DOES PRIVATE SCHOOL COMPETITION IMPROVE COUNTRY-LEVEL STUDENT ACHIEVEMENT? A CROSS-COUNTRY ANALYSIS USING PISA 2012

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ABSTRACT

This paper investigates the relationship between private competition and student achievement and whether countries with higher shares of privately-managed schools have better standardized test scores. It uses the cross-country OLS and instrumental variable estimation approaches and a covariate-rich dataset, PISA 2012, which measures math and reading literacy of 15-year-olds in more than 30 OECD and non-OECD countries. The privately-managed school share coefficient is not statistically significant at any conventional level after controlling for large subsets of student and family characteristics, school inputs, and country-level controls. These null results suggest the earlier positive cross-country evidence should be interpreted with caution and further research recommendations are briefly discussed.

I am grateful to my thesis advisor, Erica Johnson, and my friend, Ercio Muñoz, for their guidance, and helpful comments and discussions in writing this thesis. I must also acknowledge my dear wife and family for their love and support throughout my graduate studies.

Many thanks,

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Introduction

There is very little doubt education matters as an investment in human capital for both individual and country outcomes. In the last decade, experimental and quasi-experimental evidence has shown that improvements in cognitive and non-cognitive skills as well as access and attainment have large effects on development outcomes such as lower crime rates and teenage pregnancies, and increased earnings in adulthood and economic growth[1]. Education is also tightly tied to intergenerational and social mobility (Dearden et al., 1997). The value of education does not simply stem from the ethical responsibility of providing equality of opportunity, but also from an economic perspective of an efficient allocation of resources[2]. Whether it is due to low learning and literacy despite high enrollments, expanding access to children who are still out of school, promoting social mobility, tightening budgets or ramped up accountability by the public or international donors, policymakers are under increased pressure to smartly allocate scarce education resources.

One of the key concerns and ongoing debates for policymakers and scholars is whether or not private schooling can help tackle the issues above. Seeking to guarantee access to the poor, most governments expanded and systematized public schooling in the 19th and 20th century (Ramirez and Boli, 1987; Nishimura and Ogawa, 2009). Since then, many countries have gradually experimented with private options with varying degrees of administration, autonomy and funding by non-government for-profit and non-profit organizations (Lewis and Patrinos, 2011). In countries that began privatizing, public schools were seen as ineffective and inefficient[3], two evaluations typically made of public organizations that have little incentive to produce quality services. Either by law or parental preferences (i.e. shorter distance to school is preferred), students were deemed captive in their neighborhood schools. The main

[1]For instance, Chetty et al. (2014), and Hanushek and Woessmann (2012)
[2]A low degree of equality of opportunity means that investments in human capital are more related to social origin than on ability. On average, these investments will yield a lower return and are, thus, inefficient.
[3]Bok (2000) argues public schools may have too many one-size-fits-all that overlook circumstance. Chubb and Moe (1990) argue that, because they may be run democratically, public schools are vulnerable to: special interests that have little connection to students' educational needs; inflated expenditures driven by politics; corruption; fraud; and waste.

argument in favor of schooling privatization[4] draws from the economic theory[5] that, in a market of a complex and highly-valued service like education, introducing private alternatives will lead to both private and public schools to compete on quality (i.e. effectiveness). School administrators would have incentives to improve school quality (e.g. management, instruction, facilities) to attract parents and students, and survive the entry of new competitors. In turn, parents would seek more information and choose based on quality. Low-quality providers would then be driven out of market, which would result in incumbents possessing a higher average quality and student achievement. Evidence supporting the theory is mixed which suggests that one or more of these mechanisms are not working: (a) parents are not choosing schools based on quality or quality is not weighted heavily in their decision, (b) schools do not (or cannot due to lack of capacity) compete on quality, (c) schools compete for the better able students (who are cheaper to educate and better for the bottom-line profits) and (d) schools possess enough autonomy that allows them to react to market forces such as a changing demand.

This paper seeks to shed more light on the effectiveness claim from the often less-visited international perspective by testing some of the theoretical mechanisms through which private competition may affect student performance. Specifically, it examines whether the share of privately-managed schools improves country-wide student achievement using the 2012 Programme for International Student Assessment (PISA), a nationally-representative literacy test in mathematics, reading and science for 15-year-olds conducted in 65 countries.

Throughout this paper, student achievement is measured by performance on cognitive skill learning and tests. While using test scores as a measure of learning is not without detractors, there is currently no better proxy of student learning that allows for the evaluation of educational public policies, especially in the international realm. The focus on cognitive skills as opposed to non-cognitive is merely practical.

[4] This is the only theory of change hypothesis that this study will address. Others include higher private-sector productivity (relative to public) in the use of resources due to superior management capacity (Day Ashley et al, 2014)

[5] Friedman (1962); Neal (2010)

This study's contribution is to add to the cross-country estimation evidence by Woessmann (2009) and West and Woessmann (2010) who used PISA 2003, by estimating the effects of private competition on student achievement a decade later not only in – a slightly higher number of – OECD countries but also with specifications that include some non-OECD developing countries. The results lack statistical significance, warrant interpreting the earlier evidence with caution, and suggest more evidence on the role of private competition on country-level student achievement is needed.

This paper begins with a review of within-country and cross-country evidence. It continues with a description of the empirical approach, the data used, and the results. It ends with some robustness checks, and a discussion of the results and directions for future research.

Literature Review

Research on the effects of private competition on student achievement has evolved in both quantity and quality in the last two decades with a growing (but still small) number of experimental and quasi-experimental studies but it remains largely observational and within-country based. This study adds to the cross-country evidence which is better suited to deal with selection bias and capture general equilibrium effects. The evidence remains inconclusive when an all-encompassing view of the literature - observational, experimental, within-country and cross-country – is considered.

Within-country studies

Developing countries

Drago and Paredes (2011) conducted a meta-analysis of 17 studies[6] done for Chile, one of the few countries with a nation-wide system of school vouchers introduced in 1981, of which 10 suggested that private subsidized schools increased student achievement, 5 found null results, and 2 put public schools

[6] Which include the observational studies by McEwan and Carnoy (2000) and McEwan (2001) that found contradictory private and public school premiums, respectively.

atop. The authors estimate a 0.1 standard deviation edge of private subsidized over public schools in the national math test. Although all of these studies control for a rich set of school, individual, family and geographic factors, only some of them address selection bias and none of them use experimental or quasi-experimental methods. Similarly, and in one of the only experiments conducted in Chile, Hsieh and Urquiola (2006) showed no differences between the student achievement in private subsidized and public schools.

In a fairly comprehensive review of the impacts of private schools in six developing countries[7] since the 2000s, Day Ashley et al (2014) find "moderate evidence" that private school students achieve better learning outcomes than public schools and suggest that the true effect size is ambiguous. Fourteen studies found positive effects (of which two are experimental) and seven found null results (of which one is experimental). Only studies deemed of high and moderate quality were included in the review (see Day Ashley, 2014, appendix 6 for description of quality criteria).

Murnane and Ganimian (2014) reviewed experimental evidence in developing countries and found positive effects in Colombia (Angrist et al, 2002) on the order of 0.2 test score standard deviation increases in math, reading and writing. Barrera-Osorio et al. (2011) showed an effect of 0.67 standard deviations in math and language tests for students who enrolled in publicly funded private primary schools in Sindh, Pakistan. On the flip side, in an experimental design, Muralidharan and Sundararaman (2013a), found no differences in achievement for the winners and losers in a private-school voucher lottery in Andhra Pradesh, India.

United States

Belfield and Levin (2002) reviewed 25 observational studies for the United States that estimated the effect of private competition on public schools' student achievement and found that most results

[7]The review focused on countries considered priority countries by the evaluation sponsor U.K. Department for International Development (DFID). Of the 11 countries, only 6 had studies on student achievement: Ghana (1, null), India (7 positive, 5 null), Kenya (2 positive, 1 null), Nepal (1 positive), Nigeria (1 positive), and Pakistan (3 positive).

lacked statistical significance and that the positive effects that few studies found were too small and likely due to questionable methodologies, data quality, and publication bias. The majority of these studies estimated the association between private competition and public school student test scores.

In a review of studies using experimental or quasi-experimental methods, Lewis and Patrinos (2011) also found ambiguous evidence of the effects of privatization on test scores: while Abdulkadiroglu et al. (2009) found positive effects, Hoxby et al. (2004), and Booker et al (2008), found mixed effects.

Within and cross-country studies using international test data

Hanushek and Woessmann (2014) review studies on the institutional determinants[8] of student achievement that use international test data. Below, studies that focus on private competition (management/operation) are discussed in more detail.

Within-country studies

Using the 1981 International Association for the Evaluation of Educational Achievement (IEA) math test conducted in Belgium, France, New Zealand, Canada, U.S., Toma (1996) finds that privately-operated schools add more value than public schools (school value-added approach) after controlling for family, school, and peer factors. Also, the author suggests decision-making autonomy of private schools as an important mediating factor as opposed to funding.

Vandenberghe and Robin (2004) use econometrics methods to attempt to overcome selection bias (IV, Heckman two stages and matching) using PISA 2000 in 9 countries and find mixed results of the privately-managed school premium in tests scores over public schools. Positive results are found for Belgium and Brazil but null results are found for Mexico, Denmark and Spain. For Austria, France and Ireland, different methods yield contradictory results, making any conclusions difficult.

[8] For instance: curriculum-based external exit exams, source of funding, school autonomy, accountability, choice, and management/operation

Also using PISA 2000 but for 19 developed countries, Corten and Dronkers (2006) find "some, though modest, support" for the hypothesis that privately-managed schools are relatively more effective when accounting for school funding (mirroring Toma (1996)) which the authors suggest Vandenberghe and Robin (2004) omitted. These results are positive (and "rather small") but only for lower social strata students with low cultural capital[9].

Dronkers and Robert (2008) again use PISA 2000 in 22 western advanced countries and find a student achievement premium of private government-dependent schools (50% or more of public funding) over private independent, and public schools. As in Corten and Dronkers (2006), they use multilevel analysis and account for sociological characteristics of students and parents; school composition; teaching and learning conditions; and school climate. However, they also include school autonomy[10] and students' attitudes on school climate as opposed to only the principals' perceptions on climate. School climate, they argue, explains the private premium.

Cross-country studies

In order to deal with selection bias[11] and capture general equilibrium effects[12], the cross-country approach has been complemented with country-level institutional measures such as GDP per capita, educational expenditure per student, school entry age, external entry exams, and share of privately-managed schools. In this vein, Woessmann (2003), Woessmann et al (2007), and Woessmann (2009) have found positive associations between the country share of privately-managed school and student achievement.

[9]Measured as an index of students' parents' cultural possessions (books and art at home)
[10]Whether the school or local/national government agencies make decisions about personnel, curriculum, etc.
[11]Selection bias arising from unobserved student/parent heterogeneity that may drive selection into private instead of public schools in a country.
[12]Private competition, in theory, creates incentives for both private and public schools to improve quality which could result in an aggregate country-level achievement boost. This effect cannot be captured by within-country (or district, or state) studies estimating the private-public school gap or the effect of private competition on public student achievement.

While others had used cross-country variation in international tests to estimate the relationship between student achievement and country-level determinants[13], Woessmann (2003) using TIMSS[14] 1994/1995 for 39 countries was the first to also exploit the cross-country institutional variation of private competition using student-level data and find positive associations between private competition and country student performance (with government funding being an important mediating variable). Further, Woessmann et al (2007) find positive interactions between private competition and external accountability measures, and private competition and autonomy. This means that privately-managed schools do better than public schools when there is a higher degree of accountability in the system (use of assessments to compare the school to district or national performance, or external reviewers of lessons) and schools are able to make more decisions (formulating the budget or staffing). Similarly, Woessmann (2009) shows that the interaction between the share of privately-managed schools and the share of government funding matters and suggests that the most effective school systems are those in which the government funds a large share of school budgets but allows for a large share of private schools to manage themselves.

Very few cross-country studies[15] have attempted to measure causal effects of institutional features of the educational system on student achievement and only West and Woessmann (2010) have done so for private competition. Using PISA 2003 for 29 OECD[16] countries, they estimate a positive causal effect of the share of privately-managed schools and student achievement where the country-level proportion of Catholics is a strong instrument to derive the exogenous variation in the share of privately-managed schools. The effect of a 10 percent point increase in the share of privately-managed schools increases test

[13]See Bishop (1995), Hanushek and Kimko (2000), and Lee and Barro (2001).
[14]The third International Mathematics and Science Study (TIMSS) was run by the International Association for the Evaluation of Educational Achievement and conducted in 39 countries and more 260,000 middle-school students.
[15]Ammermueller (2005), difference-in-differences; Hanushek and Woessmann (2006), difference-in-differences; Waldinger (2006), difference-in-differences; Fuchs and Woessmann (2007), instrumental variables; and Schuetz (2009), difference-in-differences.
[16] The Organization for Economic Cooperation and Development (OECD) is a 34-member country research institution established in 1961 and headquartered in Paris, France, whose mission is to promote policies that will improve the economic and social well-being of people around the world (http://www.oecd.org/about/).

scores in mathematics by 0.039-0.142 standard deviations. This study adds to West and Woessmann (2010) who used PISA 2003, by estimating the effects of private competition on student achievement a decade later not only in – a slightly higher number of – OECD countries but also with specifications that include some non-OECD developing countries.

Conceptual Framework and Hypotheses

There is a vast empirical literature[17] supporting the theory that student achievement or cognitive skill formation is a function of (a) student ability and IQ, (b) other student/family characteristics, (c) teachers and other school inputs, and (d) institutional factors. Regardless of whether or not educational systems allow for private provision of education, these systems can be thought of as a marketplace [18]set up by local or national governments where families demand educational services which are produced and supplied by principals, teachers and other staff in schools. In the education marketplace, this paper's main variable of interest is the country-level share of privately-managed schools. Through vouchers, partial or complete contracting of educational services, and management-and-funding-independent private provision, governments around the world have chosen different market competition strategies, allowing for-profit and non-profit private organizations to compete for students alongside public schools. Consequently, the private sector share has grown significantly and especially in the developing world (World Bank (2014)). For instance, it reached about 22, 12, and 11 percent in low, middle and high-income countries in 2010 respectively from about 12, 10, and 9 percent in 1990. As seen in Figure 1, other variables of interest include institutional features of the educational system that are related to how the student, family, teachers, and other school factors interact in order to produce student learning and achievement. These include public funding, and school autonomy and accountability. The two hypotheses are that (a) these variables operate through school management and allow private schools to

[17]For (a) and (b) see Heckman and Lochner (2000), for (c) see Chetty et al (2014), and Hanushek and Woessmann (2014), for (d) see Hanushek and Woessmann (2014).
[18]See Belfield and Levin (2003) for a more thorough examination of the education marketplace.

outperform public schools even after controlling for student and family factors[19] (e.g. parental education, socio-economic status, immigrant status, etc.) and (b) private competition is positively related to overall (country-wide) student achievement.

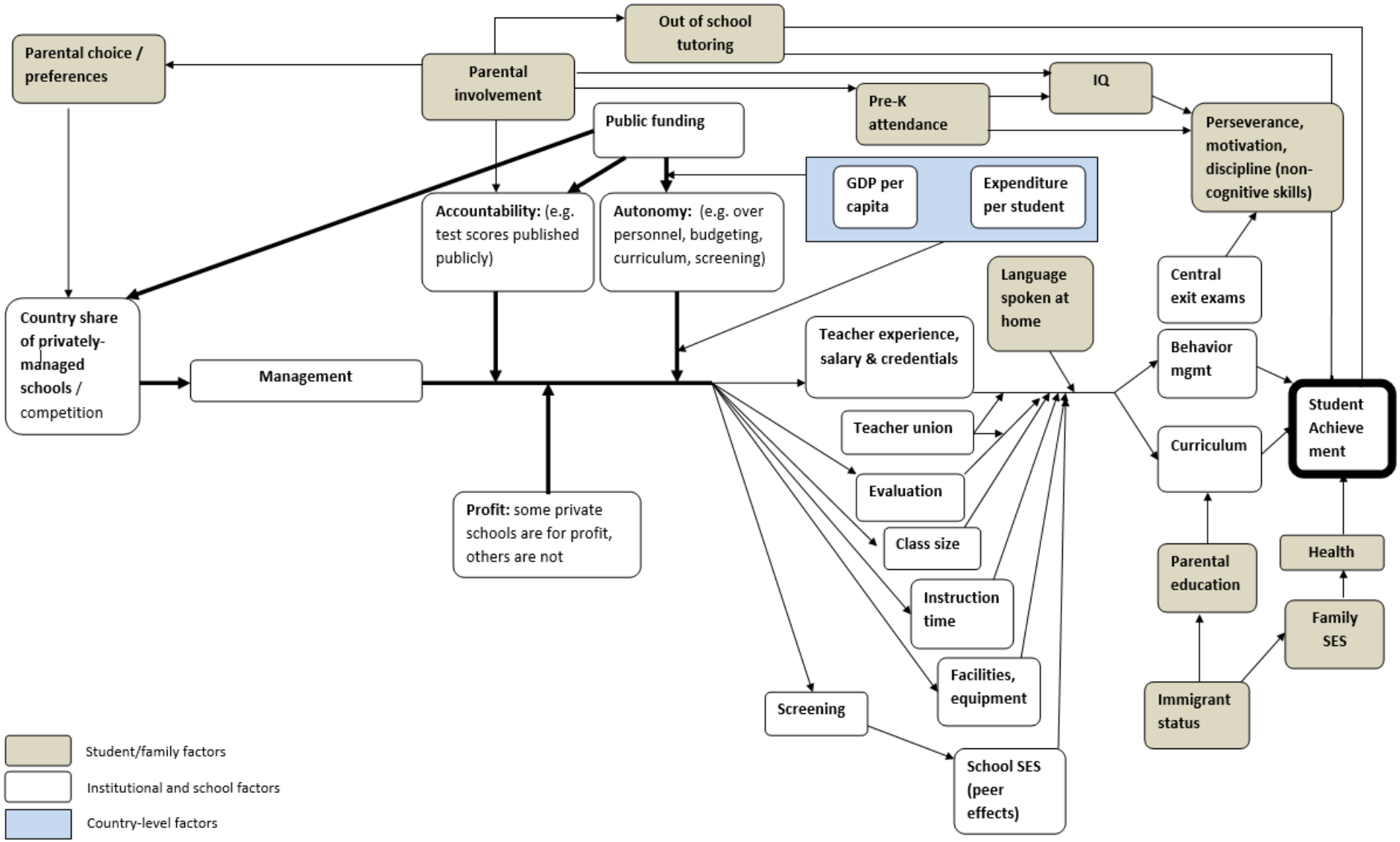
Data and Empirical Methods

Data

The main dataset for the study is the 2012 Programme for International Student Assessment (PISA), a nationally-representative standardized literacy test in mathematics, reading and science for 15-year-olds conducted in 65 countries. PISA has been conducted 5 times since 2000. The test length is roughly 2 hours and asks both multiple-choice and open-ended questions. Participating countries in 2012 included 34 OECD countries and 31 partnering countries. The median sample size per country was 5,090 and 5,231 student-level observations for the former and latter groups respectively for a total of 480,174 observations. A minimum of 150 schools and 4,500 students to be selected was required. Within countries, a two-stage stratified sample design was used. Schools were selected from a PISA sampling frame (of schools which taught grades 7 and higher) with probabilities[20] proportional to the estimated number of 15-year-olds enrolled in the school. Then, a target cluster size of 35 fifteen-year-old students per school was typically used. Exclusion rules were consistent across countries and include: intellectually and functionally disabled students, and non-native speakers with severe linguistic limitations. Exclusion students represented 5% or less of the PISA target population in each country. School response rates were typically 85% and replacement was done when this rate fell below 85%.

[19] Some controls such as motivation, attitudes toward learning and out-of-school tutoring are available in PISA 2012 but missing more than 30% of observations. For this reason, they are left out of the models (see Results section).
[20]Referred to as systematic Probability Proportional to Size (PPS) sampling.

Figure 1: The logic model

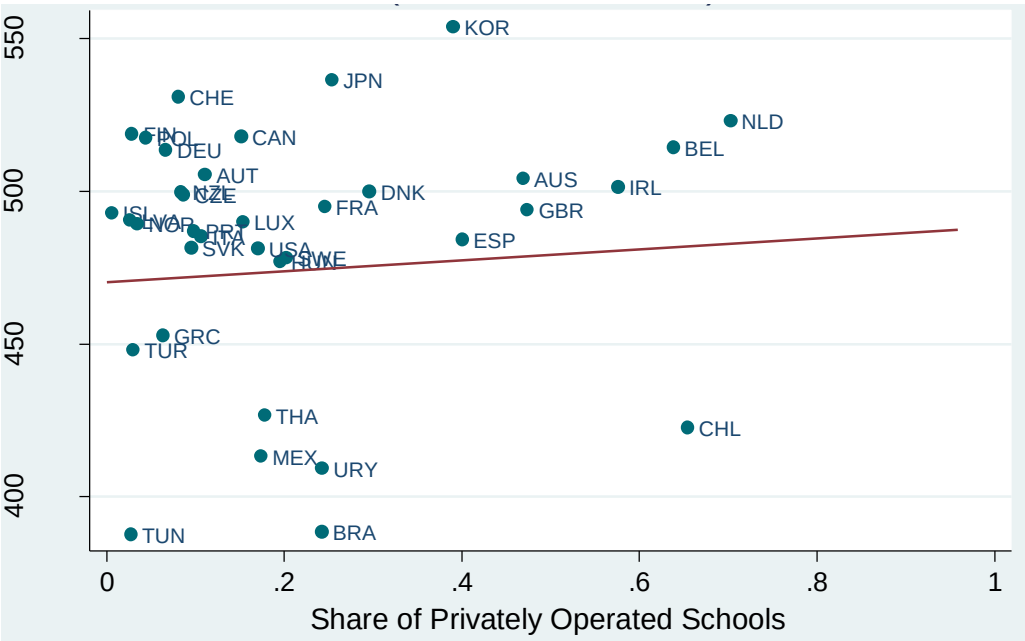


Source: the author based on studies in literature review.

Countries[21] that were missing key independent variables for all or the majority of the student-level observations were excluded from all models which brought the analytic sample to a tally of 35 countries (of which 29 are OECD) and 301,460 observations.

Private operation of schools, the main variable of interest, is defined as whether the school is managed directly or indirectly by a non-government organization such as a church, trade union, or business in PISA 2012. As shown in Figure 2, this measure's spread is large across countries in the analytics sample of 35 countries. While some countries like Island, Tunisia, and Turkey have almost no privately-managed schools, others like Belgium, Chile and Netherlands have educational systems where the share of private operation is over 60 percent.

Figure 2: Country share of privately-operated schools & math scores (35 countries)



Through item response theory scaling, scores were calculated to have a mean score of 500 and standard deviation of 100 points across countries. Figure 2 shows a slight positive correlation between private

[21] This data issue mainly affected non-OECD countries and only 5 of 34 OECD countries had to be dropped for this reason. See table 1 for the list of countries included in the main models.

competition (faced by public schools) and student achievement. This relationship will be examined below.

Methods

The basic model will be estimated following the literature of education production functions that goes back to The Coleman Report (Coleman (1966)), the first known study to relate school inputs to student achievement. Todd and Wolpin (2003) lay out the following preferred cognitive achievement model that conceives knowledge acquisition as a production process in which the students' genetic endowment of ability is combined with past and current family and school inputs:

$$T_{ija} = T_a\left[F_{ij}(a), S_{ij}(a), \mu_{ij0}, \varepsilon_{ija}\right] \quad (1)$$

T_{ija} is the cognitive achievement of student i in household j at age a; $F_{ij}(a)$ is a vector of family inputs, which reflect choices made by parents; $S_{ij}(a)$ is a vector of school inputs, which reflect choices made by principals and teachers; μ_{ij0} is the students' at-birth ability; and ε_{ija} is the measurement error in test scores. Due to data limitations in PISA 2012 which does not include μ_{ij0}, we have to use the 'contemporaneous' specification for students age 15 in 2012:

$$T_{ij15} = T_{15}\left(F_{ij15}, S_{ij15}\right) + \varepsilon'_{ij15} \quad (2)$$

ε'_{ij15} is now an additive error that includes all omitted factors: family and school inputs up to age 14, the students' at-birth ability, and measurement error. Although the limitations of cross-sectional specifications are well known[22], this paper exploits the rich cognitive skill data in PISA 2012 not only on family and school inputs but also on institutional features of the educational system (I) and re-write (2) as an Ordinary Least Squares (OLS) model as follows:

$$T_{isc15} = \beta_0 + \beta_1 F_{isc15} + \beta_2 S_{sc15} + \beta_3 I_{c15} + \beta_4 P_{c15} + \varepsilon'_{isc15} \quad (3)$$

[22]Per Todd and Wolpin (2003), these specifications assume that (a) only contemporaneous family and school inputs matter to the production of cognitive skills or that inputs are time-invariant (and current inputs capture past inputs); and current family and school inputs are unrelated to the unobserved at-birth student ability.

T_{isc15} is now the cognitive achievement of student i in school s in country c at age 15; F_{isc15} is a student-level vector of student/family inputs; S_{sc15} is a vector of school location and resources; $I_{c15}$is a country-level vector of institutional features relevant to the educational system; P_{c15} is a country-level variable that measures the extent of private school competition or share of privately-managed schools; and ε'_{ijc15} is a zero-mean error term adjusted to allow for clustering at the country level (West and Woessmann, 2010).

A typical problem with OLS estimates is that the main coefficient of interest ($\beta_4$in this case) will be biased if the main policy variable and the outcome are simultaneously determining each other. That is, larger shares of private schools may cause student achievement to go up but it is also possible that this higher student achievement may be causing policymakers and parents to increase the share of private schools. If this is true, privatization is endogenous to student achievement and $\beta_4$will not only be estimated inconsistently but it will also likely overestimate the effect of privatization on student achievement. In the absence of experiments where students are randomly assigned into private schools, researchers (see Hoxby (1996), Dee (1995)) have used the school-district-level share of Catholics as an instrumental variable that is positively correlated with private school attendance in the United States and unrelated to student achievement. This historical correlation is documented going back to at least the late 18th century (Ramirez and Boli, 1987) when the Catholic Church used its influence to prevent and slow down secular state schools from entering the education system in response to the ensuing challenges of a rapidly growing populace and the separation of state and Church.

This paper's empirical strategy follows West and Woessmann (2010) who used the (a) weighted least squares and (b) and two-stage[23] weighted least squares frameworks for the cross-country estimation

[23] With the country-level share of Catholics in 1900 (and the share in 2010 as a control) as an instrument for the country-level share of privately-managed schools. In the first stage, the country-level share of Catholics is used as an independent variable that determines the country-level share of privately-managed schools unrelated to student achievement after controlling for a number of factors. The exogenous variation of country-level share of privately-managed schools is then used in the second stage to determine its causal effect on student achievement.

of the effect of private competition on student achievement with clustering at the country level[24].

Limitations

Estimating parameters at the country level deals with individual student selection bias but it introduces two main problems. First, it reduces the degrees of freedom which is not a problem in this study given the large sample size. Second, the unobserved heterogeneity at the country level may introduce other types of omitted variable bias such as cultural factors that make societies more likely to perform better educationally and are also correlated with other covariates in the student achievement model. This problem is solved by using an instrument for the main variable of interest (country share of privately-managed schools) but causal interpretations remain problematic for other variables that may be of interest.

This study relies on one cross-section of data for each country. Cross sections are appropriate in experimental designs where the assignment of the treatment is made randomly which ensures that the differences in outcomes (e.g. student achievement) between the treatment and control groups are due to the treatment (e.g. private competition). Although this issue can be circumvented with quasi-experimental methods such as instrumental variables (as in this study), further research using other methods such as regression discontinuity and the use of longitudinal data are within reach and would give more support to findings of international education production functions.

Using standardized test scores as a proxy for student learning and achievement also poses certain problems. These tests are usually not adapted to accommodate students with mental and physical disabilities which may introduce bias especially because the prevalence of these students differs by region/country, and ensuring compliance with exclusion rules is technically and politically difficult[25].

[24]School-level observations are weighted proportional to the population they represent in their country. All countries are given the same weight (as opposed to assigning weights based on population size) in order to keep a handful of large countries that comprise almost half of the population in the overall sample from contributing disproportionately to the estimates.

[25] The OECD stated that a "handful of countries exceeded the 5% (of the relevant population) exclusion limit by a small margin".

There is also criticism that these tests do not capture learning in other important non-cognitive skills like self-control, motivation, and self-discipline. This point is well taken and there are research efforts (Heckman and Rubinstein (2001); Cunha et al (2006)) that support their importance on schooling and returns to schooling. However, as seen in the literature section, cognitive skill standardized test scores have been shown to predict long-term economic outcomes and they are currently the only means to study education from an international perspective[26].

Finally, in terms of data limitations: a number of variables were missing observations (see Table 6) in the school and student questionnaires, a common problem with survey data. Except for instruction time in math which was missing 39.83% of observations, missingness was not worryingly high for any particular variable: 6 variables were missing 0% of observations, 30 between 1-5%, and 16 between 6-16% but only 60% of observations in the analytical sample (35 countries) had no missing value in any of the variables. In order to avoid this large loss of information, variables were imputed using the fully conditional specification method described in Appendix B.

Results

Table 1 shows the results of the basic models using OLS which mirror the specifications used by West and Woessmann (2010) and are almost the same as those of Woessmann et al. (2009)[27]. The main result is that the private school share coefficient on student achievement is not statistically significant (10% level) in any of the six models which stands in contrast to the positive association found by Woessmann et al. (2009) and the causal effect found by West and Woessmann (2010) using PISA 2003.

Models 1 through 3 include the same group of OECD countries used by West and Woessmann (2010) except that Germany and Hungary drop out of all models due to missing all observations in the shares of certified teachers and teachers with a tertiary degree respectively. Also, France did not fill out

[26] Other international tests include TIMSS and PIRLS.
[27] The authors do not use Catholic population share in 2000 and communist background as controls but include two school autonomy measures.

the school questionnaire in PISA 2003 but it did in PISA 2012 so it makes it into models 1 and 2. Finally, Australia was excluded in model 3 in their paper (due to missing the government funding variable completely) but it is included here. Models 3-6 include predominantly Christian countries for which the share of Catholics (used as a control in the basic model and as an instrument in the IV models) is relevant[28]; this makes Japan, Korea and Turkey drop out. All in all, the list of countries remains fairly similar in this paper with 28, 28, 26, 25, 25, and 23 OECD countries in models 1-6 versus 29, 29, 27, 26, 26, and 24 in their paper respectively.

The two papers are also similar in terms of controls. This paper uses the same vectors of (a) student characteristics, (b) family background, (c) school location and resources, and (d) country-level measures. The R-squares are around 0.37 in both papers.

On the other hand, three possible explanations for the differing results come to mind and might be operating in isolation or simultaneously.

First, the key policy variable, the share of privately-managed schools at the country-level, shows less dispersion in 2012 (standard deviation of 0.19) compared to 2003 (standard deviation of 0.22). This lesser variability may make it more difficult to obtain precise estimates of the association/effect of private shares and/on student achievement.

Second, the proportions of missing data by variable changed from 2003 to 2012 and the kind or direction of the measurement error and, thus, imputation bias in the coefficient estimates is difficult to know. The most notable differences in reduced missingness in 2012 are seen in private school shares (2.27% versus 5.60% in 2003), government funding shares (3.56% versus 8.80%), school starting age (5.51% versus 11.70%), and teacher tertiary degree (13.13% versus 34.00%). In turn, the most pronounced differences in increased missingness are instruction time in math (39.83% versus 7.90%), parents' working status (8.02% versus 2.00%), and parents' occupation (15.96% versus 4.20%).

[28] Countries that have higher shares of Catholics in the population tend to have larger shares of privately-managed schools. For a thorough description of this country level trait, see West and Woessmann (2010).

Table 1: Descriptive statistics and OLS results

	Mean	OECD countries			Predominantly Christian ^^		
	Std. dev.	(1)	(2)	(3)	(4)	(5)	(6)
Math score	496.28						
	93.51						
Share of schools: Privately-managed	0.20	28.14	24.28	24.76	22.10	12.56	6.90
	0.19	(19.05)	(18.84)	(18.92)	(21.01)	(21.95)	(22.02)
Catholic pop share in 2000	0.63		9.21	8.88		17.14	17.45
	0.22		(9.32)	(9.89)		(10.15)	(10.68)
Share of gov. funding in private schools	0.41			-7.89			4.45
	0.37			(18.79)			(20.07)
Student characteristics		Y	Y	Y	Y	Y	Y
Family background		Y	Y	Y	Y	Y	Y
School location & resources		Y	Y	Y	Y	Y	Y
Country-level measures		Y	Y	Y	Y	Y	Y
Imputation dummies ^		Y	Y	Y	Y	Y	Y
Interaction term with imputed variable		Y	Y	Y	Y	Y	Y
Observations (students)		263,004	263,004	253,636	246,772	246,772	237,404
Clusters (countries)		28	28	26	25	25	23
R-squared		0.37	0.37	0.36	0.36	0.37	0.36

Descriptive statistics: international means and standard deviations for OECD countries (PISA 2012 sample).
Basic model: Least squares regression weighted by students' sampling probabilities. Robust standard errors in parentheses, adjusted for clustering at the country level. OECD countries include: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Greece, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, UK, and US. Austria and France drop out of model 3 due to missing data on the share of government funding in private schools.
^ An imputation variable (=1 if observation was imputed) and its interaction with the relevant variable/control were included if the latter was imputed.
^^ Models 4-6 include countries whose population in 1990 was more than 85% Christian; thus Japan, Korea and Turkey drop out. Again, model 6 excludes Austria and France due to the aforementioned reason.
Significance level: *** p<0.01, ** p<0.05, * p<0.1

Although this papers follows the imputation strategy used by the previous two papers where imputation dummies and interactions terms with their respective variables are included in all regressions[29], the missing at random (MAR) assumption[30] that was made in order to impute may be too strong an assumption to make given the large number and variety of variables with missing data in both rounds of PISA.

Third, and most policy-relevant hypothesis of all three is that the lack of association is related to a change in how school systems and their stakeholders (especially school administrators and parents) are responding to increased or decreased levels of private school competition a decade later. Also, there might simply be a convergence in how private and public schools are administered or in student achievement. Increased private school competition may drive public counterparts to improve student achievement in some countries (or even school districts) but no others. Alternatively, effects across countries might cancel each other out and yield too small an effect to be estimated with precision.

Robustness Checks

Tables 2 and 3 show that the results do not change when the number of countries is expanded to all OECD countries in PISA 2012 (31, 31 and 29 countries in models 1-3 respectively) or when the number of countries is that of the combined group of OECD and non-OECD countries (35, 35 and 33 countries in models 1-3 respectively). In addition to the OECD countries listed in Table 1, the five non-OECD countries include: Brazil, Latvia, Thailand, Tunisia, and Uruguay. Of 27 non-OECD countries that participated in PISA 2012, these were the only ones for which no key control was missing.

Also, the results in tables 1-3 remain qualitatively similar regardless of (a) whether countries carry equal weights or weights relative to their population size, (b) the inclusion of imputation dummies and their interactions with their respective controls, and (c) the use of reading instead of math scores.

[29] In order to prevent possible bias from imputation errors, this approach allows observations with missing and imputed data to have their own intercepts and slopes (Woessmann et al. 2009).
[30] See appendix for a more detailed description of the imputation strategy.

Table 2: OLS results - All OECD countries

	(1)	(2)	(3)
Share of schools: Privately-managed	18.93	16.29	16.59
	(17.02)	(16.98)	(16.26)
Catholic pop share in 2000		6.52	6.04
		(8.71)	(9.10)
Share of government funding			-6.14
			(16.87)
Observations (students)	280,826	280,826	271,458
Clusters (countries)	31	31	29
R-squared	0.37	0.37	0.37

Robust standard errors in parentheses, adjusted for clustering at the country level;
Significance level: *** p<0.01, ** p<0.05, * p<0.1

Table 3: OLS results - OECD and non-OECD countries

	(1)	(2)	(3)
Share of schools: Privately-managed	21.80	17.08	17.21
	(15.83)	(16.38)	(16.02)
Catholic pop share in 2000		10.04	9.99
		(8.04)	(8.46)
Share of government funding			-2.83
			(13.32)
Observations (students)	301,460	301,460	292,092
Clusters (countries)	35	35	33
R-squared	0.40	0.41	0.40

Robust standard errors in parentheses, adjusted for clustering at the country level.
Significance level: *** p<0.01, ** p<0.05, * p<0.1

As expected given the OLS findings, the instrumental variable results also yield a private school share coefficient that lacks statistical significance (at 10% or less). The instrument, Catholic population share, also seems to be weak (F-statistic is lower than the rule of thumb[31] of 10 in models 1-3 in Table 4) and does not satisfy the relevance criterion. This is in contrast to West and Woessmann (2010) who used the same instrument (F-statistic was in the 6.18-14.31 range) and found that a 10 percent point increase in private shares led to a math score hike of 9 score points (or 9.1% of a standard deviation in math scores with a 95% confidence interval bounding the effect between 3.9 and 14.2% of a standard deviation) using PISA 2003.

[31] Stock et al., 2002.

Table 4: Instrumental variable two-stage least squares results

	(1)	(2)	(3)
2nd Stage:			
Dependent: math scores			
Share of schools: Privately-managed	19.72	58.79	59.18
	(136.95)	(53.93)	(63.85)
Catholic pop share in 2000		4.85	3.18
		(12.53)	(15.38)
Share of government funding			-16.55
			(33.22)
1st Stage:			
Dependent: Share of schools: Privately-managed			
Share of Catholics ^	-0.07	-0.26	-0.24
	(0.08)	(0.12)	(0.10)
Catholic pop share in 2000		0.32	0.32
		(0.13)	(0.12)
Share of government funding			0.29
			(0.11)
Observations (students)	263,004	263,004	253,636
Clusters (countries)	28	28	26
R-squared (2nd stage)	0.37	0.36	0.36
R-squared (1st stage)	0.30	0.44	0.53
Instrument's F-Statistic	0.88	4.83	5.38

^ First stage instrument: Share of Catholics at the country level interacted with a binary variable (1,0) that indicates whether the country had a Catholic state in 1900. Instrumented: Share of schools: Privately-managed. Robust standard errors in parentheses, adjusted for clustering at the country level. Significance level: *** p<0.01, ** p<0.05, * p<0.1

Discussion

The differing results found here are difficult to interpret given that it is hard to know whether this paper failed to detect an effect that existed in 2012 (type II error) or whether Woessmann et al. (2009) and West & Woessmann (2010) detected an effect that wasn't present in 2003 (type I error). Although the results here do not refute the earlier results, they at least warrant interpreting them with caution and suggest more evidence is needed, especially as decisions about privately-managed school expansion (or contraction) are currently being debated both in developing and developed countries.

Future research could look into whether there is an effect or association that is not being captured by this specification. Such cross-country estimation would benefit from increasing the number of clusters and degrees of freedom so as to improve the estimates' precision. In practice, this would require

obtaining data for non-OECD countries that were part of PISA 2012 but that had to be dropped from the models due to their missing key control variables. It may also prove helpful to try a more flexible specification that allows for random effects such as clustering at the school or state/regional levels. For instance, mixed effects or hierarchical models (West et al., 2015) allow independent variables to have their own slopes and intercepts in order to account for the likely higher intraclass correlations of observations within clusters lower than the country level (e.g. schools or regions/states).

Appendix

Table 5: Full descriptive statistics and OLS results

	Mean	OECD countries			Predominantly Christian ^^		
	Std. dev.	(1)	(2)	(3)	(4)	(5)	(6)
Math score	496.28						
	93.51						
Share of schools: Privately-managed	0.20	28.14	24.28	24.76	22.10	12.56	6.90
	0.19	(19.05)	(18.84)	(18.92)	(21.01)	(21.95)	(22.02)
Catholic pop share in 2000	0.63		9.21	8.88		17.14	17.45
	0.22		(9.32)	(9.89)		(10.15)	(10.68)
Share of gov. funding in private schools	0.41			-7.89			4.45
	0.37			(18.79)			(20.07)
Student Characteristics							
Male	0.50	17.26***	17.29***	16.68***	17.21***	17.19***	16.56***
		(1.37)	(1.36)	(1.37)	(1.52)	(1.51)	(1.52)
Age of student	15.78	10.64***	9.70***	10.80***	11.90***	10.44***	11.52***
	0.29	(3.50)	(3.28)	(3.34)	(3.84)	(3.47)	(3.56)
Preschool: attended more than 1 year	0.69	9.32***	8.88***	9.12***	9.58***	8.89***	8.54***
		(2.40)	(2.30)	(2.24)	(2.60)	(2.41)	(2.26)
Age started school	6.20	-1.37	-0.54	-0.44	-3.18*	-2.31	-2.50
	0.92	(1.71)	(1.73)	(1.77)	(1.70)	(1.72)	(1.72)
Retained in grade - primary school	0.08	-44.97***	-45.85***	-43.11***	-41.65***	-42.67***	-39.88***
		(5.61)	(5.80)	(6.10)	(4.88)	(4.92)	(5.40)
Retained in grade - secondary school	0.08	-25.26***	-26.67***	-25.57***	-31.91***	-35.27***	-33.98***
		(5.74)	(6.06)	(5.97)	(4.09)	(4.67)	(4.94)
Grade 7	0.01	-57.21***	-58.54***	-59.56***	-52.92***	-54.18***	-56.08***
		(5.72)	(5.38)	(6.14)	(5.91)	(5.31)	(6.35)
Grade 8	0.05	-37.17***	-37.48***	-37.51***	-32.08***	-31.37***	-31.55***
		(6.66)	(6.59)	(7.18)	(7.29)	(7.12)	(7.51)
Grade_9	0.34	-16.39***	-16.75***	-15.97**	-11.92*	-11.57*	-10.91
		(5.87)	(5.63)	(6.47)	(6.48)	(6.07)	(6.69)
Grade 10	0.52						
Grade 11	0.07	-20.23**	-18.17*	-19.80**	-16.15*	-10.84	-10.30

Table 5: Full descriptive statistics and OLS results - continued

	Mean	OECD countries			Predominantly Christian ^^		
	Std. dev.	(1)	(2)	(3)	(4)	(5)	(6)
		(8.87)	(9.06)	(9.14)	(8.65)	(8.52)	(9.82)
Grade 12	0.00	-3.29	-0.58	-3.80	1.20	7.60	7.14
		(13.86)	(14.05)	(13.67)	(14.07)	(13.99)	(15.39)
Immigration status: native	0.91						
Immigration status: 2nd gen	0.05	-2.56	-2.25	-0.37	-1.62	-0.67	1.61
		(3.41)	(3.53)	(3.39)	(3.47)	(3.65)	(3.67)
Immigration status: 1st gen (non-native)	0.04	0.07	0.31	1.29	1.70	2.68	3.90
		(3.67)	(3.70)	(3.60)	(3.75)	(3.83)	(3.89)
Lang spoken at home: other than test language	0.11	-8.78**	-10.21***	-9.79**	-8.65**	-11.44***	-11.04***
		(3.58)	(3.41)	(3.67)	(3.52)	(3.28)	(3.47)
Family Background							
Living with no parents	0.03						
Living with one parent	0.14	41.36***	41.12***	42.59***	41.63***	41.57***	42.64***
		(3.69)	(3.66)	(3.91)	(4.43)	(4.29)	(4.58)
Living with both parents	0.83	40.89***	40.62***	42.09***	41.12***	40.81***	42.01***
		(3.88)	(3.82)	(4.00)	(4.77)	(4.62)	(4.93)
Parents' work status: other	0.07						
Parents' work status: one half time	0.05	-4.16*	-4.54**	-5.14**	-2.21	-2.72	-3.36
		(2.09)	(2.09)	(2.04)	(2.02)	(2.03)	(2.02)
Parents' work status: one full time	0.30	6.35***	5.97***	6.03***	7.79***	7.10***	7.20***
		(2.07)	(1.97)	(1.95)	(2.02)	(1.77)	(1.81)
Parents' work status: one full, one half	0.16	13.98***	13.62***	13.43***	16.53***	16.05***	16.09***
		(3.04)	(2.95)	(2.86)	(3.05)	(2.80)	(2.99)
Parents' work status: both full time	0.41	8.20***	7.95***	8.04***	11.00***	10.77***	10.42***
		(2.75)	(2.59)	(2.53)	(2.56)	(2.18)	(2.26)
Parents' occupation: blue collar, low skill	0.06						
Parents' occupation: blue collar, high skill	0.17	7.89***	7.83***	8.86***	8.38**	8.20**	9.18**
		(2.82)	(2.69)	(2.74)	(3.42)	(3.16)	(3.31)

Table 5: Full descriptive statistics and OLS results - continued

	Mean	OECD countries			Predominantly Christian ^^		
	Std. dev.	(1)	(2)	(3)	(4)	(5)	(6)
Parents' occupation: white collar, low skill	0.26	9.22***	9.50***	10.88***	10.00***	10.39***	11.78***
		(2.88)	(2.86)	(2.84)	(3.30)	(3.16)	(3.27)
Parents' occupation: white collar, high skill	0.51	20.90***	21.30***	23.58***	22.75***	23.28***	26.17***
		(3.77)	(3.81)	(3.34)	(4.05)	(3.95)	(3.56)
Books at home: 1-10	0.18						
Books at home: 11-25	0.19	14.72***	14.75***	14.27***	14.07***	14.03***	13.36***
		(1.73)	(1.68)	(1.76)	(1.92)	(1.82)	(1.94)
Books at home: 26-100	0.29	36.07***	36.20***	35.70***	35.11***	35.13***	34.34***
		(2.06)	(2.02)	(2.16)	(2.25)	(2.13)	(2.35)
Books at home: 101-200	0.15	51.35***	51.42***	50.92***	51.27***	51.02***	50.25***
		(2.67)	(2.67)	(2.82)	(2.84)	(2.78)	(3.08)
Books at home: 201-500	0.11	71.56***	71.63***	70.88***	71.44***	71.02***	70.00***
		(3.28)	(3.31)	(3.47)	(3.48)	(3.40)	(3.70)
Books at home: > 500	0.06	74.21***	74.01***	73.40***	72.94***	71.95***	71.02***
		(3.96)	(4.03)	(4.22)	(3.87)	(3.82)	(4.12)
Index of economic, social and cultural status	-0.24	8.69***	8.99***	8.65***	8.30***	9.25***	8.42***
		(1.85)	(1.73)	(1.63)	(2.00)	(1.79)	(1.70)
School Location & Resources							
School location: village	0.10						
School location: town	0.53	8.19***	7.56***	8.69***	8.96***	7.97***	9.09***
		(2.62)	(2.31)	(2.25)	(2.73)	(2.32)	(2.31)
School location: city	0.23	10.91***	11.09***	11.75***	10.58***	10.62***	11.52***
		(2.33)	(2.31)	(2.20)	(2.40)	(2.29)	(2.41)
School location: large city	0.12	12.25***	12.36***	12.35***	9.65**	8.99**	10.28***
		(3.63)	(3.55)	(3.27)	(3.90)	(3.45)	(3.57)
Class size	28.43	0.50*	0.48*	0.35	0.33	0.18	0.11
	9.25	(0.25)	(0.25)	(0.27)	(0.23)	(0.23)	(0.23)
Shortage: school instructional materials - No	0.43	8.74***	8.80***	9.14***	9.47***	9.59***	10.22***
		(2.16)	(2.15)	(1.98)	(2.20)	(2.10)	(2.09)
Shortage: school instructional materials - A lot	0.04	-13.04*	-13.48**	-12.60**	-12.24	-12.87*	-11.81*
		(6.39)	(5.94)	(5.82)	(7.63)	(6.68)	(6.35)

Table 5: Full descriptive statistics and OLS results - continued

	Mean	OECD countries			Predominantly Christian ^^		
	Std. dev.	(1)	(2)	(3)	(4)	(5)	(6)
Instruction time: math (mins/week)	219.43	0.05**	0.05**	0.05*	0.03	0.02	0.03
	95.32	(0.02)	(0.02)	(0.03)	(0.02)	(0.02)	(0.02)
School share: certified teachers	0.85	17.47***	19.26***	19.19***	14.70**	17.02***	15.96***
	0.29	(5.16)	(4.86)	(4.50)	(5.63)	(5.22)	(4.91)
School share: teachers with tertiary degree	0.84	-4.15	-3.74	-8.22	-4.95	-4.72	-9.36**
	0.29	(5.54)	(5.67)	(5.01)	(6.08)	(6.17)	(4.27)
Country-level Measures							
GDP per capita ($1,000)	26.27	-1.58*	-1.56*	-1.38	-1.21	-1.01	-0.76
	14.33	(0.84)	(0.81)	(0.91)	(1.06)	(1.00)	(1.17)
Educ. expenditure per stud ($1,000)	66.73	0.76**	0.76**	0.67*	0.65	0.58	0.47
	38.87	(0.35)	(0.34)	(0.38)	(0.42)	(0.39)	(0.48)
External exam; end of high school	0.59	18.53***	19.71***	22.55***	12.91*	13.21*	13.73*
		(6.41)	(6.47)	(6.06)	(7.17)	(6.81)	(6.70)
Communist country in 1970	0.10	24.34***	18.03**	16.25	29.69***	20.38**	21.12*
		(7.12)	(8.54)	(10.16)	(7.82)	(8.56)	(10.85)
Imputation dummies		Y	Y	Y	Y	Y	Y
Interaction of imputation dummies and variables ^		Y	Y	Y	Y	Y	Y
Observations (students)		263,004	263,004	253,636	246,772	246,772	237,404
Clusters (countries)		28	28	26	25	25	23
R-squared		0.37	0.37	0.36	0.36	0.37	0.36

Descriptive statistics: international means and standard deviations (latter only for continuous variables) for OECD countries (PISA 2012 sample).
Basic model: Least squares regression weighted by students' sampling probabilities. Robust standard errors in parentheses, adjusted for clustering at the country level.
^ An imputation variable (=1 if observation was imputed) and its interaction with the relevant variable/control were included if the latter was imputed.
OECD countries include: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Greece, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, UK, and US. Austria and France drop out of model 3 due to missing data on the share of government funding in private schools.
^^ Models 4-6 include countries whose population in 1990 was more than 85% Christian; thus Japan, Korea and Turkey drop out of models 4 and 5. Again, model 6 excludes Austria and France due to the aforementioned reason. Significance level: *** p<0.01, ** p<0.05, * p<0.1

Imputation Strategy

The imputation strategy followed Rubin (1987) and the conditional mean imputation. It was implemented assuming the student or school level observations were missing values at random (MAR) and using multivariate imputation by chained equations. This iterative multivariable regression technique allows for simultaneous imputation of different variable types (continuous, binary, and categorical in this paper) using the appropriate regression type (least squares, logit, and multinomial respectively). Variables are sorted and the variables with the smallest proportion of missing data are imputed first. Once the first variable with missing data is imputed with all of the other variables with the non-missing observations, then the second variable is imputed using the first imputed variable. This process is repeated sequentially and produces a new and complete dataset which also contains dummies for each imputed variable. Imputation dummies take the value of 1 if the observation was imputed and the value of 0 otherwise.

Given that the functional form of the (chained) equations lacks theoretical basis (van Buuren et al. 1999) and in order to guard against imputation bias, these imputation dummies and their interaction with the respective variable are included in all models shown in this paper. It is important to note that the specification shown in the empirical strategy section changes accordingly.

Table 6: Percent missing and imputed by variable; descriptive statistics

	% Missing	Mean	Std. dev.	Min	Max
Math score	0.00	496.28	93.51	78.84	848.35
Share of schools: Privately-managed	2.27	0.20	0.19	0.01	0.68
Catholic pop share in 2000	0.00	0.63	0.22	0.24	0.99
Share of gov. funding in private schools	3.56	0.41	0.37	0.00	0.92
Male	0.00	0.51		0.00	1.00
Age of student	0.03	15.77	0.29	15.17	16.33
Age started school	5.51	6.04	0.88	4.00	16.00
Preschool: attended more than 1 year	1.53	0.74		0.00	1.00

Table 6: Percent missing and imputed by variable; descriptive statistics - continued

	% Missing	Mean	Std. dev.	Min	Max
Retained in grade - primary school	8.97	0.08		0.00	1.00
Retained in grade - secondary school	11.95	0.07		0.00	1.00
Grade 7	0.24	0.00		0.00	1.00
Grade 8	0.24	0.04		0.00	1.00
Grade 9	0.24	0.34		0.00	1.00
Grade 10	0.24	0.52		0.00	1.00
Grade 11	0.24	0.09		0.00	1.00
Grade 12	0.24	0.00		0.00	1.00
Immigration status: native	2.53	0.88		0.00	1.00
Immigration status: 2nd gen	2.53	0.06		0.00	1.00
Immigration status: 1st gen (non-native)	2.53	0.05		0.00	1.00
Lang spoken at home: other than test language	4.62	0.11		0.00	1.00
Living with no parents	7.74	0.02		0.00	1.00
Living with one parent	7.74	0.13		0.00	1.00
Living with both parents	7.74	0.85		0.00	1.00
Parents' work status: both full time	8.02	0.44		0.00	1.00
Parents' work status: one full, one half	8.02	0.19		0.00	1.00
Parents' work status: one full time	8.02	0.27		0.00	1.00
Parents' work status: one half time	8.02	0.04		0.00	1.00
Parents' work status: other	8.02	0.05		0.00	1.00
Parents' occupation: blue collar, low skill	15.96	0.04		0.00	1.00
Parents' occupation: blue collar, high skill	15.96	0.14		0.00	1.00
Parents' occupation: white collar, low skill	15.96	0.26		0.00	1.00
Parents' occupation: white collar, high skill	15.96	0.56		0.00	1.00
Books at home: 1-10	2.16	0.15		0.00	1.00
Books at home: 11-25	2.16	0.16		0.00	1.00
Books at home: 26-100	2.16	0.30		0.00	1.00
Books at home: 101-200	2.16	0.18		0.00	1.00
Books at home: 201-500	2.16	0.14		0.00	1.00
Books at home: > 500	2.16	0.08		0.00	1.00
Index of economic, social and cultural status	1.44	0.01	1.01	-5.32	3.27
School location: village	2.61	0.09		0.00	1.00
School location: town	2.61	0.56		0.00	1.00
School location: city	2.61	0.22		0.00	1.00
School location: large city	2.61	0.11		0.00	1.00
Class size	4.31	26.37	8.37	13.00	53.00
Shortage: school instructional materials - No	3.62	0.47		0.00	1.00

Table 6: Percent missing and imputed by variable; descriptive statistics - continued

	% Missing	Mean	Std. dev.	Min	Max
Shortage: school instructional materials - A lot	3.62	0.03		0.00	1.00
Instruction time: math (mins/week)	39.83	218.78	89.60	0.00	3000.00
School share: certified teachers	15.95	0.89	0.24	0.00	1.00
School share: teachers with tertiary degree	13.13	0.85	0.28	0.00	1.00
GDP per capita ($1,000)	0.00	32.65	12.37	12.65	78.20
Educ. expenditure per stud ($1,000)	1.95	87.41	33.40	19.82	197.60
External exam; end of high school	0.00	0.56		0.00	1.00
Communist country in 1970	0.00	0.04		0.00	1.00

Sample: 28 OECD countries included in main models (1 and 2). Number of observations in sample including imputations: 263,004 students. Mean: International mean (weighted by sampling probabilities). Standard deviation: International standard deviation (only for continuous variables). Imputations: Percentage of students with missing and thus imputed data.

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