**Achievement Gaps by Parental Income and Education Using Population-Level
Data from Norway**

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Achievement Gaps by Parental Income and Education Using Population-Level Data from Norway

Abstract

We study a decade of achievement gaps 5th through 10th grade by parental income and education in Norway using administrative population data. Norway is a wealthy and egalitarian country with a homogeneous educational system, yet achievement gaps between students at the 90th and 10th percentiles of parental income and between students with parents who have at least a master and at most a high school degree are large (0.55-0.93 and 0.70-0.99 standard deviations, respectively), increasing by grade level. Gaps are equivalent to approximately 2-2.5 years of schooling. Income achievement gaps increased by about 10% of a standard deviation over the 11-year time period, whereas education achievement gaps remained stable. This suggests that the choice of socioeconomic indicator measure may explain why researchers disagree on trends in achievement gaps.

Keywords: Achievement gaps, Educational inequality, Income, Grades, Norway, Registry data, test scores

Achievement Gaps by Parental Income and Education Using Population-Level Data from Norway

Inequitable chances for educational success are an endemic concern in democratic societies, with unfulfilled potential having lasting consequences for individuals, families, and the society at large (OECD, 2017). Indeed, large socioeconomic achievement gaps are evident in every country where it has been studied, and gaps may be widening (e.g., Chmielewski, 2019). Yet, the most comprehensive studies and vigilant discussions so far have focused on the US (e.g., Reardon, 2011a; Hanushek et al., 2020). While most wealthy nations have experienced increasing economic disparity over the last decades, the US is peculiar in the size and scope of its widening wealth gaps. Compounding this, among wealthy nations the US has exceptionally few public supports for those at the low end of the income distribution. In addition, human and financial capital are deeply entangled, no more so than in the US, and empirically unraveling the two in that context is, at best, challenging.

Juxtaposed with these unusual aspects of the US economy, is a critical larger question evoked by the work of Reardon (2011a) and others: are increasing achievement gaps a global phenomenon in wealthy nations, or isolated to the US? The answer to this question has implications for understanding underlying mechanisms as well as great practical significance for understanding the state of the global economy. While there are studies that have used international large-scale assessments to study achievement gaps (e.g. Chmielewski, 2019; Broer et al., 2019; Chmielewski & Reardon, 2016), there is considerable variance in both the size and direction of trend for the same countries. This may be due to varying samples and definitions of socioeconomic measures, making it difficult to compare results.

Our study adds to the literature in three important ways. First, following demonstrations of the power of using high-quality population-level data to investigate national inequalities (e.g., Chetty et al., 2017), we are the first to take advantage of such data

to study trends in national socioeconomic achievement gaps, making it possible to overcome many data limitations in existing studies. We use Norwegian population-level data which include national test scores and grades for students over time, as well as precise measures of parental income and parental education. This allows for the opportunity to disentangle the consequences of sample, differences in the measurement of socioeconomic background and the gap estimation method used in previous studies for estimates of the levels and trends in student achievement gaps. Also, it is possible to investigate how compositional changes related to immigration affect achievement gaps.

Second, while achievement gaps have mostly been studied using low stakes assessments such as TIMSS and PISA, we study both low stake (national test scores) and high stake (grades) outcomes for students. Grades received at the end of compulsory education determine entry into upper secondary track and possibly also school within track. This higher stakes outcomes give us a sense of how low stakes test gaps are translating into real world gaps.

Third, Norway, a wealthy welfare state, provides a particularly interesting place to study achievement gaps in a global context. Norway has relatively low income inequality and an extensive social support system, including universal health care, a strong social security net, and early education that is universal and heavily subsidized. The school system mainly consists of comprehensive public schools (including grade levels 1-10, ages 6-16), free of charge with a common curriculum, no tracking and no grade promotion or retention. Less than 4 percent of students attend private schools. The two key components of socioeconomic status, parental income and parental education, are only modestly correlated, unlike the US, allowing distinct achievement gap trends to be uniquely estimated for the two, in ways not possible in the US. Thus, the context of Norway provides insight into both mechanisms behind and possible solutions to underlying causes of rising educational disparity.

Evidence on Socioeconomic Achievement Gaps and Trends Over Time

The 90/10 income achievement gap, the difference in test scores between students from families at the 90th and 10th percentiles of the income distribution, was introduced in a seminal paper by Reardon (2011a). The study, using 19 nationally representative US studies covering 50 years, found large achievement gaps with significant increases over time. Achievement gaps for children born in 2001 were roughly 75 percent larger than for students born in the 1940s, and had steadily increased since the 1970s (Reardon, 2011a). Reardon (2011a) also studied achievement gaps by parental education, finding a relatively stable relationship in the same time period. Following this study, achievement gaps have continued to be a central focus of educational studies, particularly with increased access to achievement gap data at the school level, such as the ECLS-K and the Stanford Education Data Archive (SEDA; Reardon et al. 2018).

Other US studies on achievement gaps by income or SES include Reardon and Portilla (2016), Wolf et al. (2017), Kuhfeld et al. (2020), Hanushek et al. (2020), Hashim et al. (2020) and Reardon (2021). Reardon and Portilla (2016) reported school readiness gaps by income and race/ethnicity in Kindergarten. They found narrowing income achievement gaps for kindergarteners from 1998 to 2010 using data for the US from ECLS-K:1998, ECLS-K:2010 and ECLS-B. In contrast, Wolf et al. (2017), used the same data and time period, and found increasing achievement gaps between poor and non-poor students when stratifying by neighborhoods. Kuhfeld et al. (2020) found decreasing school readiness gaps by race and school poverty status in the succeeding time period, 2010-2017, using the Growth Research Database (GRD) at NWEA including over 2 million kindergarten students.

A recent study by Hanushek et al. (2020) directly challenged Reardon's assertion that achievement gaps between rich and poor in the US had grown. Using data from PISA, TIMSS and NAEP, they found no increase in achievement gaps in reading and mathematics

for the same period studied by Reardon (2011a), leading the Hetchinger report to write about the “Reardon-Hanushek clash over 50 years of achievement gaps” (Barshay, 2019). Hashim et al. (2020), using two alternative approaches to inferring income-based achievement gaps, even found that gaps were narrowing between cohorts born around 1980 and those born in 2000. Reardon (2021) discusses the findings of these papers and reanalyzes data from Reardon (2011a), concluding that gaps have grown, though perhaps less than originally reported.

Internationally, large-scale assessments have been used to study trends in socioeconomic achievement gaps within and across countries. Most comprehensive is a recent study by Chmielewski (2019), combining 30 international large-scale assessments over the past 50 years to study achievement gaps by SES (composite measure of parental education, parental occupation and number of books in the home). Results suggested that achievement gaps have largely increased, although there is substantial cross-national variation in both levels and trends. Broer et al. (2019) studied achievement gaps by SES from 1995 to 2015 using TIMSS data, and also found large variation between countries in whether achievement gaps have been growing or shrinking over time. In an earlier study, Chmielewski & Reardon (2016) used data mainly from PIRLS and PISA and found considerable variation across countries in income achievement gaps, relating these to features of the educational system, as well as to broader social inequality and segregation. Single country studies on achievement gaps using TIMSS include Saw (2016), who documented a rapid growth in achievement gaps by parental education in Malaysia and Salmela-Aro & Chmielewski (2019) who related educational policy changes to trends in SES achievement gaps over time in Finland. A related literature has focused on trends in race/ethnic achievement gaps and their relation to school segregation (see e.g. Kuhfeld et al., 2021; Blatt and Votruba-Drzal, 2021; Reardon et al., 2019a; Reardon et al., 2019b).

Different Approaches Yielding Different Answers?

Studies on achievement gaps require data linking student test scores to measures of student socioeconomic background. For nationally and internationally representative studies, student background characteristics are mostly self-reported, either by the parent or the student, with measures of parental education more commonly available than income. This is particularly true for international assessment studies which often have no measures of parental income. Student sample, the type of socioeconomic measure used, and gap estimation method are all potential explanations for why researchers draw contrasting conclusions about the levels and trends of socioeconomic achievement gaps. In the following, we use Reardon (2011a) and Hanushek et al. (2020) to illustrate this point.

First, studies might not represent the same student populations due to different timing and sampling designs. While both Reardon (2011a) and Hanushek et al. (2020) draw on high quality representative studies, they use test scores from different sources, making it difficult to compare results directly.

Second, socioeconomic measures can suffer from measurement error, particularly when these variables are created from coarsened data (income or education reported in categories, subsequently converted to percentiles or years of schooling) that suffer from nonresponse and attrition (Meyer, Mok & Sullivan, 2015; Meyer and Nittag, 2019), and are self-reported by parents or students who often have only a vague idea of their parents' income. Further, even if parent-reported, prior research often uses cross-sectional income measures, potentially capturing transitory rather than persistent income (Micheltmore & Dynarski, 2017). Reardon (2011a) and Hanushek et al. (2020) both use such data, and although Reardon (2011b), Ho & Reardon (2012) and Reardon & Ho (2015) alleviate some of these concerns, more accurate measures for estimating achievement gaps are preferable.

Third, measuring achievement gaps is an exercise in summarizing the shape of a distribution of student achievement (e.g., a measure of the disparity in the distribution of a given achievement score rank ordered by the achievement gap measure). The choice of summary measure used, and how it is estimated, may matter. Reardon (2011a) regression-estimated achievement gaps at the 10th and 90th percentile by predicting achievement at these percentiles. Hanushek et al. (2020), instead estimated the difference between average student achievement above the 75th and below the 25th percentile of their SES measure. Using both approaches simultaneously allows for an analysis of the importance of estimation procedure.

Fourth, results could differ as a result of different outcome measures. Both Hanushek et al. (2020) and Reardon's (2011a) used achievement scores from different sources, requiring them to harmonize measures across assessments and tests and over time. While Hanushek et al. (2020) use measures that are psychometrically linked over time, using the same achievement test outcomes alleviates any concerns about the validity of this approach.

Finally, various measures of socioeconomic background are not necessarily interchangeable. For instance, while Reardon (2011a) used parental income as the main measure, Hanushek et al. (2020) instead used an SES index on student reported parental education and home possessions as their measure. Composite SES measures aim to jointly capture the human, financial, social, and/or cultural capital factors of SES. The benefit of such a measure is potentially being able to capture the broader socioeconomic context in which children learn and develop. In contrast, studying unique components of such an index serves a complementary purpose, and may potentially reveal differential dynamics of contributing factors.

Two key components of socioeconomic status are parental income and parental education. Although these factors are supplementary indicators (Duncan & Magnuson, 2003), the associations varies by context and over time, and may affect child outcomes through

different pathways (Duncan, Magnuson, & Votruba-Drzal, 2015). Parental income may work through investment- and stress pathways (e.g., Yoshikawa, Aber, Bergman, & Beardslee, 2012), while parental education may work through pathways such as home learning environment, educational aspirations and conversational styles (e.g., Magnuson, 2007), with potentially different policy implications. Parental income and parental education, are only modestly correlated in Norway (0.41-0.46 in our data), unlike the US (above .7 after 2000; Reardon (2011a)), allowing distinct achievement gap trends to be uniquely estimated for these two key components of SES, in ways not possible in the US. This provides insight into both mechanisms behind and possible solutions to underlying causes of rising educational disparity

Our study addresses all of these issues, allowing us to disentangle the importance of each. Most importantly, we rely on population data, leaving speculations about sampling issues aside. Moreover, we are able to study the same achievement measures over time as well as the same cohorts over time in consistent samples, and we have precise register-based achievement measures that are psychometrically validated (test scores) or regulated by national curriculum-based competency measures (grades). This allows us to apply both estimation methods to make direct comparisons of the two. Finally, we have separate register-based measures for parental income and education which are consistent over time.

Methods

Data

We use data from national registries covering the entire Norwegian population of 5th, 8th and 10th graders residing in Norway from in the time period 2007-2018 (cohorts born 1991-2008), as well as their parents/guardians. The data allow us to follow the development of each achievement measure over time and the same cohorts as they progress through the educational system. The total sample used in the analyses includes 1,103,081 children/adolescents. Data is obtained from Statistics Norway, and includes the education, income, and population registries, linked by anonymized personal identification numbers.

Measures

National Achievement Tests and Grades

We use test scores from national achievement tests in reading and mathematics from 5th and 8th grade. Compulsory national assessments for children in 5th and 8th grade have been administered by the Directorate of Education and Training since 2007, in the subjects reading (Norwegian), mathematics, and English (the first two included in the present study). The tests are developed and validated by experts in test development and psychometrics. The tests are designed to capture the full range of skills in these subjects covering the competency goals from lower primary (grades 1-4) in the 5th grade test and upper primary (grades 5-7) in the 8th grade test. The test results are mainly used to collect information about students' basic skills and to track school development over time. Results are conveyed to teachers and parents but have no direct consequence for students apart from the aim of adapted education. Students also take compulsory national assessments in 9th grade. These are the same as for 8th grade in each calendar year, used to measure within-person progression. About 96% of all students in Norway take the test; students with special needs and those following introductory language courses may be exempt. Data from 2007 and onwards are available as a score summing up

correct responses. In addition, from 2014, a scaled score based on a two-parameter IRT model is available. In the present study, we standardized the summed test scores within test and year, and conduct robustness checks with scaled scores from 2014 and onwards.

We also include teacher-assessed and externally-graded exam grades from 10th grade, used to apply to study track in upper secondary education and regulated by national curriculum-based competency measures. Students typically have one oral and one (two for Norwegian) written compulsory exam in year 10, with the subject determined by random selection (Eurydice, 2021). We construct subject specific grade point averages from the grades received at the end of compulsory schooling (10th grade). For Norwegian, these included the average of all grades received in the subject Norwegian, denoted GPA Norwegian (typically 3 teacher-assessed grades in oral and written Norwegian, and potentially 1-3 exam grades). For Mathematics, we average all grades received in the subjects mathematics and science, denoted GPA STEM (typically one teacher-assessed grade for each subject, and potentially 1-2 exam grades).

Parental Income and Education

Parental income and education are both determined by the child's mother and father, regardless of whether they are in the same household. For less than 3% of the sample we observe only one parent in the data. Parental income is measured as the sum of mothers' and fathers' average disposable income (consumer price index adjusted to 2007-levels, with only the sum for one parent if the other parent is missing) in the three years prior to each test, where income is averaged over non-missing years of income data. The three year period allows for a measure of persistent rather than transitory income (Micheltore & Dynarski, 2017). Parental education is the highest degree obtained by a parent in the year prior to each test; elementary, lower secondary, upper secondary (high school), bachelor's, master's or PhD. Very few students have missing information on parental education or income.

Measuring income and education close to the time of test ensures that fewer students, particularly those with immigrant backgrounds, are lost due to missing data. Additionally, this ensures that results are more comparable to studies using assessments that measure test score, parental income and other components of SES simultaneously (Reardon, 2011a; Hanushek et al., 2020; Chmielewski, 2019).

Figure 1 displays the trend in the distribution of parental income measured at the 90th, 50th and 10th percentiles and parental education measured by the share in each of the six categories over the time period we study. We see a clear pattern of rising income inequality, with the 90th percentile increasing more than the 10th and 50th percentiles, and increasing parental education as the share with bachelor's degrees is rising and the share with a high school degree only is decreasing. Years of highest parental education and family income (winsorizing at the 3rd and 97th percentile to avoid outliers) were correlated .44 across all years. The correlation increased gradually, however, from .41 in 2007 to .46 in 2018.

[Figure 1 here]

Analyses

Our main approach for calculating achievement gaps by parental income follows Reardon (2011a) in regression-estimating achievement gaps at the 10th and 90th percentile, denoted 90/10. For each test and year, the raw achievement score Y is standardized with mean zero and standard deviation one and income is changed to a rank variable θ between 0 and 1 for students with non-missing achievement test scores.

In order to allow for a flexible association between the rank variable and outcome variable, we estimate the association between the dependent variable Y and a cubic function of θ , yielding a fitted curve, $\hat{Y} = \hat{a} + \hat{b}\theta + \hat{c}\theta^2 + \hat{d}\theta^3$. The achievement gap $\theta^{90/10}$ is the difference between $\hat{Y}$ at $\theta=.9$ and $\hat{Y}$ at $\theta=.1$: $[\hat{Y}|\theta = .9] - [\hat{Y}|\theta = .1] = .8\hat{b} + .8\hat{c} + .728\hat{d}$.

For achievement gaps by parental education, we estimate mean achievement differences between two specific groups defined by education level; having a master's degree or more (approximately at the 80th percentile) versus having no more than a high school degree (approximately at the 40th percentile). Assuming linear trends, this approximates the 90/20 achievement gap by parental education. This approach is denoted MA/HS and is similar to the Hanushek et al. (2020) approach in comparing mean achievement above and below a threshold.

For both parental income and parental education, we compare the Reardon (2011a) and Hanushek et al. (2020) estimation methods to investigate the importance of estimation procedure, see online Appendix A for details.

Note that because we use population level data covering a defined time period with very few missing observations, we do not report confidence intervals for our estimates.

Results

Achievement Gap by Parental Income

In our first set of analyses, we examine level and changes in socioeconomic achievement gaps defined by parental income. In Figure 2, we show the 90/10 achievement gap by parental income measured in standard deviations separately for reading (left) and mathematics (right), for 5th, 8th and 10th grade, respectively, across the years 2007-2018.

[Figure 2 here]

There are several notable findings from these graphs. Income achievement gaps were substantial, they were larger for older students, and they increased over time. In 2007, the achievement gap for reading for 5th graders was 0.59, with a gradual increase to 0.68 in 2018, that is, an increase of 10% of a standard deviation over the 11-year period. For 8th graders, the income achievement gap in reading was 0.72 in 2007 and increased with a similar rate to 0.88

in 2018. Both the size of the gap and the increase over time were similar for Norwegian GPA for 10th graders. For 5th grade mathematics the gap increased from 0.66 to 0.76, while it increased from 0.75 to 0.88 for 8th graders. The largest income achievement gap, in absolute terms, was for GPA STEM, increasing from 0.77 to 0.93.

To put these gaps in context, the scaled test scores of equivalent tests allow us to estimate changes across a year, which can be used as a benchmark for the practical importance of the estimated effects. The average within-person change in scaled test score from 8th grade to 9th grade was equivalent to 0.36 (between person) standard deviations in math and 0.38 (between person) standard deviations in reading. The substantive interpretation is that the 90/10 income achievement gap in reading for e.g., 8th graders in 2007 was equivalent to about two years of schooling, a substantial difference.

It is also notable that income achievement gaps were higher for mathematics than for reading, both for 5th grade and for GPA in 10th grade (about 8% of a standard deviation in both cases). These differences were quite stable over time. Finally, in online Appendix A, we demonstrate that the estimation methods by Reardon (2011a) and Hanushek et al. (2020) produced very similar estimates.

Achievement Gap by Parental Education

In our second set of analyses, we change our focus to socioeconomic achievement gaps defined by parental education. Thus, in Figure 3, we show the achievement gap by parental education measured in standard deviations separately for reading (left) and mathematics (right). The lines display results comparing achievement between children whose parents have at least a master and at most a high school degree (MA/HS), for 5th and 8th grade test scores, and for GPA, respectively, approximating a 90/20 achievement gap.

[Figure 3 here]

The most striking finding is that the achievement gaps did not increase over time when we used parental education as a socioeconomic indicator. This was true across all grades, across both math and reading and for both estimation methods (see Appendix A for results comparing these figures to the Reardon (2011) estimation method). For example, for mathematics in 5th grade, the size of the MA/HS gap hovers around 0.8 of a standard deviation across all years. There are, however, two findings that are consistent with achievement gaps by parental income. First, achievement gaps by parental education increased by grade level. The MA/HS gaps increasing from about 0.8 standard deviations to 0.9 standard deviation from 5th to 8th grade in reading. Second, the gaps were mostly larger for mathematics than for reading, at least at higher grade levels.

Finally, when we compare the 90/10 achievement gaps for income and education (Figure 3 and Figure A3 in the online Appendix, both using the Reardon (2011) estimation method, see online Appendix A for details), we see that they are larger for education. Taking reading in 5th grade as an example, the achievement gap by parental income increases from about 0.6 to 0.7 standard deviations, while the achievement gap by parental education stable at about 0.9 standard deviations. The same comparison is true across grades and outcomes.

Changes at the top or bottom?

In our main results, we document increasing achievement gaps by parental income between the 10th and 90th percentile. This may be a function of decreasing test scores at the 10th percentile of parental income, increasing test scores at the 90th percentile, or both happening simultaneously, relative to the overall distribution of scores within each year. In Figure 4, we graph the standardized test scores for the 90th and 10th percentile separately, in reading and math, respectively. While we see slight relative increases at the 90th percentile, it appears that the widening gaps are mainly driven by relative decreases at the 10th percentile.

[Figure 4 here]

For achievement gaps by parental education, when separating MA and HS, we see that both MA and HS decrease over time. When we instead separate between the 90th and 10th percentiles, there is neither convergence nor divergence in the gaps (Figure A4, see online Appendix A). This suggests that compositional changes in parental education drive the downward trend in both MA and HS, which the 90/10 estimate takes into account.

[Figure 5 here]

Robustness Checks

We conducted a number of robustness checks for our results. These are detailed in online Appendix A-I. In sum, we found that our results are consistent when: A) We compare estimation methods by Reardon (2011a) and Hanushek et al. (2020) B) We used IRT-scaled test scores available from 2014-2018; C) We probed the potential influence of missing test score values, by imputing average values for missing observations; D) We examined the change in gaps within the same sample of children over time, by restricting the analyses to individual cohorts, born from 1997 to 2002 for whom we had all outcome measures; E) We accounted for changes in the immigrant population over time by categorizing students by immigrant background and holding immigrant shares constant or removing from sample; F) We used alternative gap specifications; comparing the 90th and 50th percentiles and the 50th and 10th percentile for income and comparing at least a master's degree and at most a lower secondary degree for education; G) We included grade 9 test results in the analysis; H) We estimated the association between income and achievement, controlling for parental education, and the association between parental education and achievement, controlling for family income and I) We investigated the distribution of our outcome variables over time. Thus, all of our robustness checks support our main conclusions that education gaps are

larger than income gaps, and that income gaps, but not education gaps, have increased over time, and increase with grade level.

Discussion

In this study, we use population data from Norway to estimate achievement gaps by parental income and education in 5th and 8th grade using reading and math test scores and final grades at the end of compulsory schooling as achievement measures. There are three main findings. First, even in a fairly egalitarian country with a homogeneous educational system, achievement gaps by both parental income and parental education are disturbingly large. The 90/10 income-achievement gaps range from 0.55 to 0.93 standard deviations, and the achievement gap between students whose parents have at least a master and at most a high school degree ranges from about 0.70 to 0.99 standard deviations. We estimate this to be equivalent to approximately 2-2.5 years of schooling. Second, for income gaps, but not for education gaps, there has been an increase in the size of the gaps across the time period we cover (2007-2018) of about 0.10 standard deviations. Third, the gaps are increasing across the grades. For example, the achievement gap by parental income is about 0.11 standard deviations larger in 8th grade compared to 5th grade in 2007 for reading. All of our findings are robust to a range of sensitivity checks.

Our findings are not sensitive to which of the two predominant analytical approaches to estimating achievement gaps we use, namely those used by Reardon (2011a) and Hanushek et al. (2020). However, as implied above, the measure of socioeconomic status matters; parental income and education are not interchangeable constructs, and results (both levels and trends) are highly sensitive to choice of indicator.

Achievement Gaps in Norway Compared to the US and Other Countries

The gaps we find in Norway are substantial, but somewhat smaller than comparable estimates for the US, although as we noted above, such comparisons may not be straight forward. When we consider income gaps specifically, our estimates range from 0.59 to 0.92 standard deviations. Reardon (2011a) reported income gaps that increase from about 0.75 standard deviations in 1940 to about 1.25 standard deviations in 2000, for both reading and math. In an international comparison, Chmielewski and Reardon (2016) found the income achievement gap in Norway to be 0.75 of a standard deviation in the PIRLS 2001 data, compared with 1.25 of a standard deviation in the US, using same-age data from the ECLS-K. Focusing on younger children, Reardon and Portilla (2016) report income achievement gaps for a nationally representative sample of US kindergarteners (age 5-6) in 1998, 2006 and 2010 where all gaps were above 0.99 (see Table 4 in Reardon and Portilla, 2016), substantially above gaps for our lowest grade level. Despite smaller absolute achievement gaps in Norway compared to those found in the US, it is notable that the gaps we observe in Norway are disturbingly large, given the sociopolitical context in which they have arisen. If income disparities (being about twice as large in the US compared to Norway; OECD, 2021) relate to income achievement gaps, the relative difference in achievement gaps between the two countries is smaller than what one might expect. This is particularly evident if we juxtapose the education, social security, and health-care system in Norway with those of the US.

When we consider parental education gaps, we have to keep in mind that achievement gaps by socioeconomic status are typically based on a ranking of parents on an SES indicator, often comprised of self-reported education, as well as measures of family possessions. This is somewhat comparable—but not equivalent—to our indicator based solely on parental education. The advantage of using SES composites is that they may be capturing more socioeconomic variance by combining multiple factors that could undermine or support

achievement. Yet, conceptually, as well as from an applied perspective, such composites undermine the specificity needed both to identify mechanisms, and to seek policy interventions. For example, when forming a composite, it is not clear what factors may be drivers of the effects. Moreover, the policy levers for correction of gaps are not clear.

We find education achievement gaps, measured as the difference in achievement between children whose parents have at least a master and at most a high school degree, approximating a 90/20 gap, ranging from 0.70 to 0.99. Using the Reardon (2011a) 90/10 estimation method, we find gaps ranging from 0.86 to 1.15 standard deviations (online Appendix A, Figure A2). Reardon (2011b) found achievement gaps by parental education in the US to be stable over time largely above 1 standard deviation, with some signs of a slight increase in the end of the period (Figure 5.A19 and 5.A20, Reardon 2011b). The socioeconomic achievement gaps reported by Chmielewski (2019) for the US (Chmielewski 2019, p. 527) are estimated to be between 1.1 and 1.2 for the period 1950-2000. Trends for other countries are largely above 1.0, especially toward the end of the empirical period as most countries experienced an increase (Chmielewski, 2019). Hanushek et al. (2020), measuring the difference between average performance above the 75th and below the 25th percentile, find that socioeconomic achievement gaps in the US increased from 0.84 to 0.91 from 1961 to 2001. Using this estimation method on our data yields achievement gaps in the range of 0.51 and 0.87, again, largely lower than the US estimates, and in line with Broer et al. (2019) and OECD (2018), showing that Norway has large gaps but that they are relatively smaller than those for the US.

Interestingly, achievement gaps -- and gap trends -- in Norway are occurring alongside increasing evidence that the expansion of universal early childhood education and care (ECEC) is helping *narrow* achievement gaps in the country. A recent study by Zachrisson et al. (2021), for example, found that the expansion of ECEC reduced

achievement gaps as a function of parental education on national 5th grade tests in 2012-2018, while much less so as a function of parental income. Our analyses suggest that despite any narrowing function ECEC may be having, the net national gap trends in Norway remain stable or are even increasing. This is a provocative juxtaposition in light of the popularity of ECEC for improving equity in academic success, suggesting ECEC alone may not be enough to overcome cumulative forces of inequity due to socioeconomic position. This additionally evokes the question of whether we would also see increases for parental education achievement gaps without the narrowing effects ECEC.

Time Trends in Income and Education Gaps

We find that achievement gaps by parental income in Norway increased by as much as 10-15 percentage points between 2007-2018. Translated into our estimate of gains by years of education, this is equivalent to 3-4 months of schooling. Achievement gaps by parental education remained stable in the same time period. These results are consistent across estimation methods. In our data, years of education and family income are correlated .44, increasing slightly (with about 15%) across the years we cover. This is significantly lower than for the US as Reardon (2011a) shows that the correlation between parental education and income increases over time and is above 0.7 after 2000 (Figure 5.9, Reardon 2011a). It is, however, not clear how this trend in correlation affects the increasing income gaps we observe. In online Appendix H we estimate the partial associations of parental income and education, showing that while achievement gaps by parental education only slightly decrease, achievement gaps by parental income are substantially reduced. However, the partial achievement gaps by parental income are still increasing, suggesting that income is driving the trend.

An important conclusion we draw from these findings is that parental income and parental education are not interchangeable measures of socioeconomic status. This has

important implications for the comparison of achievement gaps across countries and contexts. Studies are restricted by sample, test score indicators and SES measures, and are thus not directly comparable. When conclusions differ, as is the case with the ongoing US debate between Reardon (2011a; 2021) and Hanushek et al. (2020) on whether achievement gaps in the US have increased in the past 50 years, it is unclear what methodological choice is leading to contrasting conclusions. Our results suggest that the operationalization of the SES construct is a crucial difference and that both studies can in fact be correct as they are not measuring the same achievement gap.

There are, however, additional methodological challenges to keep in mind when interpreting achievement gaps by parental education. Although both parental income and education are accurately measured, education is a categorical variable, affected by compositional changes in the share and the characteristics of those taking various degrees. For this reasons, we are cautious in our interpretation of level differences between achievement gaps by parental income and education. When comparing trends, in contrast, as estimation methods are consistently measured across years, we are more confident in our findings.

Gaps are Increasing with Student Grade Level

Another strength of our study is that we are able to estimate achievement gaps consistently across student grade level, from 5th grade through the end of compulsory schooling in 10th grade. Importantly, we are able to do this both across cohorts (in our primary analyses), and within cohorts over time (longitudinally, in our robustness analyses, see online Appendix D). Previous studies have either conflated test scores across age groups and controlled for student test-taking age (e.g., Reardon, 2011a; Chmielewski, 2019; Hanushek et al., 2020), used data on one age group (e.g. Chmielewski and Reardon, 2016; Reardon and Portilla, 2016), or used a proxy of a single cohort of students (OECD, 2018).

We are able to document that the achievement gaps increase as students grow older and are largest for school grades at the end of compulsory schooling. Across reading and math, for both income and education gaps, the increase was about 10 percentage points from 5th to 8th grade, with a similar increase to 10th grade. This increase is consistent with OECD (2018), finding large and growing gaps for Norway from age 10 to ages 25-29. We were, however, not able to correct these longitudinal gap estimates for measurement error across tests (as done e.g., by Reardon, 2011a) and the absolute increase in gaps across school years may be less precise estimates than gaps across cohorts, where the test is identical.

Strengths and Limitations

The main strength of our analysis is that we can study the whole population, rather than a sample of students, and use precise measures of both student achievement and parental income and education from administrative data. In addition, we are able to measure student performance outcomes for the same individuals over time.

There are two main limitation to our work. The first concerns our student achievement data. Statistics Norway provides summed raw test scores, but not item-level test data. We are therefore, as mentioned, not able to remove measurement error by psychometric modeling in our main analyses. However, our robustness checks with scaled IRT-scores available from 2014 and onwards are identical to those using the standardized raw score, and we do therefore not consider this to be a critical threat to the validity of our results. The second limitation is that we have are only able to measure achievement as far back as 2007, limiting our ability to make more direct comparisons with previous studies using older data, as well as our ability to see the trends we document as part of a longer time trend. Moreover, as we do not have measures of the same SES constructs, we are unable to make comparisons with the results reported by Hanushek et al. (2020).

Conclusion

In this study, we show that there are considerable socioeconomic achievement gaps, even in a relatively egalitarian society like Norway, with a progressive social welfare system and where schools are mainly public and governed largely by national standards for funding and content. We also demonstrate the advantages of using national administrative data, both to study trends in these gaps over time, and to identify the differences in results as a function of how SES is operationalized. Comparisons within countries and cross-nationally need to recognize that this operationalization of SES may be crucial when addressing trends in socioeconomic achievement gaps. Finding large and persistent (even increasing) achievement gaps in Norway suggests that there are substantial limitations to what an educational system in an affluent welfare state with relatively little income inequality can achieve in equalizing opportunity.

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Figure 1*Parental income (left) and parental education (right)*

Note: Figures display trends in achievement gaps for grade 5. The left figure shows the 90th, 50th and 10th percentile of parental income (in 2007 values) over the time period. The right figure displays the share of each parental education category over the time period. Translated into years of education this is equivalent to an increase from 14.4 in 2007 to 15.2 in 2018.

Figure 2*Parental income achievement gaps*

Note: Figures display trends in the income achievement gap for reading (left) and mathematics (right).

Circle, diamond and triangle markers indicate 5th (G5), 8th (G8) and 10th (G10) grade, respectively. Gaps are estimated using the Reardon (2011a) regression-estimation method.

Figure 3*Parental education achievement gaps*

Note: Figures display trends in the education achievement gap for reading (left) and mathematics (right).

Circle, diamond and triagle markers indicate 5th (G5), 8th (G8) and 10th (G10) grade, respectively. Gaps measure the difference in average achievement between students whose parents have at least a master's degree (MA) as highest education level and high school (HS) as highest parental education level.

Figure 4*Achievement at 90th and 10th parental income percentile*

Note: Figures display trends in the predicted achievement for reading (left) and mathematics (right), separate for the 90th (90) and 10th (10) percentiles. All estimates are based on the the Reardon (2011a) regression-estimation method Circle, diamond and triagle markers indicate 5th (G5), 8th (G8) and 10th (G10) grade, respectively.

Figure 5

Achievement separately for students whose parents have at least a master's degree and at most a high school degree

Note: Figures display trends in the average achievement for reading (left) and mathematics (right), separate for students whose parents have at least a master's degree and at most a high school degree. Circle, diamond and triangle markers indicate 5th (G5), 8th (G8) and 10th (G10) grade, respectively.

ONLINE APPENDIX

Robustness Checks**A) Comparing estimation methods by Reardon (2011a) and Hanushek et al.**

(2020). For achievement gaps by parental income, our main approach uses the Reardon (2011a) 90/10 estimation method. Hanushek et al. (2020) criticize this method for being sensitive to functional form at extreme values due to e.g., extrapolation. This problem is obviously much less severe when using precisely measured income for the whole population, although functional form could still be an issue. To check the sensitivity of our results to estimation method, we use the same income rank variable and approximate Hanushek et al. (2020) by estimating the average achievement between students above the 80th income percentile and below the 20th income percentile, i.e. the 90th and 10th income percentile when assuming achievement is a linear function of income percentile. Figure A1 displays results using both estimation methods for parental income achievement gaps.

[Figure A1 here]

We see that the two estimation methods produced very similar estimates. Regression-estimating the gaps at the 90th and 10th percentile and approximating achievement gaps as the average above and below the 80th and 20th percentile produce nearly the same estimates, supporting the assumption that achievement is linear as a function of parental income, even at the tails of the distribution. This is in line with previous studies that have used both methods.

For achievement gaps by parental education, our main specification uses an approach similar to Hanushek et al. (2020) by comparing mean achievement above (MA) and below (HS) a threshold. As an alternative approach, we create a rank variable for the categorical parental education following Reardon (2011a), where each student with a non-missing test score is given an education percentile corresponding to the middle percentile of the education

category per test and year. For example, if 52% of students have parents with less than a bachelor's degree, and 36% of students have parents with a bachelor's degree as the highest education, then students in this latter category are assigned a rank of $0.52 + \frac{1}{2}0.36 = 0.70$. As with income, a cubic function is then used to estimate the association between education rank and outcome. Figure A2 displays results using both estimation methods for parental education achievement gaps. We see that the Reardon estimation method has gaps that are larger in absolute value, as expected since the MA/HS approach approximated a 90/20 achievement gap rather than a 90/10 achievement gap. However, the trend is the same, again suggesting that estimation method does not matter for interpreting trends over time.

[Figure A2 here]

In Figure A3, we graph the standardized test scores for the 90th and 10th percentile by parental education separately, in reading and math, respectively. When we separate MA and HS (Figure 5), we see that both MA and HS decrease over time, while there is neither convergence nor divergence in the gaps between the 10th and 90th percentile. This suggests that compositional changes in parental education drive the downward trend in both MA and HS, which the 90/10 estimate takes into account.

[Figure A3 here]

B) Scaled national tests scores. Our 5th and 8th grade test scores are raw scores from a national test. Although achievement gaps rely on relative differences within each year, we might worry that these tests are not measuring the same achievement. Scaled scores were introduced starting in 2014, making test results comparable over time. Figure A4 plots results for raw scores for the period 2007-2018 and scaled scores for the period 2014-2018. The scaled scores are standardized with mean 0 and standard deviation 1 for the whole period to make results comparable. We see that the achievement gaps for scaled scores are very similar

to those for raw scores, and there is still a growing achievement gap by parental income and a stable achievement gap by parental education.

[Figure A4 here]

C) Accounting for missing test scores. Our estimates use the population of students with non-missing information on parental income or education and with non-missing test scores. The former is largely due to a growing population of immigrants in the data set for whom parental income and education information is not available. For the latter, however, we might worry that changes in selective test taking are driving our results. Students can have missing test scores either because they were exempt or because they never showed up for the test. Figure A5 plots the share of missing test scores over time. (This was not reported in 2007 for national tests.) With some fluctuations, the fraction of missing test scores has increased over time for all measures. Students with lower parental income and education are overrepresented in this group. For example, for math in 5th grade in 2008, students with missing test scores were 6 percentage points more likely to be immigrants and 2 percentage points less likely to have parents who have completed higher education.

[Figure A5 here]

To investigate whether this increase in missing test scores affects our main results, we make a very simple imputation with a test score of 0 for students with missing test scores, equivalent to the mean value as test scores are standardized per test and year. This can be considered an upper bound estimate of their performance as these students are more likely to perform below average. Figures A6 and A7 present results for achievement gaps measured by parental income and parental education, respectively. As expected, imputing average values for students with missing test scores decreases the level of achievement gaps. However, missing values does not explain the increasing trend for parental income, as this trend

remains with imputed values. For education, there is also a drop in achievement gap levels, but again, the stable trend remains the same.

[Figure A6 here]

[Figure A7 here]

D) Following the same sample over time. For cohorts born from 1997 to 2002 we can observe test scores at all three stages. We restrict the sample to students with non-missing test scores for all three tests, ensuring that there are no compositional changes within cohort. Parental income and education rank are measured 1-3 years prior to the 5th grade test. Figure A8 displays the results. Across cohorts we see an increasing gap as grade level increases, consistent with the main results. For the same population, rather than closing gaps, gaps are growing the longer the time spend in the educational system. It is less clear whether these gaps increase over time for this narrow time period.

[Figure A8 here]

Figures A9 and A10 show results by cohort (dashed lines, specifically 1997, 1999, and 2001) plotted together with the main results (solid lines). The results by cohort span 6 years as national tests are taken in the fall and grades are received in the spring (e.g. national tests fall of 5th grade in 2007, national tests fall of 8th grade in 2010 and grades received in the spring of 10th grade 2013). For income, there is a tendency for the younger cohorts to have higher achievement gaps, consistent with increasing achievement gaps over time, but we do not see the same pattern for education.

The achievement gaps for these cohorts are lower than for the entire sample. The consistent sample over time requires non-missing test scores for all time periods and also calculates achievement gaps prior to the 5th grade rather than prior to each tests and the achievement gap is calculated within the sample. The first requirement leads to a loss of sample of e.g. 13% for 5th grade reading (tested in 2007, N=57,196 for whole sample and

N=50,620 for consistent sample) and 17% for 10th grade for the cohort born in 1997 (tested in 2013, N=60,741 for whole sample and N=50,620 for consistent sample). The individuals that are lost are typically the incoming immigrant population and low performing students that may be exempt from testing. This means that the achievement gaps are calculated for children with higher socioeconomic background, and are expected to be lower in level.

[Figure A9 here]

[Figure A10 here]

E) Accounting for Immigration. Norway has a large and increasing immigrant population, 18.5% in 2021, of which 25% are second generation immigrants (Statistics Norway, 2021). The period we studied was characterized by a net influx of immigrants, particularly from Eastern Europe. Figure A11 displays the trend in the share of immigrants among 5th and 10th grade students over time, where immigrants are divided into six mutually exclusive categories, first- and second- generation immigrants for each of three country groups defined as:

- Group 1: Countries in Western Europe, countries in North America, Australia and New Zealand (Denmark, Sweden, Finland, Iceland, Greenland, Farroe Islands, Belgium, Andorra, France, Gibraltar, Greece, Ireland, Italy, Malta, Netherlands, Liechtenstein, Luxembourg, Monaco, Portugal, Sam Marine, Spain, Great Britain, Switzerland, Germany, Austria, Vatican City, Cyprus, Canada, the US, Australia, New Zealand, Guernsey, Jersey, Sint Maarten, Curacao, Bonaire, Sint Eustatius and Saba)
- Group 2: 11 Eastern European countries that joined EU in 2004 or later (Bulgaria, Estonia, Croatia, Latvia, Poland, Romania, Lithuania, Slovenia, Hungary, Slovakia, Czech Republic)
- Group 3: All other countries not in Groups 1 or 2.

There are two groups in particular that increase during this time period for both tests, the share of second-generation immigrants with parents who are in group 3 (i.e., are not from the EU, the US, Canada, Australia or New Zealand) and the share of first-generation immigrants from group 2 (i.e., the 11 Eastern European countries that joined the EU in 2004 or later). For 10th grade, the share of first-generation immigrants from group 3 is also increasing.

[Figure A11 here]

These compositional changes in immigration might be driving our results. We used two approaches to account for immigration. In the first approach, for parental income, both income rank and regression-based achievement gaps were calculated with immigrant weights from 2007 using the same six categories for immigrant background. For parental education, mean achievement above MA or below BA were estimated using the same immigrant weights. In the second approach, for both parental income and education, all immigrants were dropped from both estimation procedures. In Figure A12, we present the results from these two approaches in separate graphs for income gaps in reading for 5th, 8th, and 10th graders, respectively. For reading, the gaps were similar, both in terms of level and change over time, when we used with weights (dashed lines) and without weights (solid lines, equivalent to 90/10 from Figure 2). When we removed immigrants (dot dashed lines), the gaps were smaller, while the increase in gaps over time was still evident. The same results were evident for math, though the reduction in the size of the gaps was somewhat smaller when we removed the immigrants.

[Figure A12 here]

When we did the same for education gaps, displayed in Figure A13, there were much smaller changes in the gaps as a function of removing immigrants, and the results were, across these two specifications, largely similar to those presented earlier in Figure 3 (denoted with solid lines in Figure A13).

[Figure A13 here]

F) Alternative specifications of the gaps: The 90/10 measure uses information only at the extremes and hides whether trends are changing due to changes in the top or the bottom of the distribution. In the paper, we report trends separately for the 90th and 10th percentiles for income (Figure 4), which showed that the growth in achievement gaps by parental income was occurring because of declining achievement in the bottom of the distribution. 90/50 and 50/10 gaps are another way of investigating this, comparing the 90th and 10th percentiles, respectively, to the median. Figure A14 show the same patterns; achievement gaps by parental income are increasing in the bottom and stable in the top.

[Figure A14 here]

For education, we investigate whether trends change when changing the lowest group from students whose parents have at least a master degree (MA) to students whose parents have at most a lower secondary degree (LS). The gaps are actually decreasing over time. Figure A16 shows the trend separate for MA and LS and we see that this is driven by a decrease over time for MA while LS is stable, likely due to compositional changes in the share and characteristics of students in this group.

[Figure A15 here]

[Figure A16 here]

G) Including 9th grade test scores: In addition to taking national tests in 5th and 8th grade, students take a national test in 9th grade. These are the same as for 8th grade in each calendar year, used to measure within-person progression. In Figures A17 and A18, we include the 9th grade test results in the analysis, and see that our results hold. Parental income achievement gaps from 9th grade are roughly the same as for 8th grade. For parental education, achievement gaps for 9th grade gaps are slightly lower than for 8th grade.

[Figure A17 here]

[Figure A18 here]

H) Partial associations of parental income and education: Income and parental education are correlated, slightly increasing with time. Similarly to Reardon (2011a), we investigate whether the growth in the income achievement gap is due to increases in the association between income and achievement or parental education and achievement by estimating partial associations. We estimate the association between income and achievement, controlling for parental education, and the association between parental education and achievement, controlling for parental income (see Section 5.A8 in Reardon (2011b) for details). For achievement gaps by parental education, gaps are slightly lower when controlling for parental income, with signs of a decrease. For achievement gaps by parental income, when controlling for parental education, the level decreases substantially but the trends remain consistent, increasing over time.

[Figure A19 here]

I) Distribution of outcome variables over time: In Figures A20 and A21 we investigate the distribution of our outcome variables over time to see whether changes could be driving our results. We see that the distribution is roughly normal for mathematics, while somewhat skewed for reading. However, the pattern is the same across years, suggesting that we can have confidence in our analysis of trends in achievement gaps for all outcomes. Additionally, if the distribution was not roughly normal across years, we would likely see some evidence of this in the comparison of the Reardon (2011a) and Hanushek et al (2020) estimates. This does not seem to be the case.

Figure A1

Note: Figures display trends in the income achievement gap for reading (left) and mathematics (right).

Circle, diamond and triangle markers indicate 5th (G5), 8th (G8) and 10th (G10) grade, respectively. Gaps are estimated using the Reardon (2011a) regression-estimation method are the solid lines denoted R90/10, equivalent to Figure 2. Gaps using the Hanushek et al. (2020) estimation method are the dashed lines denoted H90/10.

Figure A2

Note: Figures display trends in the education achievement gap for reading (left) and mathematics (right).

Circle, diamond and triangle markers indicate 5th, 8th and 10th grade, respectively. Gaps using the Reardon (2011a) regression-estimation method are the solid lines denoted R90/10. The dashed lines, denoted H MA/HS, measure the difference in average achievement between students whose parents have at least a master's degree as highest education level and high school as highest parental education level, equivalent to Figure 3 and approximating a 90/20 achievement gap.

Figure A3*Achievement at 90th and 10th parental education percentile*

Note: Figures display trends in the predicted achievement for reading (left) and mathematics (right), separate for the 90th and 10th percentiles using R90/10 estimates. Circle, diamond and triagle markers indicate 5th (G5), 8th (G8) and 10th (G10) grade, respectively.

Figure A4*Achievement gaps with raw and scaled national test scores*

Note: Figures display trends in the achievement gap by parental income (left) and by parental education (right). Circle, diamond and triangle markers indicate 5th grade test reading, 8th grade test reading, 5th grade test mathematics and 8th grade test mathematics, respectively. Achievement gaps are R90/10 estimates where solid lines use raw scores and dashed lines use scaled scores.

Figure A5*Share of missing test scores*

Note: Figure displays trends share of missing test scores for each test, including both students who were except and other student who did not participate. Participation data is not available for national tests in 2007.

Figure A6*Parental income achievement gaps with imputed values for missing test scores*

Note: Figures display trends in the achievement gap by parental income for reading (left) and mathematics (right). Circle, diamond and triangle markers indicate 5th, 8th and 10th grade, respectively. The solid lines are the R90/10 estimates from Figure 2, while the dashed lines are the estimates when missing test scores are imputed with average values. Participation data is not available for national tests in 2007.

Figure A7*Parental education achievement gaps with imputed values for missing test scores*

Note: Figures display trends in the achievement gap by parental income for reading (left) and mathematics (right). Circle, diamond and triangle markers indicate 5th, 8th and 10th grade, respectively. The solid lines are the R90/10 estimates from Figure 3, while the dashed lines are the estimates when missing test scores are imputed with average values. Participation data is not available for national tests in 2007.

Figure A8*Achievement gaps by cohort*

Note: Figures display trends in the achievement gap by parental income (left) and parental education (right). All estimates are R90/10 estimates. Each line represents a cohort from 1997-2002, with solid lines for reading and dashed lines for mathematics. Rank is estimated based on parental income or education in the 1-3 years prior to the 5th grade test.

Figure A9*Parental income achievement gaps, by year and cohort*

Note: Figures display trends in the achievement gap by parental income for reading (left) and mathematics (right). All estimates are R90/10 estimates. The solid lines are the same as the R90/10 estimates from Figure 2. The dashed lines plot the 97, 99 and 01 cohorts (from Figure 10) with non-missing scores on all tests in the same figure, giving an indication of whether the increase is also apparent for consistent samples.. The results by cohort span 6 years as national tests are taken in the fall and grades are received in the spring (e.g. national tests fall of 5th grade in 2007, national tests fall of 8th grade in 2010 and grades received in the spring of 10th grade 2013. For these cohorts, rank is estimated based on parental income or education in the 1-3 years prior to the 5th grade test.

Figure A10*Parental education achievement gaps, by year and cohort*

Note: Figures display trends in the achievement gap by parental education for reading (left) and mathematics (right). All estimates are R90/10 estimates. The solid lines are the same as the R90/10 estimates from Figure 3. The dashed lines plot the 97, 99 and 01 cohorts (from Figure 10) with non-missing scores on all tests in the same figure, giving an indication of whether the increase is also apparent for consistent samples. For these cohorts, rank is estimated based on parental income or education in the 1-3 years prior to the 5th grade test.

Figure A11*Immigrant background, grade 5 (left) and grade 10 (right)*

Note: The figures plot the share over each immigrant category over time for grade 5 (left) and grade 10 (right). The categories are six mutually exclusive immigrant categories for first/second generation immigrant (both parents and child born abroad or both parents born abroad) with country background from group 1/2/3 (Statistics Norway, 2021). Group 1 is western European countries, as well as North America, Australia and New Zealand. Group 2 includes the 11 Eastern European countries that joined EU in 2004 or later. Group 3 includes all remaining countries. See Appendix E for details. .

Figure A12*Parental income achievement gaps, accounting for immigrant background*

Note: The figures show achievement gaps by parental income over time when accounting for immigrant background. Black lines display results for reading while grey lines display results for mathematics. The solid lines are the same as the R90/10 gaps from Figure 1 for reference. The dashed lines are results when weighing cut-offs and test scores by immigrant shares (six mutually exclusive categories + natives) in 2007. The dashed-dotted lines are results when only including natives.

Figure A13*Parental education achievement gaps, accounting for immigrant background*

Note: The figures show achievement gaps by parental education over time when accounting for immigrant background. Black lines display results for reading while grey lines display results for mathematics. The solid lines are the same as the R90/10 gaps from Figure 1 for reference. The dashed lines are results when weighing cut-offs and test scores by immigrant shares (six mutually exclusive categories + natives) in 2007. The dashed-dotted lines are results when only including natives.

Figure A14*Parental income achievement gaps for reading, 90/50 and 50/10* *Parental income achievement gaps for mathematics, 90/50 and 50/10*

Note: Figures display the 90/50 and 50/10 achievement gaps using the Reardon (2011a) regression-estimation method. Circle, diamond and triagle markers indicate 5th, 8th and 10th grade, respectively. The first panel displays results for reading while the second panel displays results for mathematics.

Figure A15*Parental education achievement gaps, MA/LS*

Note: Figures display trends in the education achievement gap for reading (left) and mathematics (right).

Circle, diamond and triagle markers indicate 5th (G5), 8th (G8) and 10th (G10) grade, respectively. Gaps measure the difference in average achievement between students whose parents have at least a master's degree (MA) as highest education level and at most lower secondary (LS) as highest parental education level.

Figure A16

Achievement separately for students whose parents have at least a master's degree and at most a lower secondary degree

Note: Figures display trends in the average achievement for reading (left) and mathematics (right), separate for students whose parents have at least a master's degree and at most a lower secondary degree. Circle, diamond and triangle markers indicate 5th (G5), 8th (G8) and 10th (G10) grade, respectively.

Figure A17*Parental income achievement gaps, including grade 9*

Note: Figures display trends in the income achievement gap for reading (left) and mathematics (right).

Circle, diamond, square and triangle markers indicate 5th (G5), 8th (G8), 9th (G9) and 10th (G10) grade, respectively. Gaps are estimated using the Reardon (2011a) regression-estimation method.

Figure A18*Parental education achievement gaps, including grade 9*

Note: Figures display trends in the education achievement gap for reading (left) and mathematics (right).

Circle, diamond, square and triangle markers indicate 5th (G5), 8th (G8), 9th (G9) and 10th (G10) grade, respectively. Gaps measure the difference in average achievement between students whose parents have at least a master's degree (MA) as highest education level and high school (HS) as highest parental education level.

Figure A19*Parental achievement gaps, estimated partial associations*

Note: Figures display trends in the estimated partial associations for reading (left) and mathematics (right).

Circle, diamond and triangle markers indicate 5th (G5), 8th (G8) and 10th (G10) grade, respectively. Gaps are estimated using the Reardon (2011a) regression-estimation method. The estimates are the association between income and achievement, controlling for parental education, and the association between parental education and achievement, controlling for family income, equivalent to online appendix section 5.A8 in Reardon (2011b).

Figure A20*Distribution of outcome variable across years, reading*

Note: Figures display the kernel density estimate for every third year for reading 5th, 8th and 10th grade.

Figure A21*Distribution of outcome variable across years, mathematics*

Note: Figures display the kernel density estimate for every third year for mathematics 5th, 8th and 10th grade.