, something we would ideally like to control for. However, we do not find any of the variables reported by PISA 2006 to be suitable.

Figure 4.1: Nonlinear Estimation

	SCIENCE							MATH						
	rho	delta1	delta2	delta3	delta4	mu	gamma	rho	delta1	delta2	delta3	delta4	mu	gamma
SPAIN	-1.351***	0.038**	0.501***	0.609***	-0.008***	0.550***	162.506***	*-0.369****	*0.032****	*0.155****	*0.973****	*-0.006*	*0.526****	*142.181****
Constant	*(0.068)*	*(0.017)*	*(0.053)*	*(0.055)*	*(0.001)*	*(0.012)*	*(5.799)*	(0.029)	(0.005)	(0.013)	(0.021)	(0.004)	(0.013)	(3.918)
Observations	18,383	18,383	18,383	18,383	18,383	18,383	18,383	18,226	18,226	18,226	18,226	18,226	18,226	18,226
R-squared	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999
FINLAND	*-0.565****	*0.025*	*0.231****	*0.843****	*0.002*	*0.538****	*171.665****	*-0.361****	*0.011*	*0.107****	*0.913****	*0.008*	*0.607****	*138.563****
	(0.073)	(0.015)	(0.035)	(0.060)	(0.007)	(0.029)	(12.672)	(0.079)	(0.008)	(0.020)	(0.036)	(0.007)	(0.029)	(9.474)
Observations	4,363	4,363	4,363	4,363	4,363	4,363	4,363	4,348	4,348	4,348	4,348	4,348	4,348	4,348
R-squared	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999
KOREA	*-0.468****	*0.091****	*0.097****	*0.572****	*-0.042****	*0.478****	*261.888****	*-0.470****	*0.092****	*0.122****	*0.427****	*-0.034****	*0.565****	*272.621****
	(0.055)	(0.015)	(0.014)	(0.058)	(0.007)	(0.031)	(19.144)	(0.037)	(0.008)	(0.010)	(0.035)	(0.004)	(0.029)	(16.989)
Observations	5,054	5,054	5,054	5,054	5,054	5,054	5,054	5,037	5,037	5,037	5,037	5,037	5,037	5,037
R-squared	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
CANADA	*-0.725****	*-0.016*	*0.304****	*1.349****	*0.002*	*0.568****	*109.213****	*-0.634****	*-0.060****	*0.206****	*1.195****	*-0.009****	*0.549****	*123.673****
	(0.059)	(0.014)	(0.061)	(0.179)	(0.003)	(0.017)	(9.639)	(0.069)	(0.014)	(0.035)	(0.105)	(0.003)	(0.016)	(7.953)
Observations	16,122	16,122	16,122	16,122	16,122	16,122	16,122	15,984	15,984	15,984	15,984	15,984	15,984	15,984
R-squared	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999
MEXICO	*-0.293****	*-0.018****	*0.027****	*0.999****	*0.071****	*0.519****	*124.894****	*-0.324****	*0.008***	*0.151****	*0.876****	*0.052****	*0.564****	*118.796****
	(0.042)	(0.004)	(0.005)	(0.014)	(0.004)	(0.008)	(2.512)	(0.019)	(0.004)	(0.007)	(0.010)	(0.003)	(0.009)	(2.374)
Observations	20,696	20,696	20,696	20,696	20,696	20,696	20,696	20,551	20,551	20,551	20,551	20,551	20,551	20,551
R-squared	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999
GREECE	*-0.499****	*-0.008*	*0.312****	*1.074****	*0.047****	*0.598****	*104.745****	*-0.415****	*0.027****	*0.156****	*1.044****	*0.028****	*0.726****	*77.593****
	(0.040)	(0.010)	(0.039)	(0.051)	(0.011)	(0.026)	(6.754)	(0.052)	(0.008)	(0.023)	(0.034)	(0.009)	(0.028)	(5.244)
Observations	4,401	4,401	4,401	4,401	4,401	4,401	4,401	4,379	4,379	4,379	4,379	4,379	4,379	4,379
R-squared	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999
TURKEY	*-1.698****	*0.087****	*0.540****	*0.538****	-0.008***	*0.609****	*133.615****	*-0.819****	*0.068****	*0.197****	*0.627****	-0.014***	*0.756****	*108.305****
	(0.140)	(0.034)	(0.066)	(0.064)	(0.003)	(0.020)	(7.226)	(0.082)	(0.012)	(0.019)	(0.040)	(0.005)	(0.023)	(5.998)
Observations	4,610	4,610	4,610	4,610	4,610	4,610	4,610	4,574	4,574	4,574	4,574	4,574	4,574	4,574
R-squared	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
OECD	*-0.663****	*-0.036****	*0.168****	*0.851****	-0.001**	*0.840****	*80.758****	*-0.501****	*-0.004****	*0.137****	*0.859****	0.002***	*0.842****	*78.422****
	(0.012)	(0.002)	(0.003)	(0.005)	(0.000)	(0.004)	(0.763)	(0.011)	(0.001)	(0.003)	(0.004)	(0.000)	(0.004)	(0.696)
Observations	208,702	208,702	208,702	208,702	208,702	208,702	208,702	206,959	206,959	206,959	206,959	206,959	206,959	206,959
R-squared	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999

*** p<0.01, ** p<0.05, * p<0.1

SCIENCE **MATH**

Computed Marginal Products

Increase	homework	class	index _ESCS	computers per	teachers pe	homewor	class	index _ESCS	computers per	teachers pe
in	time	time	adjusted	100 students	10 students	time	time	adjusted	100 students	10 students
by	*1 hour*	*1 hour*	*1 unit*	*1 computer*	*1 teacher*	*1 hour*	*1 hour*	*1 unit*	*1 computer*	*1 teacher*
leads to increase in PISA score (*% of respective mean score*) by:										
	0.83	13.46	24.37	-0.35	-2.44	2.44	8.17	25.06	-0.13	-17.72
SPAIN	*0.17%*	*2.76%*	*4.99%*	*-0.07%*	*-0.50%*	*0.50%*	*1.67%*	*5.13%*	*-0.03%*	*-3.63%*
	2.11	12.24	26.64	0.05	-9.08	1.56	7.66	30.62	0.18	-6.08
FINLAND	*0.38%*	*2.17%*	*4.73%*	*0.01%*	*-1.61%*	*0.28%*	*1.36%*	*5.44%*	*0.03%*	*-1.08%*
	10.40	6.25	21.35	-0.94	45.75	14.23	10.66	21.66	-1.03	86.17
KOREA	*1.99%*	*1.20%*	*4.09%*	*-0.18%*	*8.76%*	*2.73%*	*2.04%*	*4.15%*	*-0.20%*	*16.51%*
	-0.57	8.31	28.36	0.03	-28.89	-2.77	6.71	27.48	-0.15	-21.15
CANADA	*-0.11%*	*1.56%*	*5.31%*	*0.01%*	*-5.41%*	*-0.52%*	*1.26%*	*5.15%*	*-0.03%*	*-3.96%*
	-1.15	1.30	22.81	1.52	-13.11	0.54	7.84	22.35	1.25	-14.79
MEXICO	*-0.28%*	*0.32%*	*5.62%*	*0.38%*	*-3.23%*	*0.13%*	*1.93%*	*5.50%*	*0.31%*	*-3.64%*
	-0.47	13.98	27.32	1.15	-30.15	2.27	9.56	33.05	0.84	-26.73
GREECE	*-0.10%*	*3.05%*	*5.95%*	*0.25%*	*-6.57%*	*0.50%*	*2.08%*	*7.20%*	*0.18%*	*-5.82%*
	1.27	11.60	25.19	-0.30	-1.36	4.54	11.90	30.95	-0.73	9.52
TURKEY	*0.30%*	*2.74%*	*5.94%*	*-0.07%*	*-0.30%*	*1.07%*	*2.81%*	*7.30%*	*-0.17%*	*2.24%*
	-3.08	11.25	38.98	-0.04	1.93	-0.44	10.63	37.95	0.06	0.93
OECD	*-0.63%*	*2.29%*	*7.94%*	*-0.01%*	*0.39%*	*-0.09%*	*2.16%*	*7.73%*	*0.01%*	*0.19%*

All parameters are significant with the exception of the coefficient δ_1 related to homework time for students in Finland and for science homework in Canada and Greece and the coefficient δ_4 related to the computer-student ratio in Finland and Canada for the science score and Spain for the math score.[17] To be able to better interpret results we calculate the marginal products (Equation 4.3) of each factor for both subjects (evaluated at the weighted means for each group). The marginal product of one additional hour of class time per week in science and math is clearly positive across all countries and lays in the range of an increase of 1.2% to 3.1% in the test score (evaluated at the mean PISA score), with the exception of science classes in Mexico with an additional hour incrementing the science score by only 0.3%. One additional unit, i.e. one standard deviation, of the ESCS-index has an important effect on the PISA test score in all countries; ranging from around 4% to 7% for most countries for both subjects. One additional hour of individual study time has strong effects in Korea, even stronger than one additional hour of class time, increasing students' test scores by 2-3%. In all other countries effects are clearly smaller or even negative for Canada, and the average OECD and Mexico and Greece for the science test score. This seems to indicate that in most countries more individual effort, everything else equal, does not lead to better scholarly achievement and can even be counterproductive.

The other two variables concerning school environment show contradicting signs but have little effect on the PISA tests core for most countries. More computers per students, i.e. one more computer per 100 students is associated to a higher PISA test score in Finland, Greece and Mexico but to a lower test score in Spain, Korea, and Turkey. While more computers per student might indicate better funding in some cases and thus be associated to a higher test score, this variable might also indicate less funding in other areas which might be better for improving students' test scores, thus related to lower test scores. Contrary to our expectations a higher teacher-student ratio is associated to slightly worse achievement in most countries. PISA test scores are reduced in all countries but Korea, the average OECD and Turkey when considering math scores only. In Korea the effect of more teachers is quite important. Increasing the number of teachers by one for 10 Korean students leads to an increase in science and math scores by 9% and 17% respectively, while in Canada, Mexico, and Greece one additional teachers are associated to a reduction test score of around 4-5%.

In a last step we consider the marginal rates of substitution among factors. Figure 4.2 displays matrices for the marginal rates of substitution.

[17] Table A5 of the Appendix A-1 show the results for reading.

Figure 4.2: Marginal Rates of Substitution

MARGINAL RATES OF SUBSTITUTION

SCIENCE	homework time	class time	index _ESCS adjusted	computers per 100 students	teachers per 10 students	*MATH*	homework time	class time	index _ESCS adjusted	computers per 100 students	teachers per 10 students
SPAIN											
homeworktime	1,00	0,06	0,03	-2,36	-0,34	homeworktime	1,00	0,30	0,10	-18,81	-0,14
classtime	16,18	1,00	0,55	-38,13	-5,52	classtime	3,35	1,00	0,33	-63,02	-0,46
index_ESCS (adj.)	29,30	1,81	1,00	-69,04	-10,00	index_ESCS (adj.)	10,28	3,07	1,00	-193,29	-1,41
computers per 100	-0,42	-0,03	-0,01	1,00	0,14	computers per 100	-0,05	-0,02	-0,01	1,00	0,01
teachers per 10	-2,93	-0,18	-0,10	6,90	1,00	teachers per 10	-7,27	-2,17	-0,71	136,70	1,00
FINLAND											
homeworktime	1,00	0,17	0,08	43,13	-0,23	homeworktime	1,00	0,20	0,05	8,48	-0,26
classtime	5,79	1,00	0,46	249,82	-1,35	classtime	4,90	1,00	0,25	41,54	-1,26
index_ESCS (adj.)	12,61	2,18	1,00	543,99	-2,93	index_ESCS (adj.)	19,58	4,00	1,00	166,01	-5,04
computers per 100	0,02	0,00	0,00	1,00	-0,01	computers per 100	0,12	0,02	0,01	1,00	-0,03
teachers per 10	-4,30	-0,74	-0,34	-185,42	1,00	teachers per 10	-3,88	-0,79	-0,20	-32,94	1,00
KOREA											
homeworktime	1,00	1,66	0,49	-11,08	0,23	homeworktime	1,00	1,33	0,66	-13,76	0,17
classtime	0,60	1,00	0,29	-6,66	0,14	classtime	0,75	1,00	0,49	-10,31	0,12
index_ESCS (adj.)	2,05	3,41	1,00	-22,75	0,47	index_ESCS (adj.)	1,52	2,03	1,00	-20,94	0,25
computers per 100	-0,09	-0,15	-0,04	1,00	-0,02	students/computers	-0,07	-0,10	-0,05	1,00	-0,01
teachers per 10	4,40	7,32	2,14	-48,76	1,00	students/teacher	6,06	8,08	3,98	-83,32	1,00
CANADA											
homeworktime	1,00	-0,07	-0,02	-16,95	0,02	homeworktime	1,00	-0,41	-0,10	18,10	0,13
classtime	-14,64	1,00	0,29	248,08	-0,29	classtime	-2,43	1,00	0,24	-43,93	-0,32
index_ESCS (adj.)	-49,98	3,41	1,00	846,99	-0,98	index_ESCS (adj.)	-9,93	4,09	1,00	-179,78	-1,30
computers per 100	-0,06	0,00	0,00	1,00	0,00	computers per 100	0,06	-0,02	-0,01	1,00	0,01
teachers per 10	50,91	-3,48	-1,02	-862,79	1,00	teachers per 10	7,64	-3,15	-0,77	138,39	1,00
MEXICO											
homeworktime	1,00	-0,08	-0,02	-0,29	0,02	homeworktime	1,00	0,07	0,02	0,44	-0,04
classtime	-13,14	1,00	0,32	3,85	-0,23	classtime	14,41	1,00	0,35	6,27	-0,53
index_ESCS (adj.)	-41,68	3,17	1,00	12,22	-0,73	index_ESCS (adj.)	41,07	2,85	1,00	17,88	-1,51
computers per 100	-3,41	0,26	0,08	1,00	-0,06	computers per 100	2,30	0,16	0,06	1,00	-0,08
teachers per 10	57,23	-4,36	-1,37	-16,78	1,00	teachers per 10	-27,18	-1,89	-0,66	-11,83	1,00

With our initial questions of this section in mind: How many more hours of homework time are necessary to offset the negative effect caused by fewer classes? Or can children from less advantageous family backgrounds compensate by more individual study time? , results of Figure 4.2 are rather disappointing. Given the production function specified before, it seems almost impossible for students to compensate for fewer science classes by more individual study time. As expected and as results of Figure 4.1 already indicated, for countries where marginal products of homework time are negative, students cannot compensate for fewer classes by more study time. In case science classes are reduced it is even optimal for students in Canada, Greece, Mexico and the average OECD to reduce their individual study time, given its negative marginal product. On the other hand compensation would require the enormous increase of science homework time of 5.8, 9.2 or even 16.2 hours a week for each hour of class time in Finland, Spain, or Turkey. Results for Korea stick out as rather counterintuitive, with students being able to compensate for 1 hour less of science class by 36 minutes of science homework, something that was already indicated by the larger marginal product for homework time compared to class time in Korea. Considering marginal rates of substitution calculated for the PISA math score, results are a little more promising. Only Canada and the average OECD show negative rates of substitution and thus do not allow for any compensation of fewer math classes by

more individual study time. While additional homework hours required to make up for the reduction of one hour of math class a week are somewhat lower and are 2.6, 3.4, 4.2, 4.9 and to 14.2 hours a week in Turkey, Spain, Greece, Finland and Mexico respectively. The result for Korea again sticks out as 45 minutes of additional homework time make up for one hour of math class.

Considering the possibility of compensating for a less advantageous family backgrounds by putting in more individual study time, results are even worse. While compensating for fewer classes seems to require a large or even impossible increase in homework time, compensation for a lower socio-economic status (by about one standard deviation) requires more than double the amount of additional individual study time. Ranging from a relatively low and possible 1.5 and 2 hours in Korea to an impossible 29 hours a week for science in Spain and 41 hours of math homework in Mexico, even in Finland compensating for a lower socio-economic background would require an increase of 12 or 19.6 hours of homework time. It seems more promising to consider the possibility of compensating for a lower socioeconomic background by additional class time. Across all countries and for both subjects, math and science, increasing hours of class time by between 1.8 and 4.1 hours a week could compensate for a lower socioeconomic background. Results for variables concerning the school environment, i.e. computers and teachers relative to students are mixed. While in some countries like Spain and Finland more teachers cannot compensate at all for fewer classes or study time or lower socio-economic background, in Korea, more teachers can make up for deficiencies in all of these areas. By hiring between 1 and 5 more teachers for any 100 students the effect of the reduction of these input factors can be set off. More computers per students cannot offset the effect of fewer classes, homework of lower parental background in Korea, Spain, nor Turkey while in Finland Mexico and Greece there seems to be the possibility of investing in computers to offset the negative effect of the reduction in these other inputs to education. Note though that the required investment would be particularly large n Finland, requiring an increase of up to 544 computers per 100 students to offset the effect of a lower socioeconomic background.

5 Conclusion

Time input is one of the main ingredient for scholarly achievement. Looking at data from PISA 2006, we find that across countries, absolute time spent studying is negatively related to scholarly achievement, while a larger fraction of total study time spent in the classroom is associated to better performance. However, at the country level more total study time (class time plus homework time) is associated to better performance. When

considering different groups of students, this positive relationship between time input and scholarly achievement breaks down. In particular girls and students with a migratory background spend more time in class rooms and doing homework but perform worse. We estimate a non-linear production function for education and the resulting marginal rates of substitution among different input factors for the production of education as different time inputs, family background, and school environment. We find that compensating for less class time or lower socio-economic background by individual study time, is enormously time-costly or even impossible for students in Spain, as well as for students in the three best and the three worst performing OECD countries. Our results also show that in particular additional hours of class time rather than more teachers or better-equipped schools can compensate for a less advantageous family background.

In order to be able to further explain cross country differences in the effectiveness of time inputs a closer look at students' studying techniques is necessary. We think that along this line an interesting road for future research could emerge that might help us to better understand the negative cross-country relationship between individual study time and scholarly achievement as well as the differences in effectiveness of time input across genders and socio-economic groups of students.

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A-1 Appendix

Table A-1.1: Average Hours per Year of Instruction Time at Age 15

	Total Hours	Reading	Maths	Science
Spain	978	158	112	106
Finland	858	110	99	114
Korea	1020	130	110	110
Mean OECD	962	150	121	114
Mexico	1124	161	161	193
Turkey	959	141	132	151
Greece	1307	162	149	124

Data: OECD [2006]. Average number of hours per year of compulsory and non-compulsory instruction time in public institutions at age 15 (typical programme); Due to data limitations, hours for subjects have been calculated using information on: Instruction time per subject as a percentage of total compulsory instruction time for 12-to-14-year-olds.

Table A-1.2: Fractions of Study Time and Proficiency Level

	Fraction of weekly hours dedicated to class/homework: according to type of achiever			
Mathematics	Low (< 420)	Moderate (420-544)	Strong(545-606)	Top(> 606)
Spain	0.28/ 0.55	0.30/0.58	0.31/0.61	0.32/0.64
Finland	0.24/0.63	0.23/0.70	0.23/0.72	0.23/0.74
Korea	0.18/0.69	0.19/0.63	0.23/0.55	0.28/0.48
Canada	0.27/0.55	0.26/0.62	0.26/0.66	0.25 /0.69
Mean OECD	0.29/ 0.54	0.27/0.61	0.27/0.64	0.28/0.64
Mexico	0.33/0.52	0.30/0.59	0.28/ 0.64	0.28 /0.66
Turkey	0.27/0.52	0.27/0.52	0.27/0.49	0.26/0.50
Greece	0.27/0.50	0.24/ 0.50	0.25/0.50	0.27/0.51
Science	Low (< 409)	Moderate (409-558)	Strong(559-632)	Top(> 632)
Spain	0.30/ 0.55	0.31/0.59	0.32/ 0.63	0.31/0.66
Finland	0.27/0.60	0.23/ 0.69	0.23/0.73	0.23/0.74
Korea	0.17/0.74	0.18/0.70	0.20/0.64	0.23/0 .62
Canada	0.28/0.58	0.26/0.65	0.26/0.69	0.25/0.72
Mean OECD	0.32/0.53	0.28/ 0.61	0.27/0.66	0.26/0.69
Mexico	0.37/0.48	0.37/0.51	0.34/0.59	0.33/0.60
Turkey	0.30/0.51	0.27/0.54	0.25/0.52	0.23/0.52
Greece	0.31/0.42	0.24/0.51	0.24/0.53	0.25/0.53
Reading	Low (< 407)	Moderate (407-552)	Strong(553-625)	Top(> 625)
Spain	0.30/ 0.64	0.30/0.64	0.32/0.67	0.31/0.69
Finland	0.23/0.71	0.22/0.70	0.24/0.72	0.25/0.71
Korea	0.17/0.67	0.16/0.70	0.18/0.65	0.20/0.61
Canada	0.24/0.66	0.24/0.64	0.24/0.69	0.25/0.71
Mean OECD	0.26/0.63	0.25/0.65	0.25/0.68	0.28/0.59
Mexico	0.30/0.58	0.30/0.59	0.29/0.65	0.27/0.67
Turkey	0.25/0.56	0.26/0.56	0.22/0.63	0.19/0.68
Greece	0.27/0.53	0.27/0.53	0.27/0.56	0.27 /0.59

Figure A-1: Table A3: Logit: Resultados

Subject:	***Science***				***Mathematics***				***Reading***			
Achievers:	low	moderate	strong	top	low	moderate	strong	top	low	moderate	strong	top
Average OECD												
girl	-0.004	0.164***	-0.078*	-0.350***	0.229***	0.135***	-0.149***	-0.504***	0.814***	0.036	0.335***	0.520***
	(0.046)	(0.036)	(0.044)	(0.062)	(0.040)	(0.029)	(0.038)	(0.043)	(0.062)	(0.025)	(0.030)	(0.054)
private school	-0.476***	-0.026	0.232***	0.311***	-0.592***	-0.104**	0.266***	0.530***	0.475***	-0.032	0.179***	0.243***
	(0.084)	(0.042)	(0.056)	(0.082)	(0.091)	(0.043)	(0.055)	(0.070)	(0.116)	(0.036)	(0.054)	(0.065)
1st or 2nd generation immigrant	0.486***	-0.009	-0.431***	-0.476***	0.195**	0.097	-0.280***	-0.404***	-0.548***	-0.118***	-0.178***	-0.170**
Highest occupation among parents	(0.072)	(0.054)	(0.092)	(0.100)	(0.076)	(0.076)	(0.089)	(0.104)	(0.093)	(0.045)	(0.055)	(0.080)
High white-collar occupation	-0.583***	-0.158***	0.370***	0.687***	-0.602***	-0.123***	0.353***	0.722***	0.721***	-0.213***	0.448***	0.812***
	(0.044)	(0.034)	(0.042)	*(0.064)*	(0.041)	(0.030)	(0.044)	(0.049)	(0.060)	(0.028)	(0.030)	(0.056)
High blue-collar occupation	0.538***	-0.092**	*-0.491***	-0.725***	0.559***	-0.164***	-0.412***	-0.570***	-0.591***	-0.145***	-0.453***	-0.644***
	(0.055)	(0.043)	(0.055)	(0.106)	(0.051)	(0.045)	(0.056)	(0.077)	(0.079)	(0.036)	(0.041)	(0.096)
Low blue-collar occupation	0.717***	-0.143***	-0.796***	-1.024***	0.785***	-0.276***	-0.642***	-0.904***	-0.684***	-0.121***	-0.741***	-0.839***
	(0.056)	(0.054)	(0.115)	(0.202)	(0.049)	(0.048)	(0.094)	(0.118)	(0.065)	(0.038)	(0.054)	(0.092)
homeworktime_subject	0.067***	-0.011	-0.025*	-0.029*	0.046***	-0.044***	-0.010	0.045***	-0.108***	-0.011*	-0.047***	-0.032***
	(0.012)	(0.008)	(0.013)	(0.015)	(0.011)	(0.009)	(0.013)	(0.012)	(0.017)	(0.006)	(0.009)	(0.011)
classtime_subject	-0.258***	-0.036***	0.164***	0.260***	-0.272***	0.037***	0.157***	0.179***	0.277***	0.033***	0.113***	0.132***
	(0.013)	(0.008)	(0.008)	(0.012)	(0.013)	(0.009)	(0.013)	(0.013)	(0.019)	(0.006)	(0.008)	(0.010)
Constant	*-0.596***	0.197***	-2.044***	-3.376***	-0.197**	-0.116**	-2.267***	-3.075***	1.376***	0.054	-2.090***	-3.552***
	(0.069)	(0.049)	(0.056)	(0.086)	(0.082)	(0.055)	(0.070)	(0.063)	(0.068)	(0.035)	(0.044)	(0.071)
Observations	*207.927*	*207.927*	*207.927*	*207.927*	*208.758*	*208.758*	*208.758*	*208.758*	*204.250*	*204.250*	*204.250*	*204.250*
Spain												
girl	0.229***	0.131*	-0.240***	-0.487***	0.217***	0.145***	-0.177*	-0.645***	0.969***	0.156**	0.528***	0.776***
	(0.084)	(0.068)	(0.073)	(0.123)	(0.078)	(0.054)	(0.100)	(0.111)	(0.208)	(0.079)	(0.108)	(0.286)
private school	-0.339***	-0.010	0.233***	0.157	-0.513***	0.011	0.245***	0.489***	0.823***	0.047	0.564***	0.764***
	(0.115)	(0.073)	(0.089)	(0.152)	(0.113)	(0.064)	(0.082)	(0.151)	(0.205)	(0.087)	(0.112)	(0.274)
1st or 2nd generation immigrant	0.937***	-0.356**	-0.521**	-1.029*	0.975***	-0.357**	-0.788***	-0.775**	-0.770***	-0.425***	-0.504*	-0.595
Highest occupation among parents	(0.141)	(0.151)	(0.228)	(0.543)	(0.160)	(0.179)	(0.236)	(0.320)	(0.208)	(0.132)	(0.281)	(0.796)
High white-collar occupation	-0.719***	-0.214***	0.544***	*0.935***	-0.661***	-0.168**	0.469***	0.911***	0.704***	0.023	0.649***	0.905***
	(0.100)	(0.078)	(0.094)	(0.151)	(0.104)	(0.071)	(0.096)	(0.183)	(0.177)	(0.071)	(0.105)	(0.312)
High blue-collar occupation	0.182	-0.060	*-0.147*	-0.136	0.226*	-0.060	-0.224**	-0.176	-0.242*	-0.131*	-0.211*	-0.125
	(0.117)	(0.086)	(0.141)	(0.216)	(0.126)	(0.088)	(0.104)	(0.227)	(0.136)	(0.078)	(0.122)	(0.314)
Low blue-collar occupation	0.235*	-0.050	-0.196	-0.181	0.245*	-0.111	-0.177	-0.067	-0.114	-0.143	-0.151	0.187
	(0.136)	(0.109)	(0.165)	(0.268)	(0.148)	(0.102)	(0.159)	(0.311)	(0.218)	(0.121)	(0.268)	(0.360)
homeworktime_subject	-0.043	-0.038**	0.075***	0.082**	-0.092***	0.029	0.032	0.033	0.011	0.003	0.014	-0.044
	(0.034)	(0.019)	(0.022)	(0.036)	(0.033)	(0.023)	(0.032)	(0.031)	(0.056)	(0.022)	(0.025)	(0.073)
classtime_subject	-0.266***	-0.087***	0.222***	0.367***	-0.214***	0.040*	0.118***	0.135***	0.376***	0.139***	0.126***	0.153**
	(0.030)	(0.021)	(0.018)	(0.047)	(0.032)	(0.024)	(0.028)	(0.033)	(0.056)	(0.026)	(0.031)	(0.064)
Constant	-0.700***	0.765***	-2.549***	-4.797***	-0.247*	-0.059	-2.173***	-3.401***	0.670***	-0.069	-3.162***	-5.776***
	(0.108)	(0.074)	(0.103)	(0.265)	(0.142)	(0.101)	(0.141)	(0.201)	(0.186)	(0.105)	(0.155)	(0.392)
Observations	*18.312*	*18.312*	*18.312*	*18.312*	*18.308*	*18.308*	*18.308*	*18.308*	*18.340*	*18.340*	*18.340*	*18.340*
Finland												
girl	-0.273	0.149**	0.083	-0.259***	0.142	0.303***	-0.001	-0.421***	2.757**	-0.763***	0.479***	1.045***
	(0.224)	(0.061)	(0.061)	(0.091)	(0.194)	(0.068)	(0.074)	(0.074)	(1.094)	(0.076)	(0.080)	(0.117)
private school	1.314***	-0.146	-0.377*	0.182	0.991**	-0.036	-0.407	0.054	-1.938***	-0.498	-0.037	0.210
	(0.485)	(0.241)	(0.221)	(0.366)	(0.467)	(0.194)	(0.255)	(0.365)	(0.645)	(0.314)	(0.221)	(0.404)
1st or 2nd generation immigrant	2.030***	0.555*	-0.985**	-1.819**	1.834***	0.255	-0.943*	-1.337**	-0.910	0.566	-0.979*	-0.723
Highest occupation among parents	(0.514)	(0.334)	(0.440)	(0.766)	(0.429)	(0.303)	(0.506)	(0.631)	(1.502)	(0.416)	(0.577)	(0.694)
High white-collar occupation	-0.448*	-0.486***	0.182**	0.564***	-0.517**	-0.554***	0.138	0.728***	0.018	-0.492***	0.196*	0.733***
	(0.261)	(0.087)	(0.089)	(0.106)	(0.214)	(0.083)	(0.123)	(0.137)	(0.714)	(0.090)	(0.105)	(0.141)
High blue-collar occupation	-0.012	0.057	-0.025	-0.053	0.075	0.019	-0.012	-0.046	-0.321	0.171	-0.218*	-0.063
	(0.394)	(0.134)	(0.126)	*(0.165)*	(0.250)	(0.122)	(0.143)	(0.149)	(0.784)	(0.119)	(0.130)	(0.227)
Low blue-collar occupation	0.273	0.396**	*-0.358**	-0.402	0.392	0.376**	-0.389	-0.432	-0.567	0.347*	-0.423**	-0.501
	(0.487)	(0.196)	(0.190)	(0.277)	(0.303)	(0.156)	(0.303)	(0.361)	(1.198)	(0.206)	(0.212)	(0.422)
homeworktime_subject	0.208*	-0.032	-0.040	0.043	0.048	-0.007	0.005	-0.009	0.146	-0.065	0.007	0.075
	(0.113)	(0.039)	(0.044)	(0.038)	(0.103)	(0.036)	(0.042)	(0.035)	(0.549)	(0.044)	(0.044)	(0.049)
classtime_subject	-0.456***	-0.258***	0.097***	0.317***	-0.354***	-0.117***	0.068**	0.170***	0.467	-0.074**	0.099***	0.068*
	(0.072)	(0.024)	(0.024)	(0.029)	(0.069)	(0.026)	(0.028)	(0.036)	(0.307)	(0.034)	(0.036)	(0.038)
Constant	-2.185***	0.688***	-1.108***	-2.588***	-1.804***	0.195	-1.210***	-1.905***	3.546***	0.784***	-1.373***	-2.944***
	(0.257)	(0.108)	(0.133)	(0.151)	(0.298)	(0.120)	(0.145)	(0.212)	(0.772)	(0.135)	(0.139)	(0.186)
Observations	*4.475*	*4.475*	*4.475*	*4.475*	*4.484*	*4.484*	*4.484*	*4.484*	*4.482*	*4.482*	*4.482*	*4.482*
Korea												
girl	-0.222	0.133*	0.006	-0.137	0.129	0.227**	0.048	-0.342***	1.950***	-0.424***	0.141	0.673***
	(0.159)	(0.073)	(0.095)	(0.129)	(0.163)	(0.101)	(0.130)	(0.130)	(0.516)	(0.108)	(0.087)	(0.123)
private school	-0.062	0.072	-0.016	-0.062	0.217	0.153	-0.053	-0.236	-0.167	-0.014	0.016	-0.022
Highest occupation among parents	(0.260)	(0.116)	(0.122)	(0.198)	(0.266)	(0.119)	(0.132)	(0.154)	(0.529)	(0.130)	(0.100)	(0.175)
High white-collar occupation	-0.230	-0.285**	0.242**	0.570***	-0.162	-0.155	-0.053	0.357***	-0.005	-0.331***	0.053	0.450***
	(0.153)	(0.111)	(0.107)	(0.151)	(0.152)	(0.098)	(0.098)	(0.112)	(0.463)	(0.096)	(0.132)	(0.136)
High blue-collar occupation	0.118	-0.061	0.019	-0.022	0.074	0.070	-0.027	-0.137	0.010	-0.128	0.139	-0.091
	(0.184)	(0.139)	(0.162)	(0.350)	(0.238)	(0.167)	(0.171)	(0.173)	(0.656)	(0.204)	(0.162)	(0.219)
Low blue-collar occupation	0.235	-0.171	0.020	0.170	0.433*	-0.062	-0.087	-0.046	0.076	-0.172	0.029	0.107
	(0.212)	(0.165)	(0.194)	(0.289)	(0.222)	(0.183)	(0.200)	(0.220)	(1.012)	(0.167)	(0.205)	(0.245)
homeworktime_subject	-0.308***	-0.163***	0.123***	*0.239***	-0.375***	-0.242***	0.020	0.300***	0.173	-0.171***	0.035	0.195***
	(0.090)	(0.039)	(0.026)	*(0.039)*	(0.067)	(0.021)	(0.026)	(0.026)	(0.202)	(0.030)	(0.024)	(0.028)
classtime_subject	-0.312***	-0.048	0.156***	*0.125**	-0.452***	-0.076***	0.162***	0.183***	0.558***	-0.172***	0.154***	0.209***
	(0.064)	(0.035)	*(0.032)*	(0.066)	(0.043)	(0.028)	(0.036)	(0.038)	(0.142)	(0.031)	(0.037)	(0.038)
Constant	-0.600*	0.619***	-1.965***	-3.266***	-0.064	0.345**	-1.847***	-2.594***	1.772***	1.023***	-1.567***	-3.195***
	(0.325)	(0.206)	(0.162)	(0.343)	(0.238)	(0.157)	(0.166)	(0.197)	(0.530)	(0.178)	(0.201)	(0.230)
Observations	*4.950*	*4.950*	*4.950*	*4.950*	*4.948*	*4.948*	*4.948*	*4.948*	*4.956*	*4.956*	*4.956*	*4.956*

Figure A-2: Table A4: Logit: Resultados

Subject:	***Science***				***Mathematics***				***Reading***			
Achievers:	low	moderate	strong	top	low	moderate	strong	top	low	moderate	strong	top
Canada												
girl	0.032	0.248***	-0.111*	-0.320***	0.306***	0.292***	-0.121	-0.488***	1.031***	-0.196***	0.217***	0.484***
	(0.109)	(0.056)	(0.064)	(0.081)	(0.111)	(0.053)	(0.080)	(0.086)	(0.157)	(0.050)	(0.062)	(0.095)
private school	-0.994***	-0.432***	0.238**	0.671***	-0.970***	-0.645***	0.124	0.929***	0.917**	-0.563***	0.253*	0.793***
	(0.247)	(0.120)	(0.111)	(0.127)	(0.300)	(0.131)	(0.121)	(0.129)	(0.443)	(0.173)	(0.139)	(0.153)
1st or 2nd generation immigrant	0.659***	-0.018	-0.145*	-0.138	0.290**	-0.073	-0.073	0.057	-0.473*	-0.121	0.064	-0.024
Highest occupation among parents	(0.122)	(0.068)	(0.086)	(0.132)	(0.139)	(0.082)	(0.114)	(0.135)	(0.264)	(0.088)	(0.104)	(0.112)
High white-collar occupation	-0.559***	-0.433***	0.344***	0.702***	-0.670***	-0.391***	0.267***	0.762***	0.537***	-0.385***	0.320***	0.714***
	(0.114)	(0.064)	(0.077)	(0.116)	(0.092)	(0.062)	(0.093)	(0.099)	(0.202)	(0.070)	(0.091)	(0.098)
High blue-collar occupation	0.279*	-0.063	-0.054	-0.162	0.293*	-0.050	-0.051	-0.192	-0.498*	0.055	-0.107	-0.434
	(0.165)	(0.121)	(0.181)	*(0.265)*	(0.176)	(0.125)	(0.176)	(0.284)	(0.282)	(0.167)	(0.199)	(0.307)
Low blue-collar occupation	0.366**	0.146	*-0.369***	-0.365	0.354**	0.056	-0.281	-0.204	-0.478	0.104	-0.412**	-0.336
	(0.165)	(0.127)	(0.153)	(0.248)	(0.173)	(0.143)	(0.201)	(0.234)	(0.293)	(0.137)	(0.169)	(0.267)
homeworktime_subject	-0.051	-0.029	0.034	0.024	0.032	0.019	0.004	-0.050*	-0.082	0.003	-0.025	0.008
	(0.044)	(0.024)	(0.026)	(0.028)	(0.027)	(0.016)	(0.021)	(0.027)	(0.061)	(0.022)	(0.027)	(0.024)
classtime_subject	-0.246***	-0.100***	0.097***	0.213***	-0.249***	-0.061***	0.073***	0.168***	0.219***	-0.077***	0.093***	0.155***
	(0.026)	(0.014)	(0.016)	(0.018)	(0.024)	(0.016)	(0.020)	(0.021)	(0.043)	(0.014)	(0.015)	(0.027)
Constant	-1.375***	0.555***	-1.524***	-3.048***	-1.238***	0.263**	-1.500***	-2.552***	2.479***	0.630***	-1.640***	-3.265***
	(0.116)	(0.076)	(0.095)	(0.143)	(0.139)	(0.104)	(0.118)	(0.126)	(0.208)	(0.096)	(0.122)	(0.150)
Observations	*19.522*	*19.522*	*19.522*	*19.522*	*19.571*	*19.571*	*19.571*	*19.571*	*19.633*	*19.633*	*19.633*	*19.633*
Mexico												
girl	0.138**	-0.067	-0.434***		0.254***	-0.138**	-0.409***		0.744***	0.454***	0.555***	
	(0.069)	(0.065)	(0.122)		(0.070)	(0.064)	(0.141)		(0.099)	(0.055)	(0.124)	
private school	-0.552***	0.359***	0.507**		-0.536***	0.302**	0.616***		0.898***	0.346***	0.421**	
	(0.172)	(0.112)	(0.225)		(0.195)	(0.141)	(0.235)		(0.222)	(0.127)	(0.213)	
1st or 2nd generation immigrant	2.108***	-2.103***	-0.841		1.673***	-1.681***	-1.462		-1.709***	-2.019***	-1.699*	
Highest occupation among parents	(0.321)	(0.355)	(0.877)		(0.306)	(0.371)	(1.553)		(0.348)	(0.372)	(1.008)	
High white-collar occupation	-0.538***	0.326***	0.957***		-0.513***	0.330***	0.532***		0.456***	0.178**	0.603***	
	(0.094)	(0.088)	(0.164)		(0.091)	(0.094)	(0.195)		(0.160)	(0.079)	(0.136)	
High blue-collar occupation	0.575***	-0.528***	-0.784***		0.499***	-0.389***	-0.946***		-0.559***	-0.522***	-0.713***	
	(0.105)	(0.104)	(0.294)		*(0.114)*	(0.105)	(0.328)		(0.201)	(0.091)	(0.262)	
Low blue-collar occupation	0.410***	-0.356***	*-0.706***		0.475***	-0.372***	-0.771***		-0.399***	-0.358***	-0.658***	
	(0.128)	(0.124)	(0.281)		(0.104)	(0.104)	(0.292)		(0.138)	(0.101)	(0.216)	
homeworktime_subject	0.014	-0.010	-0.024		0.005	-0.004	-0.004		-0.069**	-0.037**	-0.039	
	(0.019)	(0.019)	(0.045)		(0.018)	(0.016)	(0.033)		(0.034)	(0.018)	(0.043)	
classtime_subject	-0.045***	0.025**	0.109***		-0.207***	0.159***	0.208***		0.171***	0.093***	0.136***	
	(0.012)	(0.011)	(0.029)		(0.018)	(0.018)	(0.036)		(0.030)	(0.015)	(0.024)	
Constant	-0.084	0.008	-3.809***		0.842***	-0.901***	-3.880***		0.789***	-0.396***	-3.715***	
	(0.100)	(0.100)	(0.221)		(0.113)	(0.114)	(0.292)		(0.137)	(0.083)	(0.166)	
Observations	*27.088*	*27.088*	*27.088*		*27.469*	*27.469*	*27.469*		*27.445*	*27.445*	*27.445*	
Greece												
girl	-0.165	0.324***	-0.160	-0.515**	0.089	0.167*	-0.204	-0.685***		0.309***	0.573***	0.666***
	(0.111)	(0.083)	(0.109)	(0.226)	(0.108)	(0.093)	(0.164)	(0.180)		(0.093)	(0.127)	(0.229)
private school	-1.290**	-0.408**	0.378*	0.726**	-1.016***	-0.323*	0.636***	0.836***		-0.408*	0.875***	1.068***
	(0.533)	(0.178)	(0.222)	(0.314)	(0.385)	(0.184)	(0.236)	(0.288)		(0.224)	(0.231)	(0.339)
1st or 2nd generation immigrant	0.478**	-0.234	-0.461	-0.259	0.309*	-0.069	-0.510	-0.503		-0.213	-0.194	-0.583
Highest occupation among parents	(0.236)	(0.207)	(0.405)	(0.824)	(0.171)	(0.148)	(0.369)	(0.486)		(0.189)	(0.344)	(0.887)
High white-collar occupation	-0.440***	-0.036	0.429***	0.904**	-0.562***	0.060	0.592***	0.693**		0.018	0.424***	0.746**
	(0.143)	(0.105)	(0.159)	(0.421)	(0.113)	(0.102)	(0.207)	(0.278)		(0.091)	(0.130)	(0.358)
High blue-collar occupation	0.394**	-0.276*	-0.117	-0.476	0.416***	-0.310**	-0.226	-0.380		-0.208	-0.456**	-0.645
	(0.162)	(0.147)	(0.238)	(0.539)	(0.142)	(0.146)	(0.259)	(0.476)		(0.132)	(0.216)	(0.707)
Low blue-collar occupation	0.509**	-0.339**	*-0.478**	0.135	0.549***	-0.396***	-0.481	-0.378		-0.251	-0.568**	-0.510
	(0.208)	(0.164)	(0.245)	(0.504)	(0.152)	(0.153)	(0.358)	(0.487)		(0.167)	(0.243)	(0.633)
homeworktime_subject	0.069**	-0.085***	0.025	0.085*	-0.030	-0.037*	0.053*	0.125***		-0.038	-0.014	-0.004
	(0.031)	(0.025)	(0.033)	(0.050)	(0.026)	(0.021)	(0.031)	(0.035)		(0.024)	(0.041)	(0.060)
classtime_subject	-0.447***	0.080***	0.286***	0.376***	-0.273***	0.093***	0.180***	0.250***		0.130***	0.118***	0.059
	(0.038)	(0.023)	(0.030)	(0.063)	(0.034)	(0.025)	(0.041)	(0.065)		(0.028)	(0.029)	(0.049)
Constant	-0.031	0.285**	-2.993***	-5.409***	0.235	-0.189	-2.932***	-4.313***		-0.147	-2.650***	-4.410***
	(0.147)	(0.137)	(0.181)	(0.489)	(0.146)	(0.133)	(0.287)	(0.324)		(0.124)	(0.181)	(0.373)
Observations	*4.455*	*4.455*	*4.455*	*4.455*	*4.454*	*4.454*	*4.454*	*4.454*		*4.455*	*4.455*	*4.455*
Turkey												
girl	-0.343**	0.355***	-0.310*		0.256**	-0.051	-0.239	-0.693***	1.084***	0.446***	0.521***	
	(0.137)	(0.123)	(0.182)		(0.119)	(0.100)	(0.149)	(0.182)	(0.216)	(0.101)	(0.153)	
private school	-0.314	0.353	-0.445		0.040	0.274	-0.731	-0.854	0.042	0.271	-0.885*	
	(0.681)	(0.452)	(0.669)		(0.642)	(0.432)	(0.769)	(0.726)	(1.153)	(0.446)	(0.453)	
1st or 2nd generation immigrant	0.085	-0.465	0.870		-1.011*	0.557	0.142	1.125	-0.660	-0.140	0.198	
Highest occupation among parents	(0.460)	(0.463)	(0.745)		(0.591)	(0.614)	(0.717)	(0.712)	(0.817)	(0.455)	(0.608)	
High white-collar occupation	-0.142	-0.156	0.661***		-0.400***	0.020	0.497**	0.829***	0.385	0.002	0.344*	
	(0.129)	(0.126)	(0.223)		(0.132)	(0.138)	(0.246)	(0.308)	(0.281)	(0.136)	(0.203)	
High blue-collar occupation	0.463***	-0.304**	-0.652**		0.296*	-0.130	-0.467*	-0.580	-0.265	-0.002	-0.739***	
	(0.135)	(0.124)	(0.306)		(0.155)	(0.155)	(0.280)	(0.556)	(0.292)	(0.131)	(0.223)	
Low blue-collar occupation	0.496***	-0.328*	*-1.065***		0.493***	-0.247	-0.646	-1.357**	-0.104	0.139	-0.850***	
	(0.192)	(0.185)	(0.539)		(0.160)	(0.162)	(0.509)	(0.653)	(0.365)	(0.144)	(0.270)	
homeworktime_subject	-0.015	-0.028	0.138***		-0.093***	0.038	0.102*	0.092	-0.069	0.031	-0.156***	
	(0.033)	(0.032)	(0.053)		(0.028)	(0.027)	(0.055)	(0.060)	(0.048)	(0.023)	(0.044)	
classtime_subject	-0.281***	0.144***	0.390***		-0.294***	0.169***	0.307***	0.401***	0.292***	0.136***	0.203***	
	(0.026)	(0.025)	(0.043)		(0.031)	(0.029)	(0.042)	(0.060)	(0.049)	(0.033)	(0.041)	
Constant	0.536***	-0.410***	-4.532***		1.234***	-1.154***	-4.130***	-5.015***	1.033***	-0.558***	-2.783***	
	(0.149)	(0.143)	(0.353)		(0.144)	(0.150)	(0.344)	(0.522)	(0.353)	(0.187)	(0.287)	
Observations	*4.174*	*4.174*	*4.174*		*4.216*	*4.216*	*4.216*	*4.216*	*4.231*	*4.231*	*4.231*	

Figure A-3: Table A5: Non linear estimation Results for Reading

READING VARIABLES	rho	delta1	delta2	delta3	delta4	mu	gamma
SPAIN	*-0.315***	*0.040***	*0.201***	*1.008***	*0.018***	*0.468***	*146.059**
Constant	(0.020)	(0.005)	(0.014)	(0.023)	(0.005)	(0.014)	(4.107)
Observations	18,253	18,253	18,253	18,253	18,253	18,253	18,253
R-squared	0.999	0.999	0.999	0.999	0.999	0.999	0.999
FINLAND	*-0.285***	*0.039***	*0.078***	*0.887***	*0.012*	*0.523***	*173.437***
	(0.058)	(0.012)	(0.016)	(0.037)	(0.009)	(0.029)	(11.671)
Observations	4,345	4,345	4,345	4,345	4,345	4,345	4,345
R-squared	0.999	0.999	0.999	0.999	0.999	0.999	0.999
KOREA	*-0.318***	*0.057***	*0.190***	*0.620***	*-0.074***	*0.389***	*309.223***
	(0.038)	(0.010)	(0.019)	(0.054)	(0.010)	(0.029)	(20.326)
Observations	5,047	5,047	5,047	5,047	5,047	5,047	5,047
R-squared	1.000	1.000	1.000	1.000	1.000	1.000	1.000
CANADA	*-0.778***	*-0.034**	*0.289***	*1.551***	*0.002*	*0.670***	*74.098***
	(0.080)	(0.017)	(0.081)	(0.289)	(0.003)	(0.018)	(9.662)
Observations	16,024	16,024	16,024	16,024	16,024	16,024	16,024
R-squared	0.998	0.998	0.998	0.998	0.998	0.998	0.998
MEXICO	*-0.338***	*-0.009**	*0.154***	*0.980***	*0.085***	*0.560***	*106.590***
	(0.021)	(0.005)	(0.010)	(0.015)	(0.005)	(0.010)	(2.563)
Observations	20,488	20,488	20,488	20,488	20,488	20,488	20,488
R-squared	0.999	0.999	0.999	0.999	0.999	0.999	0.999
GREECE	*-0.320***	*-0.005*	*0.180***	*1.138***	*0.057***	*0.635***	*86.884***
	(0.034)	(0.007)	(0.024)	(0.041)	(0.012)	(0.031)	(6.257)
Observations	4,375	4,375	4,375	4,375	4,375	4,375	4,375
R-squared	0.998	0.998	0.998	0.998	0.998	0.998	0.998
TURKEY	*-0.595***	*-0.037**	*0.202***	*0.819***	-0.028***	*0.601***	*134.269***
	(0.105)	(0.014)	(0.027)	(0.042)	(0.007)	(0.023)	(7.431)
Observations	4,567	4,567	4,567	4,567	4,567	4,567	4,567
R-squared	1.000	1.000	1.000	1.000	1.000	1.000	1.000
OECD	*-0.188***	*2.944*	*-3.614*	*11.756*	14.491	*0.462***	*1.089*
	(0.014)	(3.770)	(4.617)	(14.006)	(17.772)	(0.039)	(2.518)
Observations	207,050	207,050	207,050	207,050	207,050	207,050	207,050
R-squared	0.986	0.986	0.986	0.986	0.986	0.986	0.986

*** p<0.01, ** p<0.05, * p<0.1

Computed Marginal Products

Increase in	homework time	class time	index _ESC adjusted	computers 100 studen	teachers per 10 students
by	*1 hour*	*1 hour*	*1 unit*	*1 computer*	*1 teacher*
leads to increase in PISA score (*% of respective mean score*) by:					
	2.78	9.35	21.54	0.32	-28.98
SPAIN	*0.57%*	*1.92%*	*4.41%*	*0.07%*	*-5.94%*
	5.76	5.35	26.02	0.23	-2.62
FINLAND	*1.02%*	*0.95%*	*4.62%*	*0.04%*	*-0.46%*
	6.59	10.54	17.07	-1.06	37.49
KOREA	*1.26%*	*2.02%*	*3.27%*	*-0.20%*	*7.18%*
	-1.11	7.67	33.32	0.04	-32.20
CANADA	*-0.21%*	*1.44%*	*6.24%*	*0.01%*	*-6.03%*
	-0.56	7.29	23.14	1.89	-31.77
MEXICO	*-0.14%*	*1.80%*	*5.70%*	*0.47%*	*-7.82%*
	-0.41	10.33	30.28	1.43	-39.60
GREECE	*-0.09%*	*2.25%*	*6.60%*	*0.31%*	*-8.63%*
	-2.47	10.77	27.80	-1.08	4.16
TURKEY	*-0.58%*	*2.54%*	*6.56%*	*-0.26%*	*0.98%*
	38.71	-26.45	34.43	23.04	-558.72
OECD	*7.88%*	*-5.39%*	*7.01%*	*4.69%*	*-113.79%*

MARGINAL RATES OF SUBSTITUTION

READING	homework time	class time	index _ESC adjusted	computers 100 studen	teachers per 10 students
SPAIN					
homeworktime	1.00	0.30	0.13	8.73	-0.10
classtime	3.37	1.00	0.43	29.40	-0.32
index_ESCS (adj.	7.76	2.30	1.00	67.76	-0.74
computers per 10(	0.11	0.03	0.01	1.00	-0.01
teachers per 10	-10.44	-3.10	-1.35	-91.16	1.00
FINLAND					
homeworktime	1.00	1.08	0.22	24.88	-2.20
classtime	0.93	1.00	0.21	23.10	-2.04
index_ESCS (adj.	4.52	4.87	1.00	112.42	-9.94
computers per 10(	0.04	0.04	0.01	1.00	-0.09
teachers per 10	-0.45	-0.49	-0.10	-11.31	1.00
KOREA					
homeworktime	1.00	0.63	0.39	-6.24	0.18
classtime	1.60	1.00	0.62	-9.99	0.28
index_ESCS (adj.	2.59	1.62	1.00	-16.18	0.46
computers per 10(	-0.16	-0.10	-0.06	1.00	-0.03
teachers per 10	5.69	3.56	2.20	-35.53	1.00
CANADA					
homeworktime	1.00	-0.15	-0.03	-31.16	0.03
classtime	-6.89	1.00	0.23	214.59	-0.24
index_ESCS (adj.	-29.91	4.34	1.00	932.01	-1.03
computers per 10(	-0.03	0.00	0.00	1.00	0.00
teachers per 10	28.91	-4.20	-0.97	-900.88	1.00

	homework time	class time	index _ESC adjusted	computers 100 stud	teachers per 10 students
MEXICO					
homeworkt	1.00	-0.08	-0.02	-0.29	0.02
classtime	-13.14	1.00	0.32	3.85	-0.23
index_ESC	-41.68	3.17	1.00	12.22	-0.73
computers	-3.41	0.26	0.08	1.00	-0.06
teachers pe	57.23	-4.36	-1.37	-16.78	1.00
GREECE					
homeworkt	1.00	-0.04	-0.01	-0.29	0.01
classtime	-24.91	1.00	0.34	7.22	-0.26
index_ESC	-73.03	2.93	1.00	21.16	-0.76
computers	-3.45	0.14	0.05	1.00	-0.04
teachers pe	95.51	-3.83	-1.31	-27.67	1.00
TURKEY					
homeworkt	1.00	-0.23	-0.09	2.28	-0.59
classtime	-4.36	1.00	0.39	-9.95	2.59
index_ESC	-11.25	2.58	1.00	-25.66	6.69
computers	0.44	-0.10	-0.04	1.00	-0.26
teachers pe	-1.68	0.39	0.15	-3.84	1.00
OECD					
homeworkt	1.00	-1.46	1.12	1.68	-0.07
classtime	-0.68	1.00	-0.77	-1.15	0.05
index_ESC	0.89	-1.30	1.00	1.49	-0.06
computers	0.60	-0.87	0.67	1.00	-0.04
teachers pe	-14.43	21.12	-16.23	-24.25	1.00