Targeted Acceleration in Middle School Math: Impacts on College Entry, Degree Completion, and STEM

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Abstract

The traditional course sequence for math in middle and high school leaves many students ill-prepared to enter selective engineering and science programs. Attempts in several states to push all students through an accelerated curriculum starting in middle school have faltered; the latest Common Core curriculum postpones the teaching of algebra until 9th grade. We study a *targeted* multi-year accelerated curriculum that enables students to finish Algebra I and Geometry before high school. Entry to the program is based on 5th-grade scores in the statewide math test, with a cutoff at the 80th percentile, enabling a highly credible regression discontinuity analysis of the impacts of the program. Following students for 13 years after entry, we show that the accelerated curriculum has significant positive effects on the probabilities that marginally eligible girls enter selective colleges, complete a BA within 5 years, and graduate in STEM or business/economics. The share of girls with a degree in STEM nearly doubles (from 6% to 12%), with a comparable effect on degrees in business and economics. In contrast, we find negligible effects on boys, implying that the accelerated program brings girls up to the level of similar-scoring boys, or even ahead, in completion of degrees in the most highly-paid fields.

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The issues of how math courses should be sequenced, and at what grade to begin algebra, are highly controversial. They also matter: UC Berkeley's College of Engineering, for example, tells prospective students that "*Four years of mathematics, especially including calculus*" demonstrates the necessary aptitude in science and math to be considered for admission.[2] Unfortunately, the traditional U.S. high school math sequence of Algebra I, Geometry, Algebra II, and Pre-calculus does not expose students to more advanced math until their senior year, and omits calculus altogether. The conflict between the "hidden curriculum" required by many selective college programs and the traditional math curriculum has led to wide debate and tumultuous policy swings. In the 2000's several states including California began promoting "Algebra for All" in 8th grade.[3] But just a few years later, this effort was abandoned. More recently some districts have tried to ***delay*** algebra for all students until 9th grade (see e.g., Huffaker et al. 2024 and Huffaker, 2023). Nevertheless, parental demand for more advanced math in middle school is strong (Yoder, 2024), and enrollment in Algebra and Geometry in 7th and 8th grades remains relatively high in many states.[4]

In this paper we study the impacts of a targeted accelerated math curriculum available in the middle schools of a large urban school district in Florida ("the District"). The curriculum includes pre-algebra in 6th grade, algebra in 7th grade, and geometry in 8th grade, effectively accelerating students 2 years beyond the traditional curriculum, and 1 year beyond the more advanced tracks offered in many schools, including those in the District. Eligibility for the program is based on scores in the state's 5th-grade math test, with a threshold at roughly the 80th percentile. Thus, marginally eligible participants – for whom the causal effects of the program are identified in a regression discontinuity (RD) analysis – are relatively well qualified.[5] Indeed,

[2] This information is from the front page of the website https://engineering.berkeley.edu/admissions/undergraduate-admissions/ retrieved August 20, 2024.

[3] The National Mathematics Advisory Panel (2008) recommended that "School districts should ensure that all prepared students have access to an authentic algebra course and should prepare more students than at present to enroll in such a course by Grade 8. See Domina et al. (2015) for an analysis of the California initiative, which is widely perceived as having hurt lower-ability students. Similar findings are reported by Clotfelter et al. (2015) from an analysis of an 8th grade algebra initiative in North Carolina in the early 2000s.

[4] For example, Peters and Carter (2023, Table 2) report that average enrollment rates in Geometry in 8th grade in 2017-28 were around 18% in Utah, 13% in Virginia, and 8-9% in Florida, Maryland, Minnesota, and Washington. At the opposite extreme the rate was below 0.5% in Arkansas, Alabama, Louisiana, Mississippi, and West Virginia.

[5] The closest antecedent to our work is a recent study by Dougherty et al. (2017), which evaluates test-based admission to Algebra in 8th grade for students in Wake County NC. The threshold for this program is set at about the 20th percentile of the state test.

students who barely miss the threshold will typically enter an advanced math track in middle school.

We use information on middle and high school courses, combined with information from the National Student Clearinghouse on college enrollment and degree completion, to study the effects of entry to the accelerated sequence in 6th grade. Focusing on students whose 5th-grade scores are within a narrow bandwidth ($\pm 0.5\sigma's$) around the entry threshold, we follow 11,000 students for at least 13 years after 5th grade (i.e., allowing up to 6 years after they would normally graduate from high school). This relatively large sample allows us to conduct an informative RD analysis and make meaningful comparisons of the effect of the program on college entry and degree completion along two key dimensions that have been identified in previous work: gender, and participation in the free or reduced price lunch (FRL) program.[6]

For students as a whole we find that entry to the accelerated program (known as "Great Explorations in Mathematics, or GEM) leads to large gains in the probability of taking algebra and geometry in middle school (+23 percentage points (ppt) and +41 ppt respectively); a smaller but still significant +8 ppt rise in the probability of taking calculus in high school; and a marginally significant +5.5 ppt effect on the probability of obtaining a degree in STEM or business/economics fields within 5 years after high school. Importantly, ***all*** of the effects on college-related outcomes are attributable to girls. Entry to GEM leads to a near doubling of the probability that girls complete a BA in a STEM field (from around 6% to 12%), pushing their rate up to that of boys. There is an similar-sized effect on degrees in business or economics (from 6% to 12%), again catching up to the level of boys. In contrast, we find only small impacts on college-related outcomes of boys, centered on zero. We also see few differences in the impact of the program on FRL versus non-FRL students, suggesting that GEM helps close gender gaps in college major choice without widening disparities between richer and poorer students.

Our work contributes to two main literatures. The first is a relatively small set of studies that have tried to identify the causal effects of math acceleration on student outcomes. Research on the Algebra-for-All initiative in California (Domina et al, 2015) and on a related initiative in North Carolina (Clotfelter et al., 2015) showed that pushing all students into algebra in 8th grade

[6] Dougherty et al. (2017) find that admission to algebra in 8th grade has a relatively large and significant effect on the probability of taking pre-calculus in 11th grade for girls, but no effect for boys. They also find that the gains are concentrated among higher income students and are negligible for lower-income students.

was possibly helpful for better qualified students but definitely harmful for weaker students. Subsequent research by Dougherty et al. (2017) showed that a more targeted approach – leaving out the lowest-scoring quintile of students – leads to a positive effect on math course taking of girls, including pre-calculus in 11th grade, with little effect (positive or negative) on boys. They do not follow students to college. More tangentially, Cohodes (2020) examines an accelerated curriculum program for high-achievers in 4th-6th grades and finds positive effects on high school graduation and college entry. She does not follow students long enough to measure degree completion, nor does she present results separately by gender.[7]

We also contribute to the growing literature on gender differences in college major choice (see McNally 2020 for a recent review). Women and men choose different fields of study in college, with a lower share of females graduating in science, technology, engineering and math (STEM) fields, and in business-related fields. As noted by Altonji et al. (2016), graduates of these fields are among the most highly paid college workers, and observational comparisons suggest that differences in field of study can explain about one quarter of the gender earnings gap in the US.[8] While there appears to be a correlation between math preparation in high school and entry to STEM fields in college (see e.g., Speer, 2017; Card and Payne, 2021), there is almost no causal evidence that *increases* in math preparation lead to a *rise* in STEM majoring by young women.[9] Our results suggest that exposure to an accelerated math curriculum in middle school can help close the gender gap in both STEM and business-related degree attainment.

I. Background: District Setting and the GEM Program

The District is one of the 10 largest school districts in the country, serving around 20,000 students per grade. Its student body is racially diverse, with roughly equal numbers of Hispanic, Black and White students, just under one-half of whom are eligible for the FRL program. During the past two decades the District operated approximately 140 larger elementary schools with

[7] An older study by Altonji (1996) studied the effects of high school course taking on college completion and wages. He used the mean shares of students taking different courses in a students' high school as instrumental variables, potentially identifying the effects of access to course options. He found relatively small effects of math or science courses on college outcomes or wages.

[8] See Appendix A, where we present a simple analysis of data on 31-40 year old college graduates in the 2020 American Community Survey.

[9] Owen (2023) conducts an RCT among college students informing them of their relative performance on STEM-antecedent courses but finds no effect on major choice.

grades K-5, about 80 mainstream middle schools offering grades 6-8, and 70 conventional high schools. It also has a wide variety of charter and special service schools.

The District's mainstream middle schools offer two primary tracks of mathematics instruction: regular and advanced (nearly always taught in separate classrooms). There is also a course stream with additional instructional time for weaker students. As shown in the flowchart in Figure 1, the regular and advanced streams offer the standard math curriculum prescribed by the State of Florida in grades 6-8.[10] Students in the advanced track who perform well in 7th-grade math, however, can take Algebra I in 8th grade. In addition, since the 2000-2001 school year, all middle schools have offered the Great Explorations in Math (GEM) track (also taught in separate classrooms), which compresses the standard 6th and 7th-grade course content into 6th grade, and offers Algebra I in 7th grade and Geometry in 8th grade. The availability of GEM in all schools (including those that mainly serve lower income and minority neighborhoods) is an unusual feature of the District, and reflects its long-term effort to expand access to advanced academic programs for all children.

To qualify for GEM, students must have a 5th-grade score of 380 or above in Math and 300 or above in Reading on the Florida Comprehensive Assessment Tests (FCAT's).[11] Students have to maintain at least a B grade to stay in the program in later years, so entry to GEM does not guarantee they will complete Geometry before high school. It does, however, provide multiple pathways to completing Algebra 1 by the end of middle school, as shown in Figure 1. In contrast, students who miss the cutoff for GEM in sixth grade can be accelerated by at most one grade level to Algebra 1 in 8th grade.

II. Empirical Framework

a. Regression Discontinuity Model

We use a "fuzzy RD" approach to analyze the effect of entering GEM in 6th grade on subsequent student outcomes (Lee and Lemieux, 2010). Specifically, we estimate a locally linear first-stage model for entering GEM, with the 5th-grade math score as a running variable and a potential jump at the GEM cutoff. We estimate a parallel set of reduced-form models for

[10] The content of the regular and advanced courses is based on a curricular planning system operated by the State of Florida, known as CPALMS. The "advanced" track courses in the Flowchart (which was assembled by the District) correspond to "accelerated" courses in current CPALMS terminology.

[11] The statewide tests have changed over time but the GEM cutoff in math has remained at about the 80th percentile of the math test, while the minimum standard for the reading test has remained at around the median.

outcomes like college enrollment and degree attainment. Under standard assumptions (e.g., Hahn, Todd and van der Klaauw, 2001), the ratio of the estimated discontinuity in the outcome variable at the GEM cutoff to the estimated discontinuity in the fraction of students who enter GEM provides a causal estimate of the effect of GEM entry on students whose GEM entry status switches as their math score crosses the 380 point threshold.

Specifically, our first-stage model takes the form:

$$GEM6_i = \pi \cdot 1[M_i \geq 380] + g(M_i) + u_i, \quad (1)$$

where $GEM6_i$ is an indicator that student i entered GEM in 6th grade and $g(M_i)$ is a piece-wise linear function of the student's math score (M_i) that allows a slope change at $M_i = 380$:

$$g(M_i) = g_0 + g_1(M_i - 380) + g_2(M_i - 380) \times 1[M_i \geq 380].$$

We estimate (1) using data for students with math scores in a symmetric bandwidth BW around the 380 point threshold, i.e., using students with scores in the interval $[380 - BW, 380 + BW]$.

Likewise, we estimate reduced-form models for the jump in an outcome of interest, Y_i, at the 380-point threshold of the form:

$$Y_i = \delta \cdot 1[M_i \geq 380] + h(M_i) + v_i, \quad (2)$$

where $h(M_i)$ is a piece-wise linear function analogous to $g(M_i)$. Our IV estimator of the treatment effect of gifted status on the mean outcome of the compliers is $\beta = \delta/\pi$. We construct this using a two-stage least squares (2SLS) estimator for the second-stage model with GEM entry in 6th grade on the right-hand side:

$$Y_i = \beta \cdot GEM6_i + f(M_i) + e_i, \quad (3)$$

using the indicator $1[M_i \geq 380]$ as an instrumental variable, and parameterizing $f(M_i)$ in the same way as $g(.)$ and $h(.)$. Our baseline models have no controls other than cohort fixed effects (4 dummies) to allow for trends over time in GEM participation and college outcomes, but we show below that combinations of baseline characteristics that predict our outcomes are smooth at the 380-point threshold, and also present models with controls.

For our main analysis, we focus on a bandwidth of 25 points, which is equivalent to 0.5 standard deviation units of the math test. The first-stage and reduced-form relationships in our data are all relatively close to linear, so (as we show below) our estimates of δ and π are quite stable across bandwidths. We also discuss the bandwidth choices selected by the algorithm of Calonico, Cattaneo and Titiunik (2014) (hereafter, CCT): in most cases these are close to 25.

We note that the entry rules for GEM specify that the student has a score of 380 or higher on the 5th-grade statewide math test, and 300 or more on the 5th-grade reading test. The reading requirement introduces a source of "fuzziness" to the first stage model (1), since not all students who pass the 380 point math threshold have an eligible reading score, but it does not invalidate our basic approach. In fact, over 90% of students who barely satisfy the math test criterion have reading scores of 300 or above, so the requirement is not binding for most students. It is slightly more constraining for boys than girls, and for FRL students than non-FRL students, leading to slightly smaller first stage effects of passing the math threshold for boys and FRL recipients.

b. Compliers

The IV estimator in our fuzzy RD design identifies the average treatment effect of entry to GEM for the subset of *compliers* whose GEM entry status changes at the math score cutoff. We measure the characteristics of the compliers using the method of Abadie (2002), applied to an RD setting. Specifically, we estimate the mean of characteristic X among the compliers by the coefficient μ_x from a 2SLS regression of the form:

$$X_i \cdot GEM6_i = \mu_x \cdot GEM6_i + k(M_i) + \zeta_i, \quad (4)$$

using $1[M_i \geq 380]$ as an instrumental variable for $GEM6_i$, and including a piece-wise linear control function $k(M_i)$ similar to the ones included in equations (1)-(3). We use the same approach to estimate the mean potential outcomes $Y_i(1)$ and $Y_i(0)$ for compliers (i.e., the mean potential outcomes for compliers with $GEM6_i$ equal to 1 or 0). In the former case we fit a 2SLS model with $Y_i \cdot GEM6_i$ as the dependent variable, and interpret the estimated coefficient of the endogenous regressor $GEM6_i$ as an estimate of the mean of $Y_i(1)$. In the latter case we use $Y_i \cdot (1 - GEM6_i)$ as the dependent variable and switch the sign of the 2SLS estimate of the coefficient on $GEM6_i$ to estimate the mean of $Y_i(0)$.

III. Data and Analysis Sample

a. Data Sources

We use student-level data from the District's centralized record system for children who completed 5th grade between the 2003 and 2007 academic years. These records contain information on gender, age, race/ethnicity, and FRL/ELL status. They also include state-wide achievement test scores in reading and math for grades 3-8; course enrollments for grades 5-12, and course grades for middle and high school.

We obtain information on college enrollment and degree completion from data reported to the District by the National Student Clearinghouse (NSC). This information is only available for students who completed high school in the District. As we discuss in the next subsection, however, the probability that students stay in the District long enough to have college data is quite smooth through the 380 point math score threshold, so there is no evidence of a sample selection bias in our RD estimates of the effect of GEM entry.

b. Analysis Sample

Appendix Table A1 illustrates the derivation of our analysis sample. We start with 98,709 children who were in 5th grade in the District in the academic years 2003-2007. As shown in column 1 of the table, these children are about one-half female, 43% participated in the FRL program, and their racial composition is 35% White non-Hispanic ("White"), 34% Black non-Hispanic ("Black"), and 24% Hispanic. We then eliminate the 20% of grade 5 attendees who were not also in grades 4 and 6 in the District (column 2) – which has little effect on the characteristics of the sample. Next, we eliminate students who did not attend a traditional middle school in the District (column 3). This cuts the sample by nearly 40% and reduces the shares of FRL and Black students, reflecting the disproportionate shares of lower income and Black students who attend charter schools or other special schools in the District. It also raises the average 4th grade test scores of the students who remain.

Next we eliminate students who were not still in the District 6 years after entering 6 grade (column 4): this has a relatively small effect on the sample characteristics, and leaves us with around 33,000 students. Finally we drop the roughly 3,000 gifted students in the sample, yielding an analysis sample of 30,463 (column 5).[12] Students in this sample had an FRL participation rate of around 30% in 5th grade, and are more likely to be White and less likely to be Black than the overall pool of 5th graders. Their 4th-grade test scores are slightly above the overall average (+0.08σ's); they also come from elementary schools with above-average test scores. About 15% participated in GEM and 30% participated in another advanced math track math class in 6th grade.

[12] We exclude gifted students because, as discussed in Card, Chyn and Giuliano (2024) these students are often allowed to participate in GEM even if they miss the 380 point math threshold. In addition, they receive other services that could confound the interpretation of their entry to GEM.

A potential concern with our analysis sample is that students who get admitted to GEM are more likely to stay in the District, leading to differential selection biases on the two sides of the 380 point threshold for GEM entry. We investigate this issue in Appendix Figure A1, where we plot the probability of being included in the analysis sample from among the population of all 5th graders against their 5th-grade math scores. Reassuringly, the probability of sample inclusion trends very smoothly though the threshold: the estimated discontinuity at 380 points is 0.0018 with a standard error of around 0.01.

For our RD analysis sample, shown in column 6, we focus on students who were in the analysis sample described in column 5 but had a 5th-grade math score within 25 points of the GEM threshold of 380 points. This subset of 11,530 students has nearly 50-50 gender composition but has only a 21% FRL rate in 5th grade – less than half the District average. They are around 50% White but only 14% Black, reflecting racial disparities in test scores. Not surprisingly, students with scores near the GEM cutoff had higher math (+0.49σ's) and reading scores (+0.38σ's) in 4th grade than others in the analysis sample. About 26% ultimately entered GEM in 6th grade but 55% were in an advanced track math class; only about one-fifth were in the basic math stream in 6th grade.

The last four columns of the table show the mean characteristics of students in our RD analysis sample separately by gender and FRL status. Most characteristics are similar across gender and FRL lines, though 4th-grade math scores are slightly higher for boys and 4th-grade reading scores are higher for girls, while scores in both domains are lower for FRL students.

IV. Empirical Results

a. Validity of RD Design and First Stage

We begin our empirical analysis with Figure 2. The left panel probes the potential validity of our RD design by plotting the *predicted* probability of on-time high school graduation and completion of a college degree (associates or bachelors) within 5 years against 5th-grade math scores of students in our RD analysis sample. We use 1-point bins in this and all subsequent plots, reflecting the granularity of the underlying FCAT scores. In the RD sample we have about 200 observations per bin, so the confidence interval for a bin mean extends ±7 percentage points (ppt) when the mean is around 0.5. The prediction model uses pre-5th-grade characteristics of students, including their 4th-grade math and reading scores on the statewide

tests, their demographics (gender, age as of 5th grade, FRL status) and the average characteristics of students in their 5th-grade school (average test scores in 4th-grade and average FRL status).

As discussed by Lee (2008), in a valid RD there should be no discontinuity in the distribution of predetermined characteristics of sample members at the RD threshold: thus, we are looking for any evidence of non-smoothness in the predicted degree completion rate at 380 points. The predicted degree completion rate rises steadily with 5th-grade scores, suggesting that there is power to detect abnormal shifts in student characteristics around the 380 point threshold. The estimated local linear polynomial fit, however, shows virtually no jump. We also constructed similar figures by gender and FRL status. These are reported in Appendix Figure A2, and show no indication of discontinuous changes in student characteristics at the 380-point threshold.

We also looked for evidence of any discontinuity in the density of test scores around the threshold, as suggested by McCrary (2006). Plots of the density, shown in Appendix Figure A3, show no sign of bunching or other manipulation of the scores, which is understandable given that the test is statewide and graded electronically.

The right panel of Figure 2 shows the first-stage relationship between 5th-grade math scores and GEM entry. For reference, we also plot the relationship between test scores and the probability that a student either enters GEM ***or*** takes advanced math in 6th grade. Focusing on the first stage for GEM, we note three things. First, the relationships to the right and left of the 380 point cutoff are nearly linear, apart from a small upward "blip" in GEM participation for students with scores within 2 points of the threshold.[13] Second, among the students with scores near the cutoff there are both 'GEM always takers' (as evidenced by the positive rate of GEM entry for students with scores just below the 380 cutoff) and 'GEM never takers' (as evidenced by the roughly 40 percent of students with scores just above the 380 cutoff who do not enter GEM). Third, is a relatively large jump in the probability of GEM entry – around 52 ppt in magnitude – implying that our RD design has a powerful first stage ($t \approx 15$ for the pooled sample).

Comparing the first stage for GEM entry to the RD model for either advanced math or GEM shows that most of the students who move into GEM when their score crosses the 380

[13] This appears to be driven by policies to attempt to more nearly fill the 6th grade GEM classroom at schools where relatively few students meet the threshold.

point threshold come from the advanced math track. Only about 7 ppt of the 52 ppt total jump in the GEM enrollment share comes from students who would have been in the regular track.[14]

Appendix Figure A4 presents a parallel set of first-stage plots by gender and FRL status. All four of these figures look very similar to Figure 2B, with relatively low rates of GEM participation to the left of the 380 point threshold and large jumps in the probability of entering GEM at precisely the cutoff, of roughly 50-55 ppt in magnitude. We also see that for all four subgroups, there is a much smaller rise (5-10 ppt) in the probability of GEM or advanced track math in 6th grade, implying that most of the students who enter GEM come from the advanced track.

b. Characteristics of Compliers

Table 1 shows the characteristics of the compliers for the GEM entry cutoff: the set of students with scores near the threshold whose entry to GEM depends on whether they score just above or just below the cutoff. Panel A shows their baseline characteristics. Panel B shows their estimated potential outcomes without the GEM treatment (i.e., the means of $Y_i(0)$) for middle and high school outcomes, while Panel C shows similar means for college-related outcomes. The means of $Y_i(0)$ for our outcome variables – which we refer to "untreated complier means" – are analogous to the means for the *control group* in a simple 2-arm RCT: they characterize the counterfactual outcomes for the compliers who are admitted to GEM and have realized outcomes $Y_i(1)$ – which we refer to as "treated complier means." For reference, the first column of the table shows the means of the same variables for all of the students in our RD analysis sample (i.e., all those who graduated on time from the District and had a 5th-grade math score between 355 and 405 points).

Looking at the background characteristics in Panel A we see that on average, the compliers are quite similar to the students in the overall analysis sample. Comparing within the complier population, however, there are some interesting differences by gender: the female

[14] It is possible that passing the 380 point threshold causes some students who would have been assigned to the regular track to be assigned to the advanced track (rather than being pushed all the way to GEM). This would violate the identification assumptions underlying the interpretation of equation (3), since it would mean that passing the threshold has some potential effect on students whose GEM status remains constant (the GEM never takers). The maximum size of the shift from regular to advanced track is 7 ppt (under the assumption that all the students moved out of regular classes moved to advanced classes at the 380 point threshold), which is 13% of the jump in GEM enrollment. If the causal effect of moving from regular to advanced track were the same size as the effect of moving to GEM this would lead to an upward bias of about 13% in our estimated causal effects of GEM entry.

compliers appear to be somewhat less advantaged, with a higher shares of Black and FRL students (but a lower share of Hispanics). The girls also have nearly 0.2 $\sigma's$ higher 4th-grade reading scores than the boys. Likewise, comparisons between FRL and non-FRL compliers show relatively big differences in race, reading scores, and school peers.

Turning to Panel B, we first show the 6th-grade math course enrollments of the untreated compliers. As expected given our discussion of Figure 2B, 84% are in the advanced track math, with rates that do not vary too much by subgroup. Consistent with their advanced track placement, close to 60% complete algebra by the end of middle school, but only 1% also complete geometry, reflecting the near-absence of a pathway to geometry in the absence of GEM. Untreated compliers have fairly strong math GPA's (close to 3.5 in 6th grade, falling to 3.09 by 8th grade); as is usually the case, girls have higher grade than boys.

About one-half of the untreated compliers took a calculus class in high school, with slightly higher rates for the untreated female compliers (51%) than the males (47%) and for non-FRL versus FRL. Of the calculus takers, a higher fraction of girls achieved a grade of C- or better (0.45/0.51=88%) than males (0.34/0.47=72%). Another 14% of the untreated compliers took AP calculus (or calculus in the International Baccalaureate, IB, program), with similar rates across subgroups.

Nearly all high school students in the District take the PSAT and about 90% of our RD analysis sample took the SAT or ACT. Looking at PSAT math scores, the untreated compliers have an average score (in national percentile units) of 69.1, with a slightly higher mean for the boys than the girls (+2.5 percentiles).[15] Average scores in the PSAT reading test are a little lower and are also 5 percentiles higher for girls than boys.

Finally, turning to the post-secondary outcomes in Panel C, we see that 97% of the untreated compliers graduated high school on time, with similar rates by gender but a lower rate for FRL students. Just over 80% graduate on time and enter college the next year, with again similar rates by gender but a relatively large gap between FRL and non-FRL students. Nearly two thirds graduate on time and enter *selective* colleges, with a slightly higher rate for girls than boys, but a 12 ppt gap by FRL status. When we look at on-time college entry and persistence for

[15] We note that boys have higher math PSAT's than girls, even though they have lower grades in their math classes (and are somewhat less likely to take advanced math classes in high school). This pattern is also present in other samples, such as the gifted students from the District studied in Card, Chyn and Giuliano (2024).

at least a semester beyond the first year, we see the emergence of a relatively large gender gap (71% for girls versus 62% for boys) but no difference by FRL status.[16]

Our main outcomes of interest are degree completion and field of study. Among the untreated compliers, rates of degree completion and majoring in different fields closely parallel the overall means for our RD analysis sample: 54% complete a college degree within 5 years, 40% compete a bachelor's degree, and 17% complete a bachelors in a STEM or business-related field. The overall degree completion rates are substantially higher for untreated complier females than males, and for non-FRL than FRL participants. Despite their +18 ppt advantage in completion, however, girls are less likely to complete a degree in STEM or business-related fields. Indeed, only 24% (=0.12/0.49) of the untreated female compliers who complete a bachelors degree within 5 years graduate in a STEM or business field, versus 74% (=0.23/0.31) of the untreated male compliers.

c. Impacts of GEM Entry on Math Courses in Middle and High School

With this background, we turn to an analysis of the impacts of GEM entry on subsequent student outcomes, using the framework of equation (3). Figure 3 shows the reduced-form relationships between two main pre-college outcomes: whether the student completed algebra before high school, and whether she or he took calculus in high school. In panel A we see very clear jumps in the probability of taking algebra in middle school, and taking and passing the class, of around 10-12 percentage points. In panel B we see and somewhat less visually striking jumps in the probability of taking, or taking and passing calculus, of around 5 percentage points. Figure 4 shows the same outcomes, focusing on successful completion of each course and cutting the sample by gender and FRL status. We see a slightly bigger reduced-form rise in completing algebra by 8th grade for girls than boys, but a bigger gender disparity in the reduced forms for calculus. By FRL status, the reduced form models for both algebra before high school and calculus show somewhat larger effects for FRL participants than non-participants.

Table 2 presents a series of estimated RD models for our pooled sample and by gender and FRL status. Each column shows estimates for a different outcome, while the rows pertain to

[16] The gender gap in college persistence is a national phenomenon. The 5-year degree completion rate for the 2015 cohort of men who started at all 4-year institutions was 57.5%, while the rate for women in the same cohort was 64% (Digest of Education Statistics, 2022, Table 326.1). The 3 year degree completion rate for the 2015 cohort of men who started at 2-year institutions was 29.6%, while the rate for women in the same cohort was 34.7% (Digest of Education Statistics, 2022, Table 326.2).

different subsamples. For each sample we show estimates from models that include only 4 fifth-grade cohort dummies, and from models that include the full set of control variables used in the construction of our predicted probability of on-time degree attainment (graphed in Figure 2A). We cluster standard errors by 6th-grade middle school to allow for potential correlations in outcomes arising from school- or neighborhood-specific factors.

Column 1 presents the discontinuities in the *predicted* probability of on-time degree attainment. These are all small in magnitude and statistically insignificant, as expected given the patterns in Figure 2A and Appendix Figure A2. Column 2 presents the estimated first stage effects of passing the 380 point threshold on entering GEM in 6th grade (i.e., estimates of the parameter π in equation 1). Consistent with the plots of the first stage relationships, these range from 0.51 to 0.55 in magnitude, and are highly significant. Even for our smallest subsample of FRL participants (N=2,408) we have a t-statistic for the first stage of about 14.1 (or an F-statistic of 198), well above the threshold proposed by Lee et al. (2022) that allows conventional confidence intervals for 2SLS models to be used with no adjustment for the imprecision of the first stage.

Columns 3-13 present 2SLS estimates of the effect of entry to GEM on course participation and course grades. As shown in the first row of column 3, the overall effect on the probability of taking early algebra is 22 ppt. Given the 57% probability of taking algebra early for the untreated compliers, this implies that just under 80% of the treated compliers enrolled in algebra by 8th grade. The other 20% took the 6th-grade GEM class but failed to earn an A or B grade and were moved back to the advanced track course in 7th grade, where they did not perform well enough to enter algebra in 8th grade (see Figure 1). Comparing results by gender we see that the treatment effect of GEM entry is higher for girls (+25 ppt) than boys (+19 ppt). Taken together with the means of the untreated compliers, these impacts imply that only 15% of girls who entered GEM failed to enroll in algebra by 8th grade, compared to 27% of boys.

The results in column 4 show that the overall effect of GEM entry on enrolling in geometry in 8th grade is 41 ppt, with a significantly larger effect for girls (50 ppt) than boys (31 ppt). Combing these treatment effects with the means in Table 1 and the effects of GEM entry on algebra, it is straightforward to calculate the distributions of middle school enrollment outcomes for the untreated and treated compliers across three categories: never enrolled in algebra,

enrolled in algebra but not geometry, enrolled in both algebra and geometry.[17] These are visualized in Figure 5a. Entry to GEM has a noticeably bigger effect on the middle school math experiences of complying girls (51% of whom end up enrolling in geometry after successfully completing algebra, and 34% of whom end up enrolling in algebra but not geometry) than complying boys (only 32% of whom end up enrolling in both classes and 41% of whom end up enrolling only in algebra).

Column 5 presents estimates of the effect of GEM entry on the probability of taking calculus in high school. For the overall sample we see a marginally significant effect of +7.8 ppt. Comparing impacts by subgroups the effect is quite a bit larger for girls (+11.3 ppt) than boys (+4.0 ppt, and not significant). It is also much larger for FRL participants (+18.4 ppt) than non-participants (+5.2 ppt), implying that GEM entry closes the 13 ppt gap between calculus enrollment rates of the untreated compliers in these two groups.

Columns 6-9 present 2SLS estimates in which the outcome variable is the event of taking high school algebra (columns 6-7) or high school calculus (columns 8-9) ***and*** achieving a certain grade. In interpreting these models it is important to recognize that entry to GEM can increase the share of students taking a given course (the extensive margin) and also affect the grades of students who would take the course with or without GEM (an intensive margin effect).[18] For example, the effect of GEM entry on the overall share of students taking algebra in middle school and earning a C- or better is +23.0 ppt, slightly larger than the 22.2 ppt effect on the share of students taking algebra. The gap implies that entry to GEM must have had some effect on grades for the 57% of compliers who would have taken algebra by 8th grade even if they narrowly missed the GEM threshold. Comparing the estimates in column 7 and column 3 we conclude that entry to GEM had intensive margin effects on algebra performance all four subgroups.

The importance of intensive margin effects is even clearer for high school calculus. Recall from Table 1 that one-half of the untreated compliers would take calculus. Entry to GEM raises that by 7.8 ppt on average, but raises the fraction who take calculus and earn a C- or better

[17] Assuming that students who take geometry in 8th grade took algebra in 7th grade, the share of students who only enrolled in algebra equals the share who enrolled in algebra minus the share who enrolled in geometry.

[18] The standard assumptions for interpretation of an IV estimator in a fuzzy RD setting rule out effects on the "GEM always-takers" (i.e., those who would enroll in GEM regardless of their 5th-grade math score vis-à-vis the threshold), but do not rule out effects on students who would take a certain course regardless of GEM status.

by 9.4 ppt. Interestingly, for 3 of the 4 main subgroups we find a larger effect of GEM on the share taking calculus and earning C- or better than on just taking the class. The only exception is FRL students, who have a large extensive margin effect (+18.4 ppt) and a slightly smaller gain in the share earning C- or better. Assuming that entry to GEM did not lower the course grades of FRL's who would have taken calculus even without GEM, these estimates imply that at most 80% of the extensive margin FRL's (those who took calculus because of GEM) finished the course with a C- or better. While this might be seen as a problem of "mismatch," we note that the share of the *untreated* FRL compliers who took calculus and earned a C- or better is only 66% (see Table 1), so the extensive margin group may have performed comparably.[19]

Figure 5b summarizes the relative impacts on high school calculus course taking and grade outcomes for female and male compliers. As in Figure 5a, we show the distributions for the untreated and treated compliers. The effect of GEM entry on girls is larger across the board, with a gain of 11 ppt in the share of girls with scores around the 380 threshold who finish high school with a C- or better versus a 7 ppt for boys, and a gain of 8 ppt in the share of girls who have a B- or better in calculus versus 6 ppt for boys.

Finally, columns 10-13 show effects of GEM entry on math GPA's in 6th through 8th grades, and in all years of high school. For the overall sample and all subgroups there are large negative impacts of entering GEM on 6th grade math GPA's, on the order of 0.7 of a letter grade. There are also negative, but smaller, effects on 7th and 8th grade math GPA's. These impacts presumably arise because teachers in easier and harder classes tend to award similar distributions of grades: thus a student at the 80th percentile of the 5th grade math FCAT test will tend to get a higher grade in advanced track math (where she is close to the top of the distribution of abilities) than in GEM (where she is closer to the bottom). Importantly, by high school these negative impacts have largely disappeared, with the possible exception of boys. Even for boys, however, the effect is small in magnitude and far from statistical significance (t=0.75). And considering that more GEM entrants end up taking calculus, the similarity of their GPA's to those of students who missed the GEM cutoff is reassuring.

[19] For example, if GEM raised the share of the calculus "always-takers" earning a C- or better from 66% to 85% (which we regard as a plausible upper bound) then the implied share of incentivized calculus-takers earning a C- or better is 66%.

We have also investigated the effects of GEM entry in 6th grade on a variety of other high-school-related outcomes, including enrollment in *any* advanced high school math class (pre-calculus, calculus, or statistics); enrollment in AP or IB calculus; completion of AP or IB calculus with a score of 3 or better (on a 5 point scale of 1-5, with 5 being the top); overall high school GPA; PSAT math and verbal scores; and whether the student took the SAT or ACT. The estimates for these outcomes are reported in Appendix Table 2.

In brief, we find effects on advanced math that are closely aligned with the effects on calculus, with a large positive boost for girls (+12.9 ppt, t=3.3) but only a small insignificant effect for boys (+3 ppt); and a large positive effect for FRL participants (+17.0 ppt, t=3.1) with a smaller boost for non-FRL participants (+6 ppt, t=2.4). For AP/IB calculus enrollment we find a modest positive overall effect (+4.p ppt, t=1.8) that is a little larger for boys, but for completion of the class with a grade of 3 or better we find only small effects. Likewise, we find no effects on overall high school GPA, very similar to the effects on GPA in high school math.

Interestingly, we find a significant and relatively large positive effect on girls' PSAT math scores (+4.5 percentiles, t=2.9) – large enough to overcome the 2.5 percentile female disadvantage in this domain among the untreated compliers. For boys the effect on math PSAT is positive (+1.1 percentiles) but insignificant; the effects on both FRL and non-FRL students are positive, as is the overall effect for all students (+2.8 percentiles, t=2.5). We also find a noticeable boost in the probability that girls take either the ACT or SAT (+5.1 ppt, t=2.7), suggesting that girls who went through GEM become more interested in applying to selective college programs (a result confirmed below), but no effect for boys, and no large differences by FRL status.

d. Impacts of GEM Entry on College Outcomes

Next we turn to college-level outcomes. Panels A and B of Figures 6, 7, and 8 show the reduced form relationships between 5th-grade reading scores and 3 main outcomes: the probability of finishing high school on time and entering college within 1 year (Figure 6); the probability of earning any college degree within 5 years after the "normal" high school completion year (Figure 7); and the probability of earning a bachelor's degree in STEM or business-related fields within 5 years (Figure 8). In each case, panel A shows the reduced forms by gender, while panel B shows the reduced forms by FRL status. We discuss panels C and D below.

Looking first at on-time college entry in Figure 6, we see a small upward jump at the 380 point threshold for girls, a small downward jump for boys, and no jumps for FRL or non-FRL students. We also note that the reduced form relationship for FRL students is relatively noisy, reflecting the smaller sample size for this subgroup. Turning to Figure 7, we see some indication of a positive jump in the probability of obtaining a degree within 5 years for girls, but no such effect for boys. The reduced form plots by FRL status also show relatively little evidence of jumps at the GEM threshold. The reduced form plots in Figure 8 for the probability of obtaining a STEM or business degree show a clear jump for girls, but no effect for boys, and only limited evidence of any discontinuity for either FRL or non-FRL participants.

Table 3 summarizes our estimates of the effect of GEM entry on college-level outcomes, using the same format as Table 2. The first stages for all the underlying models are the same as the ones reported in column 2 of Table 2. Column 1 presents estimates of the effect of GEM entry on the probability of graduating high school 7 years after 5th grade (i.e., on-time). None of the estimated effects are large or statistically significant. Column 2 presents models for on-time college entry (the same outcome shown in Figure 6). The overall effect (in row 1) is very close to 0, but this averages a slightly positive effect for girls (+5ppt, t=1.9) with a slightly negative effect for boys (-4 ppt, t=0.9). We note that the corresponding RD estimates from models with controls are smaller in magnitude, and suspect that 0 is a good estimate for both groups.

Nevertheless, it is useful to check whether either gender-specific estimate is sensitive to choice of bandwidth. (Recall that we are using a symmetric bandwidth of 25 points in our main tables.) We investigate this issue in panels C and D of Figure 6, where we show the 2SLS estimates as we vary the bandwidth from 10 points to 40 points), along with their 95% confidence intervals. For reference we also highlight the bandwidth choice selected by the CCT algorithm (using a symmetric uniform kernel and CCT's "regularization" procedure), which turns out to be 25 points for both genders. We see that longer bandwidth choices yield more precise estimates and that the estimates for boys tend to become slightly smaller in magnitude (less positive for girls and less negative for boys) with longer bandwidths. A similar exercise for FRL and non-FRL participants (panel D) yields estimates that center around 0 for both groups for most of the range of choices.

Column 3 shows estimates for models of the probability of enrolling at a selective college or university with a year of normal high school graduation time.[20] Here the overall effect is slightly positive, arising from a relatively large positive effect for girls (+11 ppt, t=2.9) and a smaller negative effect for boys (−7 ppt, t=1.3). Again, the estimates from models with controls are slightly smaller in magnitude though the estimate for girls remains statistically significant at conventional levels (t=2.5), providing reasonable evidence of a positive impact. Interestingly, for selective college enrollment there are also estimated effects of opposite sign for FRL participants (−6 ppt, t=0.9) and non-FRL participants (+5 ppt, t=1.4), though both are statistically insignificant.

Many students who enter college stay for only a year or less (see e.g., DesJardin et al., 2002), leading to student debt but little economic benefit. Column 4 presents estimates of the effect of GEM on the probability that students enroll in college and persist for at least a year. We estimate small positive but statistically insignificant effects on this outcome for our overall sample and for boys and girls, with somewhat larger but opposite signed effects for non-FRL participants (+8 ppt, t=2.6) and FRL participants (−9 ppt, t=1.1). When we look at the probabilities of obtaining any degree in 5 years (column 5) or a bachelor's degree in 5 years (column 6), however, the effects for both FRL participants and non-participants become positive, suggesting that the negative short term effect on college persistence for FRL participants is misleading.

The estimates in columns 5 and 6 suggest that GEM entry has a positive effect on the probability that female students ultimately get a college degree, with nearly all of the gain attributable to a 9 ppt rise in bachelors attainment. The effects for males are very close to 0, while the estimates for FRL and non-FRL subgroups are both slightly positive but statistically insignificant. As shown in Figure 7C, the estimated effect of GEM on the probability that girls obtain a degree within 5 years is highly robust to bandwidth choice, while the effect for boys is more negative at low bandwidths and then tends to 0. A similar exercise comparing effects at different bandwidths for FRL and non-FRL participants (Figure 7D) suggests that the effects for both groups are fairly stably estimated once the bandwidth is larger than 18 points.

[20] The selective designation is based on the school's Carnegie Classification in the year the student enrolled. We note that 80% of the untreated compliers who enter college on time enter a selective college.

Columns 7-11 present estimated models for the probability of obtaining bachelor's degrees in various fields: any STEM field in column 7, STEM or business-related fields in column 8, health or education (two of the most common fields for females) in column 9, business-related fields in column 10, and health fields in column 11. For the overall sample (row 1) we estimate a small positive effect on STEM (+2.4 ppt, t=1.2), a comparable effect on business-related fields (+2.9 ppt, t=1.3); a marginally significant positive effect on STEM or business-related fields (+5.5 ppt, t=2.0), and marginally significant negative effects on health (−2.9 ppt, t=2.1) and health or education (−3.2 ppt, t=2.0). The sign and magnitudes of these effects are quite similar for FRL and non-FRL participants, suggesting that economically advantaged and disadvantaged students are impacted similarly by entry to GEM.

Like the impacts on degree completion, however, all of the effects of GEM on field of degree are concentrated among girls. The estimates for girls show a relatively large boost in STEM degree completion (+6.4 ppt, t=2.7) and in business or economics (+6.1 ppt, t=2.2), and a combined boost of 12.5 ppt (t=3.0) in STEM or business-related fields. Some of that gain appears to be at the expense of degree completion in health or education fields (−4.4 ppt, t=1.8). In contrast, we only small effects, all far below conventional significance levels, on the fields of degree of boys.

Figures 8C and 8D show the robustness of the estimated effects on degree completion in STEM or business related fields to choice of bandwidth. For girls, the estimated effects are remarkably similar across bandwidths, while for boys the estimated effects are slightly more negative at low bandwidths but settle down very close to 0 for bandwidths above 25 points. The estimated effects on FRL and non-FRL students are also quite robust.

Finally, columns 12-14 report estimates for three outcomes that allow more time for students to achieve post-secondary benchmarks. In column 12 we redefine on-time college entry as enrollment within 2 years of normal high school completion. The estimated effects of GEM on this outcome are very similar to those reported in column 2, which looks at enrollment within 1 year of normal high school completion. Columns 13 and 14 present models for obtaining a bachelor's degree within 6 years of normal high school completion, and obtaining a bachelor's degree in a STEM field within 6 years. The estimates from these models are very similar to those in columns 6 and 7, respectively, suggesting that conclusions based on the standard 5-year window are robust.

V. Summary and Conclusions

There is much disagreement about how to structure the math curriculum in American schools. On one hand, the science and engineering programs at many selective schools ask for evidence of mastery of advanced math in high school, especially calculus. This leads the parents of higher-achieving students to demand access to algebra and geometry in middle school so their children have a pathway to calculus by the end of high school. On the other hand, previous efforts to push "algebra for all" in middle school are perceived as having failed, especially for weaker students. A possible resolution is the availability of targeted acceleration programs like the GEM program we study in this paper.

GEM is a three-year program that compresses the standard 6th and 7th grade curriculum into a single year, leading to Algebra I in 7th grade and Geometry in 8th grade. Admission is limited to students who score above the 80th percentile on the statewide 5th-grade math test, and it has "off-ramps" after 6th and 7th grade that allow students to return to the conventional math track if they are struggling. In fact only about 40% of GEM entrants actually complete all three years, but 80% complete algebra by the end of 8th grade.

We use the admission threshold for GEM to conduct a regression discontinuity-based analysis of the effects of entering GEM on subsequent course taking and grades in middle and high school, and on post-secondary outcomes, including degree attainment and field of specialization. We reach two main findings. First, the program has little or no effect on the college outcomes of boys, but relatively large effects on outcomes for girls, leading to gains in degree attainment and the probability of majoring in math-intensive fields (STEM and business/economics). Second, the impacts are about the same for economically disadvantaged students (who were receiving free or reduced price meals in 5th grade) and more advantaged students. Thus, GEM helps narrow gender gaps without widening disparities across income groups.

The main impacts of GEM for girls are summarized in Figure 9. We show the means of each of 7 outcomes for the *untreated compliers* – the set of students who form the control group in a fuzzy RD design – as well as the causal impacts of entry to GEM on the *treated compliers* – the set of students who form the treatment group. Starting in middle school, GEM entry leads to a 27 ppt increase in completing algebra by 8th grade, relative to a baseline of 58% for the untreated compliers. The rather high baseline illustrates the fact that most participants in GEM

would have been in the advanced math sequence in the absence of GEM, which allows students who perform well in 7th grade to take algebra in 8th grade. About one-half of girls who enter GEM also enroll in geometry in 8th grade. By comparison, only 30% of boys make it all the way to the 3rd year of GEM.

In high school, participation in GEM leads to an 11.5 ppt increase in the fraction of girls who successfully complete calculus, and a 4.5 percentile increase in their PSAT math scores. Among students with math scores just below the GEM threshold, boys have higher PSAT math scores than girls. But for those with scores just above the threshold, GEM pushes girls' scores above those of boys.

At the college level, GEM leads to a 9 ppt increase in 5-year bachelor degree completion rates and most remarkably, a doubling of the fractions of girls who graduate with bachelor's degrees in STEM and business or economics. Entry to GEM leads nearly 25% of girls to graduate in the relatively highly paid STEM and business-related fields – closing the gap with boys and potentially having large effects on the future careers of these young women.

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Figure 1. Math Pathways in Middle School

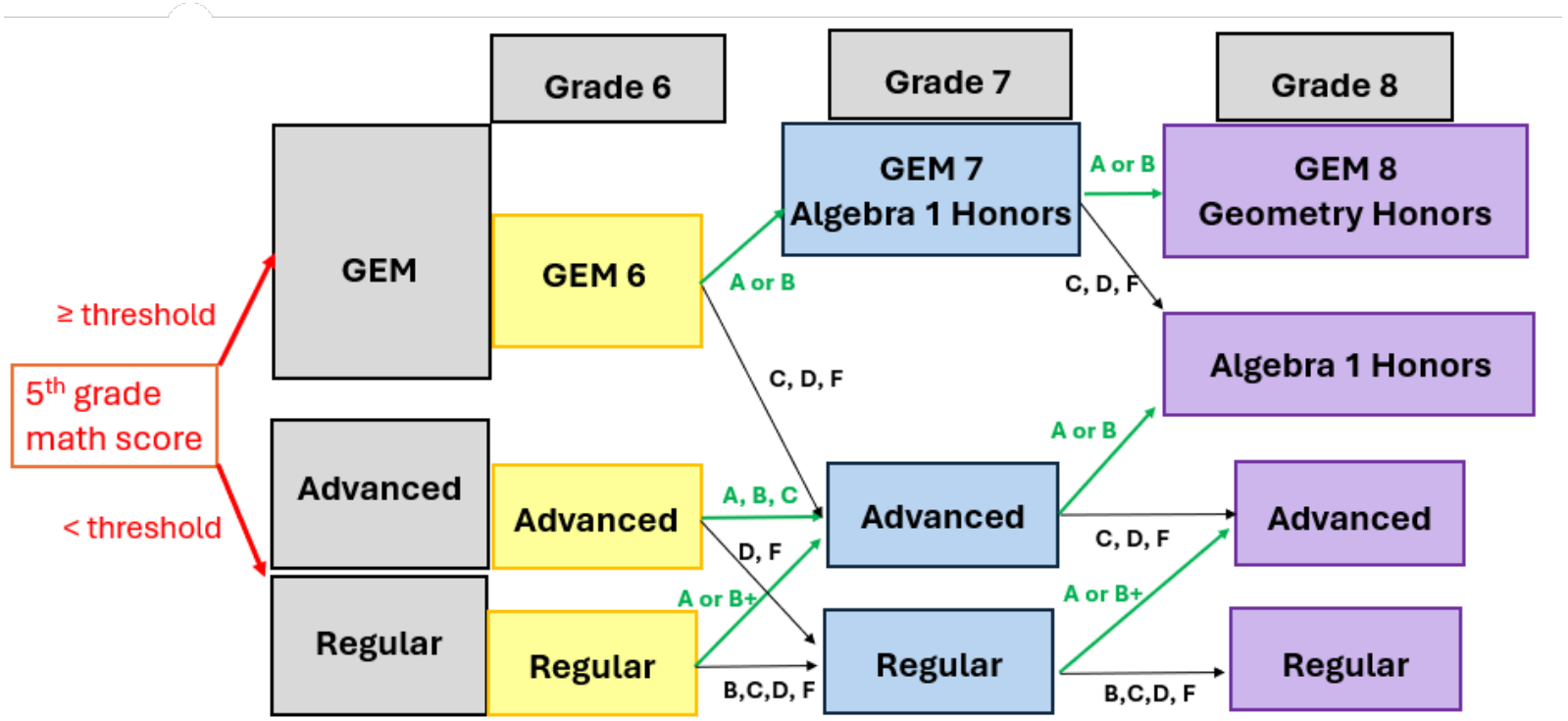
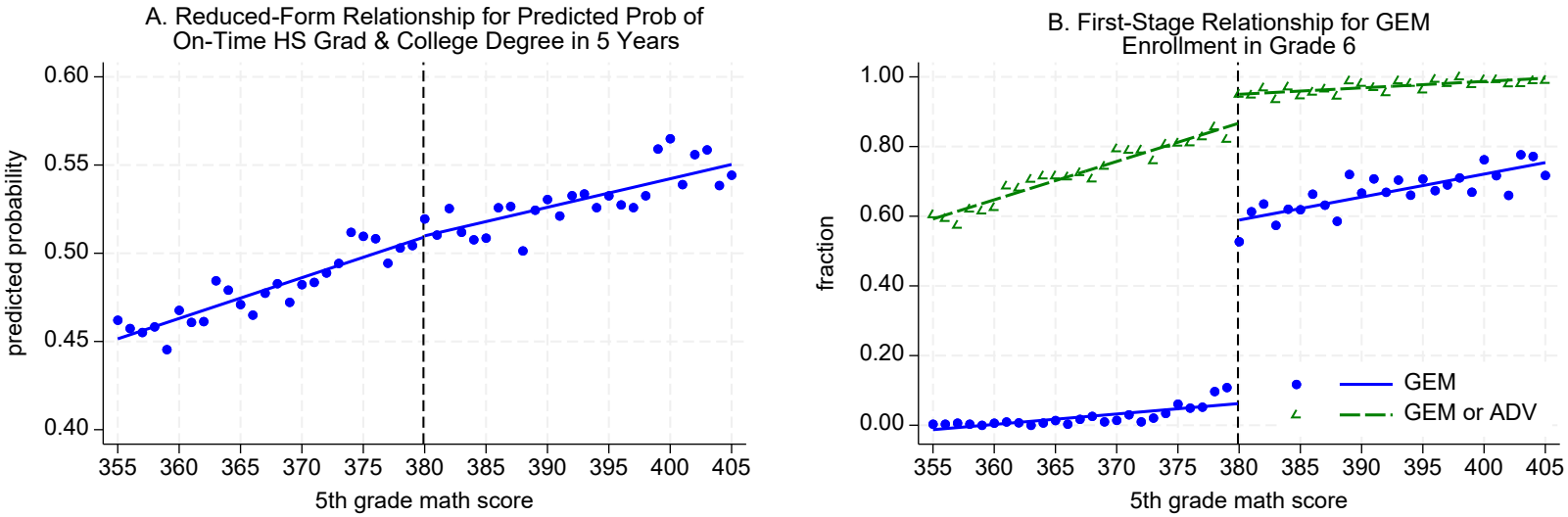
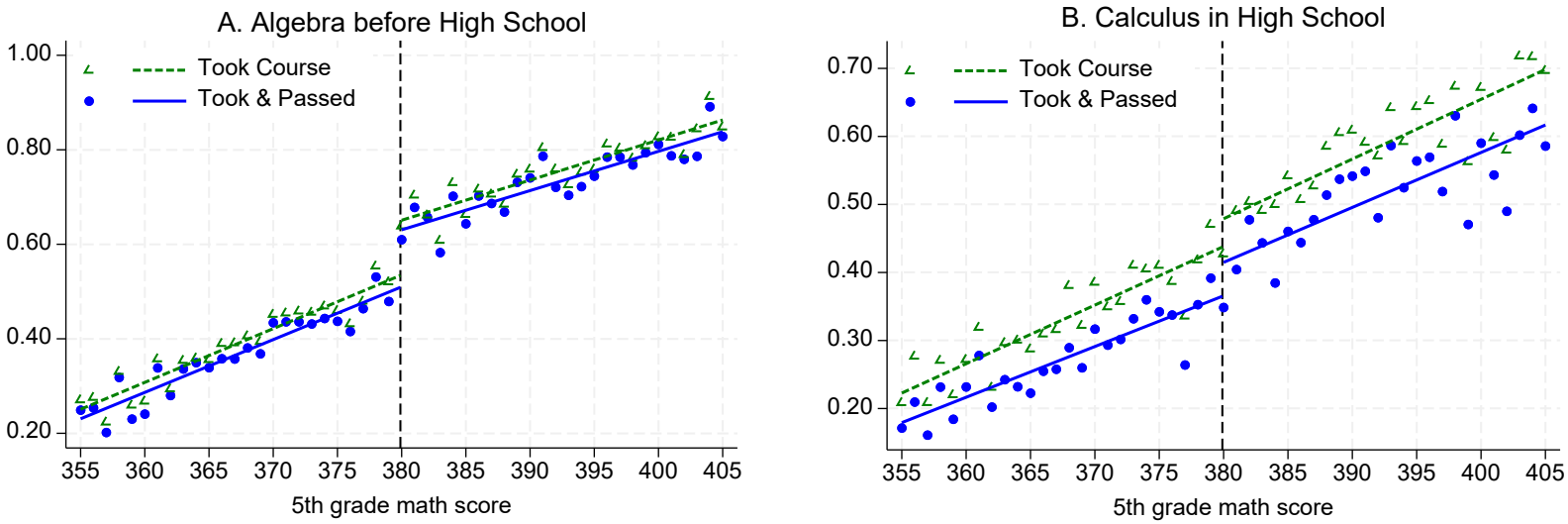


Figure 2. Predicted Outcome and GEM Enrollment by Fifth-Grade Math Score, Pooled Sample



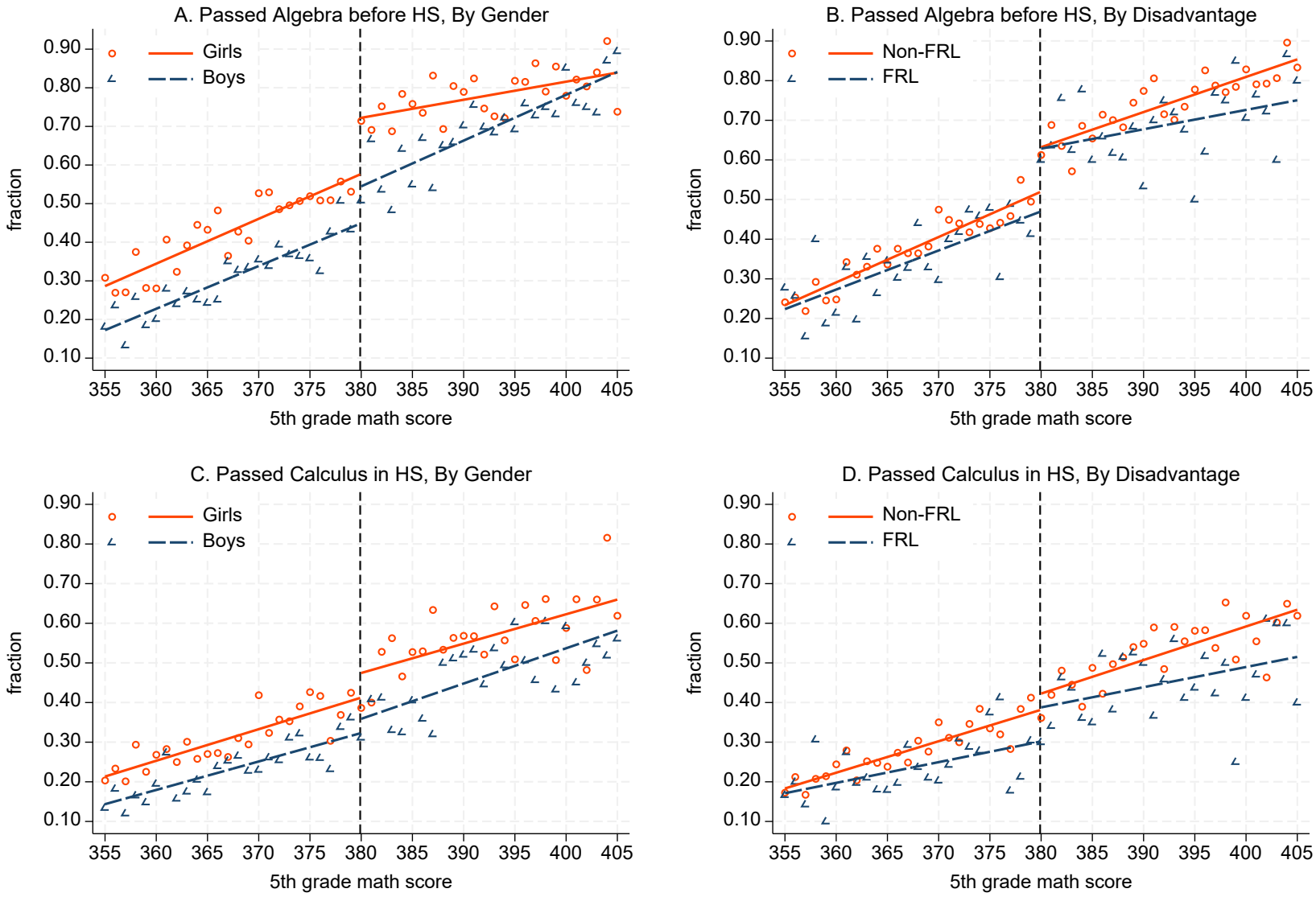
Notes: This figure plots sample means of the dependent variable at each value of fifth-grade math score (the running variable) along with fitted values from local linear RD models with a symmetric bandwidth of 25. In Panel A, the dependent variable is an index of pre-determined student characteristics constructed as the predicted probability of graduating from high school on time and earning a college degree within 5 years of high-school graduation. The prediction model is fit using students with fifth-grade math scores below the GEM eligibility threshold of 380 and includes second-order polynomials in math and reading test scores from fourth grade and in student age in fifth grade; indicators for student gender, race/ethnicity, FRL status, ELL status, and cohort; and average test scores and fraction FRL of the school where the student is enrolled in fifth grade. In panel B, the dependent variables are an indicator for participating in the GEM program in sixth grade (the treatment variable, in blue circles) and an indicator for participating in *either* GEM *or* advanced-track math (in green triangles).

Figure 3. Reduced-Form Relationship for High School Outcomes, Pooled Sample



Notes: This figure plots sample means of the dependent variable at each value of fifth-grade math score (the running variable) along with fitted values from local linear RD models with a symmetric bandwidth of 25. In Panel A, the dependent variables are indicators for having enrolled algebra in middle school (grade 7 or 8) and having completed it with a passing grade (C- or better). In Panel B, the dependent variables are having enrolled in calculus in high school (grades 9-12) and having completed it with a passing grade.

Figure 4. Reduced-Form Relationship for Successful Completion of Early Algebra / HS Calculus, by Gender and Disadvantage



Notes: This figure plots sample means of the dependent variable at each value of fifth-grade math score (the running variable), along with fitted values from local linear RD models with a symmetric bandwidth of 25, separately by gender (Panels A and C) and by FRL status (Panels B and D). In Panels A and B, the dependent variable is an indicator for taking algebra in middle school (grade 7 or 8) and earning a passing grade (C- or better). In Panels C and D, the dependent variable is an indicator for taking calculus in high school and earning a passing grade (C- or better).

Figure 5a: Complier Distributions of Middle School Math Enrollment

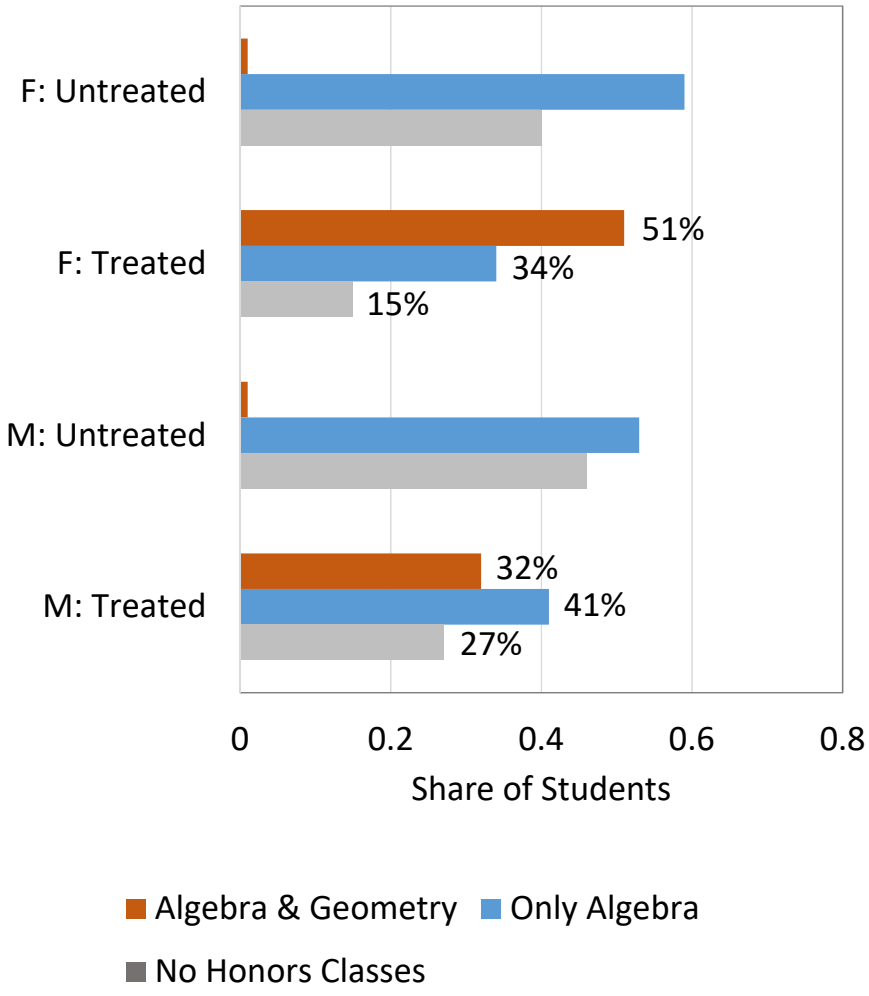


Figure 5b: Complier Distributions of High School Calculus Outcomes

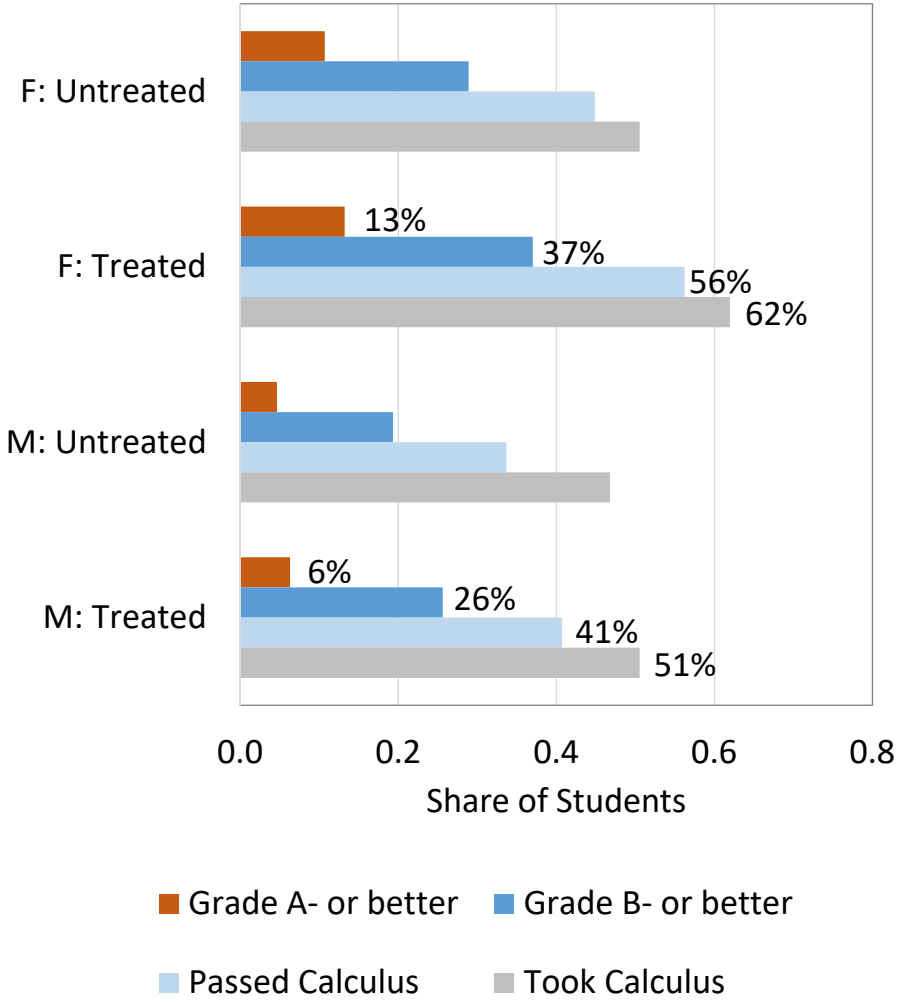
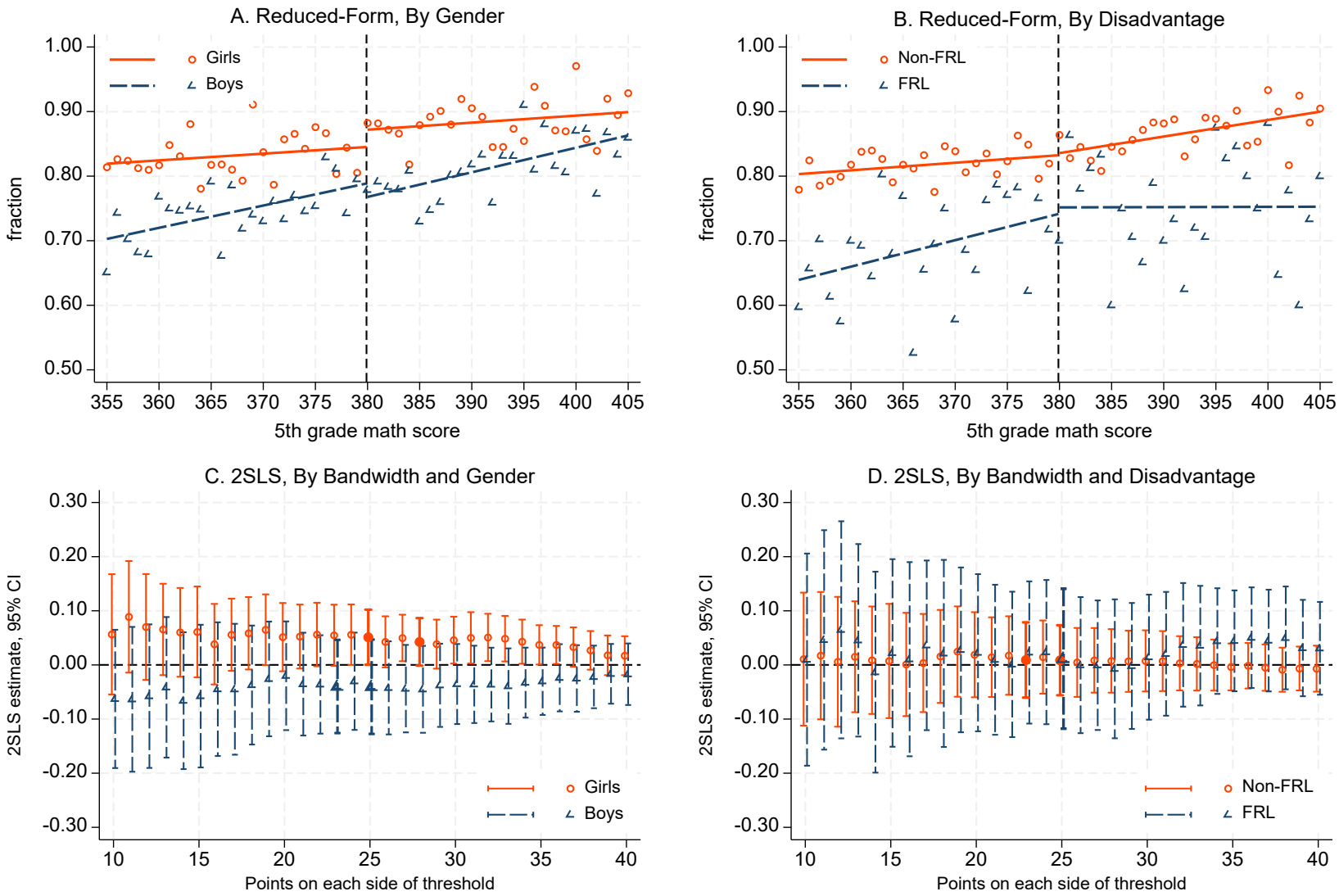
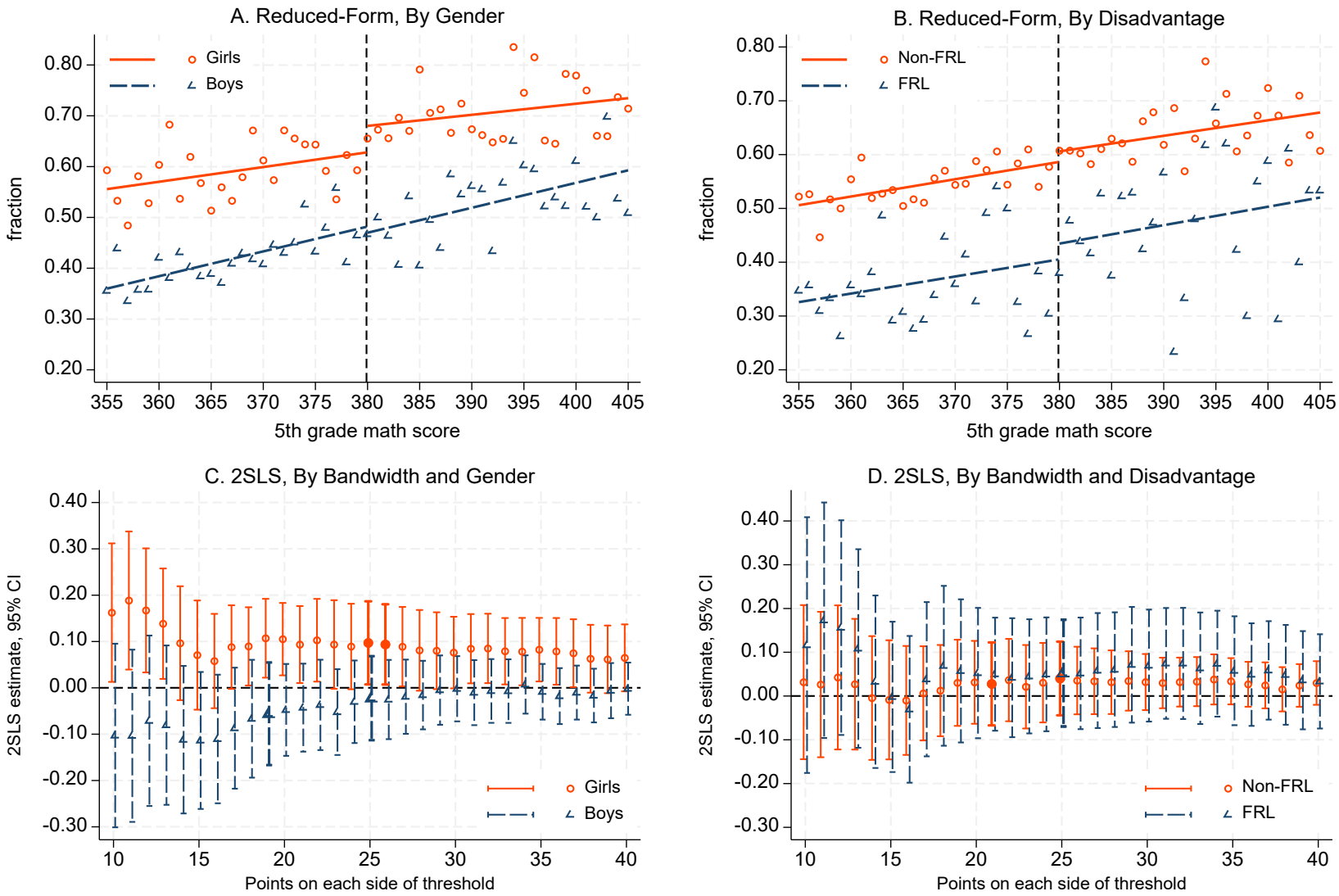


Figure 6. Graduate High School on Time and Enter College within 1 Year, by Gender and Disadvantage



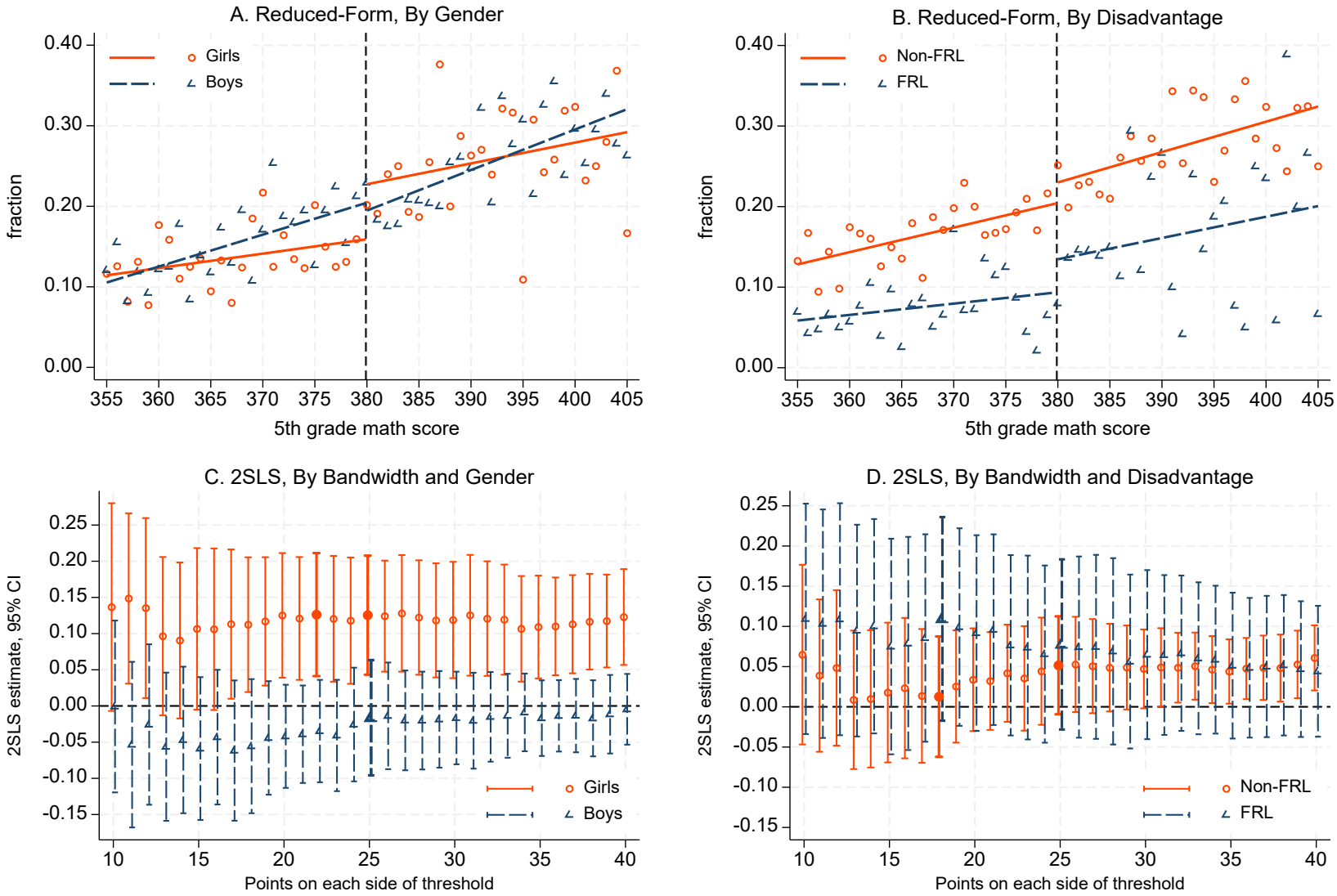
Notes: Panels A and B plot sample means of an indicator for graduating high school on time and enrolling in college within 1 year at each value of fifth-grade math score (the running variable), along with fitted values from local linear RD models with a symmetric bandwidth of 25, separately by gender (Panels A) and by FRL status (Panels B). Panels C and D plot 2SLS estimates for the treatment effect of GEM entry on the dependent variable for symmetric bandwidths between 10 and 40, with the CCT symmetric bandwidth and preferred bandwidth (+/-25) shown in bold.

Figure 7. Graduate HS on Time and Earn Any College Degree within 5 Years, by Gender and Disadvantage



Notes: Panels A and B plot sample means of an indicator for graduating high school on time and earning any college degree within 5 years at each value of fifth-grade math score (the running variable), along with fitted values from local linear RD models with a symmetric bandwidth of 25, separately by gender (Panels A) and by FRL status (Panels B). Panels C and D plot 2SLS estimates for the treatment effect of GEM entry on the dependent variable for symmetric bandwidths between 10 and 40, with the CCT symmetric bandwidth and preferred bandwidth (+/-25) shown in bold.

Figure 8. Graduate HS on Time and Earn a Bachelors Degree in STEM/Business/Econ, by Gender and Disadvantage



Notes: Panels A and B plot sample means of an indicator for graduating high school on time and earning any college degree within 5 years at each value of fifth-grade math score (the running variable), along with fitted values from local linear RD models with a symmetric bandwidth of 25, separately by gender (Panels A) and by FRL status (Panels B). Panels C and D plot 2SLS estimates for the treatment effect of GEM entry on the dependent variable for symmetric bandwidths between 10 and 40, with the CCT symmetric bandwidth and preferred bandwidth (+/-25) shown in bold.

Figure 9: Summary of Effects of GEM Entry on Girls

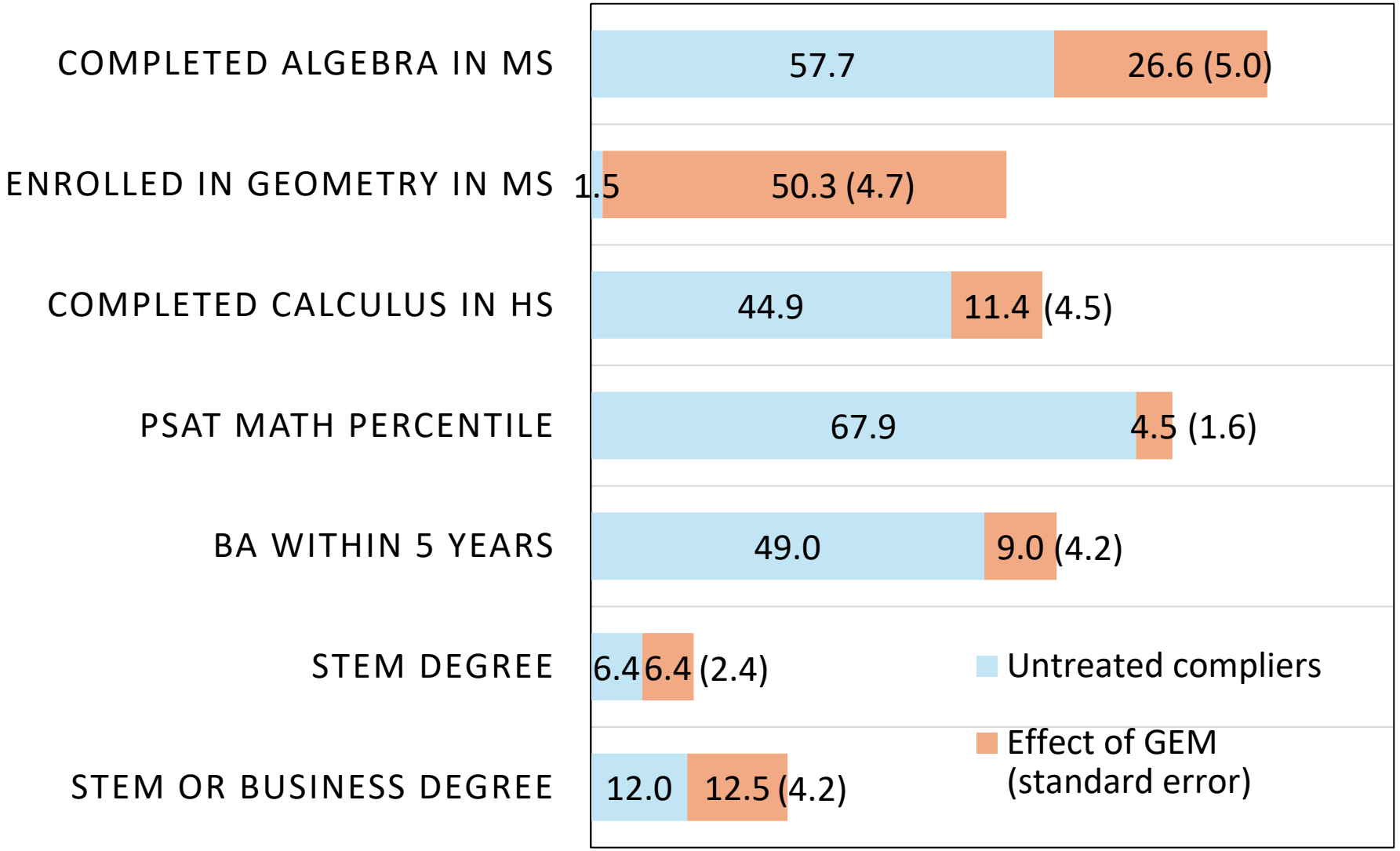


Table 1. Estimated Means for Main Analysis Sample and for Compliers

	Main Analysis	Compliers				
A. Baseline Characteristics	**Sample**	**All**	**Girls**	**Boys**	**Non-FRL**	**FRL**
Demographic characteristics						
female	0.49	0.49	1.00	0.00	0.46	0.57
FRL	0.21	0.20	0.24	0.16	0.00	1.00
White	0.51	0.47	0.45	0.48	0.54	0.20
Black	0.14	0.14	0.18	0.09	0.10	0.28
Hispanic	0.26	0.28	0.24	0.33	0.25	0.41
Baseline achievement						
grade 4 math score (standardized)	0.68	0.79	0.78	0.79	0.80	0.75
grade 4 reading score (standardized)	0.55	0.66	0.73	0.59	0.69	0.54
School peer characteristics						
avg grade 4 math & reading scores	0.23	0.21	0.19	0.23	0.24	0.09
fraction FRL	0.30	0.32	0.34	0.30	0.29	0.43
fraction GEM eligible	0.25	0.24	0.23	0.25	0.25	0.20
Predicted prob graduate high school on time & earn any college degree within 5 years	0.50	0.51	0.60	0.43	0.54	0.41
B. Mean intermediate outcomes or potential outcomes for compliers not in GEM						
Math track in 6th grade						
GEM (treatment)	0.26	0.00	0.00	0.00	0.00	0.00
advanced	0.55	0.84	0.87	0.82	0.85	0.81
regular	0.19	0.16	0.13	0.18	0.15	0.19
Middle school course enrollments & grades						
algebra by 8th grade	0.52	0.57	0.60	0.54	0.59	0.49
completed algebra with B- or better by 8th grade	0.38	0.43	0.52	0.36	0.45	0.39
completed algebra with C- or better by 8th grade	0.49	0.53	0.58	0.48	0.55	0.43
geometry in 8th grade	0.14	0.01	0.01	0.01	0.01	0.01
6th grade math GPA	3.15	3.54	3.67	3.41	3.57	3.39
7th grade math GPA	3.06	3.23	3.41	3.07	3.26	3.11
8th grade GPA	2.97	3.09	3.24	2.95	3.10	3.01
High school course enrollments & grades						
took any advanced math (statistics, calculus, etc.)	0.63	0.67	0.69	0.65	0.70	0.53
took any calculus	0.42	0.49	0.51	0.47	0.51	0.38
completed any calculus with B- or better	0.24	0.24	0.29	0.19	0.26	0.15
completed any calculus with C- or better	0.35	0.39	0.45	0.34	0.43	0.25
took AP/IB calculus	0.13	0.14	0.14	0.13	0.14	0.12
took AP calculus exam + scored 3 or better	0.08	0.08	0.07	0.09	0.08	0.05
high school math GPA (all grades, all courses)	3.24	3.28	3.37	3.19	3.30	3.18
College boards						
PSAT math percentile	65.74	69.1	67.9	70.4	70.1	64.8
PSAT reading percentile	59.91	62.9	65.5	60.5	64.2	57.9
Took SAT or ACT	0.89	0.89	0.90	0.89	0.90	0.87

Note: table continues. See notes at end of second page.

Table 1, Cont'd. Estimated Means for Main Analysis Sample and for Compliers

	Main Analysis Sample	Compliers				
		All	Girls	Boys	Non-FRL	FRL
C. Mean post-secondary outcomes or potential outcomes for compliers not in GEM						
College enrollment						
graduate high school on time	0.95	0.97	0.97	0.98	0.98	0.94
+ enter any college within 1 year	0.81	0.82	0.82	0.82	0.84	0.75
+ enter selective college within 1 year	0.65	0.65	0.68	0.64	0.68	0.56
+ enter any college w/in 1 yr & persist >1 yr	0.66	0.67	0.71	0.62	0.66	0.66
College degree earned						
+ earn any college degree within 5 years	0.54	0.54	0.60	0.48	0.57	0.40
+ earn bachelors (BA or BS) within 5 years	0.39	0.40	0.49	0.31	0.44	0.25
+ earn BA/BS in STEM or Econ/Bus within 5 years	0.18	0.17	0.12	0.23	0.20	0.06
+ earn BA/BS in STEM within 5 years	0.08	0.08	0.06	0.10	0.10	0.01
+ earn BA/BS in Econ/Bus in 5 yrs	0.10	0.09	0.06	0.13	0.11	0.04
+ earn BA/BS in Health/Educ in 5 yrs	0.06	0.08	0.12	0.04	0.09	0.04
+ earn BA/BS in Health in 5 yrs	0.05	0.07	0.10	0.04	0.08	0.05

Notes: The first column shows means of variables for all students in the main analysis sample (with math scores between 355 and 405). The remaining columns show estimated mean characteristics of all the compliers (Panel A), or estimated mean potential outcomes for compliers if they do not enter GEM (Panels B & C). See text for description of method of estimating mean characteristics of compliers and mean potential outcomes.

Table 2. Estimated Treatment Effects on Math Course Enrollment and Performance

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
			Course Enrollments			Took Algebra by 8th & Earned:		Took Calculus in HS & Earned:		Grade Point Avg in Math Courses			
	Predicted College Degree in 5 Years	First Stage (GEM in Grade 6)	Algebra by 8th Grade	Geometry in 8th Grade	Calculus in HS	B- or better	C- or better	B- or better	C- or better	6th Grade	7th Grade	8th Grade	All HS Math
1. Pooled	**0.001**	**0.526****	**0.221****	**0.407****	**0.078***	**0.153****	**0.230****	**0.074***	**0.094***	**-0.724****	**-0.373****	**-0.137***	**-0.000**
(N = 11,530)	(0.003)	(0.035)	(0.052)	(0.038)	(0.036)	(0.042)	(0.046)	(0.031)	(0.035)	(0.107)	(0.059)	(0.062)	(0.055)
with controls			0.214**	0.402**	0.074*	0.146**	0.223**	0.069*	0.088*	-0.737**	-0.385**	-0.151*	-0.011
			(0.051)	(0.038)	(0.033)	(0.040)	(0.045)	(0.030)	(0.032)	(0.108)	(0.056)	(0.062)	(0.054)
2. Girls	**0.006**	**0.546****	**0.253****	**0.503****	**0.113***	**0.192****	**0.266****	**0.082+**	**0.114***	**-0.654****	**-0.376****	**-0.114**	**0.059**
(N =5,601)	(0.004)	(0.036)	(0.060)	**(0.047)**	(0.051)	(0.060)	(0.059)	(0.043)	(0.045)	(0.109)	(0.059)	(0.081)	(0.051)
with controls			0.251**	0.499**	0.111*	0.187**	0.263**	0.077+	0.109*	-0.669**	-0.387**	-0.130	0.050
			(0.056)	(0.047)	(0.049)	(0.058)	(0.057)	(0.042)	(0.042)	(0.112)	(0.058)	(0.082)	(0.050)
3. Boys	**-0.006**	**0.508****	**0.185****	**0.310****	**0.040**	**0.109***	**0.190****	**0.064**	**0.073**	**-0.804****	**-0.391****	**-0.179***	**-0.070**
(N =5,929)	(0.004)	(0.036)	(0.057)	(0.045)	(0.051)	(0.048)	(0.047)	(0.054)	(0.055)	(0.125)	(0.091)	(0.085)	(0.107)
with controls			0.177**	0.306**	0.035	0.105*	0.183**	0.060	0.068	-0.806**	-0.387**	-0.173+	-0.079
			(0.057)	(0.045)	(0.050)	(0.047)	(0.046)	(0.054)	(0.055)	(0.122)	(0.092)	(0.086)	(0.106)
4. Non-FRL	**0.005**	**0.520****	**0.206****	**0.419****	**0.052**	**0.156****	**0.216****	**0.077+**	**0.080***	**-0.705****	**-0.350****	**-0.140***	**0.005**
(N = 9,122)	(0.004)	(0.038)	(0.058)	(0.043)	(0.038)	(0.049)	(0.052)	(0.038)	(0.036)	(0.111)	(0.068)	(0.066)	(0.065)
with controls			0.197**	0.412**	0.043	0.142**	0.205**	0.065+	0.067*	-0.735**	-0.384**	-0.173*	-0.018
			(0.057)	(0.043)	(0.034)	(0.047)	(0.050)	(0.036)	(0.032)	(0.114)	(0.064)	(0.062)	(0.062)
5. FRL	**-0.011**	**0.549****	**0.286****	**0.358****	**0.184***	**0.150****	**0.292****	**0.072**	**0.152+**	**-0.777****	**-0.426****	**-0.104**	**-0.028**
(N = 2,408)	(0.007)	(0.039)	(0.065)	(0.046)	(0.072)	(0.047)	(0.059)	(0.050)	(0.076)	(0.151)	(0.127)	(0.105)	(0.112)
with controls			0.310**	0.359**	0.208*	0.174**	0.321**	0.084	0.170*	-0.708**	-0.348*	-0.055	0.006
			(0.065)	(0.046)	(0.076)	(0.050)	(0.059)	(0.054)	(0.081)	(0.147)	(0.135)	(0.112)	(0.115)

Notes: Table entries are 2SLS estimates for the effect of entry into GEM in sixth grade, from fuzzy RD models as specified in equation (3) in the text. (I.e., the entries are estimates of beta). The baseline models include four dummy variables for the student's cohort but no other controls. The models with controls include dummies for student gender, FRL and ELL status, and race; age; and quadratics in fourth-grade math and reading scores. Standard errors clustered on the middle school where the student was enrolled in 6th grade.

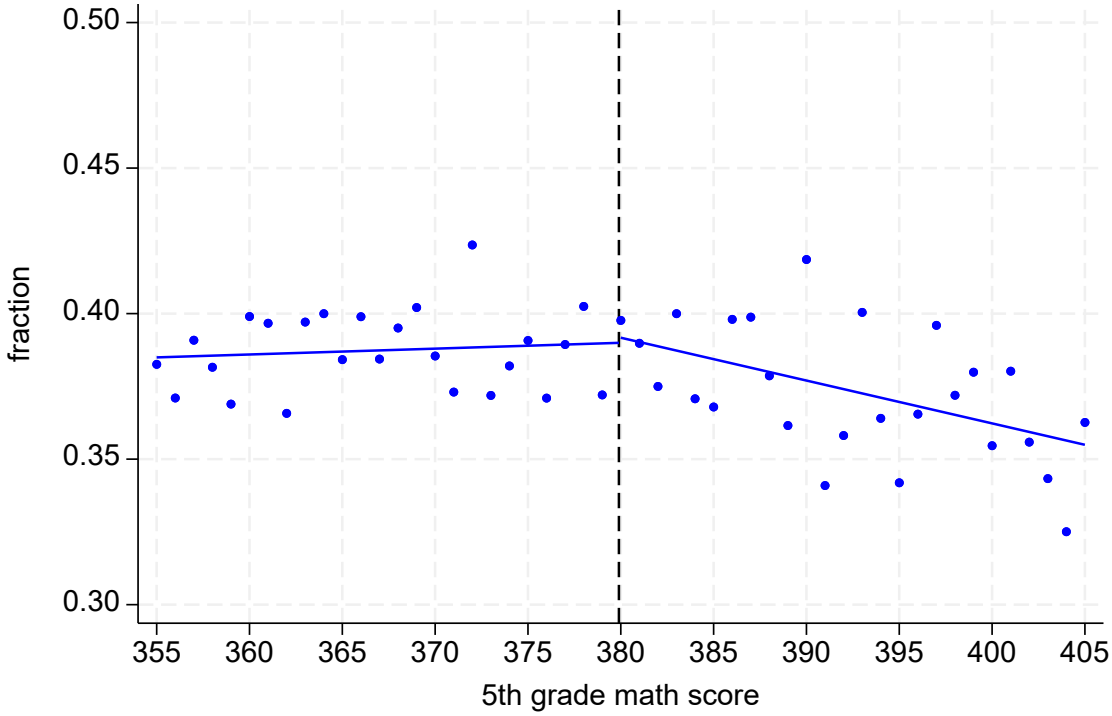
Table 3. Estimated Treatment Effects on Post-Secondary Outcomes

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
							Bachelors degree within 5 years in (field):					Longer windows		
	On-Time High School Grad	On-Time College Entry	Enroll in Selective College	Enroll & Persist 1+ Yrs, Any College	Any College Degree in 5 Years	Any Bachelors Degree in 5 Years	STEM	STEM or Bus/Econ	Health or Educ.	Bus/Econ	Health	College Entry within 2 Years	Any Bachelors Degree in 6 Years	STEM Degree in 6 Years
1. Pooled	**-0.000**	**0.007**	**0.026**	**0.038**	**0.040**	**0.042**	**0.024**	**0.055+**	**-0.032+**	**0.029**	**-0.029***	**0.010**	**0.013**	**0.019**
(N = 11,530)	(0.010)	(0.029)	(0.034)	(0.028)	(0.035)	(0.032)	(0.020)	(0.028)	(0.016)	(0.022)	(0.014)	(0.024)	(0.033)	(0.019)
with controls	0.000	0.005	0.020	0.035	0.035	0.035	0.023	0.053+	-0.034*	0.027	-0.031*	0.009	0.006	0.018
	(0.010)	(0.029)	(0.035)	(0.028)	(0.035)	(0.032)	(0.020)	(0.027)	(0.016)	(0.022)	(0.014)	(0.025)	(0.033)	(0.019)
2. Girls	**0.012**	**0.051+**	**0.112****	**0.057**	**0.097***	**0.090***	**0.064***	**0.125****	**-0.044+**	**0.061***	**-0.042+**	**0.049+**	**0.094***	**0.073***
(N =5,601)	(0.011)	(0.026)	(0.039)	(0.037)	(0.046)	(0.042)	(0.024)	(0.042)	(0.025)	(0.028)	(0.022)	(0.024)	(0.042)	(0.028)
with controls	0.010	0.044	0.098*	0.049	0.084+	0.072+	0.062*	0.121**	-0.047+	0.057*	-0.044+	0.044+	0.077+	0.072*
	(0.011)	(0.026)	(0.038)	(0.039)	(0.046)	(0.042)	(0.024)	(0.040)	(0.024)	(0.027)	(0.022)	(0.024)	(0.041)	(0.028)
3. Boys	**-0.014**	**-0.040**	**-0.067**	**0.015**	**-0.022**	**-0.011**	**-0.016**	**-0.016**	**-0.022**	**-0.004**	**-0.017**	**-0.031**	**-0.076**	**-0.036**
(N =5,929)	(0.020)	(0.044)	(0.051)	(0.042)	(0.046)	(0.057)	(0.030)	(0.041)	(0.018)	(0.031)	(0.018)	(0.038)	(0.055)	(0.026)
with controls	-0.009	-0.029	-0.053	0.027	-0.011	-0.005	-0.015	-0.014	-0.022	-0.002	-0.017	-0.021	-0.068	-0.035
	(0.019)	(0.044)	(0.047)	(0.040)	(0.048)	(0.057)	(0.030)	(0.040)	(0.018)	(0.030)	(0.018)	(0.038)	(0.053)	(0.026)
4. Non-FRL	**0.000**	**0.009**	**0.053**	**0.076***	**0.040**	**0.049**	**0.025**	**0.052**	**-0.039***	**0.025**	**-0.033***	**0.008**	**0.016**	**0.021**
(N = 9,122)	(0.011)	(0.033)	(0.038)	(0.028)	(0.043)	(0.035)	(0.020)	(0.031)	(0.018)	(0.025)	(0.016)	(0.026)	(0.036)	(0.019)
with controls	-0.001	0.002	0.041	0.067*	0.024	0.030	0.023	0.048	-0.045*	0.023	-0.037*	0.002	-0.001	0.019
	(0.011)	(0.033)	(0.039)	(0.029)	(0.044)	(0.036)	(0.020)	(0.030)	(0.019)	(0.025)	(0.016)	(0.027)	(0.038)	(0.018)
5. FRL	**0.003**	**0.012**	**-0.058**	**-0.094**	**0.052**	**0.025**	**0.025**	**0.078**	**-0.010**	**0.052**	**-0.018**	**0.024**	**0.012**	**0.018**
(N = 2,408)	(0.031)	(0.066)	(0.066)	(0.087)	(0.062)	(0.079)	(0.044)	(0.054)	(0.026)	(0.033)	(0.027)	(0.059)	(0.070)	(0.048)
with controls	0.012	0.034	-0.033	-0.070	0.082	0.046	0.026	0.081	-0.000	0.055	-0.009	0.045	0.040	0.018
	(0.031)	(0.068)	(0.063)	(0.088)	(0.068)	(0.082)	(0.045)	(0.055)	(0.025)	(0.033)	(0.025)	(0.060)	(0.072)	(0.049)

Notes: Table entries are 2SLS estimates for the effect of entry into GEM in sixth grade, from fuzzy RD models as specified in equation (3) in the text. (I.e., the entries are estimates of beta). The baseline models include four dummy variables for the student's cohort but no other controls. The models with controls include dummies for student gender, FRL and ELL status, and race; age; and quadratics in fourth-grade math and reading scores. Standard errors clustered on the middle school where the student was enrolled in 6th grade.

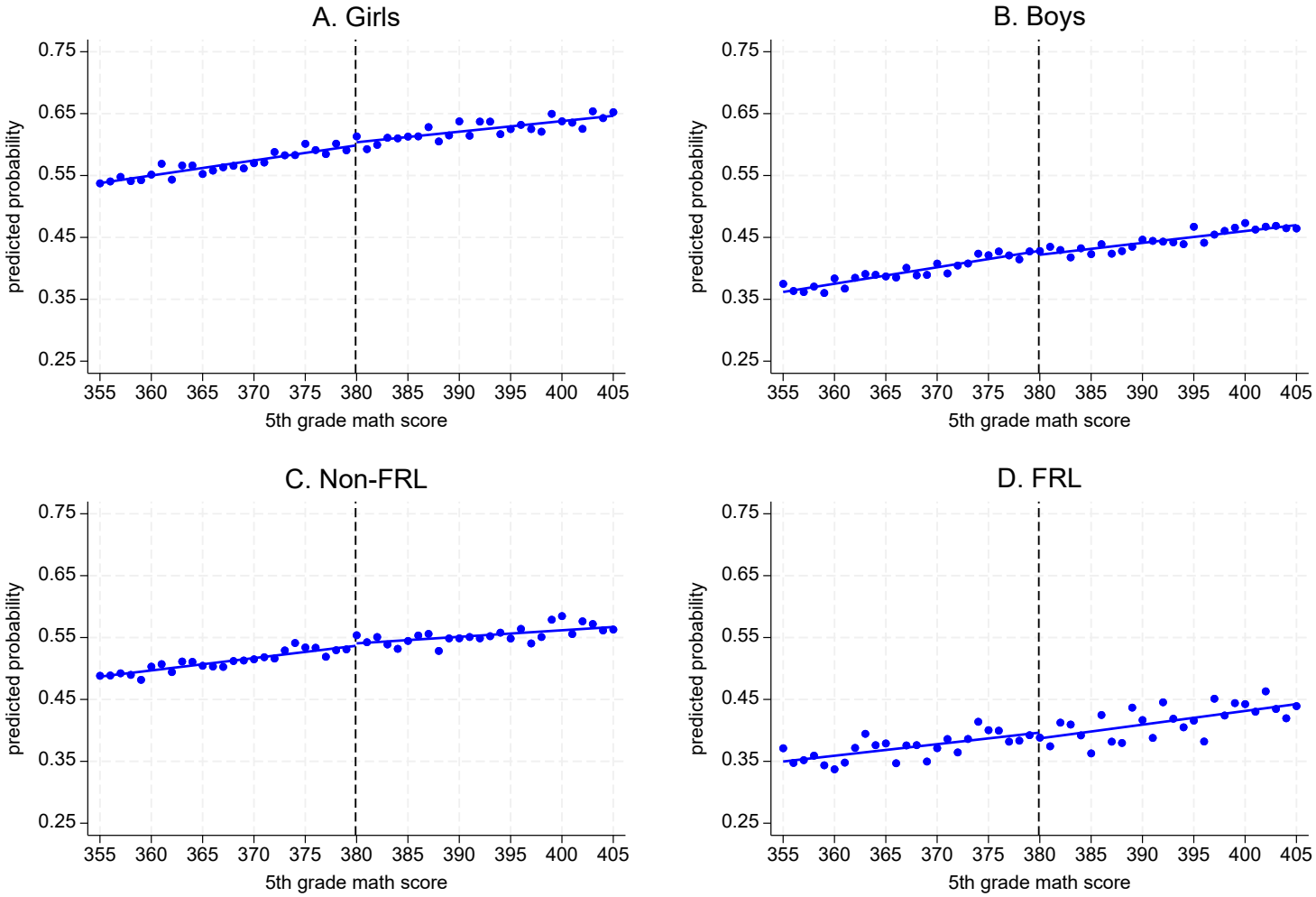
Appendix A: Additional Figures and Tables

Figure A1: Reduced-Form Relationship for Meeting Sample Criteria



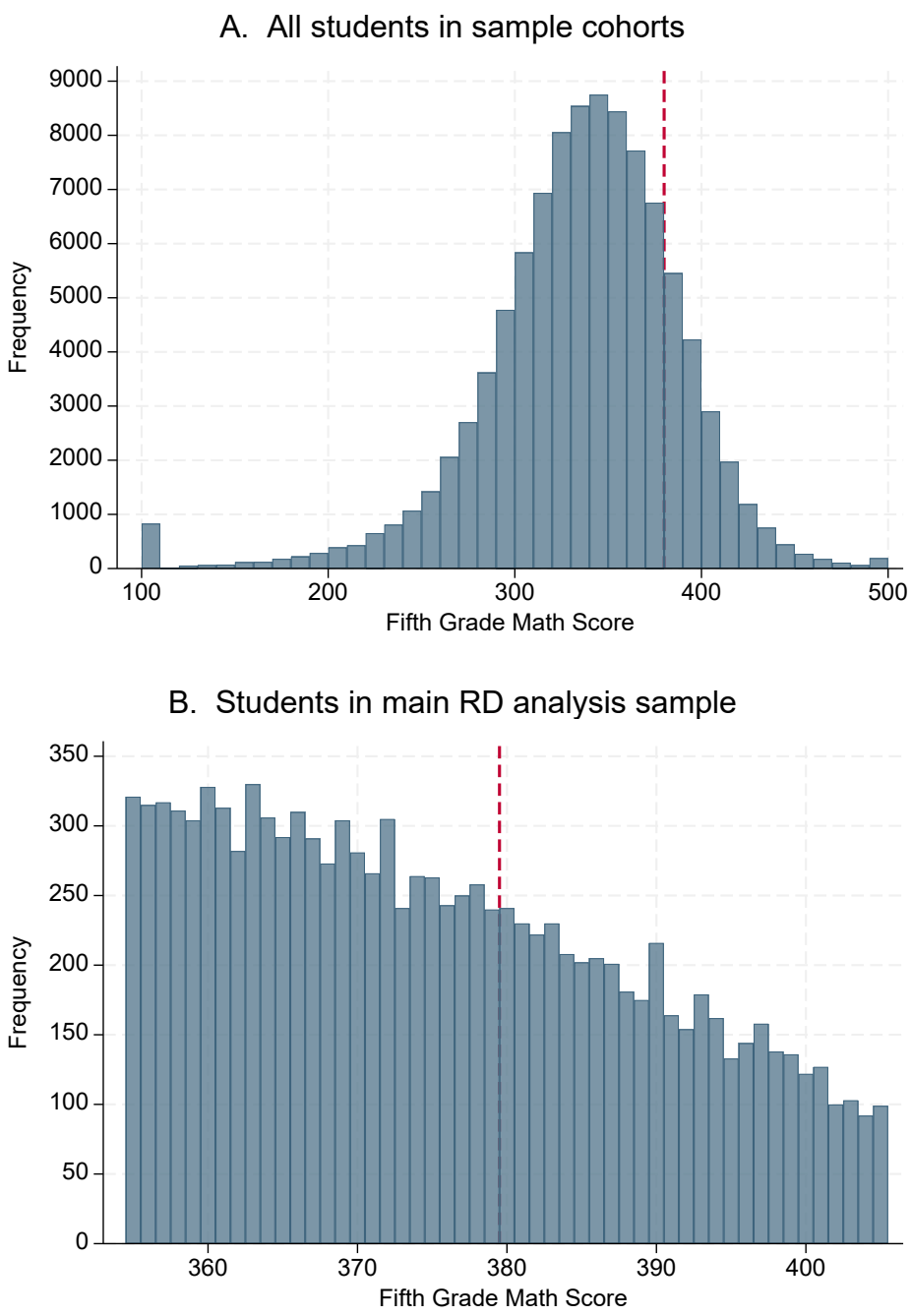
Notes: This figure plots means, for the full population of students enrolled in the District for fifth grade between 2004 and 2008, of an indicator for meeting the inclusion criteria for the main analysis sample (see Appendix Table A1 for details). It also shows fitted values from a local linear RD model with a symmetric bandwidth of 25. The estimated discontinuity is 0.0018 with a clustered standard error (clustered on elementary school) of 0.0108.

Figure A2: Reduced-Form Relationships for Predicted On-Time Graduation and College Degree within 5 Years, by Gender and Disadvantage



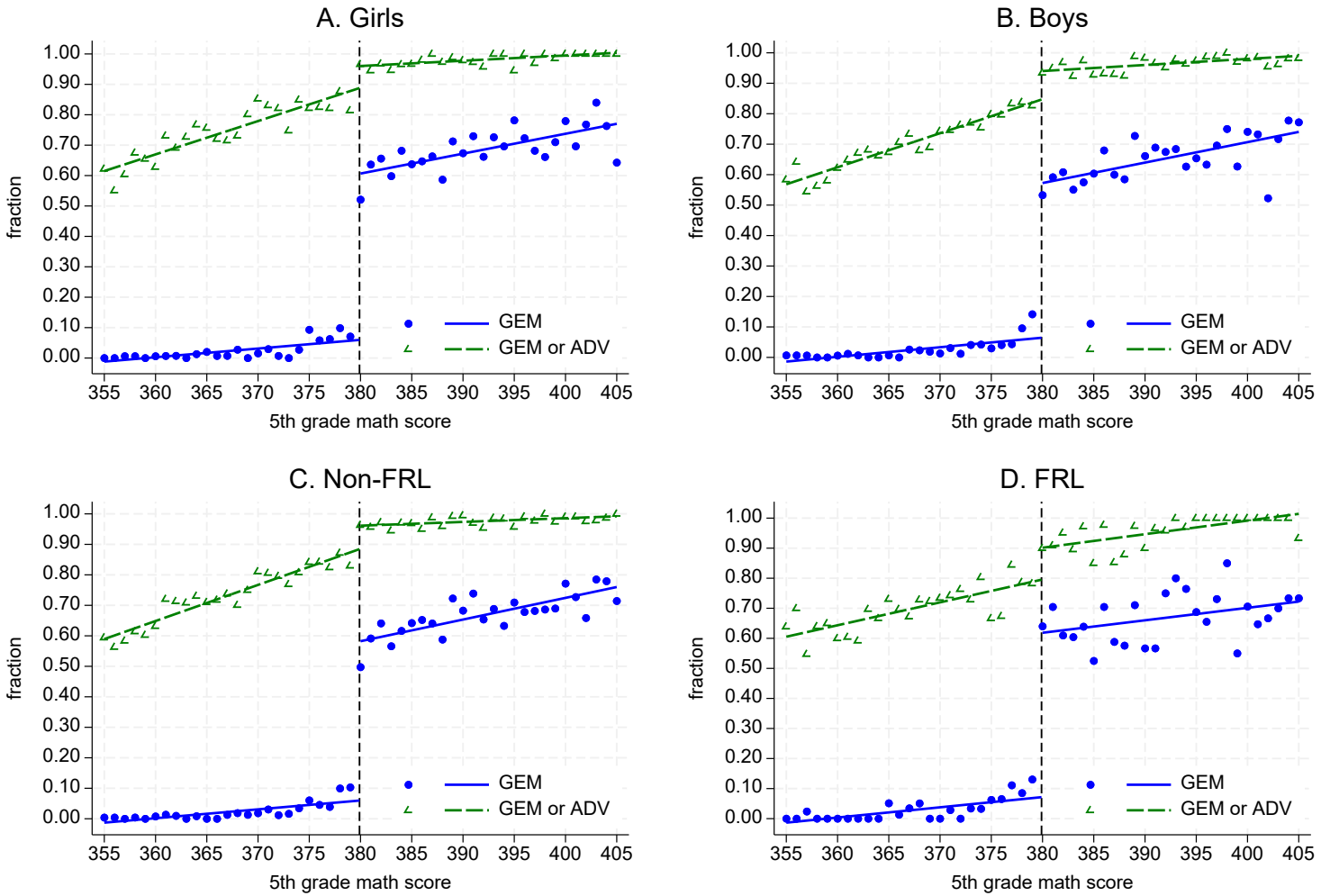
Notes: This figure plots sample means, along with fitted values from local linear RD models with symmetric bandwidths of +/- 25 points, of the predicted probability of graduating high school on time and completing any college degree (associates or bachelors) within 5 years. The prediction models include second-order polynomials in 4th-grade math and reading test scores; student age; and indicators for student race/ethnicity, FRL status, ELL status, and cohort.

Figure A3: Histogram of Running Variable



Notes: This figure shows the frequency distribution of fifth-grade math scores for all students in our sample cohorts (Panel A) and for students in the main RD analysis sample (Panel B). The sample consists of all students in the District who completed fifth grade in between 2003 and 2007, were not identified as gifted, had non-missing fourth-grade test scores, were enrolled in sixth grade in the following year (between 2004 and 2008), and were enrolled in (or graduated from) a District high school six years later (between 2010 and 2014). The RD analysis sample is further restricted to scores within +/- 25 points of the threshold for eligibility to participate in the GEM program in sixth grade. The dashed vertical lines in each panel indicate the threshold.

Figure A4: First-Stage Relationships for GEM Enrollment, by Gender and Disadvantage



Notes: This figure plots sample means of an indicator for participating in the GEM program in sixth grade (the treatment variable, in blue circles) and an indicator for participating in *either* GEM *or* advanced-track math (in green triangles) at each value of fifth-grade math score (the running variable), along with fitted values from local linear RD models with a symmetric bandwidth of 25.

Appendix Table A1. Sample Criteria & Sample Means

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
						Main RD Analysis Sample				
	All in Grade 5	Observed in Grades 4-6	Traditional Middle School	Followed Through HS Grad	Not Gifted	Pooled	Girls	Boys	Non-FRL	FRL
Demographic characteristics										
female	0.49	0.49	0.49	0.50	0.51	0.49	1.00	0.00	0.48	0.49
FRL	0.43	0.43	0.31	0.28	0.30	0.21	0.21	0.21	0.00	1.00
White	0.35	0.35	0.44	0.44	0.43	0.51	0.50	0.52	0.58	0.24
Black	0.34	0.34	0.22	0.22	0.23	0.14	0.16	0.13	0.10	0.31
Hispanic	0.24	0.24	0.26	0.26	0.27	0.26	0.25	0.26	0.23	0.36
Baseline achievement										
grade 4 math score (standardized)	0.08	0.08	0.21	0.29	0.19	0.68	0.65	0.70	0.71	0.54
grade 4 reading score (standardized)	0.08	0.08	0.20	0.26	0.17	0.55	0.65	0.47	0.61	0.36
School peer characteristics (6th grade)										
avg grade 4 math & reading scores	0.07	0.07	0.19	0.20	0.19	0.23	0.23	0.23	0.27	0.09
fraction FRL	0.46	0.46	0.33	0.32	0.33	0.30	0.30	0.30	0.27	0.41
fraction GEM eligible	0.20	0.20	0.23	0.24	0.23	0.25	0.25	0.25	0.26	0.20
Math track in 6th grade										
GEM (treatment)	0.16	0.16	0.18	0.20	0.15	0.26	0.26	0.26	0.27	0.22
advanced math	0.27	0.27	0.28	0.30	0.30	0.55	0.57	0.54	0.55	0.55
regular math	0.57	0.57	0.54	0.51	0.55	0.19	0.17	0.20	0.18	0.23
Number of observations	98,709	79,494	46,648	33,356	30,463	11,530	5,601	5,929	9,122	2,408

The sample in column 1 includes five cohorts of students who entered fifth grade in 2003-2007. Column 2 is restricted to students who were observed in 4th grade (and have 4th-grade test scores) and were also observed in 6th grade the following year (2004-2008). Column 3 further restricts the sample to those enrolled in a traditional (e.g., non-charter) middle school in 6th grade. Column 4 is limited to students who were enrolled in (or graduated from) a District high school six years later (between 2010 and 2014). Column 5 drops students who were identified as gifted (which usually occurs no later than 5th grade). Finally, columns 6-10 report means for the analysis samples for the RD models, which include students who meet the criteria in column 5 and also had 5th-grade math score within 25 points of the GEM eligiblity threshold (our preferred RD bandwidth).

Appendix Table A2. More High School Outcomes

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Took Any Advanced Math Course	**Took AP/IB Calculus Course**	**Took Calc AP Exam + Got Score of >=3**	**High School GPA (Overall)**	**PSAT Math**	**PSAT Verbal**	**Took SAT/ACT**
1. Pooled	**0.082****	**0.049+**	**0.020**	**0.009**	**2.817***	**1.075**	**0.002**
(N = 11,530)	(0.023)	(0.027)	(0.019)	(0.029)	(1.128)	(1.491)	(0.018)
2. Girls	**0.129****	**0.040**	**0.022**	**0.062**	**4.518****	**2.668**	**0.051***
(N =5,601)	(0.039)	(0.044)	(0.027)	(0.037)	(1.575)	(2.234)	(0.019)
3. Boys	**0.030**	**0.057***	**0.018**	**-0.052**	**1.103**	**-0.642**	**-0.050**
(N =5,929)	(0.037)	(0.025)	(0.023)	(0.062)	(1.978)	(2.326)	(0.035)
4. Non-FRL	**0.060***	**0.065***	**0.032+**	**0.004**	**3.299***	**1.015**	**0.007**
(N = 9,122)	(0.025)	(0.030)	(0.018)	(0.035)	(1.434)	(1.472)	(0.022)
5. FRL	**0.179****	**-0.008**	**-0.021**	**0.035**	**1.382**	**1.809**	**-0.010**
(N = 2,408)	(0.058)	(0.045)	(0.047)	(0.072)	(2.147)	(3.606)	(0.043)

Notes: Table entries are 2SLS estimates for the effect of entry into GEM in sixth grade, from fuzzy RD models as specified in equation (3) in the text. (I.e., the entries are estimates of beta). The models include four dummy variables for the student's cohort but no other controls. Standard errors clustered on the middle school where the student was enrolled in 6th grade.