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Abstract

Parents are crucial to children's educational success, but the role of parental education in fostering academic excellence remains underexplored. Using longitudinal administrative data covering all North Carolina public school students, we document five facts about first-generation excellence gaps. We find large excellence gaps emerge by 3rd grade across all demographics and persist through high school. Yet, socioeconomic status and school quality explain only one-third of the gaps. The overarching facts reveal that excellence gaps reflect deeper challenges rooted in parental human capital that manifest early and compound over time, rather than merely consequences of socioeconomic disadvantage or school quality differences.

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Introduction

A child's path to academic excellence depends not only on their own abilities but critically on their parents' educational experiences, yet we know surprisingly little about how parental human capital shapes children's prospects for reaching the highest levels of achievement. Parental financial circumstances importantly determine access to certain educational inputs, like school quality. Parents themselves also serve as an important input who provide information, motivation, and guidance in line with their own knowledge and experience, in addition to the time they dedicate to teaching their children. Therefore, even conditional on family income, parents with more education are often better able to help their children reach the highest levels of academic achievement. That is, in economic models of human capital formation (e.g. Todd and Wolpin, 2003) parents are a key input in the education production function and parental human capital increases productivity in the production of children's human capital (Becker et al., 2018). With less parental experience to draw on, first-generation college students ("first-gen")—individuals for whom neither parent has a college degree (Congress, 1980)—face specific challenges and barriers throughout their education.

This paper documents educational disparities between first-gen and continuing-gen students in the likelihood of reaching the highest levels of academic achievement (or "excellence," Plucker et al., 2010) as students progress through school. We use statewide administrative data from North Carolina covering all public school students from third grade through the end of high school, including information about college readiness and intentions to pursue higher education. Despite extensive research on average achievement gaps, we lack systematic evidence on how first-gen status affects students' ability to reach and sustain academic excellence—the top 10% of performance—that is crucial for accessing elite educational opportunities. These differences remain important to understand, particularly as both in the US and North Carolina specifically, more than 60% of children under the age of 18 are associated with a head of household who did not obtain a college degree (2022 American Community Survey, Figure A1).

We first measure the magnitude of first-gen excellence gaps, and then consider the extent that family circumstances and school environments, including heterogeneity in teacher value-added, serve as drivers for who reaches and persists at the top of the achievement distribution. Overall, our analyses shed light on inter-generational policy concerns in which first-gen students are at a disadvantage for upward mobility and economic opportunity, reinforcing social and wealth inequalities. Understanding when and why these excellence gaps emerge is crucial for policy design. If gaps appear early and compound over time, interventions focused solely on college access may be insufficient—requiring instead comprehensive support beginning in elementary school.

We establish five key empirical facts: (1) large excellence gaps emerge by 3rd grade and persist through high school; (2) first-gen students are less likely to enter and remain in the top decile; (3) the excellence gaps are universal across demographics and schools; (4) socioeconomic status and school quality explain only around one-third of the gaps; and (5) teachers vary in their effectiveness with first-gen versus continuing-gen students. Together, these facts reveal that excellence gaps are not merely a consequence of socioeconomic disadvantage or school quality differences, but reflect deeper challenges rooted in parental human capital that manifest early and compound over time. In this way, the excellence gaps we document represent a hidden dimension of educational inequality that has received insufficient attention from researchers and policymakers. While much focus has been placed on bringing struggling students to proficiency, our findings highlight the importance of ensuring that all students—regardless of their parents' educational background—have equal opportunities to reach their full academic potential.

Our focus on the first-gen excellence gap complements past evidence on the magnitudes of other education gaps and disparities in two ways. First, our facts on academic excellence extend prior research that assesses parental-education based average achievement gaps (e.g. Pascarella et al., 2004; Sirin, 2005; Martins and Veiga, 2010; Kalil et al., 2012; Lundborg et al., 2014; Betancur et al., 2018; Chmielewski, 2019; Hanushek et al., 2019; Assari et al., 2021) in standardized test scores, math and reading skills, and key post-secondary outcomes. Second, we consider differences for first-gen students, while prior work on excellence gaps has largely focused on disparities by race, gender, and household income (e.g. Wyner et al., 2007; Plucker et al., 2010; Meinck and Brese, 2019; Hoxby and Avery, 2013; Rambo-Hernandez et al., 2019; Karna et al., 2025). Since, by definition, first-gen students have parents with less experience navigating how to reach the highest levels of education, they are likely to face different and particular challenges in progressing through their education, even conditional on income and other demographics (Startz, 2022), stressing the importance of measuring these gaps.

In doing so, we build on past work on the role of parents throughout childhood in human capital formation (e.g. Cunha and Heckman, 2007, 2008; Doepke et al., 2019; List et al., 2021). In line with the direct connection between parents' lack of college experience and barriers to college access, much of the literature has specifically focused on the first-gen difference in college outcomes (Holmlund et al. (2011) gives a review; Pascarella et al., 2004; Harackiewicz et al., 2014; Stephens et al., 2014; Patnaik et al., 2021; Aucejo et al., 2025) and the implications for labor market opportunities including educational attainment beyond college and elite jobs (e.g. Gardner, 2013; Friedman and Laurison, 2020; Shukla, 2022; Aghion et al., 2023; Stansbury and Schultz, 2023; Stansbury et al., 2024). We complement these works by considering the differential evolution of student human capital by first-gen status during primary and secondary school, which importantly determines college admission, enrollment, and success. We focus on students from 3rd grade into high school when they take college admissions tests (SAT/ACT) and start to make college attendance plans. Our findings suggest that because first-gen students are less likely to reach and persist in the highest levels of academic achievement as they progress through school, policymakers should intervene earlier to improve college outcomes for first-gen students.

Finally, our exploration of the role of teachers on first-gen excellence builds on the large literature on teacher value-added that has focused on teachers' average effects on achievement (Chetty et al., 2014), rather than reaching the right tail, and other life outcomes (e.g. Jackson, 2018; Rose et al., 2022; Petek and Pope, 2023) as well as how these impacts vary by student race, gender, and socioeconomic status (Delgado, 2023; Bates et al., 2025). We extend these works by estimating teacher value-added on students' attainment of excellence and heterogeneity across first-gen and continuing-gen students. More specifically, we estimate teacher impacts on the likelihood of reaching the top of the achievement distribution on state standardized tests, the SAT/ACT, and AP tests, and investigate how a teacher's effect varies across first-gen and continuing-gen students. We find that some teachers exhibit significant comparative advantage for helping first-gen students reach the top of the achievement distribution. Overall, by considering heterogeneous value-added for first-gen and continuing-gen students on excellence, our results complement past work to shed new light on match effects and teacher comparative advantage that have important implications for optimal educational policies (e.g. Biasi et al., 2021; Aucejo et al., 2022; Graham et al., 2023; Eastmond et al., 2025).

The remainder of our paper is organized as follows. Section I summarizes our administrative data and illustrates the setting. Section II presents five facts about the first-gen excellence gap, as well as our methodology. Section III concludes. We also provide a simple theoretical framework in the Appendix that formalizes how parental human capital affects the efficiency of educational investments. This simple framework generates the key predictions we test in our empirical analysis and provides economic intuition for why first-gen excellence gaps emerge and persist.

I Data and Measurement

We use comprehensive administrative data from the North Carolina Education Research Data Center (NCERDC) covering all public school students in North Carolina. Our data include student-level demographics including socioeconomic indicators and parental education, standardized achievement measures from grades 3 through 8, and high school outcomes including Advanced Placement (AP) and college entrance exam (SAT and ACT) scores. The longitudinal nature of these data allows us to track entire cohorts of students over time, examining how excellence gaps evolve from elementary school through college preparation.

Our primary analytic sample includes students who began 3rd grade between 1995 and 2006 (data on parental education ends in 2006). We construct a balanced panel of students who progressed through grades 3-8 on schedule with complete test score records for each grade. This approach ensures we can observe achievement trajectories without confounding from grade retention or missing data, while the multi-cohort design enhances the generalizability of our findings.

Our key measure of academic achievement comes from North Carolina's End-of-Grade (EOG) assessments in mathematics and reading, administered annually in grades 3-8. These criterion-referenced tests were the state's primary accountability measures from 1995 to 2013, providing consistent metrics across our study period. We define academic "excellence" as scoring in the top decile of achievement within each grade-year, following established research on excellence gaps (Plucker et al., 2010; Rambo-Hernandez et al., 2019).

To examine how elementary and middle school excellence gaps translate into college preparedness, we link students to their high school outcomes. We observe AP exam participation and performance (2010-2017), SAT scores (2009-2021), and ACT scores (2013-2022). Importantly, the ACT became part of North Carolina's school accountability program in 2012-2013. We convert ACT scores to SAT-equivalent scores using year-specific concordance tables to create comparable college entrance exam measures. These data allow us to trace the long-term consequences of early excellence gaps through the critical college preparation phase.[1]

The first-gen excellence gap is the difference in the likelihood of reaching the highest levels of achievement in the entire state for first-generation students compared to continuing-generation students. We label a student as "first-gen" if neither of her parents completed a college degree, which is recorded in the administrative data. This definition corresponds to the federal definition in the Higher Education Act of 1980 and is similar to the definition used by the National Center for Educational Statistics (NCES).[2] We acknowledge that there is not universal agreement by colleges and universities or the public on a definition of first-gen, while some opting for a stricter definition including only those with no family member to have ever attended college. Students with at least one parent with a college degree are considered continuing-gen students.

Our measure of the excellence gap focuses on whether a student reaches the top decile of achievement, following Plucker et al. (2010) and Rambo-Hernandez et al. (2019):[3]

$$\text{Excellence Gap} = \mathbb{P}(\text{Top Decile}_i|\text{Continuing-gen}_i) - \mathbb{P}(\text{Top Decile}_i|\text{First-gen}_i) \qquad (1)$$

We additionally consider how the first-gen excellence gap varies by gender and race. In total, our data set includes 827,371 students, of whom roughly 63% are White and 35% are non-White. Of the White students, nearly 56% are first-gen students and nearly 42% of non-White and non-Asian students are first-gen. Table A1 provides a further summary of our data.

[1]Since the ACT became mandatory for North Carolina student's in 2012-2013, we conduct a robustness check for key SAT results in Appendix H by restricting our sample to those cohorts beginning 3rd grade between 2000 and 2004 (for whom neither the SAT nor ACT were required).

[2]The Higher Education Act notes "[T]he term 'first generation college student' means a person neither of whose parents completed a baccalaureate degree; the NCES states that first-gen students are "Students who had parents with no postsecondary education experience."

[3]Due to ties in test scores, we do not always have a threshold score that defines exactly the top 10%. Table A3 shows the fraction of students categorized as excellent in each grade and subject.

II Empirical Results

In this section, we summarize our empirical results as five key facts concerning the first-generation excellence gap. We begin by documenting the gap, its persistence over time, and its prevalence across demographic subgroups. We proceed to explain the gap and its moderators, and conclude by discussing the impact of teachers on the gap. Throughout, we additionally include more grade, race, and gender specific analyses in the Appendix. We interpret our results through an economic model of parental human capital investment (Appendix A).

1. The first-gen excellence gap is large from 3rd grade to high school

The first-gen excellence gap in standardized exam performance exists for the youngest students in our data, 3rd graders (Figure 1a; see Figure A7 for reading).[4] Indeed, the data suggest a large and significant disparity: in math, first-gen students are 17 percentage points less likely to reach excellence than continuing-gen students (76% from a mean of 22.5% for continuing-gen). This disparity grows to over 19 percentage points (80%) by 8th grade. This result shows that the difference in the likelihood of reaching the top decile of achievement between first-gen and continuing-gen students is evident, and large, at young ages.

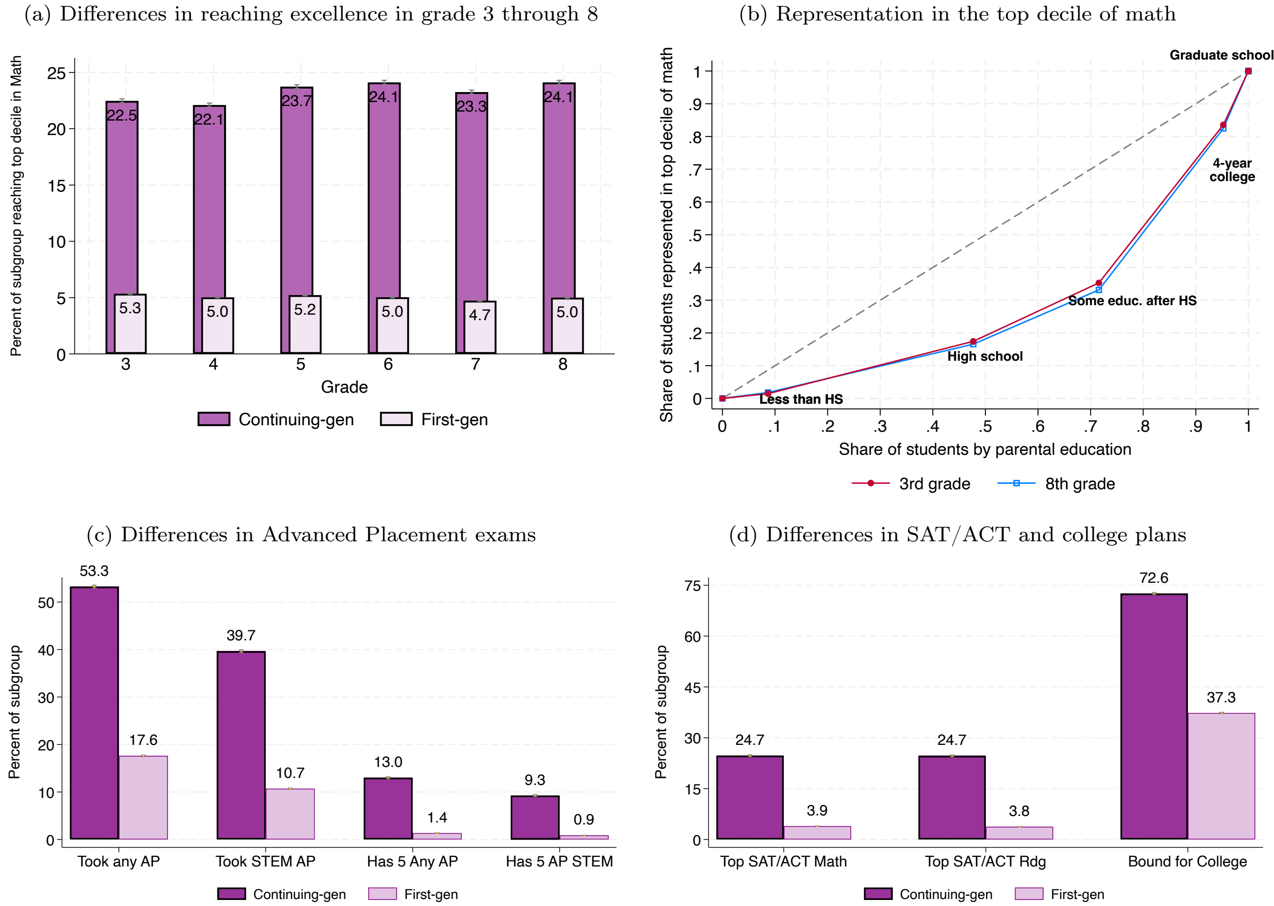
Breaking down further the composition of the gap, we find that first-gen students make up around 70% of the student population, but represent less than 40% of those who reach excellence (Figure 1b). By contrast, continuing-gen students make up just under 30% of the student population, and make up over 60% of those who reach excellence. Students with parents who did not complete high school are almost entirely unrepresented in the share of students who reach excellence.

Figure 1b also sheds light on the persistence of the excellence gaps from third to eighth grade. At each level of parent education, the share of students represented in the top decile of math achievement remains strikingly similar in both 3rd and 8th grade. We can visualize this persistence for both math and reading in Figure A6.

These gaps during elementary school continue persist through high school into measures of college readinesss: took any AP exam, scored a 5 on an AP exam, took a STEM AP exam, scored a 5 on a STEM AP exam, scored in the top decile of the SAT/ACT math or reading sections, and plans to attend college (Figures 1c and 1d). We find large differences in rates of taking and achieving a 5 on any AP exam and any STEM AP exam between first-gen and continuing-gen students. Continuing-gen students are about 35 percentage points more likely to take any AP exam, and 30 percentage points more likely to take a STEM AP exam than first-gen students. Moreover, continuing-gen students are over 10 percentage points more likely to score a 5 on an

[4] While the end-of-grade tests are taken at the end of each respective grade, we additionally observe beginning-of-3rd-grade exams for cohorts beginning 3rd grade in 1997-2005 and observe an excellence gap of similar magnitude (Figure A8).

Figure 1: First-generation disparities in reaching academic excellence



Notes: These figures display (a) the first-generation excellence gap in math in grades 3 through 8, (b) the Lorenz curve of the share of students in the top decile of math achievement that is cumulatively represented by each parent education subgroup in the population, (c) the percentage of students in each parent education group that takes at least one AP exam, takes at least one STEM AP exam, has a 5 on at least one AP exam, and has a 5 on at least one STEM AP exam, (d) the percentage of each parent education group that reaches the top decile in SAT/ACT math or reading at the state level, and has plans to attend a 4-year college. Ticks in Figures (a,c,d) correspond to 95% confidence intervals. Excellence is defined as reaching the top decile on the End-Of-Grade test within grade-year. Analysis in Figures (a,b) uses our main sample as described in Section I, which consists of 827,371 students in total: 602,780 with parents having attended less than 4-year college and 224,591 with parents having attended a 4-year college or more. Analysis in Figures (c,d) uses a subset of the main dataset described in Section I, which consists of cohorts beginning 3rd grade between 2001 and 2006 for AP outcomes and and cohorts beginning 3rd grade between 2000 and 2006 for SAT/ACT outcomes.

AP exam, and 8 percentage points more likely to score a 5 on a STEM AP exam, than first-gen students.[5] Patterns are analogous for SAT/ACT achievement, as can be observed in Figure 1d. Continuing-gen students are 20 percentage points more likely to score in the top decile of the SAT math or reading sections than first-gen students. Lastly, we find that continuing-gen students are almost twice as likely to have plans to attend a 4-year college at the end of high school than

[5] Results are similar when we condition on school-specific AP exam offerings in Figure A9a.

first-gen students.

2. Dynamics of entering, and staying in, the right tail of achievement is critically linked to first-gen status

We next use the longitudinal nature of our data to investigate the dynamics of entering and staying in academic excellence. We find that over 60% of continuing-gen students who were excellent in 3rd grade remain excellent in 8th grade, while less than 40% of first-gen students who were excellent in 3rd grade remain excellent in 8th grade. Figure 2a plots the likelihood that an individual student in each 3rd grade percentile is in the top decile in 8th grade, as well as the distributions of 3rd grade achievement by first-gen status. We find, at each level of 3rd grade achievement, that first-gen students are less likely to be in the top decile by the time they reach the 8th grade compared to continuing-gen students with *identical* 3rd grade test scores.

In Figure 2b, we zoom in on students who were in the top decile of math achievement in 3rd grade to consider persistence in the top decile. First-gen students who reach the top decile in 3rd grade are nearly 15 percentage points more likely to fall out of the top decile than their top achieving continuing-gen counterparts. Part of this difference in persistence comes from the fact that even among students in the top decile, first-gen students have lower average test scores–that is, they are more likely to be in the 90-94th percentiles, while continuing-gen students are more likely to be in the 96-99th percentiles. However, at every percentile of 3rd grade achievement from 90 to 99, continuing-gen students are at least 10 percentage points more likely to remain in the top decile than their first-gen peers with identical test scores. Differences in the distribution of third grade achievement alone only minimally explain differential persistence.

These dynamics continue as students progress through elementary school to high school. Across the distribution of 8th grade academic achievement, first-gen students are less likely to reach the top decile in SAT Math (Figure 2c) and to have plans for college (Figure 2d) than their continuing-gen counterparts.

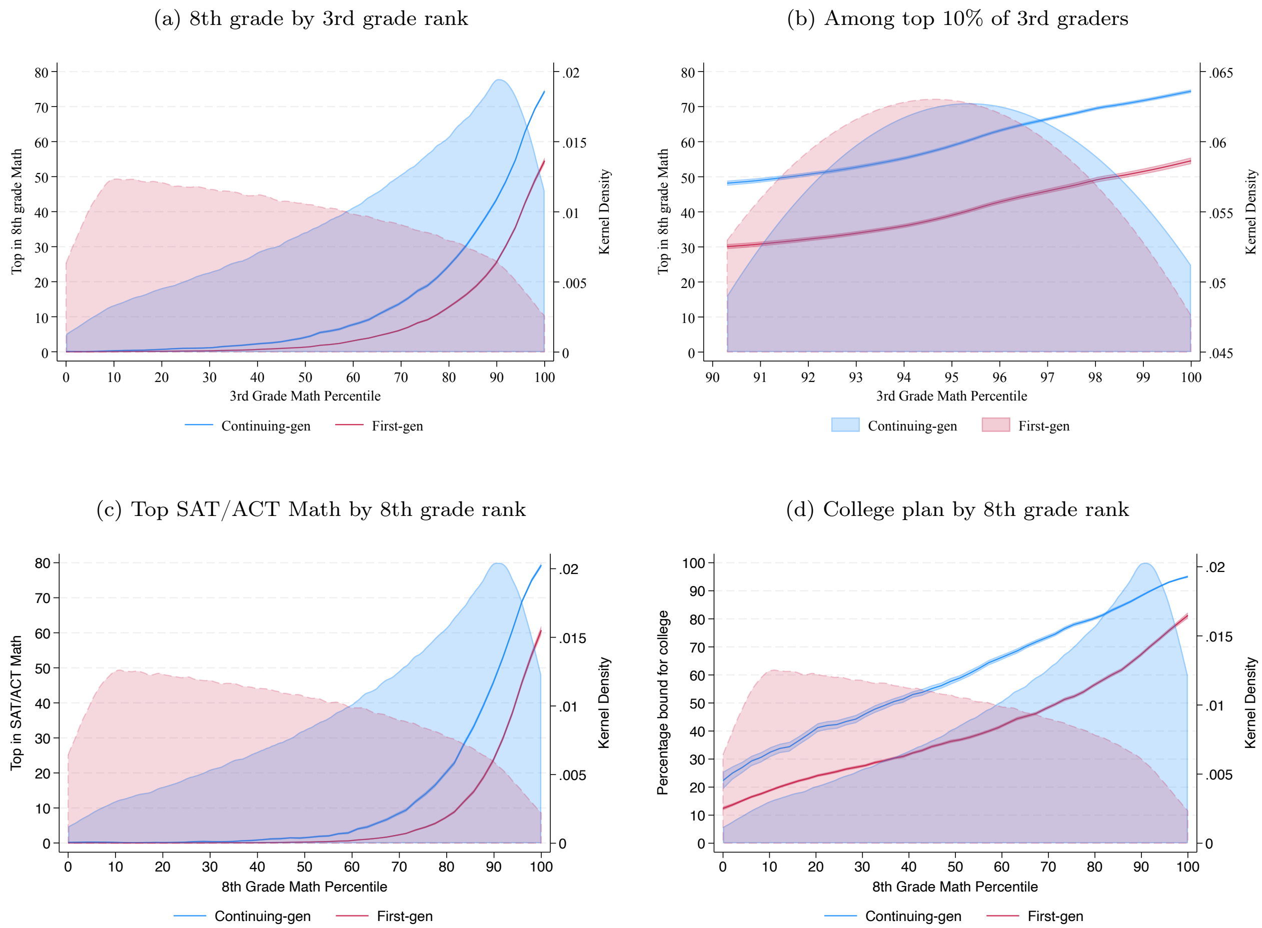
3. First-gen excellence gaps are ubiquitous–they exist for all subgroups (SES, race, and gender) and across nearly all schools

We next examine the existence and heterogeneity of the first-gen excellence gap across SES, race, and gender subgroups, and its prevalence across schools in North Carolina.[6] In Figure 3a, we find that the first-gen excellence gap among males is slightly higher than the gap we measure across our entire sample, and slightly lower among females. As we move from 3rd to 8th grade, the differences narrow.[7]

[6]Appendix Table A2 estimates the relationship between these demographics and first-gen status.

[7]Note the subgroup-specific excellence gaps in Figure 3 need not average to the overall excellence gap (black line) despite the subgroups being mutually exclusive and exhaustive. Using gender subgroups as an example

Figure 2: First-generation disparities in the dynamics of excellence

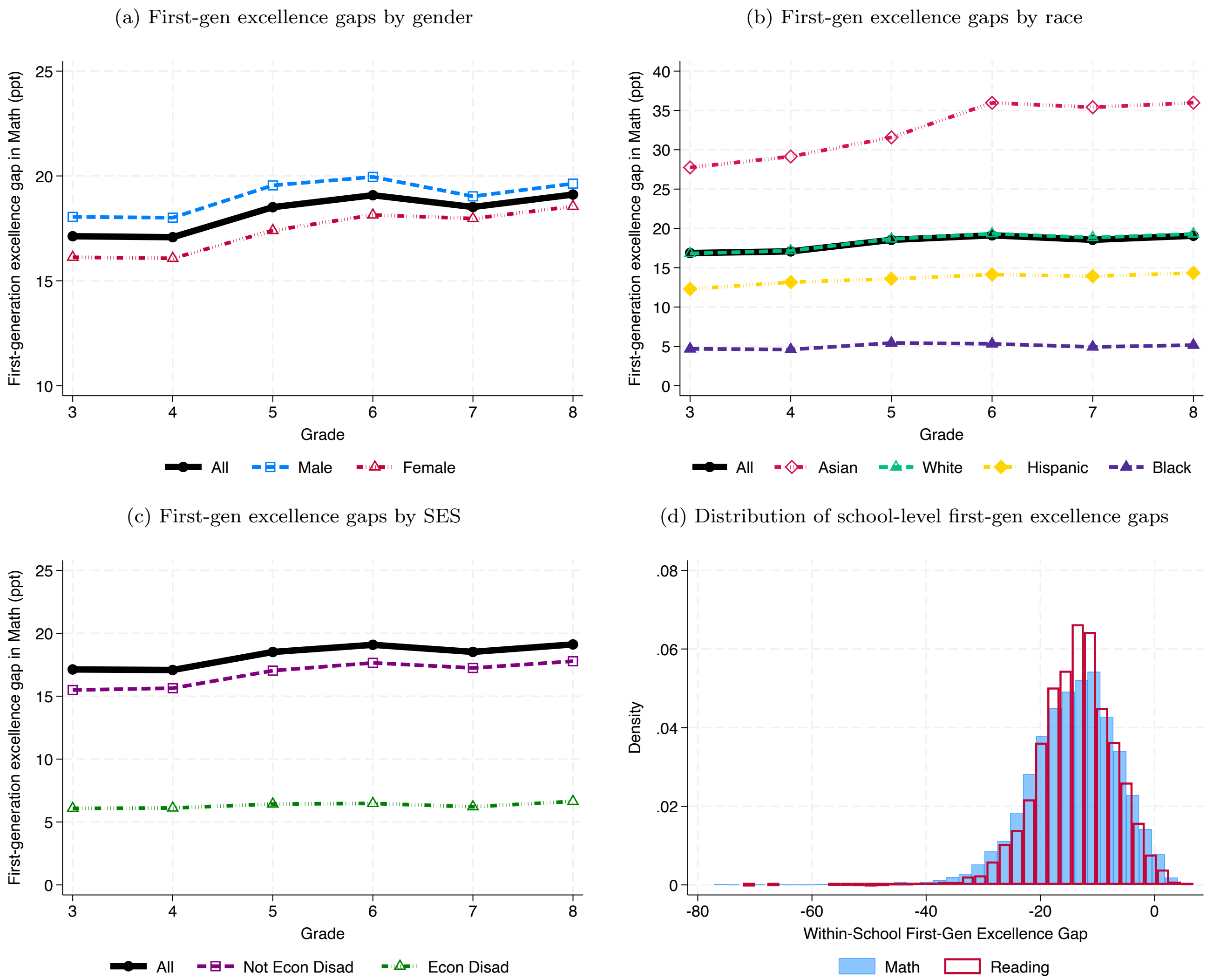


Notes: These figures display the proportion of students who reach the top decile of the 8th grade achievement by 3rd grade achievement, and the distribution of 3rd grade achievement, with (a) displaying the entire range of 3rd grade math distribution, and (b) each percentile in the top 10 percent. Figures (c) and (d) display the proportion of students who reach the top decile of SAT/ACT math and who have plans to attend a 4-year college by 8th grade achievement, and the distribution of 8th grade achievement. Excellence is defined as reaching the top decile on the End-Of-Grade test within grade-year. Analysis in Figures (a,b) uses our main sample as described in Section I, which consists of 827,371 students in total: 602,780 with parents having attended less than 4-year college and 224,591 with parents having attended a 4-year college or more. Analysis in Figures (c,d) uses a subset of the main dataset described in Section I, which consists of cohorts beginning 3rd grade between 2000 and 2006 for whom we observe college readiness outcomes through high school.

First-gen excellence gaps display more variation across race-ethnicity groups but are prevalent in all (Figure 3b). The gap for Asian students is at least 10 percentage points larger than the gap for White students in 3rd grade, and widens to over 15 percentage points larger by 8th grade. The first-gen excellence gap among Black and Hispanic students is smaller than the gap for our entire

(Figure 3a), the overall excellence gap is $\frac{N_{\text{top first-gen females}}+N_{\text{top first-gen males}}}{N_{\text{first-gen females}}+N_{\text{first-gen males}}} - \frac{N_{\text{top cont-gen females}}+N_{\text{top cont-gen males}}}{N_{\text{cont-gen females}}+N_{\text{cont-gen males}}}$, while the subgroup-specific excellence gaps are $\frac{N_{\text{top first-gen females}}}{N_{\text{first-gen females}}} - \frac{N_{\text{top cont-gen females}}}{N_{\text{cont-gen females}}}$ and $\frac{N_{\text{top first-gen males}}}{N_{\text{first-gen males}}} - \frac{N_{\text{top cont-gen males}}}{N_{\text{cont-gen males}}}$.

Figure 3: First-generation disparities in reaching the top decile



Notes: These figures display (a) the first-generation excellence gap in math by gender in grades 3 through 8, (b) the first-generation excellence gap in math by race-ethnicity group, and (c) the first-generation excellence gap in math by socioeconomic status, in grades 3 through 8. Figure (d) displays the distribution of the math and reading excellence gaps across schools, pooling 3rd through 8th graders. Excellence is defined as reaching the top decile on the End-Of-Grade test within grade-year. Analysis uses our main sample as described in Section I, which consists of 827,371 students in total: 602,780 with parents having attended less than 4-year college and 224,591 with parents having attended a 4-year college or more.

sample: this holds even when considering proportional differences in reaching excellence rather than the percentage point difference (Figure A5). This indicates that parent education is a much more important factor in explaining top achievement for Asian students, than it is for traditionally underrepresented minorities.

Measuring the first-gen excellence gap within high and low socioeconomic status groups (Figure 3c), we find that the gap for low-SES students is about 10 percentage points lower than the gap for higher-SES students at each grade level (also in proportional terms: Figure A5). We further consider the role of socioeconomic status as a driver of the overall excellence gap in our next fact. In Appendix E, we similarly analyze the first-gen excellence gap in reading.

Finally, we consider how first-gen differences in excellence vary across schools in North Carolina. We measure school-specific excellence gaps in math and reading by calculating excellence gaps for each school-year-subject in the data, and then average over years in each subject. Figure 3d illustrates their distributions. We find that the average excellence gap masks heterogeneity and reject the null hypothesis that excellence gaps are homogeneous across schools (Pearson Chi-squared test, $p < 0.001$).[8] Although excellence gaps vary across grades, this across-school heterogeneity is not driven by differences in grades associated with schools: accounting for grades minimally changes the results.

While first-gen students are around 14 percentage points less likely to reach excellence in math in the average school, this gap widens to around 22-24 percentage points for schools in the 10th percentile of the excellence gap in both subjects. We estimate a standard deviation of around 7-8 percentage points in both subjects.[9] However, despite across-school variation in the magnitude of the excellence gap, less than 3% of all schools exhibit a positive excellence gap in math and reading. This pattern persists across grades (Figure A23). In other words, in nearly all schools, first-gen students reach excellence at higher rates than continuing gen students. A school's excellence gaps across subjects are positively linked: the correlation between a school's math and reading excellence gap is 0.82 (Figure A21). We find similar patterns when measuring excellence gaps as proportional differences in the rates of reaching excellence (Figure A24).

4. SES and schools explain a third of the first-gen excellence gap

Next, we explore the moderators of the first-gen excellence gaps. We consider the extent to which variation in students' socioeconomic status and heterogeneity in schools explain the excellence gaps. Our main specification estimates, for student i of cohort c in grade g at school s and of socioeconomic status $e(i)$:

$$Y_{i,g} = \alpha + \beta_1 F_i + \gamma_{g,c(i)} + \lambda_{e(i),s} + \epsilon_{i,g} \tag{2}$$

where $Y_{i,g}$ is an indicator for whether i reaches the top decile in grade g, F_i is an indicator for whether the student is first-gen, and $\lambda_{e(i),s}$ captures school fixed effects and controls for student socioeconomic status interacted with grade and cohort. β_1 is our main coefficient of interest, which measures the percentage point difference between the likelihood first-gen and continuing-

[8] We estimate predictors of the school level excellence gaps in Appendix Tables A5 and A6.

[9] Our school-specific measures of observed excellence gaps face minimal sampling error for the corresponding school-year, given our use of comprehensive administrative data. Notably, our observed school-grade excellence gaps are stable over time (Figure A22). We describe our procedures further in Appendix L.

gen students reach the highest levels of achievement, that is, the magnitude of the excellence gap (Excellence Gap $= -\beta_1 = \mathbb{P}(Y_{i,g}|F_i = 0) - \mathbb{P}(Y_{i,g}|F_i = 1)$).

We conduct a Gelbach decomposition to understand the role of each covariate in explaining the excellence gap. This decomposition allows us to treat each factor as an "omitted variable" in the relationship between excellence and first-gen status, and measure the bias that results if the factor were excluded. Thus, we are able to disentangle the impact on the excellence gap of each factor. This approach is of particular value when our observables are correlated, which we expect in our case. where the income distribution across schools varies substantially. We therefore estimate the unconditional excellence gap and compare the magnitude to estimates that additionally control socioeconomic status and school fixed effects. We present the estimates as a percent of the unconditional gap in Figure 4.

We find that first-gen differences in economic disadvantage explain about 20% of the first-gen excellence gap in math and reading from 3rd-8th grade (Figure 4a). First-gen differences in schools attended explain almost 12% (10%) of the gap in math (reading). School fixed effects likely capture a large set of factors such as spending policy, teacher quality, and peer effects, and moreover, could be correlated with county-wide and city-wide features. Almost 70% of the gaps in math and reading remain unexplained, suggesting the role of other important factors such as information gaps.[10]

We find important differences in the decomposition across each race-ethnicity group, and less by gender (Figure A17). Particularly, variation in school quality explains around 32% of the first-gen excellence gap for Asian students, while only 3.5% for Black and 8.5% for Hispanic students. We additionally find that variation in socioeconomic status explains over 20% of the gap for traditionally underrepresented minorities (Black and Hispanic students), while only 11% for White students.

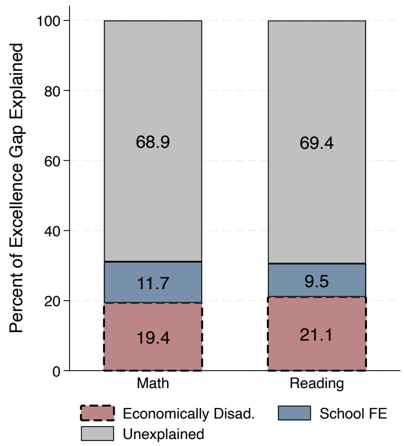
We further investigate the role of socioeconomic status and school environments on the dynamics of excellence by considering mobility into and out of the right tail from 3rd to 8th grade in Figure A25. These two factors jointly explain approximately 30% of the first-gen gap in both persistence and entry into excellence from 3rd to 8th grade. Socioeconomic status explains a slight percent of the gap for persistence and school quality explains slightly more of entry, into both math and reading excellence.

These patterns differ when considering first-gen disparities in other parts of the achievement distribution. We find that variation in schools explains a smaller portion of differences in reaching above the median or bottom 10% of achievement than it does in explaining the excellence gap (Figure A20). In comparison, socioeconomic status explains a much larger portion of the variation. This suggests that the drivers of the excellence gap are not necessarily the same drivers of disparities in lower levels of academic performance.

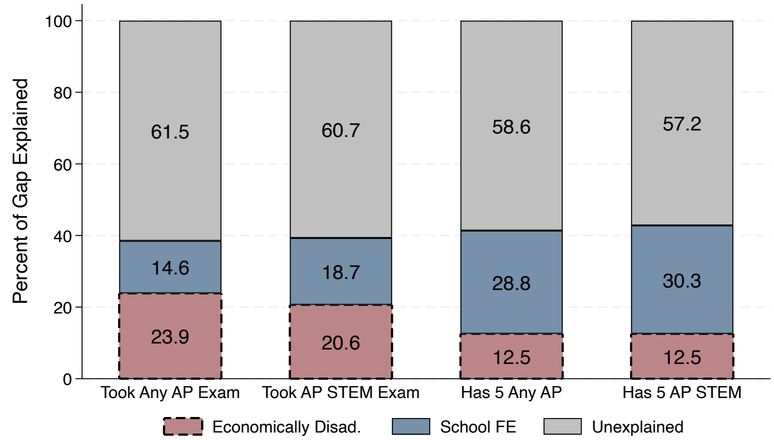
[10]Including an indicator of whether the student is non-White and non-Asian minimally increases the percent of the gaps we explain. See Figure A12b.

Figure 4: Explaining the first-generation excellence gap

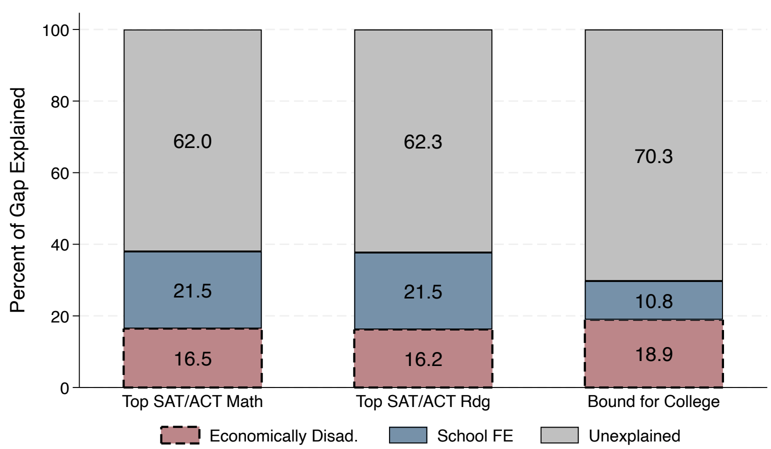
(a) During elementary school



(b) Advanced Placement exams



(c) SAT/ACT and college plan



Notes: These figures display the Gelbach decompositions of the difference between first-generation and continuing-generation students in (a) reaching excellence in math and reading during 3rd through 8th grade, (b) taking advanced placement exams and scoring a 5 on an advanced placement exam, or (c) reaching excellence in the SAT or ACT and having plans for a 4-year college after high school graduation. During elementary school, excellence is defined as reaching the top decile on the End-Of-Grade test within grade-year. The advanced placement "Has 5" outcome is unconditional, and thus treats students who did not take an advanced placement exam as zero. Analysis in Figure (a) uses our main sample as described in Section I, which consists of 827,371 students in total: 602,780 with parents having attended less than 4-year college and 224,591 with parents having attended a 4-year college or more. Analysis in Figures (b,c) uses a subset of the main dataset described in Section I, which consists of cohorts beginning 3rd grade between 2001 and 2006 for AP outcomes and and cohorts beginning 3rd grade between 2000 and 2006 for SAT/ACT outcomes.

Next, we turn to documenting the drivers of first-gen differences in college readiness outcomes: AP exam taking, AP exam scores, SAT/ACT scores, and plans to attend college (Figures 4b and

4c).[11] Across all of these measures of college readiness, socioeconomic status and fixed school environments jointly explain 40% of the gap, while around 60% remains unexplained. Overall, school environments, likely quality, are more important for scoring well on the exams (i.e. scoring a 5 on the AP and to a lesser extent on the SAT and ACT), while socioeconomic status plays a large role in explaining taking the AP exam. Since these exams play an important role in college admissions and access, we additionally consider the drivers of the first-gen gap in plans for attending college, presented in Figure 4c. We find that school environments explain around 11%, which is nearly half of the percent explained for the SAT and ACT. Socioeconomic status, on the other hand, explains roughly the same percent (19%).

We further investigate how socioeconomic status and school quality moderate the dynamics of reaching excellence. Since college readiness and plans to attend are only measured at one point in time, we consider persistence and entry based on a student's 8th grade scores. Figures A26 and A27 present the results from Gelbach decompositions separately for students who were at the top of the achievement distribution in 8th grade to measure persistence, and those who were not to measure entry. Our estimates suggest that schools play an important role for persistence, especially for taking and scoring a 5 on a STEM AP exam. For the other exams and for plans to attend college, the percents explained by these two factors are more similar across students who were and were not at the top of the 8th grade achievement distribution.

5. Teachers are an important ingredient for producing excellence, and are heterogeneous in their effects on first-gen and continuing-gen students

We next dive deeper into a key input for human capital formation–teachers–and their role in producing excellence. Past work finds that teachers exhibit considerable heterogeneity in their value-added on a variety of student outcomes including average test scores, educational attainment, and earnings (Jackson et al. (2014) provide a review). Teachers effects are also heterogeneous by student characteristics such as race and economic disadvantagedness (e.g. Condie et al., 2014; Chetty et al., 2014; Delgado, 2023; Bates et al., 2025). We build on these works by estimating teacher value-added on academic excellence, its potential heterogeneity by first-gen status, and the link between teacher effects on early-age excellence with later-life excellence.

Our approach follows Rose et al. (2022) who non-parametrically compute the distribution of teacher value-added across subgroups and outcomes. We focus on teachers during elementary school (grades 3-5), given that the North Carolina data contain the identity of students' end-of-grade exam proctors and this is most likely to be the same as the class teachers in these earlier grades.[12] As in Rose et al. (2022), we also examine effects of teachers on students' study skills as

[11] We examine top SAT achievement at the national level in Figure A19.

[12] While course memberships are available from 2006 which allow for identifying student-teacher matches, our parental education variable ends in 2006. Following past work, we use classroom personnel reports to identify each test proctor who is indeed a classroom teacher (e.g. Clotfelter et al., 2006; Rothstein, 2010, 2017). In this section,

measured by the first principal component of self-reported hours spent on homework, reading, and television.[13] Appendix N provides details for sample construction and the estimation procedure.

We find considerable variation in teacher effects on excellence during elementary school.[14] Exposure to a teacher with a one standard deviation higher effect on math excellence increases a student's rate of reaching excellence by 3 ppt, while the corresponding increase for reading excellence is 2 ppt (top diagonal of Figure 5a).[15] The large covariance between effects on math and reading excellence reveals that teachers who have a large effect on math excellence also generally have a high impact on excellence in reading. We also find that teacher effects on academic excellence are positively linked to effects on study behaviors, with a correlation of around 0.3, implying that teachers who help students excel are also the ones who increase study behaviors. This is consistent with Rose et al. (2022) who find a positive correlation between effects on average test scores and study behaviors.

A key question for policies intended to improve teacher allocations is whether teachers exhibit a comparative advantage in helping certain student subgroups. Previous research has found that teachers' effects on linear improvements in test scores are highly correlated across a range of student characteristics, including economically disadvantaged status, gender, and race (Chetty et al., 2014; Rose et al., 2022; Bates et al., 2025). To understand this, we allow for heterogeneity in a teacher's effect on first-gen and continuing-gen students. Figure 5b displays the correlation between a teacher's effect on first-gen versus continuing-gen students. We find that a teacher's effect on first-gen students' rates of reaching excellence in math (reading) has a correlation of around 0.8 (0.4) with the teacher's effect for continuing-gen students. These results, especially for reading, indicate that certain teachers have a comparative advantage for helping first-gen students reach excellence, and therefore suggest that teachers play an important role in shaping first-gen excellence gaps. Teacher effects on study skills have a higher correlation, which may reflect a difference in the ease with which teachers can affect student inputs relative to outputs.[16]

Beyond elementary school achievement, we find that teachers influence later-life excellence (Figure 5c; see Figure A30 for the all outcomes). A teacher with one standard deviation higher effect yields 8 percentage point increases in taking an AP exam, 3 ppt in achieving a score of 5 on an AP exam, 3 ppt in reaching the top 10% on the SAT, and 5 ppt in planning to attend a 4-year college. Thus, teachers' comparative advantage for first-generation students in elementary school carries significant implications for closing excellence gaps throughout education.

we include students who are not observed for all grades in order to capture a comprehensive representation of a teacher's student body. As in Rothstein (2017), we use beginning-of-third grade exam scores that are taken in the fall as controls for third grade. Appendix N provides details.

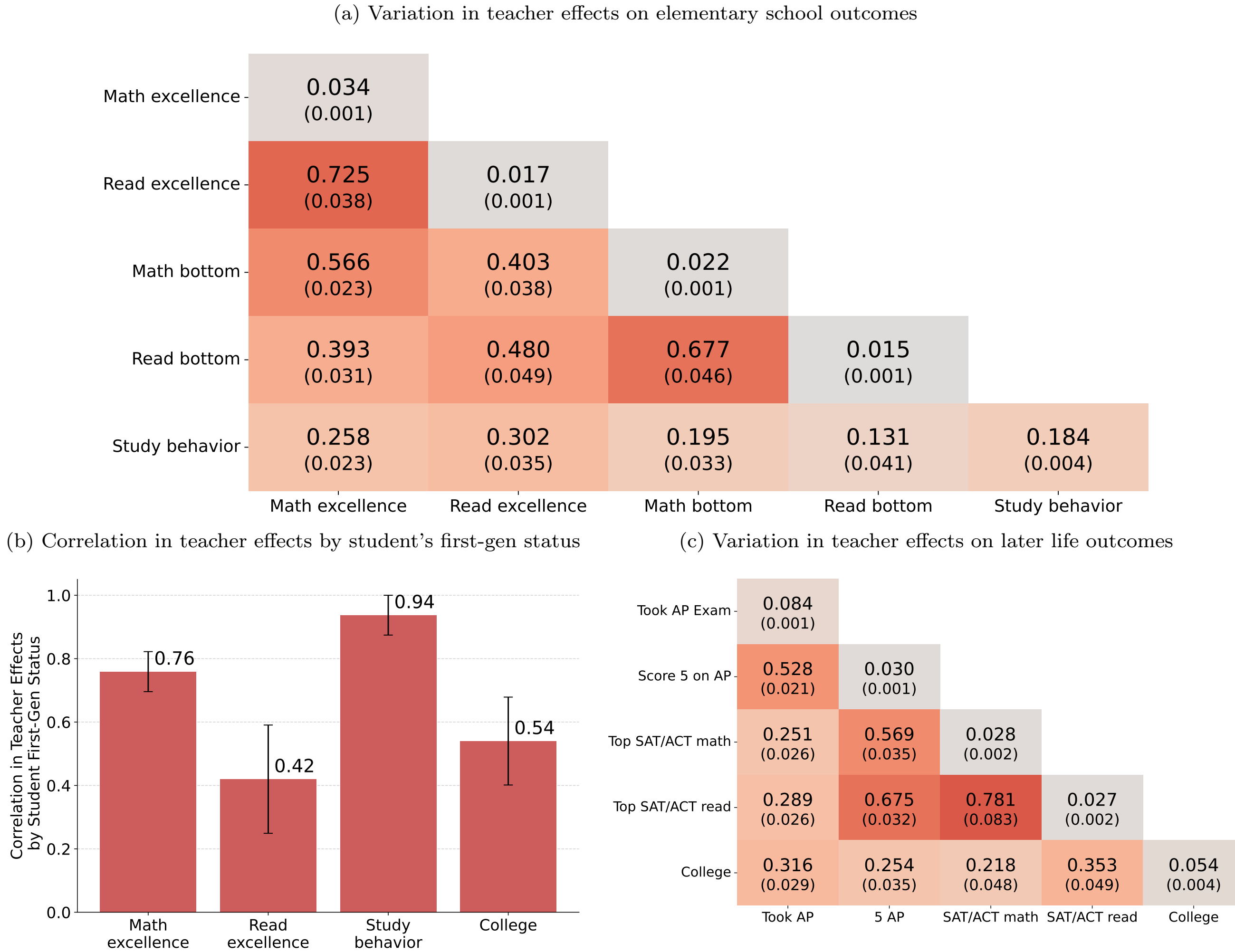
[13]These variables are first standardized at the grade-year level.

[14]We reproduce estimations on teacher effects on linear test score improvements as in Rose et al. (2022) in Figure A29.

[15]We verify through permutation simulations that variation in teacher effects is not by construction due to the fact that only 10% of students can reach excellence (Appendix N.3).

[16]We show the correlations of teacher effects on linear test score improvements in Figure A29.

Figure 5: Effects of teachers on excellence



Notes: This figure presents (a,c) estimated standard deviations (diagonal elements) and correlations (off-diagonal elements) of teacher effects, (b) the correlation in teacher effects across the teacher's students' first-generation status. Estimation procedure follows Rose et al. (2022) and is described in Appendix N. Math and reading excellence are defined as reaching the top decile on the End-Of-Grade test within grade-year in the subject. Similarly, math/reading median corresponds to being above median, and math/reading bottom to being in the bottom 10%. Study behaviors is the first principal component of standardized reported time spent on homework, reading, and electronics (watching TV and video games).

III Conclusion

Using comprehensive longitudinal data from North Carolina, we document stark and persistent gaps in academic excellence between first-generation and continuing-generation students that emerge no later than 3rd grade and compound throughout their education. These gaps represent a fundamental mechanism of intergenerational inequality that limits social mobility and perpetuates educational stratification. In a knowledge-based economy, K-12 academic excellence provides a gateway to selective colleges, prestigious careers, and economic advancement, rendering these disparities particularly consequential. Systematically excluding first-generation students from this pathway reinforces existing inequalities, undermining education's role as an engine of social mobility.

Our findings have implications for educational policy and practice across multiple dimensions. Overall, while efforts to promote college access and equity are vital, they address symptoms rather than root causes. Our evidence underscores the need for earlier interventions. For instance, since excellence gaps emerge by 3rd grade and persist, policies should target elementary years, including enhanced academic enrichment programs to build cultural and informational capital typically provided by continuing-generation parents. Parent education initiatives to aid first-generation parents in navigating school systems and understanding expectations, combined with early identification of promising students, would also be invaluable. Moreover, the greater effectiveness of some teachers with first-generation students highlights opportunities for targeted professional development. Further research into these teachers' success factors is warranted.

A key takeaway from our work is that addressing educational inequality demands more than elevating average outcomes; it requires ensuring excellence is accessible to all students, irrespective of parental educational backgrounds. Even high-achieving first-generation students struggle to sustain excellence, with persistence rates 15 percentage points lower than their continuing-generation peers. While socioeconomic status and school quality account for some disparities, the majority remain unexplained by observable factors, underscoring the critical, yet often invisible, role of parental human capital.

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Appendix

A Theoretical Model of First-Generation Excellence Gaps

This Appendix provides a formal foundation for our key empirical findings about early emergence, persistence, and variation across schools.

A.1 Basic Setup and Excellence Technology

Consider a family with a child of ability θ where parents choose educational investments I to maximize the child's expected lifetime utility net cost of the investments. The child i's achievement A at some year $t+1$ follows the production function, f:

$$\begin{aligned} A_{i,t+1} &= f(\theta_{i,t}, I_{i,t}, H_{i,t}, S_{i,t}) \\ &= \theta_{i,t} + (1 + \alpha H_{i,t}) \cdot I_{i,t} + \beta S_{i,t} + \varepsilon_{i,t+1} \end{aligned}$$

where $H_{i,t}$ is parental human capital, $S_{i,t}$ represents school quality, and $\varepsilon_{i,t+1}$ captures idiosyncratic shocks.

We parameterize the production function so that parental investment affects achievement, and allow for the value of parental investment to differ by parental human capital parents, based on α. When $\alpha > 0$, parents with more human capital are more productive as they increase their child's A by more for every unit of time spent. Children of highly educated individuals may also have higher θ if it is positively correlated with $H_{i,t}$. Finally, in addition to investing their own time, higher $H_{i,t}$ parents may also choose schools with higher quality, $S_{i,t}$.[17]

We model the likelihood that a student i reaches "excellence", the top decile of the achievement distribution in grade g in a given year t. The probability of reaching excellence is:

$$P(\text{Excellence})_{igt} = P(A_{igt} > A^{\star}_{gt}) \tag{A1}$$

where $A^{\star}$ is the level of achievement across all students that defines the cutoff for reaching excellence.

A.2 Investment Decision

Parents maximize their utility, which is increasing in A, by choosing investment $I_{i,t}$. Investments are costly:

$$\max_{I} \quad E[U(A)] - C(I) \tag{A2}$$

subject to budget constraint $I \leq Y$ where Y is family income. From the parent's first order condition:

$$I^{\star} = \frac{\partial E[U(A)]}{\partial A} \cdot (1 + \alpha H) - C'(I^{*}) \tag{A3}$$

[17] We note that this functional form is linear, and these different inputs may instead be complements (e.g. parental investments may be more important for high θ individuals). We therefore think of this function as a first-order approximation.

A.3 Key Predictions

Proposition 1: Children of college-educated parents ($H_p = 1$) have higher investment efficiency than first-generation students ($H_p = 0$) that is $\alpha > 0$, and lower costs, leading to:

- Higher achievement levels: $A_{\text{continuing}} > A_{\text{first-gen}}$
- Higher probability of excellence: $P(\text{Excellence})_{\text{continuing}} > P(\text{Excellence})_{\text{first-gen}}$

Proposition 2: School quality S can (partially) substitute for parental human capital, implying smaller excellence gaps in higher-quality schools and within-schools than across-schools.
Proposition 3: Excellence gaps should also:

1. Appear early when parental investment differences first manifest
2. Persist as advantages compound over time
3. Be larger for outcomes requiring more strategic navigation (higher α)

A.4 Notes on other factors

Information Capital: We can extend the model to include information ϕ about optimal investment strategies:

$$A_{i,t+1} = \theta_{i,t} + (1 + \alpha H_{i,t} + \gamma\phi) \cdot I_{i,t} + \beta S_{i,t} + \varepsilon_{i,t+1} \tag{A4}$$

Dynamic Investment: In a multi-period model, investment in period t affects achievement and the productivity of future investments, creating cumulative advantages for continuing-generation students.

This simple framework generates the key predictions we test in our empirical analysis and provides economic intuition for why first-generation excellence gaps emerge and persist.

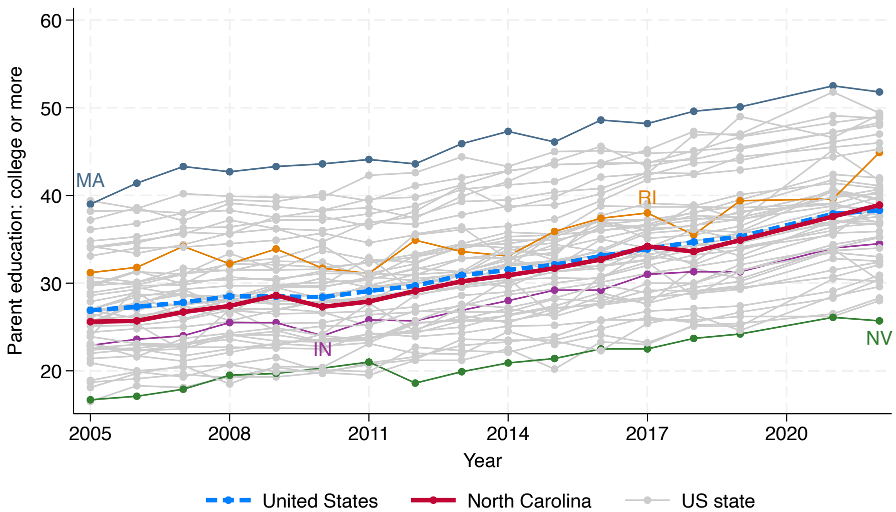
B Summary Statistics

Figure A1a illustrates the percentage of students with parents who have completed college or more, over the last two decades. While in 2005, just above 25% of students in North Carolina had parents who attended at least college, in 2024 that number has increased to 35%. Importantly, the trend in North Carolina parallels that of the average in the United States.

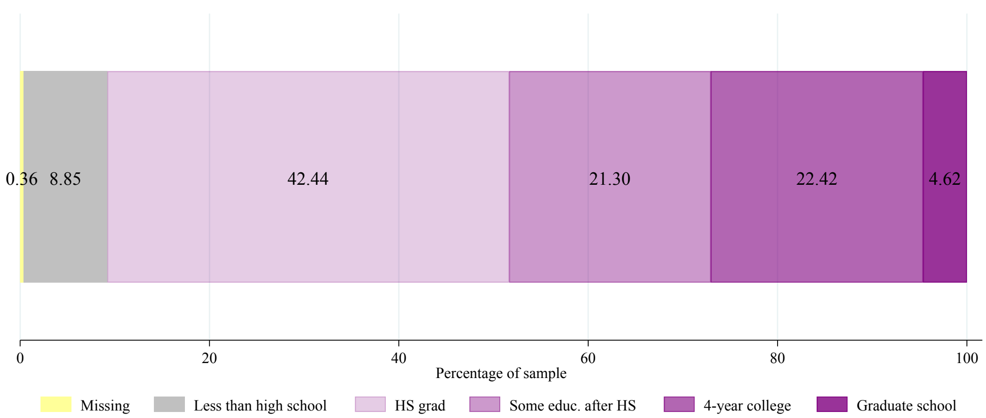
Figure A1b tells the story for our sample of North Carolina students, as described in Section I. Figure A2 further decomposes the share of students in each parental education subgroup by socioeconomic status.

Figure A1: Parental education

(a) College or more



(b) Parental education in North Carolina



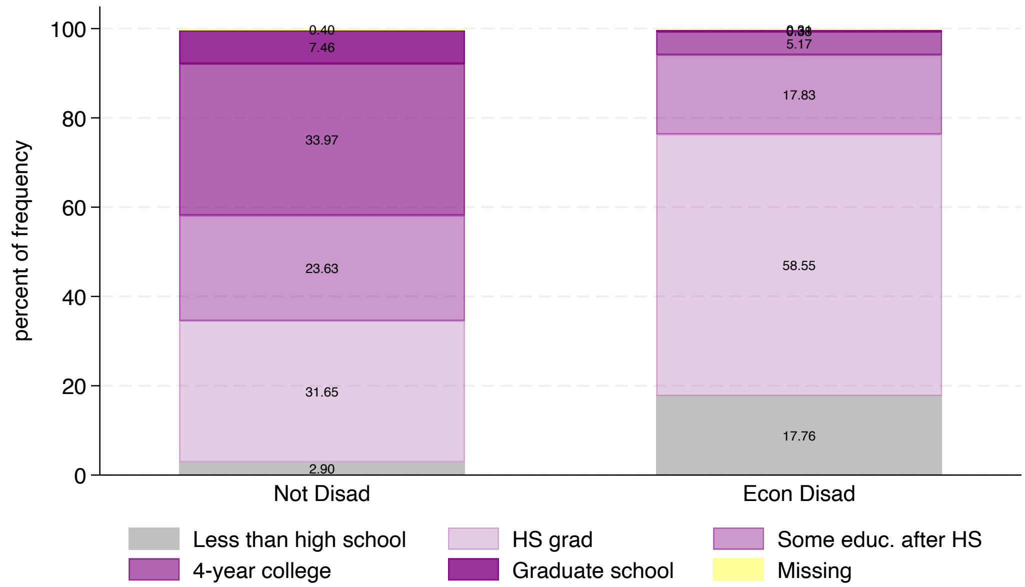
Notes: This figure displays (a) the percentage of students in each U.S. state with continuing-generation parents, and (b) the share of our sample in each parental education level. Data in (a) are from American Community Survey, children under age 18 by the head of household's educational attainment, and data in (b) from NCERDC. Analysis in (b) uses our main sample as described in Section I, which consists of 827,371 students in total: 602,780 with parents having attended less than 4-year college and 224,591 with parents having attended a 4-year college or more.

Table A1: Summary Statistics

	(1) All	(2) SD	(3) First-gen	(4) SD	(5) Continuing-gen	(6) SD
Demographics						
White	0.6293	(0.4830)	0.5613	(0.4962)	0.8120	(0.3910)
Asian	0.0172	(0.1301)	0.0145	(0.1196)	0.0240	(0.1544)
Hispanic	0.0443	(0.2058)	0.0566	(0.2311)	0.0110	(0.1056)
Black	0.2795	(0.4488)	0.3340	(0.4716)	0.1340	(0.3401)
Other	0.0456	(0.2086)	0.0503	(0.2186)	0.0330	(0.1787)
Non-White, Non-Asian	0.3537	(0.4781)	0.4243	(0.4942)	0.1640	(0.3705)
Female	0.5181	(0.4997)	0.5256	(0.4993)	0.4980	(0.5000)
Economically disadvantaged	0.4043	(0.4908)	0.5232	(0.4995)	0.0830	(0.2763)
Academic Achievement						
Math Score (standardized)	-0.001	(1.000)	-0.229	(0.930)	0.611	(0.921)
Reading Score (standardized)	0.000	(1.000)	-0.221	(0.958)	0.591	(0.861)
Took SAT/ACT	0.6790	(0.4669)	0.5991	(0.4901)	0.8630	(0.3442)
Top in SAT/ACT Math (National)	0.0287	(0.1670)	0.0072	(0.0846)	0.0780	(0.2686)
Top in SAT/ACT Reading (National)	0.0295	(0.1693)	0.0124	(0.1106)	0.0740	(0.2618)
Top in SAT/ACT Total (State)	0.1005	(0.3007)	0.0350	(0.1838)	0.2510	(0.4337)
Top in SAT/ACT Math (State)	0.1024	(0.3032)	0.0394	(0.1945)	0.2470	(0.4315)
Top in SAT/ACT Reading (State)	0.1010	(0.3013)	0.0376	(0.1902)	0.2470	(0.4311)
AP Exams						
Took at least one AP exam	0.2847	(0.4513)	0.1761	(0.3809)	0.5330	(0.4989)
Score 5 in at least one AP exam	0.0491	(0.2160)	0.0135	(0.1156)	0.1300	(0.3364)
Took AP english lang. exam	0.1108	(0.3138)	0.0594	(0.2364)	0.2280	(0.4195)
Scored 5 in AP english lang. exam	0.0084	(0.0915)	0.0016	(0.0395)	0.0240	(0.1535)
Took AP english lit. exam	0.0940	(0.2919)	0.0535	(0.2250)	0.1870	(0.3896)
Scored 5 in AP english lit. exam	0.0054	(0.0733)	0.0010	(0.0311)	0.0160	(0.1236)
Took AP psychology exam	0.0885	(0.2840)	0.0426	(0.2019)	0.1930	(0.3948)
Scored 5 in AP psychology exam	0.0148	(0.1208)	0.0031	(0.0553)	0.0420	(0.1997)
Took AP calculus AB exam	0.0664	(0.2490)	0.0385	(0.1924)	0.1300	(0.3364)
Scored 5 in AP calculus AB exam	0.0108	(0.1033)	0.0038	(0.0617)	0.0270	(0.1611)
Took AP calculus BC exam	0.0296	(0.1694)	0.0087	(0.0926)	0.0770	(0.2671)
Scored 5 in AP calculus BC exam	0.0106	(0.1023)	0.0017	(0.0414)	0.0310	(0.1727)
Took AP physics mechanics exam	0.0030	(0.0547)	0.0005	(0.0233)	0.0090	(0.0924)
Scored 5 in AP physics mechanics exam	0.0009	(0.0307)	0.0001	(0.0086)	0.0030	(0.0541)
Took AP physics elec/mag	0.0017	(0.0407)	0.0002	(0.0129)	0.0050	(0.0710)
Scored 5 in AP physics elec/mag exam	0.0005	(0.0214)	0.0000	(0.0044)	0.0010	(0.0382)
Took AP economics	0.0062	(0.0785)	0.0017	(0.0409)	0.0170	(0.1275)
Scored 5 AP economics	0.0006	(0.0250)	0.0001	(0.0088)	0.0020	(0.0433)
N Students	827371		602780		224591	

Notes: This table displays summary statistics for the entire sample of public school students from the state of North Carolina, comprising of students who began 3rd grade within the years 1995 and 2006, excluding those with no parent education data. Math and reading percentiles are calculated from North Carolina's EOG tests. "Top" academic achievement variables for the SAT and ACT indicate the percentage of the sample in the top decile of a given section, pooling those who took the SAT and ACT together by using converted ACT scores. "National" indicates that the percentile cutoffs were determined by College Board at the national level for students of a given graduating year. "State" indicates that the respective SAT percentiles were calculated using the data in the sample. Note that scoring a 5 on an AP calculus exam, or being in the top decile of an SAT or ACT section at the national level is not conditional on taking the exam, i.e., those who did not take the exam did not get a 5 or did not reach the top decile. Statistics on SAT, ACT, and AP outcomes are conditional on data availability.

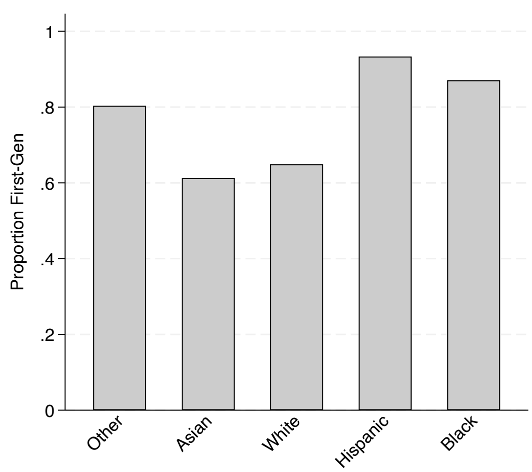
Figure A2: Parent Education Level Shares by SES



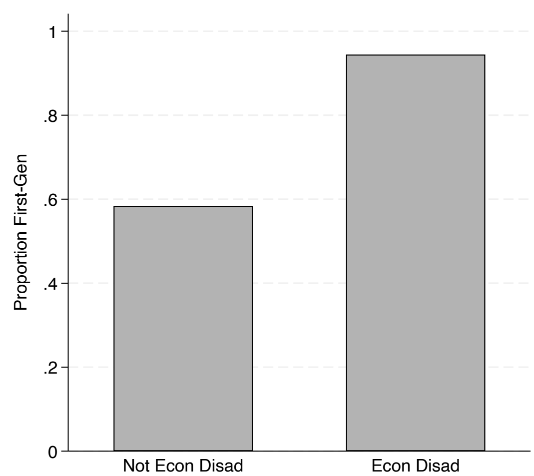
Notes: This figure displays the share of our sample in each parental education level separated by socioeconomic status. Analysis uses our main sample as described in Section I, which consists of 827,371 students in total: 602,780 with parents having attended less than 4-year college and 224,591 with parents having attended a 4-year college or more.

Figure A3: Proportion of first-generation students by income and race subgroups

(a) Race



(b) SES



Notes: These figures display the proportion of first-generation students by (a) race and (b) socioeconomic status. Analysis uses our main sample as described in Section I, which consists of 827,371 students in total: 602,780 with parents having attended less than 4-year college and 224,591 with parents having attended a 4-year college or more.

Table A2: OLS Estimates (First-gen on Race and SES)

	β	95% C.I.
White	0.00	0.00,0.00
Asian	-0.10	-0.11,-0.09
Black	0.06	0.05,0.06
Hispanic	0.09	0.09,0.09
Other	0.04	0.03,0.04
Economically disadvantaged	0.33	0.33,0.33
Constant	0.58	0.57,0.58
Observations	820214	

Notes: This table displays OLS regression estimates of first-generation status on race and SES group. 95% confidence intervals in parentheses.

Table A3: Summary statistics: fraction categorized as excellent

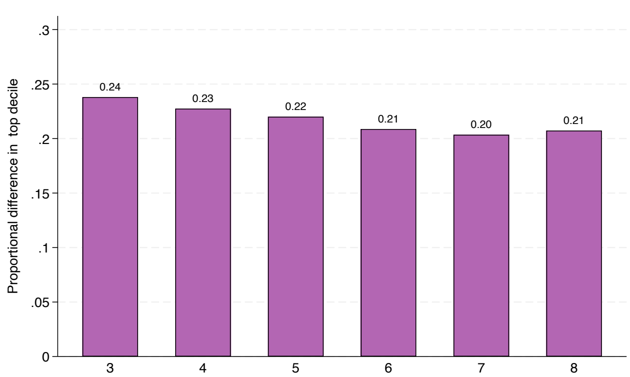
	Grade					
	3	4	5	6	7	8
Math	9.80	9.70	10.29	10.26	9.80	10.21
Reading	10.00	9.55	9.36	10.17	10.45	9.61

Notes: This table displays summary statistics for the fraction of students who are categorized as being excellent, by subject and grade. The fractions are not exactly 10 because of ties in scores.

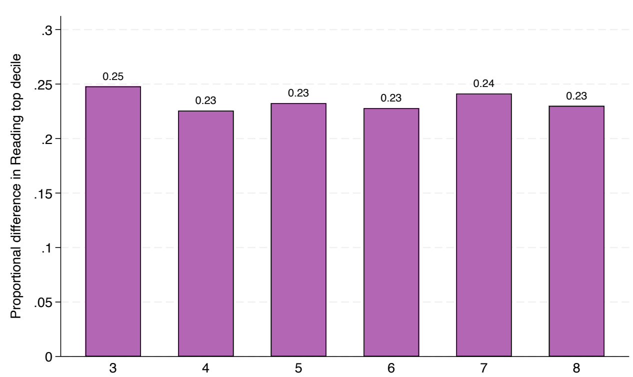
C Proportional Differences

Figure A4: Proportional differences in top achievement by grade

(a) Math



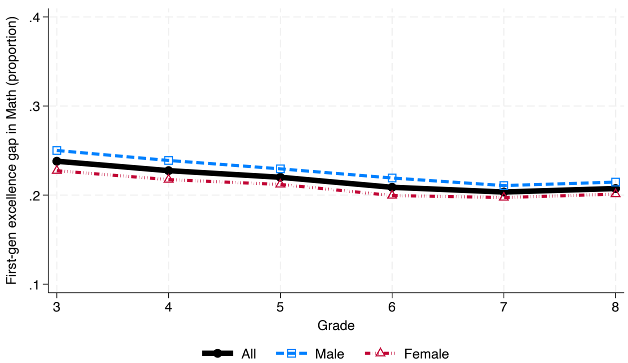
(b) Reading



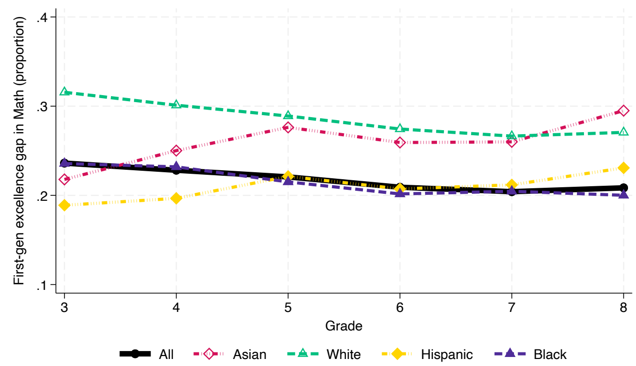
Notes: This figure displays proportional differences in top achievement, i.e., $\frac{\text{P(top decile | first-gen)}}{\text{P(top decile | continuing-gen)}}$, for (a) math, and (b) reading. Excellence is defined as reaching the top decile on the EOG math or reading test. Due to ties in test scores, we do not always have a threshold score that defines exactly the top 10%. Analysis uses our main sample as described in Section I, which consists of 827,371 students in total: 602,780 with parents having attended less than 4-year college and 224,591 with parents having attended a 4-year college or more.

Figure A5: Proportional differences in top achievement by subgroup

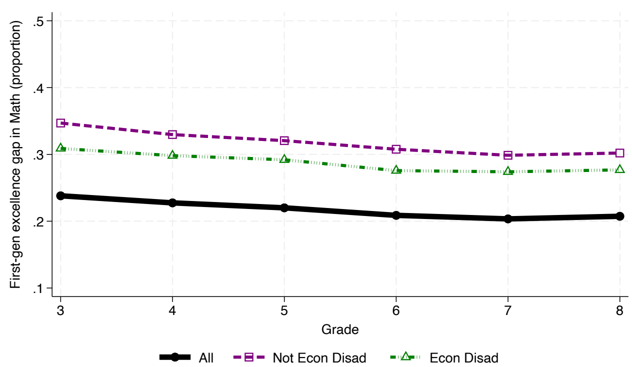
(a) Excellence gaps by gender



(b) Excellence gaps by race



(c) Excellence gaps by SES

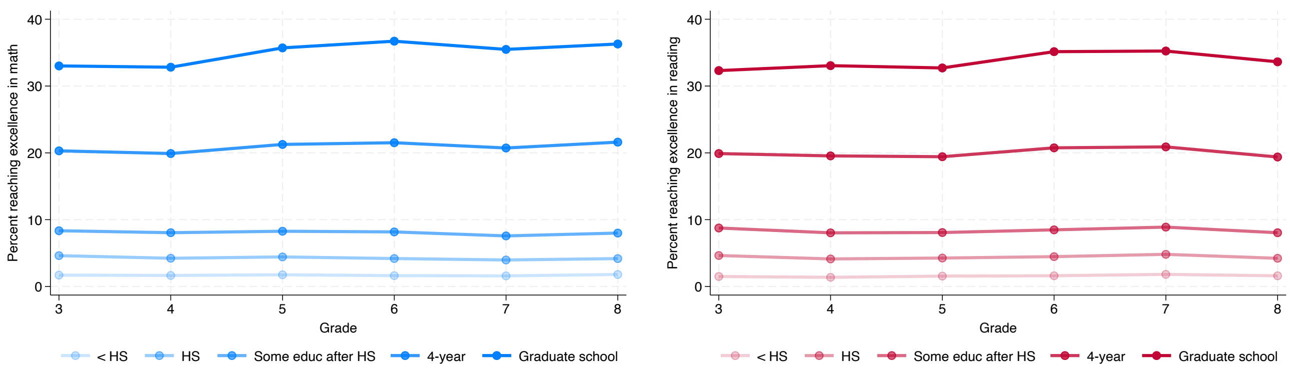


Notes: This figure displays proportional differences in top achievement, i.e., $\frac{\text{P(top decile} \mid \text{first-gen)}}{\text{P(top decile} \mid \text{continuing-gen)}}$, for by (a) gender, (b), race, and (c) socioeconomic status subgroups. Excellence is defined as reaching the top decile on the EOG math or reading test. Due to ties in test scores, we do not always have a threshold score that defines exactly the top 10%. Analysis uses our main sample as described in Section I, which consists of 827,371 students in total: 602,780 with parents having attended less than 4-year college and 224,591 with parents having attended a 4-year college or more.

D Finer Bins of Parental Education

Figure A6: Excellence gap in grades 3-8, by finer parental education bins

(a) First-gen difference in reaching top decile in math (b) First-gen difference in reaching top decile in reading



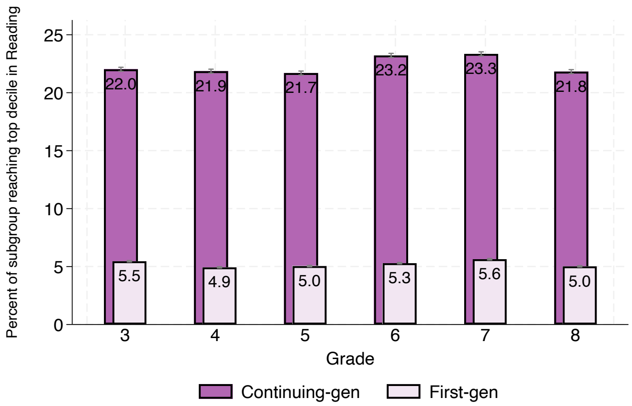
Notes: These figures display the first-generation excellence gap in (a) math and (b) reading, by grade and parent education level. Analysis uses our main sample as described in Section I, which consists of 827,371 students in total: 602,780 with parents having attended less than 4-year college and 224,591 with parents having attended a 4-year college or more.

E Excellence Gap in Reading

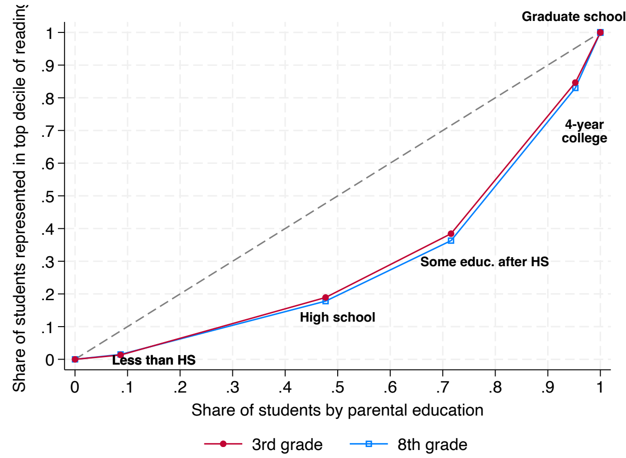
Shifting our focus to excellence in reading, we measure a first-generation disparity of about 16 percentage points in 3rd grade which remains largely steady through 8th grade. We observe similar patterns in the representation in the top decile and the excellence gaps by race in reading, as we observed for math. Interestingly, we find a that the first-generation excellence gap for females in reading is larger than that of males, while we find the opposite in math.

Figure A7: First-generation disparities in reaching the top decile in reading

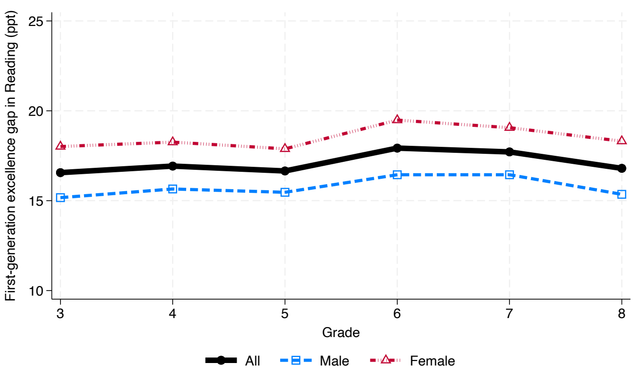
(a) Levels of reaching excellence



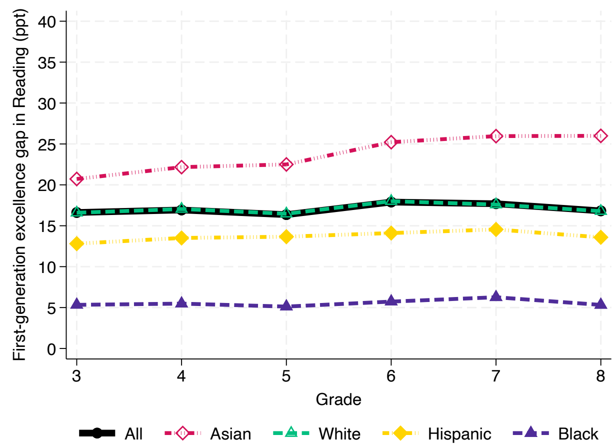
(b) Representation in the top decile of reading



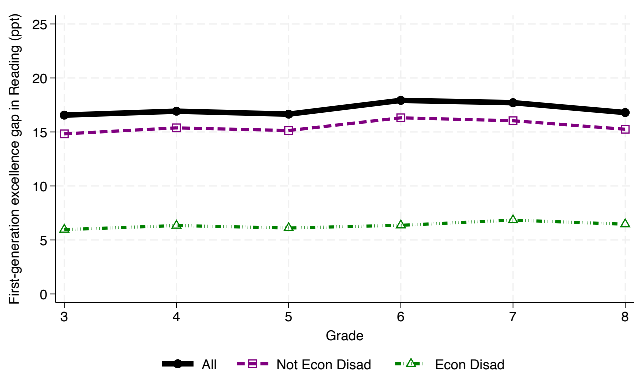
(c) Excellence gaps by gender



(d) Excellence gaps by race



(e) Excellence gaps by SES

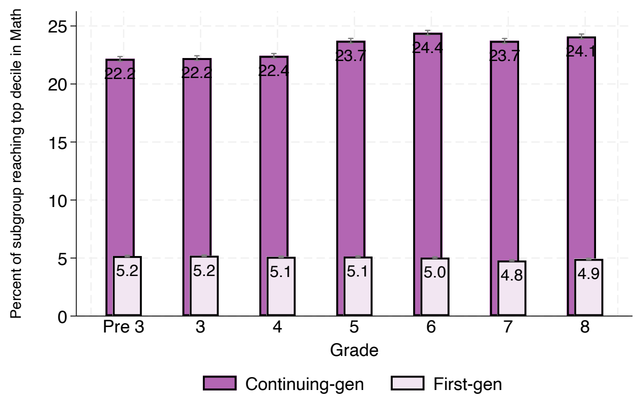


Notes: These figures display (a) the first-generation excellence gap in reading in grades 3 through 8, (b) the Lorenz curve of the share of students in the top decile of reading achievement that is cumulatively represented by each parent education subgroup in the population, (c) the first-generation excellence gap in reading by gender in grades 3 through 8, (d) the first-generation excellence gap in reading by race-ethnicity group in grades 3 through 8, and (e) the first-generation excellence gap in reading by socioeconomic status in grades 3 through 8. Excellence is defined as reaching the top decile on the End-Of-Grade test within grade-year. Analysis uses our main sample as described in Section I, which consists of 827,371 students in total: 602,780 with parents having attended less than 4-year college and 224,591 with parents having attended a 4-year college or more.

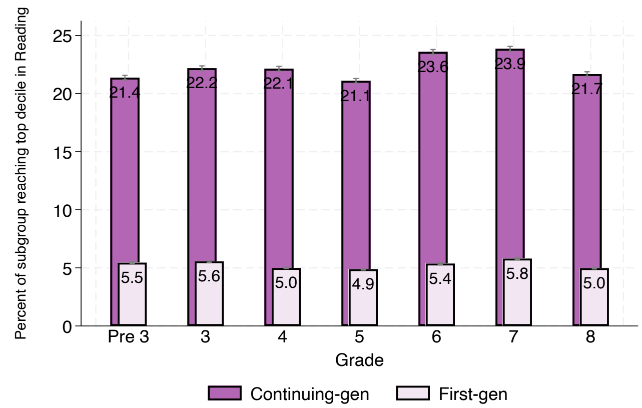
F Beginning of 3rd Grade Tests

Figure A8: First-generation disparities in reaching the top decile - including pre-3rd grade tests

(a) Levels of reaching excellence - Math



(b) Levels of reaching excellence - Reading

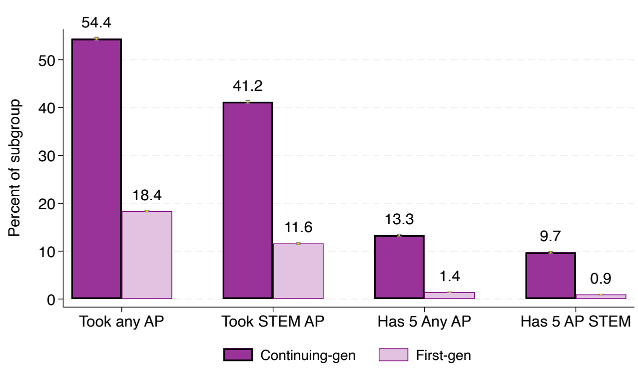


Notes: These figures display (a) the first-generation excellence gap from the beginning of 3rd grade (Pre 3) through 8th grade, in (a) math and (b) reading. Excellence is defined as reaching the top decile on the EOG math or reading test. Due to ties in test scores, we do not always have a threshold score that defines exactly the top 10%. Analysis uses a subset of the main dataset described in Section I, which consists cohorts beginning 3rd grade between 1997 and 2005 with nonmissing beginning-of-3rd grade test scores.

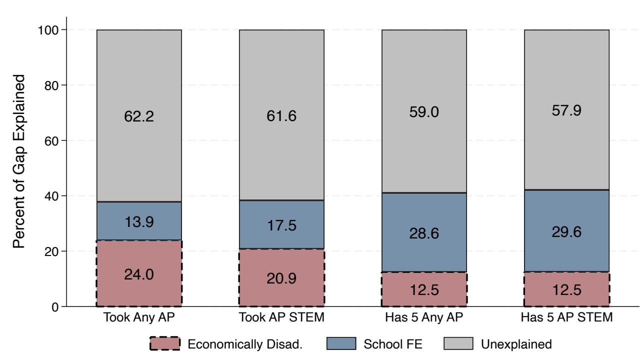
G Excellence in Advanced Placement Exams

Figure A9: First-generation disparities in reaching the top decile in AP exams - conditional on course offering

(a) Differences in Advanced Placement exams



(b) Levels of reaching excellence - Reading

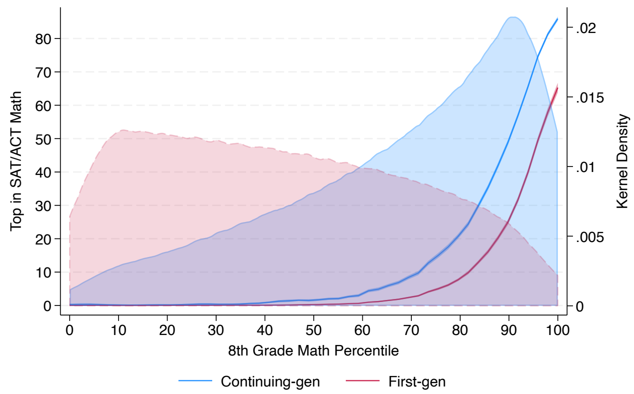


Notes: These figures display (a) the first-generation excellence gap in taking at least one AP exam, at least one STEM AP exam, achieving a 5 on at least one AP exam, and achieving a 5 on at least one STEM AP exam, and (b) the Gelbach decompositions of the difference between first-generation and continuing-generation students taking advanced placement exams and scoring a 5 on an advanced placement exam, both conditional on whether or not the school offered the respective AP course. Ticks in Figure (a) correspond to 95% confidence intervals. Due to ties in test scores, we do not always have a threshold score that defines exactly the top 10%. Analysis uses a subset of the main dataset described in Section I, which consists of cohorts beginning 3rd grade between 2001 and 2006 for whom we observe AP outcomes through high school.

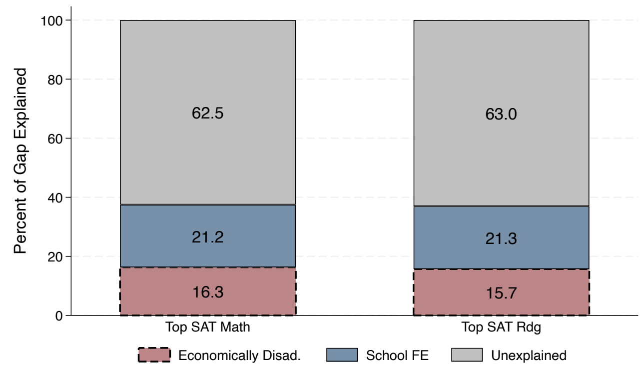
H Excellence in SAT Exams

Figure A10: First-generation disparities in reaching the top decile in SAT exams among only SAT takers

(a) Top SAT Math by 8th grade rank



(b) Explaining the first-gen gap in SAT Math



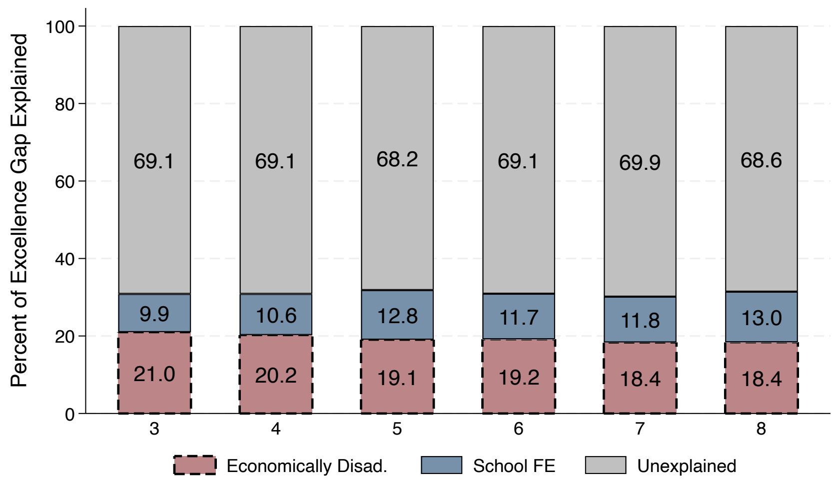
Notes: These figures display (a) the proportion of students who reach the top decile of SAT math by 8th grade achievement and the distribution of 8th grade achievement, and (b) the Gelbach decompositions of the difference between first-generation and continuing-generation students in reaching excellence in the SAT. Analysis uses a subset of the main dataset described in Section I, which consists of cohorts beginning 3rd grade between 2000 and 2004 for whom we neither the SAT nor ACT were required in high school.

I Heterogeneity

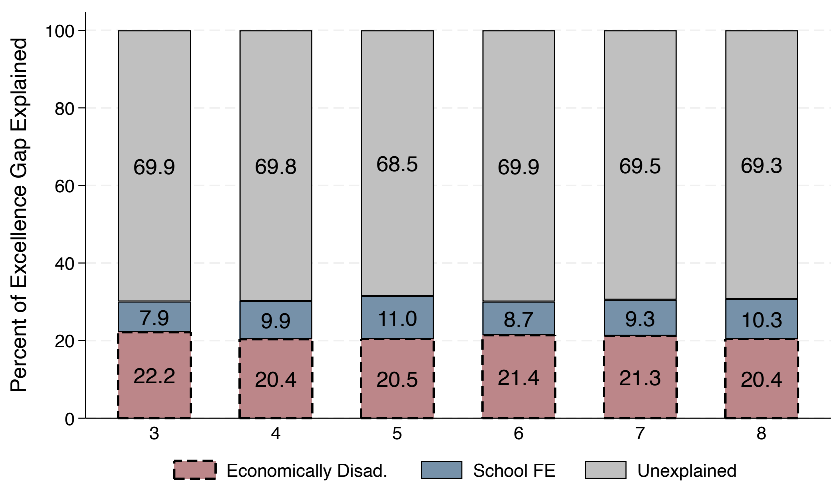
I.1 By Grade

Figure A11: Explaining first-gen differences in reaching excellence, by grade

(a) Gelbach decomposition - Math



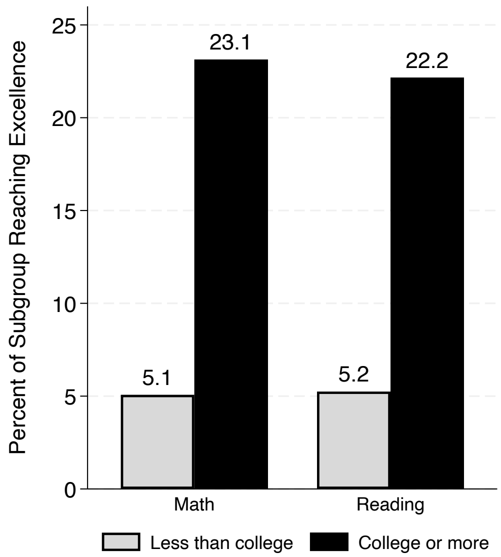
(b) Gelbach decomposition - Reading



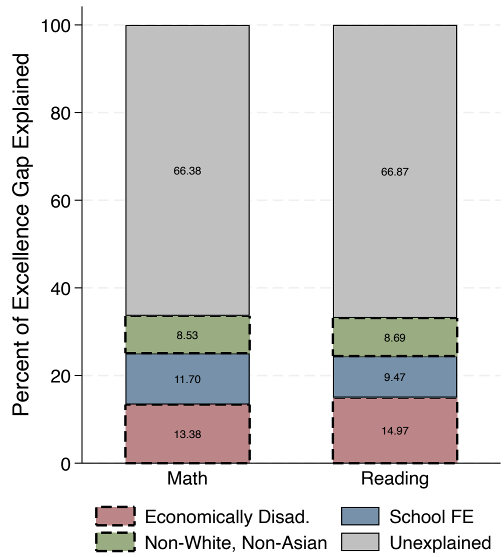
Notes: This figure displays the Gelbach decomposition of each first-generation difference for each grade 3-8, for (a) math and (b) reading. Excellence is defined as reaching the top decile on the EOG math or reading test. Due to ties in test scores, we do not always have a threshold score that defines exactly the top 10%. This approach is of particular value when our observables are correlated; for example, school fixed effects are likely endogenous to our measure of economically disadvantaged such that the difference in the point estimates of the excellence gap with and without controlling for the school fixed effects is likely also capturing differences in economic status. We therefore estimate the unconditional size of the excellence gap and compare the magnitude to estimates that additionally control socioeconomic status and school fixed effects. This figure uses the number of times that a student is observed as being economically disadvantaged, conditional on the number of times that this information is available. Analysis uses our main sample as described in Section I, which consists of 827,371 students in total: 602,780 with parents having attended less than 4-year college and 224,591 with parents having attended a 4-year college or more.

I.2 By Race and Gender

Figure A12: Explaining first-gen differences in reaching excellence during grades 3-8, including race



(a) Baseline gap



(b) Gelbach decomposition

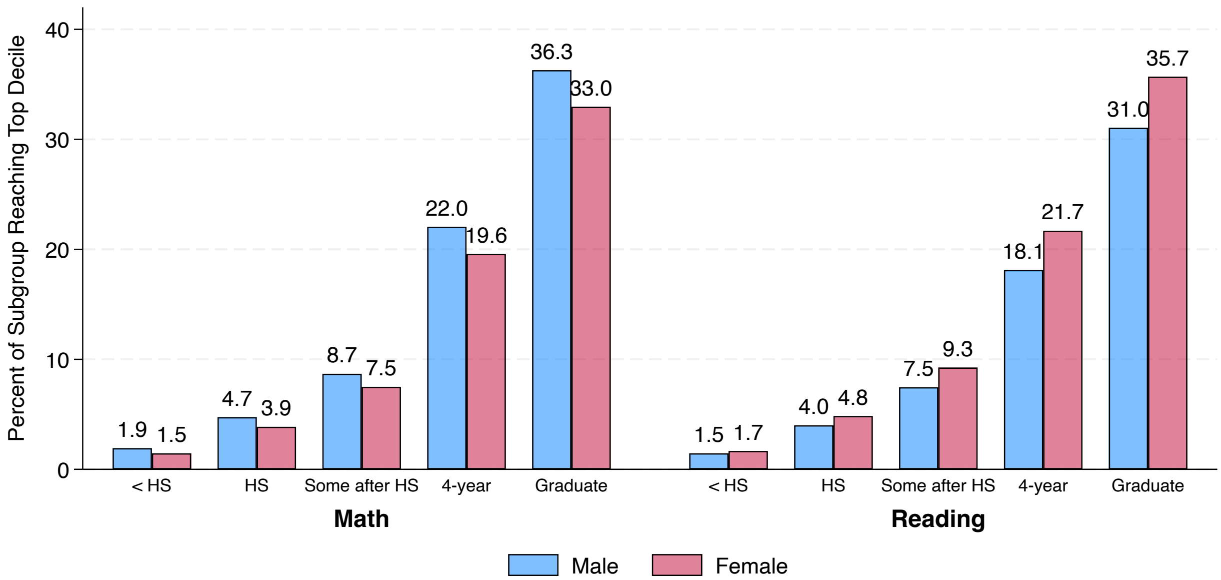
Notes: This figure displays (a) the percentage of each parent education group that takes reaches excellence in math or reading, and (b) the Gelbach decomposition of each first-generation difference. Excellence is defined as reaching the top decile on the EOG math or reading test. Due to ties in test scores, we do not always have a threshold score that defines exactly the top 10%. This approach is of particular value when our observables are correlated; for example, school fixed effects are likely endogenous to our measure of economically disadvantaged such that the difference in the point estimates of the excellence gap with and without controlling for the school fixed effects is likely also capturing differences in economic status. We therefore estimate the unconditional size of the excellence gap and compare the magnitude to estimates that additionally control socioeconomic status and school fixed effects. This figure uses the number of times that a student is observed as being economically disadvantaged, conditional on the number of times that this information is available. Analysis uses our main sample as described in Section I, which consists of 827,371 students in total: 602,780 with parents having attended less than 4-year college and 224,591 with parents having attended a 4-year college or more.

We bring our analysis to the intersection of gender and first-generation excellence gaps. This section illustrates the fact that gender disparities remain regardless of parental education level.

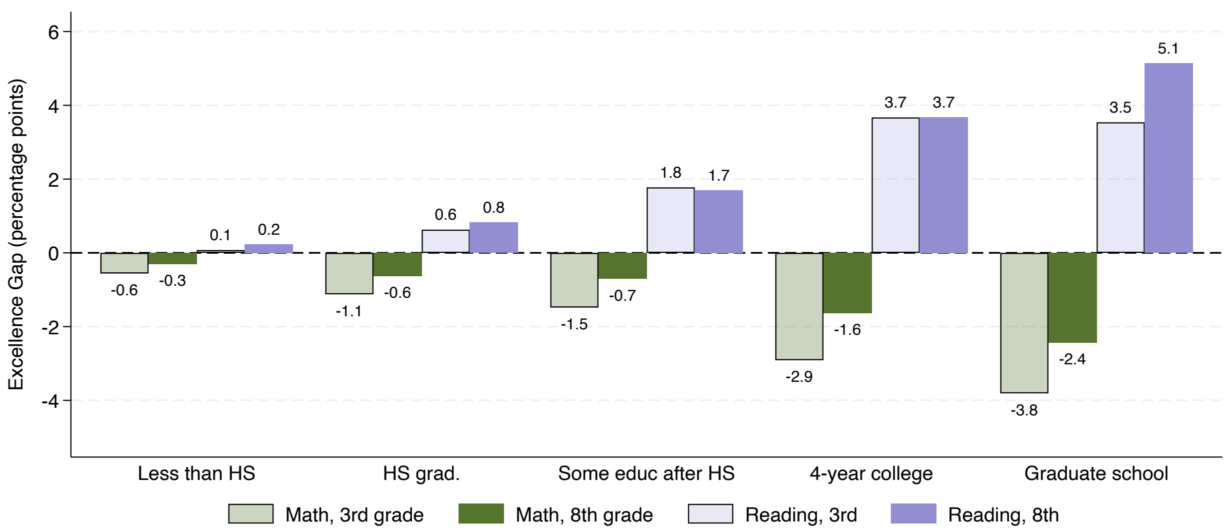
First, Figure A13a highlights that regardless of gender, parental education serves as a strong predictor of whether a student reaches academic excellence. Second, the gender excellence gap persists across the distribution of parental education: at each level of parent education, girls are less likely to reach excellence in math and more likely to reach excellence in reading than boys. In Figure A13b, we find that the reduction in the math excellence gap from 3rd to 8th grade arises across the distribution of parental education. This pattern is strongest among the highest educated parents. Among students whose parents have a college degree, the math excellence gap decreases by over 60%. Among students whose parents do not have a college degree, the gap decreases by 40-50%.

Figure A13: Gender Differences in Excellence by Parental Education

(a) Likelihood of Reaching Excellence

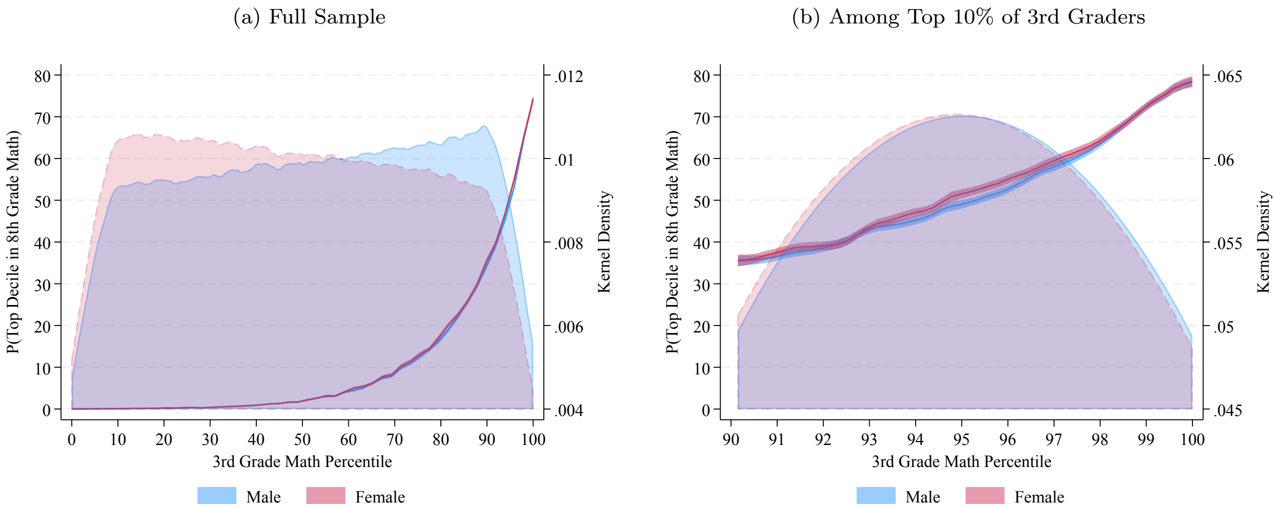


(b) Excellence Gap



Notes: These figures display (a) the likelihood that a male or female student reaches excellence conditional on parent education level and (b) the magnitude of the excellence gap from grades 3 to 8, conditional on parent education level. Positive values are in favor of girls and negative values are in favor of boys. Excellence is defined as reaching the top decile on the EOG math or reading test. Due to ties in test scores, we do not always have a threshold score that defines exactly the top 10%. Analysis uses our main sample as described in Section I, which consists of 827,371 students in total: 602,780 with parents having attended less than 4-year college and 224,591 with parents having attended a 4-year college or more.

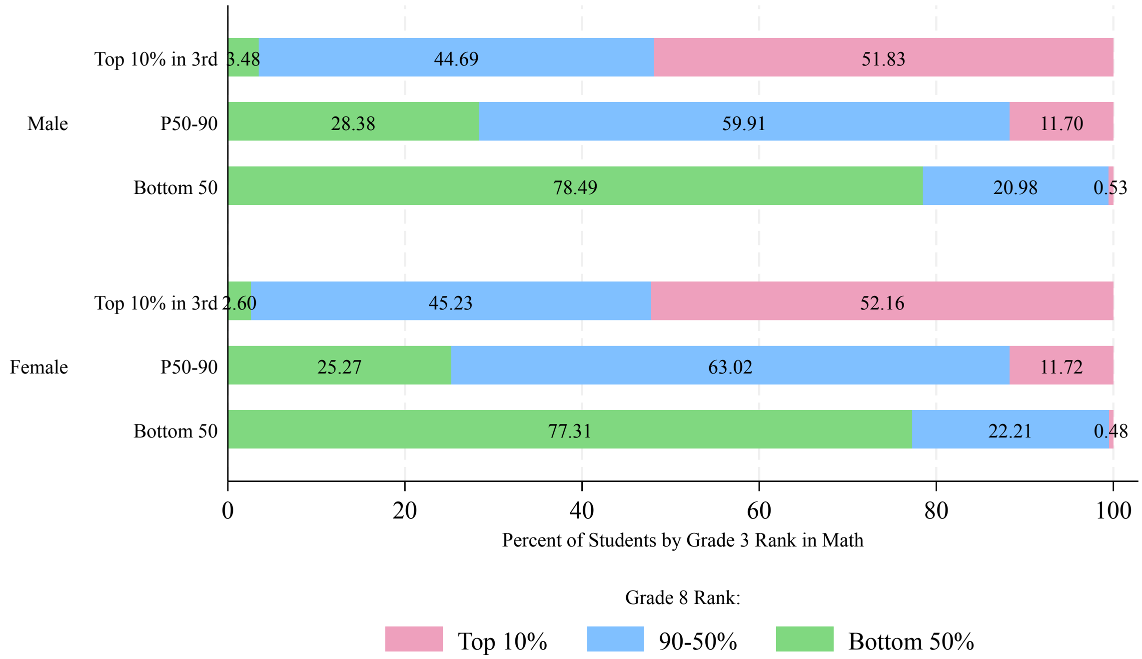
Figure A14: 8th Grade Excellence by 3rd Grade Rank



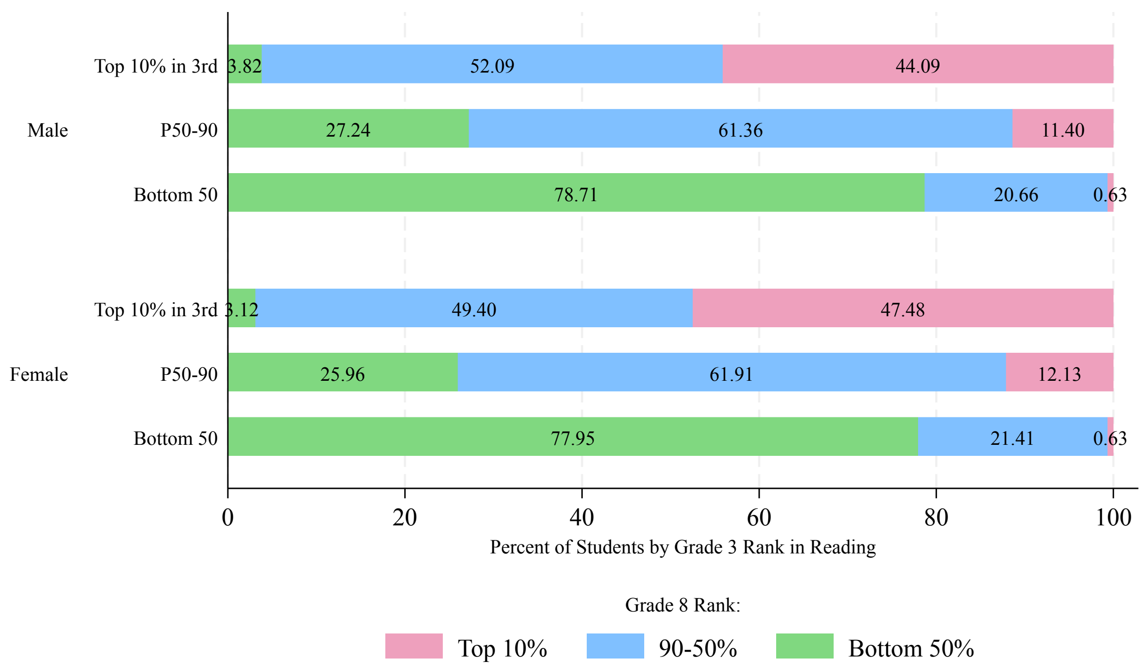
Notes: These figures show the proportion of each gender group that reach the top decile of 8th grade achievement at each level of 3rd grade achievement, and the distribution of 3rd grade achievement. Figure (a) shows for each 3rd grade decile group, while (b) shows for each percentile in the top 10 percent. Line widths correspond to 95% confidence intervals. Shaded areas around lines correspond to the 95% confidence intervals. Shaded areas reflect the density of students at each achievement level. Excellence is defined as reaching the top decile on the EOG math or reading test. Due to ties in test scores, we do not always have a threshold score that defines exactly the top 10%. Analysis uses our main sample as described in Section I, which consists of 827,371 students in total: 602,780 with parents having attended less than 4-year college and 224,591 with parents having attended a 4-year college or more.

Figure A15: Transitions between excellence in 3rd and 8th grade

(a) Math

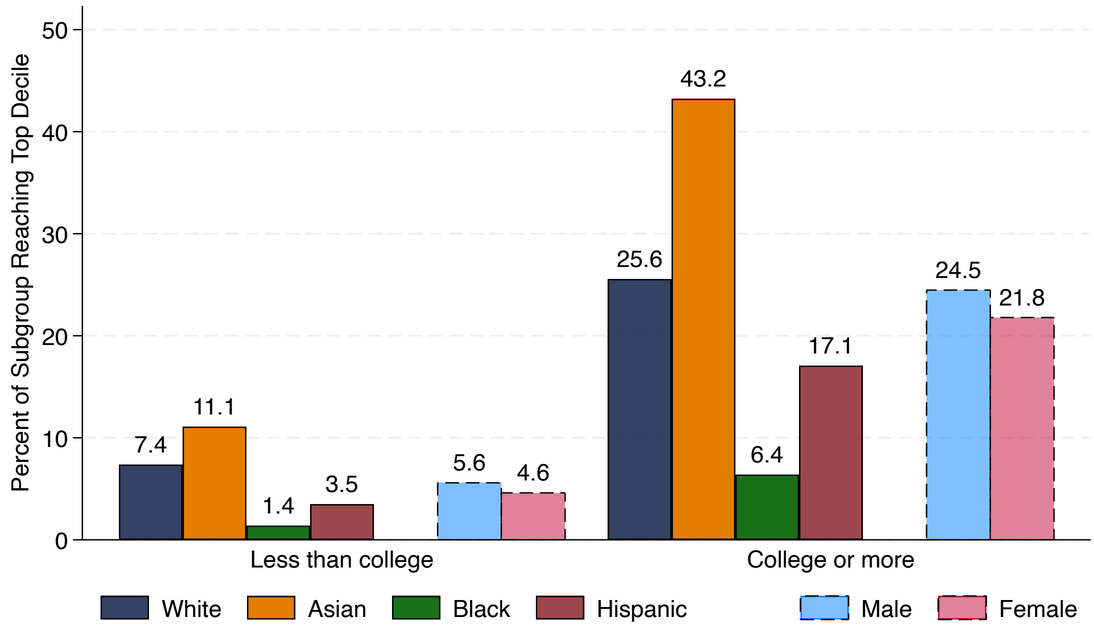


(b) Reading

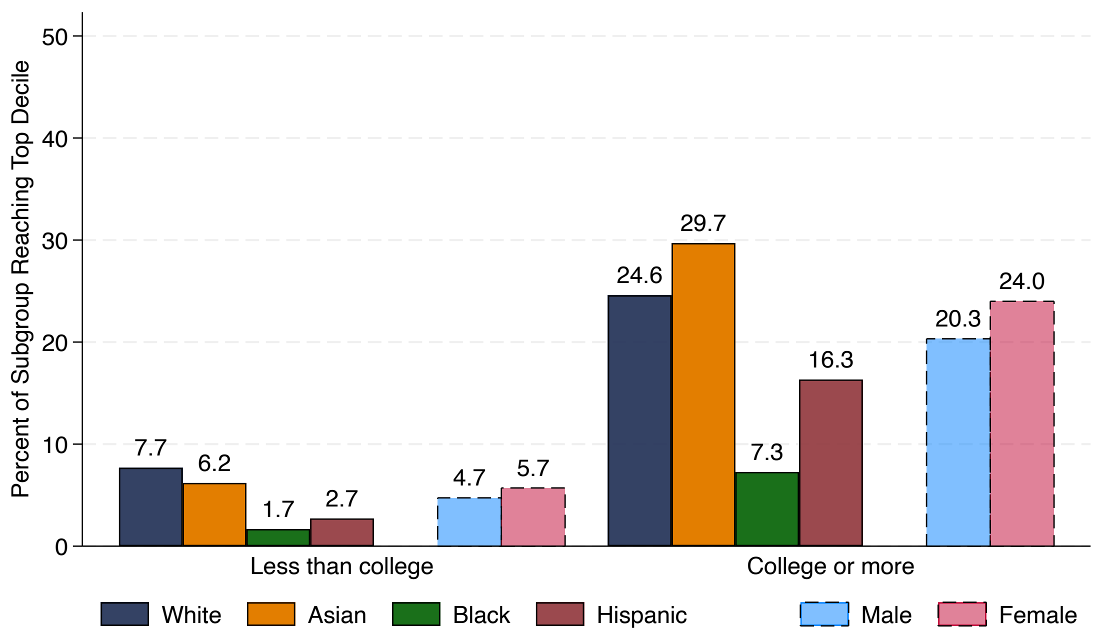


Notes: These figures split the distribution of achievement into bottom 50%, 50%-90%, and top 10% for 3rd grade and 8th grade, and show the probability of being in each achievement group in 8th grade given the achievement group in 3rd grade for (a) math and (b) reading. Excellence is defined as reaching the top decile on the EOG math or reading test. Due to ties in test scores, we do not always have a threshold score that defines exactly the percentile cutoffs. Analysis uses our main sample as described in Section I, which consists of 827,371 students in total: 602,780 with parents having attended less than 4-year college and 224,591 with parents having attended a 4-year college or more.

Figure A16: First-generation excellence gaps in grades 3-8, by gender and race subgroup



(a) Math

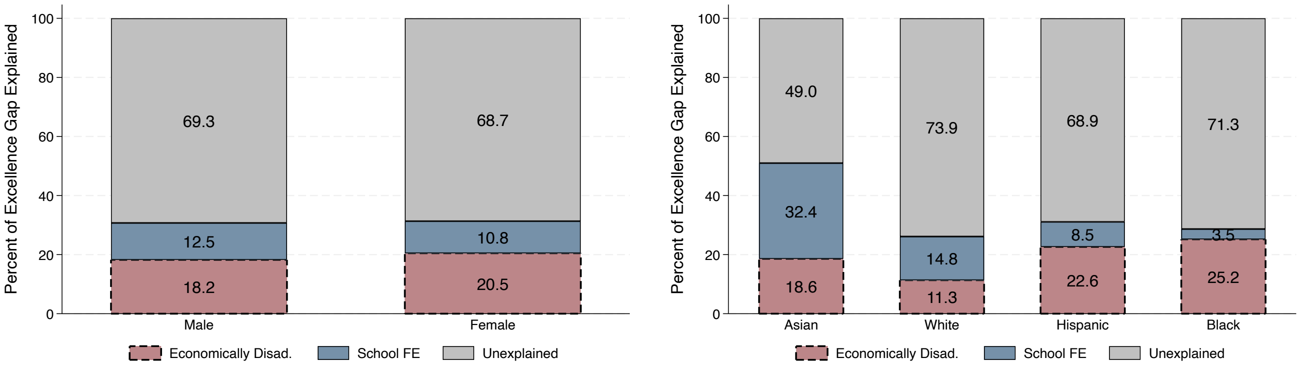


(b) Reading

Notes: These figures display (a) the percentage of each race and gender subgroup reaching the top decile in math conditional on first-generation status, and (b) the same for reading. Excellence is defined as reaching the top decile on the EOG math or reading test. Due to ties in test scores, we do not always have a threshold score that defines exactly the top 10%. Analysis uses our main sample as described in Section I, which consists of 827,371 students in total: 602,780 with parents having attended less than 4-year college and 224,591 with parents having attended a 4-year college or more.

Figure A17: Drivers of the first-generation excellence gap in each race and gender subgroup

(a) Gelbach decomposition by gender
(b) Gelbach decomposition by race



Notes: These figures display (a) the Gelbach decomposition of each gap by gender, and (b) the Gelbach decomposition of each gap by race. Excellence is defined as reaching the top decile on the EOG test. Analysis uses our main sample as described in Section I, which consists of 827,371 students in total: 602,780 with parents having attended less than 4-year college and 224,591 with parents having attended a 4-year college or more.

I.3 Dynamics

Figure A18: First-Generation Differences in Entry and Persistence of Excellence, by race and gender

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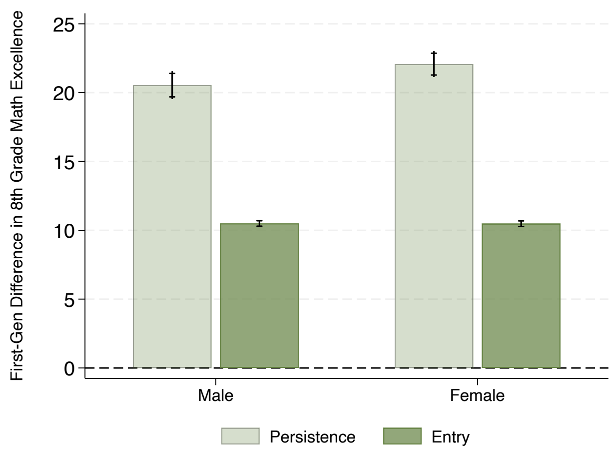
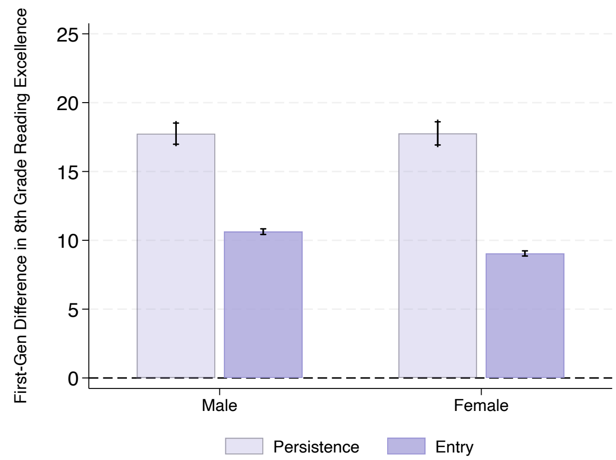
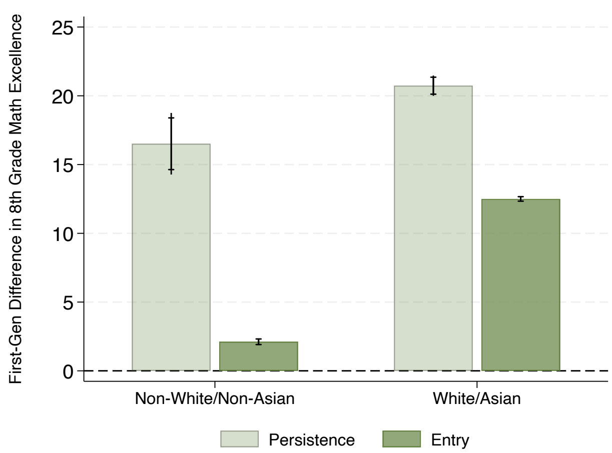
(a) Math



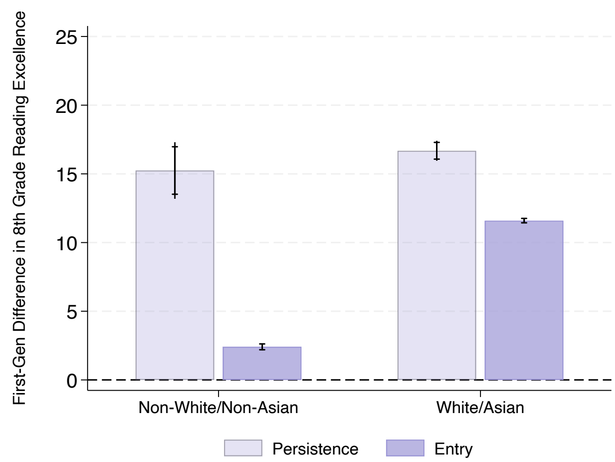
(b) Reading



(c) Math



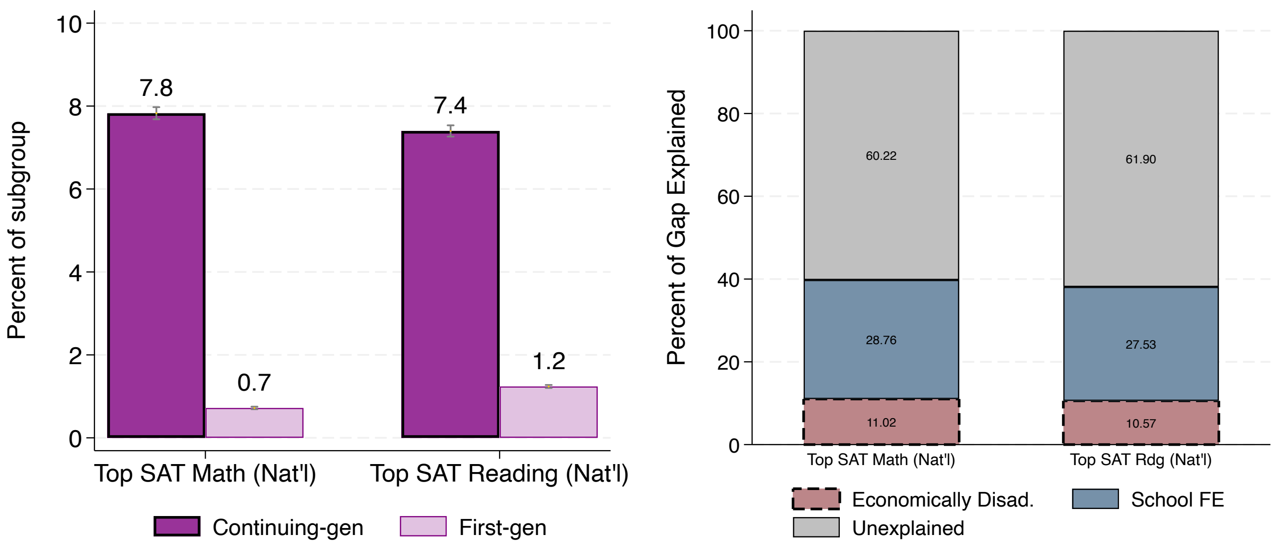
(d) Reading



Note: These figures display (a) the first-generation excellence gap in math, and (b) reading conditional on being excellent in 3rd grade ("Persistence") and not excellent in 3rd grade ("Entry"), given the student is male or female. Figures (c) and (d) show the same, respectively, given the student is either non-White/non-Asian or White/Asian. Positive values are in favor of continuing-generation students. Excellence is defined as reaching the top decile on the EOG math or reading test. Due to ties in test scores, we do not always have a threshold score that defines exactly the top 10%. Analysis uses our main sample as described in Section I, which consists of 827,371 students in total: 602,780 with parents having attended less than 4-year college and 224,591 with parents having attended a 4-year college or more.

J SAT - National Level

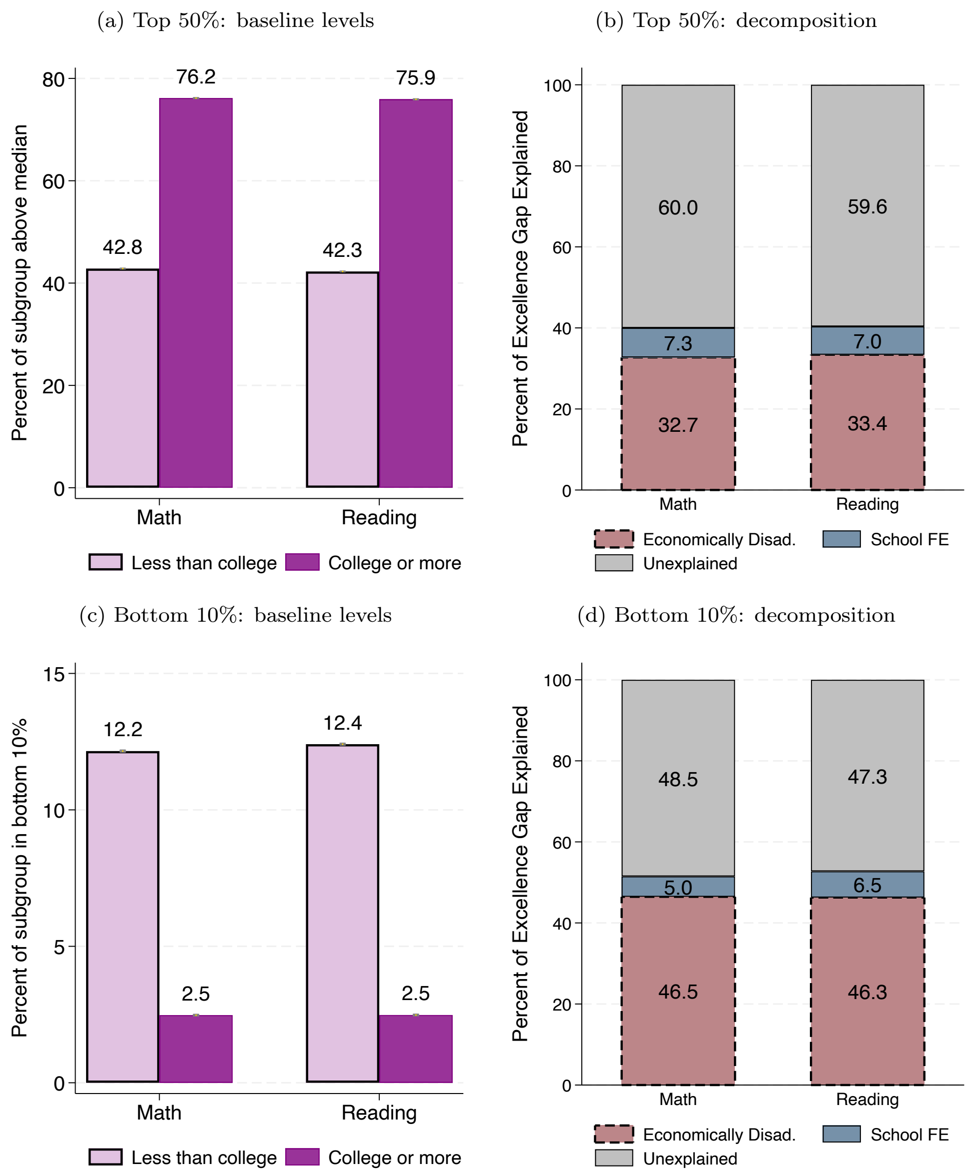
Figure A19: Explaining first-gen differences in college readiness (SAT National Level)



Notes: This figure displays (a) the percentage of each parent education group that reaches the top decile (at the state level) of SAT math and reading, and (b) the Gelbach decomposition of each first-generation difference. Note ACT scores were converted to equivalent SAT scores for a given year, and then within-state percentile cutoffs (i.e. top decile) were determined. Thus ACT test-takers are included in these figures. Analysis uses a subset of the main dataset described in Section I, which consists of cohorts beginning 3rd grade between 2000 and 2006 for whom we observe SAT and ACT outcomes through high school.

K Achievement at other points of the distribution

Figure A20: Gaps in achievement at the median and bottom 10%



Notes: These figures display the percentage of first-generation and continuing-generation groups that reach the (a) top 50 percentile and (c) bottom 10 percent on the EOG math and reading tests, and (b,d) the Gelbach decomposition of each first-generation and continuing-generation difference. These measures average over students in grades 3 through 8. Analysis uses our main sample as described in Section I, which consists of 827,371 students in total: 602,780 with parents having attended less than 4-year college and 224,591 with parents having attended a 4-year college or more.

L Excellence Gap Across Schools

In the main text, we show empirical measures for school-specific estimates of the excellence gap. Given our use of comprehensive administrative data, these estimates face minimal sampling error for the given schools and years of interest. We find that there is a high correlation in the estimated school-level excellence gap across years, particularly for math (Figure A22).

Another set of parameters of potential interest that we can estimate are school-specific latent excellence gaps, where we view a school's yearly excellence gaps as "noisy" estimates of its latent disparity parameter. Let θ_s represent the latent parameter for to school s. Figure 3d reports the standard deviation of $\hat{\theta}_s$, which describes the spread of the realized school-level excellence gaps. We may additionally ask, however, what the variation of the school-specific latent excellence gap, θ_s, is. The standard deviation of $\hat{\theta}_s$ is an over-estimate of the standard deviation of θ_s due to variability in the student sample observed across years. As Kline et al. (2022) show, the variance for this parameter can be estimated using a bias-corrected estimator that adjusts the empirical variance estimate (in our case, the variance of $\hat{\theta}_s$) using the standard error of the estimate (in our case, the standard error of $\hat{\theta}_s$). Following the steps of Kline et al. (2022), we use the estimator:

$$\hat{\sigma}^2_\theta = \left(\frac{S-1}{S}\right)\left[\frac{1}{S-1}\sum_{s=1}^{S}(\hat{\theta}_f - \bar{\theta})^2 - \frac{1}{S}\sum_{s=1}^{S} e_s^2\right] \tag{A5}$$

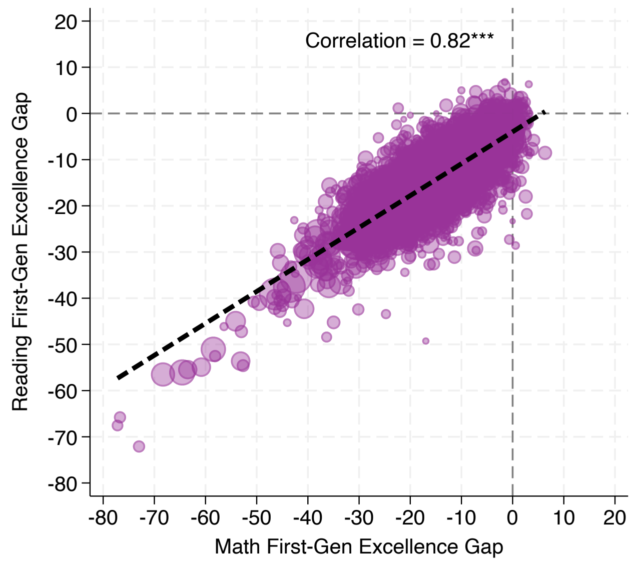
where the first component in the bracket corresponds to the variance in $\hat{\theta}_s$ that we report in Figure 3d, and the second one represents the bias-correction. Table A4 summarizes the standard deviations (the second row takes the square root of the estimate $\hat{\sigma}^2_\theta$). We find that with respect to the distribution of school-level latent excellence gaps, a school with a one standard deviation larger latent excellence gap corresponds to an increase in around a 7.25 (6.09) percentage points in math (reading).

Table A4: Across-school variation in excellence gaps

	Math	Reading
$\hat{\theta}_s$	7.67	6.65
θ_s	7.25	6.09

Notes: This table shows the estimated standard deviations in the distribution of across-school excellence gaps in math and reading. The first row shows the standard deviations of excellence gaps that are observed in the data, $\hat{\theta}_s$, as illustrated in Figure 3d. The second row shows the standard deviation of a school's latent excellence gap, θ_s. The latter standard deviation is estimated by following the bias-correction steps of Kline et al. (2022) and as described in Section L. Excellence is defined as reaching the top decile on the EOG math or reading test. Due to ties in test scores, we do not always have a threshold score that defines exactly the top 10%.

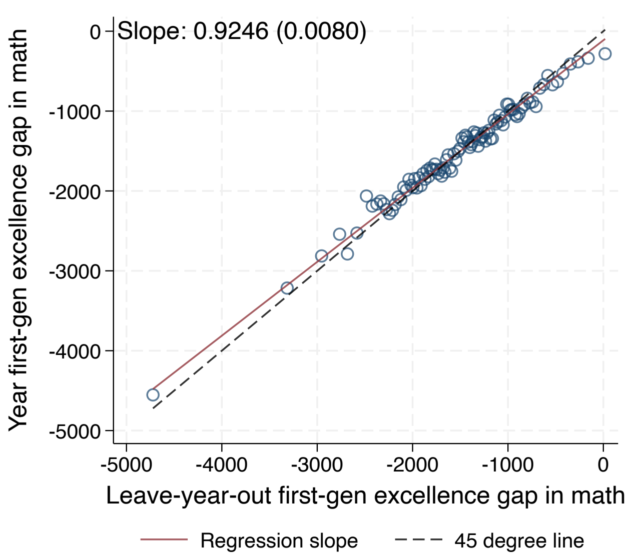
Figure A21: Joint Distribution of School-level Excellence Gaps



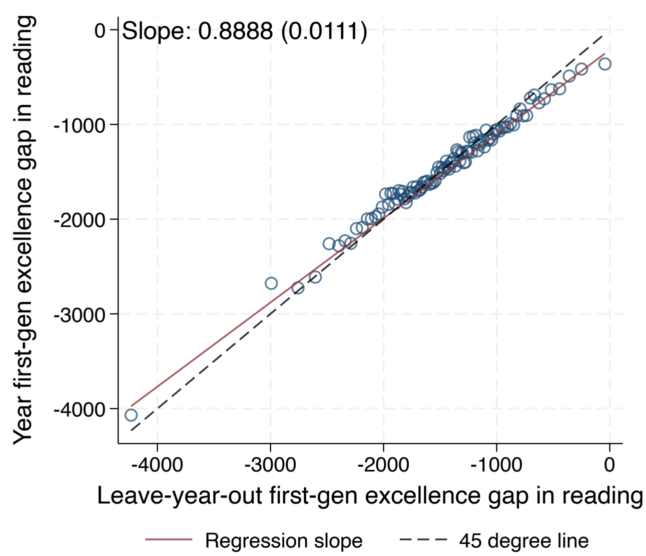
Notes: This figure displays the distribution of excellence gaps. A unit of observation is a school. These measures pool students across years. The linear fit in panel (b) weights schools by the number of students who take a standardized exam in the school. Analysis uses our main sample as described in Section I.

Figure A22: Temporal stability of observed school excellence gaps

(a) Math

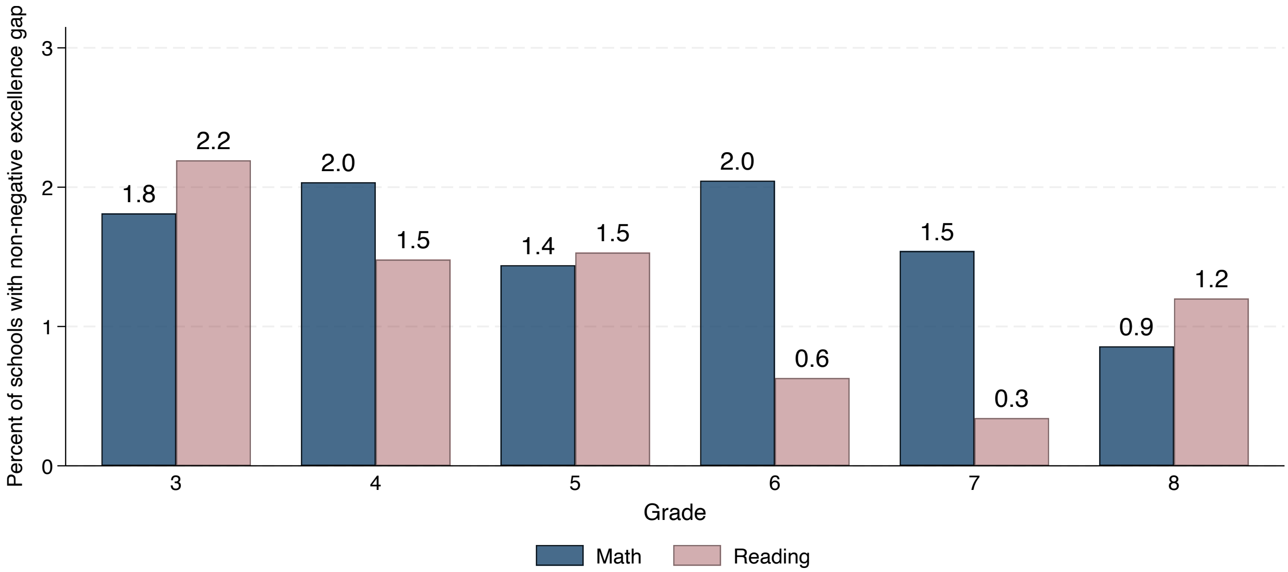


(b) Reading



Notes: These figures display the across-year correlation in a school's racial excellence gap in (a) math and (b) reading, in the spirit of Kline et al. (2022). A unit of observation is school-year. Scatter plots correspond to binned averages, with a point for each percentile over the support of the x-axis. Regression slopes are weighted by the number of enrolled students in that year. Excellence is defined as reaching the top decile on the EOG math or reading test. Due to ties in test scores, we do not always have a threshold score that defines exactly the top 10%. Analysis uses our main sample as described in Section I.

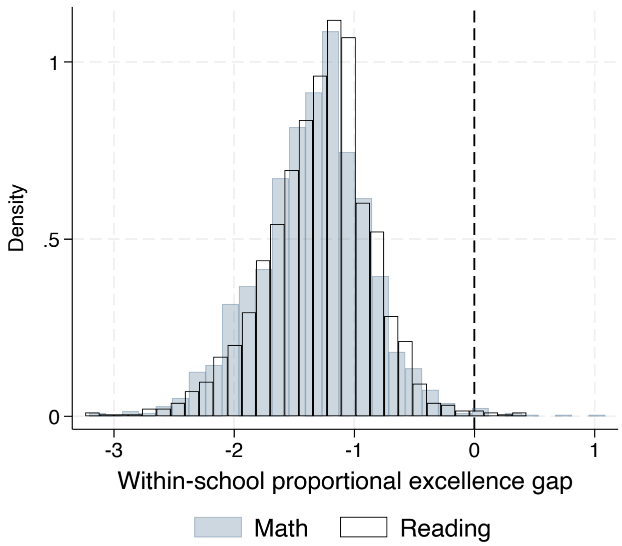
Figure A23: Percentage of schools with positive excellence gap



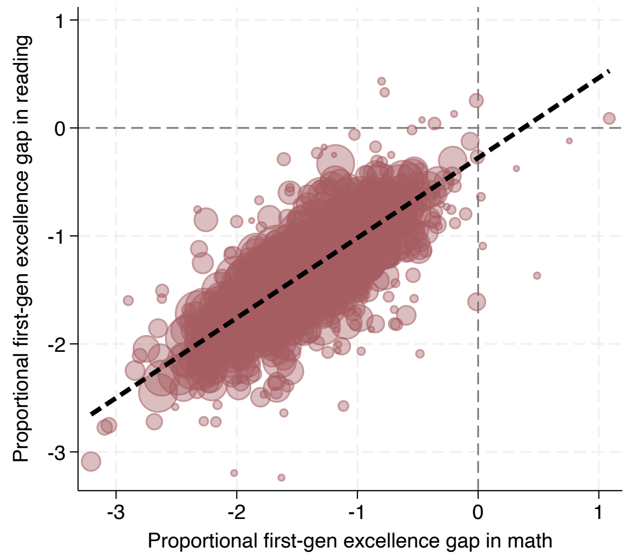
Notes: This figure displays the percentage of schools at each grade-level that have a positive excellence gap, where positive values mean that first-generation students are more likely than continuing-generation students to reach excellence. Analysis uses our main sample as described in Section I, which consists of 827,371 students in total: 602,780 with parents having attended less than 4-year college and 224,591 with parents having attended a 4-year college or more.

Figure A24: Proportional excellence gaps across schools

(a) Marginal distributions



(b) Joint distribution



Notes: These figures display the distribution of proportional excellence gaps. The proportion is calculated by dividing the likelihood that a first-generation student achieves excellence by the likelihood that a continuing-generation student does, and then taking the log: $\log\{\mathbb{P}(\text{Top Decile}_i|\text{First-gen}_i)/\mathbb{P}(\text{Top Decile}_i|\text{Not first-gen}_i)\}$. Figure (a) shows the distribution of school-level proportional excellence gap in math and reading, and (b) the relationship between the two subjects. These measures pool students across years. Analysis uses our main sample as described in Section I.

From regressing a school's excellence gap on its demographic composition and average student achievement, we find in our data that the schools that display the most negative excellence gaps are schools with a larger fraction of economically disadvantaged students (Table A5). Table A6 shows similar patterns for predicting whether a school has a non-negative excellence gap.

Table A5: Predicting excellence gaps across schools

	Math Excellence Gap						Reading Excellence Gap					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Frac. Econ Disad.	12.77***					-19.18***	9.28***					-19.13***
	(1.37)					(2.54)	(1.17)					(2.24)
Frac. Parents < College		16.42***				6.75***		13.75***				6.90***
		(1.39)				(1.70)		(1.20)				(1.55)
Frac. Non-White, Non-Asian			7.27***			1.90			5.10***			2.53**
			(0.89)			(1.40)			(0.79)			(1.27)
Average Math Score (std)				-24.21***		-25.47***				-3.69**		-5.32***
				(1.66)		(1.77)				(1.56)		(1.58)
Average Reading Score (std)				11.85***		8.70***				-7.54***		-9.89***
				(1.79)		(2.28)				(1.64)		(2.09)
N Test-takers (log)					0.04	0.90*					1.88***	1.58***
					(0.63)	(0.49)					(0.50)	(0.41)
N	1567	1567	1567	1567	1567	1567	1567	1567	1567	1567	1567	1567
Adjusted R^2	0.15	0.24	0.13	0.44	0.08	0.49	0.12	0.23	0.10	0.32	0.07	0.40

Notes: The table correlates a school's excellence gap with its observable characteristics. Positive values of the excellence gap are in favor of first-generation students. Observation is at the school-level, weighted by the number of test-takers in that school across all years. Each regression includes indicators for each grade that a school teaches, and year that the school is observed in the data for. Standard errors in parentheses, clustered at school level. Excellence is defined as reaching the top decile on the EOG test. These measures pool students across years. * $p < .1$, ** $p < .05$, *** $p < .01$

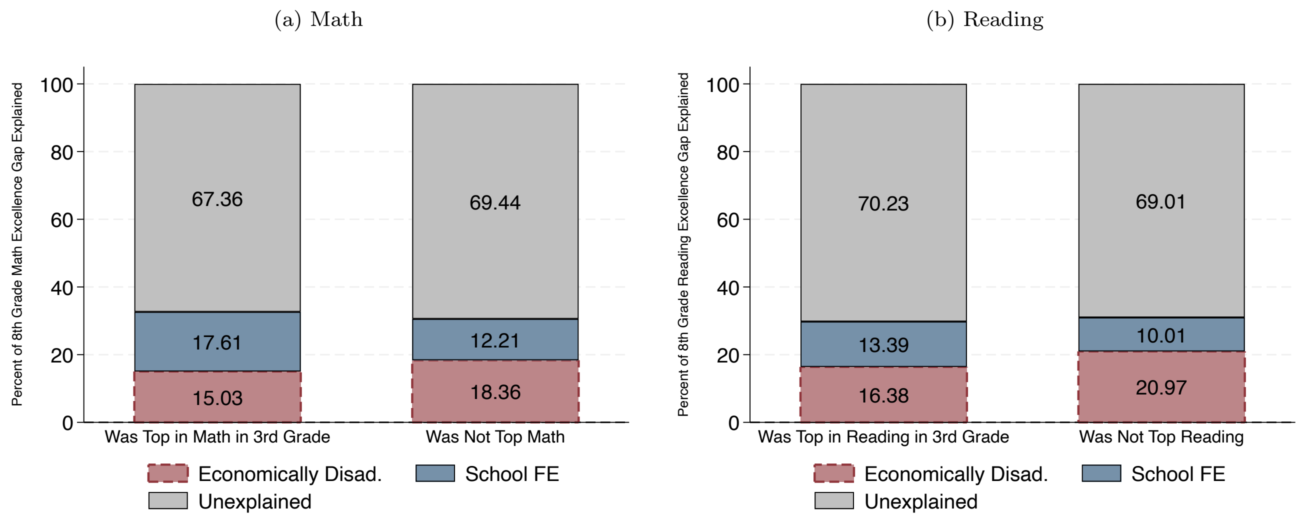
Table A6: Predicting positive excellence gaps across schools

	Positive Math Excellence Gap						Positive Reading Excellence Gap					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Frac. Econ Disad.	0.12***					0.00	0.10***					-0.02
	(0.02)					(0.03)	(0.01)					(0.02)
Frac. Parents < College		0.06***				-0.00		0.05***				0.01
		(0.01)				(0.02)		(0.01)				(0.02)
Frac. Non-White, Non-Asian			0.09***			0.05***			0.08***			0.06***
			(0.01)			(0.02)			(0.01)			(0.02)
Average Math Score (std)				-0.08***		-0.06***				-0.02		-0.00
				(0.02)		(0.02)				(0.02)		(0.02)
Average Reading Score (std)				0.01		0.02				-0.04*		-0.04
				(0.02)		(0.03)				(0.02)		(0.03)
N Test-takers (log)					-0.01**	-0.01					-0.01	-0.01
					(0.01)	(0.01)					(0.01)	(0.00)
N	1567	1567	1567	1567	1567	1567	1567	1567	1567	1567	1567	1567
Adjusted R^2	0.14	0.10	0.15	0.16	0.09	0.17	0.12	0.09	0.13	0.13	0.07	0.14

Notes: This table presents results of twelve OLS regressions to predict whether a school has a positive excellence gap with its observable characteristics. Positive excellence gap corresponds to first-gen students exhibiting a higher rate of reaching excellence than continuing-gen. Observation is at the school-level, weighted by the number of test-takers in that school across all years. Each regression includes indicators for each grade that a school teaches, and year that the school is observed in the data for. Excellence is defined as reaching the top decile on the EOG math or reading test. Due to ties in test scores, we do not always have a threshold score that defines exactly the top 10%. * $p < .1$, ** $p < .05$, *** $p < .01$

M Explaining Persistence vs. Entry

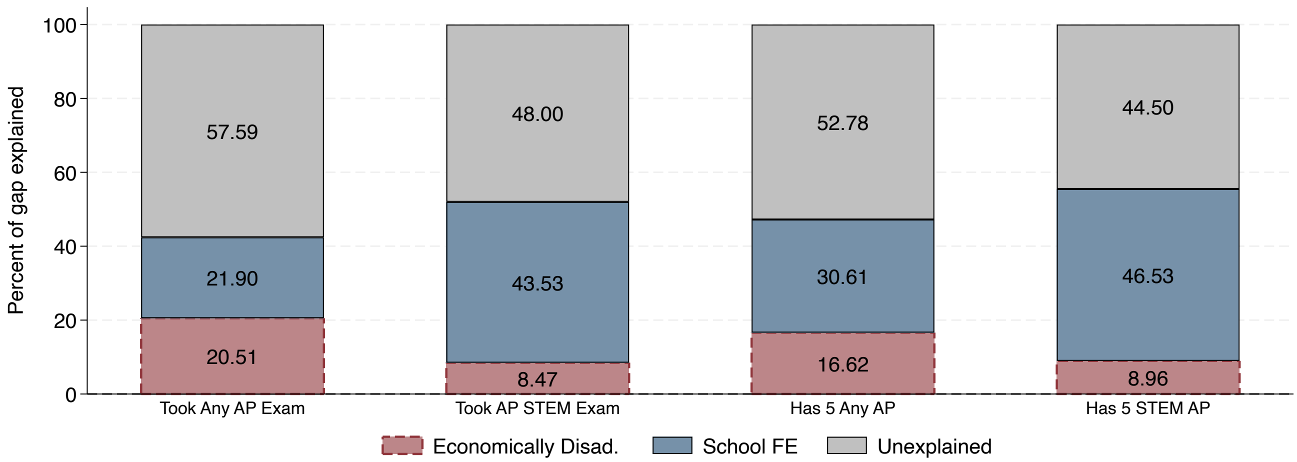
Figure A25: Explaining First-Gen Differences in Persistence and Entry into 8th Grade Excellence



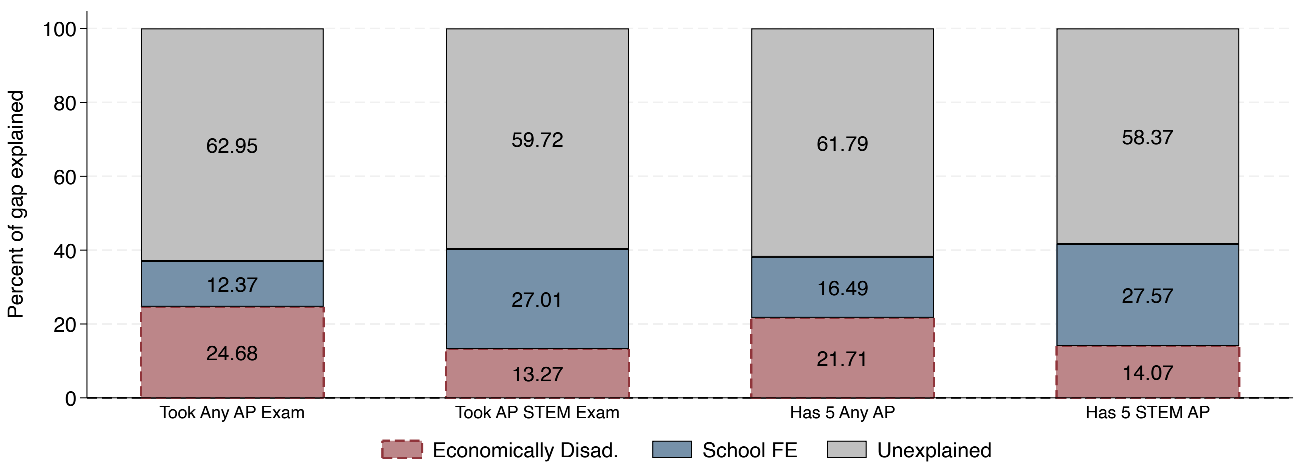
Notes: These figures display the Gelbach decomposition in the 8th grade excellence gap in (a) math and (b) reading. Both figures split the sample by whether a student achieved excellence in that subject in 3rd grade. For example, the leftmost bar of panel (a) illustrates the Gelbach decomposition for the racial difference in persistence of excellence: whether a student reaches the top decile of math in 8th grade, among students who scored in the top decile of math in 3rd grade. Analysis uses our main sample as described in Section I, which consists of 827,371 students in total: 602,780 with parents having attended less than 4-year college and 224,591 with parents having attended a 4-year college or more.

Figure A26: Explaining First-Gen Differences in Persistence and Entry into College Readiness (AP Exams)

(a) Persistence (Among Those Top in 8th Grade Math)



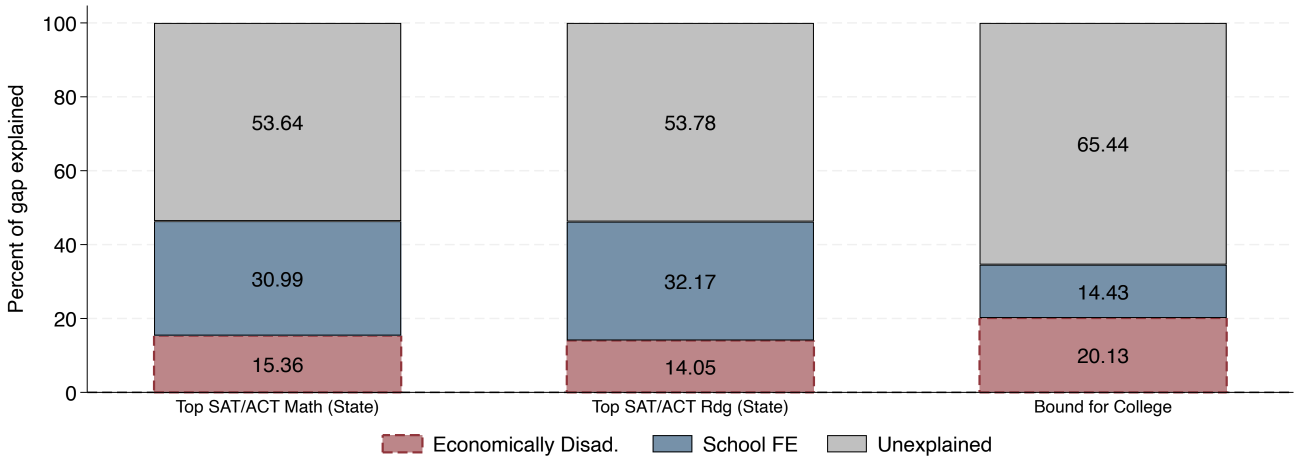
(b) Entry (Among Those Not Top in 8th Grade Math)



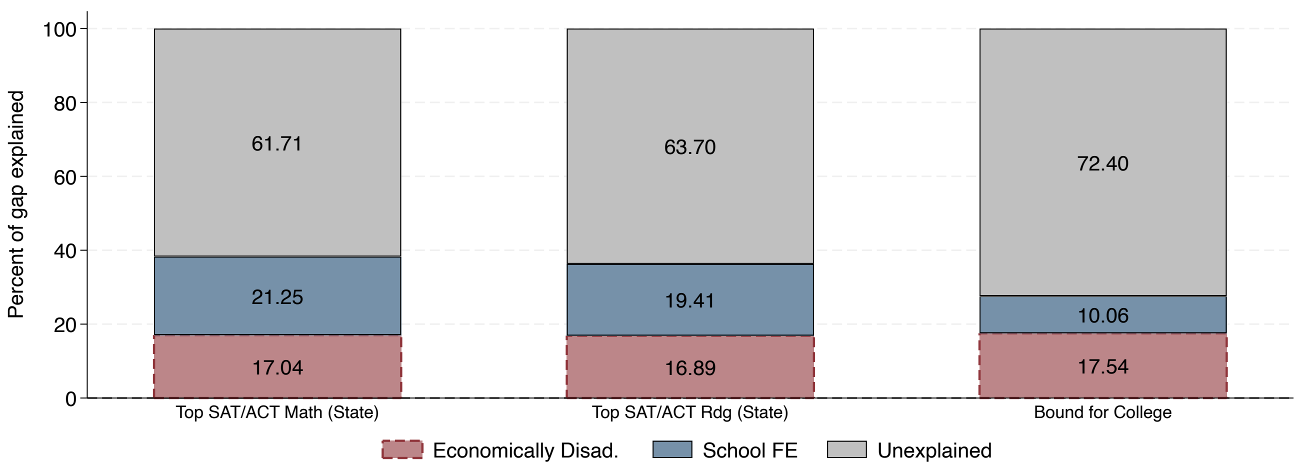
Notes: This figure displays the Gelbach decomposition of each first-generation difference in whether a student takes at least one AP exam, takes at least one STEM AP exam, has a 5 on any AP exam, and has a 5 on a STEM AP exam, among (a) students who achieved excellence in 8th grade math and (b) students who did not achieve excellence in 8th grade math. Analysis uses a subset of the main dataset described in Section I, which consists of cohorts beginning 3rd grade between 2001 and 2006 for whom we observe AP outcomes through high school.

Figure A27: Explaining First-Gen Differences in Persistence and Entry into College Readiness (SATs and College Plans)

(a) Persistence (Among Those Top in 8th Grade Math)



(b) Entry (Among Those Not Top in 8th Grade Math)



Notes: This figure displays the Gelbach decomposition of each first-generation difference in whether a student reaches the top decile of SAT Math or SAT Reading (at the state level), and in plans to attend a 4-year college, among (a) students who achieved excellence in 8th grade math and (b) students who did not achieve excellence in 8th grade math. Analysis uses a subset of the main dataset described in Section I, which consists of cohorts beginning 3rd grade between 2000 and 2006 for whom we observe SAT and ACT outcomes through high school.

N Teacher Effects on Excellence

N.1 Sample

To estimate teacher effects, we use the full sample of students in the NCERDC data instead of subsetting to a balanced panel. This ensures that we fully account for the students associated with a teacher. We construct our sample largely following Rothstein (2017) who also use data from the NCERDC. We stop our sample at 2008 given our focus on students' parental education, which was only collected until 2006: therefore, our final sample uses test scores from 1996 to 2008. The North Carolina data during these years contain the identity of the End-of-Grade (EOG) exam proctor, who is generally the student's classroom teacher but may not be in cases when a teacher has different teachers for math and English given that the proctor is the same for both subjects. We therefore focus on grades 3, 4, and 5, when classrooms are typically self-contained. As in previous work, we use classroom personnel reports to identify each test proctor who is indeed a classroom teacher (e.g. Clotfelter et al., 2006; Rothstein, 2010, 2017). Given our goal of estimating heterogeneous teacher effects by students' first-generation status, we focus on classrooms with at least 5 first-generation students and 5 continuing-generation students. This leads to an estimation sample of 1,329,633 student-year observations, which comprises 28,625 teachers.

As in the preceding main analyses, we use EOG scores as the outcome of interest, which begin from 3rd grade. Our main outcome of academic excellence during elementary school follows the main text: reaching the top 10% in the year-grade on the EOG exam. We additionally follow Rose et al. (2022) to examine effects on study skills, which are captured by the first principal component of self-reported hours spent on homework, reading, and television (we first standardize each at the grade-year level, and then take the principal component). For later-life outcomes, we use the same outcomes as in the main text: AP exam performance, SAT/ACT exam performance, and college plans. As 3rd grade achievement lags, we follow Rothstein (2017) and use beginning-of-third grade exam scores which are taken in the fall of the third grade.

N.2 Estimation

To estimate teacher effects, we follow Rose et al. (2022). We describe their procedure below, following their notation. We first estimate, for student i in year t:

$$Y_{it} = \sum_j \alpha_j D_{ijt} + X'_{it}\Gamma + u_{it}$$

where Y_{it} is the student outcome of interest, D_{ijt} is an indicator for whether student i has teacher j in year t, and X_{it} are a vector of controls. Note that Y_{it} can be an outcome that is realized in some date beyond year t, such as during high school in this setting. As controls, we include: year-grade fixed effects; cubic polynomials in lagged math and reading test scores, interacted with grade; lagged indicators for math and reading excellence and above-median, interacted with grade; lagged study skills; gender, age, economic disadvantage indicators, English language learner status, indicator for grade repetition and test repetition, race and ethnicity, indicators for special education, and indicators for missing values of each; cubics in class and school-grade mean lagged scores, class and school-grade mean lagged rates of excellence, and class size. We set missing student-level variables to zero and include indicators for missingness.

To proceed with recovering causal estimates, we assume that conditional on observables, teacher assignments are not correlated with unobserved factors that affect student outcomes. The plausibility of this assumption is supported by our rich set of controls that include demographics and past achievement at the level of the individual, class, and school-grade.

Using our estimated OLS coefficients of eq. A6, we estimate teacher-year-level mean residuals:

$$\begin{aligned}\bar{Y}_{jt} &= \frac{1}{|C(j,t)|}\sum_{i\in C(j,t)} Y_{it} - X'_{it}\hat{\Gamma} \\ &= \alpha_j + \bar{v}_{jt} \end{aligned} \tag{A6}$$

where J is the total number of teachers, $C(j,t)$ is the set of students associated with teacher j in year t, $\hat{\Gamma}$ is the vector of estimated coefficients on the vector of controls from eq. A6, and $\bar{v}_{jt} = \frac{1}{n_{jt}}\sum_{i\in C(j,t)} u_{it} + X'_{it}(\Gamma - \hat{\Gamma})$. By the properties of OLS, we know that the residuals are mean zero, so that $\mathbb{E}[\bar{v}_{jt}] = 0$. We proceed with the assumption that $\bar{v}_{jt}$ is uncorrelated across years: $(\mathbb{E}[\bar{v}_{jt}\bar{v}_{jt'}] = 0\,\forall j, t \neq t')$.

Our first parameter of interest is the variability of teacher effects on a given student outcome:

$$Var(\alpha_j) = \frac{1}{J}\sum_{j=1}^{J}\alpha_j^2 - \left(\frac{1}{J}\sum_{j=1}^{J}\alpha_j\right)^2 \tag{A7}$$

Simply estimating the variance of $\bar{Y}_{jt}$ combines both the variance in teacher effects and the variance in sampling error. As Rose et al. (2022) show, this leads to an unbiased leave-year-out estimator which allows us to non-parametrically estimate the variance in teacher effects:

$$\widehat{Var}(\alpha_j) = \left(\frac{J-1}{J}\right)\frac{1}{J}\sum_{j=1}^{J}\binom{T_j}{2}^{-1}\sum_{t=1}^{T_j-1}\sum_{k=t+1}^{T_j}\bar{Y}_{jt}\bar{Y}_{jk} - 2\frac{1}{J^2}\sum_{j=1}^{J-1}\sum_{k>j}^{J}\bar{Y}_j\bar{Y}_k \tag{A8}$$

where T_j is the number of years that teacher j is observed, $Y_j = \frac{1}{T_j}Y_{jt}$. Intuitively, this estimator avoids bias from the variance in sampling error by leaving out the products teacher-level residuals from the same year.

Second, we seek to understand the link between teacher effects across different outcomes and student subgroups. To do so, we estimate the covariance of teacher effects. Again, following the notation of Rose et al. (2022), we write our target parameter, the covariance for teacher effect on outcome (or subgroup) A and B, as:

$$Cov(\alpha_j^A, \alpha_j^B) = \frac{1}{J}\sum_{j=1}^{J}\alpha_j^A\alpha_j^B - \left(\frac{1}{J}\sum_{j=1}^{J}\alpha_j^A\right)\left(\frac{1}{J}\sum_{j=1}^{J}\alpha_j^B\right) \tag{A9}$$

We estimate this using the same logic as for the variance estimator and leaving out products of teacher-level residuals from the same year:

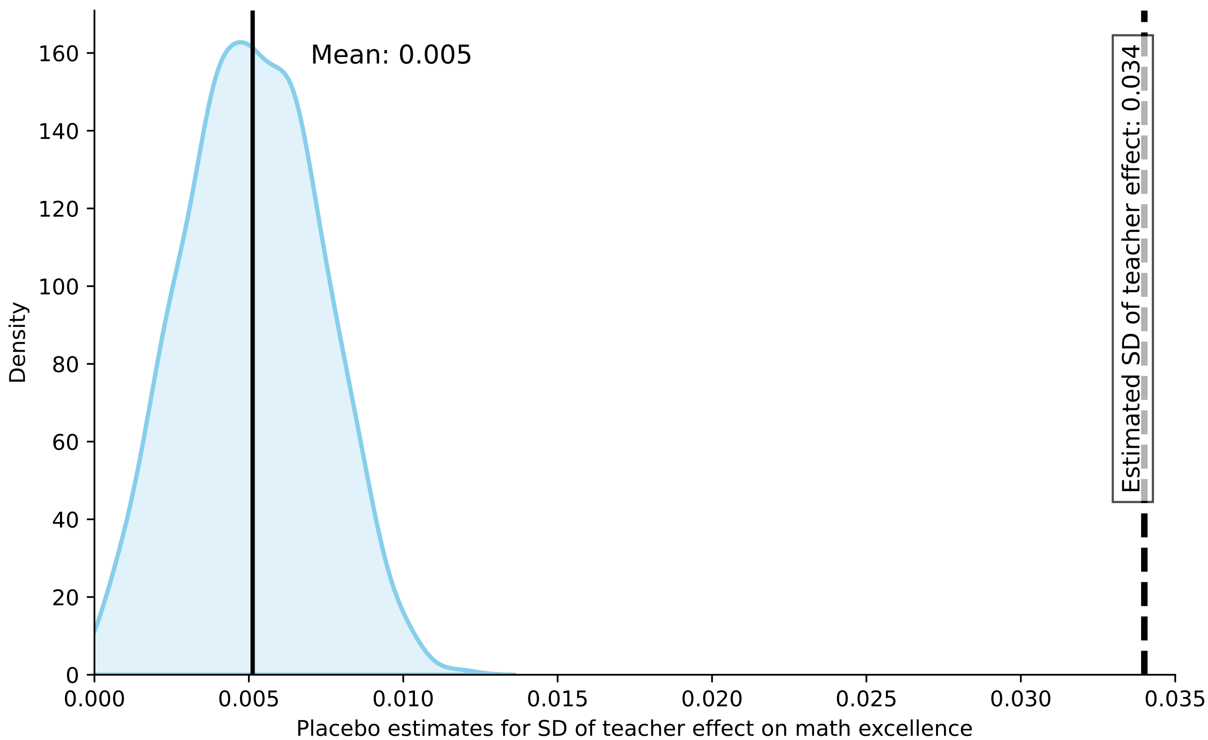
$$\widehat{Cov}(\alpha_j^A, \alpha_j^B) = \left(\frac{J-1}{J}\right)\frac{1}{J}\sum_{j=1}^{J}\binom{T_j}{2}^{-1}\sum_{t=1}^{T_j-1}\sum_{k=t+1}^{T_j}\bar{Y}_{jt}^A\bar{Y}_{jk}^B - 2\frac{1}{J^2}\sum_{j=1}^{J-1}\sum_{k>j}^{J}\bar{Y}_j^A\bar{Y}_k^B \tag{A10}$$

We calculate standard errors following the procedure of Rose et al. (2022), first calculating the covariance of our estimated variance and covariance estimates. To then calculate standard errors for our estimated standard deviations and correlations, we apply the delta method.

N.3 Estimations Under the Null

In this section, we benchmark our main estimate for the standard deviation of teacher effects on math excellence (Figure 5a) against the null that teachers do not systematically vary in their effects on math excellence. To do so, we run 1,000 simulation iterations, and at each iteration, take the student-level data as given, and randomly shuffle the outcome variable (an indicator for reaching excellence) within grade-year. Figure A28 illustrates the distribution of the placebo standard deviation estimates, relative to the estimate we get from the data. This alleviates concerns that our approach and definition of excellence as the top 10% induce variation in teacher effects simply because not all students can be categorized as meeting excellence.

Figure A28: Placebo test for teacher effect on math excellence

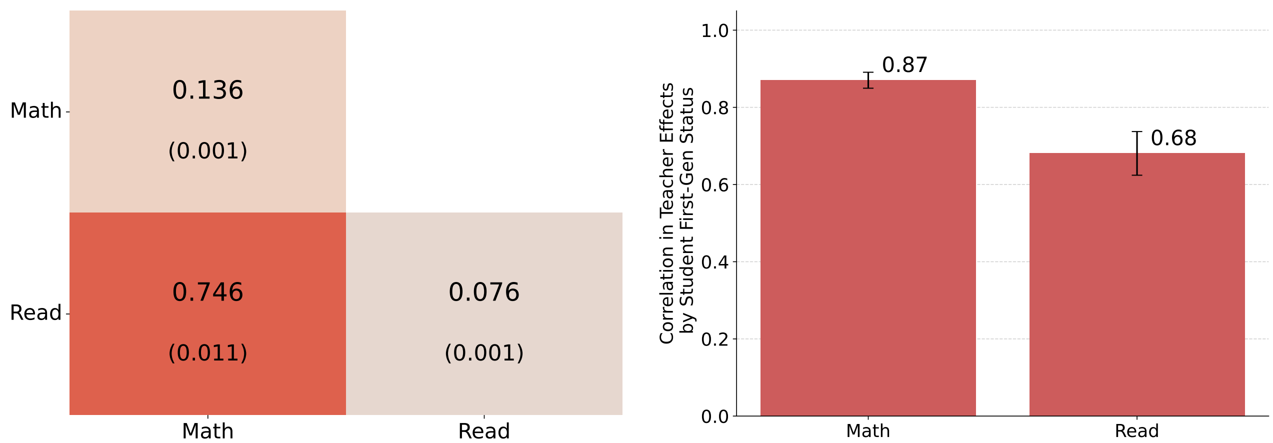


Notes: This figure shows the distribution of estimated standard deviations of teacher effects on math excellence, under the null of no systematic variation across teachers based on 1,000 iterations. At each iteration, the outcome variable (an indicator for reaching excellence) is randomly shuffled within grade-year. The dotted line shows the estimated standard deviation from the data (without shuffling), as in Figure 5a.

N.4 Additional Figures and Tables

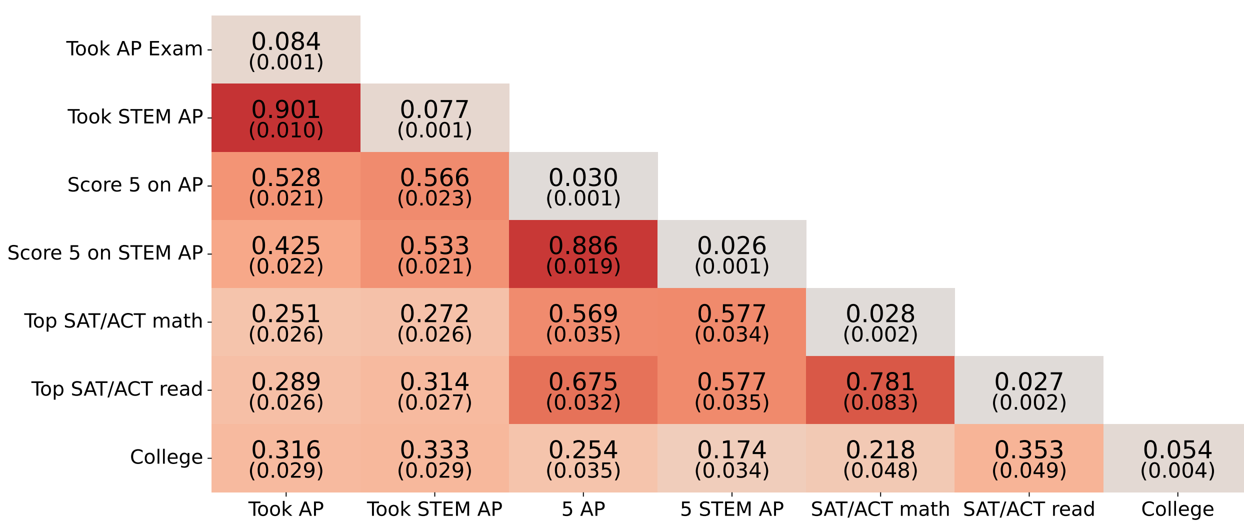
Figure A29: Teacher effects on linear improvements in test scores

(a) Differences in reaching excellence in grade 3 through 8 | (b) Correlation in effects



Notes: This figure presents (a) estimated standard deviations (diagonal elements) and correlations (off-diagonal elements) of teacher effects, (b) the correlation in teacher effects across the teacher's students' first-generation status, as in Figure 5. "Math" ("Read") corresponds to the teacher effect on the average math (reading) test score. Estimation procedure follows Rose et al. (2022) and is described in Appendix N.

Figure A30: Teacher effects on later-life outcomes



Notes: This figure presents estimated standard deviations (diagonal elements) and correlations (off-diagonal elements) of teacher effects on later-life outcomes, as in Figure 5. Estimation procedure follows Rose et al. (2022) and is described in Appendix N.