

**Schooling Resources, Educational  
Institutions, and Student Performance:  
The International Evidence**

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# **Schooling Resources, Educational Institutions, and Student Performance: The International Evidence**

## **Abstract**

The large international differences in student performance in cognitive achievement tests cannot be explained by differences in schooling resources but are mainly caused by differences in institutions of the education systems. A microeconomic student-level estimation based on data for more than 260,000 students from 39 countries reveals that positive effects on student performance stem from centralized examinations and control mechanisms, school autonomy in personnel and process decisions, influence of individual teachers on teaching methods, limits to the influence of teacher unions on curriculum scope, scrutiny of students' achievement, and competition from private schools.

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The formation of human capital is essential for the economic success both of individuals and of society at large in a modern economy. The human capital stock comprises cognitive and non-cognitive skills and is mainly produced in families, schools, universities, and firms. This paper focuses on students' cognitive skills in mathematics and science, which are mainly formed in schools. Since "[e]arly learning begets later learning" (Heckman 1999, p. 2), basic knowledge formed early in school has a substantial impact on potential future prosperity of individuals and nations.

The empirical evidence on the determinants of educational performance overwhelmingly shows that at given levels of expenditures, an increase in the amount of resources used does not generally lead to an increase in educational performance. This has been shown within the United States (Hanushek 1986, 1996), within developing countries (Hanushek 1995), across countries (Hanushek and Kimko 2000), and across time within most OECD countries (Gundlach et al. 2001) and within some East Asian countries (Gundlach and Wößmann 1999). Figure 1 presents equivalent evidence from the latest and most coherent cross-country achievement study, the Third International Mathematics and Science Study (TIMSS). Again, cross-country resource differences do not help in understanding cross-country differences in educational performance. The correlation coefficient between expenditure per student and average TIMSS test scores is 0.13 in primary education and 0.16 in secondary education. By implication, the level of schooling productivity - the ratio of educational performance to resources used - differs widely across schooling systems. While a controversial debate surrounds the within-country evidence on resource effects on student performance,<sup>1</sup> it is obvious and generally accepted that the large international differences in student performance levels in mathematics and science cannot sufficiently be attributed to differences in the amount of inputs used.

In other sectors of the economy, competition creates incentives to use resources efficiently. By contrast, schooling systems tend to be publicly managed all over the world, thereby often lacking incentives for improving students' performance or containing costs. As the Economist (1999, p. 21) put it, "[i]n most countries the business of running schools is as firmly in the grip of the state as was the economy of Brezhnev's

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<sup>1</sup> See the recent contributions to the debate by Krueger (1999a,b), Angrist and Lavy (1999), Case and Deaton (1999), Hoxby (2000b), and Krueger and Whitmore (2001).

Russia." While public provision of schooling may generally be associated with inefficiencies, the public schooling systems still differ substantially across countries in their institutional structure of educational decision-making processes. These institutional features include settings such as the centralization of examinations and of other decision-making powers, the distribution of responsibilities and influence between the administration, school principals, teachers, parents, and students, and the size of the private schooling sector. Institutional differences create different incentives for the agents involved in educational production, which should lead to different resource-allocation decisions and thereby ultimately to differences in the educational performance of students.

This paper examines whether and, if so, how differences in institutional incentive mechanisms can add to an explanation of the large international differences in students' cognitive skills. Based on a student-level data base derived from TIMSS, microeconomic education production functions are estimated which include data on institutions as explanatory variables. The link between institutions and student performance could hardly be tested using country-specific evidence since there is no significant variation in most institutional features within a single country on which such an analysis could be based. Only the international evidence which encompasses many education systems with widely differing institutional structures has the potential to show whether institutions have important consequences for student performance.

## **1. The International Micro Data Base Based on TIMSS**

TIMSS is the latest international student achievement test for which data is currently available, and it is the most extensive one ever conducted both in its coverage of countries and in the scope of its contents. In addition to testing students' cognitive skills in both mathematics and science, TIMSS gathered a wealth of contextual information about instruction and learning through student, teacher, and school-principal questionnaires. This TIMSS data base offers an unprecedented opportunity to examine the determinants of student performance. Drawing on this pool of data, I have constructed a student-level data base for more than 260,000 individual students in the middle school years. This new data set forms a representative sample in each of the 39

participating countries, representing a population of more than 30 million students.<sup>2</sup> Appendix A gives a complete exposition of the variables used in this study and includes their descriptive statistics in Table A1.

TIMSS was conducted in 1994/95 under the auspices of the International Association for the Evaluation of Educational Achievement (IEA), which has gathered 40 years of experience with international comparative studies on educational achievement and learning contexts.<sup>3</sup> In the test of students in the middle school years, where the broadest sample of countries participated, students enrolled in the two adjacent grades containing the largest proportion of 13-year-olds were tested, which are seventh- and eighth-graders in most countries. The students' achievement levels in mathematics and science were tested by a combination of multiple-choice and open-ended-response questions which covered a wide range of topics and capabilities in the two subjects. Combining the performance in the different questions of a subject, proficiency was mapped onto an international scale with a mean of 500 and a standard deviation of 100 to yield the international achievement scores.

In addition to the TIMSS mathematics and science achievement scores of the quarter of a million students, the micro data base gathers data from different TIMSS background questionnaires which enables one to control for individual family background and combines it with student-specific information on available resources and institutions as well as country-level data on the education systems. TIMSS collected contextual information about instruction and learning through student, teacher, and school questionnaires. The students who participated in TIMSS completed questionnaires about their demographics, home and family background, and classroom and out-of-school activities. The mathematics and science teachers of sampled students responded to

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<sup>2</sup> Of the 45 countries participating in TIMSS, three (Argentina, Indonesia, and Italy) were unable to complete the steps necessary to appear in the data base. Mexico chose not to release its results. For three countries (Bulgaria, Philippines, and South Africa), no background data are included in the international data base because of insufficient quality. Since in Belgium, the Flemish and French education systems participated separately, data files for 39 education systems are available: Australia, Austria, Canada, Colombia, Cyprus, Czech Republic, Denmark, England, Flemish Belgium, France, French Belgium, Germany, Greece, Hong Kong, Hungary, Iceland, Iran, Ireland, Israel, Japan, Korea, Kuwait, Latvia, Lithuania, Netherlands, New Zealand, Norway, Portugal, Romania, Russian Federation, Scotland, Singapore, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Thailand, and United States.

<sup>3</sup> For more information about the design, development, implementation, and analyses of TIMSS, see the internet homepage at <http://timss.bc.edu/>.

questions about their professional training and education, their instructional practices, their responsibilities for decision-making in several areas, and about class sizes and the availability of materials. School questionnaires, answered by the principals of the tested schools, provide information on school characteristics and resources, the degree of centralization of decision-making, the allocation of responsibility for different tasks, and topics like the extent of parents' participation. From this qualitative survey data, dummy variables were created for the institutional features (see Appendix A).

For the TIMSS questionnaire variables, missing data was a problem. While some students, teachers, and school principals failed to answer individual questions, some other questions were not at all administered in some countries. Since dropping students with missing data on some explanatory variables from the analysis would severely reduce the sample size, delete the information available on the other explanatory variables, and introduce sample selection bias, imputation of missing values was chosen.<sup>4</sup> The method used to impute data for missing values in the TIMSS questionnaires is presented in Appendix B. Results of robustness tests against dropping observations with imputed data for each individual variable are reported in Section 6.

Some country-level data on decision-making centralization was provided by the TIMSS national research coordinators of each participating country. Furthermore, the data base combines the TIMSS data with additional system-level data on the institutional structure of the schooling systems from the educational indicators collected by the OECD, concerning the level of decision-making and the extent of private school management. This data base allows an extensive student-level analysis of the determinants of educational quality through the estimation of microeconomic education production functions.

## **2. Estimating Microeconomic Education Production Functions**

To determine the influence of student background, resources, and institutions on students' educational performance, education production functions can be estimated of the form

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<sup>4</sup> Data on individual students for whom non-imputed data were available for less than 25 variables of the standard regression specification of Table 1 were dropped from the sample. This excluded 614 students from the original sample of 267,159.

$$t_i = B_i \alpha + R_i \beta + I_i \gamma + \varepsilon_i$$

where  $t$  is the test score of student  $i$ ,  $B$  are the measures of the student's background,  $R$  are the measures of resource use,  $I$  are the measures of institutional features surrounding the student's learning ( $R$  and  $I$  are measured at the classroom, school, and country level),  $\varepsilon$  is an error term, and  $\alpha$ ,  $\beta$ , and  $\gamma$  are the parameters to be estimated.

Studies such as Lee and Barro (1997) and Hanushek and Kimko (2000) have used country-level data to analyze the determination of students' performance. These macro education production functions cannot control for individual influences on a student's performance. They are also restrained to the analysis of system-level institutional determinants like central examinations (as performed by Bishop 1997, 1999). The relevant level at which to perform the analysis is the individual student (not the class, school, district, or country), because this directly links a student's performance to her teaching environment. The estimation of such a microeconomic education production function provides the opportunity to control for individual background influences on student performance when looking at the influence of resources and institutions, to assess the influence of the relevant resource and teacher characteristics with which a student is faced, and to look at the institutional features relevant to the individual student.

In using student-level data, attention has to be given to the complex data structure given by the survey design and the multi-level nature of the explanatory variables. As is common in educational survey data, the TIMSS sampling design includes varying sampling probabilities for different students as well as stratified and clustered data (see Martin and Kelly 1998). The TIMSS procedure was designed to achieve nationally representative student samples by stratified sampling within each country. To avoid bias in the estimated equation and to obtain nationally representative coefficient estimates from stratified survey data, weighted least squares (WLS) estimation using sampling weights has to be employed so that the proportional contribution of each stratum in the sample to the parameter estimates is the same as would have been obtained in a complete census enumeration. DuMouchel and Duncan (1983) show that the use of a WLS estimator is especially relevant in an omitted-predictor model, which is certainly given in the estimation of an education production function where the innate ability of

each student remains unmeasured. Therefore, the following WLS regressions use weights which assure that each student is weighted according to her probability of selection so as to yield representative samples within each country and to give each country the same weight in the international estimation.

Each country was sampled separately, so that sampling was done independently across countries, fixing the division into countries in advance. In consequence, the TIMSS data is stratified by country. Furthermore, the TIMSS sampling procedure had a two-stage clustered sample design within each country, with the first stage yielding a sample of schools and the second stage yielding a sample of classrooms (Gonzalez and Smith 1997). Thus, the primary sampling unit (PSU) in TIMSS was the school. Individual students who go to the same school may share some characteristics which are not perfectly captured by the included observable variables. Additionally, the data set is characterized by a hierarchical data structure with data collected at different levels. As the resource and institutional variables are not measured at the student level but at the classroom or school level (see above), the observations on these variables for students who share the same class or school depend on one another. As a result, observations in the same PSU are not independent, so that the structure of the error term in the equation given above may be more complicated than conventional least-squares methods assume. One method to correct estimated standard errors, usually referred to as robust linear regression (RLS), combines the WLS regression with robust estimates of standard errors which recognize the stratification and clustering of the survey design.<sup>5</sup> RLS relaxes the independence assumption and requires only that the observations be independent across the PSUs, allowing any amount of correlation within the PSUs. Thus, RLS estimates appropriate standard errors when many cases share the same value on some but not all independent variables.<sup>6</sup>

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<sup>5</sup> For a more detailed description of RLS, see Deaton (1997, pp. 74-78).

<sup>6</sup> A related method often used in educational research to account for the hierarchical data structure are hierarchical linear models (HLM), also known as multi-level models (cf. Bryk and Raudenbush 1992, Goldstein 1999). Cohen and Baldi (1998) show that RLS is superior to HLM in not requiring HLM's assumptions of random and normally distributed effects. When these assumptions are violated by outliers or by a skewed error distribution, HLM significantly underestimates the standard errors of higher-level parameters and gives biased parameter estimates, respectively, while RLS provides estimates of parameters and standard errors which are both consistent and robust. While RLS may sacrifice some efficiency at the lower level relative to HLM when HLM's assumptions are perfectly met and thus may

In the following analysis, robust standard errors based on RLS are presented in addition to conventional (raw) standard errors. The robust standard errors are based on countries as strata and schools as PSUs. As the highest level of clustering, schools were chosen as PSUs, thereby allowing any degree of dependence within schools. Therefore, the reported robust standard errors are actually upper bounds for the coefficients of those explanatory variables which are measured at the student or classroom level. The marks signaling significance levels in the results tables are based on these robust variance estimates.

### **3. Results on Family Background and Schooling Resources**

Table 1 shows OLS and WLS regression results for the mathematics achievement score of 266,545 secondary-school students from 39 countries. While the results do not differ considerably between the OLS and the WLS estimation, the following discussion refers to the WLS estimates. Furthermore, significance statements are based on the robust variance estimation which accounts for the clustered data structure.

#### *Student and Family Characteristics*

Before being able to test for institutional effects on student performance, effects of differences in student characteristics and school resources have to be controlled for. Students in higher grades perform considerably better than students in lower grades, with the 8th-grade mathematics score being 40.3 points above the 7th-grade score (holding all other influences constant). After controlling for these grade-level differences, the age of students is negatively related to performance, probably reflecting a grade repetition effect. On average, girls performed 7.6 points lower than boys. Students being born in the country in which they attend school, students living with both parents, and students with at least one parent born in the country where they attend school performed better than otherwise.

The educational level achieved by the students' parents was strongly positively related to the students' educational performance. The effect captured by the variable "books at home," which proxies for the educational and social background of the family,

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lead to overly conservative estimates, HLM can lead to invalid inference under moderate violations of its assumptions.

was even stronger. Students of schools located in geographically isolated communities performed worse than students from more urban areas. As a control for the overall level of development of the country in which the student lives, GDP per capita is positively related to mathematics achievement. All these effects of student and family characteristics are statistically highly significant.

Student and family background effects on science achievement, reported in Table 2, are very similar to the case of mathematics achievement. While being qualitatively identical, the quantitative effect differs to some extent for some variables. For example, the lead of boys' performance over girls' performance was 8.5 points larger in science than in mathematics.

#### *Resources and Teacher Characteristics*

The estimated effects of the amount of resources used on student performance are consistent with most of the literature in that no strong positive relationship exists between spending and student performance (see, e.g., Hanushek 1996). In fact, instead of resulting in higher student performance, higher educational expenditure per student (measured at the country level) and smaller class sizes (measured at the classroom level) are statistically significantly related to inferior mathematics and science results.<sup>7</sup> The statistically insignificant effect of ratios of students to total professional staff at the school also points in the "wrong" direction.

In contrast to the measured effects of teaching staff, the equipment with facilities has the expected effect when measured by the subjective assessment of the principals of the schools. Students in schools whose principals reported that the capacity to provide instruction is not affected by the shortage or inadequacy of instructional materials scored 7.2 points higher in mathematics relative to students in schools with a little or some limitation (6.5 in science), while students in schools with great shortage of materials scored 5.9 (11.6) points worse. Instruction time at the relevant grade level of the school is statistically significantly positively related to student performance in mathematics and science. While the relative importance of the explanatory dummy variables can be directly evaluated on the basis of their regression coefficients (the

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<sup>7</sup> When calculating robust standard errors on the basis of countries as PSUs, taking account of the fact that expenditure per student is measured at the country level, the expenditure effect turns statistically insignificant in mathematics.

coefficient of dummies reports the conditional test score difference between students with and without the characteristic of interest), standardized coefficients (also reported in Tables 1 and 2 for the WLS estimation) can be used to compare the relative importance of the discrete explanatory variables. For example, a change of 1 standard deviation in instruction time is related to a change of only 0.025 standard deviations in the mathematics test score, while a 1 standard-deviation change in the mathematics class size is related to a change of 0.122 standard deviations in mathematics performance.

Students of female teachers score statistically significantly higher than students of male teachers in both mathematics and science. Conditional on each other, teacher's experience is positively and teacher's age is negatively related to students' performance. This may reflect positive effects of teaching experience in combination with negative effects of age differences between teachers and students, presumably due to increasing difficulties of intergenerational understanding and declining motivation of aging teachers. Teachers' level of education is positively related to students' performance, with the effects in science being larger than in mathematics.

#### **4. Results on Educational Institutions**

I analyze the effects of six categories of institutional features: central examinations; the distribution of responsibilities between schools and administration; teachers' influence; students' incentives; parents' influence; the distribution of responsibilities between administrative levels; and extent of competition from private schools.

##### *Central Examinations*

Of the 39 education systems analyzed in this study, 15 have some kind of centralized examinations in the sense that a central decision-making authority has exclusive responsibility for or gives final approval of the content of examinations. Centrally and thus externally set examinations make schools and teachers accountable and increase students' rewards for learning (cf. Bishop 1997, 1999), which should positively impact on student performance. Accordingly, students in countries with centralized examination systems scored 16.1 points higher in mathematics and 10.7 points higher in science.<sup>8</sup>

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<sup>8</sup> Calculating robust standard errors with countries as PSUs (39 independent observations) leaves the effect of central examinations in mathematics statistically significant only at the 15 percent level,

Furthermore, students in schools where external examinations or standardized tests had a lot of influence in determining the curriculum had test scores 4.3 points higher in mathematics. In science, the effect is negative when imputed observations are included, while it is positive but insignificant when the observations with imputed data on this variable are dropped from the sample (see Section 6). The weaker effect of standardized tests in science than in mathematics may reflect that science tests lend themselves less readily to standardization.

#### *Distribution of Responsibilities between Schools and Administration*

The responsibility for decisions in several areas of the education system is distributed differently between administration and schools across countries, with Dutch schools being relatively autonomous and schools in Greece, Norway, or Portugal not having much autonomy. Since school autonomy allows better use of decentralized knowledge but increases the potential of local opportunistic behavior, centralization may be expected to be conducive for decisions on standard setting, performance control, and size of the budget, while school autonomy should be conducive for decisions on teaching techniques, personnel management, and purchase of supplies.

Students in countries both with centralized decision-making responsibilities for tuition syllabi ("central curriculum") and for the list of approved textbooks ("central textbook approval") score higher in mathematics and science than students in countries without these decisions being centralized.<sup>9</sup> However, the size of these effects is smaller than the effect of centralized examinations. Students in schools which had primary responsibility for formulating the school budget had lower scores in mathematics (5.9 points) and science (3.5 points) than students in schools which did not primarily determine their own budget.<sup>10</sup> That is, taking away responsibility for setting standards and for the amount of available resources from the school level is conducive to student performance.

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while it turns statistically insignificant in science. When increasing the threshold of non-imputed data to a sample size of 255,018 (see Section 6), the mathematics effect is significant at the 10 percent level based on robust standard errors with countries as PSUs.

<sup>9</sup> With robust standard errors calculated on the basis of countries as PSUs - taking account of the fact that there are only 39 independent observations on these two variables -, these effects cannot be statistically significantly distinguished from zero, however.

<sup>10</sup> While the mathematics effect is statistically significant, the science effect is not.

By contrast, school autonomy in process decisions on purchasing supplies goes hand in hand with superior achievement of students.<sup>11</sup> Likewise, students in schools which had freedom to decide on the hiring of teachers performed statistically significantly better in mathematics (12.7 points) and science (5.2 points), as did students in schools which could determine teacher salaries themselves (10.6 points in mathematics and 15.2 points in science). Thus, school autonomy in personnel management seems highly conducive to student performance.

In sum, the evidence supports the hypothesis that the distribution of responsibilities between schools and administration matters for the educational performance of students. On the one hand, centralized decisions on standard setting, performance control, and the size of the school budget help to assure that the producers of education look for the performance of students. On the other hand, school autonomy seems to be the best way to guarantee high student performance in process and personnel-management decisions. Thus, the most conducive combination seems to be a mechanism of control from above to limit school-level opportunistic behavior combined with a high degree of freedom to decide at the school level on subjects where school-level knowledge is important.

### *Teachers' Influence*

The degree of freedom of teachers to decide independently on several educational topics should impact on student performance by affecting the decision-making outcome in the education system. Since teachers cannot be easily monitored, the institutional setting will tilt their behavior either in the direction of furthering their own interests or of advancing students' performance. While it is the very aim of teacher unions to promote the special interests of teachers, a high influence of teacher unions may result in increased pay and decreased work-load, to the detriment of student performance. A high degree of influence of individual teachers with specific local knowledge on process decisions should be conducive to student performance, while it should be detrimental in decisions determining teacher salary levels or work-loads.

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<sup>11</sup> The low level of significance of the "purchasing supplies" coefficient in the WLS estimation for science is due to multicollinearity. Running the same regression without the other "responsibility" variables, the coefficient on "purchasing supplies" is 5.813 and statistically significant at the 10 percent level (with a robust standard error of 3.180).

Correspondingly, students in schools whose principals reported that teachers had primary responsibility for the school budget scored 13.3 points worse in mathematics (4.6 points in science).<sup>12</sup> Conversely, students scored 14.1 points better in mathematics (6.8 in science) if teachers had primary responsibility for purchasing supplies. The findings imply that decisions on the amount of money to be spent should be taken away from teachers and schools, while decisions on which specific supplies to be purchased should be decentralized to teachers and schools.<sup>13</sup>

With regard to teachers' influence on the curriculum that is taught in the school, a clear difference arises between teachers acting individually and teachers acting collectively. On the one hand, students in schools where each teacher individually had a lot of influence on the curriculum performed considerably better (12.0 points in mathematics and 10.8 points in science). On the other hand, students in schools where school teachers collectively or teacher unions had a lot of influence on the curriculum performed statistically significantly worse. This detrimental effect of teachers exercising a collective influence on the curriculum is strongest in the case of teacher unions (-32.3 points in mathematics and -18.4 points in science).<sup>14</sup>

Concerning specific influence areas of individual teachers, statistically significant results are confined to science. Students of teachers who reported that they had a lot of influence on money for supplies and on what kind of supplies are purchased showed statistically significantly better science performance. By contrast, students of teachers who reported that they had a lot of influence on the subject matter to be taught,

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<sup>12</sup> The low degree of significance of the effect in science is due to a mixture of multicollinearity and data imputation. Both if the other "responsibility" variables are dropped and if observations with non-original data on the variable of teachers' responsibility for the school budget are dropped, the effect gets statistically significant and larger in absolute terms.

<sup>13</sup> The effects of teachers being responsible for the hiring of teachers and for the determination of teacher salaries are statistically insignificant in both mathematics and science, with negative coefficients in mathematics and opposing signs of coefficients in science. This insignificance is due to the fact that only in 4 schools with a total of less than 300 tested students (out of the total of 266,545 students), heads of school reported that teachers had primary responsibility for hiring teachers (6 schools in the case of teacher salaries).

<sup>14</sup> This finding of a negative effect of teacher unions' influence corresponds to Hoxby's (1996) result derived on the basis of panel data for US school districts that teacher unionization increases school inputs but reduces the productivity with which these inputs are used sufficiently to have a negative overall effect on student performance.

determining the teachers' work-load, performed worse in science.<sup>15</sup> Whether the class teacher is allowed to decide on the specific textbook to be used does not seem to have a significant effect on students' performance.

Overall, the findings on teachers' influence give a clear picture. If individual teachers can make use of their decentralized knowledge on which teaching method may be best for their students, this will help students to learn more. This conclusion is corroborated by the positive effects of individual teachers influencing the curriculum that is taught in the school and of teachers having responsibility for the purchase of supplies. However, if teachers can use their decision-making powers primarily to reduce their work-load, this will hurt students' learning opportunities. This conclusion is corroborated by the negative effects of teachers' responsibility for the school budget and for the teaching load and of teachers exerting collective power over the curriculum.<sup>16</sup>

### *Students' Incentives*

The incentives of students to learn should be influenced by institutional features of the education system which determine the time a student spends studying and the relative benefits of studying. As reported before, instruction time in school was positively related to students' performance. Likewise, centralized examinations, which should make students' learning efforts more visible to external observers, were shown to have a positive impact on students' educational achievement. As another factor influencing the extent to which studying is rewarded and laziness penalized, the scrutiny with which teachers observe and mark students' achievement (measured by the time which the class teacher spends outside the formal school day on preparing or grading exams) has a statistically significantly positive effect on student performance in mathematics, and a statistically insignificant positive effect in science.

The amount of homework is another measure determining the amount of time which students spend studying. However, minutes of homework per week assigned by the class teacher is statistically insignificantly related to students' performance in mathematics

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<sup>15</sup> When observations with imputed data on this variable are dropped from the regression, the effect turns larger and statistically significant (see Section 6).

<sup>16</sup> The results on teachers' influence are in accordance with the evidence presented by Pritchett and Filmer (1999) that inputs which provide teachers with direct benefits are generally over-used in educational production relative to inputs which contribute only to student performance.

and negatively to students' performance in science. This may reflect that minutes of homework assigned may be very different from minutes of homework actually done by each student. Alternatively, it may reflect a non-linear, more complex relationship between minutes of homework assigned and student performance. Both in mathematics and in science, the frequency of homework assignments per week is negatively related to student performance, while the length of one homework assignment is actually positively related to student performance. It seems that assigning homework less often but on a more ambitious scale each is particularly conducive to students' learning.

### *Parents' Influence*

Evidence was previously reported that parents' education and the number of books in a student's home were strongly positively related to the student's educational performance. Apart from the learning environment at home, the influence which parents exert on curricular matters and on teaching in the formal education system should also impact on students' learning opportunities. Accordingly, students in schools where parents had a lot of influence in determining the curriculum scored higher both in mathematics and science; however, these effects are not statistically significantly different from zero.

With regard to parents' influence on teaching, the class teacher reported whether parents uninterested in their children's learning and progress strongly limited how she teaches her class, e.g. because she then could not rely on parents in scrutinizing homework. Students in classes where uninterested parents strongly limited class teaching performed 10.1 points worse in mathematics and 11.0 points worse in science. The class teacher also reported whether interested parents limited class teaching, presumably by preventing her from teaching in the way she judged most suitable. When interested parents were deemed a cause of limitation, students scored 10.9 points worse in mathematics. However, this effect is very small and statistically insignificant in science. That is, even though science teachers maintained that their teaching was greatly limited by parents being excessively interested in their children's learning, this interference did not cause inferior performance of the students.

These positive effects of parents' involvement were not replicated in a positive effect of the time parents spent on meeting with teachers. In fact, the number of hours outside the formal school day reported by the class teacher to be spent on meetings with parents

each week ("parent-teacher meetings") was negatively related to student performance. However, this may reflect the fact that teachers have more to discuss with parents of poor students than with parents of good students, so that the time spent on parent-teacher meetings is not exogenous to students' performance. Furthermore, the hours for parent-teacher meetings are preventing the teachers from doing other useful work like preparation and evaluation of classes and exams.

## **5. Institutional Evidence from OECD Indicators**

Additional evidence on the effects of institutional features of the education system was obtained from the institutional measures of the OECD educational indicators. Table 3 reports the WLS mathematics results for these indicators, which are all measured in percentages within a country. Since the OECD indicators are country-level variables, the number of countries equals the number of independent observations for these effects. Consequently, the standard errors reported are robust standard errors based on countries as PSUs. To save on degrees of freedom given that the OECD variables are available only for a limited number of countries participating in TIMSS and for differing samples of countries each, each row in Table 3 reports the results for a separate regression. The regressions are again controlling for all the student background, resource, and other institutional variables reported in Table 1. Table 4 reports equivalent results for science performance.

### *Distribution of Responsibilities between Schools and Administration*

Evidence based on TIMSS questionnaire measures presented above showed that the distribution of responsibilities between schools and administration in different educational decision-making areas has a significant impact on student performance. An OECD indicator of school autonomy reports the percentage of educational decisions in a country taken at the school level in full autonomy without consultations or preset frameworks from the administration. This general indicator of full school autonomy ("school autonomy" in Tables 3 and 4) - which comprises the decision-making domains of organization of instruction, personnel management, planning, and resources - is statistically significantly positively related to student performance in science, and statistically insignificantly positively in mathematics. The standardized coefficients

show that if the percentage of decisions taken at the school level in full autonomy increased by 1 standard deviation (equivalent to 11.3 percentage points), students scored 0.062 standard deviations (6.1 test score points) higher in science. Equivalent results are obtained when school-level decisions taken within frameworks from or after consultation with other levels of administration are included ("school level decisions").

The variables on school responsibility are also given for the four sub-groups of decisions separately. For science performance, the coefficients on school level decisions are statistically significantly positive in the decision-making domains of organization of instruction, personnel management, and planning and structures. For mathematics performance, only the positive effect in organization of instruction is statistically significant.

#### *Distribution of Responsibilities between Administrative Levels*

When educational decision-making authority lies with the administration (as opposed to the school level), the remoteness of this authority from the school level establishes another feature of the institutional system of education. The dominant levels of administrative decision-making and control over funding differ widely across countries, with the local level of government taking central stage in the United States, the intermediate level in Germany, and the central level in Greece. While efficient monitoring of schools' actions and resource use by a central administration seems elusive because of information problems and a self-interested central administration may tend to excessive bureaucracy, closer ties between local administration and school personnel may mean increased potential for lobbying of school-based interest groups and for collusion.

Tables 3 and 4 report the effect of the extent of decision-making at the central level of government ("central government decisions"), where the residual category (the percentage of decisions not taken at the central level) encompasses the decisions taken at the school level and at the local and intermediate (sub-regional, provincial, and state) levels of government. Students in countries with a higher percentage of decisions taken at the central level of government scored lower in both the mathematics and the science tests, with only the science effect being statistically significant. The effects in each of the four sub-groups of decision-making in both mathematics and science are also

negative, with the effects of instructional and resource decisions in both mathematics and science and the personnel management effect in science being statistically significant. By contrast, the percentage of decisions taken at an intermediate level of government (part of the residual category in the regressions presented in the tables) were positively related to student performance.

The distribution of responsibility for and control over funding between the different government levels is related to student performance in a similar way to the distribution of decision-making authority. The larger the share of funds provided at the local or the central level of government, the lower was students' performance in mathematics. Consequently, students performed considerably better the more funding was decided on at an intermediate level of government (the residual category). Once responsibility lies with the administration, an administrative level close enough to individual schools to be familiar with local needs, yet distant enough to limit opportunistic and collusive behavior, seems to be most conducive to focusing attention on student performance.

#### *Private Schools*

In general, production of basic education is run publicly all over the world. However, countries differ considerably in the extent of competition from private institutions in the education system. Three quarters of Dutch students attend schools which are managed privately, and Japan is the country with the largest shares of privately managed schools which are also financially independent of public funding, with one quarter of Japanese schools receiving less than half of their core funding from government agencies. At the other extreme, many countries such as Australia, France, Germany, or Sweden have virtually no financially independent private schools. Private schools are faced with monetary incentives to use resources efficiently, and they introduce competition into the public education system by offering choice to parents, thereby potentially advancing student performance.

As the results in Tables 3 and 4 show, students in countries with larger shares of enrollment in privately managed educational institutions scored statistically significantly higher in both mathematics and science. That is, countries with a higher share of private management control over schools performed better. This effect was even larger when only those private institutions were considered which were also financially independent

of funding from government sources. Similarly, countries with a higher share of (public) educational expenditure going to private institutions performed better both in mathematics and in science (with only the mathematics effect being statistically significant). Again, this effect was even stronger when focussing only on independent private institutions. Thus, student performance is higher in education systems where private schools take over resource allocation from public decision-makers.

These effects of private school management are measured at the country level. This does not allow for an assessment of the relative performance of public and private schools, for which the relevant data is not available in the TIMSS case. However, measuring the system-level effect of private school management is the appropriate way to estimate the general effects of the competitive environment prevailing in the different education systems, because increased competition from private schools may also positively impact on the effectiveness of resource use in nearby public schools. Hoxby (1994) finds such positive effects of competition from private schools on the performance of public school students in US metropolitan areas.<sup>17</sup> Furthermore, Hoxby (1996) shows that the negative effect of teacher unionization is statistically significantly reduced in the United States when a school faces competition from private schools.

## **6. Robustness**

Since some of the variables of the TIMSS data set included a substantial amount of missing values and therefore had to be imputed, it remains to be tested whether the reported results are sensitive to the imputation. The robustness can be tested by dropping observations with imputed data individually for each variable and re-running the regressions. The only changes either in significance or direction of the relationships occur in the regressions for the following institutional variables.<sup>18</sup> The effect of external

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<sup>17</sup> Concerning competition among public schools, Hoxby (2000a) finds that easier choice among public schools in US metropolitan areas leads to greater productivity of these schools, both in the form of improved student performance and of lower expenditure per student.

<sup>18</sup> The only changes for background and resource effects are that the coefficient on parents having some secondary education turns statistically insignificant both in mathematics and in science (and positive in mathematics), that the coefficient on the community location close to the center of a town turns statistically insignificantly positive in science and statistically significantly positive in mathematics, and that the positive effect of the teacher's highest education level being the BA turns statistically insignificant in the mathematics regression.

exams' influence on the curriculum turns positive (albeit statistically insignificant) in science, replicating the mathematics result. The negative effect of teachers' responsibility for the school budget turns strongly statistically significant in science, while it is statistically significant only at the 15 percent level in mathematics. The coefficient on subject teachers' influence on the curriculum turns statistically insignificant and positive in both mathematics and science, as does the coefficient on school teachers' influence on the curriculum in science. The coefficient on the class teacher having strong influence on the subject matter taught turns statistically significant in science, while the insignificant coefficient on the choice of textbooks turns positive in science (as it is in mathematics). The effect of homework in mathematics and the effect of parents' influence on the curriculum in both mathematics and science turn statistically insignificantly negative.

Since the negative impact of teachers exercising collective influence over the curriculum is anyway best represented by the strong negative effect of teacher unions, and since a statistically significant impact of parents' involvement in teaching is shown by the strong negative impact of uninterested parents, it can in sum be stated that none of the findings relevant for the argumentation in this study depend on the data imputation. Furthermore, increasing the threshold of non-imputed variables for a student to be included in the sample (see Section 1) by another 10 variables - reducing the total sample size to 255,018 students in mathematics and to 251,292 students in science - does not lead to any change in significance or sign of the coefficients.

A comparison between performance in mathematics and in science shows that all of these results are very robust across the two subjects. Family and resource effects as well as institutional effects are qualitatively the same for mathematics and science learning. The only difference is that standardization effects seem to be more positive in mathematics than in science. This shows up in the facts that the effects of centralized examinations, curricula, and textbook approval are larger for mathematics than for science, that a strong influence of external examinations on the school curriculum has a positive effect on mathematics scores but an ambiguous one on science scores, and that school authority in the four decision-making domains reported by the OECD impacts positively on science performance but is unrelated to mathematics performance (with the

exception of the organization of instructions). This difference may indicate that the propensity for standardization is higher in mathematics than in science.

## **7. Conclusions**

Student-level estimates of education production functions reveal that differences in the incentive structures determined by the institutional features of the education systems strongly matter for student performance. The combined effect of performance-conducive educational institutions measured by the dummy variables in Tables 1 and 2 amounts to a test score difference of more than 210 points in mathematics (150 points in science), which equals about 2 standard deviations in test scores and compares to an average test score difference between seventh and eighth grade of 40 points. That is, a student who faced institutions that were all conducive to student performance would have scored more than 200 points higher in mathematics than a student who faced institutions that were all detrimental to student performance. In addition to that, there are the effects of the discrete variables and the system-level results reported in Tables 3 and 4.

The following institutional features of a schooling system favorably affect student performance:

- central examinations,
- centralized control mechanisms in curricular and budgetary affairs,
- school autonomy in process and personnel decisions,
- individual teachers having both incentives and powers to select appropriate teaching methods,
- limited influence of teacher unions,
- scrutiny of students' educational performance,
- encouragement of parents to take interest in teaching matters,
- an intermediate level of administration performing administrative tasks and educational funding, and
- competition from private educational institutions.

While strong and unambiguous effects on students' educational performance can also be found for family background factors, the impact of resource factors appears to be

dubious and weak at best. The effects of expenditure per student and class size point in the "wrong" direction, while equipment with instructional materials and teachers' experience and education show positive effects. A strong and systematic relationship between resource use and student performance clearly does not exist.

International differences in the institutions of the education systems rather than in available resources help in understanding cross-country differences in students' educational performance. Actually, while the previous country-level studies by Hanushek and Kimko (2000) and Lee and Barro (1997), which constrained themselves to family and resource effects, reached a maximum of one quarter of explained cross-country variation in students' achievement test scores only, adding three aggregated measures of the institutional features analyzed in this paper helps to explain three quarters of the cross-country variation in TIMSS mathematics scores and 60 percent in science scores.<sup>19</sup> Hence differences in institutions of the education systems can explain a major part of the international differences in average student performance levels.

Cross-country differences in student performance are not a mystery. They are related to policy measures. However, the policy measures which matter for schooling output are not simple resource inputs. Spending more money within an institutional system which does not set suitable incentives will not improve student performance. The results of this paper imply that the crucial question for education policy is not one of more resources but one of creating an institutional system where all the people involved face incentives to use resources efficiently and to improve student performance. Success in educational production does not primarily depend on the amount of resources spent, but on the institutional features governing the education process.

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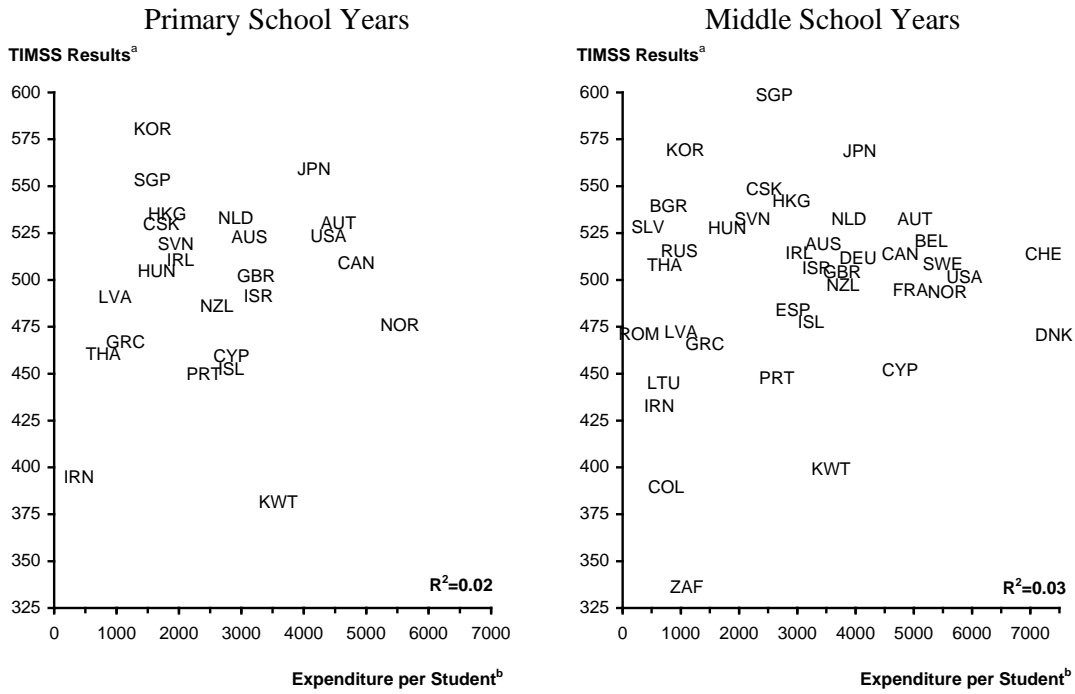
<sup>19</sup> Detailed results are available on request.

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**Figure 1: Expenditure per student and educational performance: the cross-country evidence**



<sup>a</sup> Average of mathematics and science results in 3rd/4th grade and in 7th/8th grade, respectively.  
<sup>b</sup> At primary and secondary level, respectively, in international dollars, 1994.

Sources: See Appendix A.

**Table 1: Effects on mathematics performance**

Dependent variable: TIMSS international mathematics test score. Standard errors in parentheses.

	OLS		WLS			Std. Coeff.
	Coeff.	Raw S.E.	Coeff.	Raw S.E.	Robust S.E.	
Constant	426.985	(4.360)	482.793*	(4.211)	(13.916)	
<b>Student and family characteristics</b>						
Upper grade	38.773	(0.425)	40.342*	(0.424)	(1.086)	0.202
Above upper grade	99.486	(1.464)	100.313*	(1.513)	(3.906)	0.127
Age	-9.884	(0.244)	-14.183*	(0.231)	(0.779)	-0.135
Sex	-7.229	(0.343)	-7.634*	(0.346)	(0.878)	-0.038
Born in country	8.372	(0.813)	9.199*	(0.816)	(1.338)	0.021
Living with both parents	15.276	(0.514)	12.099*	(0.519)	(0.814)	0.040
Parent born in country	5.132	(0.715)	3.983 <sup>†</sup>	(0.722)	(1.602)	0.011
Parents' education						
Some secondary	0.069	(0.707)	-3.989*	(0.702)	(1.553)	-0.014
Finished secondary	25.755	(0.654)	26.475*	(0.660)	(1.454)	0.123
Some after secondary	12.046	(0.695)	15.130*	(0.700)	(1.515)	0.066
Finished university	36.600	(0.734)	39.724*	(0.746)	(1.619)	0.152
Books at home						
11-25	10.999	(0.755)	10.326*	(0.749)	(1.360)	0.037
26-100	37.317	(0.705)	35.846*	(0.701)	(1.444)	0.168
101-200	47.570	(0.761)	46.713*	(0.756)	(1.543)	0.186
More than 200	55.145	(0.753)	54.269*	(0.750)	(1.562)	0.235
Community location						
Geographically isolated area	-14.707	(1.040)	-18.502*	(1.085)	(3.385)	-0.030
Close to the center of a town	2.451	(0.361)	1.598	(0.363)	(1.479)	0.008
GDP per capita	0.004	(5.9e-5)	0.004*	(5.8e-5)	(2.1e-4)	0.240
<b>Resources and teacher characteristics</b>						
Expenditure per student	-0.009	(2.1e-4)	-0.006*	(2.1e-4)	(6.9e-4)	-0.106
Class size	0.912	(0.018)	1.176*	(0.019)	(0.090)	0.122
Student-teacher ratio	0.011	(0.003)	0.006	(0.003)	(0.007)	0.004
No shortage of materials	8.525	(0.387)	7.230*	(0.394)	(1.585)	0.036
Great shortage of materials	-1.480	(0.563)	-5.925 <sup>†</sup>	(0.554)	(2.393)	-0.020
Instruction time	3.7e-4	(2.3e-5)	3.1e-4*	(2.3e-5)	(8.4e-5)	0.025
Teacher characteristics						
Teacher's sex	5.634	(0.372)	5.727*	(0.374)	(1.345)	0.029
Teacher's age	-0.712	(0.033)	-0.667*	(0.033)	(0.124)	-0.062
Teacher's experience	1.075	(0.032)	1.038*	(0.033)	(0.121)	0.097
Teacher's education						
Secondary	11.151	(1.674)	15.682*	(1.569)	(5.206)	0.062
BA or equivalent	10.919	(1.648)	10.571 <sup>†</sup>	(1.542)	(5.105)	0.050
MA/PhD	20.860	(1.694)	25.576*	(1.596)	(5.411)	0.090

(to be continued)

**Table 1 (continued)**

	OLS		WLS			Std. Coeff.
	Coeff.	Raw S.E.	Coeff.	Raw S.E.	Robust S.E.	
<b>Institutional settings</b>						
<i>Central examinations</i>						
Central examinations	17.842	(0.434)	16.062*	(0.402)	(1.435)	0.045
External exams influence curriculum	10.740	(0.539)	4.271 <sup>‡</sup>	(0.524)	(2.199)	0.016
<i>Distribution of responsibilities between schools and administration</i>						
Central curriculum	15.585	(0.539)	10.776*	(0.519)	(1.783)	0.048
Central textbook approval	10.053	(0.474)	9.559*	(0.460)	(1.563)	0.078
<i>School responsibility</i>						
School budget	-5.362	(0.663)	-5.852 <sup>†</sup>	(0.683)	(2.450)	-0.017
Purchasing supplies	-2.288	(0.976)	0.538	(0.997)	(3.488)	0.001
Hiring teachers	13.959	(0.454)	12.723*	(0.471)	(1.772)	0.055
Determining teacher salaries	6.539	(0.455)	10.588*	(0.464)	(2.112)	0.046
<i>Teachers' influence</i>						
<i>Teachers' responsibility</i>						
School budget	-15.478	(1.032)	-13.318*	(1.100)	(3.805)	-0.022
Purchasing supplies	11.361	(0.602)	14.148*	(0.642)	(2.576)	0.040
Hiring teachers	-4.317	(5.413)	-10.294	(6.197)	(21.456)	-0.003
Determining teacher salaries	-16.874	(5.153)	-11.069	(5.492)	(20.995)	-0.003
<i>Strong influence on curriculum</i>						
Teacher individually	9.709	(0.442)	11.952*	(0.446)	(1.730)	0.051
Subject teachers	-2.980	(0.473)	-6.855*	(0.476)	(1.897)	-0.034
School teachers collectively	-9.333	(0.459)	-12.659*	(0.459)	(1.836)	-0.063
Teacher unions	-27.532	(1.367)	-32.329*	(1.370)	(5.979)	-0.042
<i>Class teacher has strong influence on</i>						
Money for supplies	2.800	(0.905)	-0.815	(0.909)	(3.734)	-0.002
Kind of supplies	-2.701	(0.593)	-0.627	(0.606)	(1.997)	-0.002
Subject matter	-0.613	(0.414)	-0.830	(0.420)	(1.585)	-0.004
Textbook	-0.322	(0.480)	2.687	(0.478)	(1.913)	0.011
<i>Students' incentives</i>						
Scrutiny of exams	4.410	(0.109)	4.749*	(0.110)	(0.429)	0.078
Homework	-0.006	(0.002)	0.001	(0.002)	(0.010)	0.001
<i>Parents' influence</i>						
Parents influence curriculum	-0.949	(1.314)	3.714	(1.390)	(5.516)	0.005
Uninterested parents limit teaching	-12.546	(0.672)	-10.107*	(0.656)	(2.756)	-0.029
Interested parents limit teaching	-8.879	(0.871)	-10.860*	(0.825)	(4.090)	-0.025
Parent-teacher meetings	-5.966	(0.277)	-6.152*	(0.283)	(1.021)	-0.039
Observations	266545		266545			
Schools (PSUs)	6107		6107			
Countries	39		39			
R <sup>2</sup> (adj.)	0.22		0.22			

\* Significant at the 1 percent level based on robust standard errors.

† Significant at the 5 percent level based on robust standard errors.

‡ Significant at the 10 percent level based on robust standard errors.

**Table 2: Effects on science performance**

Dependent variable: TIMSS international science test score. Standard errors in parentheses.

	OLS		WLS			Std. Coeff.
	Coeff.	Raw S.E.	Coeff.	Raw S.E.	Robust S.E.	
Constant	409.230	(4.525)	455.626*	(4.315)	(11.881)	
<b>Student and family characteristics</b>						
Upper grade	43.897	(0.434)	46.568*	(0.433)	(0.990)	0.235
Above upper grade	99.908	(1.491)	105.354*	(1.544)	(3.536)	0.134
Age	-6.128	(0.249)	-10.116*	(0.236)	(0.708)	-0.097
Sex	-15.546	(0.349)	-16.130*	(0.352)	(0.753)	-0.081
Born in country	10.428	(0.828)	11.195*	(0.831)	(1.305)	0.026
Living with both parents	9.320	(0.524)	7.437*	(0.529)	(0.800)	0.025
Parent born in country	13.686	(0.728)	12.536*	(0.736)	(1.400)	0.034
Parents' education						
Some secondary	-2.142	(0.720)	-5.226*	(0.715)	(1.469)	-0.019
Finished secondary	17.830	(0.667)	20.067*	(0.674)	(1.284)	0.094
Some after secondary	8.421	(0.708)	10.423*	(0.714)	(1.330)	0.046
Finished university	30.827	(0.747)	34.304*	(0.760)	(1.424)	0.132
Books at home						
11-25	12.381	(0.769)	12.251*	(0.763)	(1.153)	0.044
26-100	35.629	(0.718)	34.174*	(0.715)	(1.248)	0.161
101-200	50.483	(0.775)	48.862*	(0.770)	(1.348)	0.196
More than 200	59.954	(0.767)	57.494*	(0.764)	(1.370)	0.250
Community location						
Geographically isolated area	-4.163	(1.058)	-7.371 <sup>†</sup>	(1.106)	(3.397)	-0.012
Close to the center of a town	-0.958	(0.369)	-2.215 <sup>‡</sup>	(0.371)	(1.306)	-0.011
GDP per capita	0.004	(6.0e-5)	0.004*	(5.9e-5)	(2.0e-4)	0.264
<b>Resources and teacher characteristics</b>						
Expenditure per student	-0.011	(2.2e-4)	-0.010*	(2.2e-4)	(6.4e-4)	-0.186
Class size	0.362	(0.019)	0.477*	(0.020)	(0.060)	0.047
Student-teacher ratio	0.010	(0.003)	0.009	(0.003)	(0.007)	0.006
No shortage of materials	6.998	(0.394)	6.543*	(0.402)	(1.374)	0.032
Great shortage of materials	-7.375	(0.573)	-11.595*	(0.565)	(2.138)	-0.039
Instruction time	3.4e-4	(2.3e-5)	3.0e-4*	(2.4e-5)	(6.8e-5)	0.024
Teacher characteristics						
Teacher's sex	5.947	(0.377)	7.801*	(0.378)	(1.166)	0.039
Teacher's age	-0.272	(0.033)	-0.216 <sup>‡</sup>	(0.033)	(0.113)	-0.020
Teacher's experience	0.457	(0.033)	0.445*	(0.033)	(0.115)	0.041
Teacher's education						
Secondary	19.882	(2.032)	24.243*	(1.801)	(4.940)	0.091
BA or equivalent	11.241	(1.993)	12.378 <sup>†</sup>	(1.758)	(4.859)	0.059
MA/PhD	25.575	(2.034)	32.106*	(1.806)	(5.042)	0.119

(to be continued)

**Table 2 (continued)**

	OLS		WLS			
	Coeff.	Raw S.E.	Coeff.	Raw S.E.	Robust S.E.	Std. Coeff.
<b>Institutional settings</b>						
<i>Central examinations</i>						
Central examinations	8.598	(0.437)	10.650*	(0.405)	(1.302)	0.024
External exams influence curriculum	2.329	(0.550)	-4.364†	(0.536)	(1.881)	-0.016
<i>Distribution of responsibilities between schools and administration</i>						
Central curriculum	5.319	(0.552)	5.573*	(0.530)	(1.649)	0.031
Central textbook approval	5.563	(0.474)	6.157*	(0.460)	(1.346)	0.052
School responsibility						
School budget	-2.065	(0.674)	-3.451	(0.695)	(2.356)	-0.010
Purchasing supplies	1.939	(0.996)	2.867	(1.016)	(3.308)	0.006
Hiring teachers	6.235	(0.461)	5.247*	(0.478)	(1.473)	0.023
Determining teacher salaries	11.381	(0.462)	15.162*	(0.473)	(1.817)	0.067
<i>Teachers' influence</i>						
Teachers' responsibility						
School budget	-9.172	(1.048)	-4.583	(1.116)	(3.025)	-0.008
Purchasing supplies	7.052	(0.613)	6.837*	(0.653)	(2.062)	0.019
Hiring teachers	6.817	(5.518)	7.595	(6.315)	(6.002)	0.002
Determining teacher salaries	-9.640	(5.249)	-6.048	(5.600)	(16.342)	-0.002
Strong influence on curriculum						
Teacher individually	8.711	(0.450)	10.768*	(0.455)	(1.536)	0.046
Subject teachers	-2.129	(0.481)	-4.573*	(0.485)	(1.625)	-0.023
School teachers collectively	-3.084	(0.468)	-5.034*	(0.468)	(1.575)	-0.025
Teacher unions	-18.901	(1.393)	-18.395*	(1.395)	(5.533)	-0.024
Class teacher has strong influence on						
Money for supplies	3.764	(0.764)	6.876*	(0.791)	(2.255)	0.018
Kind of supplies	3.871	(0.516)	4.566*	(0.530)	(1.520)	0.018
Subject matter	-0.429	(0.382)	-1.213	(0.380)	(1.186)	-0.006
Textbook	-0.978	(0.453)	-1.016	(0.459)	(1.379)	-0.004
<i>Students' incentives</i>						
Scrutiny of exams	0.513	(0.116)	0.444	(0.117)	(0.406)	0.007
Homework	-0.031	(0.004)	-0.043*	(0.005)	(0.014)	-0.017
<i>Parents' influence</i>						
Parents influence curriculum	0.264	(1.339)	5.041	(1.416)	(4.411)	0.006
Uninterested parents limit teaching	-12.980	(0.776)	-11.003*	(0.758)	(2.649)	-0.028
Interested parents limit teaching	-0.295	(0.952)	-1.333	(0.922)	(3.394)	-0.003
Parent-teacher meetings	-2.293	(0.289)	-2.662*	(0.290)	(0.859)	-0.017
Observations	266545		266545			
Schools (PSUs)	6107		6107			
Countries	39		39			
R <sup>2</sup> (adj.)	0.18		0.19			

\* Significant at the 1 percent level based on robust standard errors.

† Significant at the 5 percent level based on robust standard errors.

‡ Significant at the 10 percent level based on robust standard errors.

**Table 3: OECD evidence on institutional effects in mathematics**

Dependent variable: TIMSS international mathematics test score. WLS regression. Each row contains the result of a separate regression. Controlling for all variables of Table 1. Robust standard errors based on countries as primary sampling units in parentheses.

	Coeff.	Robust S.E.	Std. Coeff.	Obser- vations	Coun- tries	R <sup>2</sup> (adj.)
<i>Distribution of responsibilities between schools and administration</i>						
School autonomy	0.120	(0.469)	0.015	136478	21	0.19
School level decisions:						
Overall	0.227	(0.463)	0.042	134004	21	0.20
Organization of instruction	0.891 <sup>†</sup>	(0.368)	0.131	134004	21	0.20
Personnel management	-0.043	(0.295)	-0.014	134004	21	0.20
Planning and structures	0.136	(0.502)	0.027	134004	21	0.20
Resources	-0.002	(0.320)	-4.4e-4	134004	21	0.20
<i>Distribution of responsibilities between administrative levels</i>						
Central government decisions:						
Overall	-0.447	(0.271)	-0.097	134004	21	0.20
Organization of instruction	-1.734 <sup>*</sup>	(0.436)	-0.203	134004	21	0.21
Personnel management	-0.234	(0.197)	-0.078	134004	21	0.20
Planning and structures	-0.114	(0.189)	-0.037	134004	21	0.20
Resources	-0.371 <sup>‡</sup>	(0.210)	-0.108	134004	21	0.20
Government level of funds:						
Funds provided at local level	-0.410 <sup>*</sup>	(0.120)	-0.150	160615	22	0.20
Funds provided at central level	-0.346 <sup>†</sup>	(0.161)	-0.126	160615	22	0.19
<i>Private schools</i>						
Private enrollment	0.594 <sup>†</sup>	(0.243)	0.105	170846	23	0.19
Independent private enrollment	2.909 <sup>*</sup>	(0.824)	0.195	170846	23	0.20
Public expenditure on private institutions	0.621 <sup>*</sup>	(0.159)	0.132	185786	26	0.20
Public expenditure on independent private institutions	12.124 <sup>‡</sup>	(6.658)	0.101	185786	26	0.20

<sup>\*</sup> Significant at the 1 percent level based on robust standard errors.

<sup>†</sup> Significant at the 5 percent level based on robust standard errors.

<sup>‡</sup> Significant at the 10 percent level based on robust standard errors.

**Table 4: OECD evidence on institutional effects in science**

Dependent variable: TIMSS international science test score. WLS regressions. Each row contains the result of a separate regression. Controlling for all variables of Table 2. Robust standard errors based on countries as primary sampling units in parentheses.

	Coeff.	Robust S.E.	Std. Coeff.	Obs- ervations	Coun- tries	R <sup>2</sup> (adj.)
<i>Distribution of responsibilities between schools and administration</i>						
School autonomy	0.523 ‡	(0.300)	0.062	136478	21	0.19
School level decisions:						
Overall	0.779 *	(0.272)	0.142	134004	21	0.19
Organization of instruction	0.808 †	(0.358)	0.116	134004	21	0.19
Personnel management	0.429 ‡	(0.215)	0.133	134004	21	0.19
Planning and structures	0.578 †	(0.272)	0.113	134004	21	0.19
Resources	0.393	(0.253)	0.076	134004	21	0.18
<i>Distribution of responsibilities between administrative levels</i>						
Central government decisions:						
Overall	-0.554 †	(0.239)	-0.117	134004	21	0.19
Organization of instruction	-1.178 †	(0.462)	-0.134	134004	21	0.19
Personnel management	-0.411 †	(0.148)	-0.133	134004	21	0.19
Planning and structures	-0.153	(0.172)	-0.049	134004	21	0.18
Resources	-0.417 *	(0.112)	-0.118	134004	21	0.19
Government level of funds:						
Funds provided at local level	0.023	(0.116)	0.008	160615	22	0.17
Funds provided at central level	-0.196	(0.159)	-0.070	160615	22	0.17
<i>Private schools</i>						
Private enrollment	0.539 *	(0.138)	0.093	170846	23	0.17
Independent private enrollment	1.257 †	(0.522)	0.082	170846	23	0.17
Public expenditure on private institutions	0.138	(0.284)	0.029	185786	26	0.18
Public expenditure on independent private institutions	4.569	(4.149)	0.037	185786	26	0.18

\* Significant at the 1 percent level based on robust standard errors.

† Significant at the 5 percent level based on robust standard errors.

‡ Significant at the 10 percent level based on robust standard errors.

## **Appendix A: The Data Base**

A complete list of the variables used in this study and their descriptive statistics is given in Table A1. The sources of the variables - as reported in the column labeled "Origin" - are TIMSS student, teacher, and school background questionnaires, as well as country-level data on the education systems obtained also from OECD educational indicators. For dummy variables, the column labeled "True" reports the percent of students for which the state expressed by the dummy is true. For discrete variables, the international means and standard deviations are reported.

### *Data from TIMSS Student, Teacher, and School Questionnaires*

Student-level information (marked "St" in the column "Origin" of Table A1) is used to control for students' background and family characteristics. To capture the fact that performance should differ between the two adjacent grades in which students were tested, the dummy "upper grade" is set equal to one for each student in the upper one of the two grades tested. In addition, two countries (Sweden and Switzerland) have tested students in a third grade above the other two, which is captured by the dummy "above upper grade". Data on the students' age and sex are included, as well as dummies showing whether the student was born in the country where she goes to school, whether she lives with both parents, and whether at least one parent was born in the country. Furthermore, four dummies are included representing the highest educational level achieved by the students' parents, as well as four dummies for the number of books in the students' home, which acts as a proxy for the educational and social background of the family. In the production functions to be estimated, the coefficients on the dummies for parents' education show the performance of students with parents who achieved some secondary education, finished secondary education, had some education beyond the secondary level, and finished university relative to students with parents who only had primary education. Likewise, the dummies for books at home show the performance of students with four ranges of numbers of books (11-25 or enough to fill one shelf, 26-100 or enough to fill one bookcase, 101-200 or enough to fill two bookcases, and more than 200 or enough to fill three or more bookcases) relative to students with none or very few (up to 10) books at home.

Data obtained from TIMSS teacher and school questionnaires are used to show effects of school resources and institutional features. To do so, the student-specific data on achievement test scores and student characteristics has been merged with the class-level teacher data and with the school-level data. Teacher data are available separately for mathematics and science teachers. If a student had more than one teacher in either mathematics or science, the teacher who taught the most minutes per week to that student was chosen when merging student and teacher data.

The teacher data (T) give class-level information on class size and the class teacher's characteristics, behavior, and influence. Teacher characteristics considered are the teacher's sex, age, years of teaching experience, and education. The teacher's education is again given in dummy form, showing the effect of the completion of secondary education, bachelor degree, and masters or doctorate degree relative to teachers without completing secondary education. The relevant data on institutional features is derived from qualitative survey data. Teachers were asked how much influence they had on the amount of money to be spent on supplies, on what supplies are purchased, on the subject matter to be taught, and on specific textbooks to be used. The four-item response possibilities of the questionnaire ranged from "none" to "a lot". To be able to assess the impact of teachers' influence in the different decision-making areas on students' performance, dummy variables were created from these qualitative data which are set equal to one for each teacher who answered that she had "a lot" of influence in the respective field. In the same way, a dummy variable was created signifying that parents uninterested in their children's learning and progress limit "a great deal" how the teacher teaches his class, as well as one for limitations by parents interested in their children's learning. Further data gives information on the scrutiny of exams as measured by the time (in hours per week) which the teacher spends outside the formal school day on preparing or grading exams, on minutes of homework per week assigned by the teacher, and on the time which the teacher spends outside the formal school day on parent-teacher meetings.

The school-level information (Sc) was given by the principals of the schools tested. It includes dummies for schools located in geographically isolated communities and for schools located close to the center of a town (the residual category being schools located in villages or on the outskirts of a town), as well as dummies for schools whose

principal thinks that the capacity to provide instruction is "not" or "a lot" affected by the shortage or inadequacy of instructional materials like textbooks. Data is given on the ratio of total student enrollment to professional staff at the school, where the latter includes principals, assistant principals, department heads, classroom teachers, teacher aides, laboratory technicians, and learning specialists. An instruction-time variable combines information on the duration of a typical instructional period in minutes, on the number of instructional periods of an average school day, and on the number of instructional days in the school year, each reported separately for the lower and the upper grade. Apart from these resource-related data, qualitative assessment of the institutional setting is given. Principals were asked who, with regard to their school, had primary responsibility for different activities, including formulating the school budget, purchasing supplies, hiring teachers, and determining teacher salaries. Possible answers were "teachers," "department heads," "the principal," "the school's governing board," and "not a school responsibility." Dummies were created for each activity showing whether primary responsibility was with the school and whether it was with teachers. Finally, six dummies show whether external examinations/standardized tests, each teacher individually, teachers of the same subject as a group, teachers collectively for the school, teacher unions, and parents had "a lot" of influence in determining the curriculum that is taught in the school.

#### *Country-Level Data*

At the country level (C), TIMSS reported the degree of centralization regarding decision-making about examinations, curriculum syllabi, and textbooks (Beaton et al. 1996, pp. 17-19). Dummies report whether the central level of decision-making authority within the (national or regional) education system had exclusive responsibility for or gave final approval of the content of examinations, the syllabi for courses of study, and the list of approved textbooks. As a measure of the country's level of development which sets the general background for the educational opportunities of the students, data on GDP per capita (in current international dollars, 1994) is included, obtained from World Bank (1999) statistics. Unfortunately, the TIMSS data base does not contain expenditure data. In lack of expenditure data at the local level, current public expenditure per student in secondary education at the national level in 1994 was

calculated on the basis of data from UNESCO (var. iss.) Statistical Yearbooks, converted into international dollars with purchasing-power-parity exchange rates from the World Bank (1999).

Further country-level data on institutional features of the education system at large - concerning the level of decision-making and private involvement - were obtained from the 1997 and 1998 volumes of the OECD educational indicators (CO), which are devised to provide a quantitative description of the comparative functioning of education systems. Most of these indicators were gathered in the UNESCO/OECD World Education Indicators (WEI) program, which includes a number of non-OECD-member countries. The number of countries for which each indicator is available is reported in Table A1.

With regard to the organization of the schooling system, the OECD has gathered information on the distribution of decision-making responsibilities among key shareholders of education. These agents are central, state, provincial, sub-regional, and local authorities as well as schools.<sup>20</sup> The indicator relates to public lower secondary education and is available for the school year 1997/98 only.<sup>21</sup> It is based on 35 decision items included in a survey completed by panels of national experts and refers to actual decision-making practice (not to non-binding formal regulations). The variables used in this paper represent the percentages of educational decisions taken at the school level and at the central government level (OECD 1998, Tables E5.1 and E5.2). The general indicator (termed "overall" in Table A1) is calculated to give equal importance to each of the following four decision-making domains: organization of instruction, personnel management, planning and structures, and resource allocation and use. Data is also available for each of the four domains separately. Decisions on the organization of instruction include the determination of school attendance, promotion, repetition, and teaching and assessment methods. Decisions on personnel management comprise the hiring, dismissal, career influence, and duties of staff as well as the fixing of salary scales. As for planning and structures, decisions such as the creation and closure of

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<sup>20</sup> Information on names and numbers of decision-making units per decision-making level for each country can be found in Annex 3 of OECD (1998).

<sup>21</sup> This should not be a problem, however, since organizational structures in the education system are relatively stable.

schools and grades, the design of programs of study, and the setting of qualifying examinations for a certificate are combined. Resource decisions include the allocation and use of resources for different kinds of expenditure. Finally, the variable "school autonomy" captures what percentage of decisions are taken at the school level in full autonomy, as opposed to after consultations with or within frameworks from other educational authorities (OECD 1998, Table E5.3).

Another OECD educational indicator reports which share of final public funds is spent by the different levels of government (after transfers between the different government levels), showing whether local, intermediate, or central authorities are the final purchasers of educational resources (OECD 1998, Table B6.1a). The variables on the "government level of final funds" report the respective shares of total public funds provided at the local level and at the central level, giving information on the division of responsibility for and control over the funding of education between local, intermediate, and national authorities.

Data on the share of private enrollment in total enrollment refer to the school year 1994/95 (derived from OECD 1997, Table C1.1a). Educational institutions are classified as either public or private according to whether a public agency or a private entity has the ultimate power to make decisions concerning the institution's affairs (ultimate management control). That is, public institutions are institutions controlled and managed directly by a public education authority or agency or controlled by a body whose members are appointed by a public authority, while private institutions are controlled and managed by a non-governmental organization (e.g. a church or a business enterprise). As a sub-group of the private institutions, government-independent private institutions are those private institutions which receive less than 50 percent of its core funding from government agencies, while government-dependent private institutions primarily depend on funding from government sources for their basic educational services. The variable "public expenditure on (independent) private institutions" contains the share of public educational expenditure going to (independent) private educational institutions in the financial year 1995 (OECD 1998, Table B6.2).

## Data References

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Organisation for Economic Co-Operation and Development (OECD) (var. iss.). *Education at a Glance. OECD Indicators*. Paris.

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**Table A1: Descriptive Statistics**

Variable	Origin <sup>1</sup>	True Mean (Percent)	Std. Dev.	Imputed (Percent)	Countries Missing
<b>Test scores</b>					
Mathematics score	St	507.6	99.3	0.0	-
Science score	St	506.8	98.4	0.0	-
<b>Student and family characteristics</b>					
Upper grade	St	51.3		0.0	-
Above upper grade	St	1.8		0.0	-
Age (years)	St	13.8	0.9	1.4	-
Sex (female)	St	50.2		0.4	-
Born in country	St	94.1		7.6	FRA JPN
Living with both parents	St	87.3		7.3	JPN
Parent born in country	St	91.9		7.7	JPN
Parents' education	St			13.2	GBR JPN
Some secondary		14.2			
Finished secondary		31.8			
Some after secondary		24.4			
Finished university		18.1			
Books at home	St			6.0	JPN
11-25		14.8			
26-100		33.0			
101-200		19.4			
More than 200		24.9			
Community location				10.2	KWT
Geographically isolated area	Sc	3.0			
Close to the center of a town	Sc	39.7			
GDP per capita (intl. \$)	C	15404.0	6993.1	0.0	-
<b>Resources and teacher characteristics</b>					
Expenditure per student (intl. \$)	C	3242.8	1941.7	0.0	-
Mathematics class size (no. of stud.)	T	28.4	10.7	26.8	-
Science class size (no. of students)	T	28.8	10.2	35.8	-
Student-teacher ratio	Sc	25.7	61.2	21.0	GBR
No shortage of materials	Sc	41.0		12.3	SCO
Great shortage of materials	Sc	12.5		12.3	SCO
Instruction time (minutes per year)	Sc	47226.5	8248.6	30.0	GRC JPN KWT
<b>Mathematics teacher characteristics</b>					
Teacher's sex (female)	T	54.1		12.0	-
Teacher's age (years)	T	40.8	9.3	12.0	-
Teacher's experience (years)	T	16.2	9.4	13.2	-
Teacher's education	T			22.2	AUS BFL/R DNK JPN
Secondary		18.8			
BA or equivalent		64.8			
MA/PhD		15.3			
<b>Science teacher characteristics</b>					
Teacher's sex (female)	T	52.4		15.0	-
Teacher's age (years)	T	40.7	9.2	15.0	-
Teacher's experience (years)	T	15.7	9.3	16.3	-

(to be continued)

**Table A1 (continued)**

Variable	Origin <sup>1</sup>	True (Percent)	Mean	Std. Dev.	Imputed (Percent)	Countries Missing
Teacher's education	T				24.9	AUS BFL/R DNK JPN
Secondary		15.9				
BA or equivalent		66.6				
MA/PhD		16.7				
<b>Institutional settings</b>						
<i>Central examinations</i>						
Central examinations	C	34.2				-
External exams influence curriculum	Sc	15.2			20.0	BFL/R GBR KWT NOR SCO
<i>Distribution of responsibilities between schools and administration</i>						
Central curriculum	C	77.2				-
Central textbook approval	C	51.3				-
<i>School responsibility</i>						
School budget	Sc	90.5			20.4	GBR NOR SCO
Purchasing supplies	Sc	96.2			21.3	GBR NOR SCO
Hiring teachers	Sc	73.1			17.4	GBR NOR SCO
Determining teacher salaries	Sc	27.9			20.3	GBR NOR SCO BFL/R
<i>Teachers' influence</i>						
<i>Teachers' responsibility</i>						
School budget	Sc	3.2			20.4	GBR NOR SCO
Purchasing supplies	Sc	10.0			21.3	GBR NOR SCO
Hiring teachers	Sc	0.1			17.4	GBR NOR SCO
Determining teacher salaries	Sc	0.1			20.3	GBR NOR SCO BFL/R
<i>Strong influence on curriculum</i>						
Teacher individually	Sc	24.3			17.5	BFR GBR KWT NOR SCO
Subject teachers	Sc	48.9			18.0	BFR GBR KWT NOR SCO
School teachers collectively	Sc	45.0			17.4	BFR GBR KWT NOR SCO
Teacher unions	Sc	1.7			17.9	BFR GBR KWT NOR SCO
<i>Math. teacher has strong influence on</i>						
Money for supplies	T	4.9			13.7	GBR
Kind of supplies	T	13.2			13.7	GBR
Subject matter	T	28.5			13.3	GBR
Textbook	T	19.9			13.6	GBR
<i>Sci. teacher has strong influence on</i>						
Money for supplies	T	7.4			17.0	GBR ISR
Kind of supplies	T	20.1			16.8	GBR ISR
Subject matter	T	40.6			16.5	GBR ISR
Textbook	T	24.8			16.9	GBR ISR
<i>Students' incentives</i>						
<i>Mathematics</i>						
Scrutiny of exams (hours p. w.)	T		2.5	1.6	14.1	DNK
Homework (minutes per week)	T		99.3	80.0	22.4	-
<i>Science</i>						
Scrutiny of exams (hours p. w.)	T		2.4	1.6	16.9	DNK
Homework (minutes per week)	T		38.8	40.9	32.9	AUT

(to be continued)

**Table A1 (continued)**

<b>Variable</b>	<b>Origin<sup>1</sup></b>	<b>True Mean</b>	<b>Std. Dev.</b>	<b>Imputed (Percent)</b>	<b>Countries Missing</b>	
<i>Parents' influence</i>						
Parents influence curriculum	Sc	1.8		17.1	BFR GBR KWT NOR SCO	
<i>Mathematics</i>						
Uninterested parents limit teaching	T	8.3		25.9	JPN	
Interested parents limit teaching	T	4.8		24.2	FRA	
Parent-teacher meetings (hours p. w.)	T		0.6	0.6	15.6	DNK
<i>Science</i>						
Uninterested parents limit teaching	T	6.4		34.3	JPN	
Interested parents limit teaching	T	4.2		32.5	FRA	
Parent-teacher meetings (hours p. w.)	T		0.6	0.6	18.8	DNK
(in percent:)					<b>Number of Countries Available</b>	
<i>Distribution of responsibilities between schools and administration</i>						
School autonomy	CO		16.5	11.3	21	
<i>School level decisions</i>						
Overall	CO		40.1	16.9	21	
Organization of instruction	CO		80.1	13.1	21	
Personnel management	CO		29.9	29.0	21	
Planning and structures	CO		24.2	18.3	21	
Resources	CO		26.2	19.4	21	
<i>Distribution of responsibilities between administrative levels</i>						
<i>Central government decisions</i>						
Overall	CO		25.2	21.5	21	
Organization of instruction	CO		9.9	11.1	21	
Personnel management	CO		31.8	32.7	21	
Planning and structures	CO		41.0	30.6	21	
Resources	CO		18.2	28.9	21	
<i>Government level of final funds</i>						
Funds provided at local level	CO		38.0	36.4	22	
Funds provided at central level	CO		28.1	34.4	22	
<i>Private schools</i>						
Private enrollment	CO		13.8	14.0	23	
Independent private enrollment	CO		4.3	6.9	23	
Public exp. on private institutions	CO		10.6	17.2	26	
Public exp. on indep. private inst.	CO		0.4	0.9	26	

Statistics are unweighted.

<sup>1</sup> St = student, T = class teacher, Sc = school, C = country, CO = OECD country data.

## Appendix B: Data Imputation

For the TIMSS questionnaire variables, values for missing data were imputed using the data of those students with non-missing values on the variable of interest and data on a set of "fundamental" explanatory variables available for all students.

For each student  $i$  with missing data on a specific variable  $V$ , a 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 with available data for  $V$ . Using the students in  $S$ , the variable  $V$  was regressed on  $F$ . For  $V$  being a discrete variable, ordinary least squares estimation was used for the regression. For  $V$  being a dichotomous (binary) variable, the probit model was used. If  $V$  was originally (before deriving dummies) a polychotomous qualitative variable with multiple categories, an ordered probit model was estimated. The coefficients from these regressions and the data  $F(i)$  were then used to impute the value of  $V(i)$  for the students with missing data. For the probit models, the estimated coefficients were used to forecast the probability of occurrence associated with each category for the students with missing data, and the category with the highest probability was imputed.

The set of "fundamental" explanatory variables  $F$  included: the student's sex; the student's age; two dummies on the grade level which the student attended; four dummies on the parents' education level; four dummies on the number of books in the student's home; three dummies on the type of community in which the school is located; gross domestic product (GDP) per capita of the country; and educational expenditure per student in secondary education in the country. The small amount of missing data within  $F$  was imputed by taking the average value at the lowest level available, that is, class average, school average, or country average. For the three countries which did not administer one of the variables in  $F$ , these missing data were imputed by the method outlined above, using the remaining variables in  $F$  for the regression. The percentage of imputed values for each variable is given in Table A1, as well as the names of the countries which did not provide internationally comparable data for each variable.