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The Global Increase in the Socioeconomic Achievement Gap, 1964-2015: Online Appendices

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ABSTRACT

These appendices report additional details of the results from the main text of the paper, as well as supplementary analyses undertaken to test the sensitivity of results to a number of different limitations of the data. The finding of global increases in SES achievement gaps is generally robust to differences across test instruments, changes in the distribution of achievement and of SES, and changes in the measurement error of achievement and of SES. The multivariate findings predicting changing country achievement gaps from changing country characteristics and policies are generally robust across a variety of model specifications.

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November 25, 2018

Online Appendices

These appendices report additional details of the results from the main text of the paper, as well as supplementary analyses undertaken to test the sensitivity of results to a number of different limitations of the data. The finding of global increases in SES achievement gaps is generally robust to differences across test instruments, changes in the distribution of achievement and of SES, and changes in the measurement error of achievement and of SES. The multivariate findings predicting changing country achievement gaps from changing country characteristics and policies are generally robust across a variety of model specifications.

The contents of the appendices are as follows:

A1. List of Included Countries and Datasets

code	country	region	mid/low-income in 1980	fims1964	fiss1970gr4	fiss1970gr8	fircs1970gr4	fircs1970gr8	sims1980	siss1984gr4	siss1984gr8	rls1991gr4	rls1991gr8	timss1995gr4	timss2003gr4	timss2007gr4	timss2011gr4	timss2015gr4	timss1995gr8	timss1999	timss2003gr8	timss2007gr8	timss2011gr8	timss2015gr8	pirls2001	pirls2006	pirls2011	pisa2000	pisa2003	pisa2006	pisa2009	pisa2012	pisa2015
ALB	Albania	E	x																								x			x	(x)	(x)
DZA	Algeria	M	x													x						x										x
ARG	Argentina	L	x																						x			x		x	x	x	
ARM	Armenia	E	x												x	(x)	x				x	x	x										
AUS	Australia	W		x		x				x	x			x	x	x	x	x	x	x	x	x	x	x			x	x	x	x	x	x	x
AUT	Austria	W												x		x	x		x							x	x	x	x	x	x	x	x
AZE	Azerbaijan	E	x														x										x			x	x		
BHR	Bahrain	M															(x)	x			x	x	x	x									
BEL	Belgium	W		x																													
BFL	Belgium-Flemish	W			x	x	x	x	x						x		x	x	x	x	x					x		x	x	x	x	x	x
BFR	Belgium-French	W			x	x	x	x	x			x	x						x								x	x	x	x	x	x	x	x
BLZ	Belize	L	x																						x								
BIH	Bosnia & Herzegovina	E	x																			x											
BWA	Botswana	Af	x										x				x				x	x	x	x			x						
BRA	Brazil	L	x																									x	x	x	x	x	x
BGR	Bulgaria	E	x															x	(m)	x	x	x			x	x	x	x		x	x	x	x
CAN	Canada	W								(m)	(m)			x		x		x	x	x		x		x		x	x	x	x	x	x	x	x
CHL	Chile	L	x		(x)	x	x	x									x	x		x	x		x	x				x			x	x	x	x
CHN	China	As	x								x																							
TWN	Chinese Taipei	As	x												x	x	x	x		x	x	x	x	x		x	x			x	x	x	x
COL	Colombia	L	x													x			x			x			x		x			x	x	x	x
CRI	Costa Rica	L	x																													x	x	x
HRV	Croatia	E															x	x									x			x	x	x	x
CYP	Cyprus	W	x									(x)	x	x	x			x	x	x	x	x			x									
CZE	Czech Rep.	E												x		x	x	x	x	x		x			x		x	x	x	x	x	x	x
DNK	Denmark	W										x	x			x	x	x	x							x	x	x	x	x	x	x	x
DOM	Dominican Republic	L	x																														x
EGY	Egypt	M	x																		x	x		x									
SLV	El Salvador	L	x													x						x											
ENG	England	W		x	x	x	x	x	x	x	x			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
EST	Estonia	E																			x									x	x	x	x
FIN	Finland	W		x	x	x	x	x	x	x	x	x	x				x	x		x			x				x	x	x	x	x	x	x
FRA	France	W		x					x			x	x					x	x						x	x	x	x	x	x	x	x	x
GEO	Georgia	E	x													x	x	x				x	x	x		x	x			x		x	
DEU	Germany	W														x	x	x	x						x	x	x	x	x	x	x	x	x
GDR	Germany-East	W										x	x																					
FRG	Germany-West	W		x	x	x						x	x																					
GHA	Ghana	Af	x								x										x	x	x										
GRC	Greece	W										x	x	x					x						x			x	x	x	x	x	x
HND	Honduras	L	x														x						x				x						
HKG	Hong Kong	As							x	x	x	(x)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
HUN	Hungary	E	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
ISL	Iceland	W										x	x	x					x						x	x		x	x	x	x	x	x
IND	India	As	x		x	x	x	x																										
IDN	Indonesia	As	x									x		(m)				x		x	x	x	x			x	x	x	x	x	x	x	x
IRN	Iran	M	x		x	x	x	x						x	x	x	x	x	x	x	x	x	x	x	x	x	x						
IRL	Ireland	W										x	x	x			x	x	x					x			x	x	x	x	x	x	x
ISR	Israel	W		x			x	x	x	x	(m)			x					x	x	x	x	x	x	x	x	x	x		x	x	x	x
ITA	Italy	W			x	x	x	x		x	x	(x)	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
JPN	Japan	As		x	x	x			x	x	x			(m)	x	x	x	x	x	(m)	x	x	x	x				x	x	x	x	x	x
JOR	Jordan	M	x																	x	x	x	x	x						x	x	x	x
KAZ	Kazakhstan	E	x													x	x	x					x	x							x	x	
KOR	Korea, Rep.	As	x							x	x			x			x	x	x	x	x	x	x	x				x	x	x	x	x	x
KSV	Kosovo	E	x																														x
KWT	Kuwait	M												x		x	x	x	x			x		x	x	x	x						
KGZ	Kyrgyzstan	E	x																											x	x		
LVA	Latvia	E	x											x	x	x			x	x	x				x	x		x	x	x	x	x	x

Notes: Shaded countries were excluded because they participated in only one test. (m) denotes missing SES data; (x) denotes that gaps could not be computed, usually because of low-quality SES data. Regions include: Af=sub-Saharan Africa, As=east and southeast Asian and Pacific countries, M=Middle Eastern and North African countries, E=Eastern Europe and the Commonwealth of Independent States, L=Latin America and the Caribbean, and W=Western countries (Western Europe and Anglophone countries).

Appendix Table A1 (cont.)

code	country	region	mid/low-income in 1980	fims1964	fiss1970gr4	fiss1970gr8	fircs1970gr4	fircs1970gr8	sims1980	siss1984gr4	siss1984gr8	rls1991gr4	rls1991gr8	timss1995gr4	timss2003gr4	timss2007gr4	timss2011gr4	timss2015gr4	timss1995gr8	timss1999	timss2003gr8	timss2007gr8	timss2011gr8	timss2015gr8	pirls2001	pirls2006	pirls2011	pisa2000	pisa2003	pisa2006	pisa2009	pisa2012	pisa2015
LBN	Lebanon	M	x																		x	x	x	x								x
LIE	Liechtenstein	W																									x	x	x	x	x	
LTU	Lithuania	E													x	x	x	x	x	x	x	x	x	x	x	x	(m)		x	x	x	x
LUX	Luxembourg	W							x																	x	x	x	x	x	x	x	x
MAC	Macao-China	As																										x	x	x	x	x	x
MKD	Macedonia	E	x																	x	x		x		x	x	x					x
MYS	Malaysia	As	x																	x	x	x	x	x						x	x	
MLT	Malta	W	x														x					x		x		x				x		x
MUS	Mauritius	Af	x																											x		
MEX	Mexico	L	x											(m)													x	x	x	x	x	x
MDA	Moldova	E	x												x					x	x				x	x				x		x
MNG	Mongolia	As	x													x						x										
MNE	Montenegro	E																											x	x	x	x
MAR	Morocco	M	x												x	x	x	x		x	x	x	x	x	(x)	x	x					
NLD	Netherlands	W		x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x				x	x	x	x	x	x	x	x	x
NZL	New Zealand	W				x		x	x			x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x
NGA	Nigeria	Af	x						(x)	x	x		x																				
NIR	Northern Ireland	W															x	x								x							
NOR	Norway	W								x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x
OMN	Oman	M	x														x	x				x	x	x			x						
PAN	Panama	L	x																											x			
PNG	Papua New Guinea	As	x								x																						
PER	Peru	L	x																								x			x	x	x	
PHL	Philippines	As	x							x	x		x		x				x	x	x												
POL	Poland	E	x							x	x						x	x								x	x	x	x	x	x	x	x
PRT	Portugal	W	x									x	x	x			x	x	x								x	x	x	x	x	x	x
QAT	Qatar	M														x	x	x				x	x	x		x	x			x	x	x	x
ROM	Romania	E	x														x		x	x	x	x	x		x	x	x	x			x	x	x	x
RUS	Russian Fed.	E													x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
SAU	Saudi Arabia	M															x	x			x	x	x	x			x						
SCO	Scotland	W		x	x	x	x	x	x					x	x	x			x		x	x			x	x		x	x	x	x	x	x
SRB	Serbia	E	x														x	x			x	x							x	x	x	x	
QCN	Shanghai-China	As	x																												x	x	
SGP	Singapore	As								x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				x	x	x
SVK	Slovak Rep.	E	x												x	x	x	x	x	x				x	x	x		x	x	x	x	x	x
SVN	Slovenia	E										x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x	x	x	x	x
ZAF	South Africa	Af	x																x	x	x			x		x	x						
ESP	Spain	W										x	x				x	x	x						x	x	x	x	x	x	x	x
SWZ	Swaziland	Af	x						x																								
SWE	Sweden	W		(m)	x	x	x	x	x	x	x	x	x			x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x
CHE	Switzerland	W										x	x						x								x	x	x	x	x	x	x
SYR	Syria	M	x																		x	x	x										
THA	Thailand	As	x			x	x			x		x		x			x		x	x		x	x	x			x	x	x	x	x	x	x
TTO	Trinidad and Tobago	L										x	x													x	x				x		x
TUN	Tunisia	M	x												x	x	x			x	x	x	x						x	x	x	x	x
TUR	Turkey	W	x														x	x		x		x	x	x	x				x	x	x	x	x
UKR	Ukraine	E	x													x						x	x										
ARE	United Arab Emirates	M															x	x					x	x			x				x	x	x
USA	United States	W		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	(x)	x	x	x	x	x	x	x	x
URY	Uruguay	L	x																									x	x	x	x	x	x
VEN	Venezuela	L	x									x	x																				
VNM	Vietnam	As	x																												(x)	x	x
PSE	West Bank and Gaza	M	x																		x	x	x										
YEM	Yemen	M	x												(x)	x	x																
ZWE	Zimbabwe	Af	x								x		x																				

Notes: Shaded countries were excluded because they participated in only one test. (m) denotes missing SES data; (x) denotes that gaps could not be computed, usually because of low-quality SES data. Regions include: Af=sub-Saharan Africa, As=east and southeast Asian and Pacific countries, M=Middle Eastern and North African countries, E=Eastern Europe and the Commonwealth of Independent States, L=Latin America and the Caribbean, and W=Western countries (Western Europe and Anglophone countries).

B. Combining different test instruments

In order to estimate international trends in SES achievement gaps over a 50-year period, this paper combines data from a variety of different international assessments of math, science, and reading. However, among tests of the same subject, a comparison of skills frameworks from the official study reports reveals differences. For example, the IEA math and science tests—FIMS, FISS, SIMS, SISS, and TIMSS—are curriculum-based, while the PISA math and science tests, as well as all reading tests—PISA, FIRCS, RLS, and PIRLS—are literacy-based. Though the early IEA tests contained anchor items to enable studying trends in achievement, the scores were not placed on common scales, and they did not have the advantage of improvements to testing methodology in the 1990s; thus, early and recent IEA tests are not strictly comparable. The analyses in the main text of the paper deal with this issue by standardizing achievement within each study and each country and assuming only that each test is interval-scaled and that different tests rank students similarly.

However, there are six recent studies that repeat the same test instrument to enable measuring trends over time: TIMSS 4^{th} and 8^{th} grade math and science; PIRLS; and PISA reading, math, and science. These trend studies allow us to investigate the sensitivity of gap trend results to differences across test instruments—but only over the recent 9-20 years that the studies have been conducted. TIMSS trends (for both grades and subjects) can be estimated for test years 1995 to 2015 (birth cohorts 1981 to 2001 for 8^{th} grade and birth cohorts 1985 to 2005 for 4^{th} grade); PIRLS trends for test years 2001 to 2011 (birth cohorts 1991 to 2001); PISA reading trends for test years 2000 to 2015 (birth cohorts 1985 to 2000); PISA math trends for test years 2003 to 2015 (birth cohorts 1988 to 2000); and PISA science trends for test years 2006 to 2015 (birth cohorts 1991 to 2000). In addition, because each instrument remains the same over time, it is not necessary to standardize achievement within studies or countries, meaning we can examine changes in SES achievement gaps in light of possible changes in the variance of skills (which will be addressed in Appendix C).

Tables B1-B4 compute trends in SES achievement gaps separately for each test instrument. For each of the eight test instruments, Model 1 is a hierarchical multivariate variance-known model that estimates a different cohort slope for each gap type (parent education, parent occupation, or household books) using interactions between cohort birth year and gap type indicators. Model 2 estimates a single pooled cohort slope for all gap types. Thus, the specifications of Models 1 and 2 are the same as Models 1 and 2 in the main text but without control variables (as the subject and age at testing dummies from the models in the main text do not vary within each test instrument). Tables B1 and B2 report trends in gaps estimated without standardizing achievement within each country-study-year. Tables B3 and B4 report gaps estimated when achievement is standardized within each county-study-year, as in the main text of the paper.[1,2] It can be seen from the reported country sample sizes that the number of participating countries varies widely across the different test instruments. It is not possible to reliably estimate trends across all test instruments for a core group of countries that has participated in every test, as there are too few countries that have done so. Thus, the reported

[1] The Standardized Achievement models adjust each gap estimate for the reliabilities of test instruments and SES report; the Unstandardized Achievement models adjust each gap estimate only for the reliability of SES report. It is not necessary to adjust for test reliability in these models as gap estimates are not attenuated since they have not been divided by the test score variance.

[2] When computing these gaps, rather than using all available categories of each SES variable as in the main text of the paper, each SES variable was recoded to ensure that the SES instrument remained the same across test years. There were six categories for parent education and parent occupation and five categories for household books.

trends for each test instrument should be interpreted only as a rough indication of the sensitivity of the general finding of increasing SES achievement gaps over time. The size of coefficients can be compared across different test instruments only for the models using standardized achievement, not for those using unstandardized achievement, as they are in different metrics and 1 point in PISA, for example, is not the same as 1 point in PIRLS or TIMSS. Significance levels should be interpreted with caution because of changing sample sizes and the large number of significance tests conducted; significance is reported only as a general indication of the strength of association.

Overall, the estimated gap trends are positive for most test instruments. Gaps are consistently increasing for all three SES variables in PIRLS and for both available SES variables in both subjects of TIMSS at both the 4^{th} and the 8^{th} grades. However, gap trends for PISA are more mixed. In particular, trends in gaps based on unstandardized math and science achievement are negative, while trends in gaps based on standardized math and science achievement and based on reading achievement (standardized or unstandardized) are more consistently positive. This is likely due to substantial declines in the variance of PISA math and science scores (see Appendix C). Additionally, for all three PISA subject tests, trends in gaps based on parent education are negative. Further analysis shows that this pattern may be due to problems in the measurement of parent education in the PISA student survey (see Appendix H). Therefore, with the exception of some = unreliable trends, positive increases in SES achievement gaps over time are quite robust across the different test instruments that are combined in the main text of the paper.

Table B1. Coefficients from Hierarchical Growth Models Predicting Achievement Gaps between 90th and 10th Percentiles of SES, Run Separately by Test Instrument (Unstandardized Achievement) – PISA and PIRLS

Test instrument	PISA Math		PISA Reading		PISA Science		PIRLS Reading	
Test years	2003-2015		2000-2015		2006-2015		2001-2011	
Cohort birth years	1988-2000		1985-2000		1991-2000		1991-2001	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Parent education gaps intercept	88.580 ***	86.591 ***	85.725 ***	82.817 ***	92.806 ***	86.595 ***	76.698 ***	78.551 ***
	(3.696)	(3.381)	(3.337)	(3.130)	(4.189)	(3.472)	(3.715)	(3.840)
Parent occupation gaps intercept	86.131 ***	85.944 ***	83.782 ***	84.089 ***	84.459 ***	85.742 ***	68.610 ***	68.730 ***
	(3.328)	(3.278)	(3.180)	(3.193)	(3.602)	(3.620)	(3.579)	(3.447)
Household books gaps intercept	127.448 ***	127.860 ***	125.759 ***	128.238 ***	132.753 ***	132.500 ***	87.755 ***	86.356 ***
	(4.460)	(4.364)	(4.230)	(4.380)	(5.621)	(5.252)	(3.864)	(3.975)
Cohort birth year × Parent education	-0.491 *		-0.374 *		-0.865 **		0.769 +	
	(0.225)		(0.188)		(0.263)		(0.407)	
Cohort birth year × Parent occupation	-0.288 +		0.049		-0.124		0.507	
	(0.173)		(0.172)		(0.189)		(0.358)	
Cohort birth year × Books	-0.206		0.377		-0.261		0.224	
	(0.272)		(0.276)		(0.286)		(0.324)	
Cohort birth year		-0.266		0.027		-0.242		0.470
		(0.174)		(0.174)		(0.194)		(0.319)
N (Level 1 - gaps)	893	893	1030	1030	764	764	300	300
N (Level 2 - study-years)	298	298	344	344	255	255	103	103
N (Level 3 - countries)	70	70	72	72	70	70	41	41

+ p<.1, * p<.05, ** p<.01, *** p < .001. Note: To avoid very long computation times, all models in this table specify known level 1 error variances estimated using conventional non-bootstrap formulas and omit error covariances. This simplified specification appears to produce very similar results to models using bootstrapped error variances and covariances (see Appendix L).

Table B2. Coefficients from Hierarchical Growth Models Predicting Achievement Gaps between 90th and 10th Percentiles of SES, Run Separately by Test Instrument (Unstandardized Achievement) – TIMSS

Test instrument	TIMSS Grade 4 Math		TIMSS Grade 4 Science		TIMSS Grade 8 Math		TIMSS Grade 8 Science	
Test years	1995-2015		1995-2015		1995-2015		1995-2015	
Cohort birth years	1985-2005		1985-2005		1981-2001		1981-2001	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Parent education gaps intercept					70.929 ***	70.212 ***	70.426 ***	68.680 ***
					(3.629)	(3.561)	(4.224)	(3.998)
Household books gaps intercept	74.438 ***	74.438 ***	80.765 ***	80.765 ***	80.117 ***	80.820 ***	81.421 ***	83.011 ***
	(4.988)	(4.988)	(5.859)	(5.859)	(4.473)	(4.505)	(5.034)	(5.132)
Cohort birth year × Parent education					1.225 ***		1.267 ***	
					(0.255)		(0.269)	
Cohort birth year × Books	0.775 **		0.682 *		1.389 ***		1.591 ***	
	(0.275)		(0.312)		(0.309)		(0.271)	
Cohort birth year		0.775 **		0.682 *		1.318 ***		1.450 ***
		(0.275)		(0.312)		(0.257)		(0.240)
N (Level 1 - gaps)	163	163	165	165	485	485	485	485
N (Level 2 - study-years)	163	163	165	165	245	245	245	245
N (Level 3 - countries)	49	49	50	50	61	61	61	61

+ p<.1, * p<.05, ** p<.01, *** p < .001. Note: To avoid very long computation times, all models in this table specify known level 1 error variances estimated using conventional non-bootstrap formulas and omit error covariances. This simplified specification appears to produce very similar results to models using bootstrapped error variances and covariances (see Appendix L).

Table B3. Coefficients from Hierarchical Growth Models Predicting Achievement Gaps between 90th and 10th Percentiles of SES, Run Separately by Test Instrument (Standardized Achievement) – PISA and PIRLS

Test instrument	PISA Math		PISA Reading		PISA Science		PIRLS Reading	
Test years	2003-2015		2000-2015		2006-2015		2001-2011	
Cohort birth years	1988-2000		1985-2000		1991-2000		1991-2001	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Parent education gaps intercept	1.000 ***	0.972 ***	0.946 ***	0.912 ***	1.044 ***	0.980 ***	1.042 ***	1.066 ***
	(0.037)	(0.034)	(0.032)	(0.030)	(0.041)	(0.034)	(0.043)	(0.039)
Parent occupation gaps intercept	0.971 ***	0.964 ***	0.923 ***	0.925 ***	0.953 ***	0.968 ***	0.928 ***	0.934 ***
	(0.034)	(0.033)	(0.029)	(0.029)	(0.034)	(0.034)	(0.043)	(0.040)
Household books gaps intercept	1.438 ***	1.455 ***	1.401 ***	1.424 ***	1.506 ***	1.505 ***	1.209 ***	1.192 ***
	(0.044)	(0.043)	(0.040)	(0.042)	(0.051)	(0.048)	(0.041)	(0.046)
Cohort birth year × Parent education	-0.001		-0.002		-0.007 **		0.013 **	
	(0.002)		(0.002)		(0.003)		(0.004)	
Cohort birth year × Parent occupation	0.001		0.002		0.001		0.010 **	
	(0.002)		(0.002)		(0.002)		(0.004)	
Cohort birth year × Books	0.004		0.006 *		-0.001		0.006	
	(0.003)		(0.003)		(0.002)		(0.004)	
Cohort birth year		0.002		0.002 +		-0.001		0.009 **
		(0.002)		(0.001)		(0.002)		(0.003)
N (Level 1 - gaps)	893	893	1030	1030	764	764	300	300
N (Level 2 - study-years)	298	298	344	344	255	255	103	103
N (Level 3 - countries)	70	70	72	72	70	70	41	41

+ p<.1, * p<.05, ** p<.01, *** p < .001. Note: To avoid very long computation times, all models in this table specify known level 1 error variances estimated using conventional non-bootstrap formulas and omit error covariances. This simplified specification appears to produce very similar results to models using bootstrapped error variances and covariances (see Appendix L).

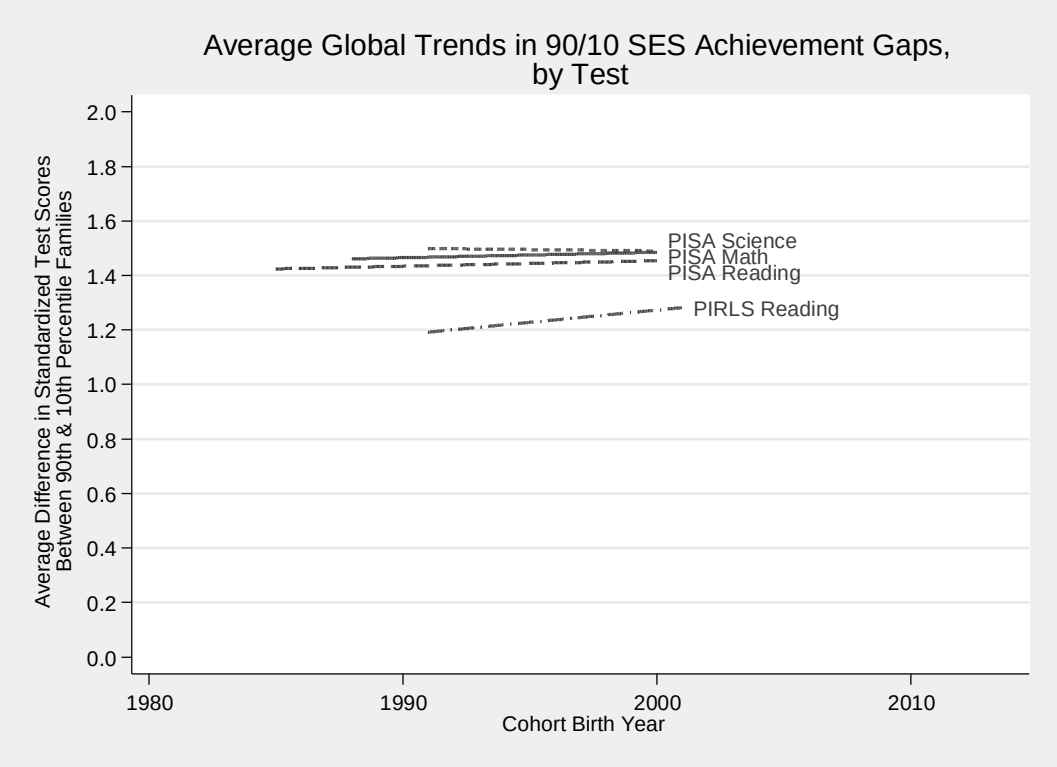
Table B4. Coefficients from Hierarchical Growth Models Predicting Achievement Gaps between 90th and 10th Percentiles of SES, Run Separately by Test Instrument (Standardized Achievement) – TIMSS

Test instrument	TIMSS Grade 4 Math		TIMSS Grade 4 Science		TIMSS Grade 8 Math		TIMSS Grade 8 Science	
Test years	1995-2015		1995-2015		1995-2015		1995-2015	
Cohort birth years	1985-2005		1985-2005		1981-2001		1981-2001	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Parent education gaps intercept					0.933 ***	0.934 ***	0.927 ***	0.918 ***
					(0.044)	(0.042)	(0.049)	(0.043)
Household books gaps intercept	1.011 ***	1.011 ***	1.046 ***	1.046 ***	1.066 ***	1.068 ***	1.100 ***	1.113 ***
	(0.068)	(0.068)	(0.077)	(0.077)	(0.052)	(0.053)	(0.058)	(0.061)
Cohort birth year × Parent education					0.012 ***		0.013 ***	
					(0.003)		(0.003)	
Cohort birth year × Books	0.013 ***		0.015 ***		0.013 ***		0.016 ***	
	(0.004)		(0.004)		(0.003)		(0.003)	
Cohort birth year		0.013 ***		0.015 ***		0.013 ***		0.014 ***
		(0.004)		(0.004)		(0.003)		(0.002)
N (Level 1 - gaps)	163	163	165	165	485	485	485	485
N (Level 2 - study-years)	163	163	165	165	245	245	245	245
N (Level 3 - countries)	49	49	50	50	61	61	61	61

+ p<.1, * p<.05, ** p<.01, *** p < .001. Note: To avoid very long computation times, all models in this table specify known level 1 error variances estimated using conventional non-bootstrap formulas and omit error covariances. This simplified specification appears to produce very similar results to models using bootstrapped error variances and covariances (see Appendix L).

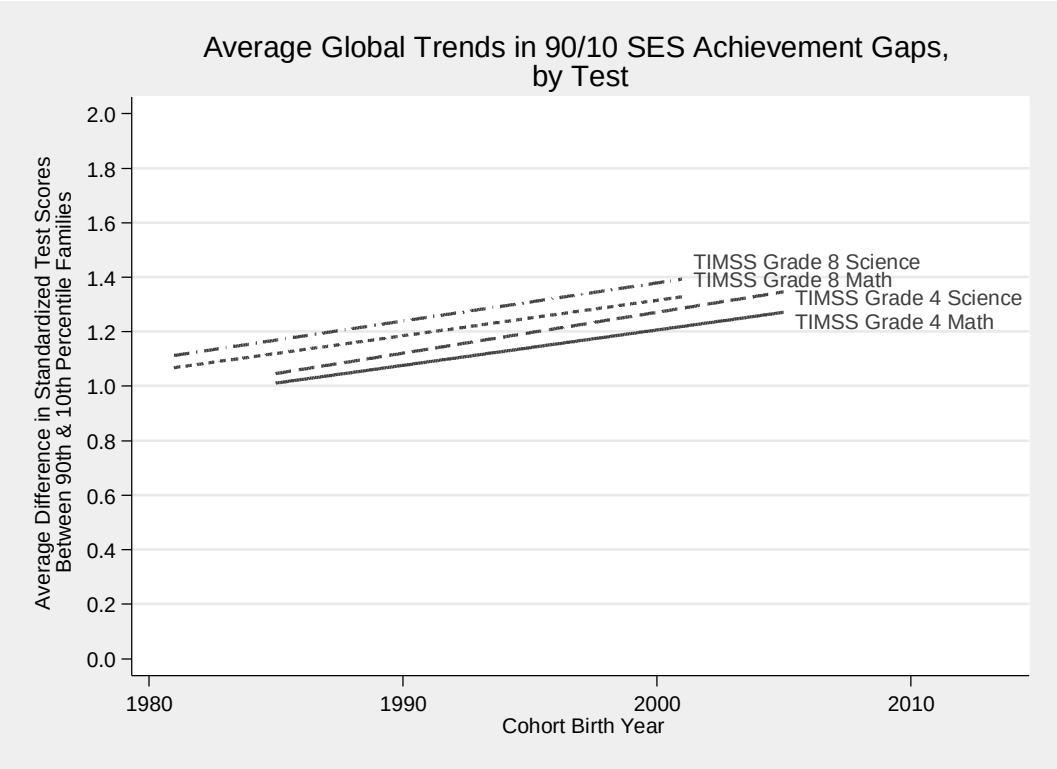
Figures B1 and B2 illustrate average global trends in 90/10 SES achievement gaps for each of the eight test instruments, estimated from the cohort birth year slope in Model 2 (based on standardized achievement). Figure B1 displays cohort slopes for the four instruments in Table B3, and Figure B2 displays cohort slopes for the four instruments in Table B4. The figures show that trends for all test instruments are positive except for PISA science, which is the PISA instrument that is available for the shortest span of cohort years. The trend in SES gaps for PISA science scores is very close to flat.

Figure B1



Note: Trend lines are estimates from Table B3, setting SES variable equal to parent education.

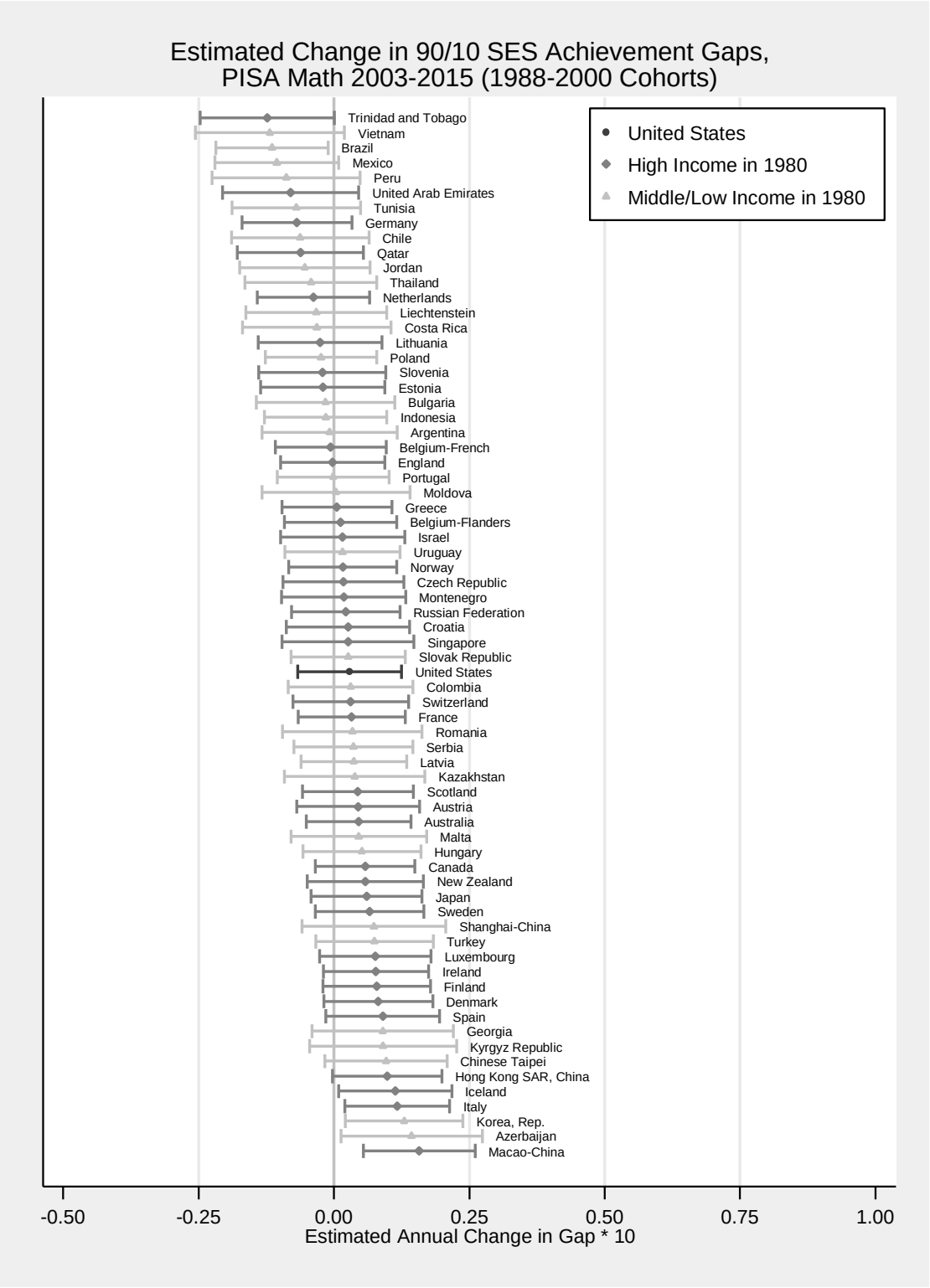
Figure B2



Note: Trend lines are estimates from Table B4, setting SES variable equal to parent education.

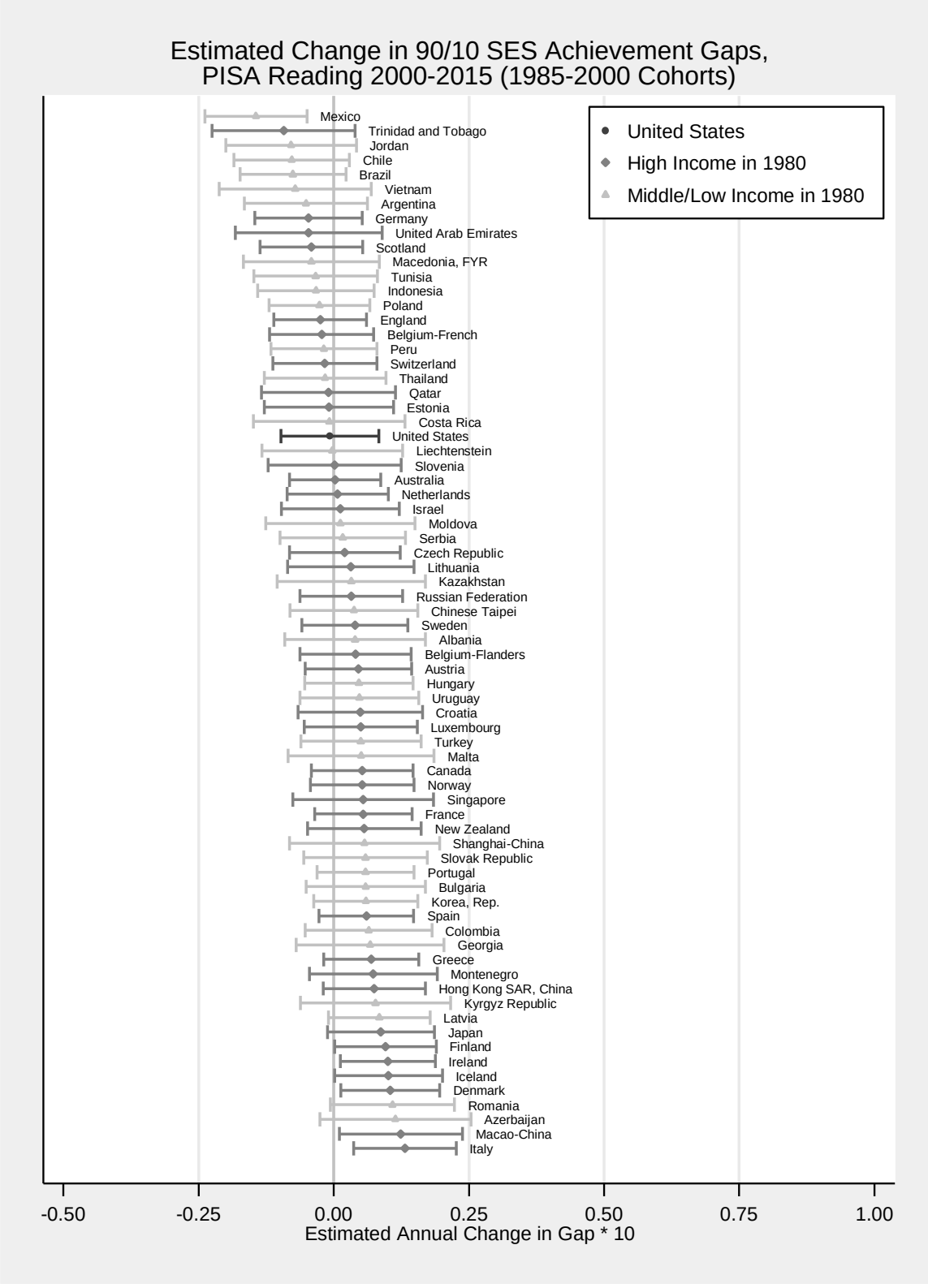
Figures B3-B10 show how the trends for each test instrument vary across countries. For each of the eight test instruments, the figure plots the estimated cohort trend for all included countries, which are derived from shrunken empirical Bayes estimates from Model 2 in Tables B3 and B4 (based on standardized achievement). For all eight figures, the estimated country annual changes in gaps are multiplied by 10 for ease of interpretation. Brackets represent 95% confidence intervals. The figures show that for all test instruments except PISA science, the majority of countries experience increasing SES achievement gaps (the estimate is greater than 0). However, estimated trends are not significant for most countries.

Figure B3



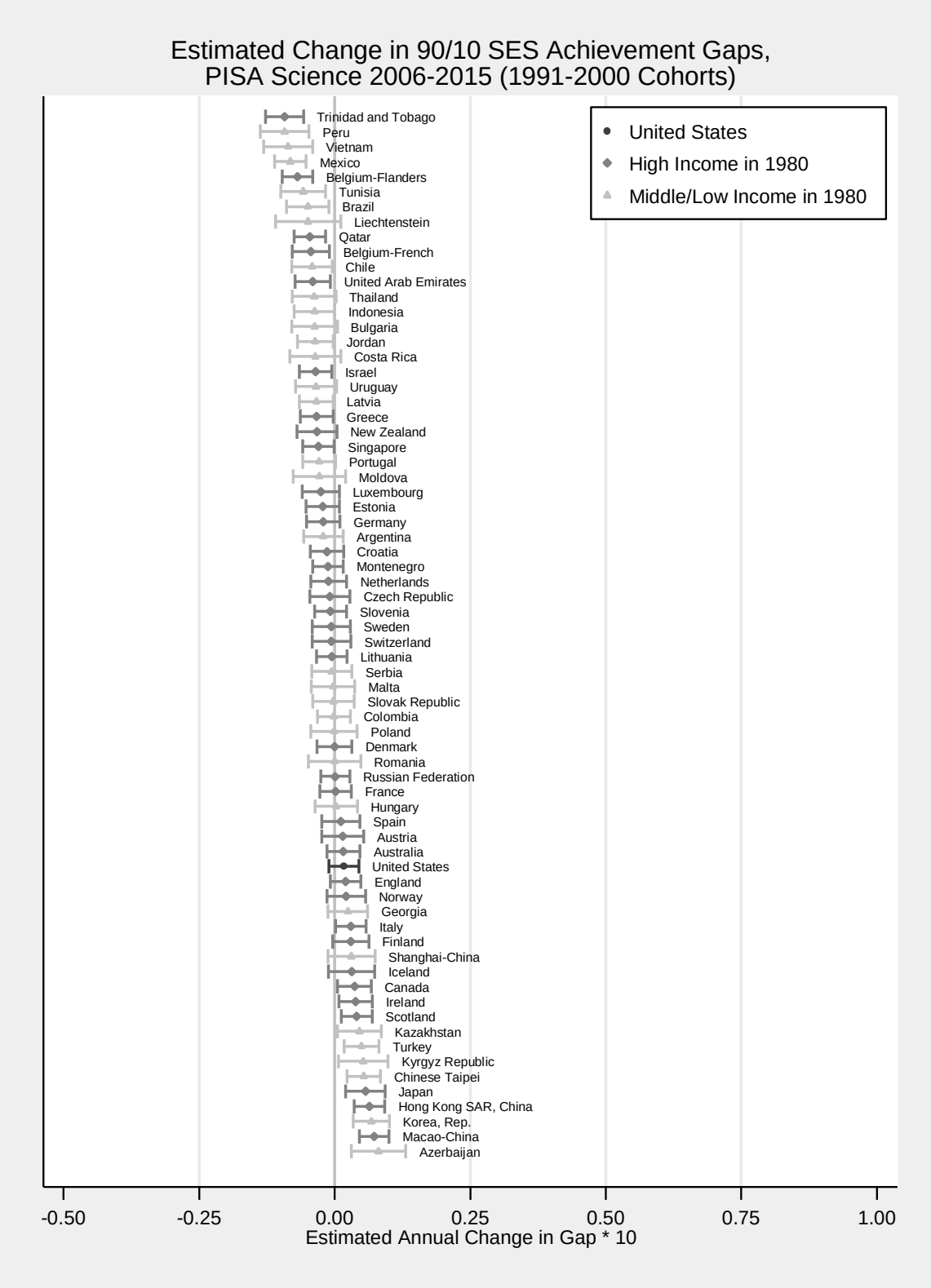
Note: Counties sorted according to size of trend estimate. Trends are derived from shrunken empirical Bayes estimates from Table B3.

Figure B4



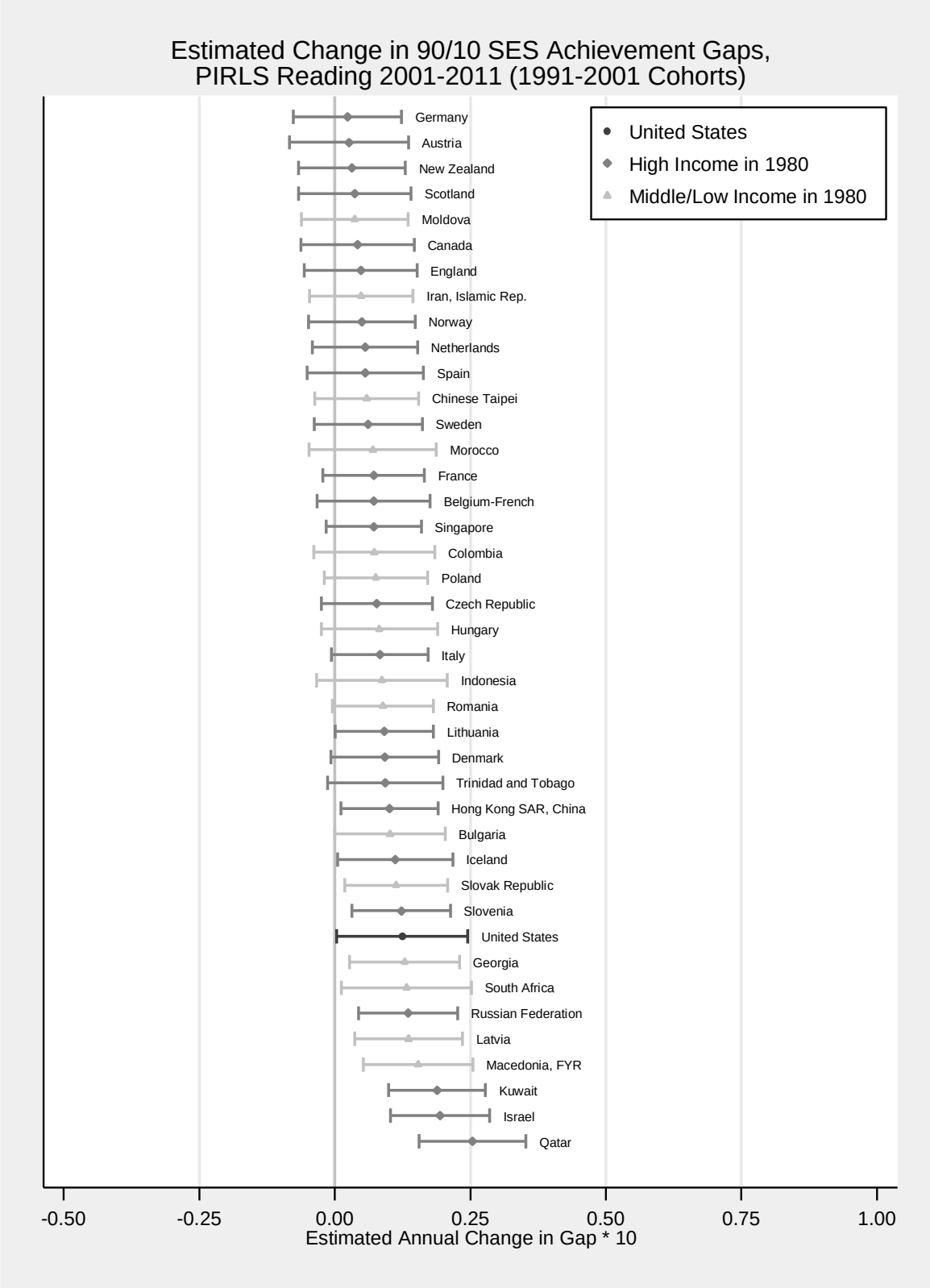
Note: Counties sorted according to size of trend estimate. Trends are derived from shrunken empirical Bayes estimates from Table B3.

Figure B5



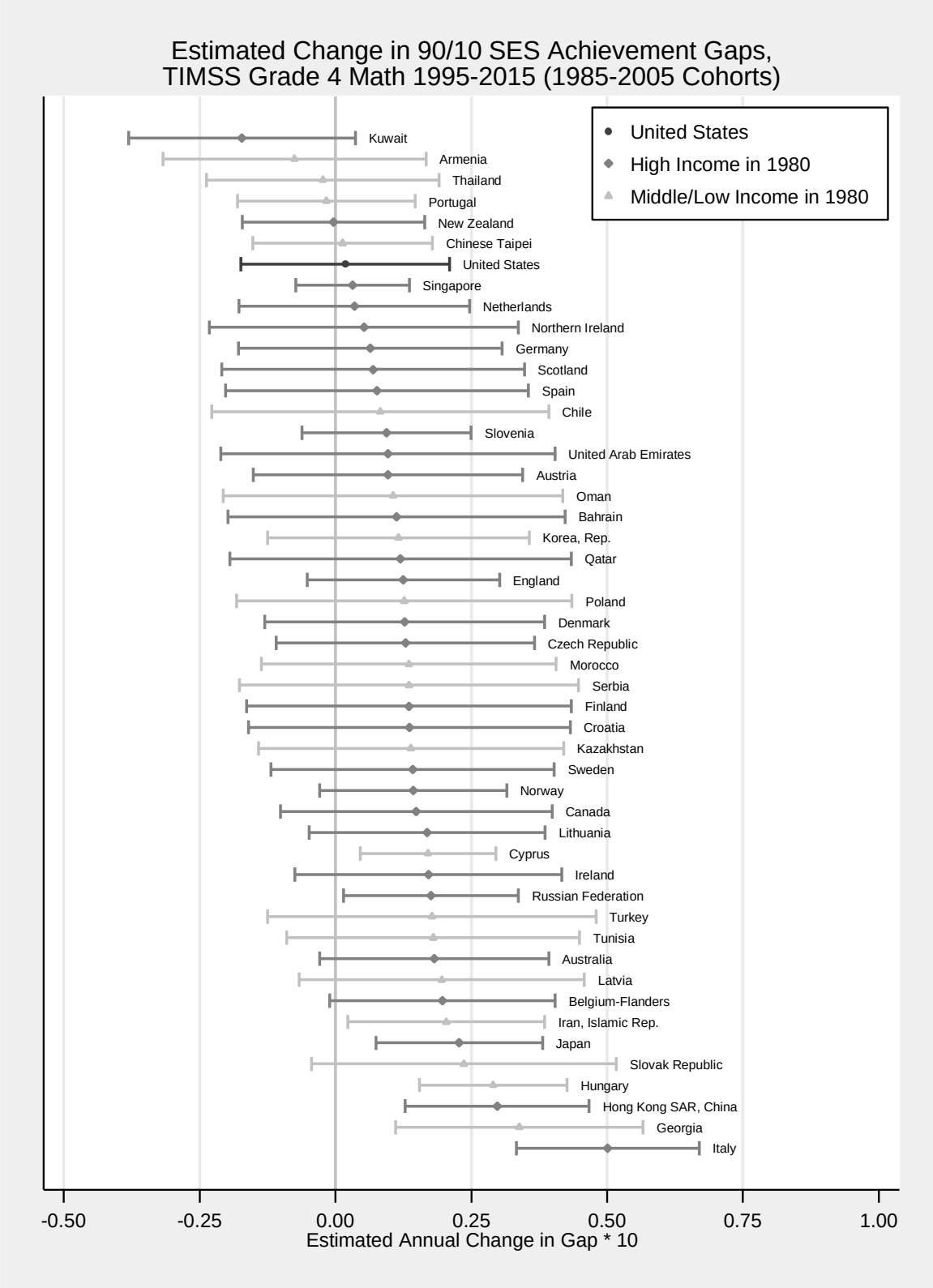
Note: Counties sorted according to size of trend estimate. Trends are derived from shrunken empirical Bayes estimates from Table B3.

Figure B6



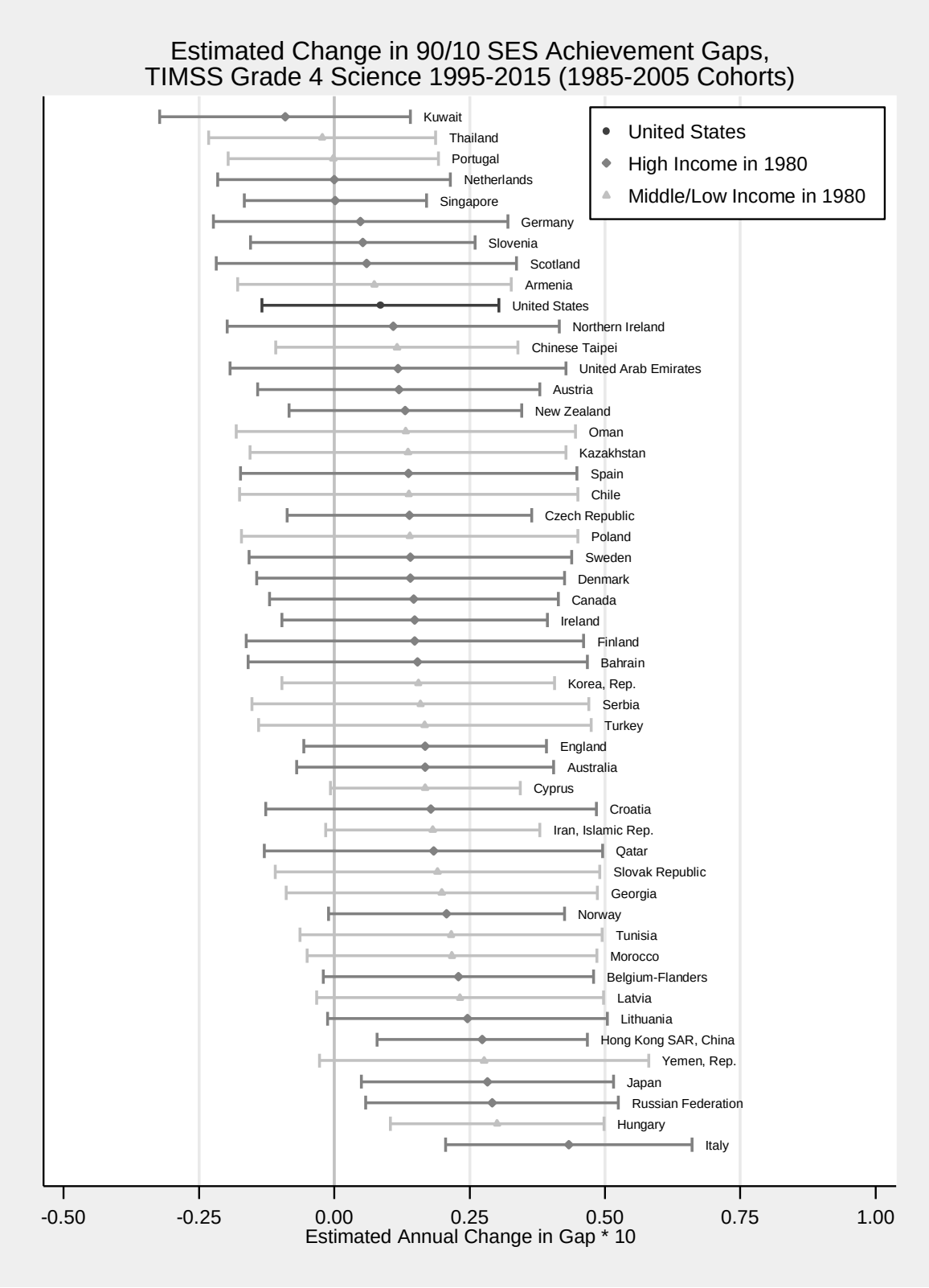
Note: Counties sorted according to size of trend estimate. Trends are derived from shrunken empirical Bayes estimates from Table B3.

Figure B7



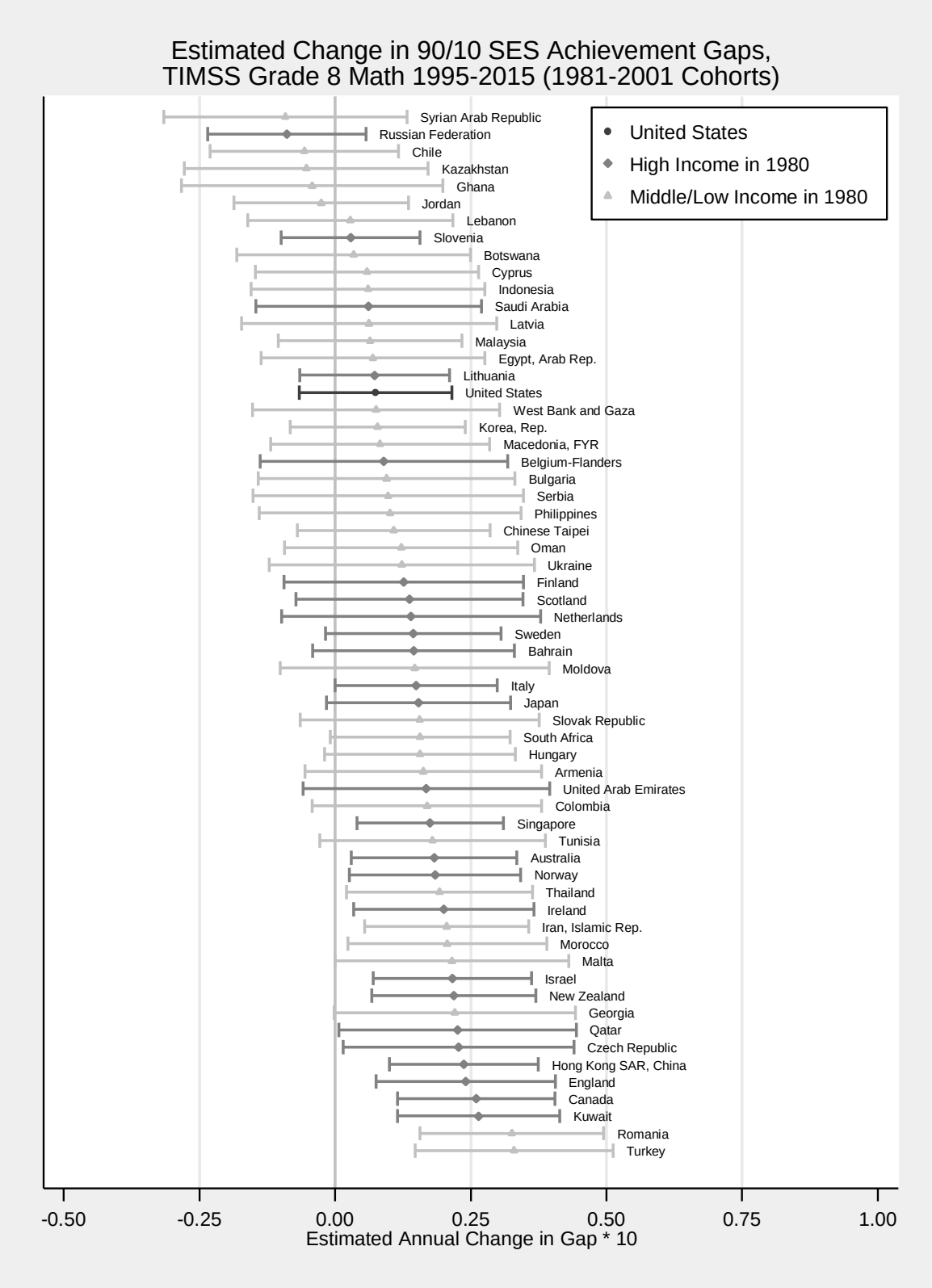
Note: Counties sorted according to size of trend estimate. Trends are derived from shrunken empirical Bayes estimates from Table B4.

Figure B8



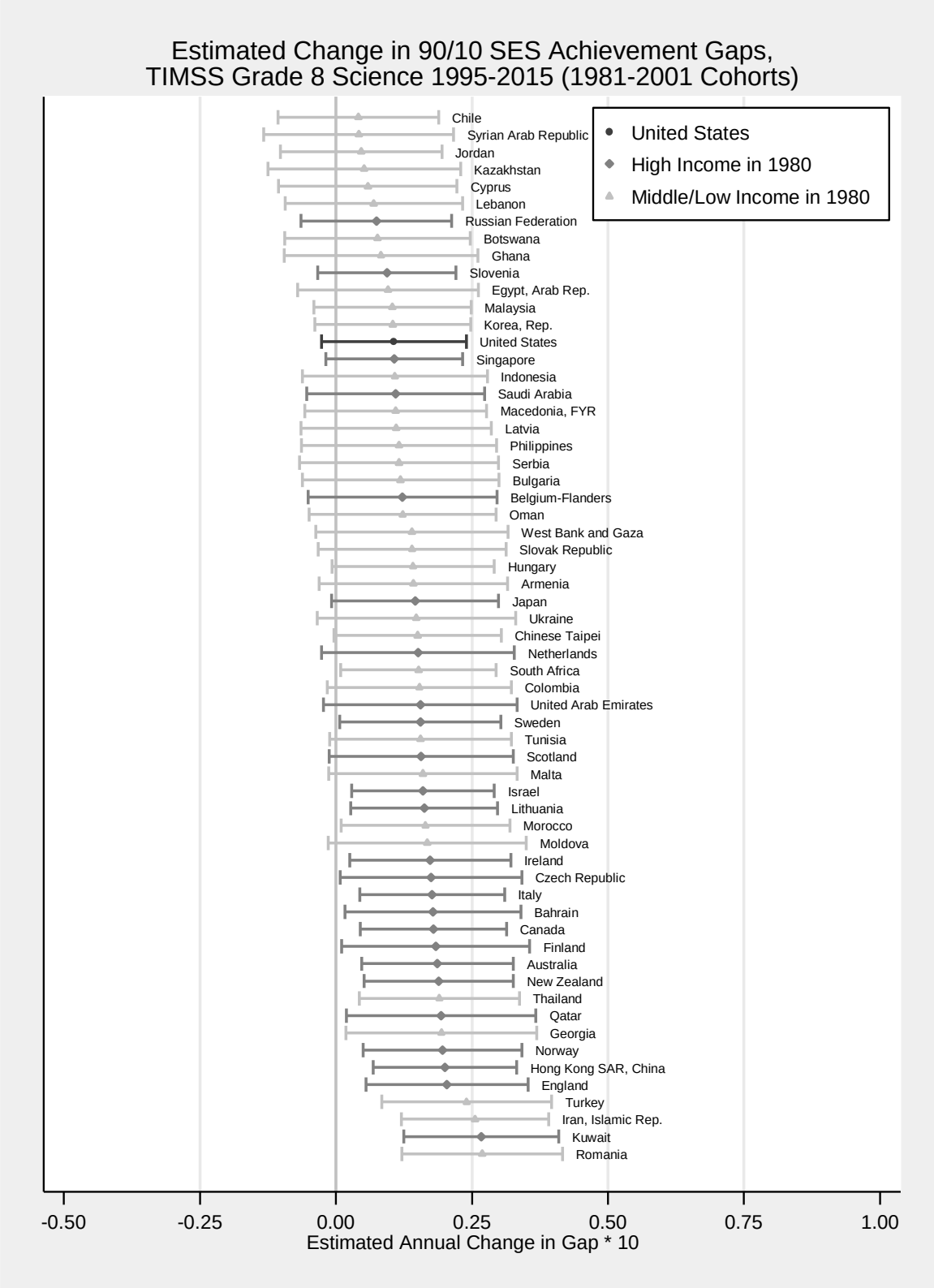
Note: Counties sorted according to size of trend estimate. Trends are derived from shrunken empirical Bayes estimates from Table B4.

Figure B9



Note: Counties sorted according to size of trend estimate. Trends are derived from shrunken empirical Bayes estimates from Table B4.

Figure B10



Note: Counties sorted according to size of trend estimate. Trends are derived from shrunken empirical Bayes estimates from Table B4.

C. Changing distribution of achievement

Tables B1-B4 report trends estimated using both unstandardized and standardized achievement in order to address a further concern: that the variance of student achievement may be changing over time. Changes in achievement variance are not captured in models where achievement is standardized within each country-year, as in the main text of the paper or Tables B3 and B4, nor in models where achievement is converted into ranks, as in Appendix N. As a result, estimated trends in standardized achievement measure changes in the relative *strength* of the SES-achievement association (e.g., the correlation) rather than the absolute *size* of the association. This decision was necessary as the models in the main text combine achievement from different studies. However, it is not immediately clear whether we should prefer to know the strength or the absolute size of the SES-achievement association. On the one hand, the strength may be preferred because it is not confounded with changes in the variance of student achievement (all else equal, if the variance of an outcome variable—achievement—increases, then its unstandardized association with an independent variable—SES—will increase; if the variance of the outcome decreases, then its unstandardized association with the independent variable will decrease). On the other hand, the absolute size of the association may be preferred because it captures whether the results are meaningful in terms of the skills that students have.

In contrast to the main analyses that pool different studies, in separate analyses of trend studies (PISA, TIMSS, PIRLS), it is possible to estimate whether the variance of student achievement has changed over time. Figures C1-C8 display score variance at the student, school/classroom, and country levels for each year of each trend study, estimated from separate three-level hierarchical models, as follows:

$$\hat{T}_{ij} = \gamma_{00} + v_k + u_{jk} + \epsilon_{ijk},$$
$$v_k \sim N(0, \tau_{000}); u_{jk} \sim N(0, \tau_{00}); \ \epsilon_{ijk} \sim N(0, \sigma^2),$$

[C1]

where $\hat{T}_{ijk}$ is the estimated test score of student *i* in school or classroom *j* in country k, τ_{000} is the between-country variance of scores, τ_{00} is the between-school variance of scores, and σ^2 is the within-school student-level variance of scores. Total student weights are applied at the student level, meaning all students are weighted in proportion to their probability of selection, and all countries are weighted in proportion to the size of their target population (i.e., more populous countries receive greater weight). Models are estimated once for each plausible value and averaged. Only countries that participated in all years of a given trend study are included. Samples of included countries vary depending on the study. After estimating the student-, school/classroom-, and country-level variances, all three are adjusted for estimated test reliability (α) for the relevant set of countries in each year, as follows:

$$\sigma^2_{True} = \alpha * \sigma^2_{Total}$$

[C2]

Figure C1

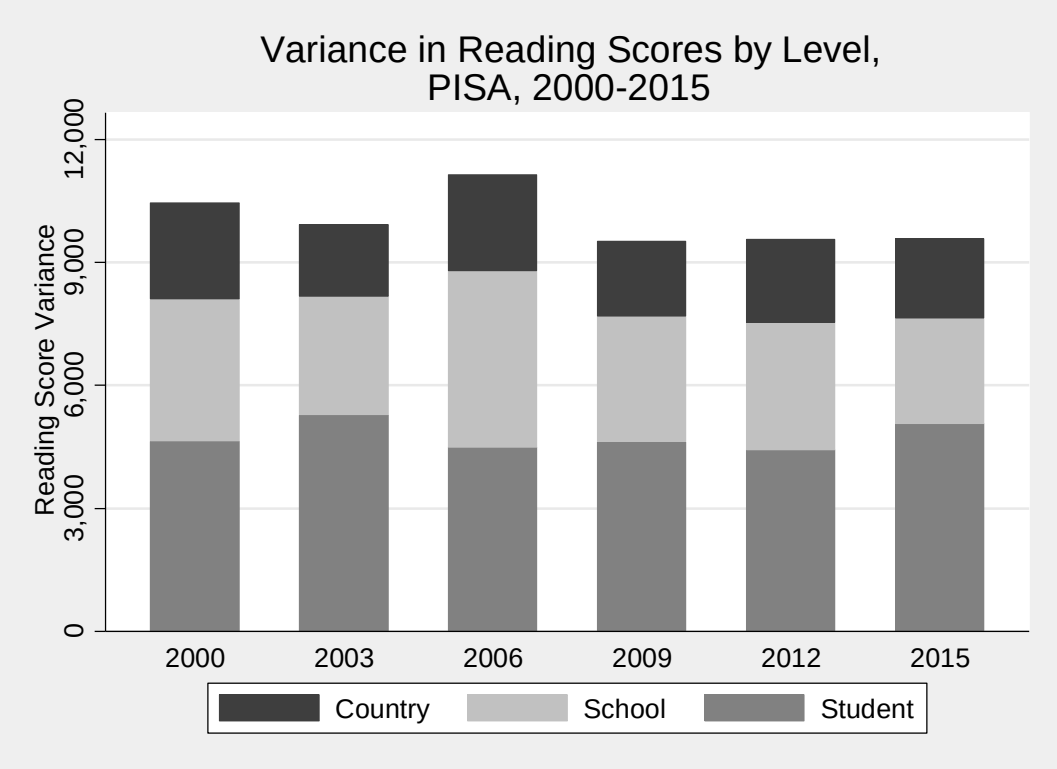


Figure C2

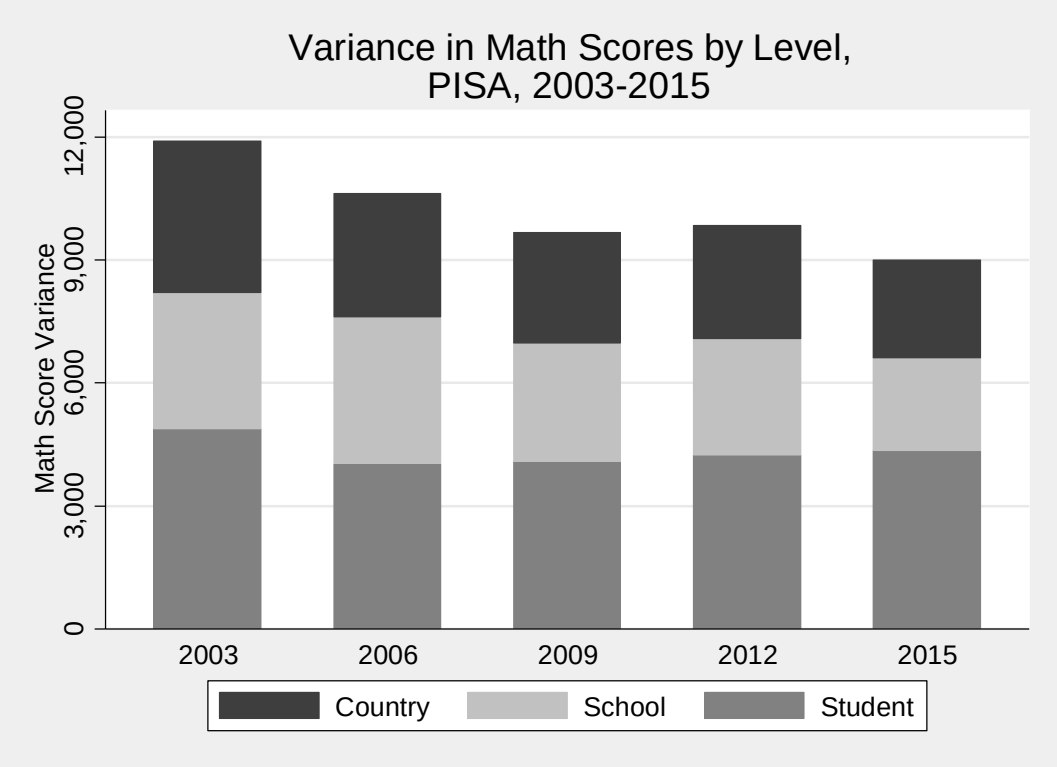


Figure C3

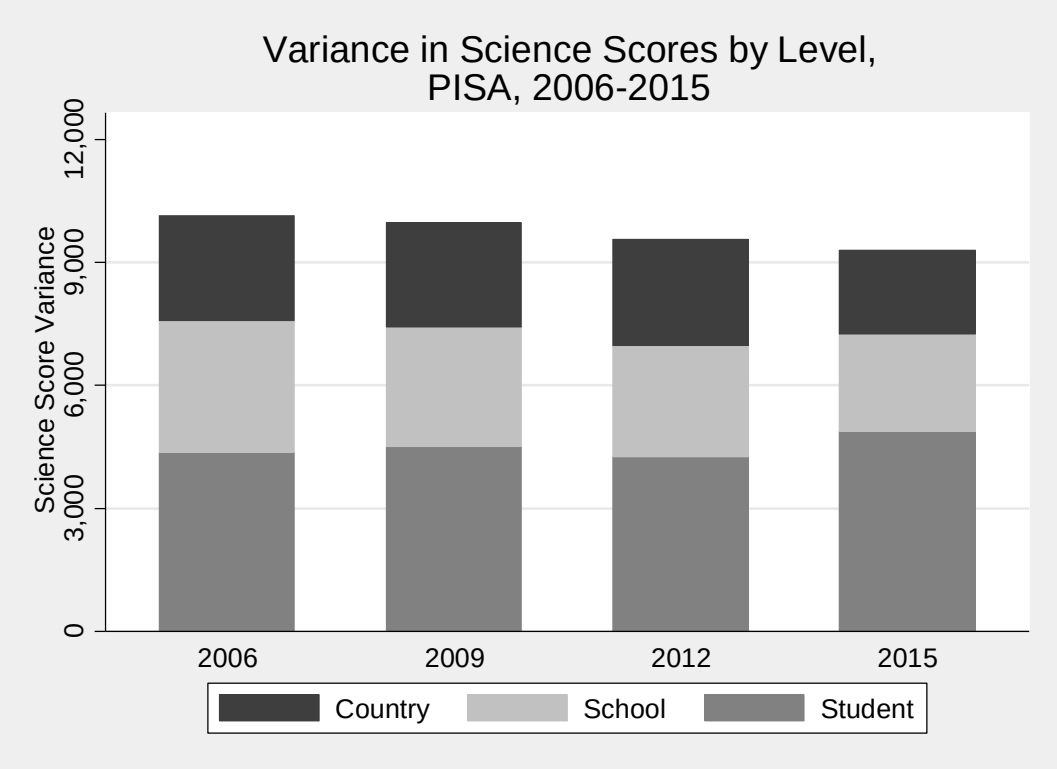


Figure C4

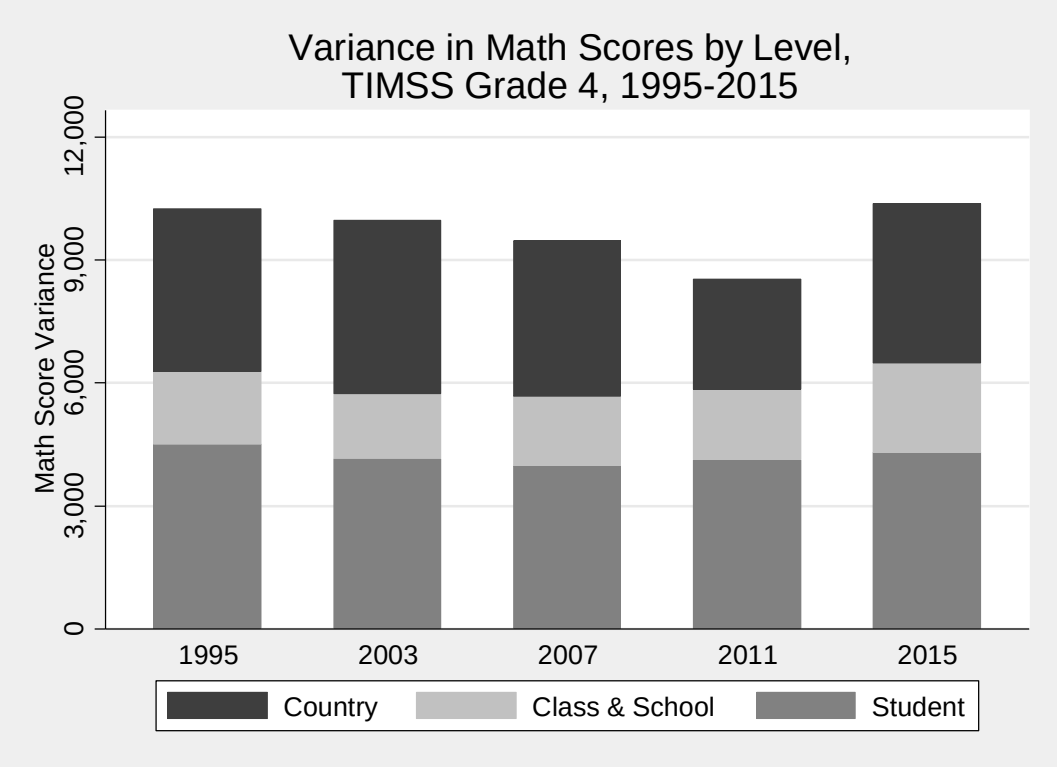


Figure C5

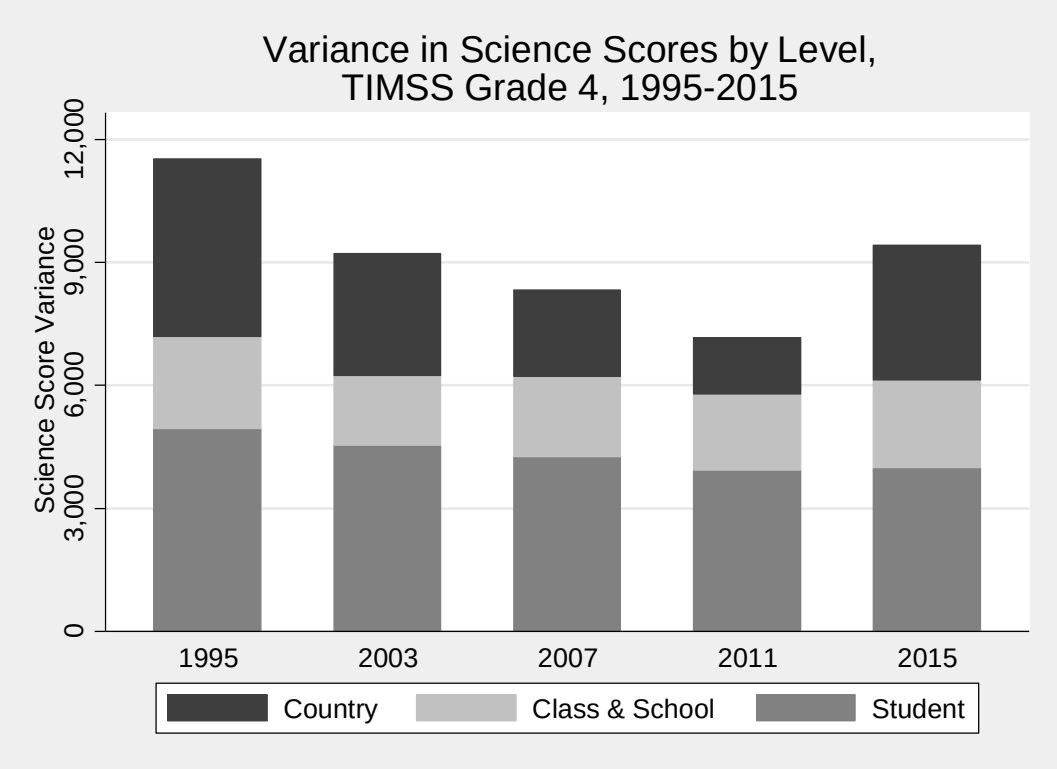


Figure C6

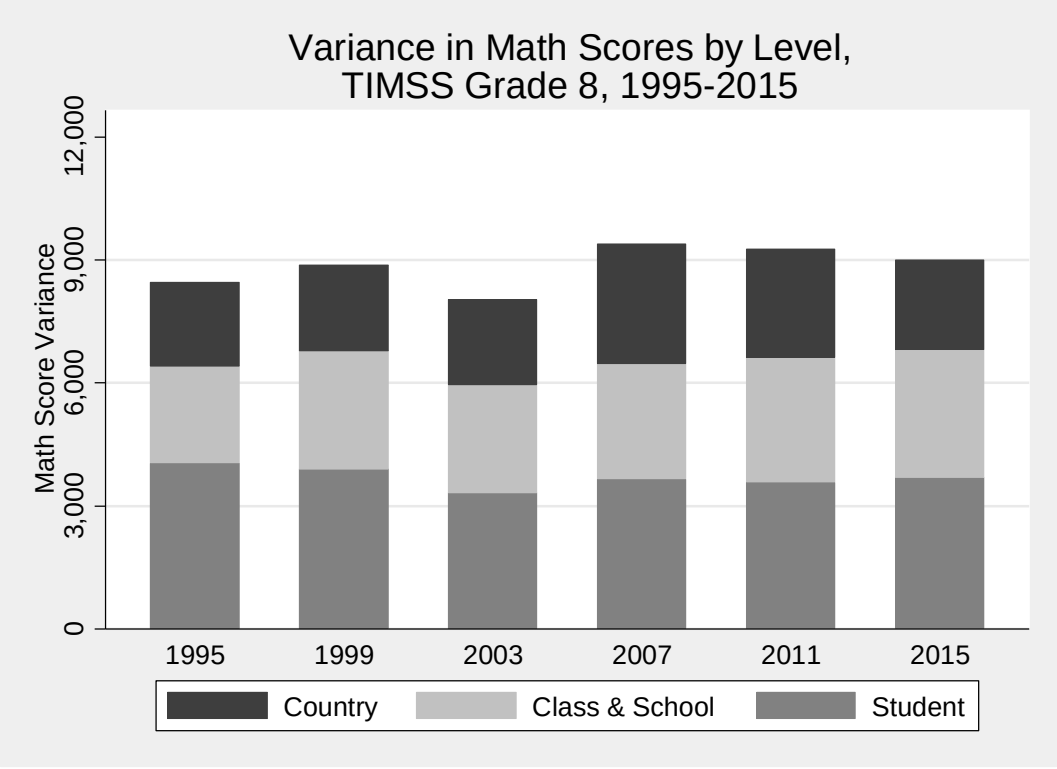


Figure C7

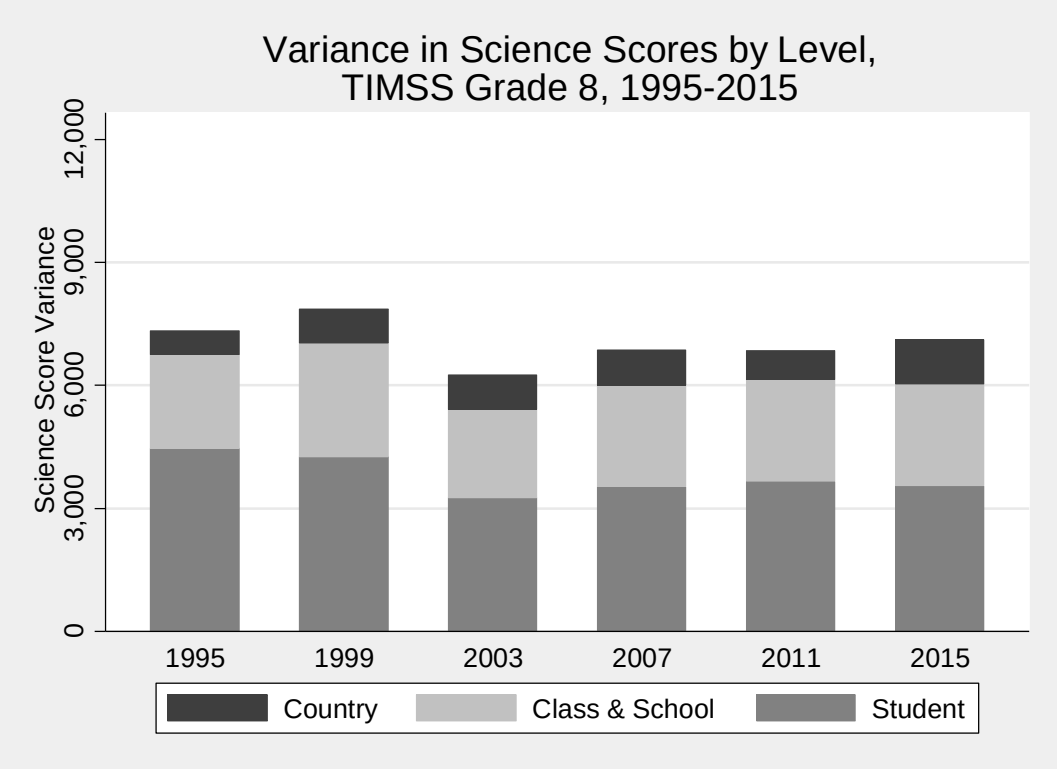
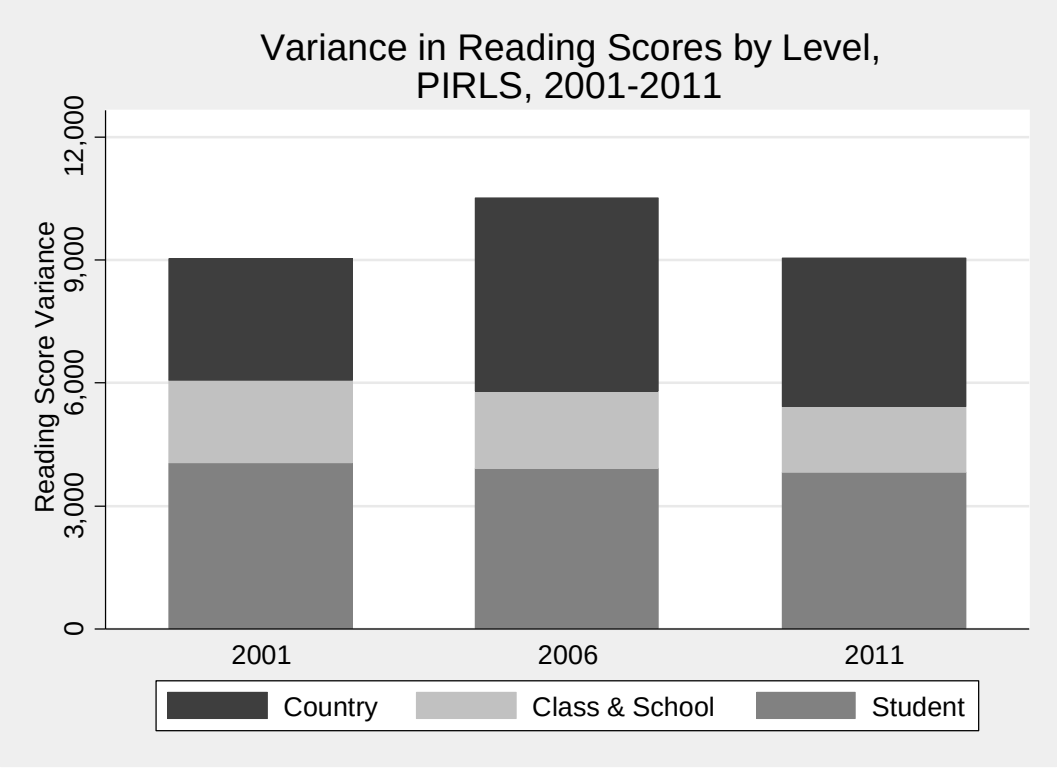


Figure C8



The hierarchal models reveal that within-country test score variance (the sum of the student- and school/classroom-level variances) has declined for all test instruments except TIMSS math (4th and 8th grades). These decreases in variance might lead us to question whether the absolute *size* of SES achievement gaps in terms of skills is declining even as their *strength* increases. However, the results for unstandardized achievement in Tables B1 and B2 show positive trends for most test instruments (except for PISA math and science). This indicates that, for the specific sets of reading, math, and science skills tested by the trend studies, differences in the degree to which high- and low-SES students have mastered those skills have mostly grown over the past 9-20 years.

The trend studies also allow us to examine not only whether achievement gaps have truly grown in size but also the changing *levels* of achievement for students of different SES. In other words, we can ask: Do SES achievement gaps increase because low-SES students' achievement is declining or because it is not rising as quickly as that of high-SES students? A series of models addressing this question, separately for each test instrument, are estimated as follows:

$$\hat{A}_{pjk} = \boldsymbol{\alpha}_{pjk}\mathbf{T}_{pjk} + \gamma_{100}P10_{pjk} + \gamma_{010}C_{jk} + \gamma_{110}C_{jk}P10_{pjk} + \boldsymbol{u}_{p1k}\mathbf{T}_{pjk} + u_{2k}C_{jk} + u_{3k}C_{jk}P10_{pjk} + \boldsymbol{r}_{p1jk}\mathbf{T}_{pjk} + r_{2jk}P10_{pjk} + \epsilon_{pjk},$$
$$u_k \sim N(0, \boldsymbol{\tau}); r_{jk} \sim N(0, \boldsymbol{\Sigma}); \epsilon_{pjk} \sim N\left(0, V_{jk}\right), \qquad \text{[C3]}$$

where $\hat{A}_{pjk}$ is the *p*th observed mean achievement of the 90th or the 10th SES percentile in study-year *j* in country *k*, $\boldsymbol{\alpha}_{pjk}$ is a vector of the true achievement means conditional on all covariates in the model, $\mathbf{T}_{pjk}$ is a vector of dummy variables indicating gap type (parent education, parent occupation, or household books), γ_{100} is the coefficient for the dummy variable $P10_{ijk}$ indicating whether the mean achievement *p* was estimated for the 10th (1) or the 90th (0) SES percentile, γ_{010} is the coefficient for cohort birth year C_{jk}, γ_{110} is the coefficient for the interaction between cohort birth year C_{jk} and the 10th percentile dummy $P10_{pjk}$, $\boldsymbol{\Sigma}$ and $\boldsymbol{\tau}$ are the within-country and between-country covariance matrices among the true gaps, and $V_{jk} = var\left(\hat{A}_{pjk}\right)$ is the sampling variance of $\hat{A}_{pjk}$, which I compute using the squared standard error of $\hat{A}_{pjk}$.[3]

Table C1 reports these models for each test instrument. The coefficient for Cohort birth year represents the trend in achievement for the reference category, the 90th SES percentile. The interaction between Cohort birth year and the 10th percentile dummy represents the difference in achievement trends for the two SES groups.[4] The sum of these two coefficients represents the trend in achievement for the 10th SES percentile, which is reported at the bottom of the table, along with significance of a Wald joint test of the hypothesis that the sum of coefficients is equal

[3] The level-1 known-variance portion of this model accounts only for the sampling variance of $\hat{A}_{pjk}$ and not for the sampling error covariances among different mean achievement estimates within the same country-study-year. Thus, the model assumes that all sampling error covariances among different mean achievement estimates are 0, which is unlikely to be true. However, the models in the main text yield very similar results when sampling error covariances are omitted (see Appendix L). Therefore, sampling error covariances are omitted from this and most appendix models due to the very long computation time of sampling error covariances via bootstrapping.

[4] Note that if the models in Tables B1 and C1 were simple OLS regression models, the coefficients for the Cohort birth year*p10 interactions in Table C1 would be equal to the Cohort birth year trends in the gaps in Table B1, but opposite in sign. This is not true in the reported models due to the precision weighting and random cohort slopes in the hierarchical growth models. However, estimated coefficients are generally similar in size and opposite in sign across Tables B1 and C1.

to 0. On average, the achievement of both high- and low-SES students has increased in all test instruments. However, in most test instruments, the achievement of low-SES students has increased by a smaller amount than that of high-SES students. The two exceptions are PISA math and science, where the achievement of low-SES students has increased more than that of high-SES students, consistent with declining SES achievement gaps for these test instruments when achievement is unstandardized, seen in Table B1. Thus, the results for the majority of test instruments show that SES achievement gaps are increasing not because low-SES students' achievement is declining, but because it is not rising as quickly as that of high-SES students.

Table C1. Models Predicting Achievement Levels for 90th and 10th SES Percentiles, Run Separately by Test Instrument

Test instrument	PISA Math	PISA Reading	PISA Science	PIRLS Reading	TIMSS Grade 4 Math	TIMSS Grade 4 Science	TIMSS Grade 8 Math	TIMSS Grade 8 Science
Test years	2003-2015	2000-2015	2006-2015	2001-2011	1995-2015	1995-2015	1995-2015	1995-2015
Cohort birth years	1988-2000	1985-2000	1991-2000	1991-2001	1985-2005	1985-2005	1981-2001	1981-2001
Parent education gaps intercept	507.127 ***	494.311 ***	513.236 ***	525.820 ***			482.550 ***	491.766 ***
	(8.761)	(7.744)	(8.354)	(10.582)			(11.904)	(10.809)
Parent occupation gaps intercept	506.873 ***	494.334 ***	512.779 ***	525.935 ***				
	(8.675)	(7.665)	(8.252)	(10.573)				
Household books gaps intercept	505.730 ***	492.764 ***	511.313 ***	525.379 ***	493.917 ***	497.314 ***	480.153 ***	489.396 ***
	(8.629)	(7.656)	(8.212)	(10.562)	(11.616)	(12.110)	(11.804)	(10.821)
p10	-81.823 ***	-78.787 ***	-83.919 ***	-63.540 ***	-49.020 ***	-55.704 ***	-54.590 ***	-54.802 ***
	(2.872)	(2.622)	(3.334)	(2.800)	(3.684)	(4.240)	(3.073)	(3.563)
Cohort birth year	0.167	0.841 ***	0.018	1.836 ***	1.444 ***	1.194 ***	1.297 ***	1.317 ***
	(0.252)	(0.241)	(0.254)	(0.531)	(0.323)	(0.327)	(0.374)	(0.362)
Cohort birth year × p10	0.294 +	-0.023	0.377 +	-0.530 *	-0.448 *	-0.273	-1.146 ***	-1.295 ***
	(0.166)	(0.158)	(0.201)	(0.248)	(0.209)	(0.232)	(0.198)	(0.185)
N (Level 1 - gaps)	1786	2060	1528	602	340	340	970	970
N (Level 2 - study-years)	298	344	255	104	170	170	245	245
N (Level 3 - countries)	70	72	70	41	51	51	61	61
	Wald test	Wald test	Wald test	Wald test	Wald test	Wald test	Wald test	Wald test
Estimated cohort birth year slope for p10	0.461 +	0.818 **	0.395	1.306 *	0.996 **	0.921 **	0.151	0.022
	(0.282)	(0.252)	(0.261)	(0.509)	(0.338)	(0.337)	(0.360)	(0.350)

+ p<.1, * p<.05, ** p<.01, *** p < .001. Note: To avoid very long computation times, all models in this table specify known level 1 error variances estimated using conventional non-bootstrap formulas and omit error covariances. This simplified specification appears to produce very similar results to models using bootstrapped error variances and covariances (see Appendix L).

D. Changing measurement error of achievement

Even assuming the true variance of achievement had remained constant over time, if measurement error of achievement declines over time (e.g., because of improvements in testing methodology), the SES achievement gap estimates in the main text of the paper will artificially appear to increase because they were attenuated in early years where measurement error was higher. This is because the method of standardizing achievement in each country-year involves dividing by the standard deviation of achievement, which will be inflated due to measurement error. That SES achievement gaps are also increasing for most of the unstandardized scores reported in Appendix B is evidence that findings are robust, even when not standardizing achievement.

Tables D1-D3 report median, minimum, and maximum test reliabilities by age group for math, reading, and science tests. Median test reliabilities have not consistently increased over time for all test subjects and age groups. Reliabilities have increased for 4th grade tests and for secondary science tests, but appear to have declined somewhat for secondary math and reading tests. However, it should be kept in mind that the sample of countries participating in international assessments has become more diverse over time, and countries at a lower level of development often have lower test reliabilities.

Table D1. Median, Minimum, and Maximum Test Reliability for Math Tests

Study	Year	Median	Minimum	Maximum
		Grade 4 Math		
TIMSS	1995	0.84	0.74	0.88
TIMSS	2003	0.87	0.76	0.91
TIMSS	2007	0.83	0.55	0.88
TIMSS	2011	0.82	0.57	0.89
TIMSS	2015	0.88	0.78	0.92
		Grade 8 Math		
FIMS	1964	0.92	0.87	0.95
SIMS[a]	1980	0.85[a]	0.81[a]	0.85[a]
TIMSS	1995	0.89	0.73	0.92
TIMSS	1999	0.89	0.69	0.94
TIMSS	2003	0.89	0.51	0.94
TIMSS	2007	0.88	0.62	0.93
TIMSS	2011	0.87	0.66	0.94
TIMSS	2015	0.91	0.81	0.94
		Age 15 Math		
PISA	2000	0.88	0.82	0.92
PISA	2003	0.90	0.83	0.93
PISA	2006	0.88	0.83	0.93
PISA	2009	0.88	0.77	0.92
PISA	2012	0.92	0.84	0.94
PISA	2015	0.85	0.67	0.89

[a] SIMS test reliability was not reported in the available documentation and was estimated for each country using a model that included age, subject, year, and countries' level of development.

Table D2. Median, Minimum, and Maximum Test Reliability for Reading Tests

Study	Year	Median	Minimum	Maximum
Grade 4 Reading				
FIRCS	1970	0.85	0.74	0.89
RLS	1991	0.93	0.89	0.97
PIRLS	2001	0.88	0.83	0.91
PIRLS	2006	0.87	0.81	0.92
PIRLS	2011	0.88	0.79	0.93
Grade 8 Reading				
FIRCS	1970	0.85	0.64	0.90
RLS	1991	0.92	0.77	0.95
Age 15 Reading				
PISA	2000	0.92	0.87	0.94
PISA	2003	0.83	0.70	0.88
PISA	2006	0.88	0.80	0.93
PISA	2009	0.92	0.86	0.94
PISA	2012	0.89	0.81	0.93
PISA	2015	0.86	0.72	0.89

Table D3. Median, Minimum, and Maximum Test Reliability for Science Tests

Study	Year	Median	Minimum	Maximum
Grade 4 Science				
FISS	1970	0.82	0.68	0.87
SISS	1984	0.74	0.70	0.79
TIMSS	1995	0.77	0.70	0.83
TIMSS	2003	0.84	0.74	0.87
TIMSS	2007	0.80	0.69	0.88
TIMSS	2011	0.78	0.62	0.85
TIMSS	2015	0.85	0.81	0.90
Grade 8 Science				
FISS	1970	0.83	0.57	0.89
SISS	1984	0.75	0.60	0.80
TIMSS	1995	0.78	0.69	0.84
TIMSS	1999	0.80	0.62	0.86
TIMSS	2003	0.84	0.63	0.91
TIMSS	2007	0.84	0.65	0.91
TIMSS	2011	0.83	0.67	0.89
TIMSS	2015	0.89	0.81	0.92
Age 15 Science				
PISA	2000	0.87	0.75	0.92
PISA	2003	0.82	0.68	0.88
PISA	2006	0.91	0.84	0.94
PISA	2009	0.89	0.79	0.93
PISA	2012	0.89	0.80	0.93
PISA	2015	0.91	0.77	0.93

For the models in the main text of the paper, which pool different tests with different scales and must standardize achievement, all SES achievement gaps (and their standard errors) are adjusted according to each country's test reliability for each study, as published in the corresponding technical reports (as well as for the estimated reliability of SES reports, which is explained in more detail in Appendix H). The adjustment is computed as follows:

$$\widehat{Gap}_{adj} = \widehat{Gap}_{raw} * \frac{1}{\sqrt{\alpha_{ach}} * \sqrt{\alpha_{SES}}} \quad [D1]$$

Table D4 reports estimated trends in SES achievement gaps without adjusting those gaps for differences in test reliability (and also without adjusting for the reliability of SES report, which is discussed in more detail in Appendix H). Gap trends are positive and significant, and are very similar to those reported in the models in the main text. Without adjusting for reliability, the increase in parent occupation gaps is nearly identical to that reported in the main text, and increases in parent education and books gaps are slightly smaller. Gaps adjusted for reliability are preferred, as they are likely more accurate.

Table D4. Estimated trends in 90/10 SES achievement gaps, without adjusting for test or SES reliability

	Adjusted for reliability		No adjustment	
	(1)	(2)	(1)	(2)
Parent education gaps intercept	1.032 ***	1.039 ***	0.741 ***	0.744 ***
	(0.030)	(0.030)	(0.022)	(0.022)
Parent occupation gaps intercept	0.958 ***	0.964 ***	0.775 ***	0.776 ***
	(0.030)	(0.030)	(0.024)	(0.024)
Household books gaps intercept	1.299 ***	1.294 ***	0.851 ***	0.850 ***
	(0.041)	(0.041)	(0.028)	(0.028)
Level 1 - Gaps				
Subject (ref=Reading):				
Math	0.020 **	0.020 **	0.017 **	0.017 **
	(0.007)	(0.007)	(0.006)	(0.006)
Science	0.034 ***	0.034 ***	0.025 ***	0.025 ***
	(0.005)	(0.005)	(0.004)	(0.004)
SES variable quality measures				
Parent-reported × Parent education	0.132 ***	0.112 ***	0.277 ***	0.265 ***
	(0.030)	(0.031)	(0.025)	(0.026)
Parent-reported × Parent occupation	0.075 **	0.073 **	0.082 ***	0.089 ***
	(0.025)	(0.024)	(0.021)	(0.020)
Parent-reported × Books	-0.039	-0.017	0.041	0.044 +
	(0.029)	(0.026)	(0.025)	(0.023)
Number of categories (centered at 7)	0.003	0.002	0.004	0.004 +
	(0.003)	(0.003)	(0.002)	(0.002)
≥ 20% in bottom category	-0.065 **	-0.063 **	-0.057 ***	-0.057 ***
	(0.021)	(0.021)	(0.015)	(0.015)
≥ 20% in top category	-0.135 ***	-0.146 ***	-0.099 ***	-0.101 ***
	(0.013)	(0.013)	(0.009)	(0.009)
Level 2 - Study-years				
Age at testing (ref=14)				
Age 10 at testing	-0.170 ***	-0.168 ***	-0.159 ***	-0.159 ***
	(0.024)	(0.024)	(0.017)	(0.017)
Age 15 at testing	-0.024	-0.023	-0.003	-0.002
	(0.020)	(0.020)	(0.014)	(0.014)
Cohort birth year × Parent education	0.007 ***		0.005 ***	
	(0.001)		(0.001)	
Cohort birth year × Parent occupation	0.007 ***		0.007 ***	
	(0.001)		(0.001)	
Cohort birth year × Books	0.008 ***		0.006 ***	
	(0.001)		(0.001)	
Cohort birth year		0.007 ***		0.006 ***
		(0.001)		(0.001)
Random effects				
Level 2 - Residual variance between studies in...				
Parent education intercepts	0.03736	0.03831	0.0219	0.02253
Parent occupation intercepts	0.02322	0.02284	0.01498	0.01496
Books intercepts	0.03698	0.03823	0.01607	0.01618
Level 3 - Residual variance between countries in...				
Parent education intercepts	0.05426	0.05362	0.03274	0.0325
Parent occupation intercepts	0.05227	0.0533	0.03748	0.0373
Books intercepts	0.1159	0.12149	0.05473	0.05587
Parent education cohort slopes	0.00004		0.00002	
Parent occupation cohort slopes	0.00003		0.00002	
Books cohort slopes	0.00007		0.00003	
Cohort slopes		0.00003		0.00002
N (Level 1 - gaps)	5541	5541	5541	5541
N (Level 2 - study-years)	1026	1026	1026	1026
N (Level 3 - countries)	100	100	100	100

+ p<.1, * p<.05, ** p<.01, *** p < .001. Note: All models in this table specify known level 1 error variances and covariances, estimated via bootstrapping, consistent with models in the main text of the paper.

Aside from test reliability, measurement error in achievement could also decline if tests are administered in a more standardized way over time. Standardization of test administration could explain the reductions in between-country achievement variance reported in Appendix C above. The hierarchical models also found declining between-school and between-classroom achievement variance (for all trend studies except TIMSS 4th and 8th grade math), which may also be partially explained by standardization of test administration. However, achievement variance has also declined within schools and classrooms for most trend studies, and it is less clear how greater standardization of test administration could explain this change.

E. Changing distribution of SES

Educational attainment and the occupational structure have shifted dramatically in most countries since 1964. The trends reported in the main text of the paper refer to changes in the achievement gap between the 90th, 50th, and 10th percentiles of each SES variable in each country-year, even though the meaning of the 90th, 50th and 10th percentiles has changed over time. Table E1 reports the median category at which the 90th, 50th, and 10th percentiles of each SES variable fall across all participating countries in an older study and the same set of countries in PISA 2015. For parent education and occupation, the older study is FIMS 1964; for household books, it is the SISS 1984 8th grade sample, the first available high-quality measure of household books. It is clear that dramatic upgrading has occurred for both parent education and occupation during this period. However, the distribution of household books has remained more stable.

Table E1. Median Category at which 90th, 50th, and 10th SES Percentiles Fall, by Study

		FIMS 1964	PISA 2015
Parent education	90th percentile	13 years	ISCED 5A+
	50th percentile	9 years	ISCED 5B
	10th percentile	7 years	ISCED 3B, C
Parent occupation	90th percentile	Semi-Professional	Professionals
	50th percentile	Clerical & Sales	Technicians and Associate Professionals
	10th percentile	Manual Workers, Skilled & Semi-Skilled	Craft Etc Trades Workers
		SISS 1984	PISA 2015
Household books	90th percentile	251-500 books	201-500 books
	50th percentile	26-100 books	26-100 books
	10th percentile	11-25 books	0-10 books

Note: Countries included in FIMS-PISA sample (parent education and occupation) are Australia, Belgium-Flanders, Belgium-French, England, Finland, France, Germany, Israel, Japan, Netherlands, Scotland, and United States. Countries included in SISS-PISA sample (books) are Australia, Canada, England, Finland, Hong Kong, Hungary, Israel, Italy, Japan, Korea, Netherlands, Norway, Poland, Singapore, Sweden, Thailand, and United States.

Another way to describe the changing SES distribution is the changing share of the sample that falls into the same, consistently-defined set of high, medium, and low SES categories over time. Table E2 reports the average share of the sample falling into each of the three SES categories for a constant sample of countries participating in an older and more recent study. Each SES variable is coded into three categories for all studies: parent education is coded into (1) less than secondary [less than ISCED 3], (2) secondary or non-degree vocational postsecondary [ISCED 3 or 4], and (3) an academically- or vocationally-oriented higher educational degree [ISCED 5A or 5B or more]. Parent occupation is coded into (1) working class [unskilled, semiskilled, or agricultural labor], (2) intermediate class [skilled trades, service, clerical, or small business], (3) salariat class [semi-professional, managerial, or professional]. Household books

are coded into (1) 0-10 books, (2) 11-100 books, (3) 101 books or more. Once again, it is clear that the average level of parent education and occupation have increased dramatically, while the distribution of books has remained relatively constant or even *decreased* slightly. Comparing the SISS 1984 8th grade dataset to PISA 2015, the average share of students reporting 10 or fewer books at home has more than doubled (from 6% to nearly 14%), while the shares of students in the high and medium books categories have both declined by a few percentage points.

Table E2. Proportion of Sample in High, Medium, and Low Categories of SES Variables, by Study

		FIMS 1964	PISA 2015
Parent education	High (ISCED 5A, 5B)	0.106	0.644
	Medium (ISCED 3, 4)	0.168	0.288
	Low (<ISCED 3)	0.726	0.067
Parent occupation	High (Salariat)	0.202	0.460
	Medium (Intermediate)	0.313	0.343
	Low (Working Class)	0.485	0.196
		SISS 1984	PISA 2015
Household books	High (101+)	0.448	0.401
	Medium (11-100)	0.492	0.461
	Low (0-10)	0.060	0.138

Note: Countries included in FIMS-PISA sample (parent education and occupation) are Australia, Belgium-Flanders, Belgium-French, England, Finland, France, Germany, Israel, Japan, Netherlands, Scotland, and United States. Countries included in SISS-PISA sample (books) are Australia, Canada, England, Finland, Hong Kong, Hungary, Israel, Italy, Japan, Korea, Netherlands, Norway, Poland, Singapore, Sweden, Thailand, and United States.

The 90/10 percentile method (Reardon 2011b) was chosen to avoid changes in the selectivity of different SES categories as their frequencies changed over time. However, treating these historical and contemporary percentiles as equivalent also makes a theoretical assumption that these SES characteristics confer mainly positional advantages to children. Alternatively, it may be that, for example, having a parent with a university degree always confers the same absolute advantage, regardless of whether that parent was among the elite few who earned a degree in the mid-20th century or the larger share who earned a degree at the turn of the 21st century. One piece of evidence that the increasing SES achievement gaps reported here are not merely an artifact of the general upgrading of SES is that increases are found not only for parental education and occupation, whose levels have increased over time, but also for household books, whose levels have remained stable or even slightly declined, as seen above.

In addition to changing levels of the three SES variables, the dispersion of SES has also changed. The variance of parent education and occupation has declined somewhat in most countries over time, while the variance of household books has remained relatively constant. (The changing variances of these ordinal SES variables were computed after recoding into the same categories in every study—6 categories for parent education and occupation and 5 categories for books.) All else equal, if the variance of an independent variable—SES—decreases, then its unstandardized association with an outcome variable—achievement—will increase. The models in the main text of the paper avoid this problem, as converting the SES variables into percentiles is a form of standardization. However, these changes in variance should be kept in mind for the next set of models, where SES is unstandardized.

An additional piece of evidence that increasing SES achievement gaps are not an artifact of changing SES distributions comes from the models reported in Tables E3 and E4, which compute achievement gaps between three consistently-defined categories of each SES variable rather than percentiles. These analyses examine the robustness of the finding of increasing SES achievement gaps to treating SES as an absolute rather than a positional good. SES variables are coded as in Table E2 above. Table E3 reports trends in the gap between the top and bottom categories of each variable, while the top panel of Table E4 reports trends in the gap between the top and middle categories, and the bottom panel of Table E4 reports trends in the gap between the middle and bottom categories. Thus, these models are an alternative way to capture changing achievement gaps across the whole SES distribution, at the top, and at the bottom, rather than the 90/10, 90/50, and 50/10 gap trends reported in the main text.

In these models, unlike in the models predicting percentile-based gaps, the size of coefficients cannot be compared across different SES variables because gaps based on categories of different SES variables are not on equivalent scales. Therefore, we look only at whether cohort birth year coefficients are positive. The results in Table E3 show that gaps have increased between the top and bottom categories of all three variables. However, the increase for parent occupation gaps not significantly different from 0. Table E4 shows that, for all three variables, increases between the top and middle categories are larger than increases between the middle and bottom categories. This is true both for parent education and occupation, where the top category has become a larger share of students, and for household books, where the top category has become a slightly smaller share of students. Thus, the achievement advantage of students with college-educated or professional parents or many books at home has increased, even as the share of students with college-educated or professional parents has increased (and the share with many books has declined).

That the gap between the top and middle SES categories has increased more than between the middle and bottom categories may at first appear inconsistent with the results from the main text of the paper showing that 50/10 gaps have increased more than 90/50 gaps in most countries. However, these two findings are simultaneously true. Comparing between descriptive Tables E1 and E2 shows why this is the case. In PISA 2015, the 50^{th} and 10^{th} percentiles of parent education and occupation in fact correspond to the “high” and “medium” categories of parent education and occupation. This demonstrates the difficulty of studying trends in achievement gaps between categories with drastically changing distributions. I choose to treat SES as a positional rather than an absolute good in this study, as it seems a more tenable assumption that the advantage conferred by a particular level of parental education or occupation changes over time with the changing distributions of these variables. However, the results of these models indicate that achievement gaps between high and low SES categories still appear to increase even when SES is treated as an absolute good.

Table E3. Estimated Trends in Achievement Gaps between High and Low SES Categories

	Education	Occupation	Books
High-low			
Age 10 at testing	-0.038	0.099 ***	-0.221 ***
	(0.032)	(0.020)	(0.028)
Age 15 at testing	-0.083 **		-0.001
	(0.030)		(0.025)
Math	0.03 **	0.002	-0.02 +
	(0.010)	(0.008)	(0.012)
Science	0.032 ***	0.001	0.044 ***
	(0.009)	(0.007)	(0.013)
Cohort birth year	0.007 ***	0.002 *	0.003 +
	(0.001)	(0.001)	(0.002)
Intercept	0.976 ***	0.825 ***	1.318 ***
	(0.029)	(0.021)	(0.044)
Residual variance (within countries)	0.03481	0.00851	0.02560
Residual variance (country intercepts)	0.05793	0.02703	0.16224
Residual variance (cohort slopes)	0.00009	0.00007	0.00015
N (observations)	1889	1334	2086
N (countries)	93	80	95

+ p<.1, * p<.05, ** p<.01, *** p < .001. Note: See text for definitions of high, middle, and low for each SES variable. To avoid very long computation times, all models in this table specify known level 1 error variances estimated using conventional non-bootstrap formulas and omit error covariances. This simplified specification appears to produce very similar results to models using bootstrapped error variances and covariances (see Appendix L).

Table E4. Estimated Trends in Achievement Gaps between High-Middle and Middle-Low SES Categories

	Education	Occupation	Books
High-middle			
Age 10 at testing	-0.029	-0.036 **	-0.169 ***
	(0.019)	(0.012)	(0.015)
Age 15 at testing	-0.088 ***		0.011
	(0.016)		(0.013)
Math	0.031 ***	0.012 *	0.001
	(0.006)	(0.005)	(0.008)
Science	0.019 ***	0.012 ***	0.0270 ***
	(0.005)	(0.004)	(0.007)
Cohort birth year	0.005 ***	0.002 +	0.002 *
	(0.001)	(0.001)	(0.001)
Intercept	0.496 ***	0.548 ***	0.62 ***
	(0.014)	(0.016)	(0.022)
Residual variance (within countries)	0.01243	0.00319	0.00907
Residual variance (country intercepts)	0.01691	0.01686	0.04203
Residual variance (cohort slopes)	0.00003	0.00005	0.00007
N (observations)	1889	1334	2086
N (countries)	93	80	95
Middle-low			
Age 10 at testing	-0.004	0.137 ***	-0.05 *
	(0.021)	(0.015)	(0.024)
Age 15 at testing	0.004		-0.004
	(0.023)		(0.018)
Math	-0.001	-0.009 +	-0.024 ***
	(0.007)	(0.005)	(0.007)
Science	0.012 +	-0.013 **	0.015 *
	(0.007)	(0.004)	(0.007)
Cohort birth year	0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)
Intercept	0.484 ***	0.273 ***	0.698 ***
	(0.020)	(0.010)	(0.026)
Residual variance (within countries)	0.01781	0.00297	0.01407
Residual variance (country intercepts)	0.02717	0.00471	0.05037
Residual variance (cohort slopes)	0.00004	0.00004	0.00005
N (observations)	1889	1334	2086
N (countries)	93	80	95

+ p<.1, * p<.05, ** p<.01, *** p < .001. Note: See text for definitions of high, middle, and low for each SES variable. To avoid very long computation times, all models in this table specify known level 1 error variances estimated using conventional non-bootstrap formulas and omit error covariances. This simplified specification appears to produce very similar results to models using bootstrapped error variances and covariances (see Appendix L).

F. Achievement gaps by mother's and father's SES characteristics

One possible explanation for increasing SES achievement gaps is the increasing educational attainment and occupational status of mothers. The dramatic global rise in women's status since the mid-20th century is easily visible in the international assessment data. In early international assessments, most students reported a higher level of educational attainment for their father than their mother. The mother's occupation was not collected at all in the earliest three datasets (FIMS 1964, FISS 1970, and FIRCS 1970). In the most recent assessments, mothers and fathers are about equally educated, and mothers have somewhat higher occupational status than fathers (reflecting women's greater likelihood of working in white collar jobs). Since the main analyses in study use only the *highest* of the two parents' education and occupation as a measure of the child's SES, the increasing education and occupational status of mothers means that the highest parent education and occupation are increasingly likely to come from the mother. If children's achievement tends to be more strongly associated with their mother's than with their father's education and occupation (because mothers perform the majority of childcare), then the increasing educational and occupational attainment of mothers could explain why SES achievement gaps are increasing. (Children and/or parents were asked to report the education and occupation of both parents, whether or not both were present in the home, and most international assessments did not collect data on whether each parent lived in the home. For parents not currently working, the most recent occupation was reported. For parents who had never worked—who were very likely to be mothers performing home duties, particularly in earlier years—this study treats that parent's occupation as missing and imputes an occupation as part of the multiple imputation model described in the Methods section of the main text of the paper.)[5]

To check the robustness of the main results to changes in the relative status of mothers and fathers, Table F1 reports trends in SES achievement gaps based on fathers' and mothers' education and occupation separately. The results show that trends in gaps based on all four characteristics are positive and significant. As expected, increases in gaps based on mothers' education and occupation are larger than those based on fathers' characteristics—a Wald joint hypothesis test shows that the increase in the mother's education gap is significantly larger than the increase in the father's education gap ($p < .001$). The trends in gaps based on mothers' and fathers' occupation differ only slightly, by less than 0.001 SD per year, a difference that is not significant ($p > 0.5$). Between the 1950 and the 2005 birth cohorts, the father's education achievement gap grew from about 0.72 SDs to 1.10 SDs (about a 54% increase), while the mother's education achievement gap grew from 0.68 SDs to 1.12 SDs (about a 65% increase). Between the 1966 and 2005 birth cohorts (1966 is the birth cohort corresponding to SIMS 1980, the first cohort for which both mothers' and fathers' occupation are available), the father's occupation achievement gap grew from 0.81 to 1.04 SDs (about a 29% increase), and the mother's occupation achievement gap grew from 0.83 to 1.07 SDs (about a 28% increase). That achievement gaps have increased not only for mothers' but also fathers' education and occupation suggests that the global increase in parent education and occupation achievement gaps is not fully explained by the increasing educational or occupational attainment of mothers.

[5] See Appendix L for models computing gap trends with listwise deletion of missing data rather than multiple imputation. In these models, for students with one missing and one nonmissing parent education or occupation, the nonmissing value was used as the "highest" parent education or occupation. Results are very similar to those from the models with imputed data.

Table F1. Trends in Achievement Gaps Based on Fathers' and Mothers' SES Characteristics

	Coef	(se)	
Father's education gaps intercept	0.991	(0.028)	***
Mother's education gaps intercept	0.993	(0.030)	***
Father's occupation gaps intercept	0.947	(0.027)	***
Mother's occupation gaps intercept	0.970	(0.029)	***
Level 1 - Gaps			
Subject (ref=Reading):			
Math	0.036	(0.007)	***
Science	0.028	(0.005)	***
SES variable quality measures			
Parent-reported × Parent education	0.091	(0.029)	**
Parent-reported × Parent occupation	-0.054	(0.025)	*
Number of categories (centered at 7)	0.001	(0.002)	
≥ 20% in bottom category	-0.044	(0.011)	***
≥ 20% in top category	-0.047	(0.009)	***
Level 2 - Study-years			
Age at testing (ref=14)			
Age 10 at testing	-0.091	(0.033)	**
Age 15 at testing	-0.116	(0.023)	***
Cohort birth year × Father's education	0.007	(0.001)	***
Cohort birth year × Mother's education	0.008	(0.001)	***
Cohort birth year × Father's occupation	0.006	(0.001)	***
Cohort birth year × Mother's occupation	0.006	(0.001)	***
Random effects			
Level 2 - Residual variance between studies in...			
Father's education intercepts	0.03050		
Mother's education intercepts	0.03658		
Father's occupation intercepts	0.01361		
Mother's occupation intercepts	0.01496		
Level 3 - Residual variance between countries in...			
Father's education intercepts	0.04857		
Mother's education intercepts	0.05634		
Father's occupation intercepts	0.03237		
Mother's occupation intercepts	0.04390		
Father's education cohort slopes	0.00006		
Mother's education cohort slopes	0.00005		
Father's occupation cohort slopes	0.00004		
Mother's occupation cohort slopes	0.00005		
N (Level 1 - gaps)	6502		
N (Level 2 - study-years)	866		
N (Level 3 - countries)	95		

+ p<.1, * p<.05, ** p<.01, *** p < .001. Note: All models in this table specify known level 1 error variances and covariances, estimated via bootstrapping, consistent with models in the main text of the paper.

Another possible explanation for increasing SES achievement gaps is increasing homogamy among the parents of participating students. That is, the SES characteristics (education and occupation) of mothers and fathers are likely growing more correlated over time. Students with two highly-educated or high-occupational-status parents may be more advantaged than students with only one highly-educated or high-occupational-status parent. Table F2 reports hierarchical growth models estimating trends in the correlation between mothers' and fathers' education and occupation. The results show that the average correlation between mothers' and fathers' education has increased only slightly (from about 0.56 in the 1950 birth cohort to about 0.60 in the 2005 cohort), and the average correlation between mothers' and fathers' occupation has remained relatively constant (declining slightly from about 0.40 in the 1966 birth cohort to about 0.39 in the 2005 cohort). These results demonstrate a less pronounced increase in homogamy than expected, which may be because this analysis treats parent education and occupation as continuous positional goods, converted into percentiles within each country-year, as in the main text of this paper. While it is true that an increasing number of children have two parents with higher education degrees or professional occupations, the associations between the *relative* positions of mothers and fathers within their own gender distributions have not increased dramatically over time.

Table F2. Trends in Correlations between Mothers' and Fathers' Education and Occupation

	Education	Occupation
Intercept	0.589 ***	0.392 ***
	(0.006)	(0.009)
Level 1 - Study-years		
Age at testing (ref=14)		
Age 10 at testing	-0.025 ***	0.090 ***
	(0.007)	(0.008)
Age 15 at testing	-0.054 ***	
	(0.006)	
Cohort birth year	0.0006 *	-0.0003
	(0.0003)	(0.0005)
Level 1 residual variance	0.00234	0.00365
Level 2 residual variance in intercepts	0.00341	0.00523
Level 2 residual variance in cohort slopes	0.00000	0.00001
N (Level 1 - study-years)	866	550
N (Level 2 - countries)	95	82

+ p<.1, * p<.05, ** p<.01, *** p < .001

G. Achievement gaps conditional on other SES variables

Results in the main paper text estimate achievement gaps separately for each SES variable (parent education, parent occupation, and household books) rather than constructing an SES index to avoid loss of information because not all SES variables are available in every dataset. However, it could be the case that only one of the three SES variables is growing more strongly associated with achievement over time, while the other two SES variables only appear

to be growing more strongly associated with achievement due to their correlations with this one most salient SES variable. Or it may even be the case that the independent associations between each SES variable and achievement have remained constant over time, but correlations between the three SES variables are growing stronger over time. This would create the appearance of increasing SES achievement gaps for all three variables because an increasing share of students would experience "double-" or "triple disadvantage." That is, students with university-educated parents would be more likely also to have parents with professional occupations and to have a large number of books at home. Conversely, students whose parents have not completed secondary education would be more likely to have parents with working-class occupations and very few books at home. Thus, there may be a pattern of increasing polarization of socioeconomic advantage and disadvantage among schoolchildren, which may completely explain away increasing SES achievement gaps for all three SES variables.

Table G1 reports hierarchical growth models estimating trends in the correlation between pairs of SES variables. The results show that the average correlation between parent education and parent occupation has increased quite substantially (from about 0.43 in the 1950 birth cohort to about 0.56 in the 2005 cohort). This finding is consistent with international research showing an increasing association between education and occupation across most countries (Kreidl, Ganzeboom and Treiman 2014).[6] In contrast, the average correlations between household books and each of parent education and occupation, respectively, have increased more moderately (the correlation between household books and parent education increased from about 0.31 in the 1956 birth cohort to about 0.35 in the 2005 cohort; the correlation between household books and parent occupation increased from about 0.31 in the 1956 birth cohort to about 0.39 in the 2005 birth cohort).

[6] Note the literature shows an increasing association between education and occupation only when both variables are treated as linear (as here); the true pattern of change may be more complex. For example, research on over-education shows a declining relationship between attainment of tertiary education and a professional occupation when treating both variables as categorical rather than linear—that is, assuming education and occupational status are absolute rather than positional goods (the opposite of the assumption made in this paper).

Table G1. Trends in Correlations between Three SES Variables

	Education & Occupation	Education & Books	Occupation & Books
Intercept	0.523 ***	0.338 ***	0.361 ***
	(0.042)	(0.007)	(0.014)
Level 1 - Study-years			
Age at testing (ref=14)			
Age 10 at testing	0.057	0.064 ***	-0.007
	(0.048)	(0.007)	(0.012)
Age 15 at testing	-0.048	-0.031 ***	-0.059 ***
	(0.044)	(0.005)	0.012
Cohort birth year	0.0025 **	0.0008 +	0.0016 ***
	(0.0008)	(0.0004)	(0.0004)
Level 1 residual variance	0.00529	0.00195	0.0018
Level 2 residual variance in intercepts	0.00437	0.00339	0.00541
Level 2 residual variance in cohort slopes	0.00001	0.00001	0.00001
N (Level 1 - study-years)	576	835	567
N (Level 2 - countries)	82	95	83

+ p<.1, * p<.05, ** p<.01, *** p < .001

But do these increasing correlations fully explain increasing SES achievement gaps for all three variables? And even if increasing correlations do not fully explain increasing gaps, could it be the case that only one or two SES variables are growing more strongly associated with achievement, while the other SES variable(s) only appear to be growing more strongly associated with achievement due to their correlation(s) with the most salient SES variable(s)? One way to address both of these questions is by computing SES achievement gaps for each variable conditional on one or both of the other SES variables. The results of these models are presented in Table G2. Conditional gaps can be estimated only from studies that collected more than one SES variable, meaning sample sizes are reduced. To obtain an accurate comparison to cohort trends in unconditional SES achievement gaps, trends in unconditional gaps are also estimated using the same reduced set of studies. In Table G2, each row reports two models estimating gaps based on a particular SES variable. The "Conditional gaps" columns report the intercept and cohort birth year coefficients for a model whose gaps are conditional on one or both of the other SES variables. The "Unconditional gaps" columns report the coefficients for a model based on unconditional gaps using the same sample of studies. In each model, the intercept is the estimated gap for the variable in question (conditional or unconditional) for the 1989 birth cohort, while the cohort trend is the estimated annual change in the gap. All models control for subject and age at testing. Since there is no established method to adjust conditional associations for attenuation due to measurement error, conditional gaps are not adjusted for test or SES reliability. For an accurate comparison, the unconditional gaps are also not adjusted for reliability.

Table G2. Intercept and Cohort Birth Year Coefficients from Models Predicting 90/10 SES Achievement Gaps Conditional on Other SES Variables

		Conditional gaps			Unconditional gaps		
Variable	Conditional on	Intercept	Cohort trend	(N)	Intercept	Cohort trend	(N)
Education	Occupation	0.444 ***	0.002	(81)	0.760 ***	0.005 **	(81)
Education	Books	0.389 ***	0.003 **	(95)	0.729 ***	0.006 ***	(95)
Education	Occupation & Books	0.302 ***	0.001	(81)	0.750 ***	0.003 *	(81)
Occupation	Education	0.361 ***	0.001	(81)	0.684 ***	0.004 ***	(81)
Occupation	Books	0.356 ***	0.001	(82)	0.672 ***	0.004 ***	(82)
Occupation	Education & Books	0.278 ***	-0.001	(81)	0.729 ***	0.003 *	(81)
Books	Education	0.483 ***	0.004 ***	(95)	0.806 ***	0.007 ***	(95)
Books	Occupation	0.502 ***	0.002 **	(82)	0.785 ***	0.005 ***	(82)
Books	Education & Occupation	0.475 ***	0.004 ***	(81)	0.797 ***	0.006 ***	(81)

+ p<.1, * p<.05, ** p<.01, *** p < .001. Note: To avoid very long computation times, all models in this table specify known level 1 error variances estimated using conventional non-bootstrap formulas and omit error covariances. This simplified specification appears to produce very similar results to models using bootstrapped error variances and covariances (see Appendix L).

By computing the predictions of the model with all three SES variables (rows 3, 6, and 9) for the 1956 birth cohort (the first cohort with all three variables available) and the 2005 cohort, it can be seen that in both years, books had the strongest independent association with achievement (0.54), followed by education (0.32) and then occupation (0.26). However, over this time period, this ranking became even more pronounced. The independent 90/10 books gap increased markedly from 0.34 to 0.54, while the independent 90/10 parent education gap increased more modestly from 0.27 to 0.32, and the independent parent occupation gap *decreased* from 0.31 to 0.26. (Note this does not mean parent occupation is not significantly related to student achievement after controlling for parent education and household books, only that the relationship between parent education and achievement is not growing, after accounting for the other two SES variables). Thus, it appears that the independent associations of each SES variable with achievement have changed at different rates over time.

That the conditional 90/10 parent education and household books gaps show increases suggests that the global increases in unconditional SES achievement gaps for these variables are not fully explained by their correlations with other SES characteristics. In contrast, the declining conditional 90/10 parent occupation gap suggests that the growing parent occupation gap may be fully explained by the correlations between parent occupation and other SES characteristics. However, it should be noted that the model with all three SES variables included is based on a substantially reduced sample of only those datasets that collected all three SES variables, and thus may not be representative.

Regardless of the relative importance of parent education, parent occupation, and books, the results in Table G2 clearly indicate that increasing correlations between SES variables do not fully explain increasing SES achievement gaps. Nearly all trends in conditional SES achievement gaps are positive, with the exception of parent occupation conditional on education and books, as noted above. These results suggest that, even after accounting for the growing number of children with "double-" or "triple-disadvantage" due to increasing correlations among SES variables, each SES variable (or at least parent education and books) has become more consequential for students' academic achievement.

One further piece of evidence that increasing SES achievement gaps for each SES variable are not entirely due to increasing correlations between variables is that the R^2 of the models used to compute conditional gaps with all three variables has increased over time. Table G3 shows results from hierarchical growth models (country-subject-years within countries) predicting R^2 from cohort birth year (with controls for age and subject). (R^2 is adjusted for test reliability before running these models.) Results indicate that the R^2 of the model including all three SES variables nearly doubled from about 0.10 in the 1956 birth cohort to about 0.18 in the 2005 birth cohort. Thus, it appears that the overall predictive power of SES on achievement has grown substantially stronger over this 49-year time period.

Table G3. Trends in R^2 from Models with Two or Three SES Variables

	R^2 (Education & Occupation)	R^2 (Education & Books)	R^2 (Occupation & Books)	R^2 (Education, Occupation & Books)
Intercept	0.107 ***	0.138 ***	0.129 ***	0.154 ***
	(0.013)	(0.006)	(0.010)	(0.016)
Level 1 - R^2 measures				
Subject (ref=Reading):				
Math	0.006 ***	0.002	0.001	0.003 +
	(0.002)	(0.002)	(0.002)	(0.002)
Science	0.005 ***	0.009 ***	0.005 **	0.006 ***
	(0.001)	(0.001)	(0.002)	(0.001)
Level 2 - Study-years				
Age at testing (ref=14)				
Age 10 at testing	0.022	-0.015 **	-0.008	-0.010
	(0.013)	(0.006)	(0.008)	(0.015)
Age 15 at testing	0.002	-0.001	0.037 ***	0.02
	(0.014)	(0.005)	0.01	0.016
Cohort birth year	0.0010 ***	0.0021 ***	0.0014 ***	0.0017 ***
	(0.0003)	(0.0002)	(0.0003)	(0.0003)
Level 1 residual variance	0.000198	0.000322	0.000293	0.000323
Level 2 residual variance in intercepts	0.000806	0.001049	0.000728	0.000853
Level 3 residual variance in intercepts	0.001443	0.002646	0.002701	0.002623
Level 3 residual variance in cohort slopes	0.000002	0.000002	0.000002	0.000002
N (Level 1 - R^2 measures)	1382	1910	1389	1351
N (Level 2 - study-years)	576	836	567	545
N (Level 3 - countries)	82	95	83	82

+ p<.1, * p<.05, ** p<.01, *** p < .001

H. Changing measurement error of SES

Another reason why SES achievement gaps may artificially appear to be increasing over time is that the reliability with which SES is measured may be increasing over time. Lower reliability of SES in early years could cause the estimated association between SES and achievement in early years to be attenuated, creating the appearance of increasing SES achievement gaps over time. Reliability is defined as the ratio of the variance in true SES to the total variance in SES (including both true variance and the variance of errors of measurement). As reported in Appendix E, the total variance of SES has declined for two SES variables—parent education and occupation—while the total variance has remained relatively constant for household books. It is likely that much of the decline in total variance in parent education and occupation reflects a decline in true variance, due to the large increase in the average *levels* of both variables as more parents attain higher education and professional occupations.

However, it is also likely that some of the reduction in the total variance of parent education and occupation is due to declining measurement error in these variables. Measurement error could potentially decline, for example, because current students have more accurate knowledge of their families' SES characteristics than in the past, because of improvements in survey wording, or because more recent SES data are more likely to be reported by parents rather than students. As stated in the main paper text, some international assessments have added parent questionnaires in recent years (PIRLS 2001-2011, TIMSS 4th grade 2011-2015, and PISA 2006-2012). The main models use parent-reported SES variables when available and student-reported SES otherwise. However, it is expected that parents report SES variables more reliably than their children. Some other patterns reported in previous appendix sections are consistent with increasing reliability of SES due to declining measurement error, while other patterns are inconsistent with this story. The large increase in the correlation between parent education and occupation (reported in Appendix G) is consistent with increasing reliability in these variables. However, the increase in the correlations between household books and each of the other two SES variables have been more modest. An increasing correlation between mothers' and fathers' education and occupation (reported in Appendix F) could also be evidence for increasing reliability of these variables. However, the correlation between mothers' and fathers' education has increased only moderately, and the correlation between mothers' and fathers' occupations has *declined* slightly.

As described in the Methods section of the main paper text, all SES achievement gaps have been adjusted for estimated reporting reliability of SES variables. Following Reardon (2011a), this adjustment consists of by multiplying each gap estimate by $\frac{1}{\sqrt{r}}$, where *r* is the reliability of the SES measure. In order to estimate the reliability *r* of each student- or parent-reported SES measure, we can take advantage of having two measures of the same variable reported by different sources (i.e., students and parents) (Jerrim and Micklewright 2014). The reliability of students' and parents' SES reports can be computed from the following formulas (Reardon 2011a):

$$r_s = corr(s,p) \cdot \frac{corr(s,y)}{corr(p,y)}$$
$$r_p = corr(s,p) \cdot \frac{corr(p,y)}{corr(s,y)}$$

where r_s is the reliability of student-reported SES variable *s*, r_p is the reliability of parent-reported SES variable *p*, and *y* is a third variable that would have a particular correlation with true SES, were SES measured without error. In reliability calculations from PISA and TIMSS, math achievement is used for this third variable *y*; in reliability calculations from PIRLS, reading achievement is used for *y*. Parent education is reported by both 15-year-old students and parents in PISA 2006, 2009, and 2012. Parent occupation is reported by both 15-year-old students and parents in PISA 2006 and 2012. Household books are reported by both 4th grade students and parents in PIRLS 2001, 2006, and 2011 and in TIMSS 2011 and 2015. I estimate the average reliability of parents' reports of their own educational attainment (across PISA 2006-2012) at 0.84 and students' reports of their parents' education at 0.62. I estimate the average reliability of parents' reports of their own occupational category (across PISA 2006 and 2012) at 0.81 and students' reports of their parents' occupation at 0.79. I estimate the average reliability of parents' reports of the number of household books (across PIRLS 2001-2011 and TIMSS 2011-2015) at 0.52 and students' reports of household books at 0.46. The higher accuracy of parent occupation reports and low accuracy of household books reports is consistent with findings by Jerrim and Micklewright (2014) using some of the same international datasets. In order to estimate reliabilities for other age groups, I assume that 8th grade students report all SES variables with the same reliability as 15-year-old students, but 4th grade students report parent education 80% as reliably and parent occupation and household books 90% as reliably as 15-year-old students. Finally, in order to estimate reliabilities for other years where parent reports are unavailable, I use the average reliabilities for each of these age groups. Since the reliabilities applied to all years are derived from parent reports in recent years, this procedure adjusts only for differences in reliability between parents and children, but cannot account for possible changes in reliability over time.

Table H1 reports estimated trends in 90/10 SES achievement gaps, using only student-reported data for all three SES variables (gaps are not adjusted for SES or test reliability). Sample sizes are reduced, mainly due to the omission of 4th grade assessments from recent years with parent-reported education and occupation. In these models, the estimated positive trends in 90/10 SES achievement gaps are reduced compared to those reported in the main paper text but are still positive and highly significant for all three SES variables. Using these results, it is possible to estimate the sensitivity of estimated gap trends to potential increases in the accuracy of students' reports of their parents' SES characteristics. For the increases in SES achievement gaps reported in Table H1 to be fully accounted for by measurement error alone, the reliability of students' reports of parental education, estimated at 0.62 for recent cohorts, would have to be only 0.46 for the 1950 cohort. The reliability of students' reports of parental occupation, estimated at 0.77 for recent cohorts, would have to be 0.50 for the 1950 cohort; and the reliability of students' reports of household books, estimated at 0.46 for recent cohorts, would have to be 0.34 for the 1956 cohort (the first cohort for which the household books variable was collected). Without parental reports, it is impossible to know from these data whether the reliability of students' reports could have increased by 35-55% over this 50 year period. However, a thorough literature search did not reveal published evidence that survey reporting of SES characteristics by either adults or children has become more accurate over time.

Table H1. Estimated trends in 90/10 SES achievement gaps, student-reported SES data only

	No adjustment					
	(1)			(2)		
	coef	(se)		coef	(se)	
Parent education gaps intercept	0.739	(0.022)	***	0.752	(0.021)	***
Parent occupation gaps intercept	0.772	(0.024)	***	0.782	(0.024)	***
Household books gaps intercept	0.829	(0.028)	***	0.838	(0.027)	***
Level 1 - Gaps						
Subject (ref=Reading):						
Math	0.018	(0.006)	***	0.019	(0.006)	***
Science	0.026	(0.004)	***	0.026	(0.004)	***
SES variable quality measures						
Number of categories (centered at 7)	-0.002	0.002		-0.001	0.002	
≥ 20% in bottom category	-0.025	0.014	+	-0.033	0.016	*
≥ 20% in top category	-0.105	0.01	***	-0.116	0.009	***
Level 2 - Study-years						
Age at testing (ref=14)						
Age 10 at testing	-0.186	(0.017)	***	-0.185	(0.017)	***
Age 15 at testing	0.014	(0.015)		0.007	(0.014)	
Cohort birth year × Parent education	0.004	(0.001)	***			
Cohort birth year × Parent occupation	0.006	(0.001)	***			
Cohort birth year × Books	0.005	(0.001)	***			
Cohort birth year				0.005	(0.001)	***
Random effects						
Level 2 - Residual variance between studies in...						
Parent education intercepts	0.01962			0.01991		
Parent occupation intercepts	0.01561			0.01553		
Books intercepts	0.01461			0.01514		
Level 3 - Residual variance between countries in...						
Parent education intercepts	0.02999			0.03059		
Parent occupation intercepts	0.03917			0.03960		
Books intercepts	0.06079			0.06187		
Parent education cohort slopes	0.00003					
Parent occupation cohort slopes	0.00002					
Books cohort slopes	0.00004					
Cohort slopes				0.00002		
N (Level 1 - gaps)	4980			4980		
N (Level 2 - studies)	1023			1023		
N (Level 3 - countries)	100			100		

+ p<.1, * p<.05, ** p<.01, *** p < .001. Note: All models in this table specify known level 1 error variances and covariances, estimated via bootstrapping, consistent with models in the main text of the paper.

The estimates of the reliability of students' SES reports from recent years (for countries that collected SES from both students and parents) do vary substantially. Reliability estimates of students' reports of parent education from PISA 2012 range from 0.43 in Croatia to 0.91 in Portugal; of parent occupation range from 0.66 in Mexico to 0.92 for Croatia; and of household books from PIRLS 2011 range from 0.03 in Kuwait to 0.67 in Bulgaria. Yet for parent education and occupation, even the countries with the lowest estimated reliabilities barely reach what would need to be the *average* level of reliability for early cohorts in order to fully explain the global increase in SES achievement gaps. For household books, in contrast, there is more variability in the estimated accuracy of students' reports, and it is conceivable that average reliability could have increased by 37% in 49 years.

Estimated SES reliability could potentially also be compared across multiple waves of each study that collects a parent questionnaire (PIRLS 2001-2011 and PISA 2006-2012). Computed SES reliabilities for students and parents do appear to vary somewhat across waves, although it is not clear that these differences represent meaningful trends, given the small number of years and countries represented. It is also possible to compare trends in SES achievement gaps estimated from students' versus parents' reports across waves of PIRLS and PISA. These estimates are reported in Table H2. The estimated trends do not appear to differ systematically depending on whether they are estimated from parent or student reports (this comparison was done before adjusting for computed SES reliability, as gaps based on parent- and student-reported data will be nearly identical after adjustment by construction). Wald tests for joint null hypotheses that trends are equal for gaps based on parent- and student-reported SES cannot be rejected in all but one model. Correlations between country-specific random cohort slopes for gaps based on parent- and student-reported SES are also strongly positive all but one model (this excludes models predicting parent occupation gaps, where random cohort slopes could not be computed due to insufficient sample size). The exception in both cases is the model predicting parent education gaps in PISA science scores, which also showed negative trends in Appendix B. The results in Table H2 suggest this finding for science gaps based student-reported parent education may be inaccurate, as it is inconsistent with the results for science gaps based on parent-reported education, which are likely to be more reliably estimated.

Table H2. Trends in Gaps by Student-Reported and Parent-Reported SES, by Test

Test instrument	PISA Math	PISA Reading	PISA Science	PISA Math	PISA Reading	PISA Science	PIRLS Reading
Test years	2006-2012	2006-2012	2006-2012	2006-2012	2006-2012	2006-2012	2001-2011
Cohort birth years	1991-1997	1991-1997	1991-1997	1991-1997	1991-1997	1991-1997	1991-2001
SES variable	Education	Education	Education	Occupation	Occupation	Occupation	Books
Parent education (parent report) intercept	0.828 ***	0.747 ***	0.810 ***				
	(0.066)	(0.069)	(0.070)				
Parent education (student report) intercept	0.747 ***	0.681 ***	0.744 ***				
	(0.064)	(0.064)	(0.069)				
Parent occupation (parent report) intercept				0.690 ***	0.649 ***	0.672 ***	
				(0.102)	(0.102)	(0.107)	
Parent occupation (student report) intercept				0.673 ***	0.629 ***	0.661 ***	
				(0.115)	(0.116)	(0.120)	
Household books (parent report) intercept							0.807 ***
							(0.029)
Household books (student report) intercept							0.756 ***
							(0.037)
Level 2 - Study-years							
Cohort birth year × Parent ed. (parent)	0.019 **	0.029 ***	0.014 *				
	(0.006)	(0.009)	(0.006)				
Cohort birth year × Parent ed. (student)	0.012 ***	0.015 *	-0.001				
	(0.003)	(0.006)	(0.007)				
Cohort birth year × Parent occ. (parent)				0.013 *	0.013 *	0.008	
				(0.005)	(0.005)	(0.005)	
Cohort birth year × Parent occ. (student)				0.017 **	0.014 *	0.010 +	
				(0.006)	(0.007)	(0.005)	
Cohort birth year × Books (parent)							0.005 *
							(0.003)
Cohort birth year × Books (student)							0.009 **
							(0.003)
N (Level 1 - gaps)	66	66	66	28	28	28	198
N (Level 2 - study-years)	33	33	33	14	14	14	99
N (Level 3 - countries)	13	13	13	7	7	7	40
p-value for H0: Cohort × SES (parent) = Cohort × SES (student)	0.233	0.025	0.071	0.272	>.500	>.500	0.118
Correlation between country random cohort slopes for parent- and student-reported SES	0.761	0.744	-0.066	a	a	a	0.951

+ p<.1, * p<.05, ** p<.01, *** p < .001 Note: To avoid very long computation times, all models in this table specify known level 1 error variances estimated using conventional non-bootstrap formulas and omit error covariances. This simplified specification appears to produce very similar results to models using bootstrapped error variances and covariances (see Appendix L).

[a] Country-level random cohort slopes could not be included in the models predicting parent occupation gaps due to an insufficient sample size.

Increased accuracy of the SES variables could result not only from improvements in students' knowledge of their family SES characteristics but also from improved questionnaire wording over time. The wording of the background questionnaires differs across the older IEA studies, the new IEA studies (TIMSS and PIRLS), and PISA. However, the wording of background questionnaires has changed very little across multiple waves of the trend studies (TIMSS, PIRLS, and PISA). Yet, as demonstrated in Appendix B, trends in SES achievement gaps estimated from each of these studies individually are still nearly always positive (though not always statistically significant, given the smaller sample sizes). Between 1995 and 2001, the IEA began including drawings of bookshelves in its TIMSS and PIRLS questionnaires for 4th grade students in order to assist them in estimating the number of books they have at home, which likely decreased measurement error and could bias estimates of books achievement gap trends upward. However, as we have seen, books achievement gaps also increased substantially for 8th grade and 15-year-old students, with no added drawings.

The one consistent exception to the increasing SES achievement gaps across all test instruments in Appendix B is trends estimated from PISA parent education, which are usually negative. This is especially surprising since 8th grade TIMSS tests a similar population in similar subjects and shows large increases in parent education achievement gaps. In the Appendix B results, it is difficult to discern whether the discrepancy between PISA and TIMSS 8th grade is the result of differences in samples, in test instruments, or in the measurement of SES. Table H3 estimates trends in parent education and household books achievement gaps for math and science in a constant sample of 42 countries that participated in at least two cycles each of PISA and TIMSS 8th grade. Trends in parent education gaps are close to 0 for PISA but are large and positive for TIMSS. Although trends in household books gaps are also larger for TIMSS than for PISA, they are nevertheless still large, positive, and significant for PISA. Wald tests for joint null hypotheses that trends are equal for PISA and TIMSS gaps can be rejected for both parent education and books gaps. Correlations between country-specific random cohort slopes for PISA and TIMSS gaps are weak for parent education but very strongly positive (over 0.90) for books gaps. These comparisons suggest that the difference in trends for PISA and TIMSS may be attributable not only to differences in test instruments and target populations but also likely due to differences in the measurement of SES, particularly parent education.

Table H3. Comparison of Trends in PISA and TIMSS 8th Grade 90/10 Parent Education and Household Books Gaps

	Math	Science
Parent education intercept × PISA	0.720 ***	0.713 ***
	(0.033)	(0.031)
Parent education intercept × TIMSS	0.765 ***	0.738 ***
	(0.032)	(0.034)
Household books intercept × PISA	0.917 ***	0.898 ***
	(0.038)	(0.039)
Household books intercept × TIMSS	0.799 ***	0.800 ***
	(0.037)	(0.044)
Level 2 - Study-years		
Cohort birth year × Parent education × PISA	0.001	0.000
	(0.002)	(0.002)
Cohort birth year × Parent education × TIMSS	0.010 ***	0.011 ***
	(0.002)	(0.002)
Cohort birth year × Books × PISA	0.005 **	0.007 ***
	(0.002)	(0.002)
Cohort birth year × Books × TIMSS	0.014 ***	0.018 ***
	(0.003)	(0.003)
N (Level 1 - gaps)	711	711
N (Level 2 - study-years)	358	358
N (Level 3 - countries)	42	42
p-value for H0: Cohort × Education × PISA = Cohort × Education × TIMSS	0.003	<0.001
p-value for H0: Cohort × Books × PISA = Cohort × Books × TIMSS	0.001	<0.001
Correlation between country random cohort slopes for PISA and TIMSS education gaps	-0.077	0.267
Correlation between country random cohort slopes for PISA and TIMSS books gaps	0.941	0.924

+ p<.1, * p<.05, ** p<.01, *** p < .001. Note: To avoid very long computation times, all models in this table specify known level 1 error variances estimated using conventional non-bootstrap formulas and omit error covariances. This simplified specification appears to produce very similar results to models using bootstrapped error variances and covariances (see Appendix L).

Table H4 compares the parent education item wording from the student questionnaire for PISA and the student/parent questionnaires for the IEA studies (TIMSS and PIRLS).[7] TIMSS has a single education item for each parent; PISA has two items (schooling and higher education). TIMSS lists education levels in ascending order; PISA lists them in descending order. TIMSS includes an option for "I don't know"; PISA does not.[8] The highest two educational categories in TIMSS are "<ISCED Level 5A, first degree>" (i.e., BA) and "Beyond <ISCED Level 5A, first degree>" (i.e., MA, PhD, and professional degrees); the highest two categories in PISA are "<ISCED level 5A>" (i.e., BA, MA, and professional degrees) and

[7] Beginning in 2015, TIMSS updated its parent education item wordings to reflect the new ISCED 2011 scheme. PISA had not yet made any update in its 2015 cycle.

[8] "I don't know" responses in TIMSS were treated as missing data and imputed as part of the multiple imputation procedure. TIMSS 8th grade still shows large and significant increases in parent education achievement gaps using unimputed data with listwise deletion of "I don't know" responses and other missing parent education data.

"<ISCED level 6>" (i.e., PhD).[9] Perhaps as a result of some or all of these differences, a substantially larger share of students select highest two categories (BA or above) in PISA than in TIMSS. Of the 29 countries participating in both PISA 2012 and TIMSS 2011 8th grade, 20 countries had a higher share of students reporting BA or above in PISA than TIMSS, by an average of 6 percentage points. For example, in Australia, 31% of TIMSS 8th grade 2011 students report BA or more, while 43% of PISA 2012 students report BA or more; in Finland, 42% of TIMSS 8th grade 2011 students report BA or more, while 55% of PISA 2012 students report BA or more. This pattern is in addition to the general increase in the share of students in the highest education categories seen across all datasets due to educational upgrading in the parents' generations. The larger share of students in the highest category in PISA means that the achievement at the 90th percentile of parent education is estimated with more error. This means that parent education achievement gaps may be underestimated in more recent years, and consequently that gap trends may be underestimated.

Table H4. Comparison of PISA and TIMSS parent education questionnaire wording

PISA 2009-2015 student questionnaire	TIMSS 2003-2011 8th grade student questionnaire, TIMSS 2011 4th grade parent questionnaire, PIRLS 2006-2011 parent questionnaire
Q14. What is the <highest level of schooling> completed by your mother? • <ISCED level 3A> • <ISCED level 3B, 3C> • <ISCED level 2> • <ISCED level 1> • She did not complete <ISCED level 1> Q15. Does your mother have any of the following qualifications? • <ISCED level 6> • <ISCED level 5A> • <ISCED level 5B> • <ISCED level 4>	6A. What is the highest level of education completed by your mother <or stepmother or female guardian>? • Some <ISCED Level 1 or 2> or did not go to school • <ISCED Level 2> • <ISCED Level 3> • <ISCED Level 4> • <ISCED Level 5B> • <ISCED Level 5A, first degree> • Beyond <ISCED Level 5A, first degree> • I don't know

Models in the main text attempt to account for differences in variable quality across different studies or variables that may confound trend estimates. This is done by controlling for four SES variable quality measures (parent vs. student reporting, number of categories, 20% of more students in the bottom category, and 20% or more students in the top category). Model 1B in Table H5 omits these controls (Model 1 is reproduced from the main text for comparison). Results for Model 1B are nearly identical to those for Model 1. The trend in parent education

[9] Due to likely inaccuracies in students' reports of very high levels of parental education in PISA, in all analyses, I combine the highest two educational categories in PISA: ISCED 5A (BA, MA, and professional degrees) and ISCED 6 (PhD). Very large shares of students in PISA report at least one parent holding a PhD (over 10% in some countries), far outnumbering national statistics on PhD attainment. When the ISCED 5A and 6 categories are kept separate, results are broadly similar, but PISA parent education gaps are even smaller than when the categories are combined, due to the large number of low-achieving students reporting parents holding PhDs.

achievement gaps increases very slightly, from 0.007 SD of achievement per year to 0.008 SD of achievement per year. Thus, the trend reported in the main text controlling for SES variable quality measures is a slightly more conservative estimate of the trend. As in the main text, a Wald joint test of the hypothesis that the trends are equal across all three SES variables cannot be rejected ($p = 0.11$).

Table H5. Comparison of Trends in Gaps, Omitting SES Variable Quality Measures

	(1) with SES quality measures			(1B) no SES quality measures		
	coef	(se)		coef	(se)	
Parent education gaps intercept	1.032	(0.030)	***	0.989	(0.028)	***
Parent occupation gaps intercept	0.958	(0.030)	***	0.927	(0.028)	***
Household books gaps intercept	1.299	(0.041)	***	1.234	(0.039)	***
Level 1 - Gaps						
Subject (ref=Reading)						
Math	0.020	(0.007)	**	0.020	(0.007)	**
Science	0.034	(0.005)	***	0.034	(0.005)	***
SES variable quality measures						
Parent-reported × Parent education	0.132	(0.030)	***			
Parent-reported × Parent occupation	0.075	(0.025)	**			
Parent-reported × Books	-0.039	(0.029)				
Number of categories (centered at 7)	0.003	(0.003)				
≥ 20% in bottom category	-0.065	(0.021)	**			
≥ 20% in top category	-0.135	(0.013)	***			
Level 2 - Study-years						
Age at testing (ref=14)						
Age 10 at testing	-0.170	(0.024)	***	-0.136	(0.022)	***
Age 15 at testing	-0.024	(0.020)		-0.034	(0.020)	+
Cohort birth year × Parent education	0.007	(0.001)	***	0.008	(0.001)	***
Cohort birth year × Parent occupation	0.007	(0.001)	***	0.007	(0.001)	***
Cohort birth year × Books	0.008	(0.001)	***	0.008	(0.001)	***
Random effects						
Level 2 - Residual variance between studies in...						
Parent education intercepts	0.03736			0.04505		
Parent occupation intercepts	0.02322			0.02435		
Books intercepts	0.03698			0.04404		
Level 3 - Residual variance between countries in...						
Parent education intercepts	0.05426			0.05021		
Parent occupation intercepts	0.05227			0.04877		
Books intercepts	0.11590			0.11679		
Parent education cohort slopes	0.00004			0.00004		
Parent occupation cohort slopes	0.00003			0.00003		
Books cohort slopes	0.00007			0.00007		
N (Level 1 - gaps)	5541			5541		
N (Level 2 - study-years)	1026			1026		
N (Level 3 - countries)	100			100		

+ p<.1, * p<.05, ** p<.01, *** p < .001. Note: All models in this table specify known level 1 error variances and covariances, estimated via bootstrapping, consistent with models in the main text of the paper.

Since the 90/10 percentile method may not perform as well when more than 20% of observations are in the bottom or top SES category (Reardon 2011a), the models in the main paper include two dummy variables indicating whether 20% or more of students fall into the bottom category (14.8% of country-study gaps) or the top category (38.7% of country-study gaps). Model 1C in Table H6 omits these gaps altogether (Model 1 is reproduced from the main text for comparison). Compared to Model 1, the sample size of Model 1C is substantially reduced—by more than half at level 1 due to the large shares of gaps with many students in the bottom or especially top categories, as reported above. While the estimates of the parent education and books gap trends remain relatively similar, the parent education gap trend is substantially reduced (from 0.007 SD of achievement per year to 0.004 SD per year). This is because parent education gaps are dropped for nearly all recent studies in high-income countries. I believe the estimate of the parent education gap trend in the main paper, while imprecise, is more accurate than the one in Model 1C omitting over half of the available data. Nevertheless, the estimate of the parent education gap trend is still positive and highly significant in Model 1C.

Table H6. Comparison of Trends in Gaps, Dropping Observations with 20% or More of Students in the Top or Bottom SES Variable Category

	including all gaps (1)			dropping if ≥ 20% in top or bottom category (1C)		
	coef	(se)		coef	(se)	
Parent education gaps intercept	1.032	(0.030)	***	1.071	(0.036)	***
Parent occupation gaps intercept	0.958	(0.030)	***	0.998	(0.037)	***
Household books gaps intercept	1.299	(0.041)	***	1.366	(0.041)	***
Level 1 - Gaps						
Subject (ref=Reading)						
Math	0.020	(0.007)	**	0.004	(0.010)	
Science	0.034	(0.005)	***	0.034	(0.006)	***
SES variable quality measures						
Parent-reported × Parent education	0.132	(0.030)	***	0.129	(0.045)	**
Parent-reported × Parent occupation	0.075	(0.025)	**	0.049	(0.035)	
Parent-reported × Books	-0.039	(0.029)		-0.137	(0.037)	***
Number of categories (centered at 7)	0.003	(0.003)		0.000	(0.003)	
≥ 20% in bottom category	-0.065	(0.021)	**			
≥ 20% in top category	-0.135	(0.013)	***			
Level 2 - Study-years						
Age at testing (ref=14)						
Age 10 at testing	-0.170	(0.024)	***	-0.181	(0.035)	***
Age 15 at testing	-0.024	(0.020)		0.013	(0.029)	
Cohort birth year × Parent education	0.007	(0.001)	***	0.004	(0.002)	**
Cohort birth year × Parent occupation	0.007	(0.001)	***	0.006	(0.001)	***
Cohort birth year × Books	0.008	(0.001)	***	0.009	(0.002)	***
Random effects						
Level 2 - Residual variance between studies in…						
Parent education intercepts	0.03736			0.07398		
Parent occupation intercepts	0.02322			0.03327		
Books intercepts	0.03698			0.02828		
Level 3 - Residual variance between countries in…						
Parent education intercepts	0.05426			0.04230		
Parent occupation intercepts	0.05227			0.05367		
Books intercepts	0.11590			0.09283		
Parent education cohort slopes	0.00004			0.00002		
Parent occupation cohort slopes	0.00003			0.00003		
Books cohort slopes	0.00007			0.00005		
N (Level 1 - gaps)	5541			2577		
N (Level 2 - study-years)	1026			820		
N (Level 3 - countries)	100			91		

+ p<.1, * p<.05, ** p<.01, *** p < .001. Note: All models in this table specify known level 1 error variances and covariances, estimated via bootstrapping, consistent with models in the main text of the paper.

In summary, it is likely that changing measurement error in SES confounds estimates of true global changes in SES achievement gaps. But it is not clear that measurement error in SES is uniformly declining over time, as error may be increasing for some variables in some recent tests (i.e., PISA parent education). This would lead gap increases to be *under*- rather than overestimated, making the main trend estimates more conservative. To the extent that the reliability of SES has improved, this increase would have to be very large to fully account for the increase in SES achievement gaps. There is no direct evidence for changes in measurement error of SES, either in the data used in this study or in published research. Future research should identify older datasets containing both children's and parents' reports of family SES characteristics in order to examine whether reliability in student reporting may have increased over time and the size of this possible increase.

J. Trend Models Run Separately by SES Variable

The models in the main text of the paper pool all gap types, regardless of which of the three SES variables was used to calculate gaps (parent education, parent occupation, or household books). Table J1 reports gap trends models run separately by the SES variable from which gaps were calculated. Results are similar to those for pooled models reported in the main text of the paper, though both the intercepts and the cohort birth year slopes are slightly smaller for all three SES variables in these models than in the main text. The discrepancy is mainly due to differences in coefficients for control variables (e.g., subject, SES quality measures, age), which are allowed to vary by SES variable in these models rather than constrained to take the same value for all gap types in the pooled models. However, it is not clear that the different results for control variables for different SES variables are meaningful, as each model in Table J1 includes a somewhat different set of study-years and countries. (Running the models only on country-study-years where all three SES variables are available would reduce the sample by 75%, eliminating a large amount of valuable information.)

In some cases, the differences in coefficients for control variables across models using different SES variables do appear meaningful. For example, the math coefficient in Table 1 in the main text of the paper is 0.02, meaning that, on average when pooling all gap types, math achievement gaps are larger than reading achievement gaps (the reference category) by about 0.02 SDs. In Table J1, the math coefficient when predicting parent education gaps is about 0.06, when predicting parent occupation gaps is about 0.03, and when predicting books gaps is about 0. It is easy to see why household books might truly have a stronger relationship with reading achievement compared to other SES variable-subject pairs. However, these coefficients may still overstate (or understate) the discrepancies across SES variables, as they are based on different samples. More importantly, though, the goal of the present study is not to describe the specific processes by which each type of achievement gap is generated, but instead to examine whether *trends* in gaps across cohorts are similar enough that they could plausibly be driven by the same underlying process of growing SES achievement gaps, broadly defined, and if so, to pool all gap types to obtain the most accurate estimate of that trend. Thus, the pooled models reported in the main text are preferred over those in Table J1, as they give the best summary of trends in SES achievement gaps, using the most complete data available.

The discrepancy between the results in Table J1 and those in the main text is also in small part due to the inability of the separate models to account for error covariances among different gap types, as the multivariate variance-known models do. However, this issue does not affect

results substantially, as the results in Appendix L show that pooled models omitting error covariances produce very similar results to models incorporating error covariances.

Table J1. Coefficients from Hierarchical Growth Models Predicting Achievement Gaps between 90th and 10th Percentiles of SES, Run Separately by SES Variable

	Parent education		Parent occupation		Books	
Intercept	1.016 ***	1.054 ***	0.921 ***	0.903 ***	1.211 ***	1.200 ***
	(0.031)	(0.033)	(0.023)	(0.037)	(0.040)	(0.061)
Level 1 - Gaps						
Subject (ref=Reading):						
Math	0.054 ***	0.055 ***	0.025 ***	0.025 ***	-0.004	-0.004
	(0.010)	(0.010)	(0.007)	(0.007)	(0.009)	(0.009)
Science	0.054 ***	0.054 ***	0.017 ***	0.017 ***	0.041 ***	0.041 ***
	(0.008)	(0.008)	(0.005)	(0.005)	(0.007)	(0.007)
SES variable quality measures						
Parent-reported		0.051		-0.051 +		0.096 ***
		(0.045)		(0.028)		(0.024)
Number of categories (centered at 7)		-0.002		0.040 **		-0.045
		(0.003)		(0.014)		(0.028)
≥ 20% in bottom category		-0.117 **		0.066		-0.120 **
		(0.044)		(0.087)		(0.037)
≥ 20% in top category		-0.101 ***		-0.096 **		-0.107 ***
		(0.020)		(0.030)		(0.023)
Level 2 - Study-years						
Age at testing (ref=14)						
Age 10 at testing	-0.003	-0.060	0.017	-0.003	-0.215 ***	-0.247 ***
	(0.030)	(0.054)	(0.019)	(0.027)	(0.028)	(0.028)
Age 15 at testing	-0.154 ***	-0.112 ***			0.105 ***	0.127 **
	(0.025)	(0.024)			(0.025)	(0.039)
Cohort birth year	0.006 ***	0.006 ***	0.004 ***	0.005 ***	0.008 ***	0.006 ***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
Level 2 residual variance in intercepts	0.03390	0.03194	0.01852	0.01687	0.03395	0.03243
Level 3 residual variance in intercepts	0.04977	0.05164	0.03793	0.03616	0.11276	0.10128
Level 3 residual variance in cohort slopes	0.00005	0.00005	0.00004	0.00004	0.00008	0.00007
N (Level 1 - gaps)	1916	1916	1405	1405	2189	2189
N (Level 2 - study-years)	852	852	590	590	993	993
N (Level 3 - countries)	94	94	82	82	100	100

+ p<.1, * p<.05, ** p<.01, *** p < .001.

Note: In models predicting achievement gaps based on parent occupation, the dummy variable for age 15 is omitted, as there are very few age 14 assessments that collected parent occupation. Therefore, in the parent occupation models, the reference category is assessments of students who are age 14 *or* 15. All models in this table specify known level 1 error variances and covariances among gaps from different test subjects (but not different SES variables, as they are in separate models), estimated via bootstrapping.

K. SES achievement gap trends by age and subject

Table K1 reports gap trends models estimating different cohort birth year trends by level of schooling (primary versus secondary), rather than by SES variable as in the main text models. SES achievement gaps have increased substantially for both primary school students (0.007 SD per year) and secondary school students (0.009 SD per year). Both estimates are statistically significant (p<0.001). Gaps for secondary school students tend to be slightly larger than those for primary school students, and gaps for secondary students have also increased somewhat more than those for primary students. However, the primary and secondary school trend estimates are similar in size; a joint test of the null hypothesis that the two cohort slopes are equal cannot be

rejected (p=0.148). Within countries, trends in gaps for primary and secondary school students tend to be similar: the correlation between country random cohort slopes for primary and secondary school gaps is positive and moderately strong (r=0.472). As differences in primary and secondary trends are small and comparing trends across age groups is not of substantive interest in the current project, I consider it justifiable to pool gaps from primary and secondary students in the main text models.

Table K2 reports gap trends models estimating different cohort birth year trends by test subject (math, science, or reading), rather than by SES variable as in the main text models. SES achievement gaps have increased substantially in reading tests (0.012 SD per year), math tests (0.010 SD per year), and science tests (0.012 SD per year). All three estimates are statistically significant (p<0.001). In the earliest birth cohorts, SES gaps in math achievement tended to be somewhat larger than those in reading or science achievement. However, SES gaps in reading and science achievement have increased at a slightly faster pace than those in math achievement, resulting in SES gaps that are very similar in size across the three subjects in the most recent cohorts. Yet the trend estimates for all three test subjects are similar in size; a joint test of the null hypothesis that the three cohort slopes are equal is only marginally significant (p=0.074). Within countries, trends in gaps based on different test subjects are very similar: pairwise correlations between country random slopes for different test subjects range from 0.785 to 0.854. As differences in trends by test subject are small and comparing trends across subjects is not of substantive interest in the current project, I consider it justifiable to pool gaps from all three test subjects in the main text models.

Table K1. Coefficients from Hierarchical Growth Models Predicting Achievement Gaps between 90th and 10th Percentiles of SES, Estimating Different Trends by Age (Primary or Secondary School)

	coef	(se)	
Primary school gaps intercept	0.988	(0.068)	***
Secondary school gaps intercept	1.079	(0.032)	***
Level 1 - Gaps			
Subject (ref=Reading):			
Math	0.021	(0.007)	**
Science	0.035	(0.005)	***
SES variable (ref=Parent education)			
Parent occupation	-0.005	(0.021)	
Household books	0.214	(0.035)	***
SES variable quality measures			
Parent-reported	0.021	(0.063)	
Parent-reported × Parent occupation	-0.072	(0.052)	
Parent-reported × Books	0.002	(0.071)	
Number of categories (centered at 7)	-0.013	(0.005)	**
≥ 20% in bottom category	-0.212	(0.038)	***
≥ 20% in top category	-0.035	(0.022)	
Level 2 - Study-years			
Age 15 at testing	-0.185	(0.029)	***
Primary × Parent occupation	-0.040	(0.046)	
Primary × Books	-0.112	(0.065)	+
Cohort birth year × Primary	0.007	(0.002)	***
Cohort birth year × Secondary	0.009	(0.001)	***
Random effects			
Residual variance between studies	0.02562		
Residual variance between countries in…			
Primary school intercepts	0.05685		
Secondary school intercepts	0.06327		
Primary school cohort slopes	0.00003		
Secondary school cohort slopes	0.00005		
N (Level 1 - gaps)	5541		
N (Level 2 - study-years)	1026		
N (Level 3 - countries)	100		
p-value for H0: Cohort × Primary = Cohort × Secondary	0.148		
Correlation between country random cohort slopes for primary and secondary gaps	0.472		

+ p<.1, * p<.05, ** p<.01, *** p < .001. Note: All models in this table specify known level 1 error variances and covariances, estimated via bootstrapping, consistent with models in the main text of the paper.

Table K2. Coefficients from Hierarchical Growth Models Predicting Achievement Gaps between 90th and 10th Percentiles of SES, Estimating Different Trends by Test Subject (Math, Science, or Reading)

	coef	(se)	
Reading gaps intercept	1.025	(0.032)	***
Math gaps intercept	1.037	(0.031)	***
Science gaps intercept	1.047	(0.032)	***
Level 1 - Gaps			
SES variable (ref=Parent education)			
Parent occupation	-0.073	(0.021)	***
Household books	0.362	(0.033)	***
SES variable quality measures			
Parent-reported	-0.034	(0.052)	
Parent-reported × Parent occupation	-0.053	(0.027)	+
Parent-reported × Books	-0.227	(0.036)	***
Number of categories (centered at 7)	-0.005	(0.005)	
≥ 20% in bottom category	-0.202	(0.037)	***
≥ 20% in top category	-0.102	(0.018)	***
Level 2 - Study-years			
Age at testing (ref=14)			
Age 10 at testing	-0.135	(0.031)	***
Age 15 at testing	-0.018	(0.019)	
Cohort birth year × Reading	0.012	(0.001)	***
Cohort birth year × Math	0.010	(0.001)	***
Cohort birth year × Science	0.012	(0.001)	***
Random effects			
Level 2 - Residual variance between studies in...			
Reading intecepts	0.03293		
Math intercepts	0.03216		
Science intercepts	0.03707		
Level 3 - Residual variance between countries in...			
Reading intercepts	0.06441		
Math intercepts	0.06027		
Science intercepts	0.07121		
Reading cohort slopes	0.00006		
Math cohort slopes	0.00003		
Science cohort slopes	0.00004		
N (Level 1 - gaps)	5541		
N (Level 2 - study-years)	1026		
N (Level 3 - countries)	100		
p-value for H0: Cohort × Reading = Cohort × Math = Cohort × Science	0.074		
Correlation between country random cohort slopes for reading and math gaps	0.808		
Correlation between country random cohort slopes for reading and science gaps	0.854		
Correlation between country random cohort slopes for math and science gaps	0.785		

+ p<.1, * p<.05, ** p<.01, *** p < .001. Note: All models in this table specify known level 1 error variances and covariances, estimated via bootstrapping, consistent with models in the main text of the paper.

L. Specification of trend model

The coefficients for some control variables were omitted from the tables in the main text due to space constraints. Tables L1 and L2 report all coefficients from Table 2. Table L1 reports those from Model 3 (with country region interactions), and Table L2 reports all coefficients from Models 4-7.

Figure 3 in the main text showed estimated trends in SES achievement gaps for only 24 selected countries due to space constraints. Figures L1-L3 show estimated gap trends for a larger set of countries. Trend lines are derived from shrunken empirical Bayes estimates from Model 5 (Table 2 and Table L2). Countries with fewer than 7 study-years or whose data span fewer than 15 cohort birth years are excluded from the figures, as their trends cannot be precisely estimated. This leaves 55 displayed in the figures (of 100 countries in the full sample). For the remaining 45 countries with less available data, true country-specific gap trends are very uncertain. However, these countries still contribute to the estimation of the average global gap trend in the hierarchical growth curve models.

Table L1. All Coefficients from Model 3 Predicting Achievement Gaps between 90th and 10th Percentiles of SES with Interactions by Country Region

	(3) Region Interactions		
	coef	(se)	
Parent education gaps intercept	1.126	(0.027)	***
Parent occupation gaps intercept	1.111	(0.029)	***
Household books gaps intercept	1.563	(0.038)	***
Level 1 - Gaps			
Subject (ref=Reading)			
Math	0.020	(0.007)	**
Science	0.034	(0.005)	***
SES variable quality measures			
Parent-reported × Parent education	0.111	(0.031)	***
Parent-reported × Parent occupation	0.069	(0.024)	**
Parent-reported × Books	-0.018	(0.026)	
Number of categories (centered at 7)	0.002	(0.003)	
≥ 20% in bottom category	-0.045	(0.020)	*
≥ 20% in top category	-0.147	(0.013)	***
Level 2 - Study-years			
Age at testing (ref=14)			
Age 10 at testing	-0.171	(0.024)	***
Age 15 at testing	-0.028	(0.020)	
Cohort birth year	0.008	(0.001)	***
Level 3 - Countries			
Region (ref=Western) × Intercept interactions			
Sub-Saharan Africa × Parent education	-0.307	(0.089)	***
Sub-Saharan Africa × Parent occupation	-0.373	(0.113)	**
Sub-Saharan Africa × Books	-0.707	(0.143)	***
East Asia & Pacific × Parent education	-0.160	(0.082)	+
East Asia & Pacific × Parent occupation	-0.316	(0.074)	***
East Asia & Pacific × Books	-0.402	(0.097)	***
Middle East & N. Africa × Parent education	-0.248	(0.078)	**
Middle East & N. Africa × Parent occupation	-0.317	(0.069)	***
Middle East & N. Africa × Books	-0.731	(0.082)	***
E. Europe & CIS × Parent education	-0.057	(0.062)	
E. Europe & CIS × Parent occupation	-0.091	(0.051)	+
E. Europe & CIS × Books	-0.162	(0.064)	*
Latin America & Caribbean × Parent education	0.077	(0.051)	
Latin America & Caribbean × Parent occupation	-0.022	(0.050)	
Latin America & Caribbean × Books	-0.220	(0.070)	**
Region (ref=Western) × Cohort interactions			
Sub-Saharan Africa × Cohort	0.004	(0.004)	
East Asia & Pacific × Cohort	-0.001	(0.002)	
Middle East & N. Africa × Cohort	-0.001	(0.004)	
E. Europe & CIS × Cohort	-0.001	(0.002)	
Latin America & Caribbean × Cohort	-0.009	(0.004)	*
Random Effects			
Level 2 - Residual variance between studies in…			
Parent education intercepts	0.03785		
Parent occupation intercepts	0.02247		
Books intercepts	0.03825		
Level 3 - Residual variance between countries in…			
Parent education intercepts	0.04199		
Parent occupation intercepts	0.03086		
Books intercepts	0.05514		
Cohort slopes	0.00003		
N (Level 1 - gaps)	5541		
N (Level 2 - study-years)	1026		
N (Level 3 - countries)	100		

+ p<.1, * p<.05, ** p<.01, *** p < .001. Note: See Table A1 for country regions.

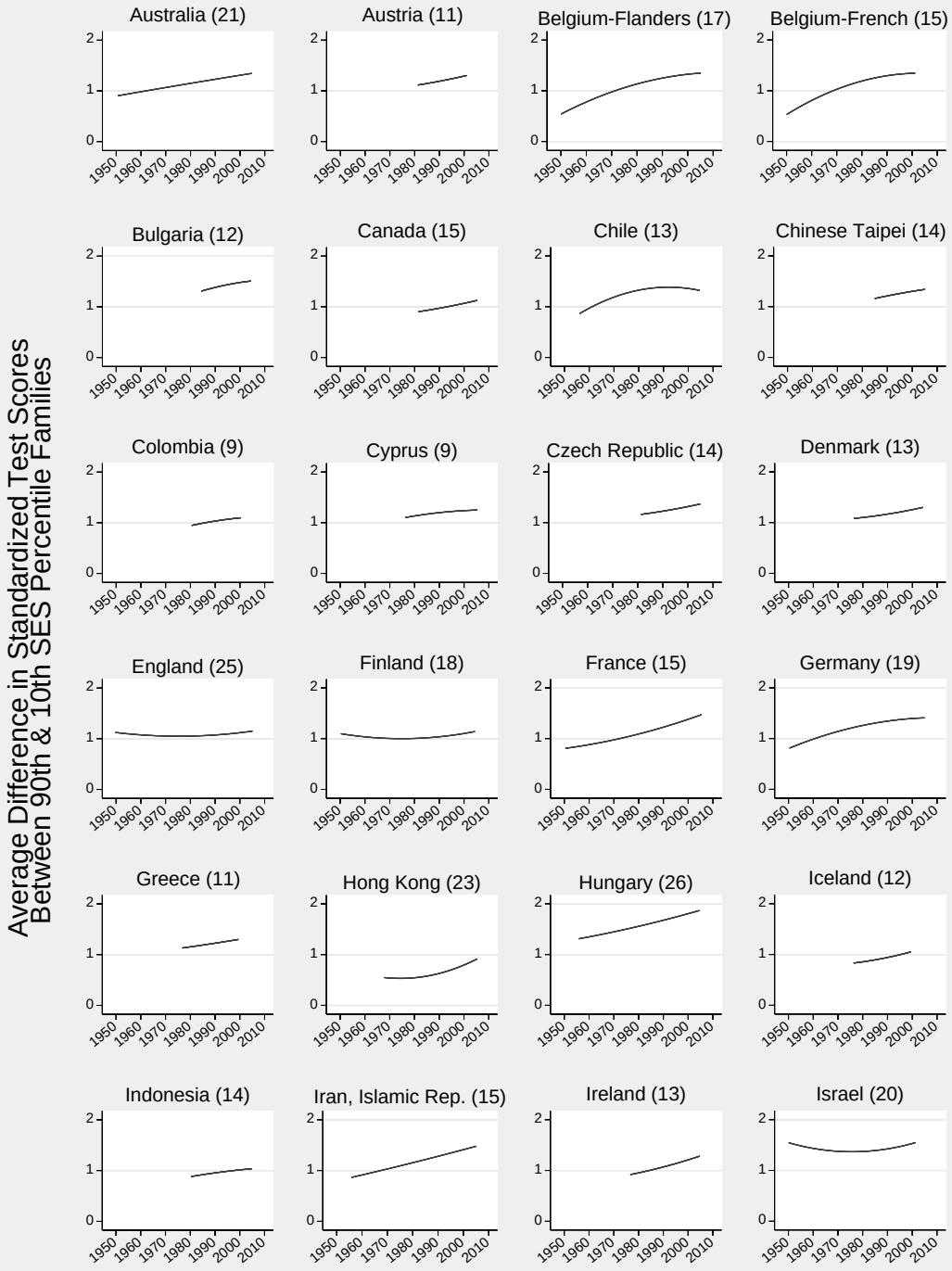
Table L2. All Coefficients from Models 4-7 Predicting Achievement Gaps between 90th, 50th, and 10th Percentiles of SES with Interactions by Country Income Level

	(4) Income Interaction			(5) Quadratic			(6) 90/50 Gap			(7) 50/10 Gap		
	coef	(se)		coef	(se)		coef	(se)		coef	(se)	
Parent education gaps intercept	1.074	(0.035)	***	1.066	(0.037)	***	0.548	(0.019)	***	0.514	(0.022)	***
Parent occupation gaps intercept	1.054	(0.038)	***	1.046	(0.042)	***	0.564	(0.020)	***	0.481	(0.022)	***
Household books gaps intercept	1.434	(0.047)	***	1.426	(0.049)	***	0.622	(0.022)	***	0.806	(0.029)	***
Level 1 - Gaps												
Subject (ref=Reading)												
Math	0.020	(0.007)	**	0.020	(0.007)	**	0.021	(0.004)	***	0.009	(0.004)	*
Science	0.034	(0.005)	***	0.034	(0.005)	***	0.022	(0.003)	***	0.013	(0.003)	***
SES variable quality measures												
Parent-reported × Parent education	0.113	(0.031)	***	0.112	(0.031)	***	0.105	(0.018)	***	0.016	(0.022)	
Parent-reported × Parent occupation	0.072	(0.024)	**	0.071	(0.024)	**	0.056	(0.017)	**	0.019	(0.017)	
Parent-reported × Books	-0.018	(0.027)		-0.018	(0.027)		0.140	(0.022)	***	-0.143	(0.022)	***
Number of categories (centered at 7)	0.002	(0.003)		0.002	(0.003)		0.002	(0.002)		0.001	(0.002)	
≥ 20% in bottom category	-0.061	(0.021)	**	-0.061	(0.021)	**	-0.055	(0.017)	**	-0.009	(0.020)	
≥ 20% in top category	-0.148	(0.013)	***	-0.147	(0.013)	***	-0.053	(0.011)	***	-0.086	(0.010)	***
Level 2 - Study-years												
Age at testing (ref=14)												
Age 10 at testing	-0.169	(0.024)	***	-0.163	(0.024)	***	-0.120	(0.016)	***	-0.041	(0.014)	**
Age 15 at testing	-0.023	(0.020)		-0.021	(0.020)		-0.044	(0.013)	**	0.020	(0.012)	+
Cohort birth year	0.007	(0.001)	***	0.007	(0.001)	***	0.001	(0.001)		0.006	(0.001)	***
Cohort birth year^2				0.00005	(0.00005)							
Level 3 - Countries												
Mid/low-income country × Intercept interactions												
Mid/low-income country × Parent education	-0.060	(0.048)		-0.040	(0.048)		0.007	(0.025)		-0.062	(0.029)	*
Mid/low-income country × Parent occupation	-0.166	(0.047)	***	-0.143	(0.050)	**	-0.007	(0.027)		-0.162	(0.028)	***
Mid/low-income country × Books	-0.251	(0.066)	***	-0.231	(0.066)	***	-0.054	(0.031)	+	-0.195	(0.042)	***
Mid/low-income country × Cohort	0.002	(0.002)		0.001	(0.002)		0.003	(0.001)	*	-0.001	(0.001)	
Mid/low-income country × Cohort^2				-0.00022	(0.00010)	*						
Random Effects												
Level 2 - Residual variance between studies in…												
Parent education intercepts	0.03822			0.03677			0.01671			0.01362		
Parent occupation intercepts	0.02302			0.02154			0.00877			0.00634		
Books intercepts	0.03839			0.03734			0.01715			0.01594		
Level 3 - Residual variance between countries in…												
Parent education intercepts	0.05256			0.05227			0.01294			0.01832		
Parent occupation intercepts	0.04810			0.05095			0.01448			0.01655		
Books intercepts	0.10677			0.10841			0.02128			0.03906		
Cohort slopes	0.00003			0.00003			0.00001			0.00001		
N (Level 1 - gaps)	5541			5541			5541			5541		
N (Level 2 - study-years)	1026			1026			1026			1026		
N (Level 3 - countries)	100			100			100			100		

+ p<.1, * p<.05, ** p<.01, *** p < .001. Note: “Middle/low income” countries had GDPs per capita of less than $6000 in 1980 (the reference category is high-income countries; see Table A1 for coding).

Figure L1. Estimated Quadratic Trends in 90/10 SES Achievement Gaps, Selected Countries

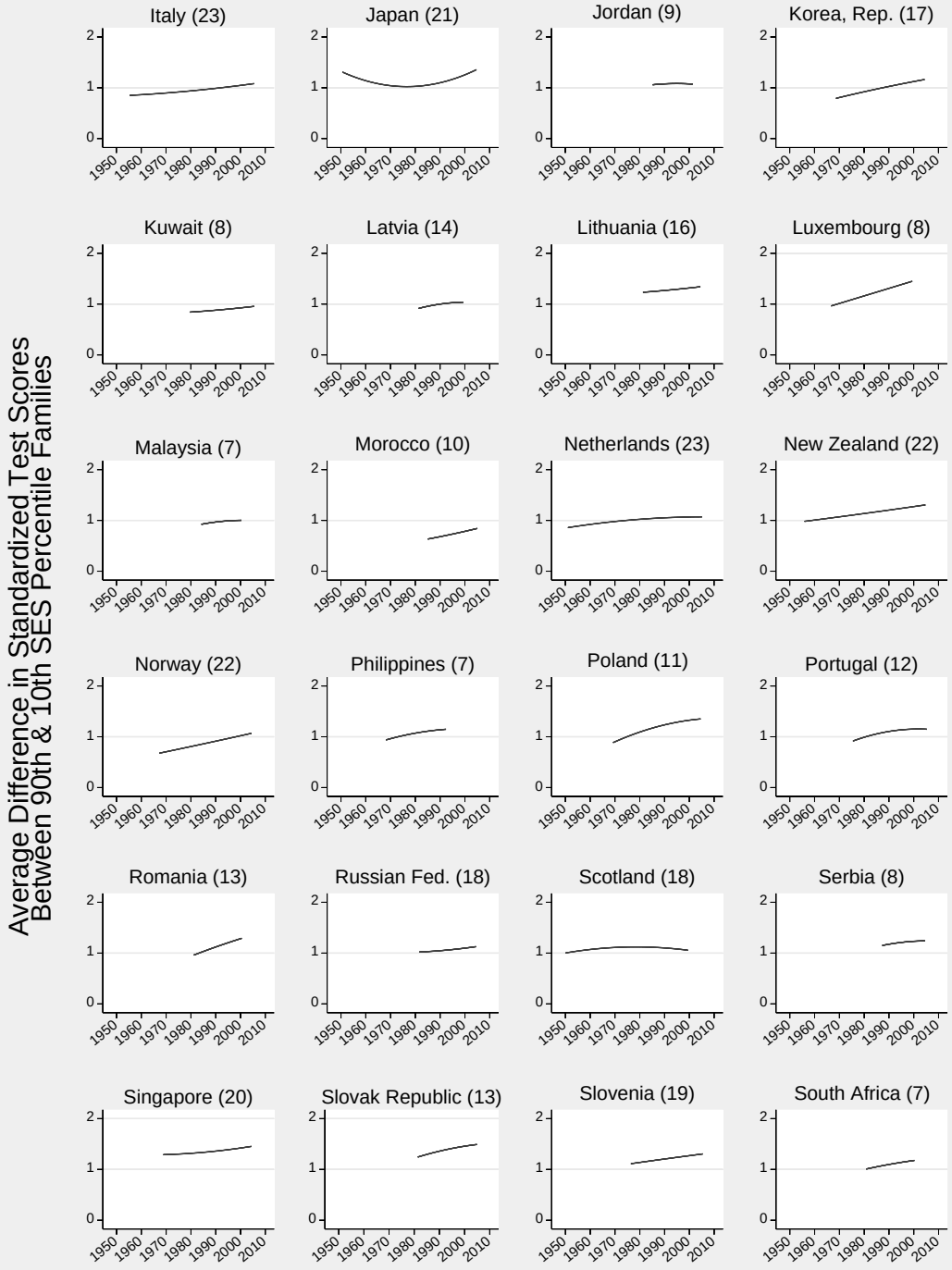
(Number of Study-Years in Parentheses)



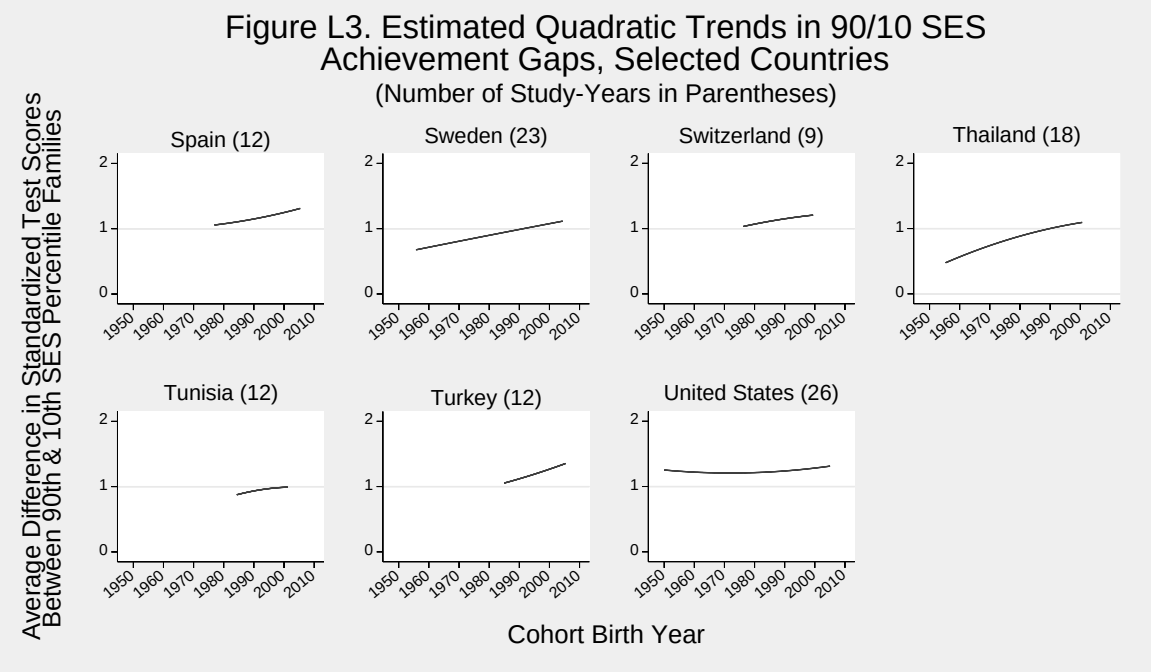
Notes: Countries sorted alphabetically. Trend lines are derived from shrunken empirical Bayes estimates from Model 5 (Table 2 and Table L2). Fixed values for control variables: SES=parent education, subject=math, all others=0 or reference category.

Figure L2. Estimated Quadratic Trends in 90/10 SES Achievement Gaps, Selected Countries

(Number of Study-Years in Parentheses)



Notes: Countries sorted alphabetically. Trend lines are derived from shrunken empirical Bayes estimates from Model 5 (Table 2 and Table L2). Fixed values for control variables: SES=parent education, subject=math, all others=0 or reference category.



Notes: Countries sorted alphabetically. Trend lines are derived from shrunken empirical Bayes estimates from Model 5 (Table 2 and Table L2). Fixed values for control variables: SES=parent education, subject=math, all others=0 or reference category.

Tables L3 and L4 report coefficients from six alternate specifications of the main gap trend model from the main text of the paper (Model 2 in Table 1). The first column of table L3 replicates Model 2 for comparison. All models in the main paper are multivariate variance-known models that specify the known the Level 1 (within-study) variance structure as equal to the estimated error variance-covariance matrix among different gap types in each country-study. Thus, the models take into account that the errors of different gap types within the same country-study are not independent. Error variances and covariances are estimated via bootstrapping. Due to the very long computation time of 1000 bootstrap estimates of 5541 SES achievement gaps, Models 2B and 2C examine the robustness of the results to excluding error covariances from level 1 while still specifying known error variances estimated via bootstrapping (Model 2B) and to specifying known error variances estimated using the conventional normality-assumption-based formula (following Reardon (2011b)) rather than bootstrapping (Model 2C). Results for both models are nearly identical to Model 2. Model 2D omits any known error variance from level 1 and freely estimates level 1 variance within the hierarchical model, meaning that the model no longer gives greater weight to more precisely-estimated gaps. Results again are nearly identical. As omitting error covariances and using conventional non-bootstrap error variances appears to produce very similar results, some subsequent models (2E and 2F) and several others throughout the appendices use this alternate level 1 variance specification to avoid excessive computation time.

Table L3. Coefficients from Hierarchical Growth Models Predicting Achievement Gaps between 90th and 10th Percentiles of Parent Education (Variety of Trend Model Specifications)

	(2) Main text (with BS error covariance)	(2B) With BS, no error covariance	(2C) Non-BS, no error covariance	(2D) No weights
Parent education intercept	1.039 ***	1.034 ***	1.044 ***	1.035 ***
	(0.030)	(0.030)	(0.031)	(0.030)
Parent occupation intercept	0.964 ***	0.959 ***	0.962 ***	0.955 ***
	(0.030)	(0.030)	(0.031)	(0.029)
Household books intercept	1.294 ***	1.291 ***	1.301 ***	1.292 ***
	(0.041)	(0.041)	(0.040)	(0.040)
Level 1 - Gaps				
Subject (ref=Reading):				
Math	0.020 **	0.018 *	0.006	0.014 +
	(0.007)	(0.007)	(0.008)	(0.007)
Science	0.034 ***	0.031 ***	0.026 ***	0.033 ***
	(0.005)	(0.006)	(0.007)	(0.006)
SES variable quality measures				
Parent-reported × Parent education	0.112 ***	0.111 ***	0.080 **	0.117 ***
	(0.031)	(0.030)	(0.027)	(0.031)
Parent-reported × Parent occupation	0.073 **	0.069 **	0.051 *	0.074 **
	(0.024)	(0.023)	(0.021)	(0.025)
Parent-reported × Books	-0.017	-0.017	-0.067 **	-0.001
	(0.026)	(0.026)	(0.023)	(0.029)
Number of categories (centered at 7)	0.002	0.003	0.003	0.003
	(0.003)	(0.003)	(0.003)	(0.003)
≥ 20% in bottom category	-0.063 **	-0.062 **	-0.066 **	-0.072 ***
	(0.021)	(0.021)	(0.021)	(0.020)
≥ 20% in top category	-0.146 ***	-0.143 ***	-0.136 ***	-0.144 ***
	(0.013)	(0.013)	(0.012)	(0.013)
Level 2 - Study-years				
Age at testing (ref=14)				
Age 10 at testing	-0.168 ***	-0.163 ***	-0.147 ***	-0.166 ***
	(0.024)	(0.024)	(0.023)	(0.024)
Age 15 at testing	-0.023	-0.021	-0.027	-0.022
	(0.020)	(0.020)	(0.019)	(0.020)
Cohort birth year	0.007 ***	0.007 ***	0.008 ***	0.007 ***
	(0.001)	(0.001)	(0.001)	(0.001)
Level 1 - Residual variance between gaps				0.00774
Level 2 - Residual variance between studies in…				
Parent education gaps	0.03831	0.03972	0.02719	0.04135
Parent occupation gaps	0.02284	0.02309	0.01877	0.02297
Household books gaps	0.03823	0.03881	0.03187	0.04111
Level 3 - Residual variance between countries in…				
Parent education gaps	0.05362	0.05231	0.05517	0.05121
Parent occupation gaps	0.05330	0.05305	0.05490	0.05326
Household books gaps	0.12149	0.12167	0.12270	0.11918
Cohort slopes	0.00003	0.00003	0.00003	0.00003
N (Level 1 - gaps)	5541	5541	5541	5541
N (Level 2 - study-years)	1026	1026	1027	1027
N (Level 3 - countries)	100	100	100	100

+ p<.1, * p<.05, ** p<.01, *** p < .001

Model 2E uses gaps computed without multiple imputation of missing student-level data; listwise deletion of student observations with missing data on any variables is used instead. Level 1 (gaps) sample sizes are slightly smaller. Point estimates for coefficients are similar, though the standard errors on the intercepts and cohort trend increase substantially, and the cohort trend loses significance. These changes are due to increased heterogeneity across countries in gap trends estimated when dropping missing data (though note that imputation models were estimated separately for each country-study).

Model 2F uses gaps for which the 90^{th} and 10^{th} percentiles of each SES categorical variable were interpolated from linear rather than cubic weighted least squares models. Level 1 (gaps) and Level 2 (study-years) sample sizes are larger because a slightly larger number of gaps can be estimated reliably from these simpler models. The cohort birth year coefficient is slightly larger (i.e., the estimated increase in SES achievement gaps is larger) because the additional observations are very small gaps in early years. Cubic models are retained as the preferred models, as the trend estimates are more conservative, cubic gap functions allow more flexibility in the shape of the relationship between SES and achievement, and for comparability with Reardon (2011b).

Model 2G uses gaps between the 75^{th} and 25^{th} percentiles rather than the 90^{th} and 10^{th} percentiles of each SES variable. As expected, the intercepts, cohort birth year coefficient, and coefficients for most control variables are smaller than in models predicting 90/10 gaps, as 75/10 gaps are smaller in magnitude. However, the size of the cohort birth year coefficient is still substantial (0.005 SD per year) and highly significant. These results demonstrate that the finding of increasing SES achievement gaps is robust to using an alternate gap measure that may be more precisely estimated, as the 75^{th} and 25^{th} percentiles are less likely to be extrapolated outside the available SES data in high-income countries with large numbers of students in the top parent education and occupation categories. Additional models predicting 75/50 and 50/25 gaps (not shown) reveal that the estimated cohort coefficient for 75/50 gaps (0.002) is slightly smaller than the estimated cohort coefficient for 50/25 gaps (0.003). Both coefficients are highly significant ($p < 0.001$). Thus, the finding that gaps have increased more between the middle and bottom of the SES distribution than between the middle and top of the SES distribution—modeled in the main paper text using 50/10 and 90/50 gaps—is also robust to using alternative percentiles of the SES distribution. The 90/10, 90/50, and 50/10 gaps are still retained as the preferred results in the main paper text for comparability with Reardon (2011b).

Model 2H omits the random effect for the cohort birth year slope and instead estimates a fixed cohort slope for all countries. Results are very similar. The random cohort slope is retained as the preferred model, as a chi-square test shows the variance in the random cohort slopes to be significantly different from 0 in the main models and all other trend model specifications.

Table L4. Coefficients from Hierarchical Growth Models Predicting Achievement Gaps between 90th and 10th (or 75th and 25th) Percentiles of Parent Occupation (Variety of Trend Model Specifications)

	(2E) No imputation	(2F) Linear gaps	(2G) 75/25	(2H) Fixed slope
Parent education intercept	1.063 ***	0.992 ***	0.561 ***	1.036 ***
	(0.225)	(0.029)	(0.019)	(0.031)
Parent occupation intercept	1.000 ***	0.923 ***	0.555 ***	0.961 ***
	(0.178)	(0.029)	(0.021)	(0.030)
Household books intercept	1.311 ***	1.276 ***	0.794 ***	1.290 ***
	(0.174)	(0.040)	(0.022)	(0.042)
Level 1 - Gaps				
Subject (ref=Reading):				
Math	-0.007	0.013 +	0.002	0.020 **
	(0.010)	(0.007)	(0.006)	(0.007)
Science	0.023 **	0.020 ***	0.005	0.034 ***
	(0.009)	(0.005)	(0.006)	(0.005)
SES variable quality measures				
Parent-reported × Parent education	0.084 **	0.067 *	0.001	0.118 ***
	(0.031)	(0.026)	(0.002)	(0.031)
Parent-reported × Parent occupation	0.013	0.046 *	0.078 ***	0.080 **
	(0.025)	(0.021)	(0.023)	(0.025)
Parent-reported × Books	-0.075 **	-0.087 ***	-0.005	-0.012
	(0.027)	(0.022)	(0.016)	(0.027)
Number of categories (centered at 7)	0.002	0.004	-0.076 ***	0.002
	(0.006)	(0.002)	(0.017)	(0.003)
≥ 20% in bottom category	-0.049 *	-0.037 +	0.004	-0.065 **
	(0.023)	(0.019)	(0.015)	(0.021)
≥ 20% in top category	-0.129 ***	-0.104 ***	-0.069 ***	-0.148 ***
	(0.016)	(0.011)	(0.009)	(0.013)
Level 2 - Study-years				
Age at testing (ref=14)				
Age 10 at testing	-0.142 ***	-0.136 ***	-0.126 ***	-0.165 ***
	(0.024)	(0.022)	(0.015)	(0.024)
Age 15 at testing	-0.031	-0.020	-0.010	-0.021
	(0.022)	(0.019)	(0.012)	(0.020)
Cohort birth year	0.007	0.008 ***	0.005 ***	0.007 ***
	(0.006)	(0.001)	(0.001)	(0.001)
Level 1 - Residual variance between gaps				
Level 2 - Residual variance between studies in…				
Parent education gaps	0.02784	0.02385	0.01715	0.04126
Parent occupation gaps	0.01356	0.01764	0.00615	0.02701
Household books gaps	0.03188	0.02749	0.01261	0.04209
Level 3 - Residual variance between countries in…				
Parent education gaps	0.05741	0.05079	0.01342	0.05533
Parent occupation gaps	0.04812	0.05529	0.01952	0.05526
Household books gaps	0.12037	0.12524	0.03298	0.12563
Cohort slopes	0.00003	0.00003	0.00002	
N (Level 1 - gaps)	5521	5584	5199	5541
N (Level 2 - study-years)	1026	1033	1015	1026
N (Level 3 - countries)	100	100	99	100

+ p<.1, * p<.05, ** p<.01, *** p < .001. Note: To avoid very long computation times, Models 2E, 2F, and 2G specify known level 1 error variances estimated using conventional non-bootstrap formulas and omit error covariances. This simplified specification appears to produce very similar results to models using bootstrapped error variances and covariances (see Table L3). Model 2H uses bootstrapped error variances and covariances.

M. Specification of multivariate model

The coefficients for some control variables were omitted from the tables in the main text due to space constraints. Table M1 reports all coefficients from Table 3 (with time-varying country covariates). Additionally, Table M1 reports two further models predicting 90/50 and 50/10 SES achievement gaps (Models 9 and 10, respectively). The coefficients for the time-varying country covariates are similar in direction whether predicting 90/50 or 50/10 gaps, but the magnitude and significance of coefficients tends to be larger when predicting 90/50 gaps than 50/10 gaps. Additionally, by comparing the level 2 residual variances for these full models to reduced models that include study fixed effects and controls but no country covariates (not shown), we can compare how well the covariates account for changes in gaps at the top relative to the bottom of the SES distribution. Compared to a reduced model predicting 90/50 gaps, the country covariates in Model 9 explain an additional 5%, 10%, and 6% of the within-country variance in 90/50 gaps based on parent education, occupation and books. In contrast, the covariates in Model 10 explain only an additional 0.2%, 0%, and 5% of the within-country variance in 50/10 gaps based on parent education, occupation, and books. This is consistent with the fact that most of the covariate coefficients are larger and more significant when predicting 90/50 than 50/10 gaps, and indicates that the country characteristics examined in this study do a better job of explaining changes in gaps at the top of the SES distribution than at the bottom. As 50/10 gaps have increased greatly in most countries (more than 90/50 gaps have increased), a large share of the within-country variance in 50/10 gaps is explained by the study-year fixed effects. Net of this large global secular increase, however, the country covariates do not tell us much about which countries experience larger or smaller increases in 50/10 gaps.

Table M1. Unstandardized Coefficients from Hierarchical Growth Models Predicting Achievement Gaps between 90th, 50th, and 10th Percentiles of SES

	(8) 90/10 Gap		(9) 90/50 Gap		(10) 50/10 Gap	
	coef	(se)	coef	(se)	coef	(se)
Parent education gaps intercept	0.970	(0.046) ***	0.552	(0.029) ***	0.401	(0.032) ***
Parent occupation gaps intercept	0.969	(0.049) ***	0.584	(0.030) ***	0.375	(0.032) ***
Household books gaps intercept	1.405	(0.057) ***	0.645	(0.033) ***	0.753	(0.034) ***
Level 1 - Gaps						
Subject controls (ref=Reading)						
Math	0.020	(0.007) **	0.021	(0.004) ***	0.007	(0.004) *
Science	0.033	(0.006) ***	0.022	(0.003) ***	0.012	(0.003) ***
SES variable quality measures						
Parent-reported × Parent education	0.023	(0.039)	0.071	(0.022) **	-0.049	(0.028) +
Parent-reported × Parent occupation	-0.026	(0.032)	0.002	(0.021)	-0.038	(0.022) +
Parent-reported × Books	-0.128	(0.039) **	0.084	(0.025) ***	-0.212	(0.026) ***
Number of categories (centered at 7)	0.000	(0.003)	0.001	(0.002)	0.001	(0.002)
≥ 20% in bottom category	-0.055	(0.023) *	-0.047	(0.019) *	0.001	(0.021)
≥ 20% in top category	-0.149	(0.015) ***	-0.061	(0.012) ***	-0.080	(0.011) ***
Level 2 - Study-years						
Study fixed effects (ref=TIMSS 2003 Grade 8)	yes		yes		yes	
School enrollment (proportion)	0.486	(0.107) ***	0.276	(0.067) ***	0.203	(0.068) **
Immigrant background (proportion)	0.226	(0.250)	0.130	(0.145)	0.090	(0.134)
GDP per capita (logged)	0.055	(0.059)	0.024	(0.049)	0.039	(0.039)
Income inequality (Gini)	-1.913	(0.887) *	-1.380	(0.476) **	-0.554	(0.489)
Mid/low-income country × Income inequality	2.539	(1.129) *	1.687	(0.628) **	0.753	(0.650)
Age when tracking begins	-0.037	(0.016) *	-0.023	(0.011) *	-0.015	(0.008) +
Private school enrollment (proportion)	0.240	(0.249)	0.147	(0.142)	0.070	(0.159)
Expecting higher education (proportion)	-0.029	(0.094)	-0.043	(0.062)	0.017	(0.046)
Level 3 - Countries						
Mid/low-income country × Intercept interactions						
Mid/low-income country × Parent education	0.192	(0.063) **	0.071	(0.033) *	0.138	(0.037) ***
Mid/low-income country × Parent occupation	0.060	(0.058)	0.056	(0.035)	0.017	(0.033)
Mid/low-income country × Books	-0.082	(0.068)	-0.016	(0.040)	-0.059	(0.043)
Mean school enrollment	0.640	(0.317) *	0.139	(0.179)	0.531	(0.162) **
Mean proportion immigrant background	0.134	(0.261)	-0.057	(0.146)	0.172	(0.140)
Mean GDP per capita (logged)	0.142	(0.041) ***	0.078	(0.024) **	0.070	(0.022) **
Mean income inequality	0.605	(0.317) +	0.594	(0.169) ***	-0.008	(0.174)
Mean age when tracking begins	-0.035	(0.011) **	-0.020	(0.005) ***	-0.018	(0.007) *
Mean private school enrollment	0.043	(0.099)	0.006	(0.058)	0.029	(0.057)
Mean proportion expecting higher education	-0.255	(0.169)	-0.113	(0.087)	-0.154	(0.101)
Random effects						
Level 2 - Residual variance between studies in...						
Parent education gaps	0.038		0.017		0.015	
Parent occupation gaps	0.021		0.008		0.006	
Household books gaps	0.037		0.015		0.014	
Level 3 - Residual variance between countries in...						
Parent education gaps	0.028		0.007		0.010	
Parent occupation gaps	0.027		0.009		0.010	
Household books gaps	0.049		0.014		0.016	
N (Level 1 - gaps)	4604		4604		4604	
N (Level 2 - study-years)	855		855		855	
N (Level 3 - countries)	78		78		78	

+ p<.1, * p<.05, ** p<.01, *** p < .001. Notes: "Middle/low income" countries had GDPs per capita of less than $6000 in 1980 (the reference category is high-income countries; see Appendix Table A1 for coding). All level 2 time-varying country covariates are mean-centered within countries, meaning results can be interpreted very similarly to a model with country fixed effects (as well as study-year fixed effects, included at level 2).

Tables M2 and M3 report intercorrelations among all country covariates, at the country-study-year level (n=855; Table M2) and at the country level (n=78; Table M3). None of the correlations is strong enough to cause concern about collinearity in the multivariate models.

Table M2. Correlations Among Time-Varying Country Covariates (n=855)

	School enrollment (proportion)	Immigrant background (proportion)	GDP per capita (logged)	Income inequality (Gini)	Age when tracking begins	Private school enrollment (proportion)	Expecting higher education (proportion)
School enrollment (proportion)	1						
Immigrant background (proportion)	0.258	1					
GDP per capita (logged)	0.587	0.441	1				
Income inequality (Gini)	-0.443	-0.281	-0.466	1			
Age when tracking begins	0.077	0.067	0.028	0.169	1		
Private school enrollment (proportion)	0.022	0.165	0.135	-0.052	-0.214	1	
Expecting higher education (proportion)	-0.063	-0.060	-0.086	0.432	0.307	0.017	1

Table M3. Correlations Among Country-Level Mean Variables (N=78)

	Mean school enrollment	Mean proportion immigrant background	Mean GDP per capita (logged)	Mean income inequality	Mean age when tracking begins	Mean private school enrollment	Mean proportion expecting higher education
Mean school enrollment	1.000						
Mean proportion immigrant background	0.320	1					
Mean GDP per capita (logged)	0.647	0.475	1				
Mean income inequality	-0.520	-0.388	-0.457	1			
Mean age when tracking begins	0.089	0.045	-0.015	0.082	1		
Mean private school enrollment	-0.009	0.089	0.151	-0.025	-0.262	1	
Mean proportion expecting higher education	-0.288	-0.251	-0.398	0.438	0.265	0.074	1

Table M4 further examines possible collinearity among time-varying country covariates by reporting seven models, each predicting 90/10 SES achievement gaps from only one time-varying country covariate at a time. The coefficients for all time-varying country covariates are very similar when each is entered individually to in models where all seven covariates are entered together. Thus, collinearity among country covariates does not appear to influence the results.

In the main text of the paper, I examined whether certain types of countries tend to have greater increases in SES achievement gaps by interacting two country-level variables (region and income level) with the cohort birth year slope. Table M5 further explores whether cohort birth year slopes systematically vary by other available country-level variables. As the country-level sample size with complete data is only 78, I run each interaction model separately. The coefficients of interest are the 'Country variable × Cohort interactions' near the bottom of the table. All coefficients are close to 0 and non-significant.

Table M4. Unstandardized Coefficients from Hierarchical Growth Models Predicting Achievement Gaps between 90th and 10th Percentiles of SES, Entering Covariates One at a Time

	Enrollment		Immigration		GDP per capita		Income inequality	
	coef	(se)	coef	(se)	coef	(se)	coef	(se)
Parent education gaps intercept	1.065	(0.043) ***	1.082	(0.040) ***	0.969	(0.045) ***	1.016	(0.044) ***
Parent occupation gaps intercept	1.066	(0.047) ***	1.083	(0.046) ***	0.970	(0.049) ***	1.015	(0.046) ***
Household books gaps intercept	1.498	(0.057) ***	1.514	(0.055) ***	1.401	(0.055) ***	1.449	(0.056) ***
Level 1 - Gaps								
Subject controls (ref=Reading)								
Math	0.020	(0.007) **	0.020	(0.007) **	0.020	(0.007) **	0.020	(0.007) **
Science	0.033	(0.006) ***	0.033	(0.006) ***	0.033	(0.006) ***	0.033	(0.006) ***
SES variable quality measures								
Parent-reported × Parent education	0.027	(0.039)	0.027	(0.039)	0.025	(0.039)	0.020	(0.039)
Parent-reported × Parent occupation	-0.022	(0.033)	-0.024	(0.032)	-0.025	(0.032)	-0.024	(0.032)
Parent-reported × Books	-0.123	(0.039) **	-0.124	(0.040) **	-0.127	(0.039) **	-0.136	(0.040) ***
Number of categories (centered at 7)	0.000	(0.003)	0.000	(0.003)	0.000	(0.003)	-0.002	(0.003)
≥ 20% in bottom category	-0.059	(0.022) **	-0.055	(0.022) *	-0.056	(0.022) *	-0.057	(0.022) **
≥ 20% in top category	-0.154	(0.015) ***	-0.153	(0.015) ***	-0.152	(0.015) ***	-0.146	(0.015) ***
Level 2 - Study-years								
Study fixed effects (ref=TIMSS 2003 Grade 8)	yes		yes		yes		yes	
School enrollment (proportion)	0.505	(0.110) ***						
Immigrant background (proportion)			0.313	(0.301)				
GDP per capita (logged)					0.076	(0.068)		
Income inequality (Gini)							-1.623	(0.838) +
Mid/low-income country × Income inequality							2.072	(1.078) +
Level 3 - Countries								
Mid/low-income country × Intercept interactions								
Mid/low-income country × Parent education	0.021	(0.061)	-0.038	(0.050)	0.168	(0.062) **	-0.070	(0.063)
Mid/low-income country × Parent occupation	-0.110	(0.056) *	-0.161	(0.051) **	0.039	(0.057)	-0.195	(0.059) ***
Mid/low-income country × Books	-0.254	(0.072) ***	-0.314	(0.069) ***	-0.102	(0.066)	-0.347	(0.078) ***
Mean school enrollment	0.583	(0.291) *						
Mean proportion immigrant background			0.358	(0.279)				
Mean GDP per capita (logged)					0.178	(0.036) ***		
Mean income inequality							0.140	(0.305)
Random effects								
Level 2 - Residual variance between studies in...								
Parent education gaps	0.03892		0.03980		0.03957		0.04075	
Parent occupation gaps	0.02241		0.02219		0.02206		0.02300	
Household books gaps	0.03788		0.03949		0.04030		0.04011	
Level 3 - Residual variance between countries in...								
Parent education gaps	0.03905		0.04544		0.03646		0.04400	
Parent occupation gaps	0.03498		0.03694		0.02962		0.03736	
Household books gaps	0.07527		0.08838		0.06152		0.08712	
N (Level 1 - gaps)	4604		4604		4604		4604	
N (Level 2 - study-years)	855		855		855		855	
N (Level 3 - countries)	78		78		78		78	

+ p<.1, * p<.05, ** p<.01, *** p < .001. Notes: "Middle/low income" countries had GDPs per capita of less than $6000 in 1980 (the reference category is high-income countries; see Appendix Table A1 for coding). All level 2 time-varying country covariates are mean-centered within countries, meaning results can be interpreted very similarly to a model with country fixed effects (as well as study-year fixed effects, included at level 2). All models in this table specify known level 1 error variances and covariances, estimated via bootstrapping, consistent with models in the main text of the paper.

Model M4 (cont.) Unstandardized Coefficients from Hierarchical Growth Models Predicting Achievement Gaps between 90th and 10th Percentiles of SES, Entering Covariates One at a Time

	Tracking		Private		Higher ed. Expect.	
	coef	(se)	coef	(se)	coef	(se)
Parent education gaps intercept	1.098	(0.039) ***	1.094	(0.040) ***	1.083	(0.043) ***
Parent occupation gaps intercept	1.098	(0.042) ***	1.095	(0.043) ***	1.084	(0.044) ***
Household books gaps intercept	1.531	(0.052) ***	1.527	(0.054) ***	1.515	(0.052) ***
Level 1 - Gaps						
Subject controls (ref=Reading)						
Math	0.020	(0.007) **	0.020	(0.007) **	0.020	(0.007) **
Science	0.033	(0.006) ***	0.033	(0.006) ***	0.033	(0.006) ***
SES variable quality measures						
Parent-reported × Parent education	0.026	(0.039)	0.025	(0.038)	0.027	(0.038)
Parent-reported × Parent occupation	-0.025	(0.032)	-0.026	(0.032)	-0.025	(0.032)
Parent-reported × Books	-0.126	(0.040) **	-0.126	(0.039) **	-0.125	(0.039) **
Number of categories (centered at 7)	0.000	(0.003)	0.000	(0.003)	0.000	(0.003)
≥ 20% in bottom category	-0.052	(0.022) *	-0.054	(0.022) *	-0.056	(0.022) *
≥ 20% in top category	-0.150	(0.015) ***	-0.152	(0.015) ***	-0.151	(0.015) ***
Level 2 - Study-years						
Study fixed effects (ref=TIMSS 2003 Grade 8)	yes		yes		yes	
Age when tracking begins	-0.032	(0.015) *				
Private school enrollment (proportion)			0.206	(0.295)		
Expecting higher education (proportion)					-0.054	(0.101)
Level 3 - Countries						
Mid/low-income country × Intercept interactions						
Mid/low-income country × Parent education	-0.068	(0.045)	-0.057	(0.046)	-0.037	(0.054)
Mid/low-income country × Parent occupation	-0.194	(0.045) ***	-0.181	(0.045) ***	-0.160	(0.049) ***
Mid/low-income country × Books	-0.346	(0.063) ***	-0.332	(0.066) ***	-0.311	(0.067) ***
Mean age when tracking begins	-0.028	(0.013) *				
Mean private school enrollment			0.213	(0.108) *		
Mean proportion expecting higher education					-0.311	(0.176) +
Random effects						
Level 2 - Residual variance between studies in...						
Parent education gaps	0.03950		0.03947		0.03939	
Parent occupation gaps	0.02165		0.02223		0.02209	
Household books gaps	0.03962		0.04009		0.04010	
Level 3 - Residual variance between countries in...						
Parent education gaps	0.04093		0.04483		0.04541	
Parent occupation gaps	0.03644		0.03729		0.03597	
Household books gaps	0.08150		0.08966		0.08300	
N (Level 1 - gaps)	4604		4604		4604	
N (Level 2 - study-years)	855		855		855	
N (Level 3 - countries)	78		78		78	

+ p<.1, * p<.05, ** p<.01, *** p < .001. Notes: “Middle/low income” countries had GDPs per capita of less than $6000 in 1980 (the reference category is high-income countries; see Appendix Table A1 for coding). All level 2 time-varying country covariates are mean-centered within countries, meaning results can be interpreted very similarly to a model with country fixed effects (as well as study-year fixed effects, included at level 2). All models in this table specify known level 1 error variances and covariances, estimated via bootstrapping, consistent with models in the main text of the paper.

Table M5. Unstandardized Coefficients from Hierarchical Growth Curve Models Predicting Achievement Gaps between 90th and 10th Percentiles, Adding Interactions by Country Variables

	Enrollment		Immigration		GDP per capita		Income inequality	
	coef	(se)	coef	(se)	coef	(se)	coef	(se)
Parent education gaps intercept	1.064	(0.031) ***	1.067	(0.033) ***	1.063	(0.031) ***	1.066	(0.033) ***
Parent occupation gaps intercept	0.993	(0.029) ***	0.995	(0.030) ***	0.988	(0.028) ***	0.994	(0.031) ***
Household books gaps intercept	1.331	(0.039) ***	1.338	(0.044) ***	1.322	(0.036) ***	1.335	(0.043) ***
Level 1 - Gaps								
Subject controls (ref=Reading)								
Math	0.020	(0.007) **	0.020	(0.007) **	0.020	(0.007) **	0.020	(0.007) **
Science	0.033	(0.006) ***	0.033	(0.006) ***	0.033	(0.006) ***	0.033	(0.006) ***
SES variable quality measures								
Parent-reported × Parent education	0.109	(0.038) **	0.108	(0.037) **	0.107	(0.037) **	0.109	(0.037) **
Parent-reported × Parent occupation	0.055	(0.027) *	0.055	(0.028) *	0.053	(0.027) +	0.055	(0.028) *
Parent-reported × Books	-0.024	(0.030)	-0.020	(0.030)	-0.024	(0.030)	-0.021	(0.030)
Number of categories (centered at 7)	0.003	(0.003)	0.002	(0.003)	0.002	(0.003)	0.002	(0.003)
≥ 20% in bottom category	-0.049	(0.024) *	-0.061	(0.025) *	-0.047	(0.024) +	-0.055	(0.024) *
≥ 20% in top category	-0.155	(0.014) ***	-0.157	(0.013) ***	-0.156	(0.014) ***	-0.156	(0.014) ***
Level 2 - Study-years								
Age at testing (ref=14)								
Age 10 at testing	-0.153	(0.026) ***	-0.152	(0.026) ***	-0.151	(0.026) ***	-0.152	(0.026) ***
Age 15 at testing	-0.014	(0.023)	-0.013	(0.023)	-0.015	(0.023)	-0.014	(0.023)
Cohort birth year	0.007	(0.001) ***	0.007	(0.001) ***	0.007	(0.001) ***	0.007	(0.001) ***
Level 3 - Countries								
Country variable × Intercept interactions								
Mean school enrollment × Parent education	0.597	(0.194) **						
Mean school enrollment × Parent occupation	0.810	(0.252) **						
Mean school enrollment × Books	1.635	(0.287) ***						
Mean proportion immigrant background × Parent education			0.358	(0.292)				
Mean proportion immigrant background × Parent occupation			0.934	(0.248) ***				
Mean proportion immigrant background × Books			1.288	(0.395) **				
Mean GDP per capita (logged) × Parent education					0.091	(0.026) ***		
Mean GDP per capita (logged) × Parent occupation					0.152	(0.027) ***		
Mean GDP per capita (logged) × Books					0.291	(0.034) ***		
Mean income inequality × Parent education							-0.020	(0.241)
Mean income inequality × Parent occupation							-0.510	(0.221) *
Mean income inequality × Books							-1.326	(0.318) ***
Country variable × Cohort interactions								
Mean school enrollment × Cohort	0.003	(0.009)						
Mean proportion immigrant background × Cohort			0.013	(0.015)				
Mean GDP per capita (logged) × Cohort					0.001	(0.001)		
Mean income inequality × Cohort							-0.010	(0.012)
Random Effects								
Level 2 - Residual variance between studies in...								
Parent education intercepts	0.04087		0.04074		0.04074		0.04071	
Parent occupation intercepts	0.02232		0.02233		0.02223		0.02237	
Books intercepts	0.04054		0.04042		0.04049		0.04051	
Level 3 - Residual variance between countries in...								
Parent education intercepts	0.03693		0.04246		0.0372		0.04387	
Parent occupation intercepts	0.03238		0.0371		0.02761		0.04022	
Books intercepts	0.06803		0.09794		0.05272		0.09185	
Cohort slopes	0.00004		0.00004		0.00003		0.00004	
N (Level 1 - gaps)	4604		4604		4604		4604	
N (Level 2 - study-years)	855		855		855		855	
N (Level 3 - countries)	78		78		78		78	

+ p<.1, * p<.05, ** p<.01, *** p < .001. Note: All models in this table specify known level 1 error variances and covariances, estimated via bootstrapping, consistent with models in the main text of the paper.

Table M5 (cont). Unstandardized Coefficients from Hierarchical Growth Curve Models Predicting Achievement Gaps between 90th and 10th Percentiles, Adding Interactions by Country Variables

	Tracking		Private		Higher ed. Expect.	
	coef	(se)	coef	(se)	coef	(se)
Parent education gaps intercept	1.068	(0.032) ***	1.065	(0.033) ***	1.065	(0.033) ***
Parent occupation gaps intercept	0.995	(0.031) ***	0.993	(0.031) ***	0.993	(0.031) ***
Household books gaps intercept	1.341	(0.044) ***	1.338	(0.045) ***	1.334	(0.044) ***
Level 1 - Gaps						
Subject controls (ref=Reading)						
Math	0.020	(0.007) **	0.020	(0.007) **	0.020	(0.007) **
Science	0.033	(0.006) ***	0.033	(0.006) ***	0.033	(0.006) ***
SES variable quality measures						
Parent-reported × Parent education	0.108	(0.037) **	0.109	(0.037) **	0.108	(0.037) **
Parent-reported × Parent occupation	0.055	(0.028) *	0.055	(0.027) *	0.054	(0.028) *
Parent-reported × Books	-0.021	(0.030)	-0.021	(0.030)	-0.022	(0.030)
Number of categories (centered at 7)	0.002	(0.003)	0.002	(0.003)	0.002	(0.003)
≥ 20% in bottom category	-0.064	(0.025) **	-0.063	(0.024) *	-0.058	(0.025) *
≥ 20% in top category	-0.156	(0.014) ***	-0.155	(0.014) ***	-0.155	(0.014) ***
Level 2 - Study-years						
Age at testing (ref=14)						
Age 10 at testing	-0.152	(0.026) ***	-0.153	(0.026) ***	-0.152	(0.026) ***
Age 15 at testing	-0.014	(0.023)	-0.014	(0.023)	-0.014	(0.023)
Cohort birth year	0.007	(0.001) ***	0.007	(0.001) ***	0.007	(0.001) ***
Level 3 - Countries						
Country variable × Intercept interactions						
Mean age when tracking begins × Parent education	-0.044	(0.013) ***				
Mean age when tracking begins × Parent occupation	-0.027	(0.014) *				
Mean age when tracking begins × Books	-0.058	(0.020) **				
Mean private school enrollment × Parent education			0.232	(0.121) +		
Mean private school enrollment × Parent occupation			0.278	(0.122) *		
Mean private school enrollment × Books			0.165	(0.157)		
Mean proportion expecting higher education × Parent education					-0.269	(0.192)
Mean proportion expecting higher education × Parent occupation					-0.615	(0.152) ***
Mean proportion expecting higher education × Books					-1.167	(0.279) ***
Mean age when tracking begins × Cohort	-0.001	(0.001)				
Mean private school enrollment × Cohort			-0.003	(0.007)		
Mean proportion expecting higher education × Cohort					-0.011	(0.007) +
Random Effects						
Level 2 - Residual variance between studies in...						
Parent education intercepts	0.04075		0.0407		0.04072	
Parent occupation intercepts	0.0224		0.02249		0.02227	
Books intercepts	0.04058		0.04035		0.04044	
Level 3 - Residual variance between countries in...						
Parent education intercepts	0.03695		0.04189		0.04211	
Parent occupation intercepts	0.04095		0.0403		0.0366	
Books intercepts	0.0959		0.10571		0.08689	
Cohort slopes	0.00003		0.00004		0.00003	
N (Level 1 - gaps)	4604		4604		4604	
N (Level 2 - study-years)	855		855		855	
N (Level 3 - countries)	78		78		78	

+ p<.1, * p<.05, ** p<.01, *** p < .001. Note: All models in this table specify known level 1 error variances and covariances, estimated via bootstrapping, consistent with models in the main text of the paper.

The country covariate models in the main text of the paper enter a series of study-year dummies in order to account for secular trends across study-years. An alternative way to account for secular trends in SES achievement gaps would be to include the cohort birth year variable in the model rather than study-year fixed effects. Table M6 reports such a model (Model 8B), along with a model omitting country covariates but using the same analytic sample of 78 countries with complete covariate data (Model 2H), and the original version of Model 8 with study-year fixed effects from the main paper text for comparison. Model 2H shows that the cohort birth year trend is identical in the reduced analytic sample of countries with full covariate data to in the full sample of 100 countries. Comparing across Models 8B and 8, coefficents for time-varying country covariates are broadly similar. Some coefficients change direction, but only those that are not significantly different from 0 in either model. The strongest predictor of increasing SES achievement gaps remains increasing school enrollment. Model 8B including both country covariates and cohort birth year also allows us to examine a different question: to what extent do the time-varying country covariates explain the average global increase in SES achievement gaps? Comparing across Model 2H and Model 8B, the cohort birth year coefficient decreases from 0.007 to 0.001, an 86% reduction. Thus, the included country covariates do explain a great deal of the average global trend in SES achievement gaps. Model 8 is preferred over Model 8B because in addition to controlling for secular time trends in SES achievement gaps, it also accounts for possible differences across studies in the measurement error of SES achievement gaps (either due to unreliability or low quality of achievement or SES measures, as discussed in Appendices D and H). If we assume that all countries are likely to suffer from similar data reliability or quality issues in the same studies—a reasonable assumption because SES survey item wording is very similar across countries in a given year of a study—then these dummies control for study-specific biases in the estimation of SES achievement gaps. Thus, the coefficient estimates for covariates in Model 8 are less likely to be confounded by uneven quality of the outcome variablew than those in Model 8B.

Table M1. Comparison between Multivariate Models Predicting 90/10 Achievement Gaps from Country Covariates and Cohort Birth Year or Study-Year Dummies

	(2H) Analytic sample		(8B) Cohort year		(8) Study-year FE	
	coef	(se)	coef	(se)	coef	(se)
Parent education gaps intercept	1.099	(0.030) ***	0.978	(0.039) ***	0.970	(0.046) ***
Parent occupation gaps intercept	1.097	(0.031) ***	0.975	(0.042) ***	0.969	(0.049) ***
Household books gaps intercept	1.522	(0.040) ***	1.391	(0.047) ***	1.405	(0.057) ***
Level 1 - Gaps						
Subject controls (ref=Reading)						
Math	0.020	(0.007) **	0.020	(0.007) **	0.020	(0.007) **
Science	0.033	(0.006) ***	0.033	(0.006) ***	0.033	(0.006) ***
SES variable quality measures						
Parent-reported × Parent education	0.108	(0.037) **	0.112	(0.037) **	0.023	(0.039)
Parent-reported × Parent occupation	0.054	(0.028) *	0.061	(0.027) *	-0.026	(0.032)
Parent-reported × Books	-0.022	(0.030)	-0.017	(0.029)	-0.128	(0.039) **
Number of categories (centered at 7)	0.002	(0.003)	0.002	(0.003)	0.000	(0.003)
≥ 20% in bottom category	-0.055	(0.024) *	-0.057	(0.025) *	-0.055	(0.023) *
≥ 20% in top category	-0.157	(0.014) ***	-0.156	(0.014) ***	-0.149	(0.015) ***
Level 2 - Study-years						
Age at testing (ref=14)						
Age 10 at testing	-0.153	(0.026) ***	-0.203	(0.031) ***		
Age 15 at testing	-0.014	(0.023)	-0.029	(0.022)		
Cohort birth year	0.007	(0.001) ***	0.001	(0.003)		
Study fixed effects (ref=TIMSS 2003 Grade 8)					yes	
School enrollment (proportion)			0.539	(0.145) ***	0.486	(0.107) ***
Immigrant background (proportion)			-0.215	(0.283)	0.226	(0.250)
GDP per capita (logged)			0.127	(0.061) *	0.055	(0.059)
Income inequality (Gini)			-0.723	(0.997)	-1.913	(0.887) *
Mid/low-income country × Income inequality			1.908	(1.138) +	2.539	(1.129) *
Age when tracking begins			-0.027	(0.016) +	-0.037	(0.016) *
Private school enrollment (proportion)			-0.042	(0.255)	0.240	(0.249)
Expecting higher education (proportion)			0.050	(0.093)	-0.029	(0.094)
Level 3 - Countries						
Mid/low-income country × Intercept interactions						
Mid/low-income country × Parent education	-0.059	(0.048)	0.206	(0.059) ***	0.192	(0.063) **
Mid/low-income country × Parent occupation	-0.185	(0.045) ***	0.071	(0.057)	0.060	(0.058)
Mid/low-income country × Books	-0.331	(0.063) ***	-0.044	(0.066)	-0.082	(0.068)
Mean school enrollment			0.652	(0.282) *	0.640	(0.317) *
Mean proportion immigrant background			0.068	(0.239)	0.134	(0.261)
Mean GDP per capita (logged)			0.143	(0.039) ***	0.142	(0.041) ***
Mean income inequality			0.653	(0.303) *	0.605	(0.317) +
Mean age when tracking begins			-0.040	(0.010) ***	-0.035	(0.011) **
Mean private school enrollment			0.004	(0.089)	0.043	(0.099)
Mean proportion expecting higher education			-0.155	(0.165)	-0.255	(0.169)
Random effects						
Level 2 - Residual variance between studies in...						
Parent education gaps	0.04067		0.03993		0.03824	
Parent occupation gaps	0.02244		0.02222		0.02065	
Household books gaps	0.04051		0.03738		0.03683	
Level 3 - Residual variance between countries in...						
Parent education gaps	0.04228		0.02359		0.02822	
Parent occupation gaps	0.03519		0.02440		0.02732	
Household books gaps	0.08273		0.04353		0.04944	
Cohort slopes	0.00003		0.00004			
N (Level 1 - gaps)	4604		4604		4604	
N (Level 2 - study-years)	855		855		855	
N (Level 3 - countries)	78		78		78	

+ p<.1, * p<.05, ** p<.01, *** p < .001. Notes: “Middle/low income” countries had GDPs per capita of less than $6000 in 1980 (the reference category is high-income countries; see Appendix Table A1 for coding). All level 2 time-varying country covariates are mean-centered within countries, meaning results can be interpreted very similarly to a model with country fixed effects (as well as study-year fixed effects, included at level 2). All models in this table specify known level 1 error variances and covariances, estimated via bootstrapping, consistent with models in the main text of the paper.

Finally, Table M7 reports multivariate results estimated using a fixed effects rather than a mixed effects (hierarchical growth curve) model. The model includes country fixed effects, meaning that country-level covariates are omitted due to collinearity. The model is estimated as follows:

$$\hat{G}_{ij} = \gamma_{00} + \gamma_{10} Y_{ij} + \left(\boldsymbol{X}_{ij}\right)\mathbf{B} + \boldsymbol{\Gamma_j} + \boldsymbol{\Lambda}_{ij},$$

where $\hat{G}_{ij}$ is the estimated gap in country j in country-study-year i, γ_{10} is the coefficient for cohort birth year Y_{ij}, $\boldsymbol{X}_{ij}$ is a vector of time-varying country covariates in country-year i, $\boldsymbol{\Gamma}$ is a vector of country dummy variables, $\boldsymbol{\Lambda}_{ij}$ is a vector of dummy variables indicating age at testing and test subject, $\boldsymbol{B}$ is a vector of coefficients for the time-varying country covariates. The country fixed effects are estimated using weighted least squares (weighted by the inverse squared standard error associated with each gap estimate, estimated via bootstrapping) and are reported with robust Huber-White standard errors.

Results for the country fixed effects models are very similar to those in the main results for Models 2 and 8 of the main text, both in terms of the cohort trend estimates in Model 2J (and for the reduced analytic sample in Model 2K) and the covariate results in Model 8C. Recall that time-varying country covariates in the hierarchical growth curve models are mean-centered within countries, meaning that they have an interpretation very similar to a fixed effects model.

Table M7. Country Fixed Effects Models Predicting 90/10 Achievement Gaps from Country Covariates and Cohort Birth Year

	(2J) Country FE - full sample		(2K) Country FE - analytic sample		(8C) Country & study FE, covariates	
	coef	(se)	coef	(se)	coef	(se)
SES variable (ref=Parent education)						
Parent occupation	-0.083	(0.011) ***	-0.063	(0.012) ***	-0.009	(0.012)
Household books	0.391	(0.012) ***	0.399	(0.013) ***	0.492	(0.014) ***
Subject (ref=Reading)						
Math	0.012	(0.008)	0.011	(0.008)	0.019	(0.008) *
Science	0.025	(0.008) ***	0.023	(0.008) **	0.031	(0.008) ***
SES variable quality measures						
Parent-reported × Parent education	0.083	(0.017) ***	0.071	(0.018) ***	-0.018	(0.019)
Parent-reported × Parent occupation	-0.080	(0.018) ***	-0.080	(0.019) ***	-0.055	(0.018) **
Parent-reported × Books	-0.206	(0.022) ***	-0.156	(0.022) ***	-0.187	(0.022) ***
Number of categories (centered at 7)	0.006	(0.004)	0.004	(0.004)	0.002	(0.004)
≥ 20% in bottom category	-0.220	(0.014) ***	-0.213	(0.015) ***	-0.152	(0.015) ***
≥ 20% in top category	-0.128	(0.008) ***	-0.144	(0.009) ***	-0.124	(0.009) ***
Age at testing (ref=14)						
Age 10 at testing	-0.136	(0.017) ***	-0.145	(0.018) ***		
Age 15 at testing	-0.058	(0.012) ***	-0.058	(0.013) ***		
Cohort birth year	0.007	(0.001) ***	0.007	(0.001) ***		
Study fixed effects (ref=TIMSS 2003 Grade 8)					yes	
School enrollment (proportion)					0.397	(0.077) ***
Immigrant background (proportion)					0.362	(0.143) *
GDP per capita (logged)					-0.051	(0.049)
Income inequality (Gini)					-2.176	(0.449) ***
Mid/low-income country × Income inequality					3.429	(0.629) ***
Age when tracking begins					-0.035	(0.009) ***
Private school enrollment (proportion)					0.025	(0.144)
Expecting higher education (proportion)					-0.095	(0.045) *
Mid/low-income country × SES interactions						
Mid/low-income country × Parent occupation					-0.113	(0.015) ***
Mid/low-income country × Books					-0.212	(0.017) ***
Country fixed effects	yes		yes		yes	
Intercept	1.152	(0.013) ***	1.178	(0.014) ***	1.979	(0.451) ***
Adjusted R^2	0.677		0.675		0.711	
N (gaps)	5541		4604		4604	
N (study-years)	1026		855		855	
N (countries)	100		78		78	

+ p<.1, * p<.05, ** p<.01, *** p < .001. Note: All models in this table are estimated via weighted least squares (weighted by the inverse squared standard error associated with each gap estimate, estimated via bootstrapping).

N. Trends in SES Achievement Gaps Using a Rank-Based Measure of Achievement

The validity of all 90/10 achievement gap estimates—whether achievement is standardized or kept in the original test score metric—depends on the assumption that all test instruments are interval scaled. Unfortunately, it is not possible to test the interval scaling assumption directly. However, it is possible to relax this assumption somewhat by converting achievement to a rank-based measure. Then we must assume only that *ranks* are interval scaled, rather than test scores. Table N1 reports results of models estimating trends in SES achievement gaps computed from achievement rank. Within each country-study-year-subject, rather than standardizing achievement to a mean of 0 and standard deviation of 1, I instead convert achievement into percentiles scaled from 0 to 1. Using this transformed achievement measure, I then compute 90/10 gaps using the same method described in the main text of the paper.

The results for trends in SES gaps in achievement rank are very similar to those for trends in SES gaps in standardized achievement. The magnitude of all coefficients is smaller because gaps based on achievement rank are smaller than gaps based on standardized achievement. (A gap of 1.0 would indicate a gap of 100 percentile points of achievement between the 90^{th} and 10^{th} percentiles of SES, compared with a gap of 1.0 standard deviations of achievement between the 90^{th} and 10^{th} percentiles of SES.) Yet the overall story is very similar. 90/10 gaps based on all three SES measures have increased significantly ($p < .001$).

Although it is not possible to test the interval scaling assumption directly, the consistency of results across the gaps using standardized achievement (in the main text), rank-based achievement in Table N1, and the original scales of PISA, TIMSS, and PIRLS (Appendix B) provides some indication that results are robust to the achievement scale used.

Table N1. Hierarchical Growth Models Predicting 90/10 SES Achievement Gaps Using a Rank-Based Measure of Achievement

	(1) 3 Cohort Slopes		(2) 1 Cohort Slope	
	coef	(se)	coef	(se)
Parent education gaps intercept	0.300	(0.009) ***	0.303	(0.009) ***
Parent occupation gaps intercept	0.272	(0.009) ***	0.275	(0.009) ***
Household books gaps intercept	0.373	(0.012) ***	0.373	(0.012) ***
Level 1 - Gaps				
Subject (ref=Reading):				
Math	-0.001	(0.002)	-0.001	(0.002)
Science	0.006	(0.002) ***	0.006	(0.002) ***
SES variable quality measures				
Parent-reported × Parent education	0.025	(0.007) ***	0.019	(0.008) *
Parent-reported × Parent occupation	0.016	(0.006) **	0.015	(0.006) *
Parent-reported × Books	-0.029	(0.008) ***	-0.020	(0.007) **
Number of categories (centered at 7)	0.001	(0.001)	0.001	(0.001)
≥ 20% in bottom category	-0.014	(0.006) *	-0.015	(0.006) *
≥ 20% in top category	-0.029	(0.003) ***	-0.033	(0.003) ***
Level 2 - Study-years				
Age at testing (ref=14)				
Age 10 at testing	-0.042	(0.007) ***	-0.042	(0.007) ***
Age 15 at testing	-0.007	(0.006)	-0.007	(0.006)
Cohort birth year × Parent education	0.0019	(0.0003) ***		
Cohort birth year × Parent occupation	0.0021	(0.0003) ***		
Cohort birth year × Books	0.0024	(0.0004) ***		
Cohort birth year			0.0022	(0.0003) ***
Random effects				
Level 2 - Residual variance between studies in...				
Parent education intercepts	0.002230		0.002270	
Parent occupation intercepts	0.001560		0.001580	
Books intercepts	0.002650		0.002750	
Level 3 - Residual variance between countries in...				
Parent education intercepts	0.004780		0.004730	
Parent occupation intercepts	0.004630		0.004750	
Books intercepts	0.010300		0.010660	
Parent education cohort slopes	0.000004			
Parent occupation cohort slopes	0.000003			
Books cohort slopes	0.000005			
Cohort slopes			0.000003	
N (Level 1 - gaps)	5541		5541	
N (Level 2 - study-years)	1027		1027	
N (Level 3 - countries)	100		100	

+ p<.1, * p<.05, ** p<.01, *** p < .001. Note: To avoid very long computation times, all models in this table specify known level 1 error variances estimated using conventional non-bootstrap formulas and omit error covariances. This simplified specification appears to produce very similar results to models using bootstrapped error variances and covariances (see Appendix L).

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