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

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# Middle School Math Wars: The battle over tracking

- Traditional sequence (in U.S.):

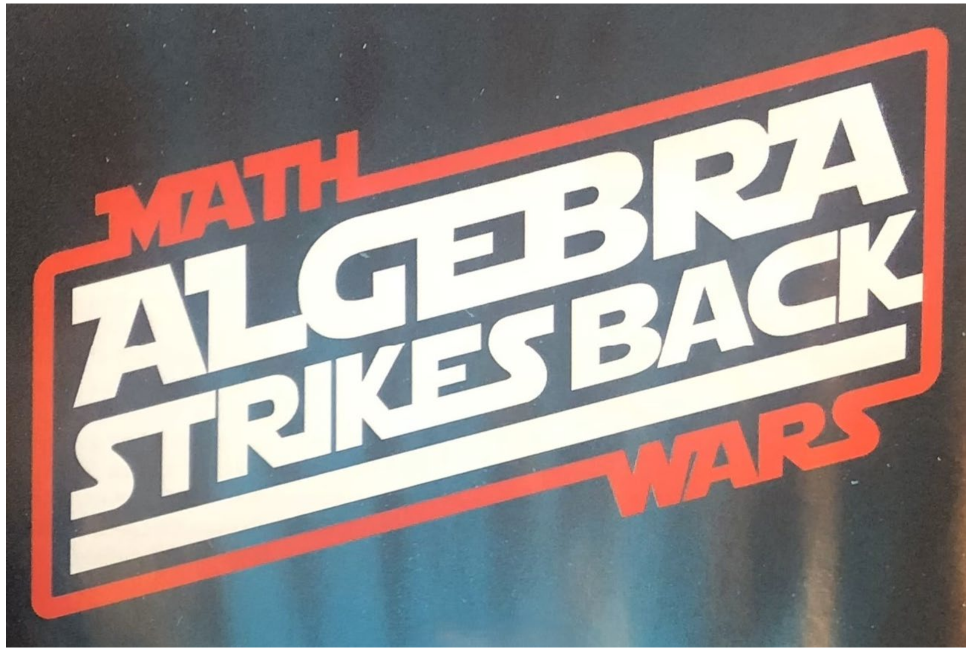
  Gr 6-8 (middle school): advanced arithmetic (***no algebra***)

  Gr 9 (first year of HS): Algebra I

  Gr 10-12: Geometry, Algebra II, Pre-Calculus or statistics

  ➢ <u>Critique</u> : ***no room for calculus!***

  But selective STEM college programs require calculus (+)




- Tracking:

  Some districts offer multiple tracks with "accelerated" options:

  - Algebra I in Gr 8 (typical)
  - Algebra I in Gr 7, Geometry in Gr 8 (less common)

  ➢ <u>Critique</u>: tracking creates /exacerbates inequities

# Accelerated middle school math – What do we know?

- In 2000s CA and NC tried to have "Algebra for All" in Gr 8
  - ➢ This was unsuccessful for lower-scoring students (Domina et al, 2015; Clotfelter et al, 2015)
- A more targeted approach: exclude bottom 20% for Algebra in Gr 8
  - ➢ Some evidence of benefits, especially for girls (Dougherty et al, 2017)

❖ **What about more tracking, with greater acceleration at the top?**

# GEM ("Greater Explorations in Mathematics")

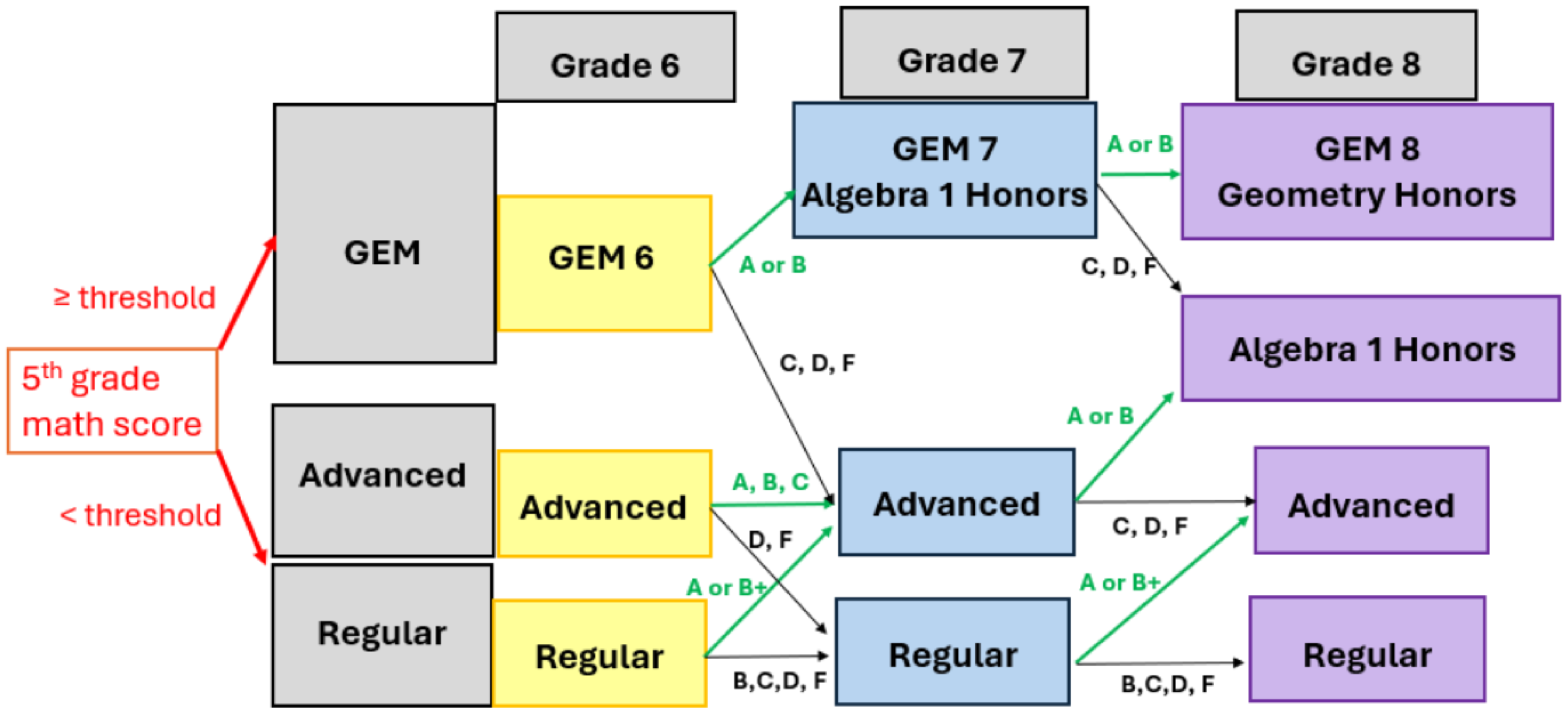
- GEM: introduced in 2002 by a large, Florida district ("**the District**")

- Gr 6: Pre-algebra (combines usual Gr 6-8)
  Gr 7: Algebra I (usually in Gr 9)
  Gr 8: Geometry (usually in Gr 10)
  → GEM completers enter high school @ Gr 11 level

- Offered in <u>all</u> **~**80 mainstream middle schools

- Entry based on state-wide 5$^{th}$-grade math test
  → requires score ≥ 380 (≈80$^{th}$ percentile)

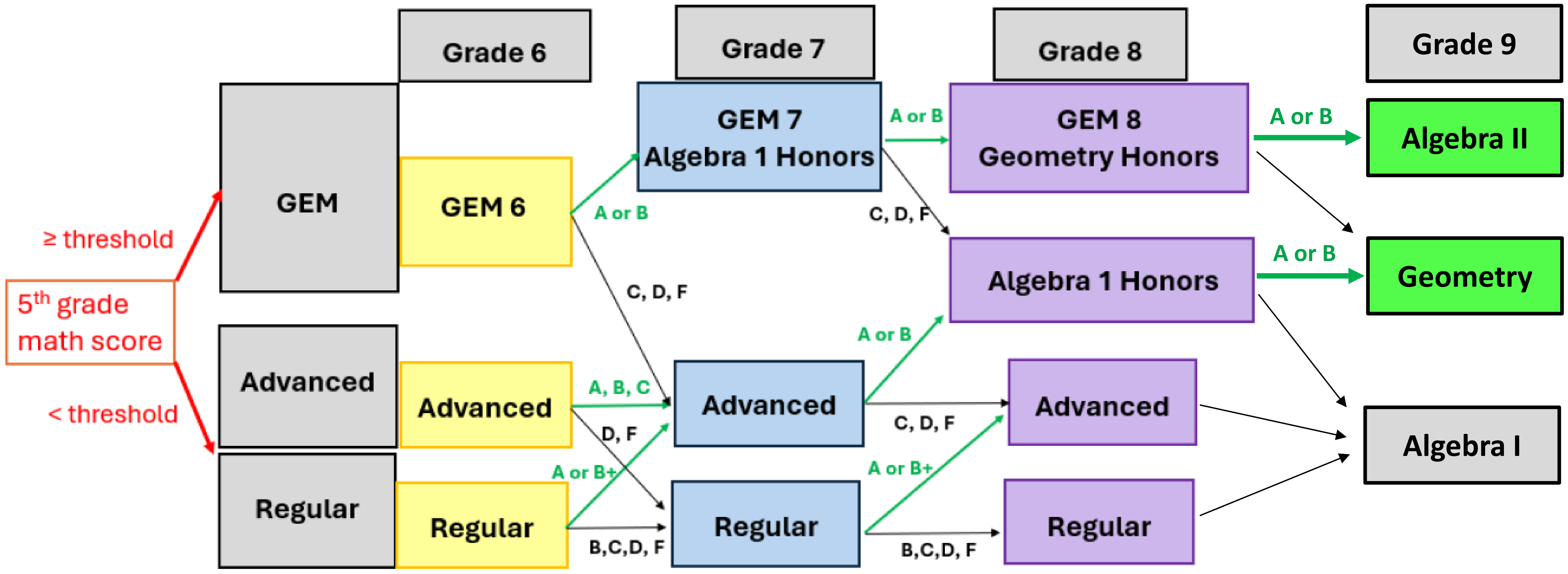
# Middle school math pathways in the District




Key features:

- 3-track system
- initial placement based on prior achievement
- on/off ramps and option to repeat offer flexibility to correct for initial mismatch

# Middle school math pathways in the District



# What we do:

1. Fuzzy RD analysis for the impact of GEM entry (in Gr 6) on:
   - middle / high school math course selections and grades
   - college entry & completion, up to 6 years after normal HS graduation
   - field of degree (STEM, Business/Econ)
2. Heterogeneity by: Gender, FRL status, Pr(successful completion)
3. Difference-in-differences comparisons with students in a 2nd district, matched on 5th-grade math score, for evidence of:
   - spillover effects on those who just miss GEM cutoff?
   - GEM impacts for higher-scoring students (well above cutoff)?

# Key findings:

1. GEM entry has big effects on **completing algebra & geometry in MS** (bigger for girls)
2. +9 ppt (↑40%) effect on **completing calculus in HS** (similar by gender & FRL status), with larger impact on calculus by 11th grade
3. no large effects on college entry
4. positive/significant effects for girls (but not boys) on other college-related outcomes:

   +7 ppt (↑10%) attend **selective** college

   +7 ppt (↑15%) any **bachelor's degree** within 6 years

   +5 ppt bachelors in **STEM**; +4 ppt bachelors in **business/econ**
   → **50% increase for girls + closes gap with boys**
5. Similar impacts by FRL/Non-FRL status
6. Similar impacts by high vs. low predicted prob of successful GEM completion
7. no evidence of spillovers on those who narrowly miss GEM

# Analysis sample

- five cohorts, completed $5^{th}$ grade in 2003-2007 (≈ 100K)
- observed in $4^{th}$ grade ( “pre” data available)
- enrolled in District $\geq$ 7 yrs. after $5^{th}$ grade
    - linked to college data from National Student Clearinghouse
    - lose about ½ of the sample due to leaving district
    - no evidence of differential attrition
- main RD analysis: scored $\pm 30$ points of GEM threshold (380) on $5^{th}$-grade standardize math test
    - roughly top 40%

$\Rightarrow$ **N** $\approx$ **23,000** for preferred specification (~50% girls; ~40% FRL)

# Fuzzy RD setup

linear function with slope change at M=380

First-stage model:

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

Reduced-form outcome models:

$$Y_i = \boldsymbol{\delta} \cdot 1[M_i \geq 380] + h(M_i) + v_i,$$

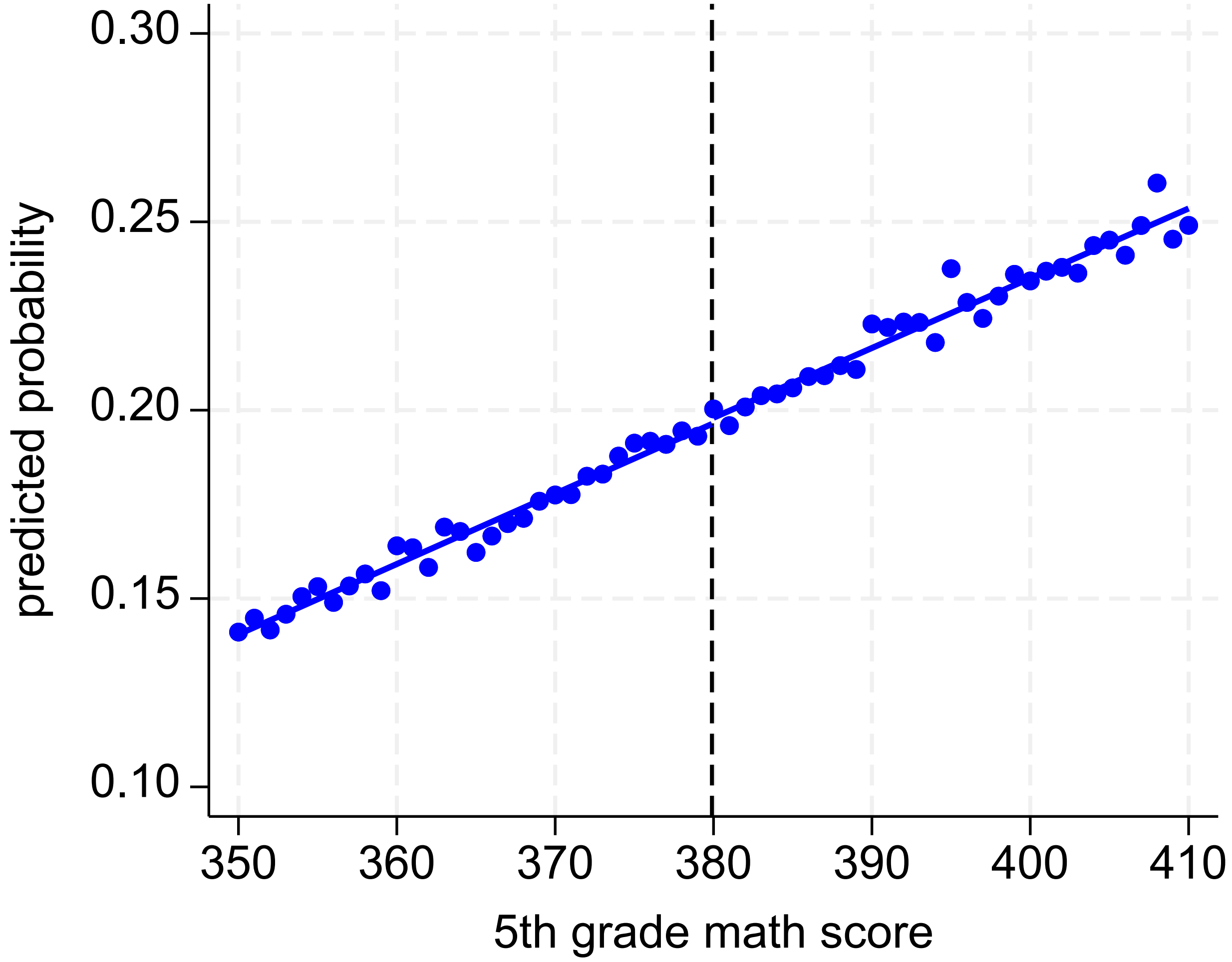
2SLS estimating equation:

$$Y_i = \boldsymbol{\beta} \cdot GEM6_i + \ f(M_i) + e_i,$$

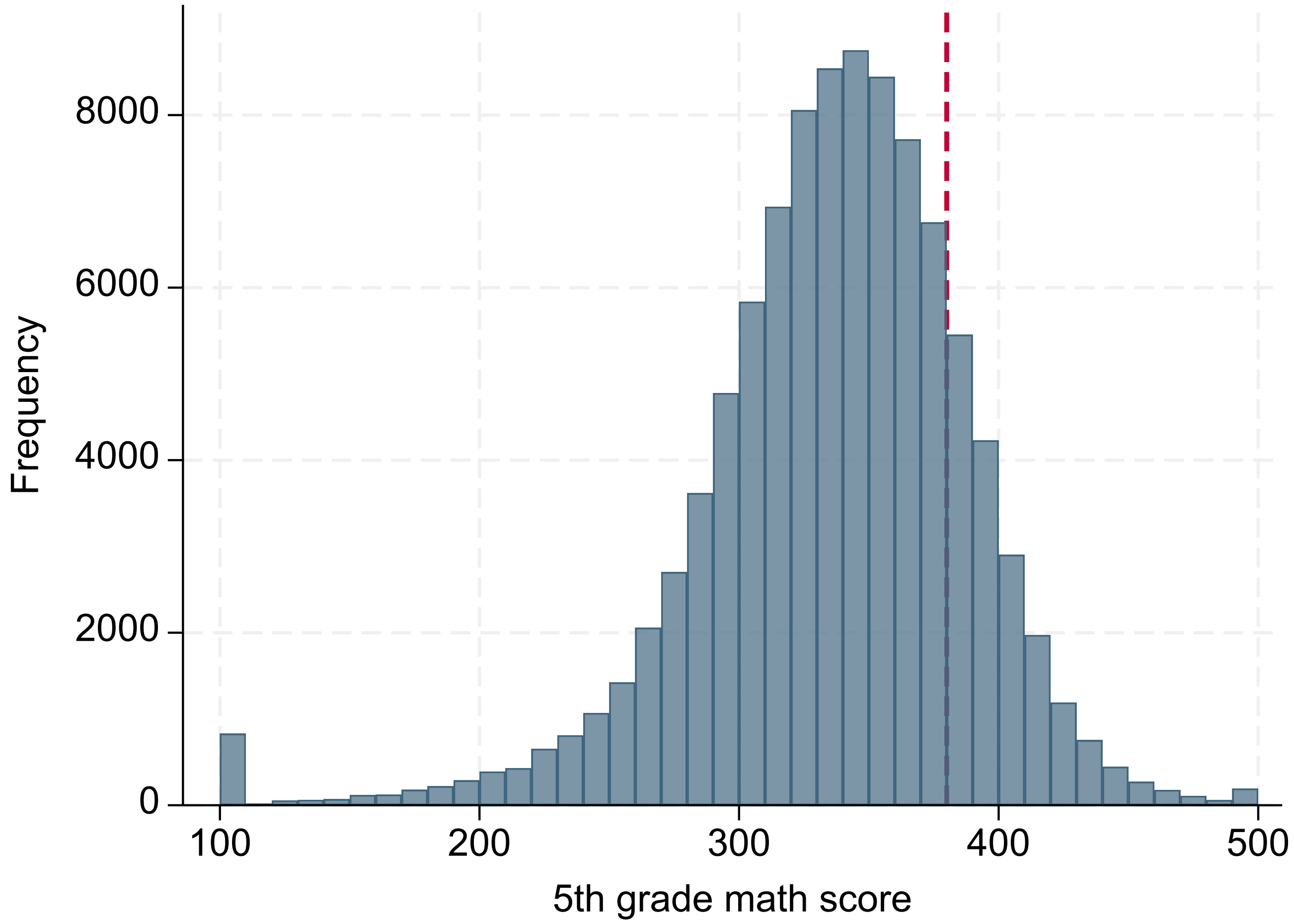
- $\boldsymbol{\beta} = \boldsymbol{\delta}/\boldsymbol{\pi}$ gives **average treatment effect for marginally eligible GEM compliers** (who are induced to participated due to having math score just above the threshold of 380)
- estimated via 2SLS using $1[M_i \geq 380]$ as instrument.

# Design validity checks:

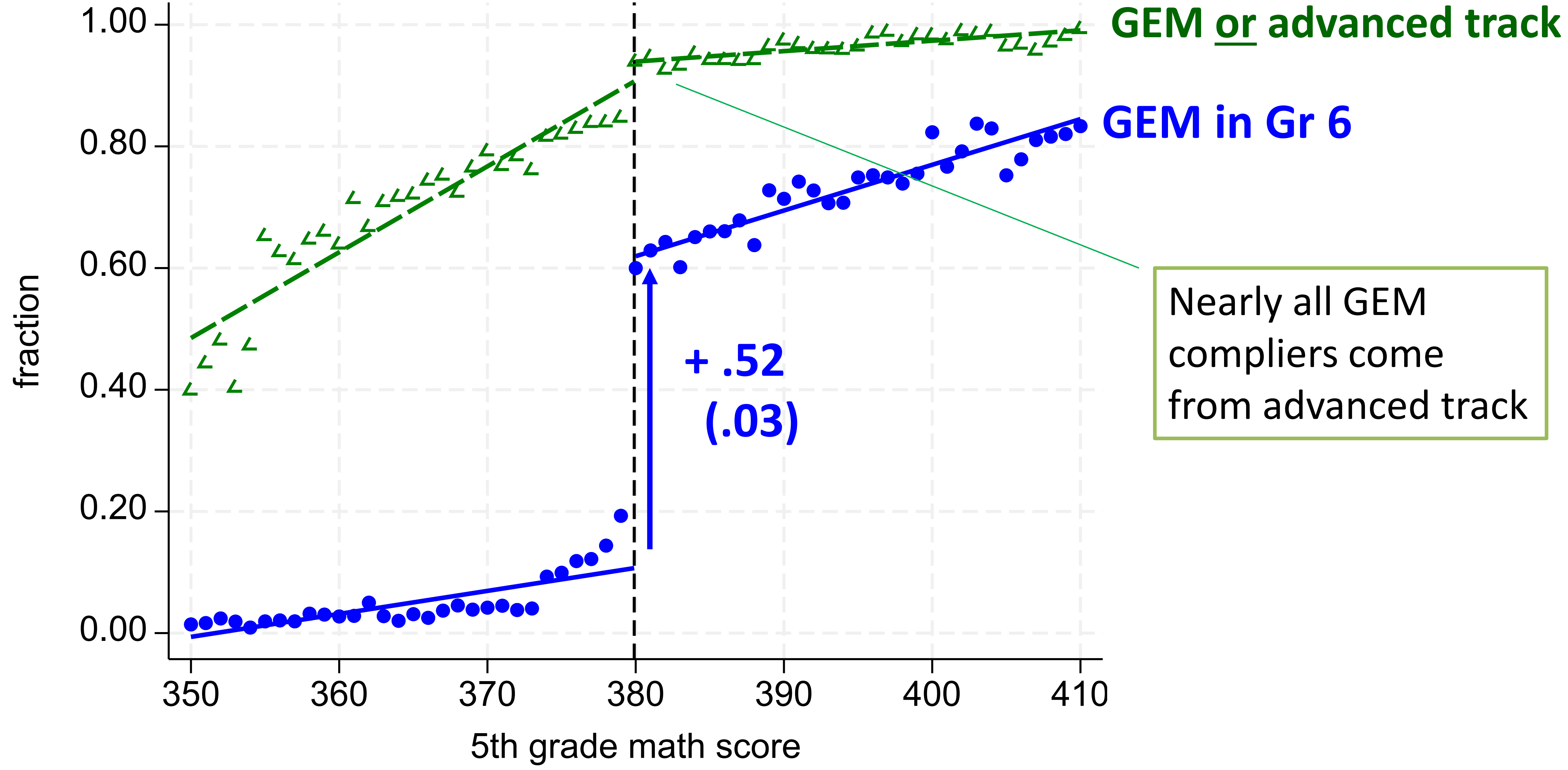
Predicted Prob. On-Time HS Grad & STEM/Business Degree in 6 Yrs




Histogram of running variable (all students in sample cohorts)

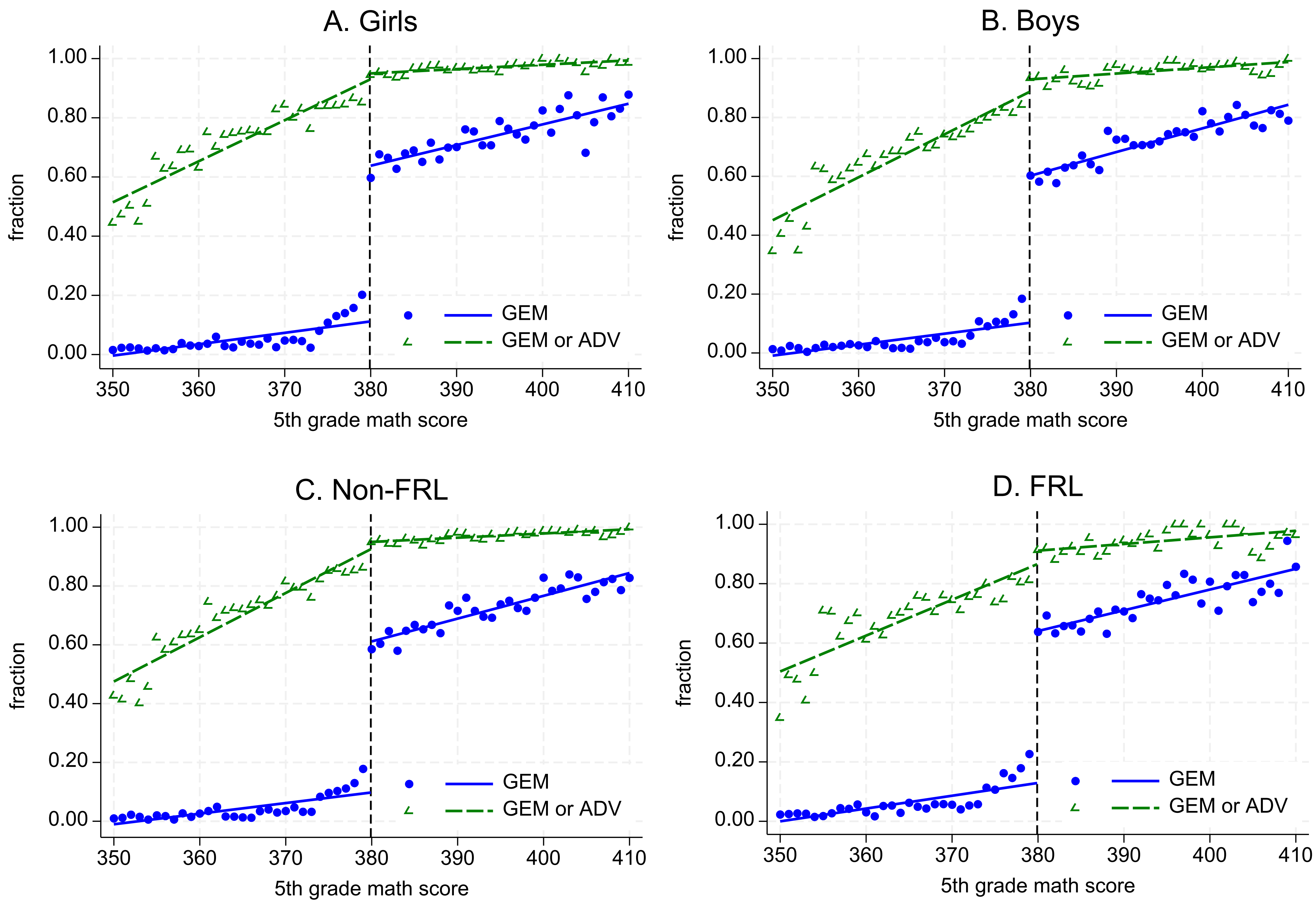


# First-stage relationship




Nearly all GEM compliers come from advanced track

# First stage relationships by gender & FRL status



# Complier characteristics

| | All | Girls | Boys | Non-FRL | FRL |
|---|---|---|---|---|---|
| **Demographic characteristics** | | | | | |
| female | 0.48 | 1.00 | 0.00 | 0.46 | 0.52 |
| FRL | 0.29 | 0.32 | 0.27 | 0.00 | 1.00 |
| White | 0.42 | 0.39 | 0.45 | 0.52 | 0.18 |
| Black | 0.22 | 0.27 | 0.17 | 0.13 | 0.44 |
| Hispanic | 0.26 | 0.23 | 0.29 | 0.25 | 0.28 |
| **Baseline achievement** | | | | | |
| 4th-grade math score ($\sigma$'s) | 0.79 | 0.76 | 0.82 | 0.82 | 0.72 |
| 4th-grade reading score ($\sigma$'s) | 0.69 | 0.74 | 0.64 | 0.72 | 0.61 |
| **School peer characteristics** | | | | | |
| avg grade 4 math & reading scores | 0.14 | 0.13 | 0.15 | 0.20 | 0.00 |
| fraction FRL | 0.41 | 0.42 | 0.40 | 0.35 | 0.56 |
| fraction GEM eligible | 0.22 | 0.21 | 0.22 | 0.23 | 0.18 |

# Outcomes in middle and high school

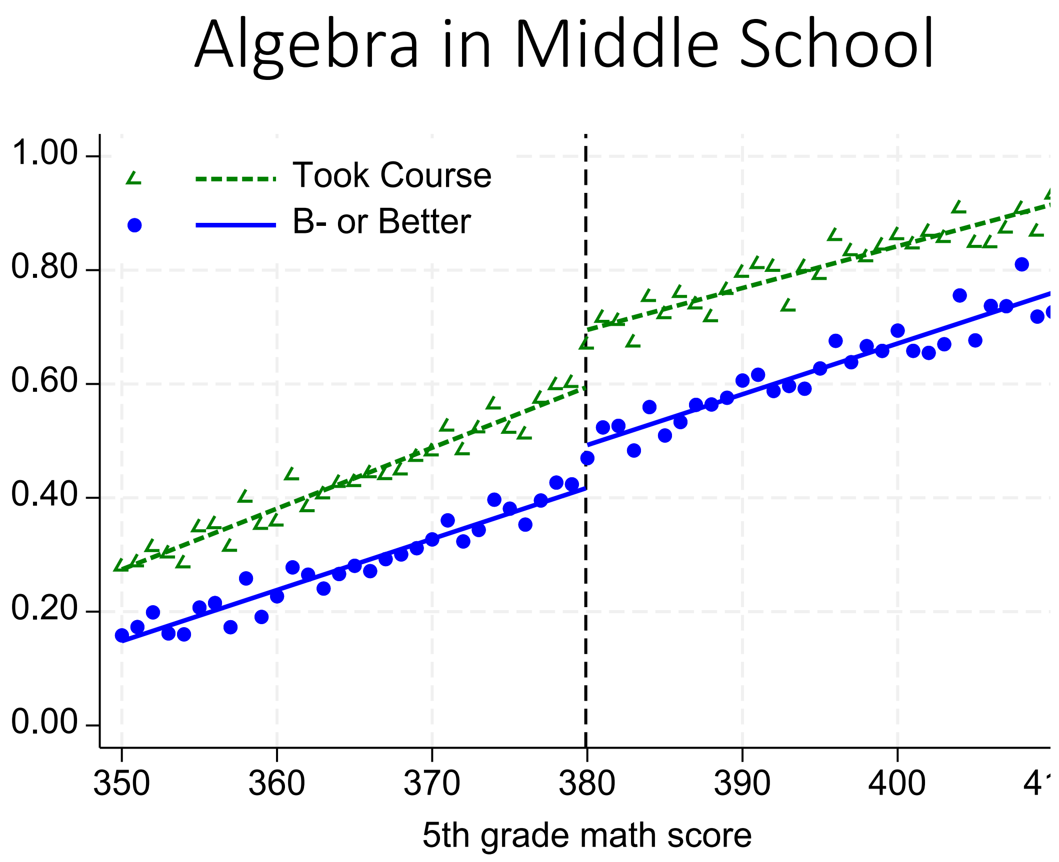
Middle school:

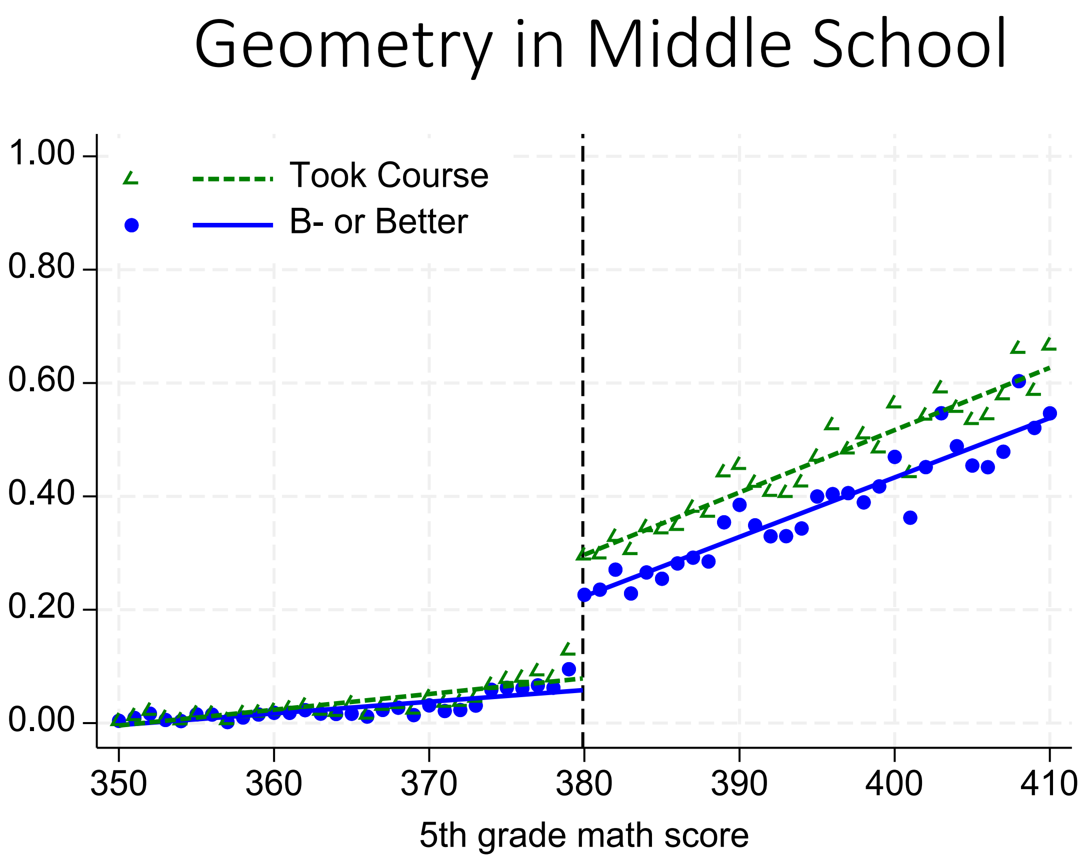
- Enroll in Algebra (in either $7^{th}$ or $8^{th}$ grade)
- Enroll in Algebra &earn grade **≥ B-** (in either $7^{th}$ or $8^{th}$ grade)
- Enroll in Geometry ($8^{th}$ grade)
- Enroll in Geometry and earn grade **≥ B-** (complete GEM successfully)
- Math GPA by grade level

High school:

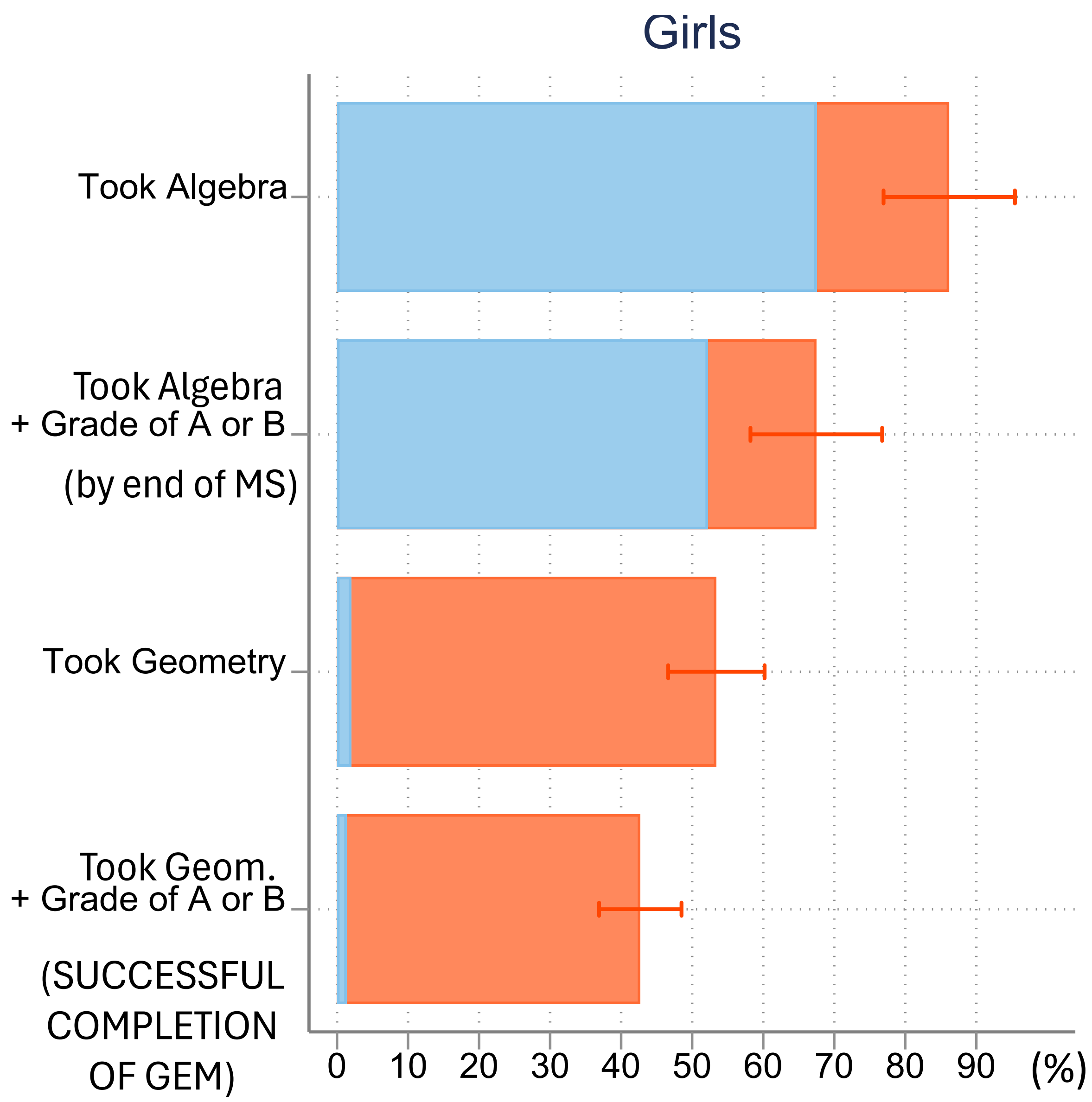
- Course enrollments (AP Stats, Calculus, AP Calculus AB/BC)
- Course sequencing (e.g., Algebra II in $9^{th}$ grade; Calculus by $11^{th}$ grade)
- AP Calculus score ≥3
- PSAT Math score
- GPA in Math/ Overall

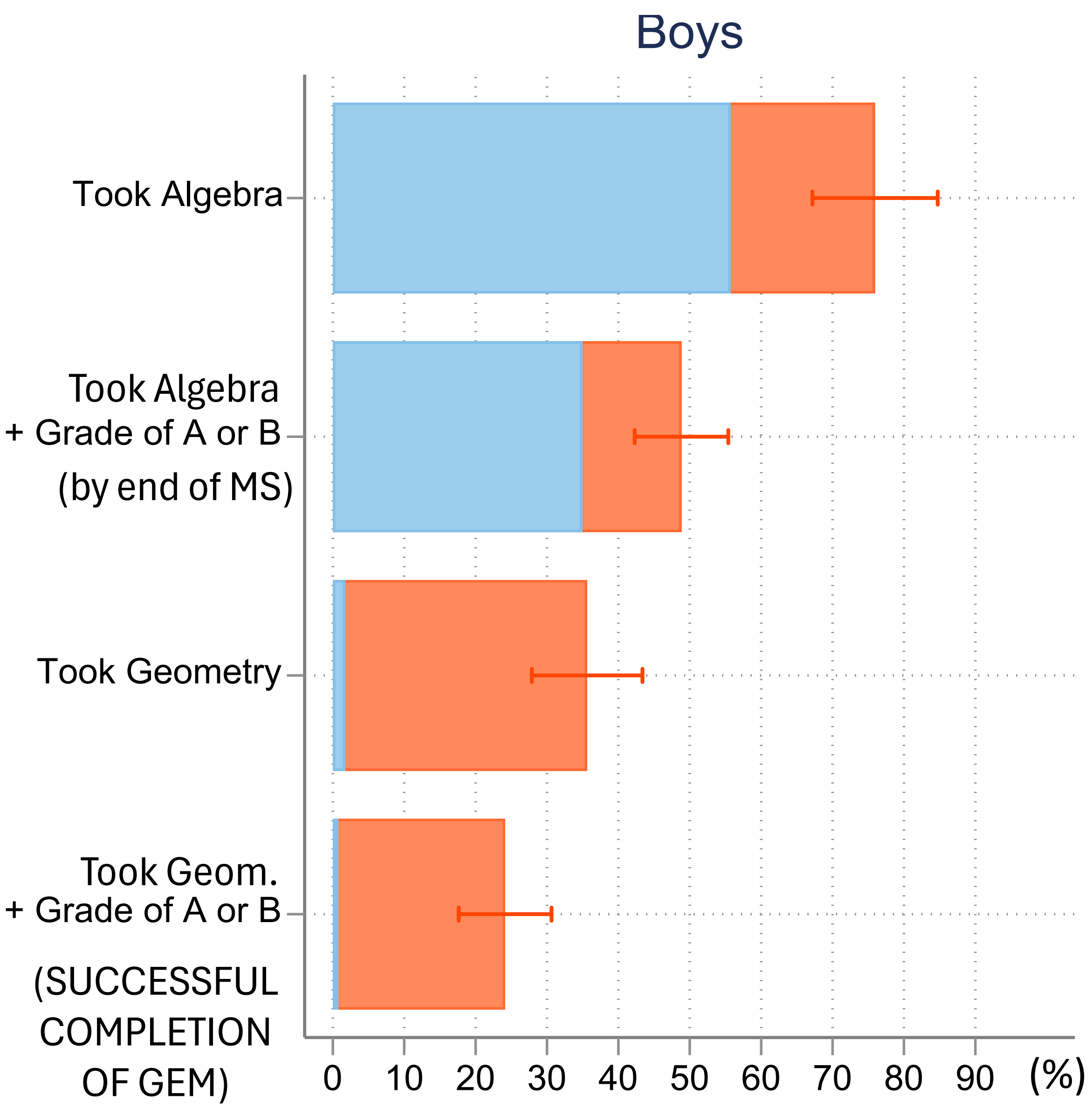
# Reduced-form relationships (pooled sample):



# Treatment Effects on Middle School Math Outcomes, by Gender



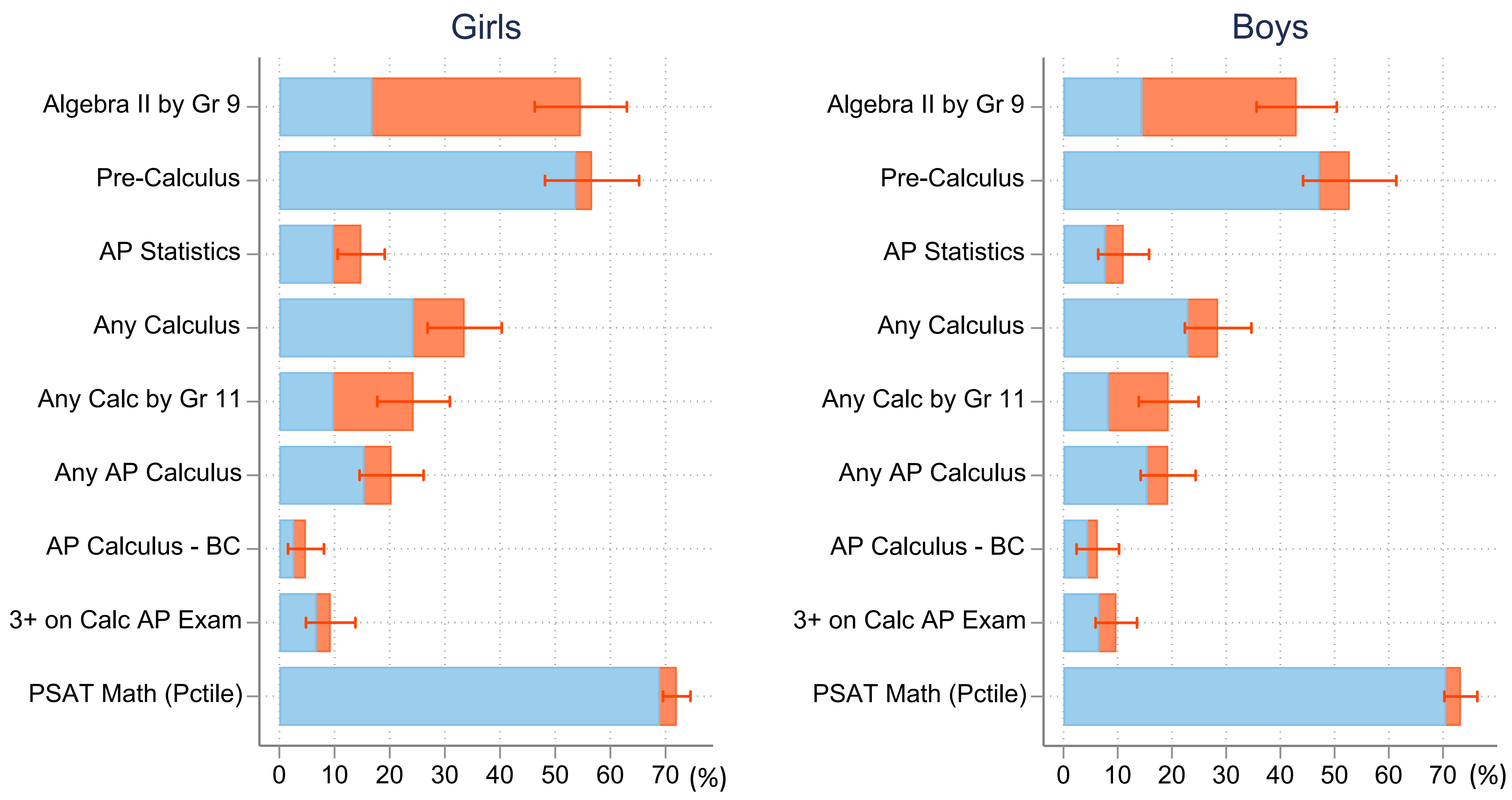



# High School Math Course Enrollment Distributions by Grade Level

| Course | Never Entered GEM | | | | | Entered GEM, Did Not Complete | | | | | Completed GEM Successfully | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Grade Level | | | | All HS | Grade Level | | | | All HS | Grade Level | | | | All HS |
| | 9th | 10th | 11th | 12th | | 9th | 10th | 11th | 12th | | 9th | 10th | 11th | 12th | |
| Algebra I | **51.6** | | | | | 21.2 | | | | | 1.3 | | | | |
| Geometry | 35.2 | **44.3** | | | | **43.1** | 20.0 | | | | 2.9 | 2.3 | | | |
| Algebra II | 8.0 | 35.4 | **40.4** | 16.1 | **99.9** | 26.0 | **41.2** | 22.5 | 10.0 | **99.8** | **70.9** | 7.5 | 4.6 | 2.6 | **85.7** |
| Other Advanced* | 2.4 | 10.3 | 28.3 | **34.9** | **75.8** | 5.2 | 17.0 | **31.3** | **28.2** | **81.7** | 19.9 | 22.1 | 14.4 | 10.2 | **66.5** |
| Pre-Calculus | 0.1 | 6.3 | 17.2 | 8.6 | **32.1** | 1.0 | 15.5 | 20.3 | 8.8 | **45.6** | 3.6 | **48.3** | 14.5 | 3.7 | **70.1** |
| AP Statistics | | 0.1 | 1.1 | 4.8 | **6.0** | | 0.2 | 2.1 | 6.7 | **9.0** | | 4.3 | 5.2 | **16.8** | **26.3** |
| Calculus | | 0.9 | 2.6 | 3.2 | **6.7** | | 2.0 | 5.2 | 4.4 | **11.7** | | 8.1 | 9.7 | 3.0 | **20.8** |
| AP Calculus AB | | | 2.8 | 4.5 | **7.3** | | | 6.3 | 5.5 | **11.8** | | | **29.0** | 9.2 | **38.1** |
| AP Calculus BC | | | 0.4 | 1.6 | **2.0** | | | 1.0 | 2.8 | **3.7** | | | 7.6 | **12.8** | **20.4** |
| Dual Enrolment Calc. | | 0.1 | 0.0 | 0.4 | **0.5** | | 0.4 | 0.0 | 0.6 | **1.0** | | 5.2 | 0.1 | 2.4 | **7.8** |
| Dual Enrolment (Other) | | 0.0 | 1.7 | 6.7 | **8.4** | | 0.0 | 2.6 | 7.3 | **9.9** | | 0.0 | 7.5 | **13.5** | **21.0** |
| *None* | *2.8* | *2.7* | *5.6* | *19.2* | | *3.5* | *3.7* | *8.6* | *25.7* | | *1.4* | *2.1* | *7.5* | *25.8* | |

* Other Advanced Math Includes: Prob/Stats w Applications, Math Analysis, Trigonometry, etc.

# Treatment Effects on High School Math Outcomes, by Gender



# Treatment effects for selected outcomes by gender & FRL status

| | | Course Enrollments | | | Enrolled & earned grade of B- or better | | |
|---|---|---|---|---|---|---|---|
| | Enter GEM (1st stage) | Algebra in MS | Geometry in MS | Calculus in HS | Algebra | Geometry | Calculus |
| **1. Pooled** | **0.513**** | **0.198**** | **0.427**** | **0.093**** | **0.149**** | **0.324**** | **0.049*** |
| (N=23,225) | (0.028) | (0.040) | (0.032) | (0.024) | (0.030) | (0.026) | (0.022) |
| **2. Girls** | **0.526**** | **0.187**** | **0.514**** | **0.094**** | **0.154**** | **0.414**** | **0.044** |
| (N=11,488) | (0.028) | (0.047) | (0.035) | (0.034) | (0.047) | (0.030) | (0.031) |
| **3. Boys** | **0.500**** | **0.207**** | **0.340**** | **0.095**** | **0.142**** | **0.235**** | **0.053+** |
| (N=11,737) | (0.032) | (0.044) | (0.039) | (0.031) | (0.034) | (0.033) | (0.027) |
| **4. Non-FRL** | **0.513**** | **0.187**** | **0.447**** | **0.088**** | **0.164**** | **0.338**** | **0.059*** |
| (N=16,235) | (0.031) | (0.050) | (0.039) | (0.029) | (0.039) | (0.032) | (0.025) |
| **5. FRL** | **0.512**** | **0.221**** | **0.373**** | **0.101*** | **0.105*** | **0.288**** | **0.020** |
| (N=6,990) | (0.033) | (0.041) | (0.040) | (0.039) | (0.040) | (0.033) | (0.032) |

Standard errors clustered by school. Models include cohort fixed effects.

# Estimated treatment effects for math grades/GPA's

| | 6th Grade Math | 7th Grade Math | 8th Grade Math | High School All Math | High School Overall GPA |
|---|---|---|---|---|---|
| **1. Pooled** | **-0.666**** | **-0.372**** | **-0.047** | **-0.019** | **0.002** |
| (N=23,225) | (0.078) | (0.053) | (0.054) | (0.039) | (0.022) |
| **2. Girls** | **-0.642**** | **-0.439**** | **-0.043** | **-0.016** | **0.044** |
| (N=11,488) | (0.082) | (0.059) | (0.066) | (0.046) | (0.027) |
| **3. Boys** | **-0.697**** | **-0.327**** | **-0.064** | **-0.031** | **-0.047** |
| (N=11,737) | (0.088) | (0.066) | (0.078) | (0.065) | (0.043) |
| **4. Non-FRL** | **-0.652**** | **-0.327**** | **-0.067** | **-0.017** | **-0.009** |
| (N=16,235) | (0.087) | (0.056) | (0.061) | (0.045) | (0.025) |
| **5. FRL** | **-0.707**** | **-0.485**** | **-0.006** | **-0.029** | **0.019** |
| (N=6,990) | (0.101) | (0.103) | (0.081) | (0.071) | (0.045) |

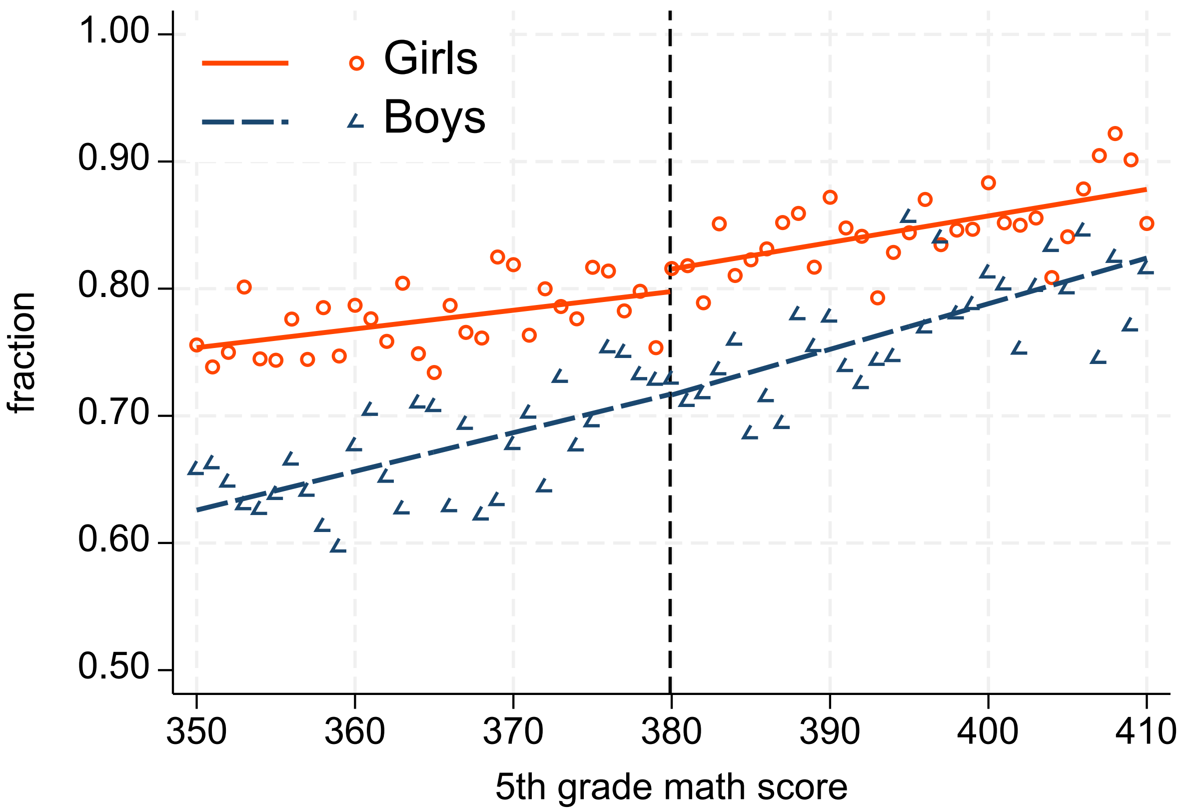
Standard errors clustered by school. Models include cohort fixed effects.

# Post-secondary outcomes

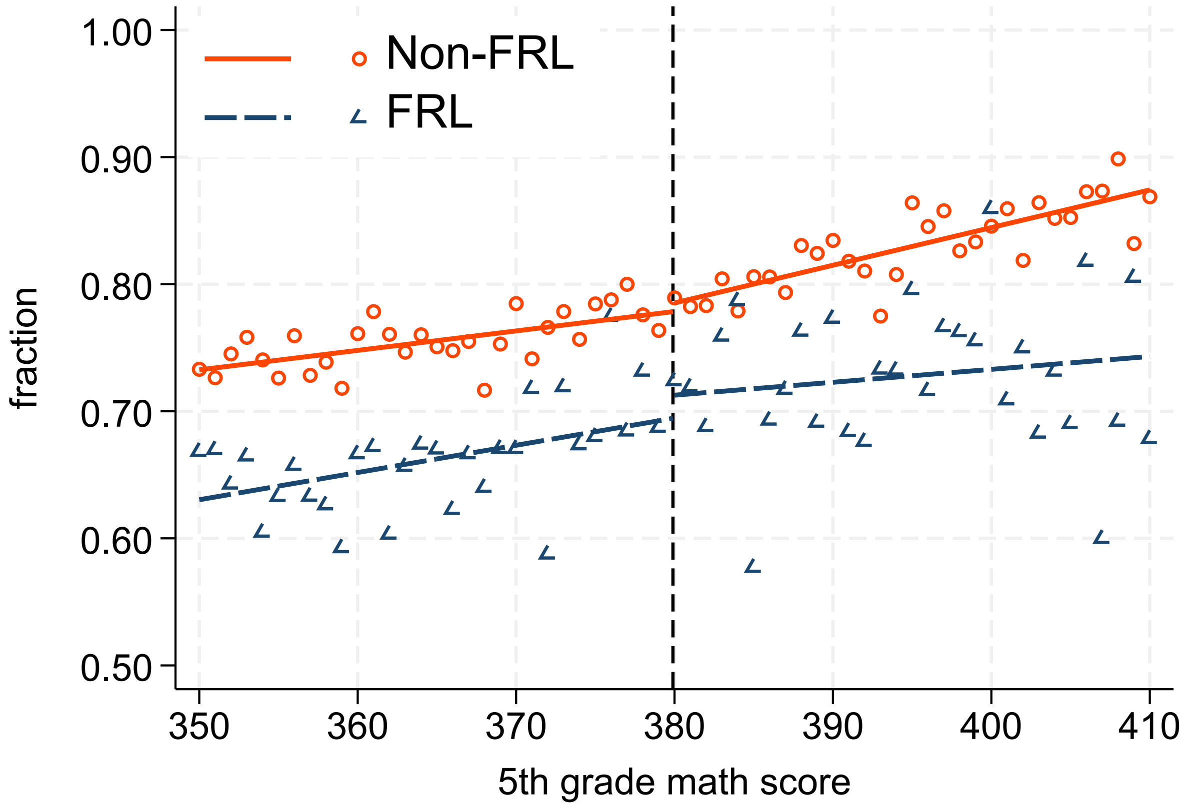
- Graduate HS and **enroll** in **any** college next year
- Graduate HS and enter **selective** college next year
- Complete **bachelor's degree** within 6 years (in any field)
- Complete bachelor's degree within 6 years in specific field:
  - STEM
  - Business/Economics

# Graduate HS on time and enter **any** college next year

by Gender

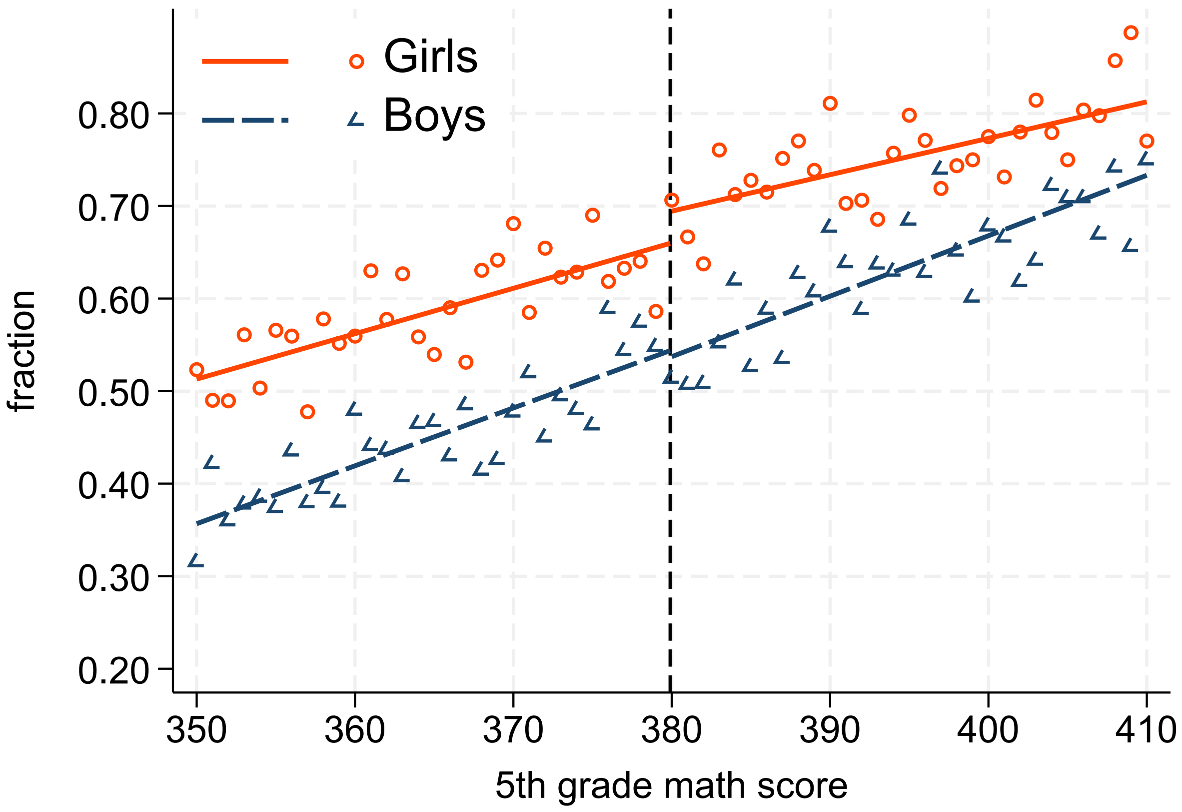



by FRL status

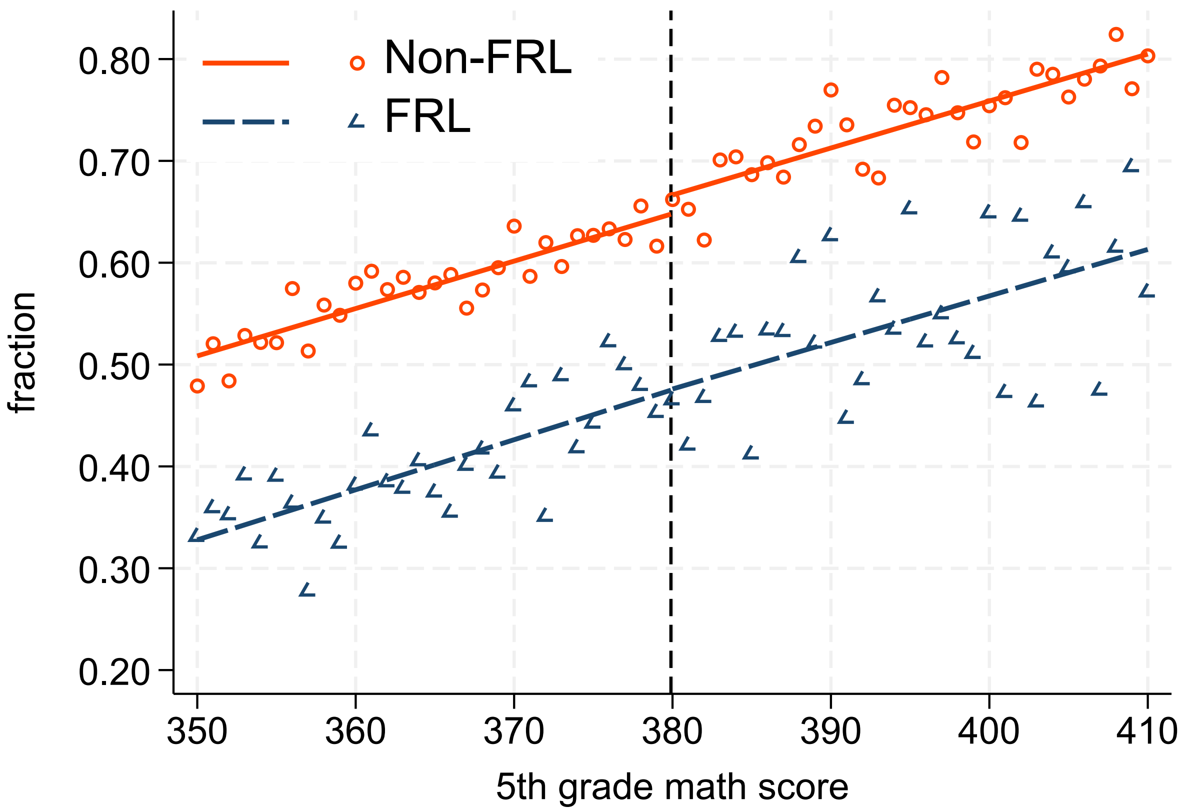


# Graduate HS on time and enter **selective** college next year

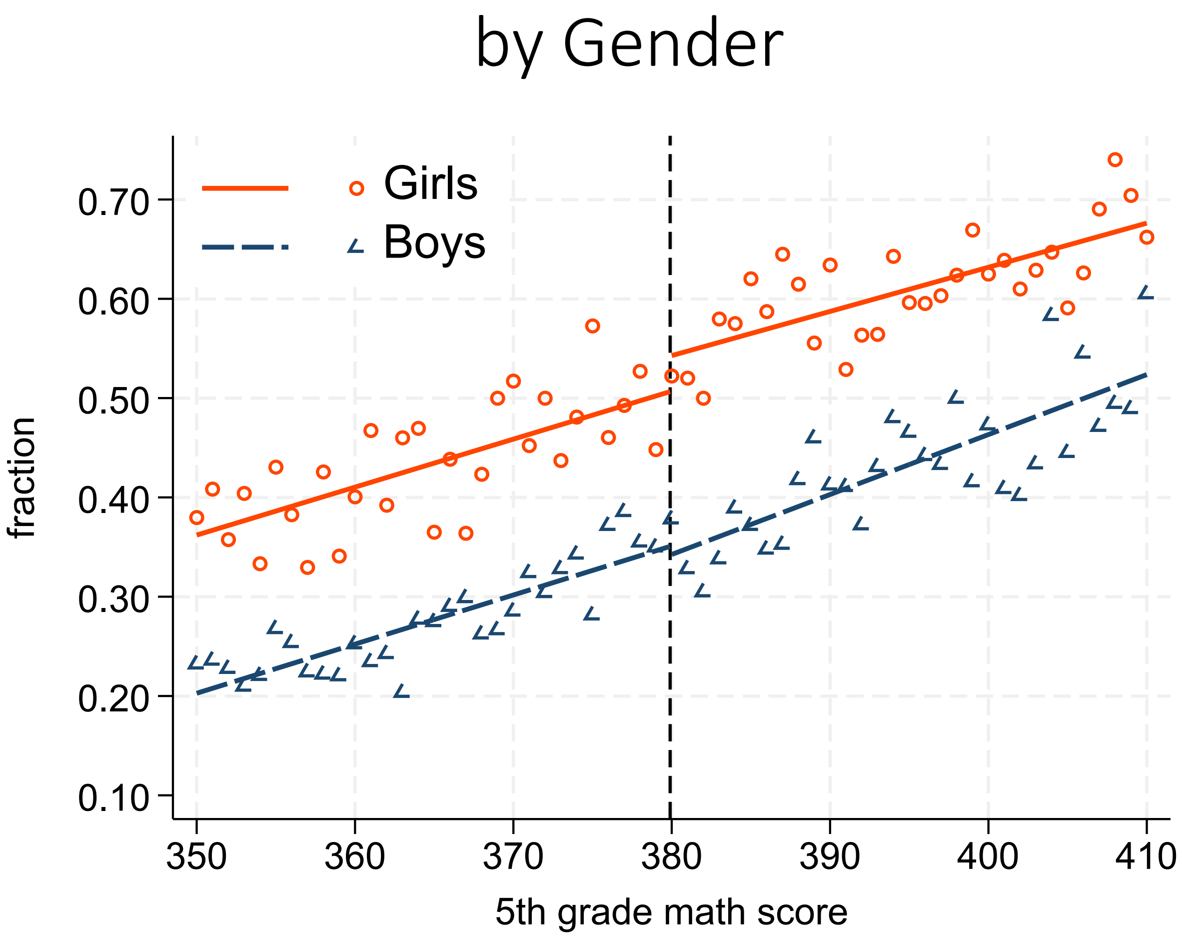
## by Gender

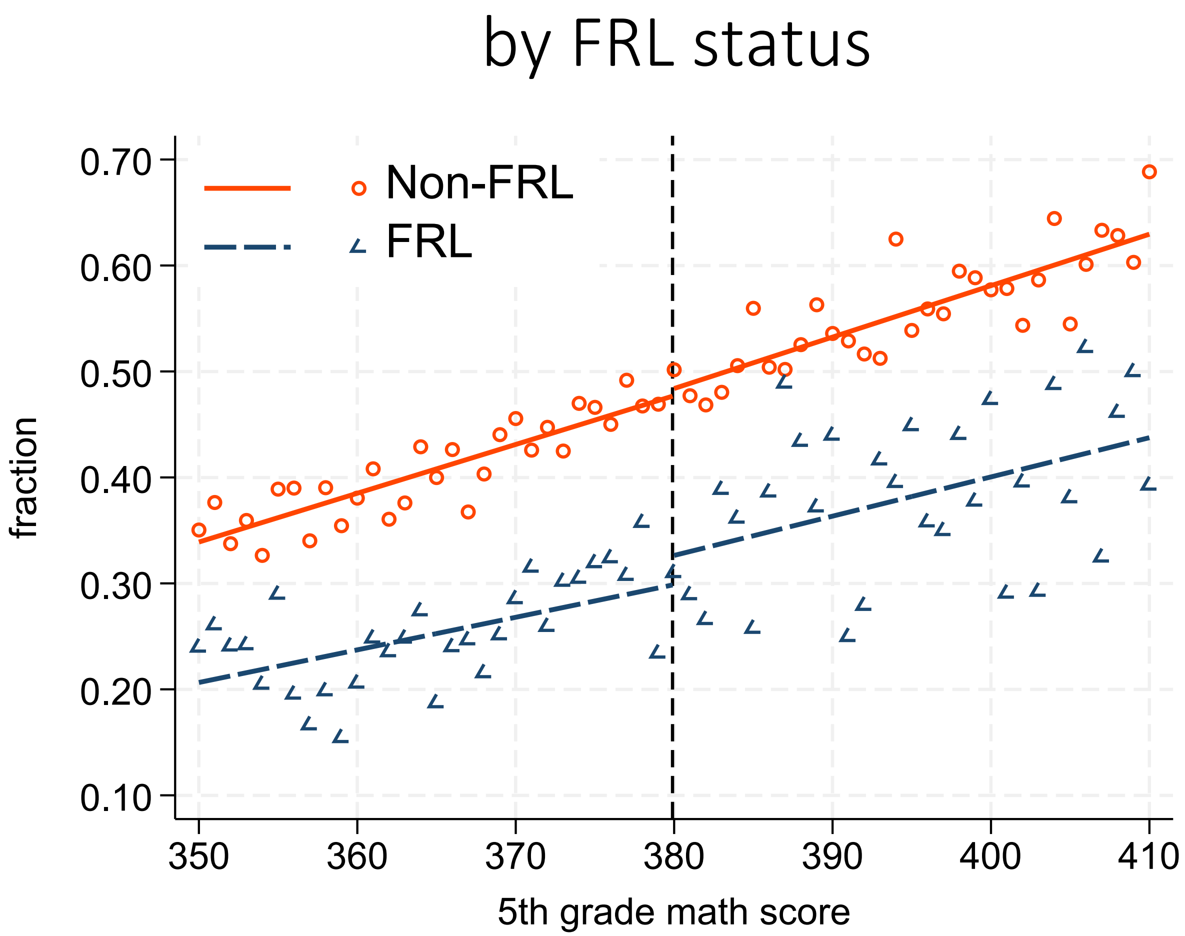



## by FRL status



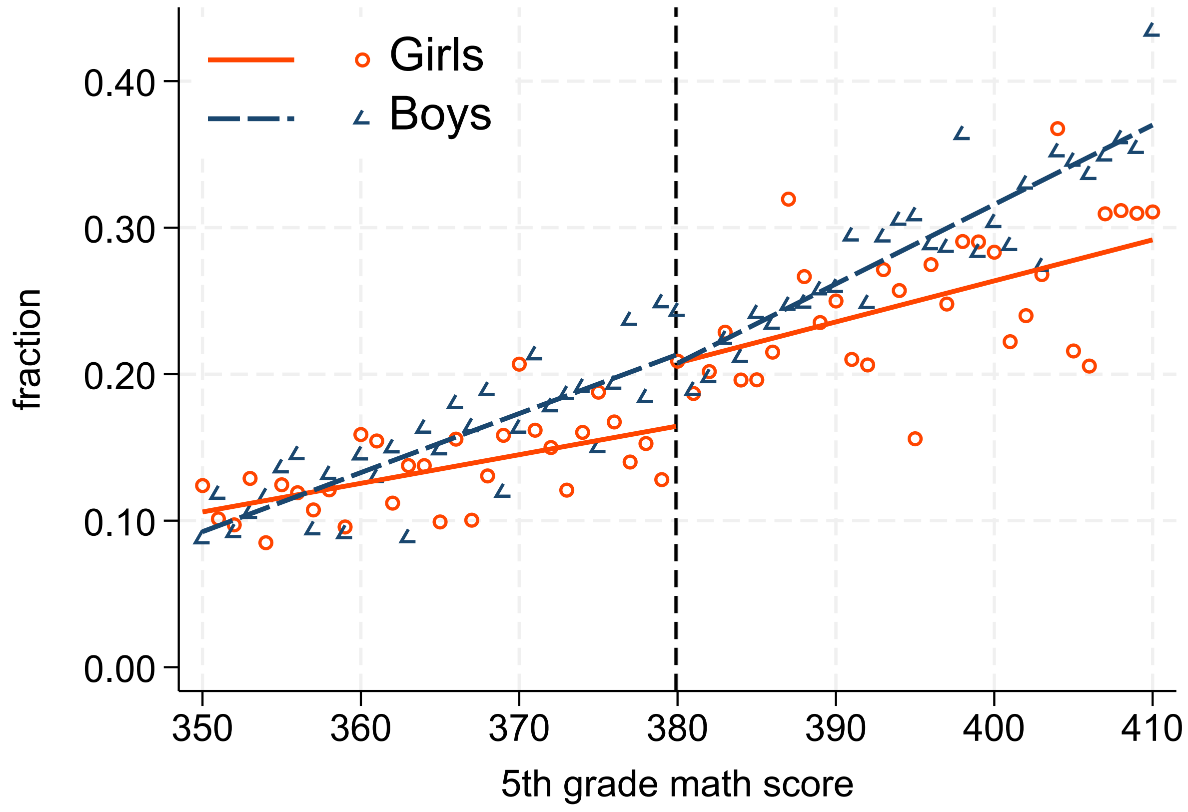
# Graduate HS on time + earn **bachelors degree** in 6 years



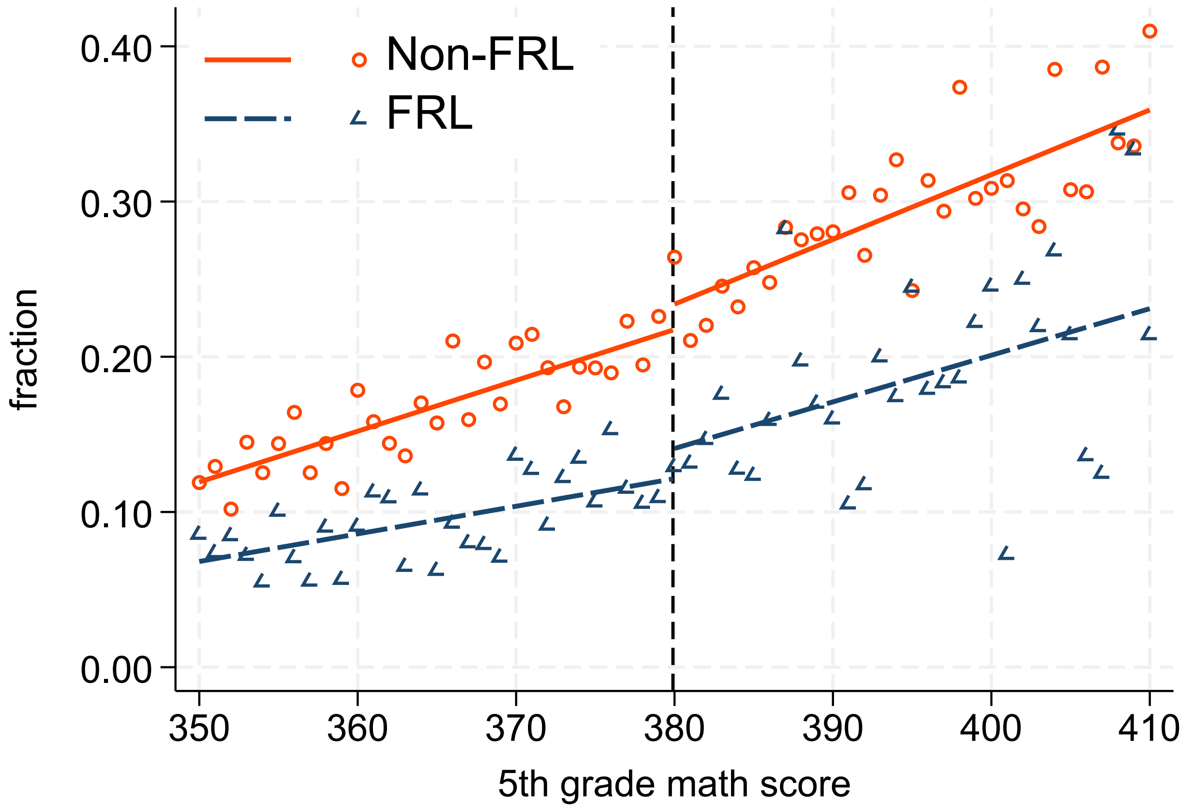



# Earn bachelor's in **STEM/Bus/Econ** in 6 years

## by Gender

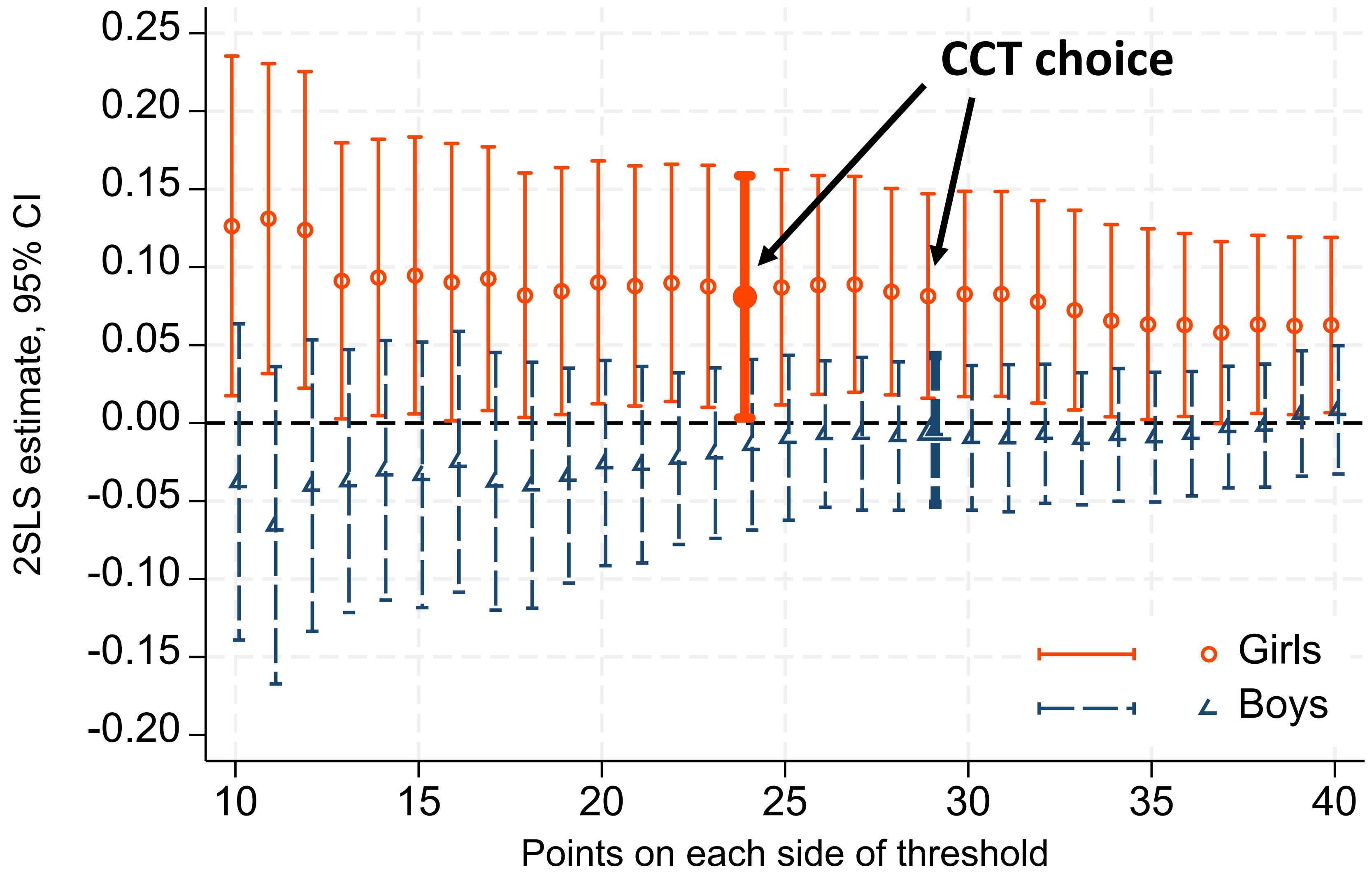



## by FRL status



# Earn bachelor's in STEM/Bus/Econ in 6 years

## 2SLS, by bandwidth and gender

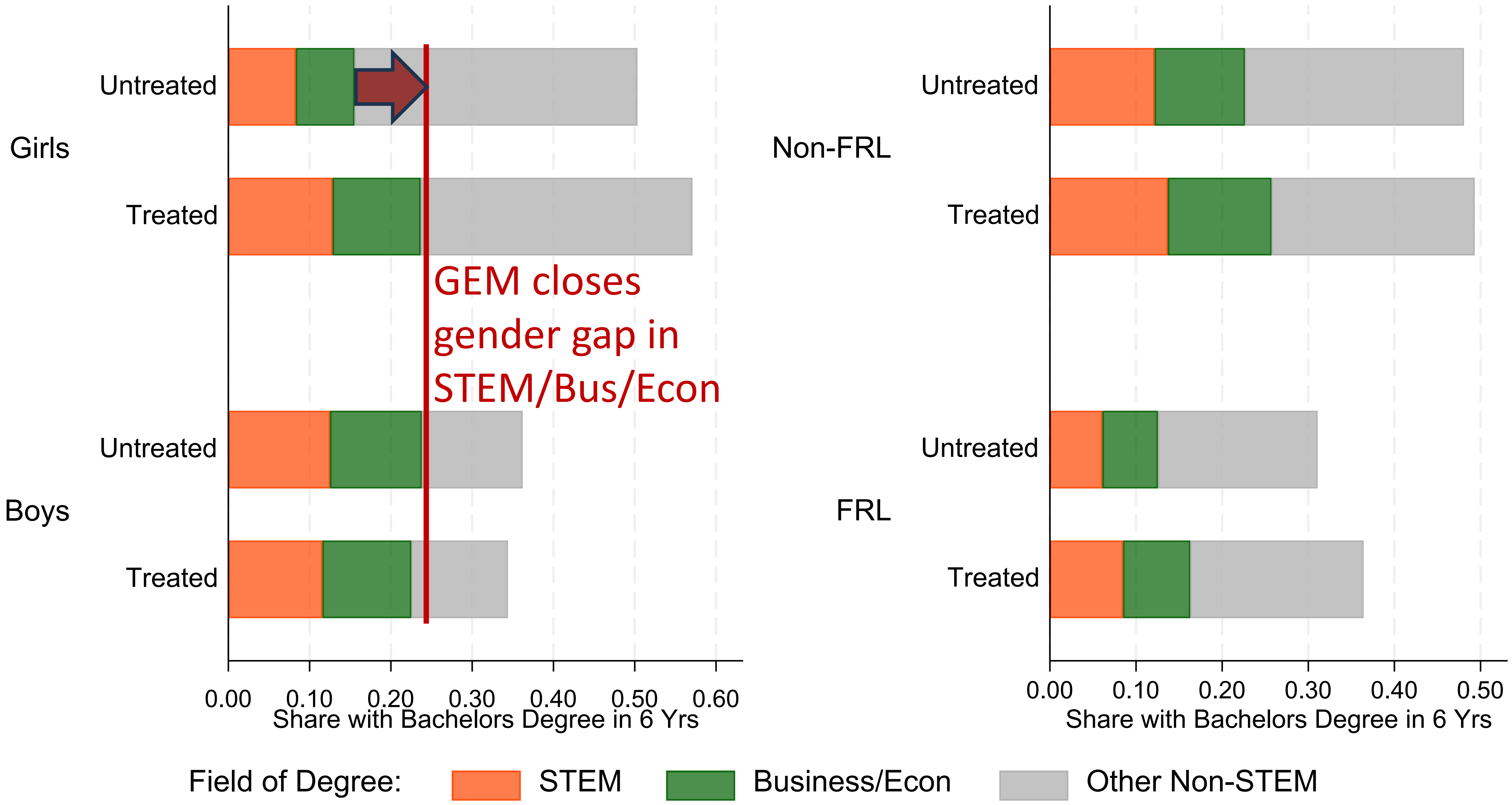


# Estimated treatment effects: Post-secondary outcomes

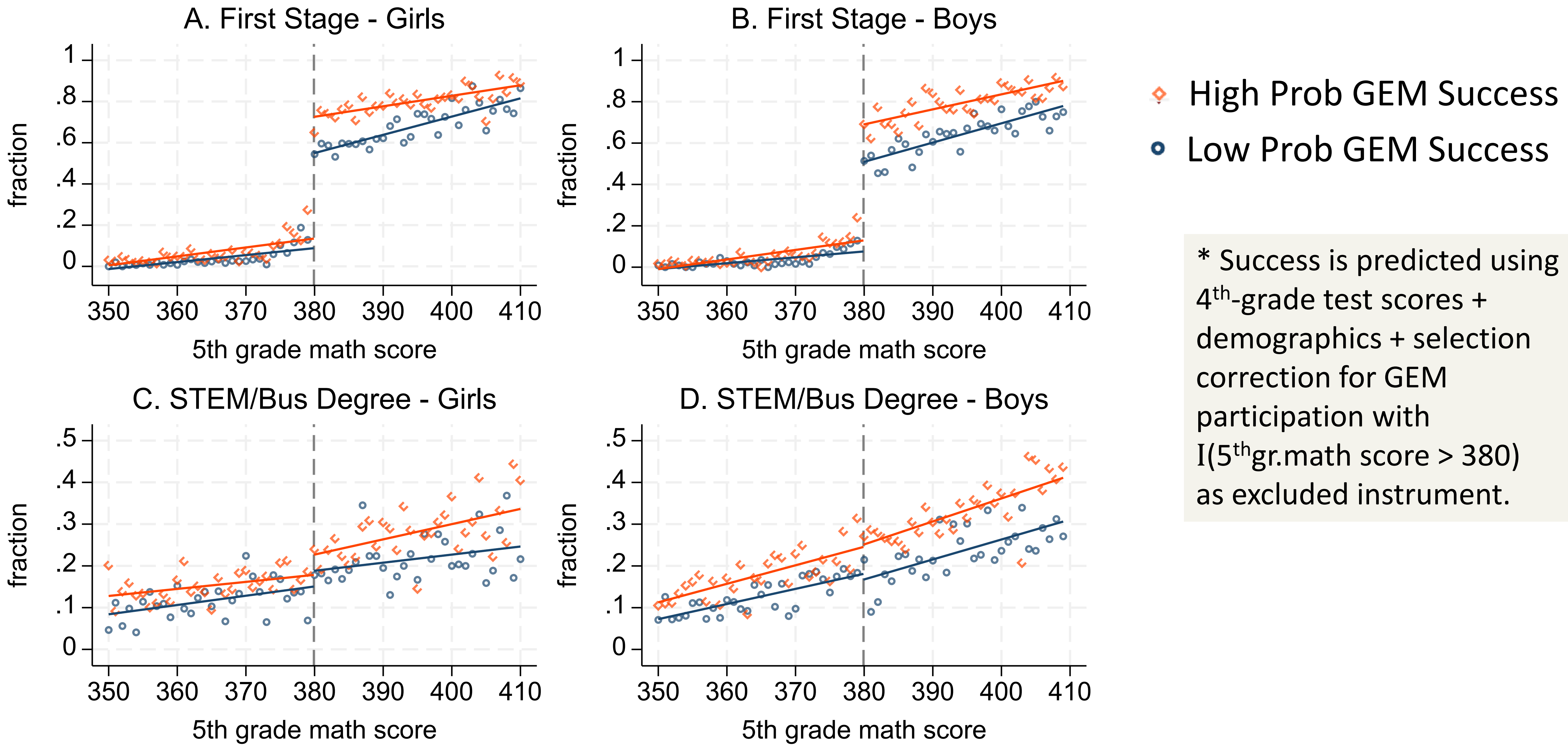
| | On-Time College Entry | Enroll in Selective College | Any BA/BS in 6 Yrs | Bachelor's in 6 years in: STEM | Bus/Econ | STEM or Bus/Econ |
|---|---|---|---|---|---|---|
| **1. Pooled** | **0.020** | **0.030** | **0.029** | **0.019** | **0.017** | **0.037+** |
| | (0.020) | (0.024) | (0.021) | (0.013) | (0.015) | (0.021) |
| **2. Girls** | **0.035** | **0.066*** | **0.070*** | **0.046*** | **0.037+** | **0.083*** |
| | (0.022) | (0.032) | (0.034) | (0.021) | (0.020) | (0.034) |
| **3. Boys** | **0.001** | **-0.009** | **-0.015** | **-0.008** | **-0.003** | **-0.009** |
| | (0.031) | (0.034) | (0.031) | (0.018) | (0.017) | (0.024) |
| **4. Non-FRL** | **0.015** | **0.038** | **0.016** | **0.017** | **0.016** | **0.034** |
| | (0.024) | (0.027) | (0.023) | (0.016) | (0.018) | (0.025) |
| **5. FRL** | **0.031** | **0.002** | **0.054** | **0.024** | **0.013** | **0.038** |
| | (0.034) | (0.045) | (0.047) | (0.034) | (0.026) | (0.041) |

Standard errors clustered by school. Models include cohort fixed effects.

# Summary of effects on field of degree , by gender & FRL



# Heterogeneity by gender & Pr(success in GEM)*




* Success is predicted using 4th-grade test scores + demographics + selection correction for GEM participation with I(5th gr.math score > 380) as excluded instrument.

# Spillover effects

- GEM program moves treated compliers to separate classrooms in Gr 6 (and Gr 7 & Gr 8 for those who perform well)
- Big concern in the literature: potential for negative spillover effects, particularly  for untreated compliers …

    a) from loss of strongest peers

    b) from “discouragement effects”
- *Policy concern*: tracking might hurt those left in lower tracks
- *Identification concern*: downward bias in estimate of mean Y(0) → upward bias in RD estimate of treatment effect

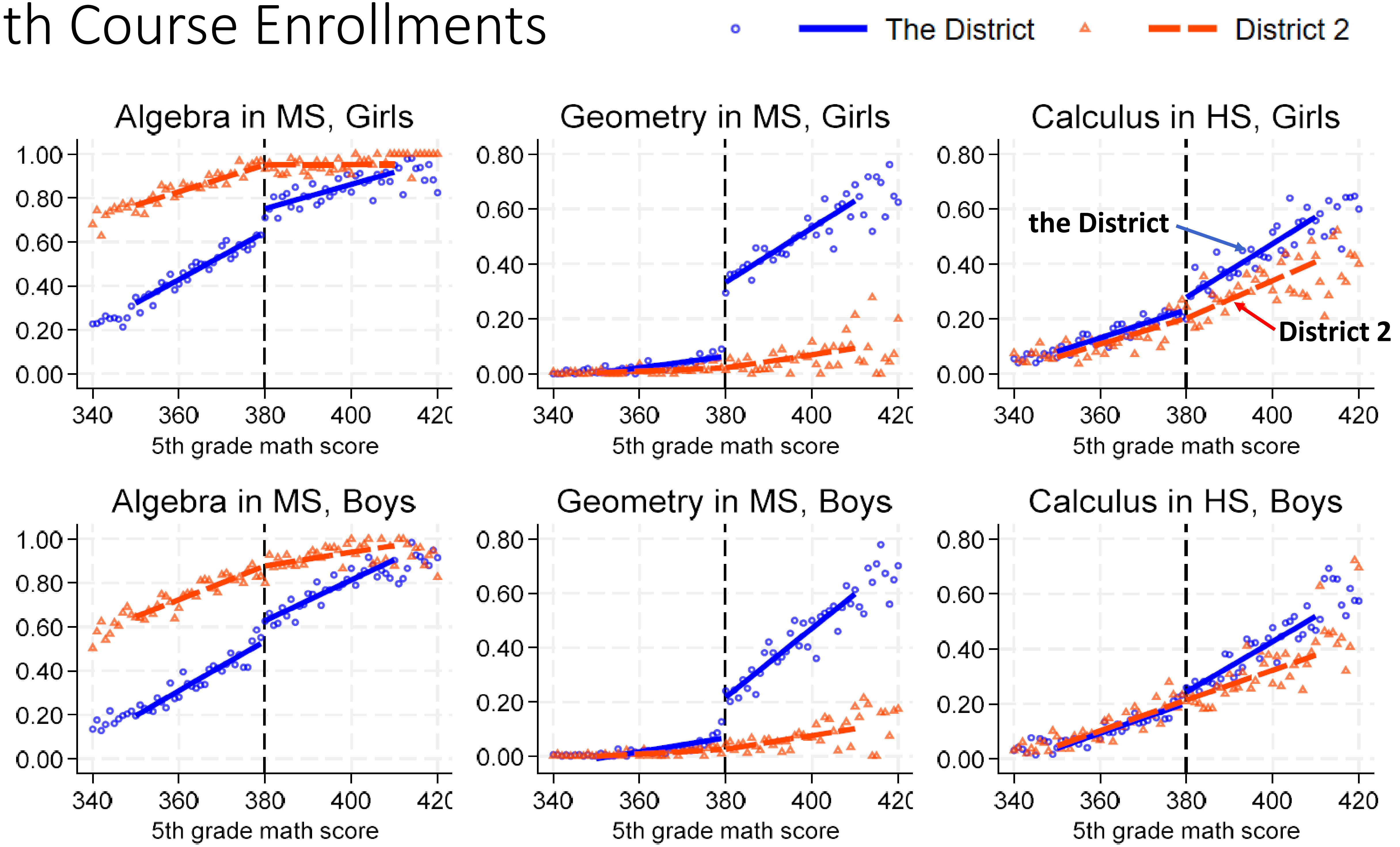
# Between-district analysis

- We obtained data for another large, urban district in FL, "**District 2**" that:
  - has 2 tracks in middle school math: regular and advanced
  - offers Algebra in Gr 8 (advanced) but not Geometry (***<u>no</u> GEM-like option***)
  - encourages most students with scores in top 1/3 of G5 math score distribution to take Algebra in G8
  - has ***<u>no</u> discontinuity*** in placement at the GEM cutoff score (380)

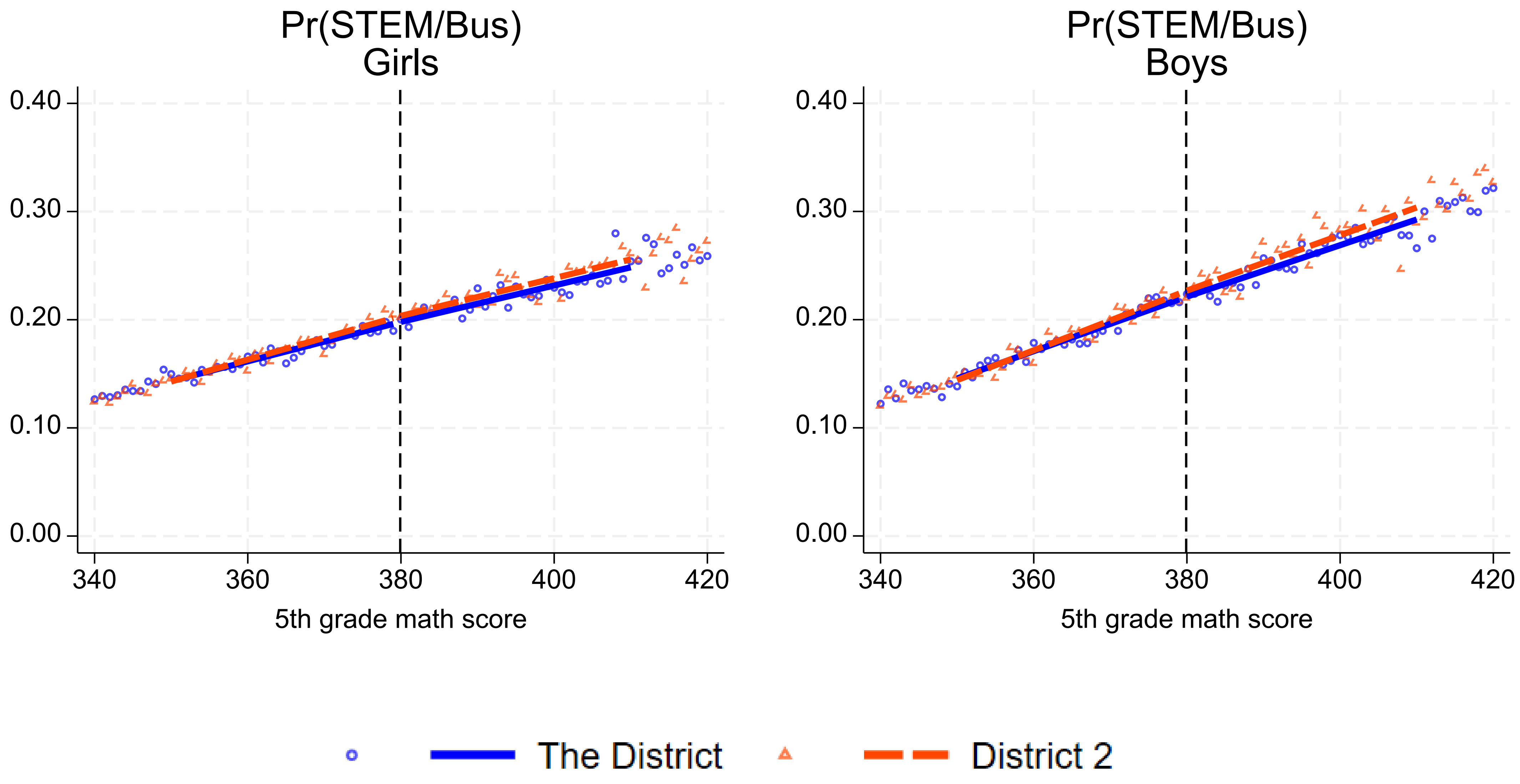
➢ Do students with scores just under 380 do better in District 2?

➢ Bonus: compare outcomes away from cutoff

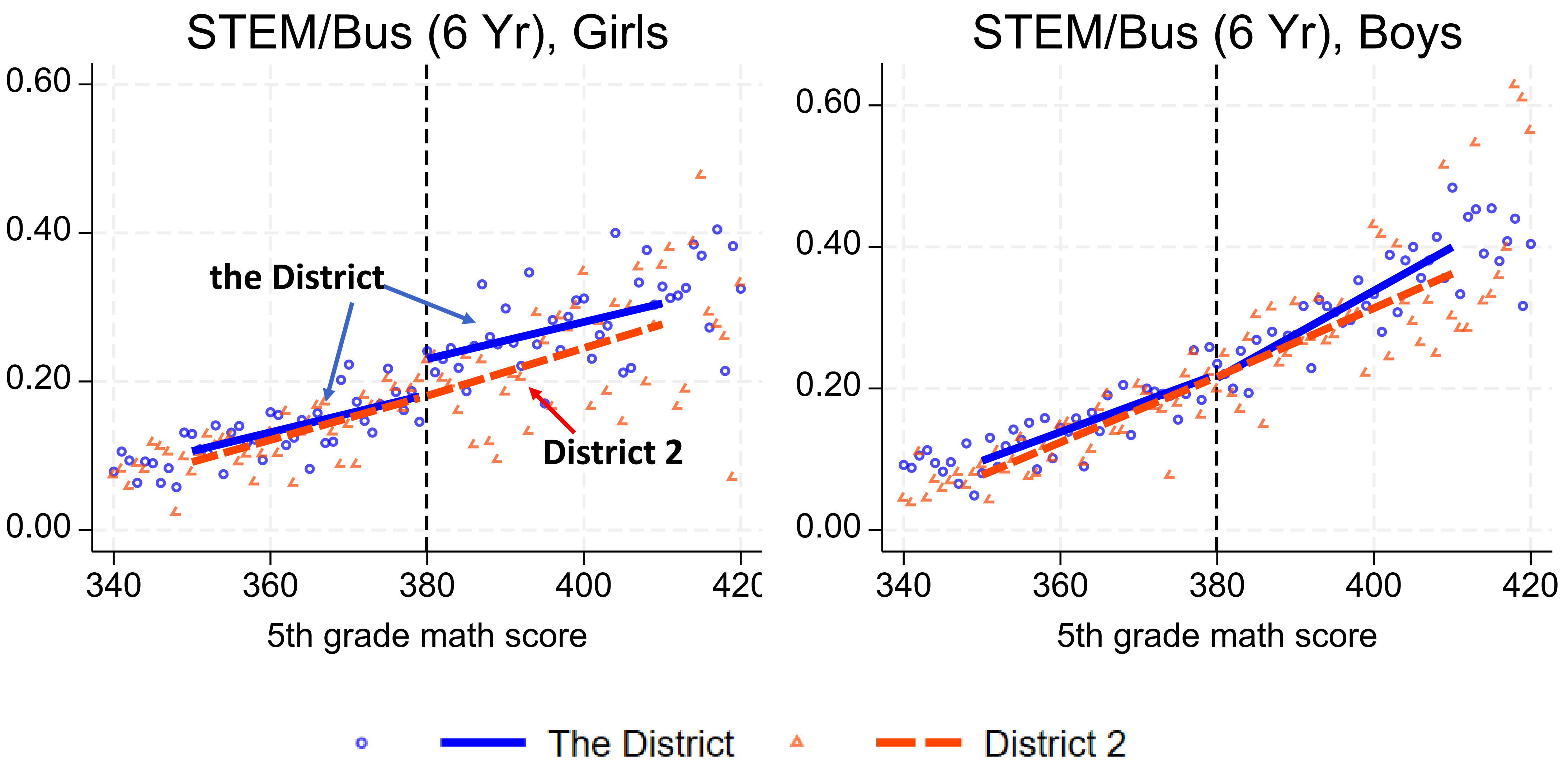
# Math Course Enrollments



# Predicted outcome (index of pre-treatment observables)



# Bachelor's in STEM/Bus/Econ in 6 years



# Why the gender difference in impact on STEM ?

- Unlikely to be driven by:
  - differences in impact on high school courses or grades
  - bias due to negative effects on untreated female compliers
  - gender differences in “match” between student math ability and GEM curriculum
  - gender composition of math classes
    (%female is higher in advanced track than in GEM)

- Instead, our findings suggest that GEM helps close gender gap between boys & girls who are similar on observable measures of ability and math prep

# What goes wrong for girls with high STEM potential?

- Gender gap in **confidence** about math ability conditional on measured ability predicts gaps in majoring/working in STEM field (Page & Ruebeck 2025)
- In a study of Romanian HS students, Ainsworth et al. (2025) find that being in a STEM (vs. humanities) track makes girls (but not boys) less likely to think that boys are naturally better in math.
  – Participating in GEM classrooms where girls tend to outperform boys may help them overcome traditional **stereotypes** and improve their own confidence.
- Accurate anticipation of gender-based **discrimination** in STEM/Business/Econ plays a role in major selection (Lepage, Li & Zafar 2025)

# Conclusions

- GEM program, targeted at top quintile in $5^{th}$-grade math test, leads to large increases in share of marginally eligible kids who take Algebra and Geometry "early" and who complete Calculus by $11^{th}$ grade.
- This has little or no effect on boys' outcomes beyond high school.
- But for girls, it has:
  1. a moderate effect on degree completion
  2. large effects on completion of degrees in STEM and business/econ
- The program does not appear to hurt students who miss the cutoff.
- The benefits for girls appear to extend to well above the threshold.
- The program helps to close the gender gap in STEM/business degree completion between observably similar boys and girls.