Appendix for "Standardized Test Scores and Academic Performance at Ivy-Plus Colleges"

John N. Friedman, Brown University and NBER
Bruce Sacerdote, Dartmouth College and NBER
Michele Tine, Dartmouth College

This Appendix describes data construction and analysis for the accompanying Data Insights on the relationship between academic success in college and commonly used measures of prior academic achievement in the admissions process, including SAT/ACT scores and high school GPA. Our focus is whether SAT/ACT scores are strong predictors of academic success or struggle within the context of Ivy-Plus colleges.

1 Data Description

We combine student-level data from the admissions process and the Office of Institutional Research for first-year first-time students from multiple Ivy-Plus colleges. We include all students in the first-year classes who started in Fall of 2017-2022 (excluding Fall of 2020, due to the disruption from COVID-19) who reported high school GPA and completed the required minimum number of courses during their first full year.

Our key admissions variables are SAT/ACT test scores and high school GPA. By SAT we mean the SAT Composite which sums the score on the Math exam and the Evidence Based Reading and Writing exam. When students submit ACT but not SAT scores, we take the composite ACT score and then convert it to the SAT's 400-1600 point scale using scale equivalence tables from ACT and CollegeBoard. We exclude the small number of students without test scores before test-optional policies came into effect at many colleges in 2020. We scale high school GPA on the standard 4.0 scale, in which a D is a 1.0 and an A is a 4.0. In many specifications we control for but do not report coefficients on gender, race and ethnicity (defined as an indicator if a student self-identifies as Black, Hispanic, American Indian or Alaskan Native, or Native Hawaiian or Other Pacific Islander), legacy status, early decision applicant status, athletic recruit status, first-generation college status, rural/urban home, and indicators for U.S. citizen or permanent resident. We also include but do not report fixed effects for family income bins. We observe family income for those students who apply for financial aid; we break this group into terciles and include an indicator for each, plus a fourth indicator for family income missing, which generally occurs in cases where the student is not applying for financial aid. Finally, we include but do not report indicators for each student based on their high school's decile on an index of challenge indicators that capture educational opportunities or disadvantages in the high school environment, variables that feed into the CollegeBoard Landscape tool (Mabel et al. 2022, Bastedo et al. 2022). We classify high schools that fall in the bottom 20 percent of this index of advantage as "advantaged." 75 percent of applicants to our Ivy-Plus colleges come from advantaged high schools with this definition.

We define three outcome variables based on a student's grades in their first year of college. Our main outcome variable is first-year cumulative GPA (scaled in the standard way as above); the mean of first-year cumulative GPA across our colleges is 3.49. We additional analyze two further measures of performance:

percent of grades that are A or A- (63% on average in our sample) and an indicator for academic struggle, defined as having any grade of C+ or lower in the first year (25% on average in our sample). Our data do not include information on the full distribution of grades for students starting as first-years in Fall 2019; we thus include only students from the remaining four cohorts (2017, 2018, 2021, and 2022) when using either of these alternative performance measures of academic struggle or the percent of grades that are As as the dependent variable.

2 Empirical Approach

We regress our three outcome measures (first-year GPA, percent As, any C or below) on SAT/ACTs, high school GPA and various sets of controls and interactions of the controls. In all specifications we include college fixed effects and school year effects to remove any level effects of grading across colleges and across years. Our baseline specification is

$$Y_i = \beta_1 * \text{SAT}_i + \beta_2 * \mathbb{I}\{SATMISSING_i\} + \beta_3 * \text{HSGPA}_i + \mu_{s(i)} + \theta_{t(i)} + \gamma_i X_i + \delta_{h(i)} + \epsilon_i, \qquad (1)$$

where Y_i is one of our academic outcomes for student i (e.g., first-year GPA,). Our key dependent variable is a student's standardized test score (SAT_i); we also include an indicator variable for students admitted without test scores. For interpretability, we norm test scores to 0 for students with an SAT score of 1400 (ACT score of 31); because we impute "0" as the score for students' missing test scores, readers can interpret the coefficient β_2 as the extent to which students without test scores differ in their outcomes from students scoring 1400 on the SAT. We further include a student's high school GPA and report the coefficient β_3 in most specifications. We then control for a set of variables including fixed effects for the college (s) and year (t) where a student is a first-year, the high school from which they applied to college (h), and a vector of individual level characteristics $\mathbf{X_i}$, including a student's gender, legacy status, early decision applicant status, URM status, athletic recruit status, first-generation college status, rural/urban home, U.S. citizen or permanent resident, family income, and (in specifications without high school fixed effects) high school challenge index.

In addition to our baseline specification in equation (1), we also test for algorithmic bias in test scores by separately estimating the relationship between test scores and academic performance in college for students from different sub-groups. To do so, we augment equation (1) with two additional terms: interactions between an indicator G_i and each of our test score variables (SAT_i and $\mathbb{I}\{SATMISSING_i\}$). We do so using three different definitions of G_i: students who attend a high school above the national 20th percentile on our index of high school challenge indicators, first generation students, and students from families with incomes in the first tercile of distribution (below $91,800).

3 Results

3.1 Association of Test Scores and Academic Performance

In Table 1 we present our regressions of outcomes on SAT/ACT scores and high school GPA with increasing sets of controls across the columns. The three panels are for first-year GPA (Panel A), percent As (panel B) and an indicator for having a C or below (Panel C). We divide SAT by 100 so the coefficients are interpreted

as the increase in the outcome for a 100-point increase in SAT.

Column (1) uses just SAT/ACT scores and only controls for college effects and year effects. Test score (or its absence) alone predict 19 percent of the variation in cumulative GPA, 24 percent of the variation in percent As (panel B), and 10 percent of the variation in the likelihood of a C or below. In column 2, we repeat the specification but with only high school GPA; the R-squared of this variable is lower than test scores. We combine both measures in Column (3).

In Figure 1, we further plot binscatters to present the estimates from Table 1 Columns (1) and (2) non-parametrically. We estimate a version of equation (1) without student-level controls and replacing the linear control for SAT with 17 indicators for quantiles of the test score distribution (since we observe test scores for roughly 85% of students). We then plot the value of these 17 coefficients (y-value) vs. the average value of test score for students in each quantile (x-value), along with the coefficient for the remaining 15% students missing a test score (on the right). The best-fit line plots the linear fit from the microdata as reporting in Columns (1) and (2).

In Column (4), we further include the vector of student-level controls $\mathbf{X_i}$ in what we consider our baseline specification. The coefficients on test scores and high school GPA each shrink somewhat towards 0 but remain both statistically and substantively significant. Holding all else fixed, a student with the highest test score (SAT of 1600 or ACT of 36) will on average earn a cumulative GPA in their first year that is 0.43 higher than a student with an SAT score of 1200 (equivalent to an ACT of 25). Students with this lower test score are also 25pp more likely to struggle academically. Students admitted without test scores perform at rates equivalent to students with relatively low test scores; for instance, students with a missing test score experience academic struggle at rates equal to that for students scoring a 1280 SAT (or ACT of 27), who are at the 6th percentile of the test score distribution of attending students. Following the procedure in Figure 1, Figure 2 plots binscatters to present the estimates from Table 1 Column (4).

We add further controls in Column (5) and (6). In Column (5), we interact the indicators for gender, race and ethnicity, and family income; the key coefficients remain essentially unchanged from our baseline specification in Column (4). In Column (6) we include high school fixed effects; the coefficients on test score fall somewhat, while the coefficients on high school GPA rise. Still, the predicted change in academic outcomes for a 1 standard deviation increase in test score (0.215) is larger than for a 1 standard deviation increase in high school GPA (0.092) in each of the three panels.

3.2 Testing for Bias in Scores

In Table 2 we allow the relationship between test scores and outcomes to vary by group, in order to test for potential bias in the test. In Column (1), we interact both SAT_i and $\mathbb{I}\{SATMISSING_i\}$ with an indicator equal to one if a student's high school lies above the national 20th percentile on a index of high school challenge. In Column (2), we instead interact these variables with an indicator for low family income; in Column (3), we interact these variables with an indicator for first generation status. For ease of interpretation, we also report the coefficients on test score separately for each group, rather than reporting the base effect and interaction. Each of these specifications has the same controls as in Table 1 Column (4).

We further present binscatter plots of these relationships (following the procedure in Figure 2, but separately by group) in Figures 3 and 4. Panel A of these Figures presents the relationship between test scores and academic performance, separately by high school type, controlling only for school and year fixed effects (similar to Figure 1). Panels B-D present specifications that match those in Table 2, Panel A, Columns (1)-(3).

Broadly we find that test scores predict academic performance more strongly for students from more advantaged backgrounds, though the relationship is strong for each group; the relationship is not statistically different for predicting academic struggle. We also report the implied performance difference at various levels of SAT scores at the bottom of each panel; though the performance gap varies somewhat depending on the group and outcome variable, generally the differences are small and show that test scores slightly overpredict the outcomes for students from less-resourced backgrounds.

References

Bastedo, Michael N., D'Wayne Bell, Jessica S. Howell, Julian Hsu, Michael Hurwitz, Greg Perfetto, and Meredith Welch (2022). "Admitting Students in Context: Field Experiments on Information Dashboards in College Admissions". In: *The Journal of Higher Education* 93.3, pp. 327–374. DOI: 10.1080/00221546.2021.1971488.

Mabel, Zachary, Michael D. Hurwitz, Jessica Howell, and Greg Perfetto (2022). "Can Standardizing Applicant High School and Neighborhood Information Help to Diversify Selective Colleges?" In: *Educational Evaluation and Policy Analysis* 44.3, pp. 505–531. DOI: 10.3102/01623737221078849.

Table 1. Association Between Test Score and College Outcomes

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Cumulative GPA						
SAT	0.1702***		0.1662***	0.1077***	0.1082***	0.0984***
	(0.00377)		(0.00381)	(0.00475)	(0.00478)	(0.00684)
Missing SAT	-0.1256***		-0.1260***	-0.0998***	-0.1008***	-0.0535***
	(0.0134)		(0.0134)	(0.0134)	(0.0135)	(0.0200)
High School GPA		0.2141***	0.1035***	0.0961***	0.0949***	0.1608***
		(0.0163)	(0.0151)	(0.0151)	(0.0151)	(0.0235)
Admissions Controls	No	No	No	Yes	Yes	Yes
URM, Gender, Family Income	No	No	No	Yes	Yes	Yes
URM x Gender x Family Income	No	No	No	No	Yes	Yes
High School FEs	No	No	No	No	No	Yes
R^2	0.193	0.050	0.196	0.233	0.235	0.653
Mean of Dep. Variable	3.506	3.506	3.506	3.506	3.506	3.506
Implied SAT with Performace Equal to Missing SAT	1326		1324	1307	1307	1346
Num of obs.	12,693	12,693	12,693	12,693	12,693	12,693
Panel B: %As						
SAT	0.1167***		0.1142***	0.0744***	0.0749***	0.0759***
	(0.0025)		(0.0026)	(0.0031)	(0.0032)	(0.0049)
Missing SAT	-0.0733***		-0.0735***	-0.0642***	-0.0636***	-0.0367***
	(0.0080)		(0.0080)	(0.0080)	(0.0080)	(0.0129)
High School GPA		0.1363***	0.0661***	0.0579***	0.0570***	0.0969***
		(0.0108)	(0.0098)	(0.0097)	(0.0097)	(0.0162)
Admissions Controls	No	No	No	Yes	Yes	Yes
URM, Gender, Family Income	No	No	No	Yes	Yes	Yes
URM x Gender x Family Income	No	No	No	No	Yes	Yes
High School FEs	No	No	No	No	No	Yes
R^2	0.243	0.061	0.246	0.290	0.294	0.688
Mean of Dep. Variable	0.639	0.639	0.639	0.639	0.639	0.639
Implied SAT with Performace Equal to Missing SAT	1337		1336	1314	1315	1352
Num of obs.	10,049	10,049	10,049	10,049	10,049	10,049
Panel C: Has C or Below						
SAT	-0.1234***		-0.1201***	-0.0635***	-0.0619***	-0.0572***
	(0.0043)		(0.0043)	(0.0054)	(0.0054)	(0.0084)
Missing SAT	0.1111***		0.1114***	0.0838***	0.0907***	0.0331
	(0.0135)		(0.0135)	(0.0136)	(0.0137)	(0.0220)
High School GPA		-0.1634***	-0.0881***	-0.0899***	-0.0891***	-0.1256***
		(0.0173)	(0.0166)	(0.0166)	(0.0166)	(0.0277)
Admissions Controls	No	No	No	Yes	Yes	Yes
URM, Gender, Family Income	No	No	No	Yes	Yes	Yes
URM x Gender x Family Income	No	No	No	No	Yes	Yes
High School FEs	No	No	No	No	No	Yes
R^2	0.105	0.016	0.107	0.143	0.146	0.625
Mean of Dep. Variable	0.239	0.239	0.239	0.239	0.239	0.239
Implied SAT with Performace Equal to Missing SAT	1310		1307	1268	1254	1342
Num of obs.	10,049	10,049	10,049	10,049	10,049	10,049

Notes: This table presents regression of academic performance during a student's first year on their test scores and high school GPA. The dependent variable for panel A is the cumulative GPA a student received in their first year; for panel B it is the fraction of courses in the first year with A or A- year; for Panel C it is an indicator equal to 1 if a student ever received a grade of C+ or lower in their first year. All columns control for school and year fixed effects. Admissions controls include legacy status, athletic recruit status, first-generation college status, rural/urban home, U.S. citizen or permanent resident, and high school challenge index. Column 4 additionally includes fixed effects for a student's gender, URM status (if a student self-identifies as Black, Hispanic, American Indian and Alaskan Native, or Hawaiian and Pacific Islander), and family income terciles (for those who applied for financial aid, with an additional indicator for applying for financial aid). Column 5 interacts these three fixed effects; column 6 instead includes high shcool fixed effects. Test scores are normed to 0 for students with an SAT scores of 1400 (ACT score of 31) and divided by 100. Samples are students started school in 2017, 2018, 2019, 2021, 2022 (although Panels B and C exclude the 2019 cohort).

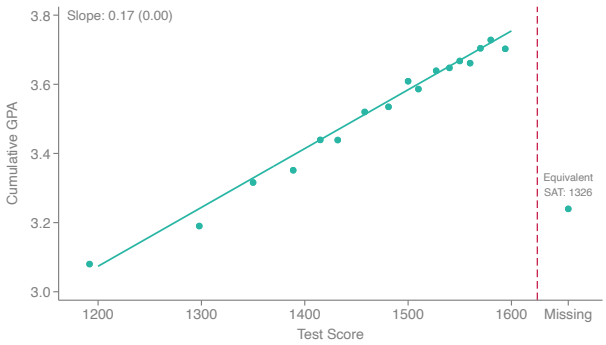
Table 2. Association Between Test Score and College Outcomes By Group

	(1)	(2)	(3)
Panel A: Cumulative GPA			
Cut Variable	-0.0210	-0.0459***	-0.0581***
	(0.0263)	(0.0135)	(0.0138)
SAT Slope For Cut = 1	0.0988***	0.0912***	0.0781***
	(0.0059)	(0.0087)	(0.0103)
SAT Slope For Cut = 0	0.1192***	0.1122***	0.1159***
	(0.0063)	(0.0052)	(0.0051)
Missing SAT Slope For Cut = 1	-0.1169***	-0.0773***	-0.1569***
	(0.0165)	(0.0278)	(0.0232)
Missing SAT Slope For Cut = 0	-0.0674***	-0.1011***	-0.0691***
	(0.0205)	(0.0147)	(0.0156)
Cut Variable	Less Advantaged HS	Bottom Quintile Family Income Among Applicants	First Generation
R^2	0.23	0.23	0.23
Mean of Dep. Variable	3.51	3.51	3.51
Implied Gap at SAT = 1300	0.00	-0.02	-0.02
Implied Gap at SAT = 1500	-0.04	-0.07	-0.10
Num of obs.	12,693	12,693	12,693
Panel B: %As			
Cut Variable	0.0078	-0.0195**	-0.0320***
	(0.0176)	(0.0091)	(0.0093)
SAT Slope For Cut = 1	0.0661***	0.0654***	0.0549***
	(0.0039)	(0.0057)	(0.0070)
SAT Slope For Cut = 0	0.0858***	0.0773***	0.0795***
	(0.0043)	(0.0035)	(0.0034)
Missing SAT Slope For Cut = 1	-0.0775***	-0.0758***	-0.0892***
	(0.0099)	(0.0167)	(0.0141)
Missing SAT Slope For Cut = 0	-0.0389***	-0.0594***	-0.0500***
	(0.0122)	(0.0087)	(0.0093)
Cut Variable	Less Advantaged HS	Bottom Quintile Family Income Among Applicants	First Generation
R^2	0.29	0.29	0.29
Mean of Dep. Variable	0.64	0.64	0.64
Implied Gap at SAT = 1300	0.03	-0.01	-0.01
Implied Gap at SAT = 1500	-0.01	-0.03	-0.06
Num of obs.	10,049	10,049	10,049
Panel C: Has C or Below			
Cut Variable	0.0013	0.0664***	0.0437***
	(0.0301)	(0.0156)	(0.0159)
SAT Slope For Cut = 1	-0.0611***	-0.0722***	-0.0595***
	(0.0067)	(0.0098)	(0.0120)
SAT Slope For Cut = 0	-0.0691***	-0.0628***	-0.0678***
	(0.0073)	(0.0059)	(0.0058)
Missing SAT Slope For Cut = 1	0.1124***	0.1741***	0.1536***
	(0.0170)	(0.0286)	(0.0242)
Missing SAT Slope For Cut = 0	0.0376*	0.0648***	0.0546***
	(0.0209)	(0.0150)	(0.0158)
Cut Variable	Less Advantaged HS	Bottom Quintile Family Income Among Applicants	First Generation
R^2	0.14	0.14	0.14
Mean of Dep. Variable	0.24	0.24	0.24
Implied Gap at SAT = 1300	-0.01	0.08	0.04
Implied Gap at SAT = 1500	0.01	0.06	0.05
Num of obs.	10,049	10,049	10,049

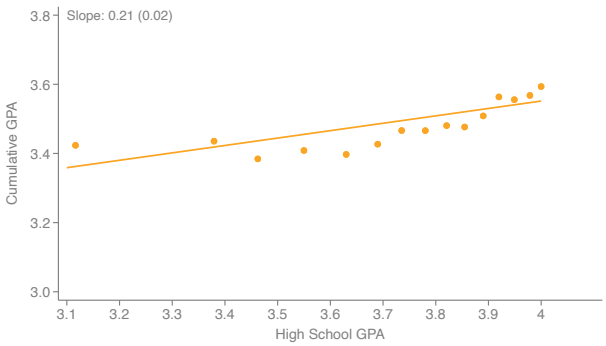
Notes: This table replicates Table 1 Column (4), except that each separately estimates the relationship between test scores and academic outcomes for two "cuts" of students. In Column (1), students are split based on the challenge index for the high school each student attended; high schools with an index value above the 20th national percentile are "less advantaged." Column (2) separately estimates the relationship for students in the bottom quintile of family income. Column (3) separately estimates the relationship for first-generation college students. See notes to Table 1 for additional detail.

Appendix Figure 1: First-Year Students' Performance by Test Score and High School GPA

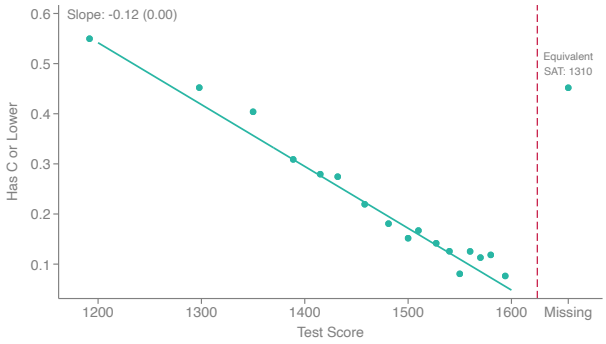
(a) Cumulative GPA by Test Score



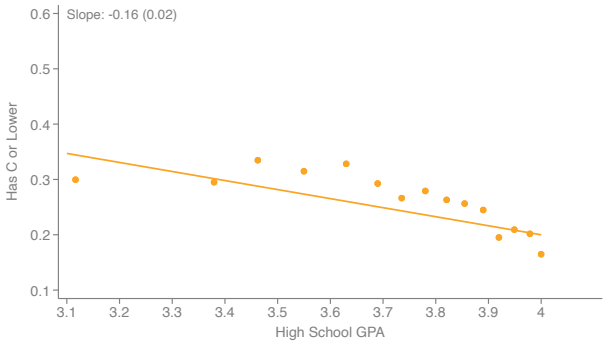
(b) Cumulative GPA by High School GPA



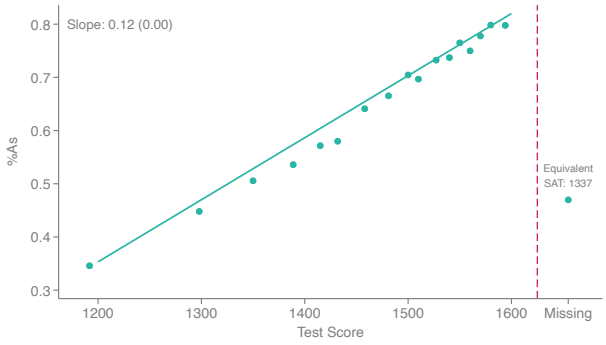
(c) Fraction of Students with C+ or Lower by Test Score



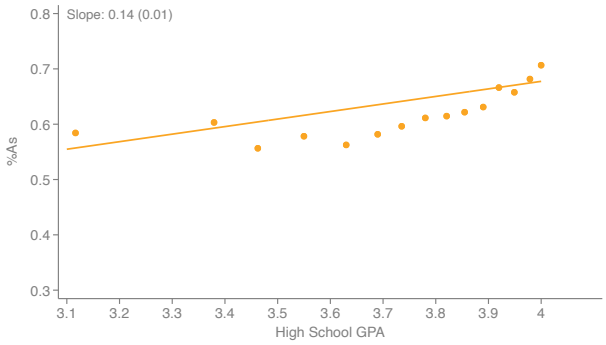
(d) Fraction of Students with C+ or Lower by High School GPA



(e) Fraction of Grade A or A- by Test Score



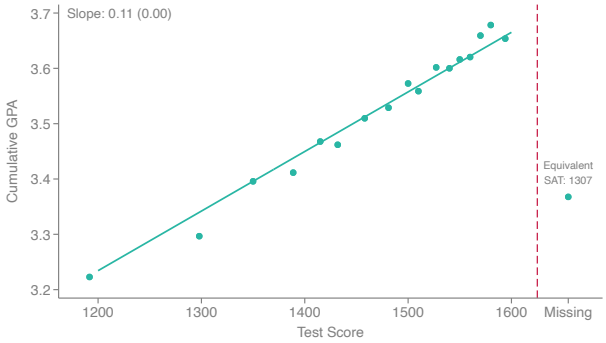
(f) Fraction of Grade A or A- by High School GPA



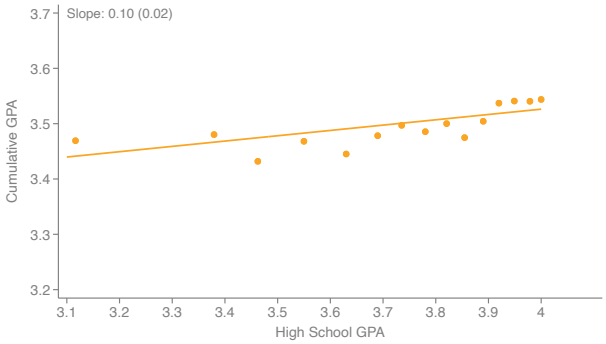
Notes: Appendix Figure 1 presents binned scatter plots of first-year academic performance vs. SAT/ACT test scores or high school GPA for students enrolled at selected Ivy-Plus colleges. Panels A, C, and E present binned scatterplots of academic outcomes vs. SAT/ACT score in a specification that matches those in Appendix Table 1 Column 1. The rightmost dot is for students who do not submit a test score when applying under a test-optional admissions regime. Panels B, D, and F similarly present binned scatterplots that replicate the specification in Appendix Table 1 Column 2.

Appendix Figure 2: First-Year Students' Performance by Test Score and High School GPA Conditional on Students' Characteristics

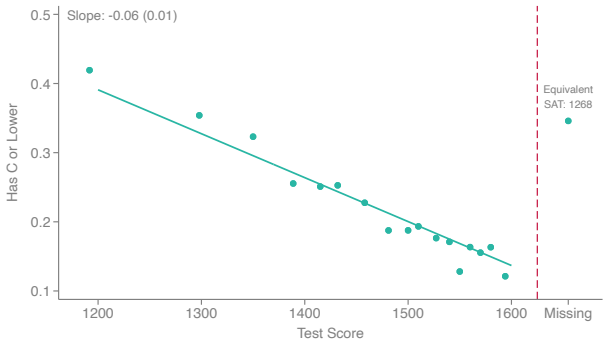
(a) Cumulative GPA by Test Score



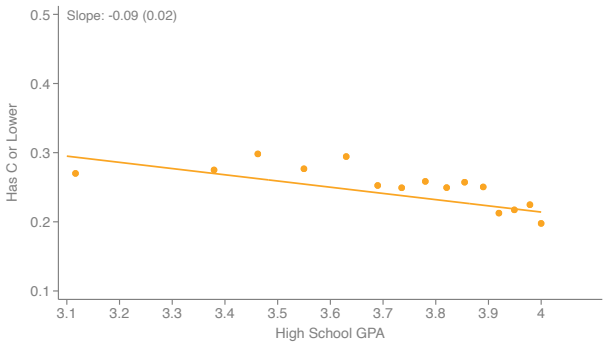
(b) Cumulative GPA by High School GPA



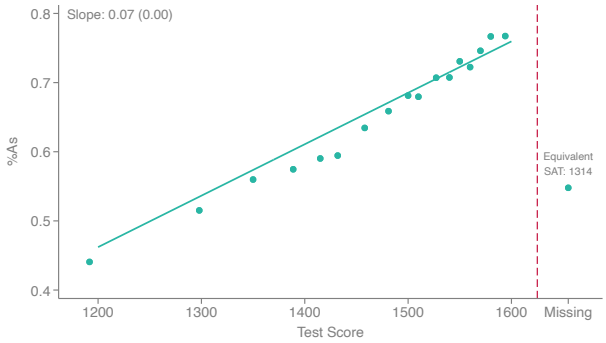
(c) Fraction of Students with C+ or Lower by Test Score



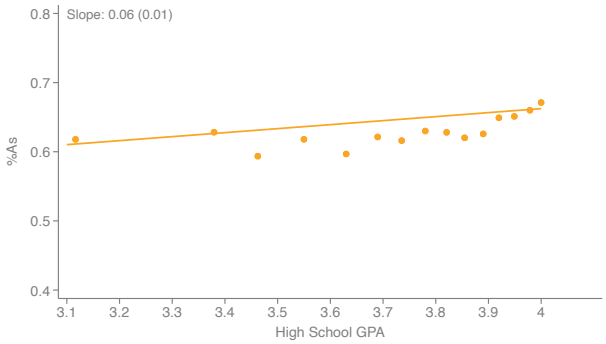
(d) Fraction of Students with C+ or Lower by High School GPA



(e) Fraction of Grade A or A- by Test Score



(f) Fraction of Grade A or A- by High School GPA

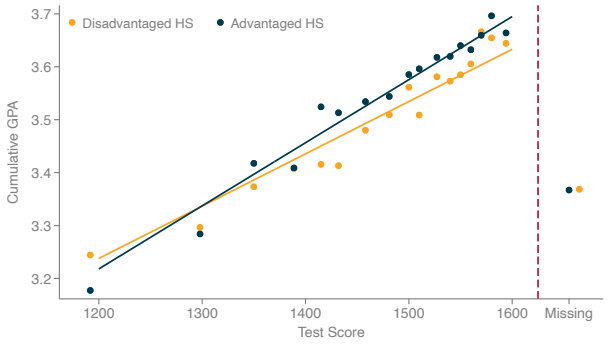


Notes: Appendix Figure 2 presents binned scatter plots of first-year academic performance vs. ACT/SAT test scores or high school GPA for students enrolled at selected Ivy-Plus colleges controlling for some students' characteristics. Panels A, C, and E present binned scatterplots of academic outcomes vs. SAT/ACT score in a specification that matches those in Appendix Table 1 Column 4. The rightmost dot is for students who do not submit a test score when applying under a test-optional admissions regime. Panels B, D, and F similarly present binned scatterplots that replicate the specification in Appendix Table 1 Column 4 for High School GPA variable.

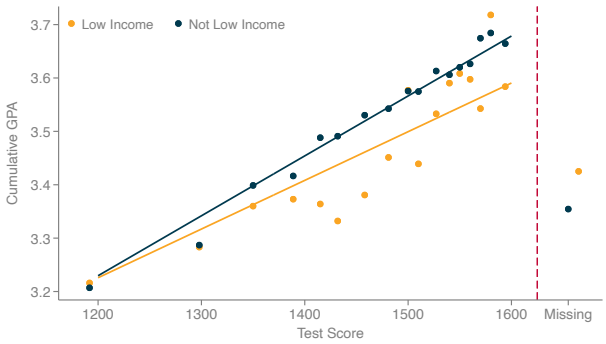
Appendix Figure 3: First-Year Cumulative GPA by Test Score and Students' Characteristics

(a) By High School Landscape Score (Raw)

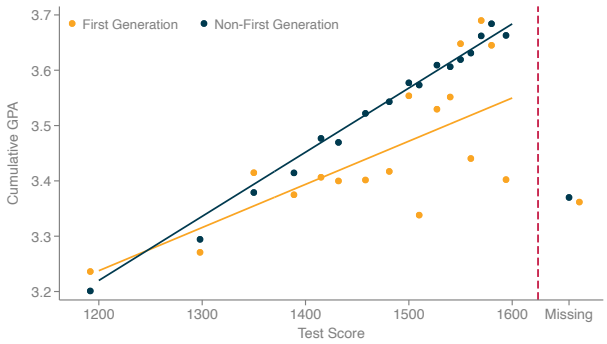
(b) By High School Landscape Score (with Controls)



(c) By Parental Income (with Controls)



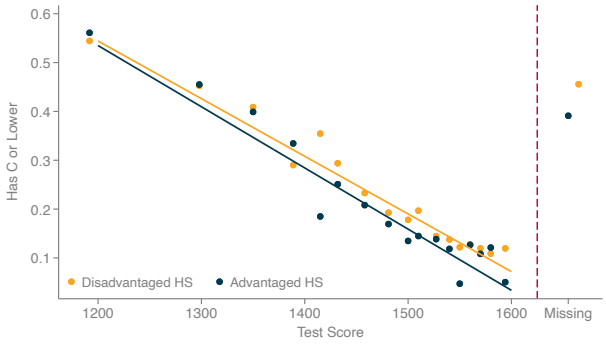
(d) By First Generation Status (with Controls)



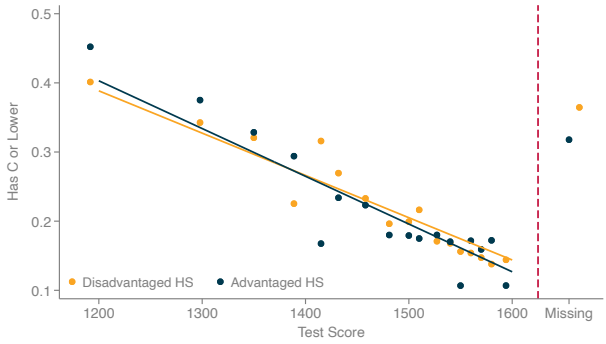
Notes: Appendix Figure 3 presents binned scatter plots of first-year cumulative GPA vs. ACT/SAT test scores for students enrolled at selected Ivy-Plus colleges by students' characteristics. Panel A presents a binscatter splitting students on a measure of high school challenge index to replicate the specification in Appendix Table 2 Panel A Column 1, except including only school and year fixed effects as controls. Panel B presents the same split binscatter with additional controls, matching the specification in Appendix Table 2 Panel A Column 1. Panels C and D replicate Appendix Figure 3b but splitting on other student characteristics, matching the specifications in Appendix Table 2 Panel A Columns 2 and 3.

Appendix Figure 4: Fraction of First-Year Students with C+ or Lower by Test Score and Students' Characteristics

(a) By High School Landscape Score (Raw)

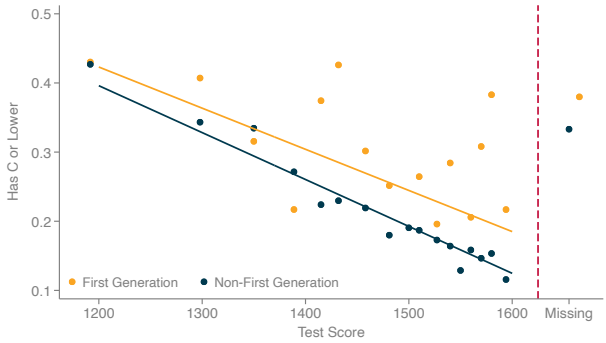


(b) By High School Landscape Score (with Controls)



(c) By Parental Income (with Controls)

(d) By First Generation Status (with Controls)



Notes: Appendix Figure 4 presents binned scatter plots of fraction of first-year students with C+ or lower vs. ACT/SAT test scores for students enrolled at selected Ivy-Plus colleges by students' characteristics. Panel A presents a binscatter splitting students on a measure of high school challenge index to replicate the specification in Appendix Table 2 Panel C Column 1, except including only school and year fixed effects as controls. Panel B presents the same split binscatter with additional controls, matching the specification in Appendix Table 2 Panel C Column 1. Panels C and D replicate Appendix Figure 4b but splitting on other student characteristics, matching the specifications in Appendix Table 2 Panel C Columns 2 and 3.