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Peer Income Exposure Across the Income Distribution

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Abstract

Children from families across the income distribution attend public schools, making schools and classrooms potential sites for interaction between more- and less-affluent children. However, limited information exists regarding the extent of economic integration in these contexts. We merge educational administrative data from Oregon with measures of family income derived from IRS records to document student exposure to economically diverse school and classroom peers. Our findings indicate that affluent children in public schools are relatively isolated from their less affluent peers, while low- and middle-income students experience relatively even peer income distributions. Students from families in the top percentile of the income distribution attend schools where 20 percent of their peers, on average, come from the top five income percentiles. A large majority of the differences in peer exposure that we observe arise from the sorting of students across schools; sorting across classrooms within schools plays a substantially smaller role.

Significance Statement

Our study provides the first comprehensive description of the income of students' school and classroom peers. Although schools have the potential to expose students to diverse peers, our novel data show substantial income segregation in schools and classrooms. We find that the high-income students are exposed to a particularly skewed set of peers, and that the highest-income students have 20 percent of their peers coming from the top five income percentiles. The uneven distribution of students is largely due to sorting across schools rather than within schools, with the relative contribution of between-school sorting higher in elementary school than middle and high school.

Main Text

Introduction

Deep economic and political fissures divide contemporary political and social life in the United States (*1–8*). In similarly contentious moments in American history, reformers have often looked to public schools for solutions, hailing their potential to provide opportunities for social and economic mobility and forge community (*9–13*).

Prior research indicates that schools advance social equality (*14, 15*), with some evidence to suggest that exposure to diverse peers may be one mechanism for education's egalitarian effects (*16–19*). The characteristics of students in a school, as well as the characteristics of students' friends and peer networks, associate closely with their academic performance, attitudes, behaviors, and mental and physical health (*20-22*). While much of the research in this area is correlational, experimental and quasi-experimental evidence suggests that peers impact youth academic, social, and emotional development and later life outcomes (*23-28*). Further, research indicates that the sorting of affluent and poor children across schools and classrooms drives school finance and resource inequalities (*29-30*). The share of high-income peers is a strong predictor of upward mobility for low-income children (*31*).

In this paper, we use a unique dataset linking K-12 student enrollment records from Oregon with family income measures derived from tax records to illuminate the degree to which students encounter peers from across the income distribution in their schools and classrooms. Our study builds on prior research exploring the degree of socioeconomic segregation in U.S. public schools (*32-35*). The dichotomous proxies for family income available in prior work—typically an indicator of free or reduced-price lunch enrollment—only allow comparisons between relatively low-income families and a wide range of middle- and high-income families. In contrast, our continuous measures of student and peer family income allow us to examine the degree to which students from across the income distribution are exposed to – or isolated from – peers from across the income distribution. Our data also allow us to identify students' classroom peers, moving beyond analyses limited to school-level peer composition and enabling comparisons of school and classroom peer income exposure.

We characterize students' exposure to peers across the income distribution and develop a novel summary statistic that enables analysis of the extent to which peer income exposure is driven by sorting across or within schools, as well as comparisons of exposure across grade levels. Our analyses reveal that students from affluent families are highly isolated in affluent school enclaves. For example, students from families in the top percentile of the income distribution attend schools where 20 percent of their peers, on average, come from the top five income percentiles. By contrast, for students in the 50th income percentile and below, just 3 percent of peers, on average, come from the top five income percentiles. To achieve an even distribution of peer income, students in the top percentile would need to see 28 percent of their high-income peers swapped with lower-income students. For perspective, students from the

bottom 80 percentiles would need to swap less than 9 percent of their peers to achieve an even distribution of peer income.

Generally, students' classroom peers reflect more uneven income distributions than their school peers, suggesting that the assignment of students to classrooms within schools results in additional clustering of students with similar income. But the differences in classroom and school peer income exposure are small, suggesting that sorting across schools – not within schools – predominantly drives uneven peer income exposure. Elementary school students experience systematically more uneven peer income distributions than middle and high school students overall. Middle and high schools students often—but not universally—experience more within-school income sorting than elementary school students.

Approach

We study the population of students enrolled in public schools in the 2016-17 school year, as documented in student-level administrative data from the Oregon Department of Education (ODE). Compared to the other 49 states and the District of Columbia, Oregon ranks 25th in terms of median family income (*36*), is the 18th most urban state (*37*), and is 29th in terms of the percentage of students who are White (*38*) (see supplemental Figs. S1-S3). Thus, although no single state is nationally representative, the patterns that we observe hold important insights for many other contexts. Our analysis requires four pieces of information about each student: school enrollment, classroom enrollment, grade, and family income percentile. School, grade, and classroom enrollment records are drawn from the ODE data, while family income percentile is calculated from linked IRS Form 1040 (tax return) records housed at the U.S. Census Bureau. We restrict our analysis to in-person classes in schools with more than 50 students and can link 92 percent of students to their family income information, for an analytic sample of 493,000 students.

We investigate two population constructs: school peers and classroom peers. School peers are defined as all the students who attend the same school as a given student on April 1, 2017. Classroom peers are defined as all the students who appear in a given student's classes on April 1, 2017, weighting peers according to the number of classes in which they appear. In settings (including many elementary schools) in which students spend the entire day in a single classroom with the same set of peers, all peers factor into our measure of classroom peer composition equally. In settings (including many middle and high schools) where students change classes throughout the school day, peers who share multiple classes with a student contribute more to our measure than peers who share a single class with a student. Defining students' classroom peers is a unique contribution of this study enabled by the ODE administrative data, which includes information on the physical classroom in which a class occurs, in addition to period, subject, teacher, and start/end dates.

Our goal is to characterize the school and classroom peer income distribution typical for students of various income levels. To do this, we create a 100-by-100 grid containing the average proportion of

peers in each income percentile for students in each income percentile. We construct one grid for school peers, and another for classroom peers. Our primary results are visualizations drawn from these 100-by-100 grids. For reference, we benchmark these distributions against the counterfactual where students are evenly distributed by income and, thus, have exactly 1 percent of peers in each income percentile.

To illustrate, consider the process we use to calculate the average proportion of school peers in the 91st income percentile for students in the 10th income percentile: For each student observed in the 10th percentile, we count the number of their peers we observe in the 91st income percentile and divide by their total number of peers. Then we average the resulting proportion across all students observed in the 10th percentile throughout the state. If this average proportion exceeds 0.01, students in the 10th percentile have more 91st percentile peers, on average, than we would expect if students were evenly distributed by income; if it is less than 0.01, students in the 10th percentile have fewer 91st percentile peers than expected under an even distribution.

To better understand the degree to which the distribution of peer income differs from a perfectly even distribution, we calculate a measure summarizing the overall unevenness of the average peer income distribution for students in each percentile. We derive this measure of unevenness by calculating the total deviation distance between the observed values and an even peer distribution. That is, for a given student income percentile, we take the absolute value of the difference between the observed average peer proportion and the theoretically even proportion (0.01) for every peer income percentile, sum this difference across all peer percentiles, and divide it by two. Formally, uneven exposure, U^m, for student percentile m is defined as

$$U^m = \frac{1}{2}\sum_{j=1}^{100}\left|0.01 - p_j^m\right|$$

where p_j^m denotes the average proportion of peers in percentile j for students in percentile m.

Intuitively, this measure is similar to the dissimilarity index, which is widely used in the study of neighborhood and school segregation (39, 40). Like the dissimilarity index, our measure of uneven exposure can be characterized as the proportion of peers, on average, that would have to be swapped with peers in other income percentiles from other schools or classrooms to achieve an even peer distribution. As a complement to the granular information in the visualizations, this summary identifies which student income percentiles have peer income distributions that deviate most from an even distribution of peer income, though it obscures which part of the peer income distribution drives unevenness.

In addition to analyzing the distribution of school and classroom peers of all Oregon K-12 students, we separately examine these distributions by grade. We elect to include select grades for visual clarity and to reduce the overall number of statistics released from our confidential data. Our conclusions are not sensitive to the specific grades we select to represent elementary, middle, and high school levels. We opt to select 2nd grade and 10th grade because, as shown in SI Appendix Fig. S4, the proportion of school-aged children in Oregon enrolled in public school increases through second grade, at which point

it remains stable until starting to decline in 11th grade. The stability of school-aged enrollment from grades 2-10 suggests that changes in peer composition across these grades are unlikely to be due to systematic changes in the overall population of public school students—for example, if high school drop-outs in 11th and 12th grade are disproportionately low-income. We use 7th grade for middle school because middle schools and junior high schools vary in the exact grade spans they cover, but they virtually all include 7th grade. By comparing peer income distributions across elementary, middle, and high school grades, we investigate whether classroom and school peer income distributions vary similarly across grade levels.

Results

School peer income composition

We first illustrate average school peer income distributions for students in a wide range of income percentiles. Fig. 1 plots the average proportion of peers in each income percentile for select student percentiles, clustered by low, middle, and high income groupings. The figure includes a dashed horizontal line at 0.01 representing a perfectly even peer income distribution.

Fig. 1 (**A**) illustrates school peer exposure for students from low-income families (percentiles 1-40, with family incomes ranging from approximately $0-$42,000 and roughly equivalent to students who would be income-eligible for free or reduced-price lunch). These students attend schools with a disproportionately large proportion of low-income peers, and a disproportionately small proportion of high-income peers, as indicated by the lines sitting above the even distribution line at lower income percentiles and below at higher income percentiles. Students in the 20th percentile attend schools where 25 percent of students, on average, are from the bottom 20 percent of the income distribution, and only 14 percent of their peers are from the top 20 percent.

Fig. 1 (**B**) reflects students from middle-income families (percentiles 41-80, with family incomes ranging from approximately $42,000-$112,000), showing that middle-income students generally attend more income-diverse schools than low-income students, with peer exposure values hovering around the 0.01 value representing a perfectly even distribution of peers. For example, students whose family income places them in the 60th percentile attend schools in which 20 percent of their peers, on average, are from the bottom 20 percent of the income distribution, and 18 percent are from the top 20 percent.

Fig. 1 (**C**) shows that students from the top of the income distribution (percentiles 81-100, with family incomes from approximately $112,000 and above) disproportionately draw peers from the top of the income distribution, and have disproportionately small shares of peers with middle-to-low incomes. For example, students in the 90th income percentile attend schools where just 14 percent of their peers come from the bottom 20 percent of the income distribution, and 32 percent are from the top 20 percent.

As the sharp spike in peer exposure at the right-hand side of Fig. 1 (**C**) makes clear, this skewed pattern of peer exposure becomes increasingly pronounced as student family income increases. Students whose families are in the highest (100th) income percentile are particularly concentrated: six percent of their school peers also come from the 100th percentile, and 20 percent come from the top 5 income

percentiles. Students in the 100th income percentile have the same proportion of peers (32 percent) in the top 10 income percentiles as they do in the bottom 58 percentiles.

In Fig. 2, we present our overall uneven exposure measure summarizing the degree to which the average distribution of school peer income deviates from even exposure for students across the income distribution. We see that for students in the bottom 30 percentiles, approximately 7-8 percent of school peers, on average, would need to be swapped with students in other percentiles to achieve an even distribution. Middle-income students experience fairly even peer income distributions, with the unevenness measure lowest (at approximately 2 percent) between the 58th and 66th percentiles.

However, unevenness in school peer income exposure rises dramatically for students in the top quintile of family income. From the 83rd percentile on, unevenness reaches heights not seen in the bottom 80 percentiles, and climbs steadily, topping out at 0.28 in the 100th percentile. More than one-in-four peers would have to be swapped for peers in other income percentiles to achieve an even peer income distribution for students in the 98th, 99th, and 100th income percentiles. As shown in Fig. 1 (**C**) these new peers would have to be drawn from the bottom three quartiles of the income distribution, and more so from the bottom half.

Classroom peers compared with school peers

If there were no additional sorting of students by income within schools, classroom peer income exposure would be equivalent to school peer income exposure. However, looking at uneven exposure of classroom peer income in Fig. 2, we find that classroom peer income is more uneven than school peer income for students from nearly all income percentiles. This pattern is consistent with the notion that schools track children for instructional purposes in a manner that clusters children with similar family backgrounds together (*41*). The only exception to this pattern occurs for students from the middle of the income distribution, for whom school and classroom unevenness are nearly equivalent.

Notably, the differences between classroom and school peer uneven exposure are small in magnitude. If classroom peer unevenness arguably reflects students “lived experience” of peer income exposure, we can interpret the ratio of school to classroom uneven exposure as the share of lived unevenness attributable to sorting across schools rather than sorting within schools. This ratio never drops below 0.70 and exceeds 0.80 for the vast majority of student income percentiles, suggesting between-school sorting generally accounts for 80 percent or more of students' uneven peer income exposure, and within-school sorting accounts for 20 percent or less. Overall, therefore, classroom tracking appears to have a relatively minor impact on student’s exposure to peers of different economic backgrounds.

Variation in peer exposure across school levels

At every student income percentile, elementary school students have less exposure to income-diverse peers than middle and high school students. Fig. 3 (**A**) highlights unevenness in school peer

exposure separately for students in grades 2 (black triangles on left), 7 (black triangles in center), and 10 (black triangles on right), with the non-featured grades displayed in gray to facilitate comparison. The magnitude of unevenness in peer exposure experienced by 7th and 10th graders is, on average, 65-75% as large as that experienced by 2nd graders. For students in the 100th income percentile, 31 percent of 2nd grade school peers would need to be swapped to achieve an even distribution of school peer income, compared to 25 percent of 7th grade peers and 21 percent of 10th grade peers. These findings might reflect residential sorting by income, since elementary schools typically serve smaller geographic areas than middle and high schools.

Fig. 3 (**B**) depicts variation in within-school cross-classroom income-based sorting across grades. Students in elementary school typically spend the whole day in a single classroom, while middle and high school students are routinely sorted into a variety of different classrooms. Middle and high school students may also be tracked into particular courses and schedules based on prior academic performance or participation in extracurriculars, yielding more opportunities for within-school sorting by factors that correlate with family income. As above, we calculate the ratio of school to classroom unevenness in order to estimate the proportion of unevenness students encounter in total that is explained by sorting across schools rather than within schools. Fig. 3 (**B**) plots this ratio separately for students in grades 2 (black line on left), 7 (black line, center), and 10 (black line, right). Like in Fig. 3 (**A**), the non-featured grades are displayed in gray to facilitate comparison.

To the extent elementary schools can sort students by income, within-school sorting has the largest impact for 2nd graders around the 50th-70th income percentiles, but this is where overall uneven exposure is quite low. For middle and high schoolers, within-school sorting is most prominent in the 60th-90th percentiles where overall unevenness begins to climb. At its most extreme, within-school sorting accounts for 40 percent or more of 10th graders' uneven exposure to peer income. High school students in the lowest third of the income distribution also experience somewhat elevated within-school sorting.

At the low and high ends of the student income distribution, the patterns one would predict from middle and high school tracking are realized, with 10th grade the most impacted by within-school sorting, 2nd grade the least impacted, and 7th grade somewhere in-between. However, this pattern is murky and sometimes inverted in the middle of the income distribution where unevenness is quite low overall. Students in income percentiles that experience relatively even school peer income distributions, on average, also enjoy relatively even classroom peer income distributions, even in grades where tracking is prevalent.

Discussion

We use unique linked data to explore the variation in school and classroom peer family income exposure for children from across the family income distribution who are enrolled in public schools. We find that low-income students have disproportionately low-income school peers, while middle-income students attend schools with students from across the income distribution. However, our analyses

indicate that the most affluent students attend schools where they are disproportionately exposed to high-income peers. The average student whose family income is in the top percentile of the public school income distribution attends a school in which six percent of their peers are also from the top income percentile, and 20 percent of their school peers are from the top 5 percentiles of the income distribution.

We find that exposure to classroom peers is not much more uneven than school peer exposure. Even in middle and high school, where academic tracking based on social class is most pronounced, classroom peer exposure is driven primarily by who attends which school. There are exceptions, such as income percentiles 70-85 for 10th graders, in which within-school sorting typically increases uneven peer exposure by one-third or more, on average.

Our finding that the highest income students have the highest disproportionality of high-income peers is notable since the highest income children in Oregon are the least likely to attend public schools. SI Appendix Fig. S5 shows that, on average, 84 percent of Oregon's school-aged children in income percentiles 1 through 90 attend public schools, but the attendance rate declines in the top decile, reaching a low of 58 percent in the 100th percentile. We cannot speak to income exposure of students not in public schools, but the disproportionate exposure to the highest income peers for the highest-income students would likely be even higher if we included non-public (e.g. private) school enrollments.

Capturing the spirit of educational reformer John Dewey, Lynch (*42*) commented a century ago that "The object of a democratic education is not merely to make an individual an intelligent participant in the life of his immediate group, but to bring the various groups into such constant interaction that no individual, no economic group, could presume to live independently of others" (see also *10*). Public schools can provide important opportunities to interact across social differences (*43, 44*) for children growing up in our deeply economically unequal (*1, 3-6*), sharply politically polarized (*45, 46*), highly residentially segregated (*47*) society. However, income-based isolation diminishes opportunities for cross-economic class connection. When students from the top one percentile of family income have as many peers from the top decile as they do from the bottom six deciles, high-income students are deprived of learning with, and from, students who are not similarly high-income.

Materials and Methods

Our dataset links records from the Oregon Department of Education containing information about students' school and classroom enrollments with IRS records housed at the U.S. Census Bureau that contain information about students' family income. We restrict our analytic sample to in-person classes in schools with more than 50 students, yielding 536,000 of the 573,000 students enrolled in Oregon public schools in the 2016-2017 school year. Of these, we can link 493,000 students (92 percent) to family income information.

We link these records using protected identification keys (PIKs) that are assigned by the Census Bureau to both ODE and IRS records using the Person Identification Validation System (*48*). We then locate student PIKs from the ODE data on the IRS Form 1040 records in which students are claimed as

dependents. We define family income as Adjusted Gross Income (AGI) from 2016 for the student's tax unit, unless a student is not claimed in 2016, in which case we use the AGI from the most recent tax record in which they were claimed, reaching back up to four additional years.

We are not able to assign 8 percent of students to a family income percentile for one of two reasons: they do not receive a PIK (5 percent) or they receive a PIK but do not appear on tax records from 2012-2016 (3 percent). Broadly speaking, students might not be assigned a PIK due to missing or erroneous information in ODE administrative records for the student, or because they do not have a social security number, since data on individuals with social security numbers are used to build the reference file used to assign PIKs. We discuss the implications of missing data below.

As family income tends to rise as students age, we calculate family income percentiles within birth cohort to avoid systematically categorizing older students as higher income. We define birth cohorts from September of one year through August of the next year to coincide with on-time grade cohorts. Within each birth cohort, we rank students according to their family income, and assign them to 100 approximately equal-sized ordered bins. This results in roughly 5,000 students assigned to each percentile. The first percentile coincides with the students with the lowest family incomes according to our measure, but, notably, taxable income is not a perfect measure of family resources, and the first percentile appears as a local outlier in many of our figures. At varying levels of family resources, there are circumstances that give rise to very low—or even zero—taxable income. For example, families with business expenses may have deductions like capital losses and depreciation that lower their AGI, and some families draw much of their income from non-taxable sources like Supplemental Security Income. While we cannot fix this conceptual misalignment—a known shortcoming of administrative income measures—the potential presence of higher-resource families in very low family income percentiles should create downward bias in our results (*49*).

SI Appendix Fig. S6 shows the pseudo-median AGI for each income percentile. To comply with Census disclosure standards, we cannot identify the exact median value, so instead we report the average income of observations within a narrow bandwidth of the true median. The 100th income percentile has a pseudo-median AGI of $678,200. Key income cut-offs for poverty ($24,300), free lunch eligibility ($31,590), and reduced-price lunch eligibility ($44,955) for a family of four correspond to approximately the 21st, 30th, and 43rd percentiles, respectively (*50*).

This study was approved by the University of California, Irvine Institutional Review Board (#2017-4050).

Missing data

Missing family income causes two problems in our analysis. First, it complicates calculating peer income proportions when we do not observe the incomes of all a student's peers. Bias might arise if low-income students are less likely to appear in tax records than high-income students, leading us systematically underestimate the proportion of peers that are low-income (*51*). Consistent with this risk,

we find that the proportion of students' peers that are missing income decreases as student income percentiles rise, as shown in SI Appendix Fig. S7. However, the proportion of peers with missing income ranges from 5-10 percent for all income percentiles, aligning with evidence that peers with missing income are not universally low-income, and certainly not all zero-income (51). To reduce the threat of bias, we assume that income is missing-at-random at the peer group level. In a paper using similar data, we find that school economic disadvantage rates derived from tax records are virtually equivalent to those that supplement tax records with program participation data, despite this supplementation bringing in a sizeable proportion of students missing tax records (*52*). This suggests that the income of students' peers is a reasonable proxy for the income of students missing income. In execution, the missing-at-random at the peer-group level assumption means that when we calculate the proportion of school peers in each income percentile for each student, the denominator count reflects the number of students in the school for whom we observe income – not the total number of students in the school.

Second, missing income complicates calculating state average peer income proportions. When we average peer income proportions across all students observed in each percentile in the state to arrive at the statistics shown in Fig. 1, we assume that income is missing-at-random at the state level. This a stronger assumption than missing-at-random at the peer group level, and gives rise to a bias concern: if students whose percentiles we do not observe have systematically different peer income proportions than their same percentile counterparts, then our averages might not truly reflect the state-wide population. We test the sensitivity of this assumption in our school peer analysis using an alternative approach described in the SI Appendix Supporting Information Text. This approach applies our preferred missing-at-random at the peer group level assumption to the step where we calculate state-wide averages, and demonstrates, in SI Appendix Fig. S8, that our main approach is conservative. Since this alternative approach is infeasible for our classroom-level analyses, we opt for our main approach to ensure comparable statistics.

Oregon as a case study

Although we analyze data from a single state, our findings from Oregon may provide insights into peer income exposure for public school students in other states (see SI Appendix Figs. S1-S3 for state comparisons). To help situate Oregon in national context, we provide information on how Oregon compares to other 49 states and the District of Columbia on several dimensions (all data are from 2017):

- Oregon ranked 38 in overall income inequality (as measured by the GINI index), with a GINI of .459; the GINI for the U.S. as a whole was .482 (*53*).
- Oregon ranked 25 in median income, with a median income of $73,202, compared to a national median income of $60,366 (36).
- Oregon's public school K-12 students were 63 percent White (ranked 29), 23 percent Hispanic (ranked 38), 2 percent Black (ranked 9), and 4 percent Asian (ranked 37).

Nationally, 51 percent of public school students are white, 25 percent are Hispanic, 14 percent are Black, and 5 percent are Asian (38).

- Oregon ranked 31 in the percent of public school students who attended charter schools, with 5.7 percent, compared to 6.0 percent nationally (*54*).
- Oregon is one of 36 states that does not have a voucher program to allow children to attend private school with public dollars (*55*). Oregon, like 43 other states, allowed for inter-district enrollment. Oregon ranks 30 on the percent of K-12 students who attended public schools (56).

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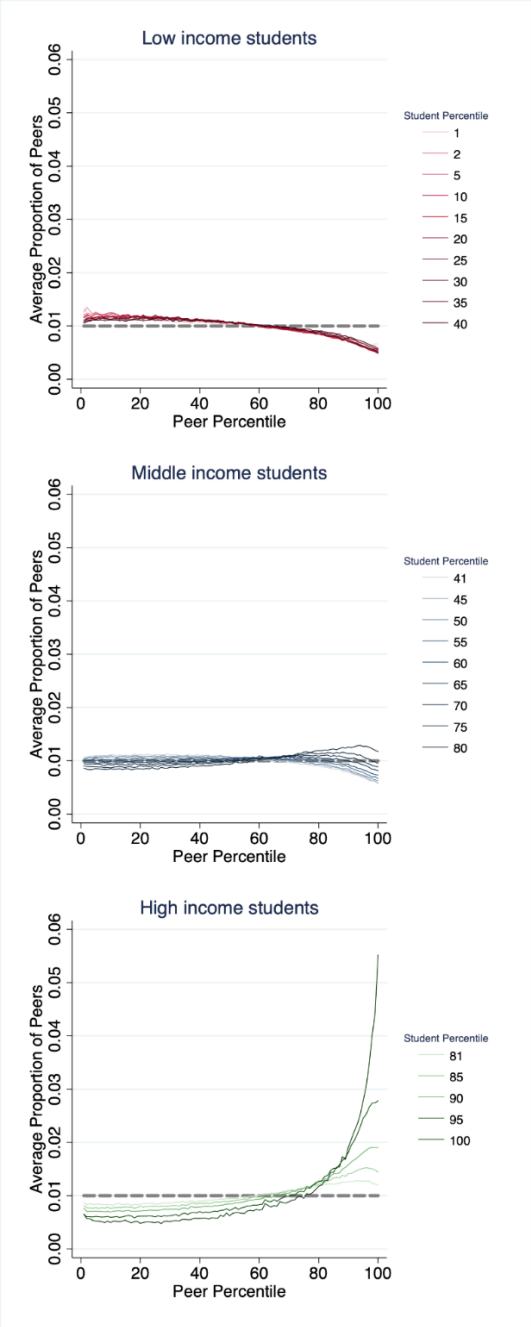

Fig 1. The average proportion of peers in each income percentile for select student income percentiles. Each line plots the average proportion of peers in each peer income percentile for students in a fixed income percentile denoted by the legend. The dashed line denotes the even distribution. Where lines fall above the even distribution, the given student percentile has a disproportionately large share of peers in the corresponding percentiles denoted on the horizontal axis. Low income student percentiles range from 1-40; middle income from 41-80, and high income from 81-100. Data from this figure come from Oregon Department of Education 2016-17 and IRS Form 1040 2012-2016. See data availability statement for more information about the data used in this figure.

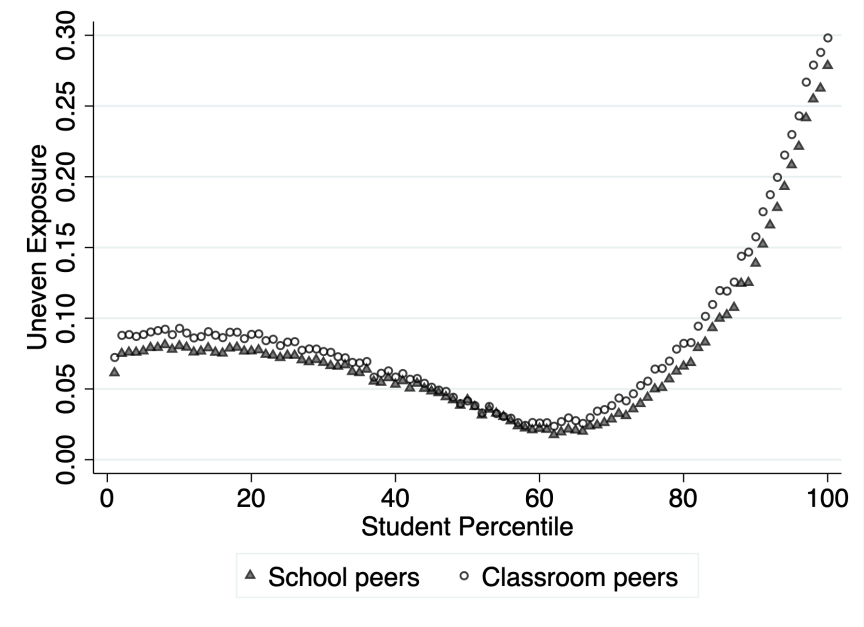

Fig 2. Summary measure of uneven exposure to school and classroom peers. Uneven exposure summarizes the degree to which the average distribution of school peer income deviates from even exposure for students in each income percentile plotted along the horizontal axis. It can be interpreted as the proportion of peers, on average, that would need to be swapped with peers in other income percentiles for students in a given income percentile to have an even peer income distribution. This statistic is plotted for both school peers (solid triangles) and classroom peers (hollow circles). Data from this figure come from Oregon Department of Education 2016-17 and IRS Form 1040 2012-2016. See data availability statement for more information about the data used in this figure.

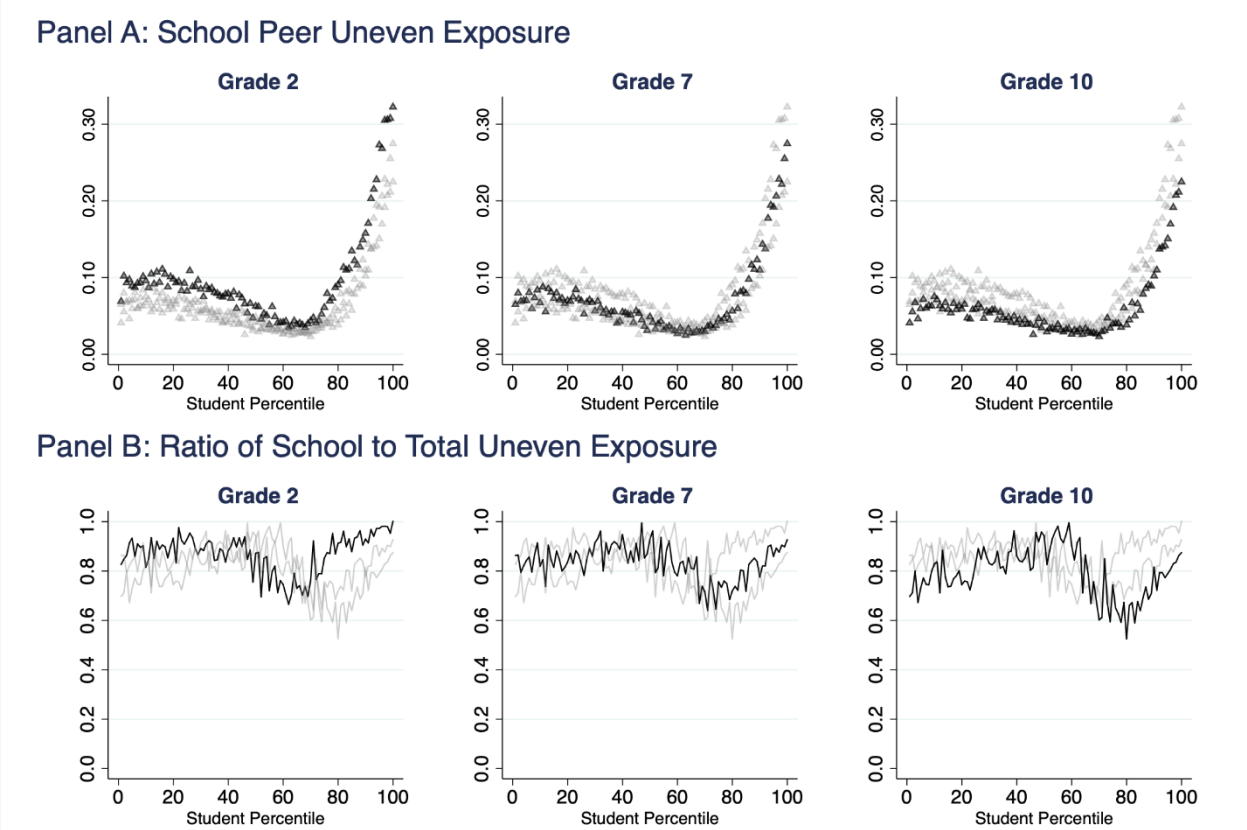

Fig 3. Summary measures of peer uneven exposure by grade. School uneven exposure and the ratio of school to total uneven exposure are calculated for peers in grades 2 (left), 7 (center), and 10 (right). In each plot, the focal grade is shown in black and the other grades in light gray for ease of comparison. The horizontal axis corresponds to student income percentiles in every plot. The ratio of school to total uneven exposure is calculated by dividing school peer uneven exposure by classroom peer uneven exposure, which is considered total uneven exposure. Data from this figure come from Oregon Department of Education 2016-17 and IRS Form 1040 2012-2016. See data availability statement for more information about the data used in this figure.

Supporting Information Text

Adjusting for missing income in state-wide averages

The building block of our analysis is the proportion of peers in each income percentile, j, for student i in each income percentile, m, which we can denote $p_{i,j}^{m}$. In our primary analysis, we average these proportions across all students in each income percentile to calculate

$$p_j^m = \frac{1}{N_m}\sum_{i \in m} p_{i,j}^m$$

where N_m is the number of students in the state in percentile m. This is the input to the uneven exposure formula shown in the main text.

For students in school s, students in percentile m share the same $p_{i,j}^{m} = p_{j,s}^{m}$, because they all share the same peer group. Thus, we can calculate the state-wide average proportions by aggregating across schools, rather than individual students:

$$p_j^m = \frac{1}{N_m}\sum_{s=1}^{S} n_{m,s} p_{j,s}^m$$

Where $n_{m,s}$ is the number of students in percentile m in school s. This is where we can implement our preferred assumption that family income is missing-at-random at the school level. Rather than define $n_{m,s}$ as the number of students *observed* in percentile m in school s, we impute $n_{m,s} = n_s \frac{\widetilde{n_{m,s}}}{\widetilde{n_s}}$, where n_s is the total number of students in school s, $\widetilde{n_s}$ is the number of students in school s for whom we observe income, and $\widetilde{n_{m,s}}$ is the number of students observed in income percentile m in school s.

SI Appendix Fig. S8 plots the uneven exposure index from the main text against one built up from our improved measure described above. For every percentile, our primary approach underestimates the uneven exposure derived from our preferred approach, but the same relative pattern across the income distribution emerges.

Why do we not use our preferred approach in the text? This approach requires students to nest in mutually exclusive subgroups, which works for schools but not for classrooms, since students who share one class often encounter different peers in their other classes. This is almost always true at the middle and high school levels, and sometimes true in elementary grades, as well. We suspect that since the approach we take in the main text is conservative for our school-level index, it will also be conservative for our classroom-level index.

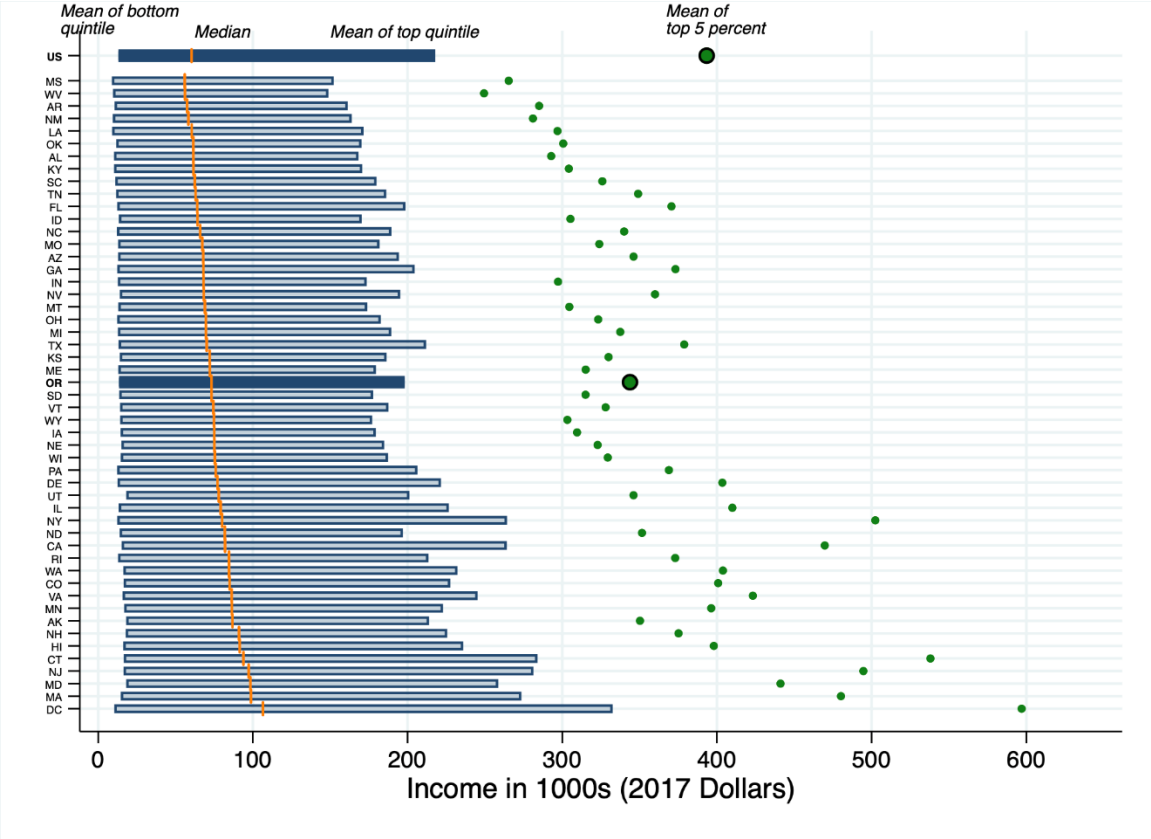

Fig. S1. Income distributions of households by state and nationally, 2017. Mean income for the bottom quintile, top quintile, and top 5 percent are of households (1). Median income is of families (2). Data Source: U.S. Census Bureau, American Community Survey (ACS), 1-year estimates.

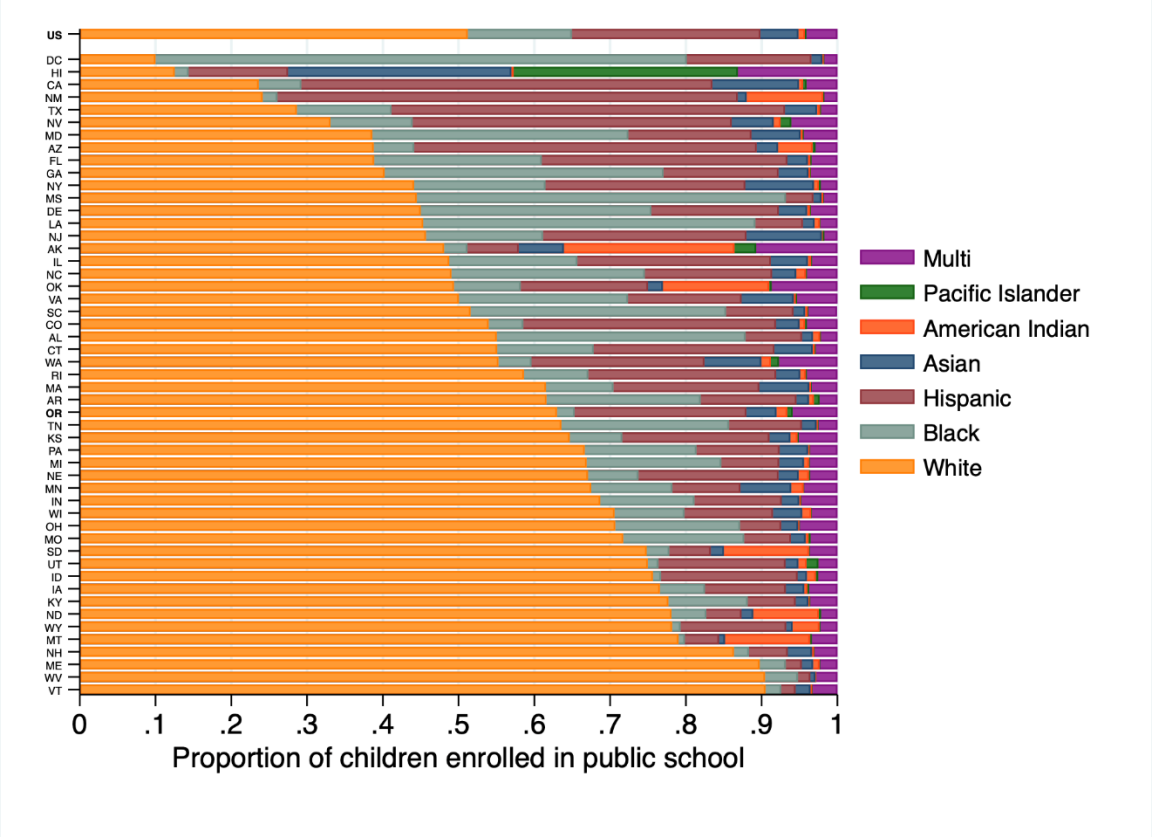

Fig. S2. Racial composition of K-12 public school students by state and nationally, 2016-2017.
Data source: U.S. Department of Education, Common Core of Data (3).

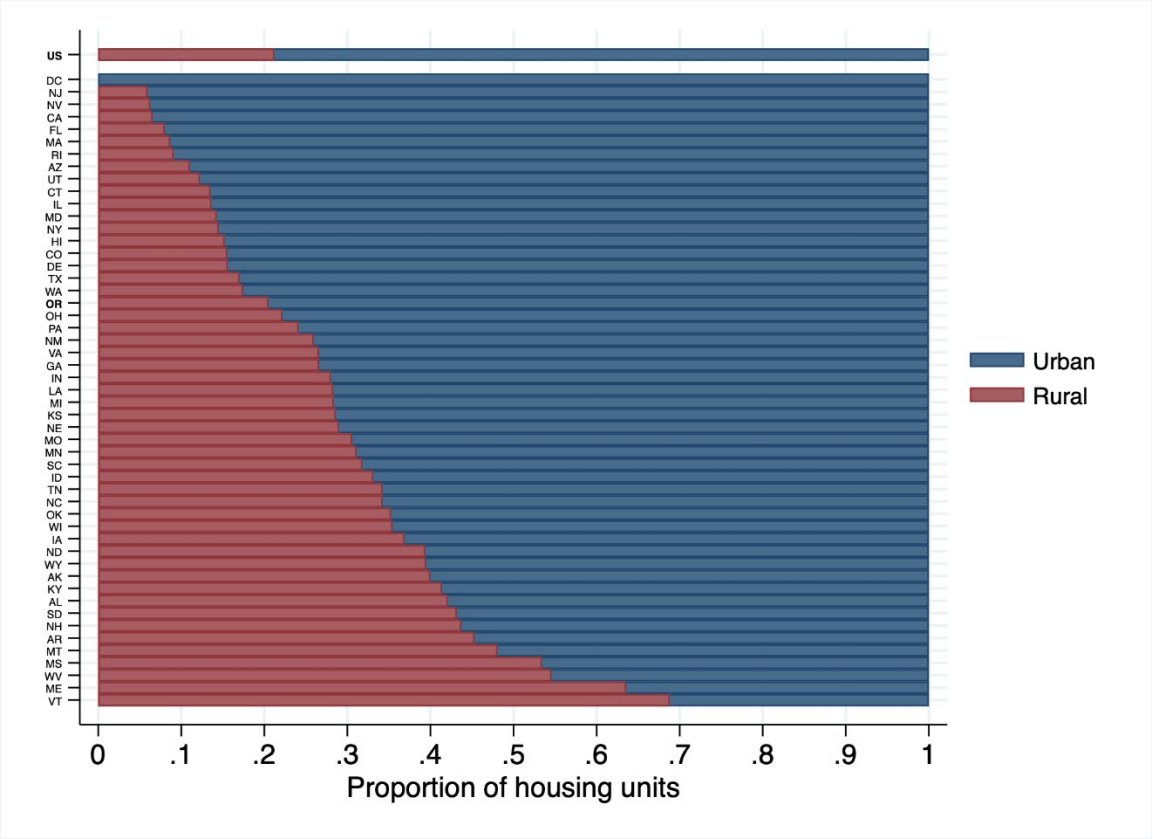

Fig. S3. Proportion of housing units located in urban and rural areas by state and nationally, 2020. This figure presents the proportion of housing units located in urban versus rural areas. For the 2020 Census, urban areas are defined as a densely populated core of census blocks that meet specific housing unit and/or population density thresholds. To be classified as an urban area, the territory must have at least 2,000 housing units or a population of at least 5,000. Data source: U.S Census Bureau public data tables, 2020 Census (4).

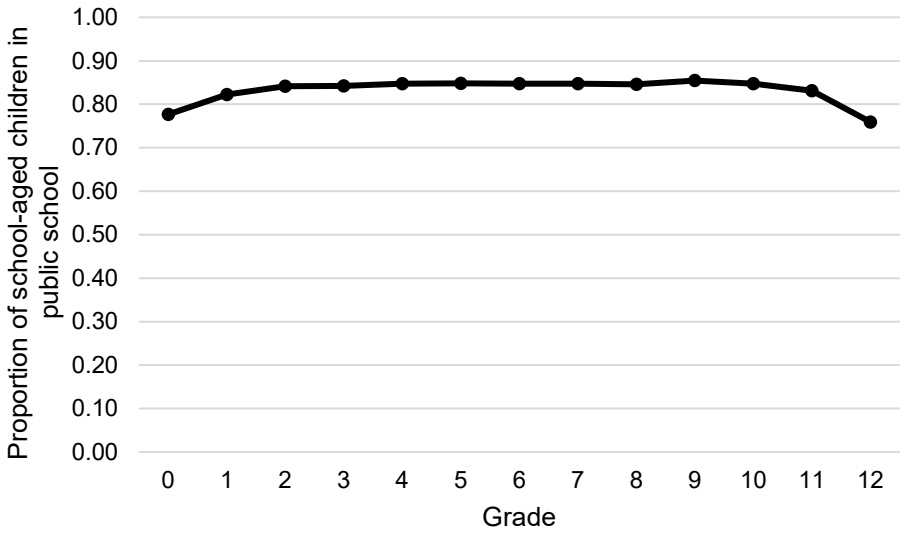

Fig. S4. The share of school-aged children in Oregon attending public school by grade.
Note. The population of school-aged children is defined as the universe of school-aged children claimed on tax returns in Oregon in 2016, and they are assigned to grades based on year of initial kindergarten eligibility. Children that additionally appear in the ODE administrative data in grades K-12 are designated as attending public school.
Data source: Oregon Department of Education 2016-17, IRS Form 1040 2016. See data availability statement for more information about the data used in this figure.

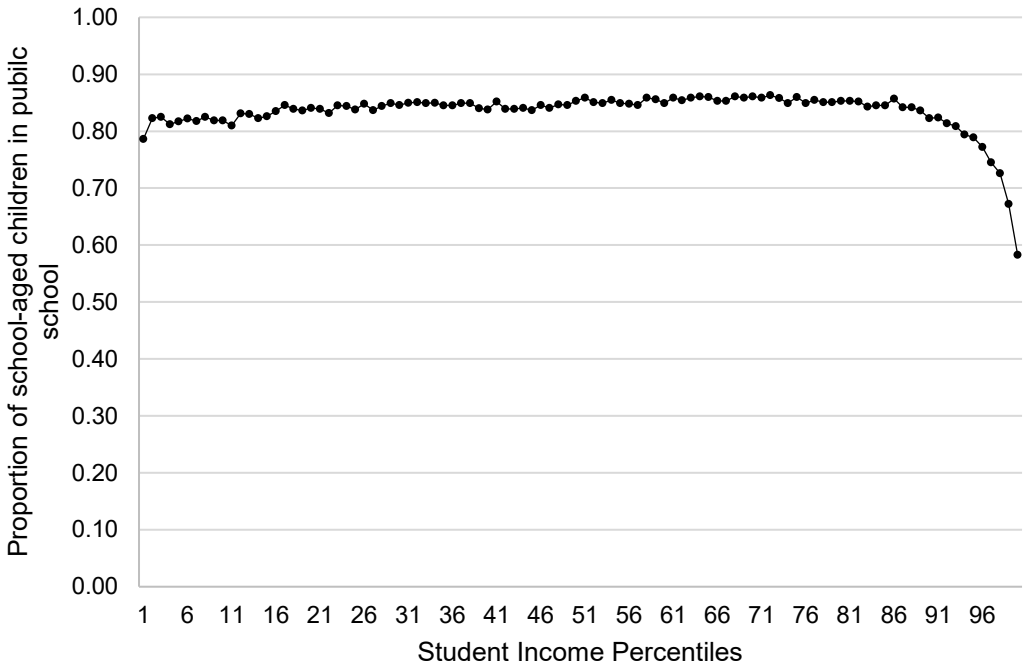

Fig. S5. The share of school-aged children in Oregon attending public school by income.
Note. The population of school-aged children is defined as the universe of school-aged children claimed on tax returns in Oregon in 2016, and they are assigned to income percentiles based on the adjusted gross income listed on those returns. Children that additionally appear in the ODE administrative data in grades K-12 are designated as attending public school.
Data source: Oregon Department of Education 2016-17, IRS Form 1040 2016. See data availability statement for more information about the data used in this figure.

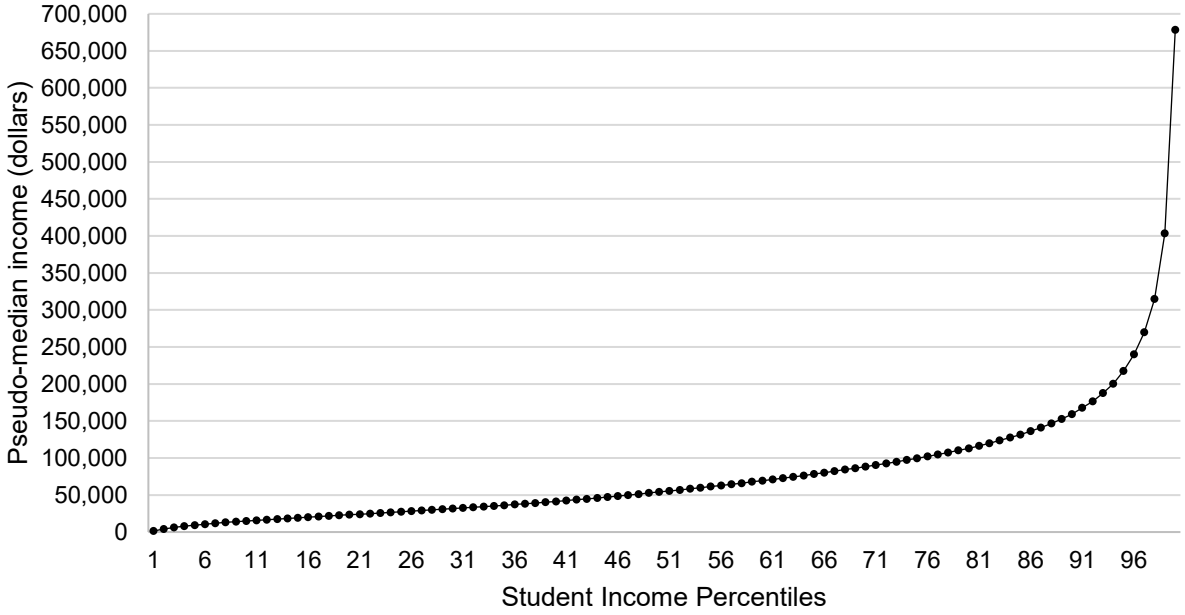

Fig. S6. Pseudo-medians of student income percentiles.

Note. To comply with Census disclosure standards, we cannot identify the exact median value, so instead we report the average income of observations within a narrow window of the true median of each income percentile.

Data source: Oregon Department of Education 2016-17, IRS Form 1040 2012-2016. See data availability statement for more information about the data used in this figure.

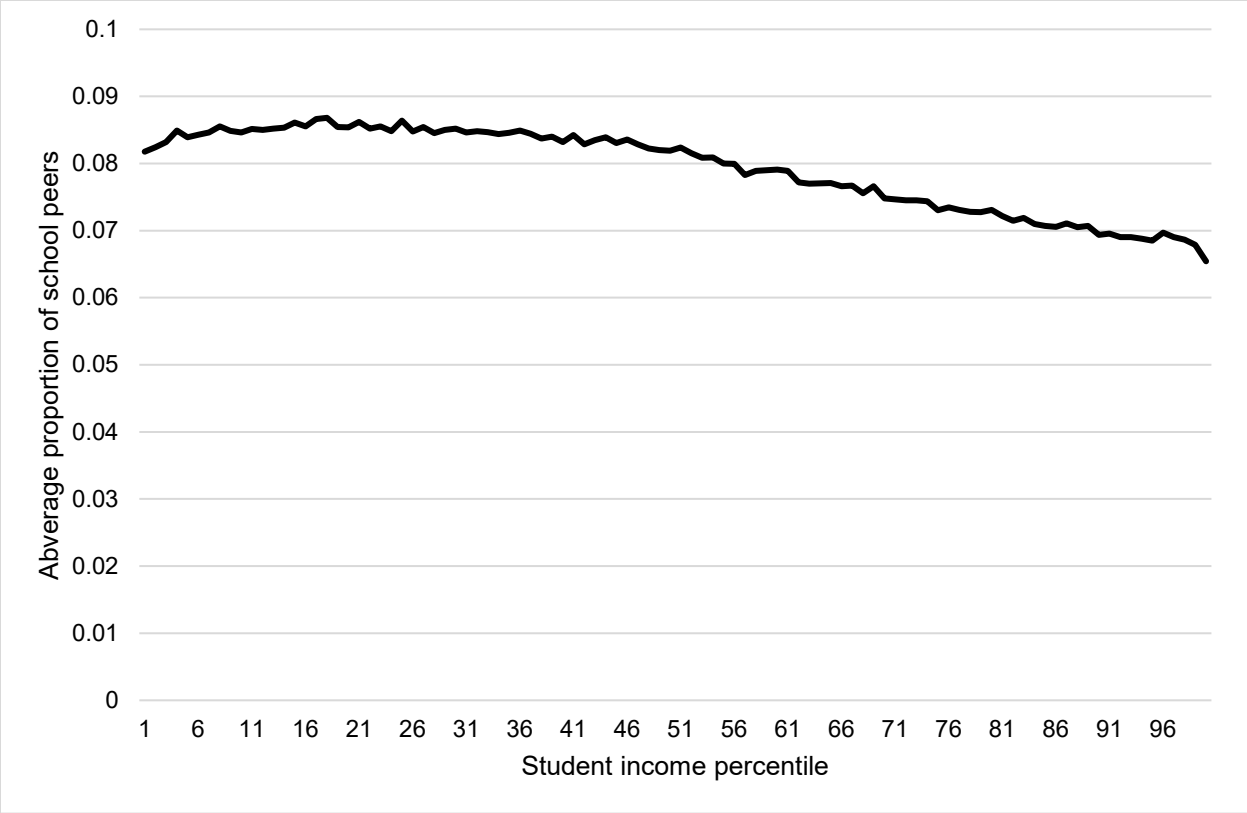

Fig. S7. The average proportion of school peers that are missing income for each student income percentile.

Note. Mimicking our analytical approach for our main results, we calculate the average proportion of peers for whom we do not observe income for each student income percentile shown on the horizonal axis.

Data source: Oregon Department of Education 2016-17, IRS Form 1040 2016. See data availability statement for more information about the data used in this figure.

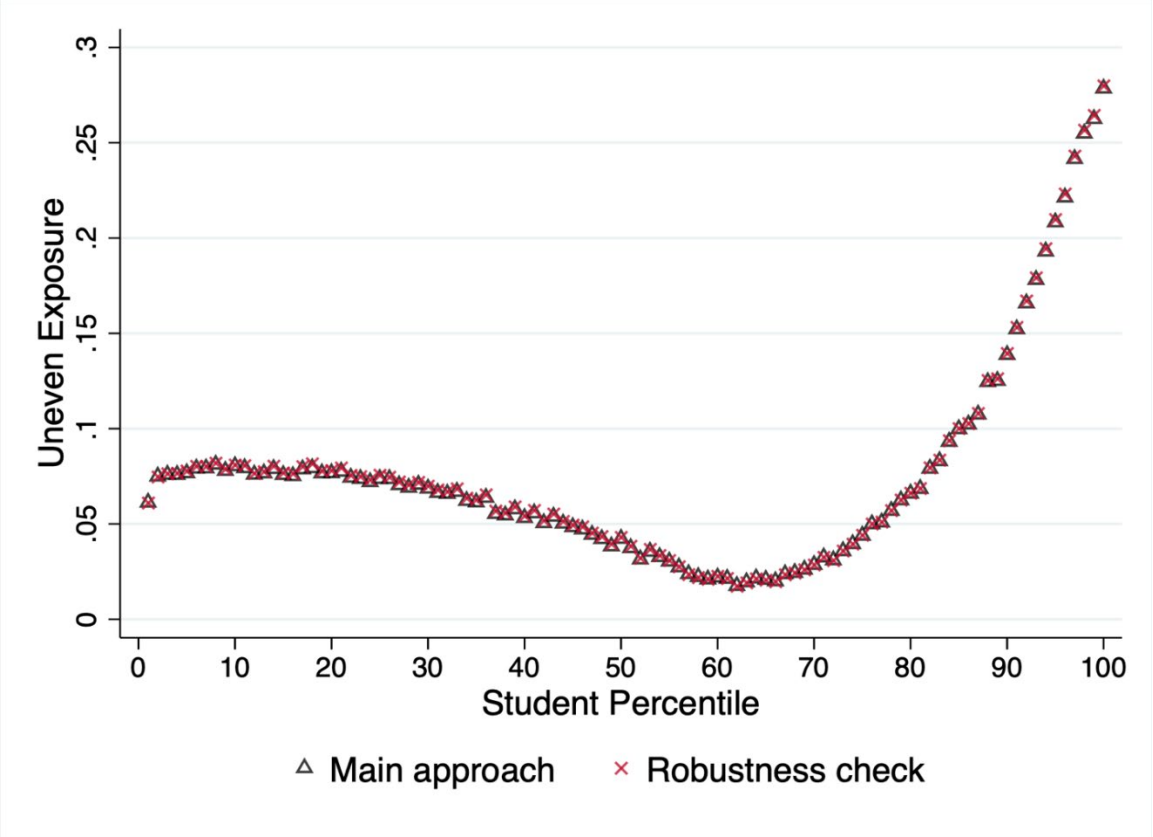

Fig. S8. Comparison of summary measures of uneven exposure to school peers across missingness assumptions.

Note. The main approach (black triangles) replicates the summary measure of uneven exposure to school peers shown in Fig. 2. The robustness check (red x's) shows the summary measure of uneven exposure to school peers using a preferred approach to handling missing income, as described in detail in the Supplemental Information document.

Data source: Oregon Department of Education 2016-17, IRS Form 1040 2012-2016. See data availability statement for more information about the data used in this figure.

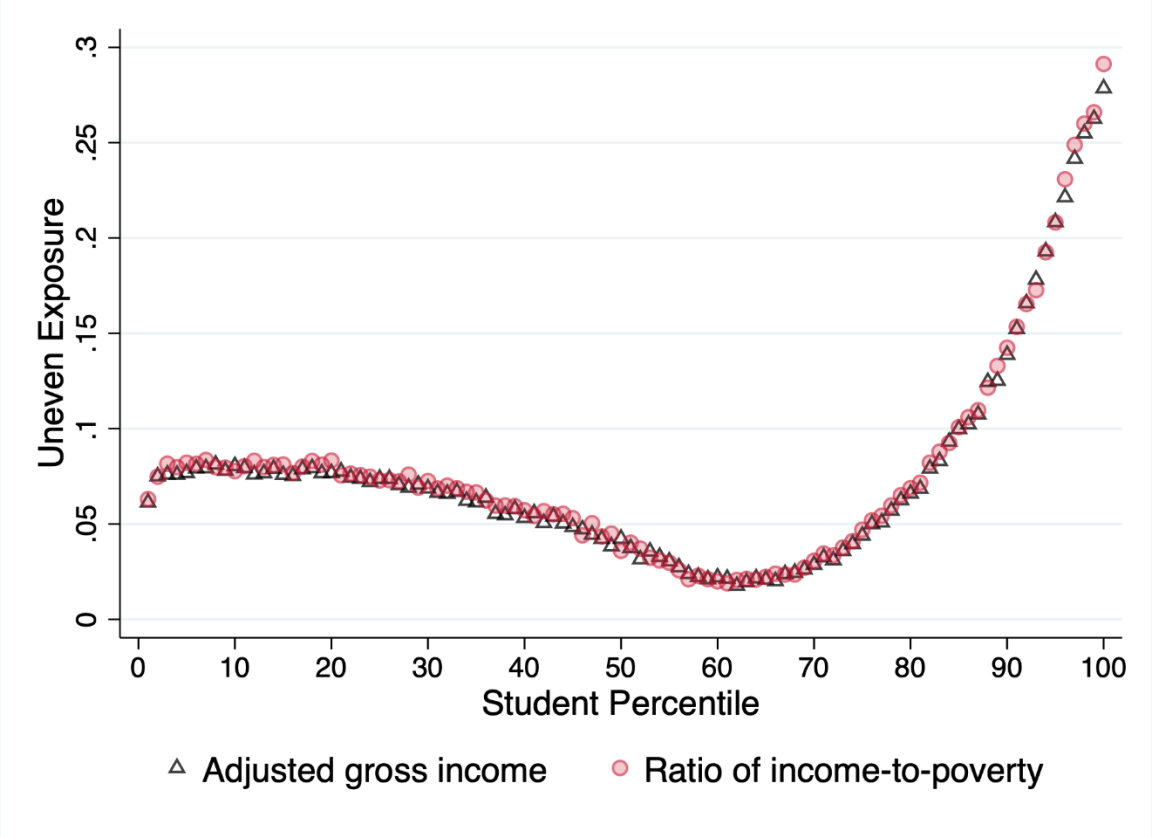

Fig S9. Comparison of summary measures of uneven exposure to school peers defining income percentiles using adjusted gross income or ratio of income-to-poverty.

Note. The AGI approach (black triangles) replicates the summary measure of uneven exposure to school peers shown in Fig. 2, while the alternative approach instead assigns percentiles by ranking observations by student family ratio of income-to-poverty. The ratio of income-to-poverty is calculated by estimating family size from IRS tax records, assigning the corresponding poverty threshold, and then dividing AGI by that threshold.

Data source: Oregon Department of Education 2016-17, IRS Form 1040 2012-2016. See data availability statement for more information about the data used in this figure.

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