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Cross-national Differences in Educational Achievement Inequality

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Abstract

School systems are called not only to instruct and socialize students but also to differentiate among them. Although much research has investigated inequalities in educational outcomes associated with students' family background and other ascriptive traits, little research has examined cross-national differences in the total amount of differentiation that school systems produce, the total achievement inequality. This article evaluates whether two dimensions of educational systems—variations in opportunities to learn and intensity of schooling—are associated with achievement inequality independent of family background. It draws data from the Programme for International Student Assessment for more than 50 school systems and models the variance in achievement. Findings suggest that decreasing the variability in opportunities to learn—in the form of greater homogeneity in teacher quality and the absence of tracking—within the school system might reduce achievement inequality. More intense schooling is also related to lower achievement inequality to the extent that this intensity is homogeneously distributed within the school system, particularly in the form of a more highly qualified teacher workforce.

Keywords

comparative education, educational achievement, achievement inequality, PISA, variance regression

Under a meritocratic ideal, scholastic achievement is a function of talent, ambition, and effort in school. Schools are called to provide equal opportunities to learn and identify differences among their students so that students are properly allocated into the labor market; schools are gatekeepers in a sorting process. Following this framework, sociologists who study educational inequality have been concerned with whether scholastic achievement and attainment are independent of ascriptive background factors (e.g., race/ethnicity, socioeconomic background) and hence whether schools reproduce or reduce social inequality. Yet inequality due to family background or other ascriptive traits represents only a portion of the total inequality in educational outcomes. The overall variation in achievement, or total achievement inequality, provides an alternative metric for assessing equality within an educational system. In this article, I examine country-to-country differences in total achievement inequality, and more specifically, I assess the extent to which two important conceptual dimensions of schooling, opportunities to learn and the intensity of schooling, help account for cross-national variation in achievement inequality.

An educational system is expected, among other things, to differentiate and sort its students by identifying or creating inequalities among them. Because educational experience and educational achievement in early, primary, and

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secondary schooling are important determinants of higher education, labor market, and adult life outcomes (Featherman, Hauser, and Sewell 1976; Kerckhoff 1993; Meyers et al. 2004; Pallas 2000), the total achievement inequality in secondary school translates into inequalities in access to higher education. These may, subsequently, become disparities in income, wealth, and occupational status. Also, total achievement inequality may have other, more immediate outcomes; at the national level, it is an important predictor of school violence (Baker and LeTendre 2005).

Although inequalities in opportunity, access, and quality of education have been historically reduced (Baker and LeTendre 2005), leading to an increased equality of human capital production both within and between countries (Castello and Domenech 2002), inequality in achievement is inherent to all educational systems and is unlikely to be eliminated. The relevant question regarding inequality in educational outcomes is, then, not about the existence of inequality but the amount of inequality that is produced by school systems.

This study examines total inequality in student learning in an international sample of schools and students. It explores the characteristics of educational systems that exacerbate or reduce inequality in achievement within nations. In addition to the influence of family background on achievement, I hypothesize that the remaining inequality is related to two primary dimensions of a nation's school system: variation in opportunities to learn and the overall intensity of schooling. In particular, does variation in opportunities to learn and in the overall intensity of schooling correspond to the total amount of inequality in a school system independent of the distribution and effects of family background?

Using achievement data from the Organization for Economic Co-Operation and Development's (OECD's) Programme for International Student Assessment (PISA) for more than 50 countries, I model the variance in achievement as a measure of the dispersion in student learning within countries as a function of indicators of family background, opportunities to learn, and intensity of schooling. I find that both variations in opportunities to learn, particularly in the form of equality in the distribution of teachers across schools and the absence of tracking, and greater intensity of schooling, in the form of better teachers across the board, are related to a reduction in total achievement inequality.

To identify the contribution of schools to educational inequality, it is critical to first account for the substantial amount of inequality produced by family and home environment.

Family Background and Home Environment

At the individual level, socioeconomic background is the most robust and consistent predictor of student achievement both in the United States and abroad (Baker, Goesling, and LeTendre 2002; Buchmann and Hannum 2001; Heyneman and Loxley 1983). As a result, students from high-income families score higher on standardized tests and are more likely to go to college than students from lower income families. Socioeconomic background is also important in explaining achievement inequality among schools. In the United States and abroad, for example, student body composition is one of the strongest predictors of school-to-school differences in achievement (Coleman 1990; OECD 2007a; Scheerens and Bosker 1997).

Given the robust relationship between socioeconomic background and achievement, we should expect that two school systems with identical institutional characteristics at the school and country level will have different amounts of inequality if one school system has a more uneven distribution of student background than the other. There is considerable variation in the amount of socioeconomic diversity of student populations across countries. Spain, Greece, and the United States, for example, have a more diverse student population than Japan, Norway, and Australia (Arnett 2007).

It is important to consider that certain social institutions may constrain socioeconomic diversity through the reduction of inequalities in living conditions, thereby reducing inequalities in opportunity. These social institutions have been at the center of the reduction in inequality of opportunity in the Netherlands, Sweden, and other countries (Breen and Jonsson 2005; Shavit and Blossfeld 1993) and include social welfare programs and welfare states. For example, social insurance and risk management institutions are crucial for redistributing outcomes (Korpi and Palme 1998), reducing poverty (Brady 2005), and reducing the variability in family background, all of which affects students' opportunities to learn (Valenzuela, Tironi Barrios, and Scully 2006).

Although informative, studies of educational inequality that focus on the relationship between family background and achievement generally miss the total amount of inequality that a school system produces. It is possible—at least theoretically—that a school system that reduces the relationship between academic achievement and socioeconomic background could still produce high levels of inequality in educational outcomes. Such is true of Taiwan, whose tracking system tends to reduce the effect of socioeconomic status on achievement while still producing considerable levels of dispersion in achievement among differently tracked students (Broaded 1997).

For this reason, studies of inequality in student learning ought to go beyond examining a few specific ascriptive factors to consider the school and instructional practices that are associated with total achievement inequality. Only a limited number of studies analyze the total inequality in achievement, and these generally focus on a narrow set of characteristics of school systems, most notably differentiation and standardization (see Van de Werfhorst and Mijs 2010 for a comparative review). The distribution of opportunities to learn in schooling systems and the intensity of schooling provide a broader conceptual framework for understanding the amount of achievement inequality that school systems produce.

Variability/Standardization of Opportunities to Learn

Sørensen and Hallinan (1977) introduce a three-part model of student learning, wherein achievement is a function of ability, effort, and opportunities to learn. According to this model, differences in opportunities to learn induce variation in student achievement growth even among students who exhibit similar effort and ability. Elements of opportunities to learn include teacher quality, school resource quality, curriculum organization, and class size. Greater standardization in opportunities to learn in the school system should provide more homogeneous school experiences for students and reduce the total inequality in achievement within a school system.

A more equal distribution of schools' human and material resources reduces variability in opportunities to learn, yet some elements of opportunities to learn have been shown to be more important than others in predicting achievement and thus in generating inequality. Student learning is sensitive to teacher attributes such as teacher training and experience (Greenwald, Hedges, and Laine 1996; Konstantopoulos 2006; Nye, Konstantopoulos, and Hedges 2004; Rivkin, Hanushek, and Kain 2005), so homogeneity in teacher attributes across schools should reduce inequality. Differences in material resources available to students, by contrast, have had less success in explaining differences in student achievement (Buchmann and Hannum 2001; Gamoran, Secada, and Marrett 2000; Greenwald et al. 1996; Heyneman and Loxley 1983). This is particularly true in industrialized societies. In less developed countries, where some schools may lack basic material resources that are crucial for instruction (e.g., textbooks), school-to-school differences in resources may affect achievement growth (Baker et al. 2002; Fuller 1987). Smaller class sizes lead to a modest increase in student performance (Ma and Klinger 2000; Nye, Hedges, and Konstantopoulos 2002) by allowing a closer relationship between the teacher and both students and parents, increasing student engagement, reducing the amount of time dedicated to disciplining students, and enabling teachers to use new pedagogical practices that are possible or even work better in smaller classes (Ehrenberg et al. 2001). Because teacher attributes, and to a lesser extent school resources and class size, are related to student achievement, greater variability in these resources within a school system will be related to increased levels of total achievement inequality.

Data from PISA 2006 suggest that educational systems have differing amounts of school-to-school variation in teacher credentials, school resources, and class size. The interquartile range statistic, which measures the difference between the scores of cases falling at the top and bottom 25th percentile, provides a simple metric for describing the variation in measures of opportunities to learn within different countries. In Colombia and Mexico, for example, schools vary widely in terms of class size: The interquartile range in class size is 25 students. The comparable range for the Netherlands and Finland is only 5 students. In terms of teacher credentials, schools in Portugal, Switzerland, and Austria are heterogeneous (the interquartile range in the proportion of teachers with International Standard Classification of Education [ISCED] 5a diplomas in the school is greater than 0.75), whereas those in Australia, Japan, and Canada are homogeneous (the interquartile range is close to 0). Finally, PISA's index of school resources has an interquartile range greater than 1.5 (the index ranges −3.4 to 2.1 at the school level) in Qatar, Argentina, Kyrgyzstan, and Brazil, signaling heterogeneity in school resources, but an interquartile range of only 0.75 in Norway, Latvia, and Croatia, indicating greater homogeneity in how school resources are distributed.

The curricular organization of school systems can also produce variations in opportunities to learn and increased inequality in achievement if different students are exposed to different instructional content. This can occur in school systems that implement tracking and in school systems that do not have a standardized curriculum. In the context of increasing equality in quality of instruction, these differentiations are often remnants of nineteenth-century educational systems that explicitly incorporated inequalities within the school system (Baker and LeTendre 2005). Tracking can occur between schools in terms of school type (as in the German system), course of study (e.g., vocational schools in Japan), tracks or streams within comprehensive secondary schools (e.g., high schools in the United States), ability grouping within classrooms (e.g., reading instruction in elementary schools in the United States), and according to geographic location (LeTendre, Hofer, and Shimizu 2003). Countries that provide different curricula for different types of students generate larger amounts of inequality than those that adopt a comprehensive schooling system (Hanushek and Wößmann 2005). By contrast, a school system with a highly standardized curriculum should produce less total achievement inequality by ensuring greater equality in the content and coverage of material across schools and classrooms (Stevenson and Baker 1991).

Certain institutional arrangements may generate greater variability in opportunities to learn across schools, which is a nontrivial element of the total inequality in an educational system. A larger private sector and greater school autonomy will allow for greater variability in curriculum organization, resources, and teacher quality across schools. In this scenario, better resources and higher quality teachers will tend to be concentrated in schools that enjoy higher budgets, increasing the differences in achievement between students across sectors (Carbonaro and Covay 2010) and total achievement inequality. There is, however, the possibility that a larger private sector may foster equality by allowing schools to be more flexible. Control over hiring decisions, curricular offerings, and budget allocations may allow private-sector schools the flexibility to meet the particular needs of low-achieving students in their local context, potentially reducing dispersion in achievement (Bryk, Lee, and Holland 1993; Chubb and Moe 1990; Coleman and Hoffer 1987; Fuchs and Wößmann 2007).

School systems vary in the magnitude of the private sector and their allowance of school autonomy. For example, all schools in Hungary, Iceland, Latvia, the Netherlands, New Zealand, and Sweden have the freedom to set the starting salaries for their teachers, whereas a quarter or less of the schools in France, Germany, Italy, Luxembourg, and Portugal have this liberty (Fuchs and Wößmann 2007). Private schools are fairly common in Ireland and Belgium, for example, where more than 60 percent of the students attend privately managed schools, but are relatively rare in Austria, Brazil, and Mexico, where less than 15 percent of the students attend privately managed schools (Vandenberghe and Robin 2004).

In sum, independent of student ability and effort, variations in opportunities to learn should lead to variations in student learning and greater total achievement inequality. These features that vary within countries, however, fail to tell the entire story about achievement inequality. Two school systems with equal distributions of opportunities to learn will have different levels of total achievement inequality if their intensity of schooling differs.

Intensity of Schooling

Coleman's call for increased equality of opportunity is a call for intense schooling that is independent of a child's social environment (Coleman 1990), such that greater intensity reduces inequalities that exist prior to children's entrance into primary schools and which are reinforced by their out-of-school experiences. To the extent that this intensity is equally distributed, achievement inequality will be reduced. Features of intense schooling include the total amount of time dedicated to instruction, the overall quality of teachers, the overall class size of the schools, the overall resource quality, and public expenditure on education.

An earlier entrance into the school system, a lengthier school year, and a lengthier school day are all signs of increased intensity of schooling because students have greater exposure to structured and homogeneous learning environments (Arnett 2007; Entwisle, Alexander, and Olson 2000; Meyers et al. 2004). Because variability in student learning is lower when school is in session (Downey, von Hippel, and Broh 2004), systems with higher intensity in terms of length of exposure will reduce total achievement inequality. The overall teacher quality of the schooling system is another dimension of intensity of schooling that is likely to affect achievement inequality. Better qualified teachers are more able to adapt curricular material, subject knowledge, and pedagogical techniques to the needs of their students, thereby providing an enhanced schooling experience for all students and affecting student achievement (Gamoran 1993; Rowan, Correnti, and Miller 2002). The presence of better teachers is especially beneficial to students from disadvantaged backgrounds (Nye et al. 2004), reducing total achievement inequality. Smaller overall class sizes allow for a closer relationship between teachers and both students and parents, increase student engagement, and reduce the amount of time dedicated to disciplining students (Ehrenberg et al. 2001), also reducing total achievement inequality.

The overall level of school resource quality and public expenditure on education should also affect achievement inequality. Better resources in schools may reduce the likelihood that schools would lack crucial instructional resources. Resources, however, may not be spent in a targeted fashion to reduce educational inequality (Condron and Roscigno 2003) and may in fact be unequally distributed to the benefit of advantaged students (Moser and Rubenstein 2002).

These features of the intensity of schooling vary across countries. For example, the total yearly hours of instruction for students aged 12 to 14 is more than 1,000 hours in Italy, France, Chile, and Mexico, but less than 800 hours in Sweden, Slovenia, and Luxembourg (OECD 2009b). Teachers have high levels of formal education in Poland and Slovakia, where more than 90 percent have attained master's degrees. In contrast, less than 8 percent of teachers have obtained MAs in Brazil, Slovenia, Turkey, and Iceland (OECD 2009a). Per-pupil expenditures on education exceeded $10,000 in Austria, Luxembourg, Norway, Switzerland, and the United States yet were less than $3,000 in Chile, Brazil, Mexico, Slovakia, and Poland (OECD 2009b).

Cross-national research on achievement has practically ignored total achievement inequality as an outcome for educational systems. Except for studies of tracking and total inequality (see Hanushek and Wößmann 2005; Huang 2009; or Gamoran 2009; and Van de Werfhorst and Mijs 2010 for reviews), studies that take a cross-national approach to education have generally looked at the effectiveness of institutional and schooling practices as a source for generalizability of findings at a national level (Baker and LeTendre 2005; Ramirez 2006). This article contributes to research on educational inequality in two ways. First, by focusing on total achievement inequality, it expands the study of educational inequality by going beyond the few discrete ascriptive sources of inequality typically examined. Second, it broadens the sources of achievement inequality by taking into account factors related to opportunities to learn and the intensity of schooling that occur at the school and country levels.

DATA AND METHOD

Data for this study are drawn from OECD's PISA. In 2006, PISA surveyed more than 400,000 15-year-old students in more than 50 countries, both OECD members and partner economies, focusing on the practical applications of knowledge in the domains of reading, mathematics, and science. This approach to measuring achievement is less sensitive to the curricular organization of subjects in each country and has a stronger link to the abilities required later in life than achievement tests that have a curricular base. PISA also asks students about family background, learning habits, engagement, and motivation in school. PISA also surveys school principals, who provide contextual information about the students' schools and an assessment of the quality of the learning environment of the school (OECD 2007a).

For each participating country, PISA adopted a stratified clustered sampling strategy. Depending on the needs of each country, a random sample of schools was selected (within strata according to regions, school types, or other categories relevant for each nation). Within each school, a random sample of approximately thirty-five 15-year-old students was drawn. To ensure the comparability of results across countries, the target population of PISA is 15-year-old individuals enrolled in a school, without regard to the grade level they attend: Different countries do not share the same grade-level definitions, rendering comparisons across grade levels difficult (OECD 2007a).

It is important to note that only 15-year-olds who attended school on the day of the survey were sampled, so the results in this study are not necessarily generalizable to the 15-year-old population. Generalizability to the 15-year-old population can be biased if enrollment rates are not full. Also, comparisons across countries can be biased if selection into schooling among 15-year-olds varies across countries. Consequently, results from this study pertain to the relationships between school systems and total achievement inequality among 15-year-olds who are enrolled in school. Nonetheless, to assess the possibility of bias in generalizing to the 15-year-old population, I estimated complementary models that include gross enrollment rates as a control, models that restrict the sample of countries to OECD members, and models that restrict the sample to countries with gross enrollment rates greater than 95. The results from these models do not alter substantively the results presented here.[1] Also, PISA is a cross-sectional study. As such, it is not well suited for assessing causality between variables or assessing historical trends in its measures.

This study focuses on the total achievement inequality in mathematics across nations. Achievement inequality is defined as the variance of student math test scores—or equivalently, the standard deviation—such that countries with more variance in their test scores are more unequal than others. The variance measures the dispersion of a distribution, thus indicating the probability that scores concentrate around the mean or spread apart from it. Moreover, because the location and scale of PISA test scores are arbitrary, the value of 0 lacks meaning; other commonly used measures of inequality such as the Gini coefficient, the Theil Index, and the Variance of the Logs are not inappropriate for use with the PISA test scores (Allison 1978). Also, PISA scores are transformed to a normal distribution, so achievement distributions for each country approximate normality. As a result, other measures of inequality—such as percentile ratios—are largely functions of the mean and variance and are thus not reported here.

Following Western and Bloome (2009), the variance in mathematics achievement is modeled through the contribution of each individual (i) in school (j) to his or her country's (k) variance: the squared deviation of individual scores from the country mean (σ^2_{ijk}). Generalized linear models estimate the expected value of this deviation from a combination of individual-, school-, and country-level variables related to socioeconomic background (*ses*), opportunities to learn (*otl*), intensity of schooling (*int*), and a set of control variables (*cont*). For specification as a generalized linear model, this model uses a log link function and a gamma distribution with one degree of freedom:

$$\log\left(\sigma^2_{ijk}\right) = \alpha_0 + \beta x^{ses}_{ijk} + \gamma x^{otl}_{ijk} + \mu x^{int}_{ijk} + \rho x^{cont}_{ijk} + \varepsilon_{ijk}$$
$$where \quad \sigma^2_{ijk} = \left(y_{ijk} - \overline{y_k}\right)^2$$

The expected value of the mean squared deviation is the average mean squared deviation, or the variance. Thus, results from this model can be used to estimate the group-level inequality (e.g., the country-level variance in achievement) based on individual-, school-, and country-level attributes. Like studies of income inequality that use individuals' incomes to estimate group-level inequality, this study uses students' test scores to measure group-level inequality (see Western, Bloome, and Percheski 2008 for a study of group-level income inequality using variance function regressions). The country-level variance in achievement can be estimated by aggregating individuals within a country. Also, the effects of the distribution of school- and individual-level attributes on country-level inequality can be estimated by comparing the distributions of these attributes across countries to produce a snapshot of inequality and its sources at the individual, school, and country levels.

SAS's procedure for the estimation of generalized linear models (PROC GENMOD) is used to estimate these models accounting for the nested structure of the data (students within schools within countries) and uses empirical standard errors to calculate the statistical significance of the estimates.[2] Because models have a logarithmic link function, interpretation of the effect of an independent variable (β_k) on the expected value of the mean squared deviation is of a factor of e^{β_k}.

The independent variables included in the models were obtained from four sources. All student- and school-level variables are obtained directly from the PISA data set. Most country-level variables were also obtained from the PISA data set by aggregating student- or school-level variables (OECD 2007b, 2007c). Other country-level variables came from the World Development Indicators data set (World Bank 2008) or a codification of United Nations Educational, Scientific and Cultural Organization's World Data on Education (Amadio 2007).

Family background and home environment are measured by the deviation of the students' parents' occupational status from the national mean, mother's educational attainment in ISCED levels, and at the school level, parent's average occupational status. At the country level, inequalities in living conditions are captured by a measure of income inequality (Gini coefficients) and out-of-pocket health expenditures. Out-of-pocket health expenditures in a country are determined by the distribution of resources within a country and a government's commitment to its population's health (Arnett 2007; Quadagno 1987) as part of the risk management dimension of welfare states (Leisering 2003). Both these measures are obtained from the World Development Indicators for 2007.

Variation in opportunities to learn is captured by the extent to which each school differs from the country average in terms of the index of material resources, the proportion of teachers with ISCED 5a degrees, and class size. Between-school tracking is measured at the country level by the number of programs available for students aged 15 and the age of selection into these programs. Both of these measures are provided by PISA. Within-school tracking is a school-level indicator from the PISA school questionnaire that measures whether students in the school are tracked/streamed according to their ability in all subjects. A measure of school selectivity—whether students are admitted to the school according to academic criteria—is also included in the models as a measure of between-school tracking. The breadth of the private sector is measured at the country level as the average school's percentage of funding that comes from private tuition fees. All these measures are constructed or obtained from the PISA school survey. Finally, curriculum standardization is gathered from the World Data on Education. The curricular policies of each country were reviewed, and countries were identified as those in which the central government determines the curriculum (2), countries in which regional or local agencies have some ability to adapt the centrally mandated curriculum (1), or countries in which there is no central government intervention in designing the curriculum (0).

I incorporate several measures for the intensity of schooling, all of which are measured at the country level. The length and duration of the lower secondary school year and the starting age of compulsory education are both obtained from the World Data on Education. The public per-pupil expenditure in secondary education (in constant 2000 dollars) comes from the World Development Indicators. Average resource quality is measured through PISA as the country-level average index of school resources. Similarly, both country-level average class size and teacher certification are aggregates of each school principal's reported class size and the proportion of teachers with ISCED 5a degrees.

Finally, models control for each country's average math achievement, an aggregate of students' scores in PISA's math test, and each country's per capita gross domestic product as available in the World Development Indicators for the year 2007.

In a limited set of countries, some independent variables are missing for the entire sample of schools.[3] In order not to lose entire countries from the analyses, dummy variable imputation is used to account for these missing data (Allison 2002; OECD 2007b). Missing values are imputed with the global mean, and analyses include a dummy variable indicating imputation. The most serious cases are France and Taiwan. France did not administer the school questionnaire, and little country-level information is available for Taiwan.

All aggregate variables were created using the appropriate student- or school-level weights provided by PISA, and models are weighted using student weights. To control for the artificial inflation of the sample size, weights are adjusted so that the unweighted sample size equals the weighted sample size.

The analytic strategy of this study follows three stages. Stage 1 describes the distribution of the variance in achievement across countries and its relationship to mean achievement to rank countries in terms of total achievement inequality.

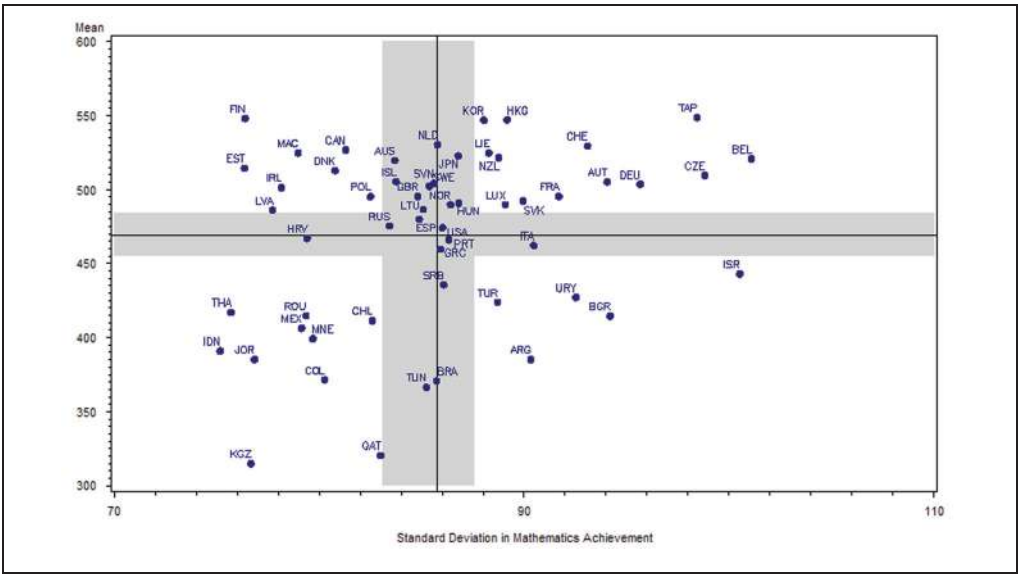

Figure 1. Mean mathematics achievement and dispersion inequality by country, Programme for International Student Assessment (PISA) 2006

Note: Reference lines depict average achievement (469.4) and average standard deviation (85.7), with all countries weighed equally. Grey bands depict the 95 percent confidence interval (±1.96 standard errors) of the estimated averages at the country level. The figure does not include Azerbaijan. Averages presented in PISA Reports (Organization for Economic Co-Operation and Development [OECD], 2007a) are calculated for the restricted sample of OECD countries and do not correspond to the averages presented here.

Stage 2 fits the generalized linear models to the set of covariates measuring variation in family background, opportunities to learn, and intensity of schooling to identify the individual-, school-, and country-level factors that contribute to total achievement inequality. Stage 3 graphs the relationship between opportunities to learn, intensity of schooling, and achievement inequality for each country to better explicate the most important nonsocioeconomic sources of achievement inequality in each participating country.

RESULTS

The horizontal axis of Figure 1 shows the level of total achievement inequality in countries that participated in PISA.[4] Indonesia,[5] Thailand, Estonia, Finland, and Kyrgyzstan experience the lowest amount of mathematics achievement inequality as measured by the standard deviation (or, equivalently, the variance) in math test scores. By contrast, Belgium, Israel, the Czech Republic, Chinese Taipei, and Germany have the highest levels of total achievement inequality in mathematics.

The relationship between total mathematics inequality and mean mathematics achievement is also shown in Figure 1. It is common to observe the joint occurrence of high and homogeneous achievement (as is the case in Finland, Estonia, Macao-China, Ireland, Denmark, and Canada). No school systems produce high levels of dispersion with low levels of achievement, but high levels of dispersion in achievement are observed among several high-achieving countries (Chinese Taipei, Belgium, the Czech Republic, Germany,[6] Austria, and Switzerland). The correlation between the standard deviation and mean mathematics achievement at the country level is .210, although it is not statistically significant.

Descriptive statistics of the variables included in the models are shown in Table 1.

Multivariate models for the variance of mathematics achievement are shown in Tables 2 and 3. Model 1 serves as a baseline model by including all variables associated with family background and home environment. Model 2 adds variables

Table 1. Descriptive Statistics for Variables Used in the Analyses, Programme for International Student Assessment 2006

Variable	Mean	Standard Deviation	Minimum	Maximum
Dependent variable				
Math score	467.8	104.3	7.6	895.2
Math score squared deviation	7383	10618	0	207458
Family background				
Parent's occupational status	42.5	15.0	16	90
Mother's educational attainment (%)				
None	6.17			
ISCED 1	9.42			
ISCED 2	15.09			
ISCED 3b, 3c	9.28			
ISCED 3a, 4	27.6			
ISCED 5b	13.57			
ISCED 5a, 6	18.84			
School's average occupational status	39.7	10.9	16.0	86.5
Gini coefficient	35.3	8.83	23	56.4
Out-of-pocket health expenditure (%)	73.9	20.6	21.9	100.0
Opportunities to learn				
Resource quality index (deviation from country mean)	0.791	0.757	0.001	4.448
Proportion of teachers with ISCED 5a qualification (deviation from country mean)	0.160	0.201	0.000	1.000
Class size (deviation from country mean)	7.79	7.94	0.07	33.55
Proportion of schools that track all students	0.208	0.461	0.000	1.000
Number of educational programs or tracks available for 15-year-olds	2.36	1.24	1.00	5.00
Years before 15 that selection takes place	1.21	1.63	0.00	5.00
Proportion of schools requiring academic record for admissions decisions	0.218	0.212	0.00	0.866
Average school's percentage of funding from tuition fees	14.1	14.9	0.1	55.7
Curriculum standardization	1.38	0.69	0.00	2.00
Intensity of schooling				
Resource quality index	−0.297	0.612	−2.372	0.874
Public per-pupil expenditure at secondary level (thousand dollars)	21.9	7.0	4.9	35.3
Proportion of teachers with ISCED 5a qualifications	0.739	0.253	0.088	1.000
Class size	27.4	5.8	17.1	44.8
Start of compulsory education	6.16	0.66	5.00	7.00
Total hours of instruction	915.6	116.0	715.2	1368.0
Controls				
Mean math achievement (country level)	469.0	59.8	310.6	549.4
GDP per capita (thousand dollars)	16142	13533	326	54178

Note: ISCED = International Standard Classification of Education. Individual- and school-level variables are weighted with weights provided by the Programme for International Student Assessment. Country-level variables are weighted such that each country has equal weight. Observations from Azerbaijan are dropped from this table.

Table 2. Generalized Linear Models Estimating the Mean Squared Deviation with Opportunities to Learn and Intensity of Schooling Variables, Programme for International Student Assessment 2006

	Model 1		Model 2	
	$\hat{\hat{\beta}}$	*SE*	$\hat{\hat{\beta}}$	*SE*
Intercept	8.343***	.132	8.417***	.139
Family background				
Family occupational status deviation	0.007***	.001	0.006***	<.001[b]
Mother's education (none)[a]	0.087***	.024	0.078**	.024
Mother's education (ISCED 1)[a]	−0.055***	.016	−0.064***	.016
Mother's education ISCED 2)[a]	−0.038***	.011	−0.041***	.010
Mother's education ISCED 3b, c)[a]	−0.029*	.012	−0.039***	.012
Mother's education (ISCED 5a, 6)[a]	0.128***	.011	0.141***	.010
Mother's education (ISCED 5b)[a]	−0.037***	.010	−0.021*	.010
School mean occupational status deviation	0.043***	.002	0.041***	.002
Gini	−0.004*	.002	−0.001	.002
Gini^2	≥0.001[c]	<.001[b]	≥0.001[c]**	<.001[b]
Out-of-pocket health expenditure	0.001	<.001[b]	≥0.001[c]	<.001[b]
Opportunities to learn				
School resource quality deviation			0.018	.013
School teacher quality deviation			0.137**	.047
School class size deviation			<0.001[b]	.002
School tracks all students			−0.014	.021
Number of years before 15 that tracking takes place			0.024***	.007
Number of programs available for 15-year-olds			0.030***	.007
Proportion of schools requiring academic history for admission			−0.024	.046
Average school's percentage of funding from fees			−0.001	.001
Standardized curriculum (0, 1, 2)			0.014	.013
Intensity of schooling				
Average school resource quality				
Average school teacher quality				
Per-pupil expenditure (thousands of dollars)				
Average school class size				
Start of compulsory education (years)				
Total hours of instruction (hundred hours)				
Controls				
Mean mathematics achievement	<0.001[b]	<.001[b]	<0.001[b]	<.001[b]
GDP per capita (thousands of dollars)	0.003***	.001	0.004***	.001
Log likelihood	−3086812		−3086456	
n observations	312,327		312,327	
n schools	11,742		11,742	
n countries	56		56	

Note: ISCED = International Standard Classification of Education. Models are weighted by individual weights provided by the Programme for International Student Assessment.
a. Reference category is ISCED 3a, 4. Effect parameterization is used so other estimates are interpreted assuming overall average mother's education level.
b. Value of the estimate is less than 0.001 but greater than 0.
c. Value of the estimate is greater than −0.001 but less than 0.
$^*p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Table 3. Generalized Linear Models Estimating the Mean Squared Deviation with Equality of Living Conditions and Full Model, Programme for International Student Assessment 2006

	Model 3		Model 4	
	$\hat{\hat{\beta}}$	*SE*	$\hat{\hat{\beta}}$	*SE*
Intercept	9.123***	.233	9.136***	.243
Family background				
Family occupational status deviation	0.006***	<.001[b]	0.007***	.000
Mother's education (none)[a]	0.088***	.025	0.081***	.024
Mother's education (ISCED 1)[a]	−0.041*	.016	−0.049**	.016
Mother's education (ISCED 2)[a]	−0.039***	.011	−0.041***	.010
Mother's education ISCED 3b, c)[a]	−0.050***	.012	−0.058***	.012
Mother's education (ISCED 5a, 6)[a]	0.129***	.011	0.138***	.010
Mother's education (ISCED 5b)[a]	−0.034**	.010	−0.022*	.010
School mean occupational status deviation	0.043***	.002	0.041***	.002
Gini	−0.001	.002	−0.001	.002
Gini^2	≥0.001[c]	<.001[b]	≥0.001[c]**	<.001[b]
Out-of-pocket health expenditure	≥0.001[c]	.001	−0.001	.001
Opportunities to learn				
School resource quality deviation			0.020	.013
School teacher quality deviation			0.119*	.049
School class size deviation			0.001	.002
School tracks all students			−0.011	.021
Number of years before 15 that tracking takes place			0.014*	.008
Number of programs available for 15-year-olds			0.026***	.008
Proportion of schools requiring academic history for admission			0.094	.049
Average school's percentage of funding from fees			<0.001[b]	.001
Standardized curriculum (0, 1, 2)			0.006	.015
Intensity of schooling				
Average school resource quality	0.107***	.031	0.098**	.032
Average school teacher quality	−0.166***	.031	−0.127***	.034
Per-pupil expenditure (thousands of dollars)	0.003	.002	0.004*	.002
Average school class size	−0.006**	.003	−0.005	.002
Start of compulsory education (years)	0.005	.012	−0.001	.015
Total hours of instruction (hundred hours)	−0.012	.008	−0.013	.009
Controls				
Mean mathematics achievement	0.001	<.001[b]	−0.001	<.001[b]
GDP per capita (thousands of dollars)	−0.001	.001	<0.001[b]	.001
Log likelihood	−3086398		−3086165	
n observations	312,327		312,327	
n schools	11,742		11,742	
n countries	56		56	

Note: ISCED = International Standard Classification of Education. Models are weighted by individual weights provided by the Programme for International Student Assessment.

a. Reference category is ISCED 3a, 4. Effect parameterization is used so other estimates are interpreted assuming overall average mother's education level.

b. Value of the estimate is less than 0.001 but greater than 0.

c. Value of the estimate is greater than −0.001 but less than 0.

$*p < .05$. $**p < .01$. $***p < .001$.

associated with opportunities to learn, whereas Model 3 provides estimates for intensity of schooling. Finally, Model 4 includes all variables jointly.

Model 1 in Table 2 shows how variations in family background are related to the variance in achievement. Within a country, family background varies both within and between schools. As expected, increased variation in school-mean parents' occupational status is strongly associated with total achievement inequality: A 1 standard deviation increase in the occupational status deviation of the school is associated with a 28.2 percent increase in achievement inequality. Net of school composition, greater polarization in the occupational status and educational attainment of parents is related to greater achievement inequality. In particular, students with parents who are one standard deviation above or below the country's average occupational status contribute 6.0 percent more to the variance of achievement inequality than students living with parents of average occupational status.[7] Similarly, greater polarization in the educational level of parents contributes more to a country's achievement inequality than a more concentrated distribution of parents' educational attainment, which is indicated by the positive and significant estimates of high (ISCED 5a or 6) or low (less than ISCED 1) parents' educational attainment. These background and contextual effects remain stable and statistically significant across models once opportunities to learn or the intensity of schooling is included. Net of the socioeconomic status of schools and students, nations with a more unequal income distribution have lower achievement inequality, but this estimate is substantively small and no longer significant when other variables are added to the models. Also, out-of-pocket health expenditures are not related to the variance in achievement.

Beyond the expected effects of socioeconomic background on inequality, variations in opportunities to learn contribute to achievement dispersion in a school system. These relationships are assessed in Model 2. Uneven distributions of teachers' formal training among schools and tracking are related to greater dispersion in math achievement. This is consistent with research showing the effects of teacher quality and tracking on achievement. Estimates indicate that a shift in the distribution of teachers from maximum heterogeneity to one of complete homogeneity (where all schools have the same proportion of ISCED 5a teachers) reduces the variance in achievement by 7.1 percent.[8]

Between-school tracking is also associated with greater total achievement inequality. Each additional educational program available for 15-year-old students is related to a 3.0 percent increase in achievement inequality. Shifting selection into these programs earlier in the course of a student's schooling increases the variance in achievement by an additional 2.4 percent per year. Surprisingly, however, within-school tracking shows no association with achievement inequality. This finding, which is contrary to the large body of research that shows how ability grouping within schools increases achievement inequality, may be a result of an unreliable measure. The measure for within-school tracking provided by PISA asks school administrators whether the school groups students by ability "in no subject," "in some subjects," or "in all subjects." Consistent with the PISA reports, the fitted models use a dichotomized measure in which only the "in all subjects" category is indicative of within-school tracking (OECD 2007a). Even though there is considerable variation in this dichotomized measure of tracking, both within and between countries, tracking is often complex (Kelly 2007, 2008), and this simple measure might not capture it reliably. For example, only 5 percent of the schools in the United States qualify as tracked schools according to this measure, yet tracking is far more common in the United States (Kelly 2004; Lucas and Berends 2002; Turner 1960).

Increased variability in resource quality and class size across schools is not related to increases in the dispersion of achievement, supporting the weak or null findings relating school resources and class size to achievement. The breadth of the private sector, the extent to which schools require academic histories for selection into schools, and curriculum standardization are also unrelated to the variance in math achievement.

Model 3 considers the relationship between measures of the intensity of schooling and achievement inequality, adjusting for socioeconomic factors. Average levels of teacher and resource quality, as well as average class size, are associated with variation in math achievement. An increase in the proportion of teachers with ISCED 5a qualifications in the school system from one quarter to three quarters is associated with a reduction in total achievement inequality of 8.4 percent. An increase in the average quality of resources of the schools, however, is associated with an even greater increase in achievement dispersion: a one-unit increase in the school resource index at the country level results in an increase in achievement inequality of 10.1 percent (at the country level, the index ranges from −2.4 to 0.8). Larger class sizes are negatively, and significantly, associated with increases in achievement inequality, although the magnitude of the effect is not substantively relevant and losses significance in the final model. Other measures of intensity of schooling such as the onset of compulsory education and total hours of instruction are not related to total achievement inequality.

The results discussed for Models 1 through 3 do not change substantially once all variables are entered simultaneously (Model 4). As discussed above, Model 4 suggests that there is a strong relationship between variability in family background and total achievement inequality. Similarly, greater variation in opportunities to learn is related to greater achievement inequality, particularly in the form of inequality in the distribution of teachers across schools and between-school tracking. In terms of the intensity of schooling, increases in overall teacher quality (as measured by teachers' educational attainment) are related to reductions in total achievement inequality. Increased overall resource quality of the schools in a country, however, is related to higher levels of achievement inequality.

Collectively, the measures in Model 4 predict total achievement inequality well. At the country level, the correlation between the observed and predicted (by Model 4) variance in achievement is .65. If Macao China and Hong Kong China are not considered in the correlation, its value increases to .78. This indicates that with information about the distribution of socioeconomic background, variations in opportunities to learn, and intensity of schooling, the model predicts more than 60 percent of the country-level variance in achievement inequality.

Figure 2 shows a scatterplot with the contribution of each set of variables (opportunities to learn and intensity of schooling) to the logged variance of achievement. It portrays graphically how intensity of schooling and variations in opportunities to learn contribute to total achievement inequality in each country. The contribution of opportunities to learn is calculated by substituting each observation's corresponding set of values in the model equations using Model 4's estimated coefficients while fixing the values for socioeconomic background and intensity of schooling at their sample means. This assumes that all countries share similar distributions in both socioeconomic background and intensity of schooling. Conversely, the contribution of intensity of schooling is calculated by fixing the values for socioeconomic background and opportunities to learn at their means. Observations per country are then averaged to calculate the coordinates for each country.

The net contribution of intensity of schooling (x-axis) is always negative. As predicted, intensity of schooling serves to reduce total achievement inequality. The countries that have the greatest reduction in achievement inequality due to intensity of schooling are Indonesia, Kyrgyzstan, Jordan, Thailand, Brazil, and Colombia. The greatest contributions to total achievement inequality from variations in opportunities to learn (y-axis) are in Liechtenstein, Germany, the Czech Republic, Slovakia, Switzerland, and the Netherlands. By contrast, Canada, the United States, Australia, New Zealand, and all five Nordic countries are among those that produce the least achievement inequality from variations in opportunities to learn.

It is noteworthy to compare the position of the United States in Figure 2 and in Figure 1. From Figure 2 we conclude that variations in opportunities to learn and intensity of schooling contribute equally to total inequality in the United States and in the Nordic countries. Yet from Figure 1 we learn that total achievement inequality in the United States is much greater than in the Nordic countries. This is the result of both the greater dispersion in distribution of socioeconomic background in the United States and the different effects socioeconomic background has on achievement in the United States when compared to the Nordic countries. The greater achievement inequality in the United States, therefore, stems from the greater variability in students' background and the stronger effects student background, rather than the institutional arrangements of the educational system, has on achievement.

DISCUSSION

In the sociology of education, research on educational inequality has often focused on equality of opportunity, the strength of the relationship

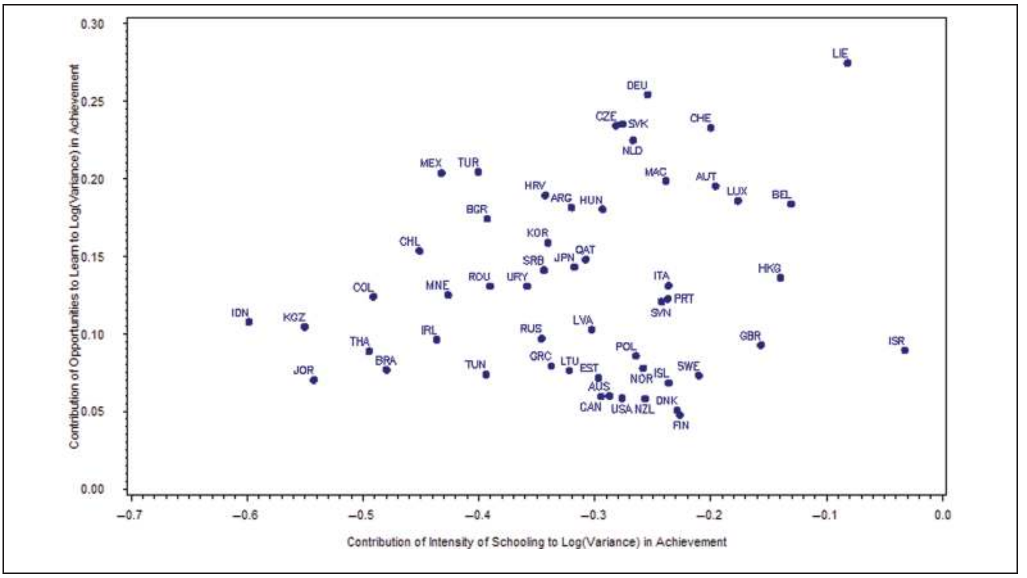

Figure 2. Predicted contributions of variations in opportunities to learn and intensity of schooling to the logged variance of achievement, Programme for International Student Assessment 2006

between background characteristics and educational outcomes. This approach ignores much of the total inequality that school systems produce, which is important because unequal outcomes are expected to endure or even grow as student cohorts advance in their educational careers and enter the labor market. Inequalities in achievement may then become inequalities in attainment, occupational status, income, or other adult outcomes.

Consistent with the large body of literature linking socioeconomic background and achievement, this article shows that achievement inequality is partly a function of the distribution of socioeconomic status. I find greater achievement inequality in countries with higher segregation in school socioeconomic status composition and higher individual socioeconomic status differences within the school. In other words, by reducing the strength of the relationship between socioeconomic status and achievement in a school system, the overall distribution of achievement is also equalized. Hence, improving the equality of opportunity of a school system not only has important meritocratic consequences for individuals and their life chances but also has important consequences in shaping the achievement distribution of a school system.

Importantly though, achievement inequality is also a function of characteristics of educational systems themselves such as variations in opportunities to learn, particularly in the form of inequities in the distribution of teachers among schools and the extent of between-school tracking. Total inequality is also a function of the intensity of schooling, such that school systems with better trained teachers have less dispersion in achievement. Overall resource quality is an exception however; countries with higher overall resource quality actually have greater variation in achievement. This result is at odds with the hypotheses of this article and could indicate differential capacity of schools to use resources effectively or an imprecise measurement of resource quality used in the analyses.[9]

These results reinforce the positive relationship between teacher quality and achievement (Greenwald et al. 1996; Rivkin et al 2005). As this article suggests, a better trained teacher workforce is also related to lower total achievement inequality. Stronger investments in the teacher workforce increase the performance of educational systems and make the distribution of outcomes more equitable. This investment may have the threefold benefit of also reducing inequalities of opportunity inasmuch as certain teacher characteristics have been linked to higher achievement among disadvantaged students (Bryk, Lee, and Holland 1993; Gamoran 1993; Nye et al. 2004). Similarly, prior research shows that reducing or eliminating tracking leads to increases in equality of opportunity (Gamoran and Mare 1989; OECD 2007a). This article extends this finding by showing that comprehensive school systems produce a more even distribution of achievement across students (Hanushek and Wößmann 2005).

The models in this article also show that curriculum standardization, starting age of compulsory education, and total hours of instruction are not related to achievement inequality. Although I expected that these variables would be related to achievement inequality, the lack of an observed relationship could be a result of the low levels of variance in these measures of intensity of schooling. As neo-institutional research shows (Baker and LeTendre 2005; Meyer and Rowan 1977), even though countries may vary in curriculum standardization, it is likely that implemented curriculums do not vary as much across schools, districts, or states. Similarly, there does not seem to be sufficient variation in the total hours of instruction or the starting age of compulsory education to produce meaningful differences in total achievement inequality.

The comparison of the effects of schooling variables on achievement inequality and the observed distribution of achievement inequality illustrates the importance of socioeconomic diversity in shaping total achievement inequality. School systems such as those of Finland and the United States produce similar levels of achievement inequality as a result of intensity of schooling and variations in opportunities to learn. Their observed achievement inequality, however, differs greatly as a result of different distributions of socioeconomic status both between and within schools and as a result of the different impact socioeconomic background has on achievement in these two countries.

This finding supports the assertion that reductions in equality of educational outcomes can be efficiently overcome by equalizing life conditions (i.e., reducing the spread of the distribution; Jencks et al. 1972; Shavit and Blossfeld 1993) through, for example, comprehensive welfare programs (Pong, Dronkers and Hampden-Thompson 2003). Educational arrangements can amplify the effect of socioeconomic background on achievement through educational practices such as tracking (OECD 2007a), shadow education where it is private (Baker et al. 2001; Stevenson and Baker 1992), and inequalities in the allocation of resources such as those that stem from educational funding mechanisms in the United States (Moser and Rubenstein 2002).

Cross-national studies of education have an important advantage over studies that concentrate on one educational system: They enable researchers to evaluate the impact of broad educational policies that remain constant within school systems (in this case, overall teacher quality, overall resource quality, total hours of instruction, and curriculum standardization) on total achievement inequality. However, most of these studies are cross-sectional and are not able to assess causality in the observed relationships (Loveless 2009).

These relationships can become the basis for future cross-national studies on achievement. They should adopt a longitudinal perspective and include a more comprehensive set of school and institutional practices to address the particular mechanisms that explain how intensity of schooling or variations in opportunities to learn affect achievement inequality.

A longitudinal account of achievement inequality could incorporate the recently observed trend toward greater schooling equality (Baker and LeTendre 2005) such as that which results from increased enrollment in secondary and higher education (Meyer, Ramirez, and Soysal 1992; Schofer and Meyer 2005), investment of resources (Baker et al. 2002), and the changes some school systems have adopted with respect to their tracking policies (a change toward general education in Poland, detracking in the United States, and a wider prevalence of comprehensive high schools in Germany and France). A longitudinal perspective on achievement inequality could also relate the decreasing inequality of opportunity observed in Sweden, the Netherlands, and other countries (Breen and Jonsson 2005; Shavit and Blossfeld 1993) to total achievement inequality. These longitudinal perspectives on total achievement inequality would shed light on the trend toward greater schooling equality.

The immediate costs and benefits of more equal distributions of schooling also offer fruitful possibilities for research. Two possible costs of an egalitarian education are a loss in academic excellence and higher financial costs. Hanushek and Wößmann (2005) conclude that tracking increases total achievement inequality but does not reduce mean achievement. They also note that offering a comprehensive education that leads to less total achievement inequality is no more expensive than offering a stratified educational system that produces more total achievement inequality.

The long-term costs and benefits or more equal distributions of schooling also offer new grounds for research. Total achievement inequality may be related to forms of inequality that have increased, mainly income inequality in industrialized countries (Smeeding and Gottschalk 1999) and the stagnation in the reduction of poverty in some parts of the world (Collier and Dollar 2001). Furthermore, as a student cohort progresses into higher education and enters the labor market, total achievement inequality may become skill inequalities that affect economic growth and income inequality (Castello-Climent and Domenech 2008; Castello and Domenech 2002; De Gregorio and Lee 2002), although these are strongly mediated by the characteristics of the labor market and other institutions such as collective bargaining and union membership (Blau and Kahn 2005; Carbonaro 2005, 2006; Devroye and Freeman 2001). The consequences of total achievement inequality may spread beyond economic grounds as education has been linked to other adult life outcomes (Pallas 2000), and equality in educational outcomes fosters political equality (Labaree 1997). These analyses may lead to discussion about the amount of total achievement inequality that is desirable for each country to produce.

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NOTES

1. Because schools are the primary sampling unit, all 15-year-olds not in school the day of the test are excluded from the sampling frame. Therefore, results are only generalizable to the enrolled population of students. To generalize to the entire 15-year-old population, it is important to keep in mind the possibility of selection bias in countries where enrollment ratios are lower. Achievement inequality in countries with lower enrollment ratios may be underestimated, but the magnitude of this bias is impossible to determine. The inability to account for selection processes is a limitation of this study, and inferences should thus be limited to total achievement inequality among students who are enrolled in school. Attempts were made, however, to account for the possibility of selection bias. Adding a control for the gross enrollment ratio in secondary schools does not alter the results presented in this study. Limiting the sample to the 30 countries that were members of the Organization for Economic Co-Operation and Development (OECD) in 2006—under the presumption that selection processes in developed countries differ as compared to developing countries—only alters the results concerning the distribution of teachers and the overall quality of teachers: Both estimates are not statistically significant in the sample for OECD-only countries. Furthermore, results are not altered substantively after restricting the sample of countries to those school systems with gross enrollment rates greater than 95 (36 countries).
2. In particular, the following MODEL options are specified in PROC GENMOD to estimate models using a gamma distribution with 1 degree of freedom: *dist=gamma link=log scoring=100 noscale scale=.5*. The nested design is incorporated in the analyses by including the *school_id * country* interaction in the REPEATED statement in SAS. Individuals within each school are assumed to be independent; thus, the *type=ind* option is specified. This specification of the REPEATED statement produces empirical (GEE) standard errors for each parameter estimate by specifying the adequate covariance structure (see SAS 2007 for details). SAS 9.1.3 is used for estimation. Because of the nested structure of the data, hierarchical linear models appear as an alternative technique to analyze this data. Unfortunately, current versions of the hierarchical linear models software allow for the analysis of variables only with a Normal, Poisson, or Bernoulli distribution, but not—as is the case in modeling the variance through the mean squared deviation—errors with a Gamma distribution.
3. Several countries have countrywide missing values on different variables. These countries are Austria, Canada, Chinese Taipei, France, Ireland, Israel, Hong Kong China, Japan, Jordan, Liechtenstein, Macao-China, Montenegro, Qatar, the Russian Federation, Serbia, Spain, and Turkey.
4. Azerbaijan presents abnormally low levels of achievement inequality: Its standard deviation in math scores is almost half that of other countries with low levels of total achievement inequality. Due to this irregularity as well as the uncommon distribution of other variables used in this analysis, all cases belonging to Azerbaijan are dropped from the analyses. Its elimination from the models does not alter the main conclusions of this study.

5. As discussed in the Data and Method section and Note 1, these estimates have to be interpreted taking into account the potential sample selection bias for each country. Indonesia has the lowest gross enrollment ratios for all secondary school systems analyzed, so low achievement inequality in this case could be a result of selection into the secondary school system; therefore, inequality for the adolescent population is highly underestimated. Inequality for the student population, however, is not biased. Models that control for gross enrollment ratios that restrict the sample to the 30 OECD countries of 2006 and that restrict the sample to 36 countries with gross enrollment rates greater than 95 do not alter substantially the results presented here (see Note 8).
6. In OECD reports, Germany is not statistically different than the OECD average and is thus not considered a high-achieving country. As noted in the figure, the country-level average used as a reference in this article is calculated for the entire sample of countries and not restricted to OECD countries.
7. Discrete percentage change (z) calculations are computed as follows: $z = e^{(\hat{\beta}_k \times \sigma_k)} \times 100$, where $\hat{\beta}_k$ is the estimates from the multivariate models for variable k, and σ_k is the observed standard deviation for variable k. For the following examples, the standard deviations used in the computations are 8.32 for absolute deviation in occupational status and 5.78 in school deviation from mean school occupational status. For categorical variables, and variables described as unit increases, discrete percentage changes (z) are computed as $z = e^{\hat{\beta}_k} \times 100$.
8. These results are not statistically significant when restricting the sample to the 30 OECD countries of 2006. This might be due to the fact that teacher certification is less relevant in explaining achievement in OECD countries. This change of effect of teacher certification does not seem to be a result of different levels of variability among OECD and non-OECD countries: Descriptive statistics for these variables signal no substantial difference in the level and variability of this variable across the two sets of countries. The other results do not change substantially by limiting the sample. A hypothesis behind the null result of teacher certification in OECD countries is that the selection of teachers (through professional tests or long selection processes) ensures a homogeneous and qualified teaching workforce, beyond that provided by the professional credential.
9. The measure for resource quality used by the Programme for International Student Assessment involves the school principals' assessing the way certain resources affect instruction. These resources include Internet connectivity, library materials, audio-visual resources, computers, instructional materials, and science laboratory equipment. It is possible that these measures address the principals' involvement or expectations of what constitutes adequate instruction and not the quality or even the use of resources for instructions.

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