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Does the Quality of Pre-primary Education Pay Off in Secondary School? An International Comparison Using PISA 2003

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Abstract

Attendance of pre-primary institutions is positively associated with PISA test scores in most countries. Several indicators of structural quality of pre-primary education are identified that can account for the variation in the estimated coefficients on pre-primary attendance across countries, based on a cross-country student-level specification with country fixed effects and interactions between individual pre-primary attendance and country-level quality indicators. The association of pre-primary attendance with test scores at age 15 is larger in countries with higher per-pupil spending in pre-primary education, larger shares of children attending privately managed pre-primary institutions, and higher relative pay and higher levels of training of pre-primary teachers.

JEL Code: I20, I28.

Keywords: Pre-primary, ISCED 0, kindergarten, educational performance, educational quality, PISA.

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1. Introduction

Employing data from the 2003 round of the Programme for International Student Assessment (PISA 2003), this paper provides information on the impact of pre-primary education on learning in secondary school and tries to identify those quality indicators of pre-primary education that are most important. The analysis focuses on measures of structural quality, i.e. the institutional framework or program standards, which are easily comparable across countries. Since structural quality builds up the framework for pre-primary education it is also of crucial importance for other aspects of quality such as interaction and process quality in pre-primary education. The estimation strategy consists of interacting pre-primary attendance at the level of the individual student with measures of quality at the country level. This international comparative approach has the advantage of a large amount of variation being available and allowing the evaluation of a wide range of quality indicators simultaneously. Under the assumption that enrollment in pre-primary education follows the same rules in all countries this approach resembles an international differences-in-differences estimation strategy and yields reliable results.

In most western countries, parents' motives to enroll their child in pre-primary education have gradually changed over the last decades. Asked about the reasons why they enrolled their child in a pre-primary institution, most parents in the 1970s responded that both parents were working and that no other family member (such as a grand parent or aunt) was available to care for the child while the mother was at work. The same question asked in the 1990s, however, now revealed that most parents took the view that pre-primary education furthered the development of the child and prepared for primary school which is why they did not want to deprive their child of this experience (European Commission 1995).

This change of attitude towards pre-primary education mirrors the development that pre-primary education itself has undergone over the years. While the pre-primary institutions of today have emerged from the necessity of providing safe-keeping for the children of working mothers at the time of the Industrial Revolution, today's institutions have very little in common with their forerunners. The purpose of pre-primary education today is generally described as preparing young children for school and

offering them a unique environment for social interactions and play with other children. Consequently, pre-primary education is regarded as an integral and important part of education.

Recent research within the field of economics of education has confirmed that early childhood education does in fact live up to its expectations.¹ According to the life cycle of skill formation, education is to be understood as a synergistic process in the sense that early learning promotes the effectiveness of later learning. The earlier an investment into education is made, the higher are the returns to this investment as well as the returns to subsequent educational investments (e.g., Heckman 2006; Cunha and Heckman 2007). Moreover, a large strand of literature indicates that pre-primary education might be particularly important for children from disadvantaged backgrounds (e.g., Currie 2001; Feinstein 2003; Spiess et al. 2003; Schütz et al. 2008). Hence, early education promises to be a valuable tool for reducing the social selectivity of schooling systems and promoting equality of educational opportunities.

Given these findings it is not surprising that a lot of countries have taken steps to increase enrollment into their early education programs. However, in their aspiration for higher coverage rates countries should also be attentive towards issues of quality. Using an international student achievement test this paper shows that early education has a higher pay-off in terms of test scores in some countries than in others. Knowing the forces that drive these differences is an important step towards identifying the most influential indicators of quality. Considering the general relevance of early childhood education for reducing inequalities in educational opportunities these questions of quality carry substantial weight.

The remainder of this paper is structured as follows. Section 2 supplies an overview of the dataset and the attendance of institutions of pre-primary education for a range of countries. Section 3 provides first results on the connection between attendance of pre-primary education and PISA test scores in the countries within the sample. Section 4 analyses the impact of structural qualities on the influence that pre-primary attendance has on PISA test scores, using international variation in these quality indicators. By interacting pre-primary attendance with measures of structural quality, it

¹ Early childhood education encompasses all stages and levels of education prior to the beginning of primary education. It is thus a broader concept as pre-primary education which is defined as the stage directly preceding primary education.

is investigated whether differences in quality can be related to the observed differences in the relationship between attendance and test scores across the countries in the sample. Finally, Section 5 concludes.

2. Data

This paper uses the database of the 2003 round of the Programme for International Student Assessment (PISA 2003) to evaluate the relationship between pre-primary attendance and later schooling outcomes and to assess whether this relationship is influenced by the quality of pre-primary education.

2.1. The PISA 2003 Database

PISA 2003 was conducted in 41 developed and emerging countries, including all 30 member countries of the Organisation for Economic Co-operation and Development (OECD).² It assessed the mathematical, scientific, and reading literacy as well as the problem solving skills of the student population in each participating country. In the context of PISA the term “literacy” signifies that not only the knowledge of the students in each of the three domains, for example based on national curricula, is assessed but also their ability to use the acquired knowledge to meet real-life challenges of modern societies. Because the PISA 2003 test focused on mathematics, with less detailed testing in science and reading, this paper will focus on achievement in mathematics. Moreover, unlike reading literacy, performance in mathematics is predominantly determined and taught within the school, while a lot of reading activities of students are furthered by their families. As in the first PISA study conducted in 2000, the target population was the 15-year-old students in each country, regardless of the grade they currently attended. Thus, in most of the countries assessed, the target population comprises young people near the end of their compulsory schooling, independent of how many years of schooling are foreseen for 15-year-olds by the structure of the national school systems. Table 1 reports the countries participating in the PISA 2003 study that are available for the purpose of the present analysis.³

² For detailed information on the PISA study and its database, see OECD (2004, 2005a, 2005b) and the PISA homepage at <http://www.pisa.oecd.org>.

³ France, Liechtenstein and Serbia and Montenegro had also participated in PISA 2003. However, for reasons stated below they had to be dropped from the sample and therefore do not appear in any of the tables in this paper.

The PISA sampling procedure ensured that a representative sample of the target population was tested in each country. Most countries employed a two-stage sampling technique. The first stage drew a (usually stratified) random sample of schools in which 15-year-old students were enrolled. In most countries, the probability of the schools to be selected was proportional to their size as measured by the estimated numbers of 15-year-old students enrolled in the school. The second stage randomly sampled 35 of the 15-year-old students in each of these schools, with each 15-year-old student in a school having equal selection probability. In schools with less than 35 students in the targeted age group, all of these students were selected into the sample. Generally, a minimum of 150 schools had to be sampled (or all schools if there were less than 150 schools in a country) and a minimum of 4,500 students had to be assessed in each country. The final sample size varied considerably between the participating countries, ranging from 3,350 students in 129 schools in Iceland to 29,983 students in 1,124 schools in Mexico (Luxembourg tested all 3,923 target-aged students in all its 29 applicable schools).

The performance tests were paper and pencil tests, lasting a total of two hours for each student. Test items included both multiple-choice items and open ended questions. The PISA tests were constructed to test a range of relevant skills and competencies that reflected how well young adults are prepared to analyze, reason, and communicate their ideas effectively. Each subject was tested using a broad sample of tasks with differing levels of difficulty to represent a coherent and comprehensive indicator of the continuum of students' abilities. The main focus of the PISA 2003 study was on mathematical literacy, with about 70 per cent of the testing time devoted to this domain. The test items were presented to the students in the form of test booklets that consisted of different clusters of test items. Each student was given one of 13 different test booklets that varied in the composition of the test items representing the four tested domains. PISA used item response theory scaling and calculated five plausible values for proficiency in each of the tested domains for each participating student. The performance in each domain was mapped on a scale with an international mean of 500 and a standard deviation of 100 test-score points across the OECD countries.

As a benchmark to which to compare the magnitude of effects reported below, note that in the sample the simple test-score difference between the two grades with the largest share of 15-year-olds (9th grade and 10th grade) is 28.4 test-score points in

mathematics (29.8 in science, 27.0 in reading). This “grade-level equivalent” gives a rough idea of how much students learn on average during one school year.

2.2. The Student-Level Micro Database

PISA 2003 does not only provide achievement data for representative samples of students in the participating countries but also a rich array of background information on each student as well as on his or her school. In separate background questionnaires, students were asked to provide information on their personal characteristics and family backgrounds, and school principals to provide information on their schools’ resource endowments and location.

The dataset combines students’ test scores in mathematical literacy and the other testing domains with students’ characteristics, family-background data, and school-related variables of resource availability. For estimation purposes, a variety of qualitative variables were transformed into dummy variables and missing observations on the questionnaire items were imputed (see Appendix B for the imputation technique and how the imputations are controlled for in the actual estimations).

Combining the available data, a dataset was constructed containing 260,334 students in 38 countries. This includes 214,411 students in 29 OECD countries. France had to be dropped from the sample because no school-level background information was provided for any of the schools sampled in this country. Liechtenstein and Serbia and Montenegro had also to be discarded from the dataset because fundamental country-level variables that were needed for imputation of missing data were not available in an internationally comparable way.

Also, because in this paper the focus is on the relationship between pre-primary attendance and test scores, all student observations with missing information on pre-primary attendance were discarded. Student weights were adjusted in such a way that all countries again contributed equally to the cross-country regressions. Table A.1 reports international descriptive statistics for all the variables employed in this paper. It also includes information on the amount of original versus missing data for each variable.

2.3. Background Controls

Since PISA 2003 collected background information about the students, their families, and schools, it is possible to control for influencing factors at these levels. To control

for family characteristics in the regressions is especially important to capture part of the selection process into pre-primary education.

Specifically, since parental working and occupational status is expected to play a leading role in the decision to enroll a child in pre-primary education, the selection bias can be reduced by including these variables.⁴ The same holds for the family structure (single parent, patchwork or traditional both parent family) and the family's socio-economic status.

The 40 variables included as controls in the model are reported in Table A.7 (descriptive statistics are given in Table A.1). These include 14 measures of student characteristics: student gender, student age, a dummy indicating whether the student's entrance into primary education was delayed, two dummies for grade repetition, a set of dummies representing the grade that the student currently attends, two indicators for the immigrant status of the student,⁵ and two indicators for the language spoken at home.⁶

The controls also include 16 measures of family background: the family structure as indicated by whether the student lived together with both parents, with only one parent, or in a patchwork family, four indicators on the parents' working status,⁷ three indicators of the highest occupational status of the parents,⁸ five indicators of the number of books in the students' home,⁹ and the PISA index of Economic, Social and Cultural Status (ESCS).¹⁰

⁴ However, this information is only available for students at the age of 15. Therefore, it has to be assumed that it is also informative of the situation in the child's early years.

⁵ The immigrant status of the students was captured by the following categories: "native" students (those students born in the country of assessment or who had at least one parent born in the country); "first generation" students (those born in the country of assessment but whose parent(s) were born in another country); and "non-native" students (those students born outside the country of assessment and whose parents were also born in another country). In the analysis, "native" students served as the residual category.

⁶ The language spoken at home most of the time was captured by the following four categories: "test language"; "other official national languages"; "other national dialects or languages"; and "other languages". Only the latter two dummies were included in the analysis, with the first two serving as residual categories.

⁷ The four indicators of parents' working status are: both parents working full time; one parent working full time and the other half time; at least one parents working full time; at least one parent working half time. Other possible combinations of working part time or looking for a job act as the residual category.

⁸ The highest occupational status of both parents was scaled in four categories: blue collar high skilled; white collar low skilled; white collar high skilled; and blue collar low skilled, which serves as the residual category.

⁹ The categories of books at home are: 1-10, 11-25, 26-100, 101-200, 201-500, and more than 500 books, with the first category acting as the residual category.

¹⁰ The ESCS index is derived from the highest occupational status of parents, the highest educational level, and an estimate related to household possessions.

The model includes 10 school-level measures of school location and resources: three indicators of the size of the community in which the school is located, the average class size in mathematics, two indicators of the availability of instructional material, instruction time in mathematics, a dummy for whether the school is a private school, and the shares of teachers in the school who are fully certified and those who have a tertiary degree in pedagogy.

2.4. *Pre-primary Education and ISCED 0*

Information on pre-primary attendance of the students comes directly from the student background questionnaire. In question 20 of this questionnaire, students were asked to provide information on their pre-primary experience. More specifically, students were asked the following question: “Did you attend <ISCED 0>?” Three answer categories were provided: “No”; “Yes, for one year or less”; and “Yes, for more than one year”. The term “ISCED” is an abbreviation for the International Standard Classification of Education which was developed to serve as an instrument for developing, gathering and presenting statistics of education both within individual countries and internationally and for making these statistics comparable. As such, it also contains a definition for pre-primary education which is labeled as ISCED 0.

According to the manual for the implementation of the ISCED 97 classification in the OECD countries (reference provided as OECD 1999), ISCED 0 - or the pre-primary level of education - is defined as the initial stage of organized instruction. It is supposed to have educational properties, is school- or centre-based and designed for children aged at least three years. The lower age bound of three years arises from the fact that most countries consider three years as the typical entrance age into pre-primary education. However, any educational program that otherwise fulfills the requirements of the above definition will be classified as ISCED 0 if it is not primarily designed to serve children at age two or below (OECD 1999).¹¹

In the national versions of the student background questionnaire the phrase <ISCED 0> was replaced by the appropriate institution(s) of pre-primary education that comply with the definition of ISCED 0 as provided in the manual for the

¹¹ In the PISA 2003 sample, even in those countries where pre-primary education is open for children at age two (Iceland, Spain and New Zealand), the targeted age group extends up to ages five or six (see Table 2).

implementation of the ISCED-97 classification (c.f. OECD 1999). Therefore, the questions answered by the students should relate to the same conceptual understanding of pre-primary education and should be readily comparable across countries.

In Section 4, information on students' attendance of ISCED 0 will be combined with statistics relating to the quality of the programs. It is therefore central to the analysis that the measures of quality used are those describing the institutions of pre-primary education attended by the students. If the quality indicators referred to a broader concept of pre-primary education (e.g., by including also early childhood care) than the ISCED 0 definition, the analysis would suffer from attenuation bias.

However, most of the quality measures used were taken from publications of UNESCO, OECD and World Bank which follow the ISCED 0 definition for pre-primary education. Thus, both the PISA 2003 student questionnaire and the quality measures use the same definition for pre-primary education and combining students' answers with official statistics should therefore be unproblematic. For each country that participated in PISA 2003, Table A.6 contains the national adaptation of question 20 of the student background questionnaire and lists the institutions of ISCED 0 in the respective country. The table illustrates that the institutions of pre-primary education itemized within the student questionnaires are in general the same as those for which the quality measures were collected, except in the United States.

In the United States, the national version of question 20 of the student background questionnaire does not itemize all relevant institutions of ISECD 0. The term <ISCED 0> was replaced by "Kindergarten".¹² Yet, institutions of ISCED 0 comprise not only kindergarten but also other programs such as Day Care, Nursery Schools or Preschools, which are targeted at children at younger ages. Statistics related to pre-primary education in the United States in general will therefore not be directly compoundable to students' answers regarding their kindergarten experience. As a consequence, results for the United States will be reported and discussed in Section 4, but it will be excluded from most of the analysis in Section 4.

¹² Enrollment in kindergarten in the United States was facultative for the cohorts of children tested in PISA 2003. Nevertheless it was widely considered as the first year of formal education and usually part of the K-12 educational system. Predominantly, elementary schools offer kindergarten classes as a grade preceding grade 1 and enroll children at the age of five. The duration of the kindergarten program is 1 year.

2.5. Pre-primary Attendance

Table 1 reports the frequency for each answer category of pre-primary attendance, the number of student observations for which information on pre-primary attendance is available and the percentages of missing information in this variable for each country. In the complete PISA 2003 dataset without France, Liechtenstein and Serbia and Montenegro, information on pre-primary experience is missing for only 2.54% of the students. The highest percentage of missing responses is observed in Canada, where 7.01% of the students did not reply. Then follow Brazil (6.13%), Uruguay (5.71%), Germany (5.39%), and Tunisia (5.02%). For all other countries, the percentage of missing observations for this variable is below 5 percent. Because the information on this variable is central to the analysis and given these low levels of missings, students with missing observations on this variable were excluded from the dataset.

Table 1: Attendance of Pre-primary Education

	ATTENDANCE			No. of students, non-missing	percentage of missing observations
	no pre-primary education	one year or less	more than one year		
Australia	7.42%	46.81%	45.77%	12,279	2.17%
Austria	4.32%	15.52%	80.15%	4,555	0.91%
Belgium	2.36%	3.80%	93.85%	8,547	2.83%
Brazil	23.57%	31.38%	45.05%	4,179	6.13%
Canada	9.00%	45.28%	45.72%	25,993	7.01%
Czech Republic	7.32%	13.90%	78.79%	6,146	2.75%
Denmark	2.35%	31.96%	65.70%	4,138	1.90%
Finland	7.90%	25.34%	66.77%	5,741	0.95%
Germany	4.43%	12.97%	82.6%0	4,409	5.39%
Greece	5.35%	32.68%	61.97%	4,562	1.40%
Hong Kong, China	6.11%	6.79%	87.10%	4,460	0.40%
Hungary	1.03%	4.72%	94.25%	4,737	0.59%
Iceland	6.63%	4.47%	88.90%	3,316	1.01%
Indonesia	49.46%	25.10%	25.44%	10,313	4.16%
Ireland	27.73%	39.79%	32.47%	3,770	2.84%
Italy	4.82%	8.43%	86.75%	11,578	0.52%
Japan	1.31%	1.66%	97.04%	4,676	0.66%
Korea (Rep. of)	3.80%	9.65%	86.54%	5,421	0.42%
Latvia	29.20%	15.07%	55.74%	4,582	0.97%

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Table 1 (continued)

	ATTENDANCE			No. of students, non-missing	percentage of missing observations
	no pre-primary education	one year or less	more than one year		
Luxembourg	11.95%	8.74%	79.31%	3,803	3.06%
Macao, China	3.82%	16.21%	79.97%	1,248	0.16%
Mexico	13.53%	20.63%	65.84%	29,458	1.75%
Netherlands	2.94%	3.12%	93.94%	3,886	2.66%
New Zealand	8.27%	20.05%	71.69%	4,422	1.97%
Norway	7.64%	14.04%	78.33%	3,944	2.95%
Poland	3.86%	51.70%	44.44%	4,359	0.55%
Portugal	27.70%	17.36%	54.94%	4,565	0.93%
Russian Federation	11.76%	9.82%	78.42%	5,942	0.54%
Slovak Republic	8.10%	15.62%	76.28%	7,284	0.84%
Spain	5.45%	10.20%	84.36%	10,643	1.37%
Sweden	11.80%	28.65%	59.55%	4,511	2.44%
Switzerland	3.13%	30.20%	66.66%	8,338	0.97%
Thailand	4.82%	20.87%	74.31%	5,213	0.44%
Tunisia	46.80%	26.21%	26.99%	4,484	5.02%
Turkey	76.66%	15.51%	7.83%	4,736	2.45%
United Kingdom	5.62%	26.04%	68.34%	9,248	3.01%
United States	2.67%	87.05%	10.28%	5,346	2.02%
Uruguay	15.61%	20.64%	63.75%	5,502	5.71%

Students' own reports on pre-primary attendance according to the question: Did you attend <ISCED 0>? Three answer categories were provided: "No"; "Yes, for one year or less"; and "Yes, for more than one year". Missing observations on this variable were deleted from the dataset. The percentage of students whose answer is missing in each country is reported in the last column. The number of students includes only those students that reported on pre-primary attendance. Observations are weighted according to the PISA student sampling weights. Countries ranked in alphabetical order.

The first column of Table 1 provides the percentages of students in each country that have no pre-school experience. Non-attendance occurs most frequently in Turkey, where 77% of the students tested in PISA 2003 did not attend pre-primary education at all. Non-attendance is also very high in Indonesia and Tunisia but already below 50% (49% and 47%). In Latvia (29%), Ireland (28%), Portugal (28%) and Brazil (24%), non-attendance is still sizable, but for most other countries non-attendance rates are well below the 10 percent level. Columns 2 and 3 of Table 1 display the shares of students reporting pre-primary attendance in the two categories.

Information on the socio-economic and socio-cultural status of the students in each category of pre-primary attendance is provided in Table A.2. The table displays for each country as well as for the complete sample the mean of the Index of Economic, Social and Cultural Status (ESCS), the percentage of students with a foreign language spoken at home and the percentage of students who were not born in the country of test.

In general, the mean ESCS is highest in the group of students that attended pre-primary education for more than one year and it is lowest in the group of students that did not attend pre-primary education at all. The share of students with a foreign language spoken at home is highest in the group of students that did not attend pre-primary education at all and lowest in the group of students that attended for more than one year. The same pattern applies for the percentages of students that were not born in the country of test. Thus, families with a favorable socio-economic and cultural background tend to send their children more often to pre-primary education and also for longer periods.

Table 2 illustrates how those students reporting attendance of pre-primary education divide themselves between the two possible categories “one year or less” and “more than one year”. As is evident from the table, most of these students have a pre-school experience that extends over more than one year. The only exceptions to this rule are the United States, Turkey, Ireland, and Poland. Since the official duration of kindergarten in the United States is one year, it is not astonishing that a majority of 89 percent of the students indicated that they attended in fact for one year or less. In Turkey, Ireland, and Poland, students who reported pre-primary experience also attended mostly for one year or less (66%, 55%, and 54%). In Australia, Canada, Indonesia and Tunisia, the difference between both categories of attendance duration is negligible; the shares of attendance are around 50 percent in both categories. In all other countries, by far most of the students attended for more than one year.

Table 2 also displays some of the structural qualities of pre-primary education: the entrance age into pre-primary education, the duration of the pre-primary cycle and the entrance age into primary education. Data for these structural qualities refer back to 1991, when most children in the sample were three years old and which therefore describe the relevant institutional background. Interestingly, in Turkey, Ireland and Poland, the majority of students reports pre-primary experience shorter than the official duration of the program. However, since in 1991 pre-primary education was not compulsory in any of the countries in the sample, it cannot astonish that for some countries a majority of students reports attendance below the official duration of the program.

In Turkey, official duration is 2 years, but 66% of the students with pre-primary experience attended for only one year or less. Yet, since attendance of pre-primary education in Turkey is generally low (only 23% of the students have pre-primary experience), the low fraction of students with a long pre-primary experience is not surprising. In the two other countries, the difference between the two attendance categories is not substantial. In Ireland, 55% percent attended for one year or less, in Poland 54%, while the official duration in these countries is 2 and 4 years.

Besides, Table 2 also calls attention to the fact that in the United States, Korea and Australia the official duration of pre-primary education is only one year. The issue of kindergarten in the United States was already addressed in Section 2.4. In Korea, 90% of the students report a pre-primary experience exceeding the official duration of one year. The reason for this deviation lies probably in the exceptional ambition of Korean parents who enroll their children in kindergartens from a very early age on to promote their educational success.¹³ Moreover, kindergarten in 1991 is not part of the public education system and therefore not regulated by the state.

Table 2: Attendance Rates and Structural Qualities

	Of those who attended pre-primary education:		Structural qualities of pre-primary education (1991)		
	one year or less	more than one year	Entrance age pre-primary	Duration pre-primary	Entrance age primary
Japan	1.68%	98.32%	3	3	6
Netherlands	3.21%	96.79%	4	2	6
Belgium	3.89%	96.11%	3	3	6
Hungary	4.77%	95.23%	3	3	6
Iceland	4.79%	95.21%	2	4	6
Hong Kong, China	7.23%	92.77%	3	3	6
Italy	8.86%	91.14%	3	3	6
Luxembourg	9.93%	90.07%	4	2	6
Korea (Rep. of)	10.03%	89.97%	5	1	6
Spain	10.79%	89.21%	2	4	6
Russian Federation	11.13%	88.87%	3	4	7
Germany	13.57%	86.43%	3	3	6
Czech Republic	15.00%	85.00%	3	3	6
Norway	15.20%	84.80%	4	3	7
Austria	16.22%	83.78%	3	3	6

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¹³ Telephone communication provided by Dr Chang Woon Nam, 2.7.2008.

Table 2 (continued)

	Of those who attended pre-primary education:		Structural qualities of pre-primary education (1991)		
	one year or less	more than one year	Entrance age pre-primary	Duration pre-primary	Entrance age primary
Macao, China	16.85%	83.15%	3	3	6
Slovak Republic	17.00%	83.00%	3	3	6
Latvia	21.28%	78.72%	3	4	7
New Zealand	21.86%	78.14%	2	3	5
Thailand	21.93%	78.07%	3	3	6
Mexico	23.86%	76.14%	4	2	6
Portugal	24.01%	75.99%	3	3	6
Uruguay	24.46%	75.54%	3	3	6
Finland	27.51%	72.49%	3	4	7
United Kingdom	27.59%	72.41%	3	2	5
Switzerland	31.18%	68.82%	4	3	7
Sweden	32.48%	67.52%	3	4	7
Denmark ¹⁴	32.73%	67.27%	3	4	7
Greece	34.53%	65.47%	4	2	6
Brazil	41.06%	58.94%	4	3	7
Tunisia	49.27%	50.73%	3	3	6
Indonesia	49.66%	50.34%	5	2	7
Canada	49.76%	50.24%	4	2	6
Australia	50.56%	49.44%	5	1	6
Poland	53.78%	46.22%	3	4	7
Ireland	55.07%	44.93%	4	2	6
Turkey	66.45%	33.55%	4	2	6
United States ¹⁵	89.44%	10.56%	5	1	6

Students' own reports on pre-primary attendance (see also Table 1). Source for entrance age into and duration of pre-primary education and of entrance age into primary education: UNESCO Institute for Statistics <http://www.uis.unesco.org/pagesen/DBSysCri.asp>, accessed 17.1.2008.

Countries ranked in ascending order according to percentage of students attending for more than one year.

In 1991, pre-primary education was not compulsory in any of the countries that form part of the sample.

Australia is also among the very few countries where the official duration of the pre-primary program is one year.¹⁶ Of those with pre-primary experience 51% attended for one year or less, while 49% attended for more than one year. The high percentage of students reporting attendance for more than one year can be explained in two ways. First, it is possible that students attended slightly more than one year because some institutions offer a "pre-entry" program which means that children may attend for one

¹⁴ In Denmark, unlike the information given by the UNESCO Institute for Statistics, the institutions of ISCED 0 are børnehav and børnehaveklasse, i.e., age-integrated kindergarten and a pre-school class in primary school (see Danish Ministry of Social Affairs (2000)). The entrance age into and the duration of pre-primary education in Denmark were corrected accordingly.

¹⁵ For the United States, the entrance age into and the duration of pre-primary education were replaced by those of kindergarten in accordance to the question in the PISA student background questionnaire.

¹⁶ The official duration of pre-primary duration in Australia is one year according to the UNESCO Institute for Statistics (<http://www.uis.unesco.org/pagesen/DBSysCri.asp>, accessed 17.1.2008) and the manual for ISCED-97 implementation in OECD countries (OECD 1999).

session per week for up to ten weeks before starting the full preschool program.¹⁷ Second, the reason may also lie in the question itself. In Australia, the student questionnaire contained two versions of question 20 and students were asked to answer according to their state or territory.

Students in Victoria, Queensland, South Australia, Western Australia, and Tasmania answered the question “Did you attend kindergarten or pre-school?”, while for students in the Australian Capital Territory, New South Wales, and Northern Territory the question was phrased “Did you attend pre-school or a long day care centre?” Kindergarten and pre-school are unambiguously institutions of ISCED 0 according to the definition of the ISCED-97 manual (OECD 1999) and have a typical program length of one year. On the other hand, long day care centers serve children that aged from birth to five years.¹⁸ Therefore, children who attended long day care centers may well have attendance durations exceeding the official one year of pre-primary education programs.

However, excluding those students from the sample that answered with regard to pre-school and long day care centers (i.e., students in the Australian Capital Territory, New South Wales, and the Northern Territory) does not substantially alter the percentages of answers in the two duration categories.

In the analyses of the following Sections 3 and 4, only information on whether a student attended institutions of pre-primary education for more than one year will be used. Thus, in the analyses, the categories “non-attendance” and “attendance for one year or less” will be considered jointly as the residual category and will not be distinguishable from each other. This is viewed as a suitable approach since the answer category “for one year or less” may encompass also very short spells within pre-primary education such as only weeks or several months, which is closer to “non-attendance” than it is to “attendance for more than one year”. Moreover, even if students had in fact attended for one year, this is still a short time span as compared to the official duration of the pre-primary education cycle in most countries. Therefore, it is argued that only a small mistake is made by combining the two categories.

¹⁷ Preschools Australia. 2008. Compare Infobase Limited. <http://preschools.indiaedu.com/australia-preschools> (accessed July 1, 2008).

¹⁸ Care For Kids. 2008. Care For Kids Internet Services. <http://www.careforkids.com.au/articlesv2/article.asp?id=63> (accessed July 1, 2008).

However, in those countries where the official duration is only one year, and in those where the answer category “one year or less” was more often chosen than “more than one year” or where both answer categories received almost equal shares, combining “non-attendance” and “one year or less” might be a less valid approach. That this is in fact a problem for some countries can be seen from the analysis in Sections 3. Therefore, for the analysis in Section 4 some countries will be discarded, but the sensitivity of results will be tested using different subgroups of countries.

3. Pre-primary Attendance and PISA Achievement

This section provides evidence on the relationship between pre-primary attendance and later school success. The impact of pre-primary education on PISA test scores is estimated separately for each country by using different sets of control variables. Thus, it can be shown that the estimated coefficients change by including different sets of control variables, which is interpreted as evidence for a reduction in selectivity bias. Pre-primary attendance will in the following be defined as having attended pre-primary education for more than one year.

3.1. Empirical Specification

For each country the impact of pre-primary education is estimated using within country variation in pre-primary attendance and achievement. Of course, student achievement depends on a lot of other factors inside and outside of school systems, which must be taken into account if the effects of pre-primary education is to be isolated. For example, if students whose parents were both working when they were still very little are more likely to have attended pre-primary institutions than children with only one working parent, and if parental work status has a direct influence on the students’ achievement, then the estimated effect of pre-primary education would be biased as long as parental work status was not accounted for.

Therefore, educational production functions are estimated which control simultaneously for differences in various student, family, and school characteristics that may influence student achievement. Thereby, possible bias due to non-random selection of children into pre-primary education can be reduced, but the estimated coefficients still cannot be interpreted as causal effects. Thus, the following model is estimated in

which the achievement test score T_{isc} of student i in school s in country c is regressed on several sets of potential influences, separately for each country c :

$$(1) \quad T_{isc} = B_{isc}\alpha + R_{sc}\beta + P_{isc}\gamma + \varepsilon_{isc}$$

In this specification, B is a vector of student background data including the set of student and family background characteristics. It consists of 30 variables, such as the student's gender and age, immigration status, family status, parental occupation and work status, and indicators of family socio-economic status. R is a vector of data on schools' resource endowments and location, comprising 10 variables such as class size, availability of materials, instruction time, teacher education, city size, and average expenditure per student in the country. (See Section 2.3 for more detailed information.) P is the dummy variable of pre-primary attendance which is of primary interest in this paper.

Within each country, the parameter vectors α , β and γ are estimated by weighted least-squares micro-econometric regressions at the level of the individual students i . As pointed out in the Data Section of this paper, the estimation accounts for students' sampling probabilities and the hierarchical structure of the data which adds higher-level components to the error term ε of the model. To be able to use a complete dataset of all students with data on achievement and pre-primary attendance, missing values were imputed as described in Appendix B. To account for this in the estimations, all regressions include a complete set of indicators identifying observations with imputed values for each variable.

3.2. The Impact of Pre-primary Attendance

Table 3 presents the outcomes of three sets of regression analyses estimating the influence of pre-primary attendance on test scores for each of the countries that participated in PISA 2003. Each of the three sets of regressions controls for a different set of control variables. The first set of columns displays the results of a regression of test scores on pre-primary attendance and a constant - without inclusion of controls. Pre-primary attendance is positively and significantly correlated with test performance in all countries, except in Switzerland, Ireland and Latvia. However, these regressions do not control for confounding factors that might influence both the parents' decisions to enroll their child in a pre-primary institution and the students' test scores.

Parents who highly value education and academic achievement might enroll their child in pre-primary education to provide them with a good start at school and might at the same time also assist their performance later in school. Thus, it is necessary to control for the value that parents assign to the education of their child. This can – to some extent – be achieved by including variables at the family level such as the occupational status and the employment status of the parents and indicators for the socio-economic background of the family such as the number of books in the students' home and the PISA 2003 Index of Economic, Social and Cultural Status (ESCS).

Therefore, the second column in Table 3 reports results for a model specification that controls for the full set of student and family background control variables. In this specification, the estimated coefficients on pre-primary attendance become smaller and drop in statistical significance. In some countries a statistically significant relationship between test scores and pre-primary attendance can no longer be estimated (Austria, Czech Republic, Finland, Iceland, Portugal and Slovakia).

In the third specification the full set of school level control variables is added to the estimation. In most countries, the additional inclusion of the school level control variables does not change the estimated coefficients on the pre-primary variable to a great extent. Yet, the inclusion of school level variables now leads to insignificantly estimated coefficients also in the Netherlands, Poland, and the United Kingdom.

Although the estimated coefficients cannot be interpreted as causal effects because of possible nonrandom selection of children into pre-primary education, the regression analysis supports the view that selection biases can be reduced by including proper control variables. A large part of the association between attendance and performance previously calculated in column (1) of Table 3 can in fact be attributed to family background. By contrast, the inclusion of school level variables does not significantly alter the estimated coefficients. In the complete model specification for the full sample of countries, including country fixed effects, PISA test scores are on average 8.2 points higher for students who attended pre-primary education. This amounts to roughly 29 percent of the grade-level equivalent in the sample, i.e. kindergarten attendances has the same impact on test scores as 29 percent of a normal school year.

In Ireland, Korea and the United States, the regression analysis led to significantly negatively estimated coefficients in the most comprehensive model specification. For

the United States, a negative association between PISA test scores and kindergarten attendance for more than one year as compared to non-attendance or attendance for one year or less is little surprising. Given that kindergarten in the United States is typically considered as the first year of formal education and given that the duration of the program is one school year, it seems plausible that children who attended kindergarten for more than one year had a delayed school entry. In fact, the data confirms that these students attend lower grades than their fellow students who attended kindergarten only for one year or less. Thus, they did not have the opportunity to learn as much mathematics.¹⁹

However, for the cases of Korea and Ireland an explanation for the negative association between attendance for more than one year and PISA test scores is not at hand. For Korea, the statistics provided in Table A.2 reveal no deviations from the general pattern of favorable family background being connected with longer attendance. This holds also for the case of Ireland where the only deviation is that the highest percentage of students that were not born in the country of test is found in the category “attendance for more than one year”.

Including both categories of pre-primary attendance in the regressions only confirms the findings from Table 3 but does not explain why a negative relationship for longer attendance duration is found.²⁰ In Korea, test performance of students attending pre-primary education for one year or less is not significantly different from that of students who did not attend pre-primary education at all. However, students who attended for more than one year perform significantly worse in PISA than students who had not attended. In the case of Ireland, attending pre-primary education for one year or less is connected with significantly higher test performance than non-attendance. On the other hand, attending pre-primary education for more than one year is negatively associated with test performance.

¹⁹ The statistics for the United States provided in Table A.2 moreover indicate that the students with the most favorable backgrounds mostly attend kindergarten for one year or less.

²⁰ Results for these regressions are available from the author upon request.

Table 3: Relationship between Attendance of Pre-primary Education and Student Performance

Country	Estimation without control variables			Estimation including student and family control variables			Estimation including student, family and school level control variables				
	Coefficient on pre-primary attendance	Standard Error	R ²	Coefficient on pre-primary attendance	Standard Error	R ²	Coefficient on pre-primary attendance	Standard Error	R ²		
Full Sample	25.001 ***	(0.778)	0.25	9.624 ***	(0.592)	0.41	8.220 ***	(0.571)	0.44	260,334	9,888
Australia	16.107 ***	(2.158)	0.01	6.557 ***	(1.896)	0.20	6.194 ***	(1.782)	0.30	12,279	321
Austria	29.328 ***	(5.087)	0.02	0.595	(3.622)	0.30	-4.215	(3.204)	0.42	4,555	187
Belgium	93.775 ***	(6.577)	0.04	44.258 ***	(5.424)	0.38	35.678 ***	(4.374)	0.52	8,547	271
Brazil	40.454 ***	(4.878)	0.04	18.741 ***	(3.227)	0.27	13.476 ***	(3.159)	0.37	4,179	225
Canada	23.952 ***	(2.175)	0.02	14.015 ***	(1.785)	0.19	13.917 ***	(1.666)	0.24	25,993	1,077
Czech Republic	11.648 ***	(4.133)	0.00	4.143	(2.982)	0.29	3.760 ***	(2.922)	0.38	6,146	250
Denmark	25.623 ***	(3.180)	0.02	18.122 ***	(2.630)	0.26	16.600 ***	(2.569)	0.31	4,138	206
Finland	11.115 ***	(2.689)	0.00	2.591	(2.434)	0.18	2.240	(2.381)	0.23	5,741	197
Germany	62.043 ***	(5.793)	0.06	28.296 ***	(3.580)	0.37	21.140 ***	(3.091)	0.46	4,409	207
Greece	19.937 ***	(4.522)	0.01	11.392 ***	(3.605)	0.24	10.712 ***	(3.055)	0.32	4,562	171
Hong Kong, China	84.889 ***	(6.350)	0.08	53.437 ***	(5.665)	0.23	38.851 ***	(4.411)	0.35	4,460	145
Hungary	36.096 ***	(7.339)	0.01	10.423 **	(4.788)	0.36	10.761 **	(4.540)	0.40	4,737	251
Iceland	9.501 ***	(4.964)	0.00	0.581	(4.552)	0.14	-1.378	(4.341)	0.19	3,316	129
Indonesia	35.587 ***	(6.436)	0.04	22.286 ***	(4.672)	0.19	21.590 ***	(4.706)	0.29	10,313	346
Ireland	-5.690 ***	(3.579)	0.00	-10.670 ***	(2.808)	0.24	-11.087 ***	(2.603)	0.31	3,770	145
Italy	29.120 ***	(5.073)	0.01	17.292 ***	(3.788)	0.23	13.393 ***	(3.407)	0.28	11,578	406
Korea (Rep. of)	9.497 **	(4.283)	0.00	-7.182	(3.251)	0.26	-8.575 ***	(2.936)	0.33	5,421	149
Latvia	5.088	(4.285)	0.00	-1.020	(3.608)	0.18	-4.454	(3.500)	0.23	4,582	157
Luxembourg	23.082 ***	(5.841)	0.01	11.406 ***	(3.831)	0.30	10.769 ***	(2.850)	0.40	3,803	29
Macao, China	23.712 ***	(5.791)	0.01	22.482 ***	(5.649)	0.14	13.867 ***	(4.754)	0.31	1,248	39
Mexico	31.654 ***	(4.059)	0.03	9.646 ***	(2.730)	0.29	6.308 **	(2.645)	0.39	29,458	1,124
Netherlands	39.193 ***	(7.545)	0.01	10.530 *	(6.197)	0.31	6.235 ***	(5.507)	0.43	3,886	150
New Zealand	26.705 ***	(3.081)	0.02	12.874 ***	(2.643)	0.24	8.998 ***	(2.539)	0.35	4,422	172
Norway	25.910 ***	(3.728)	0.01	8.874 ***	(3.238)	0.22	9.610 ***	(3.164)	0.26	3,944	182

(continued on next page)

Table 3 (continued)

Country	Estimation without control variables			Estimation including student and family control variables			Estimation including student, family and school level control variables			No. of observations (students)	Number of PSUs (schools)
	Coefficient on pre-primary attendance	Standard Error	R ²	Coefficient on pre-primary attendance	Standard Error	R ²	Coefficient on pre-primary attendance	Standard Error	R ²		
Poland	27.227 ***	(3.169)	0.02	4.969 *	(2.721)	0.25	3.171	(2.726)	0.27	4,359	166
Portugal	13.611 ***	(3.736)	0.01	-2.123 ***	(2.548)	0.30	0.413	(2.384)	0.37	4,565	153
Russian Federation	22.792 ***	(3.690)	0.01	12.618 ***	(3.289)	0.17	10.861	(2.989)	0.24	5,942	212
Slovak Republic	14.784 ***	(4.727)	0.00	1.522 ***	(2.994)	0.32	0.674	(3.100)	0.36	7,284	281
Spain	30.568 ***	(3.820)	0.02	13.726 ***	(2.683)	0.24	11.928 ***	(2.505)	0.28	10,643	383
Sweden	19.863 ***	(3.262)	0.01	5.962 **	(2.714)	0.26	5.458 **	(2.661)	0.33	4,511	185
Switzerland	6.948 ***	(5.647)	0.00	-2.192 ***	(3.980)	0.32	-2.272 ***	(3.248)	0.41	8,338	445
Thailand	27.970 ***	(4.215)	0.02	13.394 ***	(2.991)	0.18	10.916 ***	(2.839)	0.26	5,213	179
Tunisia	37.127 ***	(5.064)	0.04	12.920 ***	(3.316)	0.25	10.084 ***	(2.393)	0.47	4,484	149
Turkey	88.092 ***	(16.392)	0.05	22.693 ***	(7.190)	0.32	19.783 ***	(5.776)	0.38	4,736	159
United Kingdom	19.479 ***	(3.329)	0.01	7.255 ***	(2.569)	0.28	3.837 ***	(2.435)	0.43	9,248	379
United States	-26.557 ***	(5.417)	0.01	-17.085 ***	(4.448)	0.31	-15.763 ***	(4.214)	0.36	5,346	274
Uruguay	44.745 ***	(3.739)	0.05	19.779 ***	(3.447)	0.24	13.157 ***	(2.839)	0.38	5,502	243

Dependent variable: students' test score in mathematics in PISA 2003. The regression for the full sample consisting of all 38 countries additionally controls for fixed country effects. Significance level (based on clustering-robust standard errors): *** 1 percent, ** 5 percent, * 10 percent.

4. Effects of Quality of Pre-primary Education

Considering the observed differences in the association between test scores and participation in ISECD 0 programs which were the subject of the previous section, the question arises whether these can be related to differences in the quality of ISCED 0. The aim of this section is therefore to analyze the factors that play a role in determining the importance of pre-primary attendance for student performance and the observed differences between countries.

4.1. Measures of Quality of Pre-primary Education

In recent years, pedagogical research has done much to provide standards and measures for quality in early childhood and pre-primary education. The literature proposes to evaluate quality of pre-primary education within different domains, such as orientation quality, structural quality, educational concept, interaction quality, operational quality, child-outcome or outreach quality (OECD 2006a).

Orientation quality refers to the type and level of attention that a government brings to policies in this area, i.e., through legislation and regulations. The structural quality (also referred to as program standards) describes the overarching structures needed to ensure quality, and pertains also to clear formulation and enforcement of the legislation. Structural qualities define many things such as the environment of the children, the training of the staff and the curriculum. Another domain of quality is the educational concept and practice of centers which will evidently be guided by the curriculum framework. Interaction and process quality encompasses the quality of the relationship and interaction between children and teachers and among children and teachers themselves. Operational quality describes the management qualities of the school or centre, such as measures taken to ensure quality improvement and team building. Furthermore, since pre-primary education endeavors to promote the development of children, a central aspect of quality is the quality of child-outcome or performance. This quality domain is closely tied to the ultimate goal of pre-primary education. There, national policies may focus on language, school readiness or social interactions among children. Finally, the quality of pre-primary institutions can also be considered under aspects of standards pertaining to parent or community outreach and involvement.

These different aspects and concepts of quality are helpful tools to assess the quality of institutions of pre-primary education. However, many of these are difficult to use in the context of an international comparison. It might not be an easy task to assess the managerial qualities of a pre-primary school or learning centre, but in the context of an international study this would mean to assess the managerial qualities of the total of the country's schools and centers and to compare some sort of average of this aspect of quality between the countries. For the purpose of the present analysis this would not have been a viable road to pursue. Instead, only those measures of quality were considered which were available at an aggregated level.

One main focus of the analysis is therefore on the structural quality of pre-primary education in the countries that participated in PISA 2003. The structural quality describes the framework for pre-primary education and includes such characteristics as the typical entrance age into and the duration of pre-primary education. Similarly, the pupil-teacher ratio in pre-primary education can also be used to describe structural quality. Another interesting aspect of structural quality is the degree of private involvement in pre-primary education which can be operationalized by the share of private enrollment in pre-primary education.

Part of the structural quality of a system of pre-primary education is also the share of children in the relevant age group that are attending pre-primary institution. This measure is informative on the general acceptance of pre-primary education as a central and integral part of education that benefits the child. Therefore, the share of students in the respective country that reported that they had attended pre-primary education for more than one year was also included as an institutional measure at the country level also. The financing of pre-primary education is another central point. As a measure for the financial resources available for pre-primary education, per pupil spending in pre-primary education measured in percent of gross domestic product was used.

Crucial for the quality of pre-primary education are certainly the teacher themselves. Therefore, information on the training of pre-primary teachers was collected. More specifically, the interest was on the level of training that teachers obtained; i.e., whether the training of teachers was located at the university level or whether it consisted of a vocational professional training. This variable was coded as "1" if the training took place at the tertiary level, and "0" if the training took place at

levels below. Another aspect of teachers' characteristics is the social prestige that is associated with the profession of a pre-primary teacher. Arguably, this prestige varies between countries and might also influence selection into the profession. Information on prestige is not readily available and comparable across countries. Thus, financial compensation was used, which certainly influences to a large extent the selection process into the profession. However, also information on the salaries of pre-primary teachers in the respective countries was hard to obtain, so that eventually a comparison of the average pre-primary teacher salaries with those of other employees in the public sector was used (OECD 2003).

Although many important aspects of the quality of pre-primary education, such as the interaction and process quality could not be considered here since comparable information was not available for all countries, the measures that were collected build up the framework for pre-primary education and are as such crucial determinants for the other aspects of quality as well.

The measures of structural quality stem from different sources such as OECD, UNESCO and institutions of the European Union, but also from statistical offices or education ministries of the respective countries. Information on the variables themselves, their sources and year of reference are provided in Tables A.3 – A.5.

4.2. Identification of Institutional Effects

In the context of the present analysis the prime interest is on how structural qualities of pre-primary education institutions interact with pre-primary attendance, i.e. whether the influence of pre-primary attendance on student achievement is higher in countries with higher quality of their pre-primary education institutions.

The approach taken in the analysis in this section allows us to neglect the problem of non-random selection as long as the groups of students attending or not-attending pre-primary education do not differ across countries. This requires the assumption that the decision of the parents to enroll their child into pre-primary education follows the same rules across the countries and especially that parents are equally convinced of the beneficial effects of pre-primary education for their child. Under this assumption, interacting pre-primary attendance with measures of structural quality resembles an international differences-in-differences estimation strategy and yields reliable results.

The sample of countries will therefore be selected in such a way as to make the above assumption of no unobserved country heterogeneity most likely.

For the analysis an interaction specification with country fixed effects is employed, which requires the underlying assumption that any remaining unobserved cross-country heterogeneity is unrelated to the size of the effect of pre-primary attendance on student achievement. Including country fixed effects in the model by a vector of country dummies C , allows the education production function to have a unique intercept for each country:

$$(2) \quad T_{isc} = B_{isc}\alpha + R_{sc}\beta + P_{isc}\gamma + (P_{isc} \times Q_c)\eta + C_c\mu + \varepsilon_{isc}$$

The definition of the vectors and scalars in this specification is as before (Equation (1) in Section 3.1). B is the vector of student background data including student and family background characteristics. R is the vector of data on schools' resource endowments and location. (See Section 2.3 for more detailed information on the control variables.) New in this specification is the vector Q which consists of measures of quality for pre-primary education. P is the dummy variable for pre-primary attendance. Consequently, $P \times Q$ represents the interaction terms between pre-primary attendance and the measures of pre-primary quality. The coefficients η on the interaction terms estimate how the measures of quality impact on the effect of pre-primary attendance on student achievement.

The parameter γ and the parameter vectors α , β , δ , η , and μ are estimated by weighted least-squares regression at the level of individual students i . As before, the estimation encompasses the weighting of student observations by their sampling probabilities and the addition of higher-level components to the error term ε , and the treatment of missing values.

4.3. Sample of Countries

Since the aim is to assess whether and which quality indicators of pre-primary education have an impact on the effect of pre-primary attendance on test scores, the sample of countries was selected on the basis of a homogenous concept of pre-primary education.

Measuring pre-primary attendance as having attended pre-primary education for more than one year led to the exclusion of countries where the official duration is only

one year: Korea, Australia, and the United States. In these countries, students attending for more than one year may form a negatively selected sample. This problem has been clearly visible from the results for the United States discussed in the previous section.

Moreover, countries were excluded where a high percentage (more than 30 percent) of the students indicated that they had not attended pre-primary education at all. The motive for doing this was to make sure that in all countries attending pre-primary education was equally accepted as beneficial for children so as to reduce the probability that selection into pre-primary education differed between countries. This debarred Turkey, Indonesia, and Tunisia from the analysis.

Another set of countries was excluded based on a comparatively smaller fraction of students attending for more than one year. Again, this was done to reduce the possibility of different selection processes between the countries. It was required that among those students who had attended pre-primary education, more than 60 percent should have attended for more than one year. 60 percent was chosen as the cutoff point to balance between demanding a clear majority and not losing too many country observations. Applying this bound Brazil, Canada, Poland, and Ireland were excluded.²¹

For the purpose of the analysis in this subsection, the dataset now contained 179,454 students in 28 countries, 22 of which are OECD countries. However, to encounter the suggestion that the results discussed below might be only valid for this specific selection of countries, the analysis was repeated for the full set of countries available (see Section 4.5). All results proved to be robust.

4.4. Results

Table 4 reports the results of the regression analysis for the sample of countries described above. Additionally, Table 5 will report the results for the sample of OECD countries, but excluding the three countries with an envisaged pre-primary education of one year (Korea, Australia, and the United States) and excluding Turkey because of its exceptional low level of pre-primary enrollment. All models include the 40 variables described above to control for student and family background and school resources. Additionally, the models also control for country fixed effects.²²

²¹ Note that this would have also barred Australia, the United States, Turkey, Indonesia, and Tunisia from the sample, which had been sorted out by the two previous barriers.

²² Full results on the regression presented in column (1) are given in Table A.7.

Table 4: Quality of Pre-primary Education

Interaction with attendance					
	(1)	(2)	(3)	(4)	(5)
Pre-primary attendance ^a	8.016*** (0.877) ^a	9.303*** (0.711) ^a	9.527*** (0.716) ^a	9.328*** (0.709) ^a	7.471*** (0.869) ^a
Expenditure on pre-primary education	8.197*** (2.515)	8.688*** (2.069)	8.041*** (2.086)	11.083*** (2.296)	6.687*** (2.162)
Share of private enrollment	0.094*** (0.029)		0.074*** (0.028)		
Comparative salaries	8.790** (4.071)			10.016*** (3.665)	
Tertiary training	5.465*** (1.772)				6.229*** (1.658)
Share attending > 1 year	32.908*** (7.131)	27.359*** (6.844)	23.799*** (6.776)	33.082*** (7.067)	33.573*** (7.095)
Entrance age pre-primary	8.156*** (1.998)	6.010*** (1.894)	5.739*** (1.897)	8.004*** (1.995)	7.003*** (1.903)
GDP per capita	-0.114 (0.114)	0.019 (0.101)	0.019 (0.101)	-0.098 (0.111)	-0.018 (0.102)
Country mean test score	0.052 (0.027)	0.040 (0.025)	0.040 (0.025)	0.039 (0.025)	0.057** (0.027)
Students	168,010	179,454	179,454	179,454	168,010
Schools (clustering units)	6,422	6,877	6,877	6,877	6,422
Countries	26	28	28	28	26
R ²	0.421	0.426	0.426	0.426	0.421

Dependent variable: PISA 2003 students' test scores in mathematics. Sample: 28 countries and 179,454 students. Reported coefficients are coefficients for the interaction between the variables and attendance of pre-primary education. Least-squares regressions weighted by students' sampling probability. Controls include: 14 variables describing student characteristics, 16 variables describing family background, 10 measures of school location and resources, imputation dummies, and interaction terms between imputation dummies and the variables. Regressions include country fixed effect. Robust standard errors adjusted for clustering at the school level in parentheses. Significance level (based on clustering-robust standard errors): *** 1 percent, ** 5 percent, * 10 percent. ^a Main effect of pre-primary attendance.

Column (1) in Table 4 includes several quality indicators and builds up a model to explain differences in the importance of pre-primary attendance for later school success. The variable pre-primary attendance enters the model as a main effect to explain differences in PISA test scores. The measures of pre-primary quality were centered on the international mean, which implies that the estimated coefficient on the variable pre-primary attendance gives the impact of pre-primary attendance when the quality indicators are equal to the international mean. The coefficient on this variable is positively and significantly estimated, indicating that on average across all countries students that attended pre-primary institutions for more than one year perform better by 8 test score points. Thus, the effect of attending pre-primary education corresponds to

roughly one third of the grade-level equivalent. The variables measuring quality of pre-primary education were entered as interaction terms with pre-primary attendance. Consequently, the estimated coefficients are informative on whether the effect of pre-primary attendance is bigger or smaller with increasing quality of pre-primary education.

As can be seen from column (1), the impact of attendance on test scores increases by 8.2 test score points if expenditure per student in pre-primary education is increased by 1 percent of GDP per capita, which is about as much as the main effect of attendance on test scores. However, considering that countries spend between 1.3 and 3.1 percent of GDP per capita per student in pre-primary,²³ an increase in spending per student by 1 percent of GDP per capita would mean to increase spending by around 50 percent.

The model also includes the share of private enrollment in pre-primary education. Private involvement in education in general has been shown to have positive effects on student outcome in many settings. Especially, evidence suggests that private involvement benefits all students in the education system, not only those attending private schools (e.g., Wößmann 2001, 2003, forthcoming; Wößmann et al. 2007). This effect is supposedly due to increased competition between schools which also affects publicly operated schools. However, it is also worth noting that the positive effect of private involvement holds only in the case of private provision of education but not in the case of private funding. Because of the positive link between student achievement and private management in schooling in general, the effect of private involvement at the level of pre-primary education were probed. The results in column (1) and (3) confirm the positive influence of private management also at the level of pre-primary education. Pre-primary attendance has a bigger impact on later schooling outcomes in countries where a higher share of children attend privately managed pre-primary institutions. Yet, the results cannot be informative on the effects of private funding of pre-primary education. Especially, the data used does not distinguish between private for-profit and not-for-profit pre-primary institutions.

As an indicator of pre-primary teachers' salaries a comparison of the average pre-primary teachers' salaries with those of executive officials I in the public sector is included. The average pre-primary teachers' salary was divided by the average salary of

²³ The average across the countries in the sample lies around 2.35 percent of GDP per capita.

executive officials I in the public sector in the respective country and the resulting percentage difference was entered into the regression in decimal notation. The coefficient on the interaction between this variable and pre-primary attendance is positively estimated, which supports the view that the impact of pre-primary education is higher in countries where the difference between the average pre-primary teachers' salary and the average salary for other people employed in the public sector is lower. Since the relative salary affects the selection of people into the profession, it is connected with higher quality pre-primary education. The higher the relative wage, the higher will be the motivation of the teachers and the better will be the group of people out of which teachers are being selected or out of which select themselves. However, information for this variable was missing in 14 countries, which is why the explanatory power of this indicator will be necessarily reduced.²⁴

Training of pre-primary teachers at the tertiary level is positively connected with the impact of attendance on test scores. This can be interpreted as evidence for the beneficial effects of higher levels of training. Higher training levels may improve the quality of pre-primary education by increasing the competences of the teachers but also by attracting a different set of people. However, the level of teacher training might not be a pure quality indicator. It might also be indicative for the level of attention that the society brings to the topic and for an enhanced public awareness of the relevance of pre-primary education. This argument might likewise be applicable in the case of expenditures and salaries.

The additional models presented in columns (2) – (5) serve to validate the results discussed above. All results for the quality measures also hold if they are entered one by one into the regressions, while small quantitative changes can be observed for some variables.

The remaining four interaction terms that form part of all models presented in Table 4 were entered as additional controls: the GDP per capita²⁵, the country mean PISA test score, the share of students attending more than one year, and the entrance age into pre-primary education.

²⁴ Missing information on this country level variable was imputed using mean imputation. Considering the already small sample size, this necessarily introduces measurement error.

²⁵ GDP per capita in 2003, measured in purchasing power parities (PPP), is provided by version 6.2 of the Penn World Tables (Heston et al. 2006).

To control for country heterogeneity, the models include the interaction between attendance and GDP per capita and the interaction with the country mean PISA test score. Thereby, any bias arising from differences in the countries' economic and test performance may be reduced. As can be seen from Table 4, both measures are not significantly related to the impact of pre-primary attendance, except the country mean test score in column (5). This is interpreted as a weak indication that the impact of attendance is slightly higher on average in countries where the overall level of test performance is higher. However, the inclusion or exclusion of these two variables does not alter the presented in columns (1) – (5).

The interaction terms of attendance with the share of students that attended for more than one year, and with the entrance age into pre-primary education were also entered as control variables. Including the interaction with the share of students attending for more than one year one can control for differences in the countries' selection processes that cannot be accounted for by including student and family level variables. Yet, since this variable is an output variable of the system any interpretation should be ventured cautiously. Overall, the impact of pre-primary education on later learning seems to be higher in countries, where a high proportion of the age group attended pre-primary education. The results on the other explanatory variables reported in columns (1) – (5) do not change with the inclusion or exclusion of this variable.

The interaction between pre-primary attendance and the typical entrance age into pre-primary education is also positively estimated. Apparently, the impact of pre-primary education is higher in countries where children are older when they enter pre-primary education. This seems counterintuitive at first sight since most people would expect that pre-primary education matters more the longer the children are exposed to its influence. One possible explanation for this result may be that a late entrance into pre-primary education is indicative of a system that is more curriculum-based and focused on children's school readiness. Missing out on pre-primary education in countries where the entrance age is higher would then imply a higher drawback for children.

Table 5 displays the results for the same model specifications but for the sample of OECD countries. However, also in the sample of OECD countries the three countries with an envisaged pre-primary education of one year were excluded from the analysis

(i.e., Korea, Australia, and the United States). Because of its very low enrolment in pre-primary education, Turkey was excluded from the sample as well. The results are briefly displayed and discussed here but are qualitatively the same as in Table 4.

Table 5: Quality of Pre-primary Education, OECD countries

Interaction with attendance					
	(1)	(2)	(3)	(4)	(5)
Pre-primary attendance ^a	6.056*** (0.822) ^a	8.265*** (0.680) ^a	8.357*** (0.681) ^a	8.242*** (0.680) ^a	5.978*** (0.826) ^a
Expenditure on pre-primary education	3.622* (1.881)	6.086*** (1.510)	5.829*** (1.537)	7.077*** (1.777)	3.399** (1.581)
Share of private enrollment	0.065** (0.032)		0.028 (0.030)		
Comparative salaries	4.038 (3.563)			4.224 (3.484)	
Tertiary training	8.285*** (1.613)				7.898*** (1.556)
Share attending > 1 year	37.991*** (5.706)	19.313*** (4.708)	18.538*** (4.749)	20.254*** (4.705)	37.968*** (5.724)
Entrance age pre-primary	4.860*** (1.562)	3.900*** (1.392)	3.845*** (1.392)	4.724*** (1.553)	4.185*** (1.394)
GDP per capita	-0.210* (0.113)	-0.163* (0.095)	-0.163* (0.095)	-0.230** (0.112)	-0.148 (0.095)
Country mean test score	0.047** (0.024)	0.065*** (0.023)	0.067*** (0.023)	0.065*** (0.023)	0.044* (0.023)
Students	186,629	186,629	186,629	186,629	186,629
Schools (clustering units)	7,290	7,290	7,290	7,290	7,290
Countries	25	25	25	25	25
R ²	0.409	0.409	0.409	0.409	0.409

Dependent variable: PISA 2003 students' test scores in mathematics. Sample: 25 OECD countries and 186,629 students. Reported coefficients are coefficients for the interaction between the variables and attendance of pre-primary education. Least-squares regressions weighted by students' sampling probability. Controls include: 14 variables describing student characteristics, 16 variables describing family background, 10 measures of school location and resources, imputation dummies, and interaction terms between imputation dummies and the variables. Regressions include country fixed effect. Robust standard errors adjusted for clustering at the school level in parentheses. Significance level (based on clustering-robust standard errors): *** 1 percent, ** 5 percent, * 10 percent. ^a Main effect of pre-primary attendance.

Within the sample of OECD countries, GDP per capita is significantly negatively linked to the impact of pre-primary education on PISA test scores. Moreover, country mean test score is now significantly positively linked in all estimated specifications. Further, the estimated coefficients for the variables private enrollment and comparative salaries are no longer significantly estimated within this sample, albeit with the same sign and a comparable size. This might also be due to the reduced variation that exists

within these variables in the OECD sample. More generally, the estimated coefficients across all specifications are smaller in the sample of OECD countries.

In addition to the variables included in the models described above, the effects of the countries' average pupil-teacher ratios were explored. Presumably, lower pupil-teacher ratios would be connected with a higher impact of pre-primary attendance on test scores since children would benefit from more attentive care. Such a result would also be consistent with findings from the project Star in the United States (e.g., Krueger and Whitmore 2001). However, pupil-teacher ratio was not significantly related to the impact of pre-primary attendance on PISA test scores in any of the estimated model specifications. This quality indicator does not seem to play an important role in explaining quality differences across countries. Yet, this is not the only possible explanation. The student-teacher ratio is more likely to vary considerably within countries than any other system variable included in the model. Student-teacher ratio and group size vary tremendously between centers of pre-primary education with the legislators generally only setting minimum standards that some centers may well choose not to exhaust. Thus, the pupil-teacher ratio variable collected by the UNESCO is a country average that might not sufficiently describe the reality of the children in the sample. Thus, one cannot rule out the possibility that if measured at lower levels, the variable may be found to have an impact.

Another measure of quality that would have been interesting to explore is the duration of the pre-primary programs. However, this variable could not be included in the estimations because restricting the sample to harmonize between the measure of attendance and the measures of quality led to a reduction in sample variation. Yet, in the large sample consisting of all countries weak evidence was found for a positive influence of duration on the impact of pre-primary education.

4.5. Robustness Checks

Several robustness checks were performed to verify the results presented and discussed above and to test whether the selection of the country sample might have influenced the results. All specifications were estimated with different subsets of countries. For each model specification the regression analysis was carried out several times while a different country was left out of the sample each time. Thus, with a sample consisting of n countries, each model specification was estimated for the original sample and for n

sub-samples. All results proved to be robust. In this way it was ensured that the presented results do not depend on the inclusion or exclusion of a single country.

Moreover, the same regressions as in Table 4 were also carried out with the complete sample of countries available, i.e. all countries that took part in PISA 2003 without France, Liechtenstein and Serbia and Montenegro. The results are displayed in Table 6. The estimated interaction effects are somewhat smaller in the larger sample but the estimated coefficients are still highly significant. Apparently, differences between countries in the concept of pre-primary education and in the selection processes of students might be less important than previously assumed.

Table 6: Quality of Pre-primary Education, full sample

Interaction with attendance					
	(1)	(2)	(3)	(4)	(5)
Pre-primary attendance ^a	6.229*** (0.797) ^a	7.273*** (0.555) ^a	7.485*** (0.567) ^a	7.353*** (0.554) ^a	6.065*** (0.797) ^a
Expenditure on pre-primary Education	8.481*** (1.674)	4.349** (1.755)	3.606** (1.745)	7.977*** (1.738)	8.107*** (1.504)
Share of private enrollment	0.058** (0.025)		0.046* (0.025)		
Comparative salaries	7.890** (3.279)			16.374*** (3.859)	
Tertiary training	3.281** (1.339)				2.830** (1.332)
Share attending > 1 year	21.779*** (3.878)	10.247*** (3.920)	9.696** (3.950)	14.625*** (3.597)	20.548*** (3.926)
Entrance age pre-primary	4.306*** (1.162)	2.419** (1.086)	1.745 (1.086)	5.036*** (1.158)	4.105*** (1.019)
GDP per capita	-0.140 (0.098)	-0.087 (0.087)	-0.067 (0.087)	-0.249** (0.097)	-0.095 (0.089)
Country mean test score	0.011 (0.018)	0.013 (0.015)	0.016 (0.016)	0.026 (0.016)	0.004 (0.018)
Students	244,154	260,334	260,334	260,334	244,154
Schools (clustering units)	9,274	9,888	9,888	9,888	9,274
Countries	35	38	38	38	35
R ²	0.487	0.49	0.49	0.49	0.487

Dependent variable: PISA 2003 students' test scores in mathematics. Sample: 38 countries and 260,334 students. Reported coefficients are coefficients for the interaction between the variables and attendance of pre-primary education. Least-squares regressions weighted by students' sampling probability. Controls include: 14 variables describing student characteristics, 16 variables describing family background, 10 measures of school location and resources, imputation dummies, and interaction terms between imputation dummies and the variables. Regressions include country fixed effect. Robust standard errors adjusted for clustering at the school level in parentheses. Significance level (based on clustering-robust standard errors): *** 1 percent, ** 5 percent, * 10 percent. ^a Main effect of pre-primary attendance.

5. Conclusion

It was shown in this paper that attendance of pre-primary institutions is positively correlated with PISA test scores for 15 year old students in most countries. This is true even after controlling for a large set of student, family and school background characteristics.

When trying to explain the variation in the measured coefficients across countries, several variables are identified that have an influence on how strongly pre-primary attendance influences later achievement. The analysis focused on structural qualities of pre-primary education:

Higher levels of spending may mean increased quality. Effects of pre-primary attendance on test scores are larger in countries where the per-pupil spending in pre-primary education is higher. Moreover, pre-primary attendance has a bigger impact on later schooling outcomes in countries where a higher share of children attends privately managed pre-primary institutions. Yet, the results are only meaningful with respect to the private management of institutions. Especially, it is not possible to draw conclusions about the effects of private versus public funding of institutions or about the benefits and drawbacks of for-profit and not-for-profit operators in pre-primary education.

Two proxies for teacher quality were included in the analysis: the comparative salaries of pre-primary teachers and a dummy representing the occurrence of teacher training at the tertiary level. Both variables potentially capture the attractiveness and reputation of the profession and thus may influence which group of people is selected or selects themselves into the profession. Moreover, training of teachers at the tertiary level is expected to improve the competences of the teachers. Thus, teacher quality proves to be an important aspect of overall pre-primary quality.

At a more general level, the results seem to indicate that pre-primary education has a larger impact on later school success in countries where the attendance rates are higher and where children enter pre-primary institutions at later ages. By contrast, no significant impact of the pupil-teacher ratio in pre-primary education is found. But it was pointed out that this is not necessarily evidence for nonexistent effects. Because of restrictions in the sample a positive impact of longer program duration could not be unambiguously established.

Summing up, the question raised in the heading of this paper is to be answered in the affirmative. The quality of pre-primary education indeed pays off in terms of increased test scores for 15 year old children. The evidence presented strongly suggests that structural qualities of pre-primary education form an important aspect of overall quality of pre-primary education in such a way that differences between countries in the importance of attending pre-primary education can be explained by differences in structural quality. To improve the structural quality of pre-primary education is therefore a valuable tool for improving the overall performance of the education system. Because of the established importance of pre-primary education for children from disadvantaged family background, by improving the structural quality of pre-primary education, equality of educational opportunities will be likewise improved.

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Appendix A: Additional Tables

Table A.1: Descriptive statistics of the international dataset

	Incl. imputations		Only original data		Imputations
	Mean	Std. Dev.	Mean	Std. Dev.	
TEST SCORES					
Math	486.831	106.273	486.831	106.273	0.00%
Science	490.151	106.815	490.151	106.815	0.00%
Reading	483.248	102.642	483.248	102.642	0.00%
STUDENT CHARACTERISTICS					
Female	0.503		0.503		0.03%
Age (years)	15.784	0.291	15.784	0.291	0.01%
Pre-primary education					
no pre-primary education	0.125		0.125		0.00%
1 year or less	0.215		0.215		0.00%
more than 1 year	0.659		0.659		0.00%
School starting age	6.099	0.822	6.106	0.853	9.82%
Grade repetition in primary school	0.100		0.097		10.86%
Grade repetition in secondary school	0.088		0.078		14.31%
<i>Grade</i>					
7 th grade	0.018		0.018		0.26%
8 th grade	0.067		0.067		0.26%
9 th grade	0.365		0.364		0.26%
10 th grade	0.498		0.499		0.26%
11 th grade	0.051		0.051		0.26%
12th grade	0.001		0.001		0.26%
<i>Immigration background</i>					
Native student	0.898		0.898		1.59%
First generation students	0.054		0.054		1.59%
Non-native students	0.048		0.048		1.59%
<i>Language spoken at home</i>					
Test language or other official national language	0.932		0.933		2.89%
Other national dialect or language	0.026		0.026		2.89%
None of above	0.042		0.041		2.89%
FAMILY BACKGROUND					
<i>Living with</i>					
No parent	0.022		0.023		3.95%
Single mother or father	0.194		0.201		3.95%
Patchwork family	0.058		0.061		3.95%
Both parents	0.726		0.715		3.95%
<i>Parents' working status</i>					
Both full-time	0.367		0.367		0.84%
One full-time, one half-time	0.161		0.161		0.84%
At least one full time	0.302		0.302		0.84%
At least one half time	0.087		0.087		0.84%
Other (less than one half but not both missing)	0.082		0.082		0.84%
<i>Parents' job</i>					
Blue collar low skilled	0.126		0.125		2.77%
Blue collar high skilled	0.157		0.157		2.77%
White collar low skilled	0.230		0.230		2.77%
White collar high skilled	0.487		0.488		2.77%

(continued on next page)

Table A.1: Descriptive statistics of the international dataset

	Incl. imputations		Only original data		Imputations
	Mean	Std. Dev.	Mean	Std. Dev.	
<i>Books at home</i>					
1-10 books	0.126		0.125		1.86%
11-25 books	0.172		0.169		1.86%
26-100 books	0.300		0.300		1.86%
101-200 books	0.180		0.180		1.86%
201-500 books	0.138		0.140		1.86%
More than 500 books	0.084		0.086		1.86%
Index of socio-economic & cultural status (ESCS)	-0.177	1.070	-0.177	1.071	0.43%
SCHOOL LOCATION AND RESOURCES					
<i>School's community location</i>					
Village or rural area (<3,000)	0.120		0.120		7.51%
Town (3,000-100,000)	0.550		0.550		7.51%
City (100,000-1,000,000)	0.213		0.212		7.51%
Large city with > 1 million people	0.117		0.117		7.51%
Class size (mathematics)	25.697	9.291	25.638	9.558	7.02%
<i>Shortage of instructional materials</i>					
Not at all	0.349		0.347		2.60%
Strongly	0.095		0.096		2.60%
Instruction time (mathematics, minutes per week)	205.467	94.484	205.404	97.508	6.18%
<i>Teacher education (share at school)</i>					
Fully certified teachers	0.893		0.897		19.37%
Tertiary degree in pedagogy	0.656		0.666		34.81%
GDP per capita (1,000 \$)	20.606	9.913	20.606	9.913	0.00%
Educational expenditure per student (1,000 \$)	48.327	27.733	48.327	27.733	0.00%

Sample: 38 countries participating in PISA 2003, excluding France, Liechtenstein and Serbia and Montenegro. Number of observations in sample incl. imputations: 260,334 students. Mean: International mean (weighted by sampling probabilities). – Std. Dev.: International standard deviation (only for continuous variables). Imputations: Percentage of students with missing and thus imputed data, weighted by sampling probabilities.

Table A.2: Family Background Statistics and Attendance in Pre-primary Education (ISCED 0)

	mean of ESCS		percentage of students with foreign language spoken at home		percentage of students that were not born in the country		statistics over all categories of pre-primary attendance					
	no ISCED 0	one year or less than one more year	no ISCED 0	one year or less than one more year	no ISCED 0	one year or less than one more year	mean ESCS	% foreign language	% not born in country			
Complete Sample	-0.89	-0.21	0.06	0.05	0.04	0.08	0.09	0.08	0.06	-0.18	0.04	0.07
Australia	-0.05	0.15	0.31	0.07	0.07	0.10	0.39	0.10	0.11	0.23	0.09	0.12
Austria	-0.41	-0.28	0.31	0.17	0.06	0.19	0.37	0.19	0.07	0.06	0.09	0.10
Belgium	-0.38	-0.25	0.20	0.15	0.04	0.26	0.35	0.26	0.06	0.15	0.05	0.08
Brazil	-1.39	-1.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01	-0.94	0.01	0.01
Canada	0.15	0.36	0.18	0.09	0.11	0.22	0.22	0.09	0.13	0.45	0.11	0.12
Czech Republic	0.01	0.08	0.02	0.01	0.01	0.03	0.03	0.02	0.01	0.16	0.01	0.01
Denmark	-0.16	0.10	0.23	0.05	0.03	0.06	0.42	0.06	0.04	0.20	0.04	0.05
Finland	0.07	0.09	0.06	0.01	0.01	0.08	0.08	0.03	0.03	0.25	0.02	0.03
Germany	-0.51	-0.21	0.29	0.14	0.05	0.38	0.38	0.22	0.07	0.15	0.08	0.11
Greece	-0.50	-0.19	0.14	0.03	0.02	0.33	0.33	0.10	0.07	-0.15	0.03	0.09
Hong Kong, China	-1.36	-1.00	0.08	0.07	0.04	0.84	0.84	0.62	0.17	-0.76	0.04	0.24
Hungary	-0.50	-0.37	0.02	0.02	0.01	0.10	0.10	0.04	0.02	-0.07	0.01	0.03
Iceland	0.27	0.45	0.03	0.03	0.02	0.06	0.06	0.10	0.06	0.69	0.02	0.06
Indonesia	-1.56	-1.07	0.02	0.02	0.03	0.00	0.00	0.00	0.00	-1.26	0.02	0.00
Ireland	-0.38	0.02	0.01	0.00	0.01	0.04	0.04	0.08	0.09	-0.08	0.01	0.07
Italy	-0.35	-0.22	0.07	0.04	0.02	0.12	0.12	0.06	0.02	-0.11	0.02	0.03
Japan	-0.20	-0.16	0.01	0.02	0.01	0.00	0.00	0.02	0.00	-0.07	0.01	0.00
Korea (Rep. of)	-0.52	-0.30	0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.10	0.00	0.00
Latvia	0.01	0.12	0.01	0.01	0.00	0.03	0.03	0.03	0.03	0.11	0.01	0.03
Luxembourg	0.05	0.09	0.30	0.39	0.22	0.29	0.29	0.34	0.17	0.20	0.24	0.20
Macao, China	-1.15	-0.96	0.01	0.06	0.04	0.51	0.51	0.30	0.19	-0.91	0.05	0.22

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Table A.2 (continued)

	mean of ESCS		percentage of students with foreign language spoken at home		percentage of students that were not born in the country		statistics over all categories of pre-primary attendance		
	No ISCED 0	one year or less than one year more than one year	no ISCED 0	one year or less than one year more than one year	no ISCED 0	one year or less than one year more than one year	mean ESCS	% foreign language	% not born in country
Mexico	-1.93	-1.30	0.03	0.01	0.07	0.02	-1.13	0.01	0.03
Netherlands	-0.28	0.05	0.29	0.11	0.49	0.19	0.09	0.05	0.06
New Zealand	-0.20	0.10	0.27	0.09	0.37	0.19	0.21	0.09	0.17
Norway	0.26	0.44	0.11	0.05	0.13	0.09	0.61	0.05	0.06
Poland	-0.25	-0.41	0.01	0.00	0.02	0.00	-0.20	0.00	0.00
Portugal	-1.12	-0.59	0.01	0.02	0.06	0.11	-0.64	0.02	0.07
Russian Federation	-0.24	-0.14	0.12	0.08	0.14	0.11	-0.10	0.05	0.10
Slovak Republic	-0.34	-0.16	0.03	0.03	0.01	0.02	-0.08	0.01	0.01
Spain	-0.69	-0.49	0.05	0.03	0.15	0.09	-0.29	0.02	0.04
Sweden	-0.05	0.16	0.17	0.07	0.17	0.07	0.26	0.07	0.08
Switzerland	-0.76	-0.09	0.52	0.09	0.74	0.12	-0.06	0.10	0.13
Thailand	-1.60	-1.55	0.04	0.04	0.00	0.00	-1.19	0.03	0.00
Tunisia	-1.92	-1.02	0.00	0.01	0.01	0.02	-1.33	0.01	0.01
Turkey	-1.27	-0.17	0.01	0.01	0.01	0.03	-0.98	0.01	0.01
United Kingdom	-0.24	0.00	0.09	0.05	0.19	0.06	0.12	0.04	0.05
United States	-0.09	0.32	0.26	0.07	0.36	0.05	0.30	0.09	0.08
Uruguay	-0.92	-0.60	0.04	0.03	0.03	0.05	-0.33	0.02	0.04

Country means or shares within each of the three categories of pre-primary (ISECD 0) attendance. Observations are weighted with students' sampling probabilities. ESCS = PISA index of Economic, Social and Cultural Status.

Table A.3: Measures of Structural Quality of Pre-primary Education

Country	Entrance age (1991)	Duration (1991)	Pupil-teacher ratio (1990)	Percentage of private enrollment (1990)	Comparative teacher salaries (1999)	Training of teachers at tertiary level (1990s)	Expenditure on pre-primary education (1991)	Share of students having attended more than one year (PISA 2003)
Australia	5	1	-	26	0.67	1	1.8	45.77%
Austria	3	3	21	26	0.50	0	2.2	80.15%
Belgium	3	3	18	57	-	0	3.1	93.85%
Brazil	4	3	21	26	-	0	-	45.05%
Canada	4	2	31	4	0.67	1	-	45.72%
Switzerland	4	3	14	5	-	0	1.3	66.66%
Czech Republic	3	3	11	2	0.50	0	2.6	78.79%
Germany	3	3	20	54	0.60	0	2.4	82.60%
Denmark	6	1	13	9	1.00	1	2.7	65.70%
Spain	2	4	25	39	0.57	1	3.1	84.36%
Finland	3	4	12	6	1.33	0	1.4	66.77%
United Kingdom	3	2	26	6	1.25	1	2.4	68.34%
Greece	4	2	16	5	1.00	0	1.4	61.97%
Hong Kong, China	3	3	26	100	-	0	-	87.10%
Hungary	3	3	12	0	0.43	1	2.6	94.25%
Indonesia	5	2	17	100	-	0	-	25.44%
Ireland	4	2	28	2	1.00	1	1.5	32.47%
Iceland	2	4	7	6	1.00	0	2.8	88.90%
Italy	3	3	14	29	0.83	0	3	86.75%
Japan	3	3	18	78	0.71	1	2.6	97.04%
Korea (Rep. of)	5	1	22	69	0.71	1	0.9	86.54%
Latvia	3	4	9	0	-	0	-	55.74%

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Table A.3 (continued)

Country	Entrance age (1991)	Duration (1991)	Pupil-teacher ratio (1990)	Percentage of private enrollment (1990)	Comparative teacher salaries (1999)	Training of teachers at tertiary level (1990s)	Expenditure on pre-primary education (1991)	Share of students having attended more than one year (PISA 2003)
Luxembourg	4	2	17	1	1.00	0	2.2	79.31%
Macao, China	3	3	31	-	-	0	-	79.97%
Mexico	4	2	26	9	0.43	0	1.8	65.84%
Netherlands	4	2	17	69	0.71	0	1.7	93.94%
Norway	4	3	4	36	0.67	0	2.6	78.33%
New Zealand	2	3	15	0	-	0	2.8	71.69%
Poland	3	4	14	0	-	1	1.1	44.44%
Portugal	3	3	19	64	0.71	0	2.3	54.94%
Russian Federation	3	4	9	7	-	-	-	78.42%
Slovak Republic	3	3	12	0	-	0	2.2	76.28%
Sweden	3	4	20	10	0.80	1	2.6	59.55%
Thailand	3	3	23	24	-	1	-	74.31%
Tunisia	3	3	26	63	-	0	-	26.99%
Turkey	4	2	17	6	1.67	-	0.3	7.83%
Uruguay	3	3	30	30	-	-	-	63.75%
United States	3	3	28	38	0.57	1	1.8	10.28%

Country level variables for institutional characteristics of pre-primary education. Training of pre-primary teachers: 1 = training takes place at the tertiary level; 0.5 = Training takes place at the tertiary level but not at a university; 0 = training is vocational or at a lower level; in the case of Denmark and Tunisia the figures represent the percentage of teachers that are trained at the tertiary level. - = not available.

Table A.4: Sources of Institutional Variables

Variable	Year	Source
Entrance age into pre-primary education	1991	UNESCO Institute for Statistics (2008): http://www.uis.unesco.org/pagesen/DBSysCri.asp , 17.1.2008.
Duration of pre-primary education	1991	UNESCO Institute for Statistics (2008): http://www.uis.unesco.org/pagesen/DBSysCri.asp , 17.1.2008.
Entrance age into primary education	1991	UNESCO Institute for Statistics (2008): http://www.uis.unesco.org/pagesen/DBSysCri.asp , 17.1.2008.
Pupil-teacher ratio in pre-primary education	1990	UNESCO (2000), World Education Report 2000: http://www.unesco.org/education/information/wer/htmlENG/tablesmenu.htm , Table 7, 6.5.2007. Exemptions: Data for the United States, Sweden, New Zealand, Iceland, France, Finland, Germany and Switzerland are for 1996. Data for Austria is from 1995 and is taken from UNESCO (1998), World Education Report 1998. Data for Macao, China, is for 1999 and is taken from UNESCO (2006), Education for All Global Monitoring Report 2007, Table 10A, page 304.
Private enrollment as percentage of total enrollment in pre-primary education	1990	UNESCO: http://www.unesco.org/education/information/wer/htmlENG/tablesmenu.htm , Table 10, 6.5.2007. Exemptions: Data for the Czech Republic, Germany, Finland, Iceland, Latvia, Slovak Republic and Sweden are for 1996. Data for Liechtenstein was provided by Mr. Dr. Jürg Dinkelmann, of the Schulamt Liechtenstein, via e-mail on 19.11.2007. Data for the Russian Federation and Luxembourg are for 1995 and are taken from UNESCO (1998), World Education Report 1998.
Comparative teacher salaries = Comparison of average pre-primary teacher' salaries with those of executive officials I in the public sector	1999	OECD (2003), Education at a Glance 2003, Table D5.3, page 382. The symbols were recoded as follows: ■ as a 1; ▼ as 0.8; as 0.6; ▲ as 1.2; Δ as 1.4. The comparison between the average salaries of pre-primary teachers and secondary teachers was divided by the comparison between the average salaries of executive officials I in the public sector and secondary teachers, i.e., the entries in column 3 divided by the entries in column 11. Thus, the salaries of secondary teachers were cancelled out and a comparison of average pre-primary teacher' salaries with those of executive officials I in the public sector was obtained. Missing data in Ireland and the United Kingdom were replaced by 1. This was done because pre-primary and primary teachers receive the same training in those countries and therefore should receive the same salaries relative to secondary teachers. Since the difference in the average salaries of primary teachers and secondary teachers is negligible (see column 14), the difference in the average salaries of pre-primary teachers and secondary teachers should also be negligible.
Expenditure on pre-primary education	1991	Per pupil expenditure for pre-primary education as percent of GDP per capita; Source: World Bank (2007).
Share of students that attended pre-primary education for more than one year	betw. 1991 and 1995	PISA 2003 student micro dataset.

Table A.5: Sources of the Variable “Tertiary Training of Pre-primary Teachers”

Country	Source
Australia	OECD Family Database.
Austria	OECD Family Database.
Belgium	European Commission (1995).
Brazil	UNESCO/OECD (2006).
Canada	OECD Family Database.
Switzerland	Information provided by Ms Rejane Deppierraz of the Swiss Office fédéral de la statistique (OFS) via e-mail and telephone, 24.1.2008
Czech Republic	OECD Family Database.
Germany	OECD Family Database.
Denmark	Information provided by Ms Tine Dahl Jensen of the Danish Velfærdsministeriet via e-mail, 14.2.2008.
Spain	European Commission (1995).
Finland	Information provided by the Finnish Education Ministry via telephone,
United Kingdom	European Commission (1995).
Greece	UNESCO/OECD (2006).
Hong Kong, China	Information provided by Mrs. Belinda Cheng of the Education Bureau of the Government of the Hong-Kong Special Administrative Region via e-mail, 17.1.2008.
Hungary	Information provided by Pethő Orsolya of the Hungarian Education Ministry via e-mail, 18.2.2008.
Indonesia	Wallet, Peter (2006).
Ireland	European Commission (1995).
Iceland	Information provided by Ms Sigríður Lára Ásbergisdóttir of the Icelandic Ministry of Education, Science and Culture via e-mail, 20.2.2008.
Italy	OECD (2006a), Starting Strong II, p.145.
Japan	OECD Family Database.
Korea (Rep. of)	OECD Family Database.
Luxembourg	European Commission (1995).
Latvia	Eurydice: SUMMARY SHEETS ON EDUCATION SYSTEMS IN EUROPE - Latvia http://www.see-educoop.net/education_in/pdf/eurypres-lat-misc-t05.pdf , 15.1.2008.
Macao, China	Information provided by the Macao Education and Youth Affairs Bureau via e-mail, 15.1.2008.
Mexico	OECD (2006a), Starting Strong II.
Netherlands	OECD Family Database.
Norway	OECD Family Database.
New Zealand	OECD Family Database.
Poland	Information provided by Ms Gabriela Veith via e-mail, 15.1.2008.
Portugal	European Commission (1995).
Russian Federation	n.a.
Slovak Republic	See Czech Republic.
Sweden	OECD Family Database.
Thailand	Wallet, Peter (2006).
Tunisia	Wallet, Peter (2006).

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Table A.5 (continued)

Country	Source
Turkey	n.a.
Uruguay	n.a.
United States	OECD Family Database.

Detailed information on sources:

OECD Family Database: www.oecd.org/els/social/family/database; also available as <http://www.oecd.org/dataoecd/45/30/37864559.pdf>, Table PF14.2: Qualifications of pre-school teachers and main place of work, 14.1.2008.

European Commission (1995): Die Vorschulerziehung in der Europäischen Union: Ein Problemaufriß, Allgemeine und Berufliche Bildung Jugend, Studien Nr. 6.

UNESCO/OECD (2006): UNESCO/OECD Early Childhood Policy Review Project, Policy Review Report: Early Childhood Care and Education in Brazil, Table 3, p. 27, 2006.

Wallet, Peter (2006): Paper commissioned for the EFA Global Monitoring Report 2007: "Strong foundations: Early Childhood Care and Education".

Table A.6: National Adaptations of Question 20 of the Student Background Questionnaire and National Institutions of ISCED 0

Country	PISA 2003: National Adaptations of Question 20 of the Student Background Questionnaire	National Institutions of ISCED 0
Australia	Did you attend kindergarten or pre-school? (VIC, QLD, SA, WA, TAS)	– Pre-school/ Kindergarten
	Did you attend pre-school or a long day care centre? (ACT, NSW, NT)	
Austria	a. Hast du den Kindergarten besucht?	– Kindergarten
	b. Hast du die Vorschule besucht?	– Vorschulstufe (pre-primary stage)
Belgium - Flemish	Heb je kleuteronderwijs gevolgd?	– Gewoon kleuteronderwijs
Belgium - French	Avez-vous fréquenté l'école maternelle?	– Enseignement préscolaire
Brazil	Você frequentou a Pré-escola?	– Pré-escola (Preschool) – Educação Infantil (Pre-primary education)
Canada - English	Did you attend pre-school, nursery school or kindergarten?	– Preschool – Kindergarten/ Junior Kindergarten
Canada - French	Avez-vous fréquenté une école préscolaire, une école prématernelle, maternelle ou un jardin d'enfants?	– Preschool – Kindergarten/ Junior Kindergarten
Czech Republic	Navštěvoval (a) jsi mateřskou školu?	– Materská škola (kindergarten)
Denmark	Har du gået i børnehave eller børnehaveklasse?	– Børnehave (kindergarten) – Børnehaveklasse (pre-school class in primary school)
Finland - Finnish	Oletko ollut päiväkodissa tai käynyt esikoulua?	– Esiopetus
Finland - Swedish	Har du gått i daghem/förskola?	– n.a.
Germany	Warst du im Kindergarten oder in einer Vorschule?	– Kindergärten (kindergartens) – Schulkindergärten
Greece	n.a.	– Nepiagogeion (kindergarten)
Hong Kong, China	n.a.	– n.a.
Hungary	Jártál óvodába?	– Óvoda (kindergarten)
Iceland	Varst þú í leikskóla?	– Leikskóli (pre-primary schools)
Indonesia	n.a.	– n.a.
Ireland	Did you attend preschool or kindergarten?	– Pre-primary education
Italy	Sei andato/ a all'asilo?	– Scuola Materna (pre-school education)
Japan	n.a.	– Hoikusho (day nursery) – Yochien (kindergarten)
Korea (Rep. of)	n.a.	– Yuchiwon
Latvia	Vai esi gajis bernudarza?	– Bernudarzs
Luxembourg	Avez-vous fréquenté l'enseignement préscolaire ?	– Enseignement préscolaire (pre-primary education)

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Table A.6 (continued)

Country	PISA 2003: National Adaptations of Question 20 of the Student Background Questionnaire	National Institutions of ISCED 0
Macao, China	n.a.	– n.a.
Mexico	¿Asististe al jardín de niños o preescolar?	– Educación preescolar (pre-primary education)
Netherlands	Heb je in groep 1 en groep 2 van de basisschool gezeten?	– Groep 1 en 2 basisonderwijs
New Zealand	n.a.	– Early childhood education
Norway	Gikk du i barnehage/ førskole?	– Barnehage (kindergarten) – og Førskole (pre-school)
Poland	Czy chodziłaś/chodziłeś do przedszkola lub zerówki?	– Wychowanie przedzkolne (pre-school education)
Portugal	Frequentou a pré-primária?	– Educacao Pré-Escolar (pre-school education)
Russian Federation	n.a.	– n.a.
Slovak Republic	Navštevoval/a si materskú školu?	– Materska skola
Spain	n.a.	– Educación Infantil (pre-school education)
Sweden	Har du gått i daghem/ förskola?	– Daghem (day care centres) – Förskolan (preschool)
Switzerland	Hast du den Kindergarten besucht?	– Kindergarten, Vorschule, préscolarité, prescolarità
Thailand	n.a.	– Kindergarten – Nursery
Tunisia	n.a.	– n.a.
Turkey	n.a.	– Okul Öncesi Egitim
United Kingdom	Did you ever attend a reception class, nursery school or nursery classes, a play group or day nursery?	– Nursery schools and classes – Playgroups and day nurseries
Uruguay	¿Asististe a Educación Preescolar?	– n.a.
United States	Did you attend kindergarten?	– Preschool or pre-kindergarten (1 - 2 years) – Kindergarten (1 year)

The national adaptations of Question 20 of the student background questionnaire were made available by national PISA coordinators, whose help is gratefully acknowledged. The national institutions of ISCED 0 are taken from the manual for the implementation of the ISCED 97 classification in the OECD countries (reference provided as OECD 1999). Since intellectually disabled students were predominantly excluded from the PISA sample by design, institutions of pre-primary education serving students with special education needs were not relevant in the context of question 20 and are therefore omitted from this table.

Table A.7: Full results for the regressions presented in Tables 4, 5 and 6

	Table 4 Column (1) Homogen. sample	Table 5 Column (1) OECD sample	Table 6 Column (1) Full sample
Pre-primary attendance	8.016*** (0.877)	6.056*** (0.822)	6.229*** (0.797)
Expenditure on pre-primary education	8.197*** (2.515)	3.622* (1.881)	8.481*** (1.674)
* pre-primary attendance	0.094*** (0.029)	0.065** (0.032)	0.058** (0.025)
Share of private enrollment	8.790** (4.071)	4.038 (3.563)	7.890** (3.279)
* pre-primary attendance	5.465*** (1.772)	8.285*** (1.613)	3.281** (1.339)
Tertiary training	32.908*** (7.131)	37.991*** (5.706)	21.779*** (3.878)
* pre-primary attendance	8.156*** (1.998)	4.860*** (1.562)	4.306*** (1.162)
Entrance age pre-primary	-0.114 (0.114)	-0.210* (0.113)	-0.140 (0.098)
* pre-primary attendance	0.052* (0.027)	0.047* (0.024)	0.011 (0.018)
Country mean test score			
* pre-primary attendance			
STUDENT CHARACTERISTICS			
Female	-17.491*** (0.692)	-18.646*** (0.641)	-17.648*** (0.569)
Age (years)	0.418 (1.182)	1.752* (1.044)	-0.339 (0.985)
Delayed entering of primary school	-8.940*** (0.925)	-11.731*** (0.887)	-9.303*** (0.832)
Grade repetition in primary school	-28.102*** (1.675)	-29.934*** (1.480)	-23.766*** (1.285)
Grade repetition in secondary school	-20.900*** (1.590)	-21.263*** (1.542)	-19.254*** (1.346)
<i>Grade</i>			
7 th grade	-82.307*** (4.717)	-79.448*** (4.116)	-80.952*** (3.168)
8 th grade	-56.086*** (2.159)	-55.378*** (2.187)	-56.723*** (1.854)
9 th grade	-26.296*** (1.372)	-25.463*** (1.354)	-24.853*** (1.132)
11 th grade	19.126*** (2.198)	12.399*** (2.019)	17.682*** (1.917)
12 th grade	45.960*** (4.869)	43.220*** (4.823)	46.037*** (4.772)
<i>Immigration background</i>			
First generation students	-9.156*** (1.663)	-15.071*** (1.663)	-8.045*** (1.418)
Non-native students	-3.101 (1.906)	-11.105*** (1.736)	-2.710* (1.631)
<i>Language spoken at home</i>			
Other national dialect or language	-14.511*** (3.008)	-9.367*** (2.082)	-12.476*** (2.862)
Foreign language	-13.670*** (1.914)	-4.099** (1.729)	-11.293*** (1.611)

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Table A.7 (continued)

	Table 4 Column (1) Homogen. sample	Table 5 Column (1) OECD sample	Table 6 Column (1) Full sample
FAMILY BACKGROUND			
<i>Living with</i>			
Single mother or father	12.330*** (1.907)	18.974*** (2.075)	12.195*** (1.546)
Patchwork family	12.805*** (2.146)	18.971*** (2.251)	12.374*** (1.751)
Both parents	17.951*** (1.886)	25.249*** (2.039)	18.924*** (1.521)
<i>Parents' working status</i>			
Both full-time	-2.752* (1.575)	-4.683*** (1.429)	-1.367 (1.163)
One full-time, one half-time	4.057*** (1.181)	5.214*** (1.144)	4.873*** (0.899)
At least one full time	8.937*** (1.292)	9.721*** (1.251)	9.476*** (1.006)
At least one half time	4.974*** (1.292)	5.811*** (1.207)	5.778*** (0.981)
<i>Parents' job</i>			
Blue collar high skilled	-0.187 (1.080)	-0.670 (1.013)	-0.987 (0.883)
White collar low skilled	-0.202 (1.021)	0.324 (0.970)	-0.011 (0.863)
White collar high skilled	6.792*** (1.116)	7.493*** (1.019)	7.288*** (0.927)
<i>Books at home</i>			
11-25 books	2.986* (1.524)	5.268*** (1.027)	3.405*** (1.109)
26-100 books	19.748*** (1.307)	21.935*** (1.037)	20.362*** (0.998)
101-200 books	29.915*** (1.451)	32.101*** (1.160)	31.328*** (1.122)
201-500 books	48.139*** (1.556)	48.474*** (1.260)	49.450*** (1.205)
More than 500 books	50.857*** (1.735)	51.113*** (1.427)	52.348*** (1.361)
ESCS	16.190*** (0.532)	16.931*** (0.472)	15.325*** (0.431)
SCHOOL LOCATION AND RESOURCES			
<i>School's community location</i>			
Town (3,000-100,000)	0.208 (1.612)	2.597* (1.424)	2.074 (1.296)
City (100,000-1,000,000)	6.672*** (2.007)	9.285*** (1.813)	7.730*** (1.629)
Large city with > 1 million people	8.561*** (2.931)	9.446*** (2.562)	8.931*** (2.155)
Private School	-2.104 (2.157)	0.898 (1.951)	0.090 (1.725)
Class size (mathematics)	1.477*** (0.075)	1.662*** (0.070)	1.378*** (0.059)

(continued on next page)

Table A.7 (continued)

	Table 4 Column (1) Homogen. sample	Table 5 Column (1) OECD sample	Table 6 Column (1) Full sample
<i>Shortage of instructional materials</i>			
Not at all	5.296 ^{***} (1.349)	4.976 ^{***} (1.232)	5.812 ^{***} (1.129)
Strongly	-7.302 ^{***} (2.416)	-5.980 ^{**} (2.325)	-5.864 ^{***} (1.875)
Instruction time (minutes per week)	0.043 ^{***} (0.006)	0.031 ^{***} (0.004)	0.034 ^{***} (0.004)
<i>Teacher education (share at school)</i>			
Fully certified teachers	7.179 ^{**} (3.223)	7.535 ^{**} (3.343)	7.734 ^{**} (3.024)
Tertiary degree in pedagogy	18.730 ^{***} (2.492)	18.561 ^{***} (2.382)	14.971 ^{***} (2.208)
<i>Country Fixed Effects</i>			
	yes	yes	yes
Students	168,010	186,629	244,154
Schools	6,422	7,290	9,274
Countries	26	25	35
R^2	0.42	0.41	0.49

Dependent variable: PISA 2003 international test score in mathematics. Least-squares regressions weighted by students' sampling probability. The models additionally control for imputation dummies and interaction terms between imputation dummies and the variables. Full set of country fixed effects included. Robust standard errors adjusted for clustering at the school level in parentheses. Significance level (based on clustering-robust standard errors): *** 1 percent, ** 5 percent, * 10 percent.

Appendix B: Data Imputation and Its Implications for the Estimation Model

Like in any survey dataset, there are missing data in the PISA 2003 dataset. Although this problem is minor for almost any single variable as can be seen from Table A.1, it becomes more problematic when estimating international educational productions. Given the large set of explanatory variables considered and given that each variable has missing values for some students, dropping all student observations that have a missing value on at least one variable would mean a severe reduction in sample size. Data on teacher education are not available for up to a third of the students, and data on school starting age and grade repetition are missing for 11.7 percent to 16.0 percent. While the percentage of missing values for the other variables individually ranges from 0.0 percent to 8.8 percent (see Table A.1), the percentage of students with a missing value on least one control variable is 63.4%. Thus, the sample size would be considerably reduced.

Apart from the general reduction in sample size which would reduce the statistical power of the estimation, dropping all students with a missing value on at least one variable would delete information available on other explanatory variables for these students and introduce bias if values are not missing at random. Thus, data imputation is the only viable way of performing the broad-based analyses of this paper.

Missing values are imputed using a conditional mean imputation method (see Little and Rubin 1987), which predicts the conditional mean for each missing observation on the explanatory variables using non-missing values of the specific variables and a set of explanatory variables observed for all students. Specifically, in order to obtain a complete dataset for all students for whom performance data are available, missing values of explanatory variables were imputed using a set of “fundamental” explanatory variables F that were available for all students. These fundamental variables F include gender, age, five grade dummies, four dummies on the students’ family structure, five dummies for the number of books at home, GDP per capita²⁶ as a measure of the country’s level of economic development, and the

²⁶ GDP per capita in 2003, measured in purchasing power parities (PPP), is provided by version 6.2 of the Penn World Tables (Heston et al. 2006).

country's educational expenditure per student.²⁷ The small amount of missing data on the variables in F was imputed by the use of median imputation on the lowest available level (school or country). For the three countries with missing data on educational expenditure in OECD (2006b) or other versions of the OECD's Education at a Glance, comparable data for these countries is used based on information from the World Development Indicators of the World Bank and data from both sources for countries where both are available to predict the missing data for the three countries by ordinary least squares.

For each student i with missing data on a specific variable M , the set of "fundamental" explanatory variables F with data available for all students was used to impute the missing data in the following way. Let S denote the set of students j with available data for M . Using the students in S , the variable M was regressed on F :

$$M_{j \in S} = F_{j \in S} \phi + \varepsilon_{j \in S} \quad (\text{B1})$$

Then, the coefficients ϕ from these regressions and the data on F_i were used to impute the value of M_i for the students with missing data:

$$\tilde{M}_{i \notin S} = F_{i \notin S} \phi \quad (\text{B2})$$

The imputation method for implied variables was WLS estimation for continuous variables, ordered probit estimation for ordinal variables, and probit estimation for dichotomous variables. For continuous variables, predicted values were then filled in for missing data. For ordinal and dichotomous variables, in each category the respective predicted probability was filled in for missing data.

Generally, data imputation introduces measurement error in the explanatory variables, which should make it more difficult to observe statistically significant effects.²⁸ However, if values are not missing conditionally at random, estimates could still be biased. For example, if among observationally similar students the probability of a missing value for a variable depends on an unobserved student characteristic that

²⁷ Cumulative educational expenditure per student between age 6 and 15 in 2002, measured in PPP are provided in OECD (2006b) and other versions of the OECD's Education at a Glance.

²⁸ In an analysis of the PISA 2000 data, Fuchs and Wößmann (2007) employ an adjustment mechanism for standard errors suggested by Schafer and Schenker (2000) that accounts for the degree of variability and uncertainty in the imputation process as well as for the share of missing data and find that all qualitative results are highly robust to the alternatively computed standard errors.

also influences achievement, imputation would predict the same value of the variable for students with a missing value that was observed for the other students, which would result in biased coefficient estimates.

To account for this possibility of non-randomly missing observations and to make sure that the results are not driven by imputed data, a vector of imputation dummy variables is included as controls in the estimation. This vector contains one dummy for each variable of the model that takes the value of 1 for observations with missing and thus imputed data and 0 for observations with original data. The vector allows the observations with missing data on each variable to have their own intercepts. Additionally, interaction terms between each variable and its imputation dummy are included, which allows observations with missing data to also have their own slopes for the respective variable. These imputation controls make the results robust against possible bias arising from imputation errors in the variables. Thus, the models actually estimated in this paper have the following structure:

$$T_{isc} = B_{isc}\alpha + R_{sc}\beta + P_{isc}\gamma + D_{isc}^B\mu_1 + (D_{isc}^B B_{isc})\mu_2 + D_{sc}^R\mu_3 + (D_{sc}^R R_{sc})\mu_4 + D_{sc}^I\mu_5 + \varepsilon_{isc} \quad (B3)$$

which adds the vectors of imputation dummies D and their interactions with the variables to equations (1) and (2).

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