Shifting College Majors in Response to Advanced Placement Exam Scores*

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Abstract

We test whether signals of high aptitude offered to high school students shapes the course of their collegiate study. Mapping continuous raw scores from millions of Advanced Placement examinations onto the 1 to 5 integer scoring scale, we apply a regression discontinuity design to understand how students' choice of college major is impacted by receiving a higher integer score, despite similar exam performance, to students who received a lower integer score. Attaining higher scores increases the probability that a student will major in that exam subject by approximately 5 percent (0.64 percentage points), with some individual exams demonstrating increases in major choice by as much as 30 percent. These direct impacts of a higher score explain approximately 11 percent of the unconditional 64 percent (5.7 percentage points) gap in the probability of majoring in the same subject as the AP exam when attaining a 5 versus a 4. We estimate that a substantial portion of the overall effect is driven by behavioral responses to the positive signal of receiving a higher score.

*The contents of this paper represent the views of the authors and not their corresponding institutions.

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1. Introduction

A student's choice of college major may have long-lasting implications, including on future earnings. The average difference in lifetime earnings between the top-paying and lowest-paying majors is estimated to be several million dollars (Carnevale, Cheah, and Hanson, 2015), and there is growing evidence that at least some portion of the connection between college major and wages is causal (Hastings, Neilson, & Zimmerman, 2013; Kirkebøen, Leuven, & Mogstad, forthcoming). Despite these seemingly strong labor market incentives, there remains a mismatch between demand and supply of workers in some relatively lucrative fields. For example, a 2012 Federal Government report estimates a ten-year shortfall of 1 million college graduates with STEM ("Science, Technology, Engineering, and Mathematics") majors.[1] As these findings suggest, some students may not be choosing their college majors optimally, either because they lack adequate information on the relative benefits and challenges of certain majors, or because they enter college with inadequate academic preparation for a preferred major (Betts, 1996; Oreopoulos & Dunn, 2013; R. Stinebrickner & Stinebrickner, 2012; Wiswall & Zafar, 2015a, 2015b).

In addition to the earnings potential associated with each field of study,[2] the previous literature emphasizes the importance of heterogeneous tastes and predilections on a student's choice of major. Morgan, Gelbgiser, and Weeden (2013) find in their analysis of Educational Longitudinal Survey (ELS) data that specific occupational plans reported by students prior to entering college yield much sharper predictions of their college majors than test scores and other observable performance data. Similarly, Altonji, Arcidiacono, and Maurel (2015) suggest that a combination of major-specific abilities and individual preferences drive the choice of major for

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[1] https://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_2-25-12.pdf
[2] See for example, (Arcidiacono, Hotz, & Kang, 2012; Beffy, Fougère, & Maurel, 2011; Long, Goldhaber, & Huntington-Klein, 2015; Shu, 2013; T. Stinebrickner & Stinebrickner, 2013; Wiswall & Zafar, 2015a; Zafar, 2011)

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most students, while Wiswall and Zafar (2015a) estimate that 80% of the variation in major-specific tastes remains unexplained by observable characteristics.

Although this literature suggests that each student's chosen field of study can be highly personal and driven by factors in place before entering college, there is also a small body of evidence that the choice of major is subject to external factors that can be shaped by policy. For instance, peers (Ost, 2010), early exposure to a subject via required coursework (Fricke, Grogger, and Steinmayr, 2015) and the final grade achieved by a student in an introductory course (Goldin, 2015) can also have strong influence on a student's subsequent course of study. Several recent papers assess the effects of explicit financial incentives in directing students to particular fields of study. Denning and Turley (2015) find that the "SMART" Program, which provides US Department of Defense scholarships to college juniors and seniors pursuing STEM majors, significantly increased the probability of completing college with a major in those fields, though Evans (forthcoming) finds no significant effects in Ohio. Similarly, Castleman, Long, and Mabel (2015) find that the Florida State Access Grant (FSAG) program significantly increased the probability of completing college with a STEM major even though FSAG funding was not tied in any way to the choice of major.[3]

In this paper we focus on the role of Advanced Placement (AP) exam scores and their signals, which reflect a nationally-recognized college-level curriculum taken by hundreds of thousands of high school students each year, in encouraging students to choose a college major in a subject of interest. In particular, to isolate the causal impact of different AP exam scores among students with similar mastery of the content and skills of an AP course, we compare students with very similar performance on the AP exam, but who receive different AP scores by falling on either side of the cut score that separates an AP integer score of 5 from an AP integer

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[3] In related work, Stange (2011) finds that differential tuition policy can alter the demand for a particular degree.

score of 4, the cut score that separates an AP 4 from an AP 3, and so on. We investigate two channels by which a higher reported AP exam score, among students with otherwise comparable mastery of the course content and skills, can increase the probability that the student completes a college major in a field of study connected to that AP course. First, a higher AP score can coincide with an increase in college credits (and/or preferential course placement), both towards graduation requirements and towards completion of a particular major at a given college. Second, students may have a behavioral response to a higher AP score, such that they perceive themselves to have more ability in the field, or use the high score as a guidepost for choosing initial courses or major.

As in our previous and related study, which finds a causal effect of AP exam scores on degree completion (Smith, Hurwitz, and Avery, 2017), we apply a regression discontinuity design to AP exam scores from millions of students who graduated high school between 2004 and 2009. Students and colleges only observe an integer exam score between 1 and 5 but we rely on the underlying continuous scores that map to the integer score. These data allow us to compare the majors of students who just barely attain a 3, for example, relative to those just shy of the threshold who instead attain a 2. Isolating the impact of attaining a higher score by comparing identical students distinguishes our paper from previous work, which establishes the strong predictive component of AP scores and major (Mattern, Shaw, and Ewing, 2011). To be clear, our analyses compare two essentially identical students who have both elected to take an AP, but we are unable to measure the effect of exposure to or quality of the AP curriculum on major choice. Participating in AP courses may have strong and independent causal impacts on student major (and other outcomes), but, in these analyses, we are not able to separate this effect from other unobserved factors that might impact both AP exam performance and student major.

Similar to previous work in the area, we show a strong positive relationship between AP integer scores and choice of college major. For example, students in our sample who attain a 5 on an AP exam – the highest possible score – are 5.7 percentage points (64 percent) more likely to major in the same subject as the AP exam than students who attain a 4 on the exam. However, when comparing students whose raw scores barely placed them into the5 category compared to those who just missed a score of 5, we find a 0.64 percentage points (5 percent) increase in majoring in the same subject as the AP exam. This implies that approximately 11 percent of the increase in the probability of majoring in the same subject as the AP exam can be explained not by differences in students but rather, the direct impact of receiving a higher integer score. We also see causal effects that are smaller in magnitude by attaining a 3 over a 2 and 4 over a 3. AP and its scoring impacts millions of students each year across the entire nation and is delivered prior to the beginning of college, which is unique among causal studies on major choice. Further, for students with nearly identical performance on the AP Exam (adjacent scores on the continuous scale), we find evidence that the effect of an increase in AP score on the choice of college major is primarily driven by the behavioral effect of the positive signal communicated by the higher integer score, as shifts occur even when the higher integer score does not coincide with an jump in potential college credits.

Finally, we document several other results about how AP scores influence a student's choice of college major. First, our estimates do not detect any strong heterogeneous effects, suggesting that the causal impacts on major choice hold across students differing on gender and underrepresented minority status. Second, the strong impact of a score of 5 is attentuated when students also receive additional high AP scores, implying that the power of an additional signal depends on how many other positive signals the student has received. Finally, although students

who attain higher AP scores on STEM exams are, on average, considerably more likely to major in STEM (e.g. students scoring a 5 on a STEM AP exam are 42 percent more likely than students scoring a 4 on a STEM AP exam), the impact of a higher AP integer score among students with otherwise comparable AP exam performance shifts students across STEM disciplines, which we discuss later in the paper. In other words, factors, many of which are unobservable, such as quality of AP instruction, students' mastery of the required content and skills, or student interest and motivation in a subject, likely explain the strong positive relationship between AP integer scores and the student's likelihood of majoring in that AP discipline, rather than the unique signalling effect of a higher integer score to a student who has otherwise similar content and skill mastery to a student who received a lower integer score.

This paper is organized as follows. Section 2 describes the Advanced Placement program, scoring and literature. Sections 3 and 4 describe our data and methodology, respectively. Section 5 presents our main findings on the response to relatively higher AP scores, along with the exploration of underlying mechanisms, including credit policies and behavioral responses to positive signals. Section 6 investigates some of the broader impacts of our findings, including heterogeneous effects, the impact of multiple signals, and changes in STEM degree production. Section 7 concludes.

2. AP Background & Literature Review

The history of the Advanced Placement Program is rooted in the philosophies that college-level academic opportunities should be extended to high-achieving high school students and that demonstration of proficiency in such coursework should exempt college students from re-taking courses. (See Smith et al., 2017 for more details) Collaborating with high school teachers and college professors, the AP program develops curricula that are reflective of the content typically

taught in introductory-level college courses and exams are constructed to certify whether students have mastered the content and skills required for course exemption. Since its introduction in the 1950s, the AP program has extended its reach beyond college preparatory schools and well-funded public schools, and currently, more than 9 out of 10 public school students in the United States have access to at least one AP exam at their schools (Theokas & Saaris, 2013).[4] In 2015, high school students took nearly 4.5 million AP exams in 36 subjects. Exams take place over a two-week period in May with only one administration per subject per year, and scores are released several months later.[5] The exact number of AP exams has varied over time, as some exams were retired due to low participation rates and new exams were introduced as a result of high student demand. This paper only considers the 19 most popular subject exams, with at least 100,000 exam takers between 2004 and 2009 (see Appendix Table 1 for details on all 34 exams).

AP scores are reported to students and colleges on a 1 through 5 scale, where 1 translates into "no recommendation" and 5 translates into "extremely well-qualified". The integer scores are based on students' raw scores, which reflect performance on multiple choice and free-response sections. Because the AP exams are criterion-based, cut scores are established based on earning a pre-determined number of points that predict college-performance at varying levels and not on relative performance. The exams are designed so students earning a score of 3 on one test administration have an identical mastery of material as students earning a 3 on a separate administration.[6]

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[4] The College Board official statistics are slightly lower at around 60 percent. (See http://apcentral.collegeboard.com/apc/public/program/index.html)
[5] Approximately 0.3 percent of students retake an AP exam.
[6] Continuous raw scores range from 0 to 180 points, though there is considerable variation in the scoring range and maximum across exams.

In order to receive credit, course exemption and placement, students must submit AP scores to the institutions at which they enroll. There exists variation in how AP exam scores are treated, both across postsecondary institutions and across exams within postsecondary institutions. Most students enrolling at four-year institutions attend colleges that award credits toward graduation if students meet certain threshold minima- generally a 3 or 4 on the standard 1-5 scale. Along with receipt of college credit, the student is generally eligible to enroll immediately in the sequent course. Colleges independently decide how many credits students receive for meeting AP thresholds, the sequent courses for which they are eligible, and whether scores exceeding the credit-granting thresholds are appropriate for the awarding of additional credits and course exemptions.

2.1. AP Literature Review

Our paper contributes to a small, but expanding body of literature that separates out the predictive effects of AP participation and performance from the causal effects of receiving higher AP integer scores. A substantial prior literature documents a positive relationship between early college credit and choice of major (Dodd, Fitzpatrick, De Ayala, & Jennings, 2002; Keng & Dodd, 2008; Morgan & Klaric, 2007; Murphy & Dodd, 2009; Tai, Liu, Almarode, & Fan, 2010).[7] More recently, K. Mattern, E. Shaw, and Ewing (2011) find that students who take a particular AP exam are much more likely to major in that subject: students who take AP Computer Science are 4.5 times more likely to major in computer science than students who did not take the AP course. These large estimates rest on a selection on observables identification

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[7] There also exists a series of studies that demonstrate a strong positive correlation between AP participation, AP exam scores and subsequent academic performance across a range of measures including college attendance (Chajewski, Mattern, & Shaw, 2011) and success in subject performance (Patterson & Ewing, 2013), overall performance (K. D. Mattern, Marini, & Shaw, 2013), and college completion (Dougherty, Mellor, & Jian, 2006; Hargrove, Godin, & Dodd, 2008; K. D. Mattern et al., 2013; Morgan & Klaric, 2007). There is a similar line of research on dual enrollment. For example, see Karp, Calcagno, Hughes, Jeong, and Bailey (2007).

strategy, which relies on logistic regressions that include demographic and academic (e.g., SAT scores, self-reported GPA) characteristics in an attempt to control for observed differences between students with higher and lower AP exam scores.

Sources of randomization in the context of AP research are hard to come by, and many of the most compelling studies examining the long and short term consequences of AP course and exam taking have relied on models that control for observed covariates to deal with potential confounders between high- and low-performing students (Evans, 2013; Long, Conger, & Iatarola, 2012; Murphy & Dodd, 2009).[8] Two notable exceptions are our own study linking AP scores to college graduation outcomes (Smith, Hurwitz and Avery, 2017) and Jackson (2010), who finds that the introduction of a program that paid teachers and students for success on AP examinations increased SAT/ACT scores and college matriculation. Despite the convincing case for causality, Jackson is unable to generalize about the relative contributions of improved teaching, increased exposure to rigor and the direct effects of the fact that some students may have earned higher AP scores as a result of this incentive program. In what follows, we isolate the effect of higher AP scores and demonstrate its effects on choice of major.

3. Data and Descriptive Statistics

3.1. College Board Data

This paper uses student-level data from the 2004-09 graduating high school cohorts collected from two main sources, College Board (CB) data on AP examinees and National Student Clearinghouse (NSC) data. CB maintains a database of all students who take at least one AP exam. This database contains not only the students' AP exam scores on the 1-5 integer scale,

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[8] There are currently some randomized AP evaluations underway, which will be very informative, but they are limited in their scope of exams and populations (Long, Conger, & McGhee, 2014).

but their underlying continuous scores on most exams taken between 2004 and 2009. From these two pieces of information, we identify the exact continuous scores that sharply form the boundaries of the scaled scores.[9] In addition to student performance on each AP exam, the CB data also contain a host of student demographic information, such as a student's gender, race/ethnicity, and parental income.[10] We also observe student SAT scores, if they take the exam. We frequently divide our analyses into separate results for STEM and non-STEM AP exams, which are listed in Appendix Table 1. AP exams used in this paper that are considered STEM include Biology, Calculus, Chemistry, Environmental Sciences, Physics, and Statistics.

3.2. National Student Clearinghouse, CIP Codes, and IPEDS

CB data are then merged with the NSC data. As of 2015, over 3,600 postsecondary institutions participate in NSC, which collects postsecondary enrollment information on more than 98 percent of students enrolled in public and private colleges within the United States.[11] In this study, we track a student's postsecondary trajectory including enrollment and degree completion. We observe students college trajectories for six years after they graduate high school for the 2004-2007 cohorts, five years for the 2008 cohort, and four years for the 2009 cohort.

The majors in the NSC data are provided only for graduating students, and we focus exclusively on majors associated with a bachelor's degree. NSC provides full six-digit Classification of Instructional Program (CIP) code information,[12] which we simplify by focusing

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[9] Data on raw scores are available only for exams taken during the 2003-04 school year or later. Therefore some AP test takers, particularly in the 2004 and 2005 cohorts, will not have raw scores that can be mapped to their scaled scores taken in sophomore or junior year of high school. The few exams without an accompanying raw score are removed from our analyses,

[10] Parental income is collected on the SAT registration forms, and so some AP test takers who did not participate in the SAT will have missing demographic information. Even among SAT participants, some students fail to respond to these questions.

[11] Due to data privacy laws and potential complications with student matching, the actual NSC coverage may be a bit lower than 98 percent rate (Dynarski, Hemelt, & Hyman, 2015).

[12] The CIP codes are a taxonomic scheme created by the U.S. Department of Education to ensure a uniform system of tracking across colleges.

on the first two digits.[13] Two-digit CIP codes translates into general fields such as biology, history, or English.

In order to assess whether college majors are impacted by different AP scores for similar exam performance, we match each AP subject to the closest two-digit CIP code, documented in Appendix Table 2. In some cases the match is fairly exact; for example, students taking AP Biology are linked to the CIP code related to Biological Sciences. In other cases we are required to group AP exams, as both Chemistry and Physics are most closely linked to the two digit CIP code of Physical Sciences.[14] In addition, we consider whether AP exams alter whether students major in the broader field of STEM majors. We select all CIP codes where the first two digits correspond to our STEM AP exams, namely 11, 14, 15, 26, 27, and 40. Although we do not capture all STEM majors with this approach, we do capture most STEM degrees at four-year universities.[15]

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[13] CIP codes are not provided for the 2004 cohort and approximately one-third of institutions in other cohorts but are instead in text form that we unify into CIP codes. Since there is the chance for classification error, we test the sensitivity of the results by only using the students with a CIP code. Results hold and are in the appendix.

[14] The only deviation from this approach that we adopt is a grouping of AP Calculus and Statistics with majors in either math/statistics or engineering, primarily because relatively few students major in math and engineering is far more prevalent among test takers in these subjects. Also, 4 percent of students double major. If one of the two majors is related to the AP exam, students are counted as majoring in that subject. Results are not sensitive to excluding double majors (see Appendix Table 5).

[15] This is most problematic for students without CIP codes (but a textual description of major), of which we exclude in robustness tests. Other commonly used STEM classification systems typically include a relatively small number of CIP codes in the two-digit fields of 1 (Animal and Plant Sciences), 3 (Natural Resource Conservation), 29 (Military Technologies), 30 (Multi-disciplinary Studies), 41 (Science Technologies), and 51(Pharmaceutical Sciences), along with a small number of other specific majors. As most majors in these broad two-digit disciplines are not STEM-related, their inclusion was deemed incorrect. In alternate analyses not presented here, we show that our STEM results in Table 9 are robust to using only schools that report six-digit STEM codes and using alternate STEM classifications, such as U.S. Immigration and Enforcement lists of STEM programs that qualify foreigners for expedited work visas.

Finally, we append to our data several variables from the Integrated Postsecondary Education Data System (IPEDS). These include the average standardized test scores (ACT and SAT) of incoming students and whether the college is public or private.[16]

3.3. AP Credit Policies

We use AP credit policies from two sources: the Annual Survey of Colleges (ASC) and data collected by the authors from college websites. Administered annually by the College Board to nearly 4,000 colleges, the 2004 survey included information on the minimum credit-granting scores by AP subject (only to be removed after 2005). We supplement these data, by constructing an enhanced "policy sample." To accomplish this, we collected the more nuanced AP credit and placement data directly from the websites of the 500 largest four-year institutions in the country, as measured by full time equivalent students. This inclusion rule captures a wide swath of postsecondary institutions: both selective and non-selective colleges, along with a representative mix of public and private colleges, and represents approximately 82% of students who take an AP exam. We create a binary "AP Credit" variable for each combination of AP exam and threshold at each college. We code the AP Credit variable as a "1" for each exam-college-threshold combination if a college provides any beneficial advantage at that threshold, including credit towards graduation, credit towards major, or placement into any advanced course.[17] For example, some colleges provide 4 units of credit for a scaled score of "at least a 3." In this example, the AP credit variable would be coded as "1" for an AP scaled score of 3 and "0" for any other AP scaled score (2, 4, or 5). As another example, a college may provide 4 units of credit for a score of 3 and 8 units of credit for a score of 4 on a given AP exam. In this

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[16] To estimate average composite SAT scores, we add the 25th and 75th percentiles of the Math and Critical Reading sections, as reported by IPEDS, and divide by 2. For colleges that only report ACT scores to IPEDS, we use an SAT conversion table found at http://research.collegeboard.org/sites/default/files/publications/2012/7/researchnote-2009-40-act-sat-concordance-tables.pdf

[17] Note that we use the word "credit" but in some instances it is only placement with no credit.

example we would code the AP Credit variable as "1" for a scaled score of 3, "1" for a scaled score of 4, and a "0" for a scaled score of 5. Appendix Table 1 provides summary statistics of the credit policies across these 500 colleges.

We highlight several limitations in the use of the AP credit data that we collected for these 500 colleges in the summer and fall of 2015. First, these policies reflect current practices at these colleges, whereas our data applies to students who graduated from high school between 2004 and 2009. Even so, we find that at least 70% of colleges have identical minimum credit-granting policies from 2004 (derived from ASC data) and in 2015 (from our manual data collection), and so we conduct sensitivity analyses on the subset of colleges and thresholds with identical minimum credit-granting thresholds for AP credit in 2004 and 2015. (See section 5.3 for results) Second, the coding of our binary AP credit variables does not account for a variety of nuances in policies across colleges. For example, some colleges may place caps on AP credits used towards college graduation, and/or provide conditional credit for scores on certain AP exams based on a student's choice of major. For this reason, we intentionally adopt a conservative approach through expansive coding rules in the creation of the AP Credit variables – ensuring that imprecision in the coding of these variables will induce downward bias since some fraction of students will not be receiving credit despite being coded as having done so in a relevant AP credit variable. In the case of shifts in major that are driven by a behavioral response to higher AP scores, these caveats about the coding of the AP credit variables should have no impact on our estimates.

3.4. Descriptive Statistics

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We present summary statistics of students in our analytic sample in Table 1. We find that approximately 69 percent of the sample is white, 43 percent are male, and 50 percent reported having a parent who attended at least some college. On average, students earned a 1207 on the SAT, took almost 3 AP exams, and scored an average of 2.7 on the exams. We further disaggregate our summary statistics to describe students close to each of the four integer score thresholds (i.e., from the 1/2 threshold up to the 4/5 threshold). As regression discontinuity designs assess causal impacts that are local to students near the threshold, understanding characteristics of marginal students helps us assess to whom we might be able to extrapolate these results. Students who perform better on AP exams are more likely to be White, Asian, male, have more educated parents, and come from families with higher income. As might be expected, AP-taking students have high SAT scores; the average composite scores of 1147 and 1324 at the 1/2 and 4/5 thresholds correspond to roughly the 65th and 90th percentile of the national SAT distribution, respectively. Roughly one-third of students at the 4/5 threshold attend a postsecondary institution that belongs to the Barron's Most Competitive ranking, and close to 90% will earn a bachelor's degree within six years.

Table 2 lists the probability that a student with a given AP score on an AP exam chooses the college major most closely associated with that subject, and then more generally in any STEM field.[18] Consistent with previous research, there is a systematic increase in the probability of choosing the most related college major for every field. Using AP Biology as one example, the probability of majoring in biology monotonically increases with each integer score, such that students who receive a 5 are nearly five times as likely to major in the subject as students who receive a 1. Similar patterns exist across all the exams, though the exact magnitude varies,

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[18] These probabilities look similar when conditioning on graduates. Our primary analyses do not condition on graduating and so we only present these statistics on the entire sample of graduates and non-graduates.

demonstrating the strong predictive power of AP scores in major choice. The second set of columns show similar patterns on the likelihood of majoring in any STEM field, regardless of whether it is directly tied to the particular AP subject. As the interests, abilities, and supportive structures of students with a higher scaled score on a given AP exam are (presumably) systematically different than those of students with a lower scaled score on that same test, the values in Table 2 can be viewed as unrealistically large upper bounds on the causal effect of an increase in scaled score on the choice of college major. In general the relationships between AP integer scores and the probability of majoring in STEM are stronger for the STEM than for the non-STEM exams. We still observe a strong correlation between integer scores in English Language or World History and majoring in a STEM field, though we would not assume that the curricular content in these courses has any particular impact on scientific knowledge.

Taking the previous table one step further, Table 3 reports the distribution of college majors for students with scaled score of "3" or higher on each of 19 most popular AP exams, indicating a conspicuous correlation between AP exam performance and choice of college major.[19] Typically, the most popular college major for students who score 3 or higher on a particular AP exam is the major most closely associated with that exam. For example, students with scaled score of 3 or higher in AP Biology were more than twice as likely to major in Biology (18.9%) than in any of the other tabulated subjects.

The two previous tables demonstrate the predictive power of AP scores in determining major for all students. The next section focuses in on students just around the integer thresholds so to compare students who are identical across all dimensions and to estimate the impact of receiving higher AP scores, independent of differences in student attributes.

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[19] Students with scaled scores of "3" or higher on more than one AP exam are counted multiple times in this table.

4. Methodology

In this section, we describe the methodology to estimate the effect of a marginal change in AP exam scores on major choice. This notation and methodology is similar to that of Smith, Hurwitz and Avery (2017). Each student i on AP exam j receives a continuous score C_{ij}. This continuous score maps into the scaled score, T_{ij} as follows[20]:

$$T_{ij} = \begin{cases} 1 \text{ if } C_{ij} < t_j^2 \\ 2 \text{ if } t_j^2 \leq C_{ij} < t_j^3 \\ 3 \text{ if } t_j^3 \leq C_{ij} < t_j^4 \\ 4 \text{ if } t_j^4 \leq C_{ij} < t_j^5 \\ 5 \text{ if } t_j^5 \leq C_{ij} \end{cases}$$

where t_j^n are the thresholds for each scaled score n on exam j. For each value of $n \in \{2,3,4,5\}$, we create two variables. The first is the forcing variable:

$$Dist_{ijn} = C_{ij} - t_j^n$$

which captures how far student i's score on exam j is from threshold n. A $Dist_{ijn} \geq 0$ implies that the student has a scaled scores of at least an n. This leads to the second variable for each value of n, the dichotomous threshold variable:

$$Threshold_{ijn} = \begin{cases} 1 \text{ if } Dist_{ijn} \geq 0 \\ 0 \text{ if } Dist_{ijn} < 0 \end{cases}$$

After generating these variables, our basic empirical framework is shown by the standard regression discontinuity equation presented in equation (1), where X_{ij} is a vector of fixed effects for the student's year of high school graduation and the interaction of the AP exam subject and year the exam is taken.

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[20] Technically, T_{ij}, varies by year but for ease of exposition, we omit a year subscript.

$$Outcome_{ijn} = \alpha_0^n + \alpha_1^n Threshold_{ijn} + \alpha_2^n Dist_{ijn} + \alpha_3^n Threshold_{ijn} \times Dist_{ijn} + X_{ij} + \varepsilon_{ijn} \qquad (1)$$

We are primarily interested in the estimate of α_1^n, which is the coefficient on $Threshold_{ijn}$ that

represents the discontinuous effect of being above the AP scaled n threshold on the outcome of

interest. In practice, we separately estimate the effects of each scaled threshold.

The dependent variable in equation (1) is often an indicator variable for an outcome at

each threshold n, which is typically whether a student majors in the same subject or the same

field as the AP exam subject. In order to capture trends in the forcing variable that exist on either

side of the boundary, we fit a local linear regression with a triangular kernel. The triangular

kernel puts more weight on the observations closest to the threshold. In all regressions, we use a

bandwidth of 10, which is roughly equal to the optimal bandwidth suggested by Imbens and

Kalyanaram (2012).[21]

Researchers implementing regression discontinuity designs may confront challenges if

score manipulation or gaming takes place in the vicinity of thresholds. In this context, such

manipulation is essentially impossible, as grading standards and score thresholds vary from year

to year and are never reported to students. Score thresholds are also pre-determined by

psychometricians, and do not result from natural variation in students' scoring patterns on an

exam within a given year. In the next section, we run covariate balancing tests with similar

specifications to equation (1), but using the covariates as outcomes, and find no indication of

manipulation of raw scores near scaled score thresholds.

5. Main Results

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[21] We test the sensitivity to bandwidth and kernel choices and find no measurable differences. These robustness tests are presented in Appendix Table 4. We obtain the IK-estimated optimal bandwidth using software designed by Calonico, Cattaneo, and Titiunik (2014).

5.1.Testing the Assumptions of Regression Discontinuity

In Figure 1, we show the density of raw scores near each threshold. For each of the 19 exams in each of the years the exam is offered, the threshold is centered at zero, and then the raw scores from the stacked exams are collapsed into one point bins. Continuous density in the vicinity of each of the 1/2, 2/3, 3/4 and 4/5 thresholds is evident in this figure.[22]

Covariate balancing tests in Table 4 generally show balance across the thresholds. Among the 68 separate covariate balancing tests, which examine student sex, ethnicity, parental education and income, high school poverty, SAT scores, and AP course-taking, seven yield statistically significant parameter estimates at the 0.05 level.[23] All seven precisely estimated differences are extremely small in magnitude. In addition, some of the imbalanced covariates are highly related (i.e., an imbalance in one race category naturally lends itself to an imbalance in another race category). Appendix Figure 1 shows graphical results for the few variables that exhibit the highest level of imbalance, and none of the pictures are suggestive of large jumps in student characteristics at the threshold.

We test overall balance two ways. First, we construct threshold-specific predicted raw scores based on a model that includes SAT scores, ethnicity, sex, parental education level, and income level, using only those observations below the relevant threshold. Estimates of changes

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[22] The formal approach recommended by (McCrary, 2008) to test for continuous density around thresholds may not be appropriate in light of the scoring rubric of most AP exams. Raw scores generally extend out to four decimal places, but most raw scores are simply unattainable based on the combination of correct and incorrect responses. Moreover, the distances between consecutive attainable raw scores appear to differ within AP exams, as does the probability of achieving these raw scores based on combinations of points earned/deducted from the multiple choice and free response sections. To illustrate, among students who took the 2008 administration of AP Biology and were just on the cusp of 2/3 threshold, 18 had forcing variable values of -0.0435, followed by one student who had a forcing variable value of exactly 0, twelve students with forcing variable values of 0.0008, and so on. As is also case when the data are discrete (See Frandsen (2014)), this type of clustering, which is obviously not reflective of score manipulation, presents a challenge to the traditional McCrary test.

[23] Earlier work (Smith et al., 2017) finds that a higher AP score in 11th grade produces a small causal increase in the likelihood that a student takes AP courses in 12th grade. In order to avoid this endogeneity we only focus on within-year course-taking, as crossing a AP score threshold should have no impact on the amount of APs taken or scores in the same year.

in this predicted score at the threshold are null, and included as the last column in Table 4. Second, running a seemingly unrelated regression to jointly test for balance shows small imbalances on the 2/3 and 3/4 thresholds, though there is no evidence of imbalance on the 4/5 threshold, where we have our most prominent results. Finally, though not shown, results are largely the same when using IK bandwidths for each covariate.[24]

5.2. Main Regressions

Figure 2 presents our primary set of results on whether receiving higher AP exam scores causes students to major in the same subject as the AP exam. There are clear, observable differences in student major at the thresholds, particularly as students cross into AP scores of 4 or 5. Table 5 provides regression estimates for the magnitude of these effects, with each coefficient from a separate regression that represents the causal effect of receiving a higher AP score on the corresponding threshold. Results in the first row show parameter estimates for the full sample, with separate results in subsequent rows for the set of STEM and non-STEM exams. Results for STEM and non-STEM exams are also shown graphically in Figure 3.

The first coefficient shows that receiving a score of 2 over a 1 on the sampled AP exams does not shift students' college majors into the AP exam field. This finding is unsurprising because scores of 1 and 2 are both considered non-passing scores and colleges rarely offer credit for either score (though, a 1 could be construed as an extremely negative signal and result in a disincentive to major in the subject). Each successive integer jump above the 1/2 margin leads to a larger boost in the probability that a student will choose a major in the same subject as the AP exam. Across all sampled exams, jumps in the probability that the student major matches that AP exam subject increases by approximately 0.2 pp (3.3 percent), 0.4 pp (4.7 percent), and 0.6

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[24] Despite the overwhelming evidence that there is no manipulation around the threshold, we estimate regressions that remove donut holes and heaps around the thresholds. These robustness tests are described at the end of the next section.

pp (5.2 percent) from receiving AP scores of 3, 4 and 5 respectively. Subject-by-subject results are presented in Appendix Table 3 and demonstrate that there appears to be a distribution of effects, with upper bound estimates in the range of two percentage points (and 30 percent). This is more succinctly demonstrated in Figure 4, which plots the coefficient estimates of the 19 exams at each threshold. There is a clear pattern of positive results, particularly at the 4/5 threshold and in the non-STEM subjects.

When AP exams are separated into STEM and non-STEM exams, two different stories emerge. Receiving a higher integer AP score on a STEM exam tends to yield a statistically insignificant change in student major, except at the 4/5 threshold, where students are 0.5 pp (3.4 percent) more likely to major in the AP subject. By contrast, coefficients for non-STEM exams are statistically significant at all margins other than the 1/2 threshold and are larger than the STEM results.

In a set of robustness tests, we repeat the analysis reported in Table 5, while imposing some changes in the underlying empirical specification. Appendix Table 4 reports the results of analysis with different choices of bandwidth, kernel, the choice of controls and the number of higher order expressions of the forcing variable (thereby altering the functional form). Results are very similar to those in Table 5.[25]

Appendix Table 5 reports the results of analyses using different rules for inclusion and exclusion of students from the sample, restricting analyses to: students who graduated from high school in the 2005-2007 cohorts so that all students are tracked for 6 years (Panel 1); students who majored in a field where the CIP codes were provided by NSC and not hand coded by the

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[25] Using smaller bandwidths and triangular kernels alleviates the small issue that a 10 point bandwidth includes two thresholds on three exams in a few years (never 1/2 or 4/5). In nearly identical results not shown, we also drop these exam-years.

researchers (Panel 2); and students with a unique rather than a "double" major (Panel 3). All results are similar to those reported in Table 5.

Appendix Table 6 deals with any potential concerns related to the bunching of the exam distributions. The left panel utilizes a "donut hole" approach and removes all observations within one point of the threshold.[26] The right panel removes any "heaps" within the distribution that are outsized relative to their neighboring raw scores.[27] Neither robustness check changes the results.

5.3. Mechanisms

Higher AP scores may alter college major through multiple mechanisms, which we explore in two subsections. First, we separately explore the contributions of endogenous college enrollment and that of producing more graduates; the former of which we rule out and the latter of which is only marginally altered by a higher AP integer score among students with otherwise similar exam performance. Second, we decompose the estimates into the mechanical effect of credit receipt versus the behavioral response to a strong signal. We find strong support that the behavioral responses to higher AP scores are the primary drivers of our estimates, though we cannot discount the possibility that credit-granting policies are playing a small role in the shifting of majors.

5.3.1. College Enrollment and Graduation

The first four columns of Table 6 indicate whether students alter their college enrollment decisions from the receipt of a higher integer AP score. These results help differentiate whether the impacts on student major arise from changes in the schooling environment, as opposed to

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[26] Alternative sized donut holes produce similar results.

[27] In order to implement this method we bin raw scores to reduce the variance, run linear regressions over short bandwidths across each test-by-year distribution, and remove heaps that are more than 25% greater than their predicted value by the linear regression. This identifies roughly 15% of the distribution. Choice of initial binning, regression bandwidth, or deviance from predicted value do not change the results.

shifts in individual preferences. The first two columns show trivial differences in college choice arising from different integer scores, with small and often insignificant effects on school quality, as measured by average SAT or Barron's ranking.[28]

To further allay any concerns that our primary results are being driven by shifts in college choice, we repeat the primary analyses from Table 5 in two distinct ways. First, we re-fit our main models using only students taking AP exams in their senior year (column 3), after college enrollment decisions have already been made, and we continue to find positive and statistically significant results comparable to those shown in Table 5. In fact, results that differentiate between senior and non-senior exams (Appendix Table 7) indicate that higher AP scores earlier in high school have significant impacts on college quality, and shifts in college major for this group are roughly twice as large as for senior exams. These results suggest that earlier signaling allows students more opportunities to make decisions prior to graduation (e.g., senior year courses and college application and enrollment) that facilitate major choice. Second, we then re-fit our main models using college fixed-effects specification (column 4), and, again, our results are unchanged from those shown in Table 5. Taken together, these results suggest that there are impacts of the AP score that go beyond the college environment.

Finally, we test whether students with virtually similar exam performance, but different integer scores, endogenously choose colleges that offer credit for the scores they attain. Column 5 of Table 6 tests whether students are more likely to enroll at a college that college offers additional credit for a higher AP score. We find no statistical evidence to support this at the integer score thresholds, other than a small negative coefficient on the 3/4 threshold which

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[28] We also test other measures of college quality, including each Barron's ranking individually, college graduation rates, and other potentially relevant measures, such as attending school out of state. We similarly find insignificant results, which are available upon request. Our earlier paper (Smith et al., 2017) studies this possibility in more detail and similarly finds no evidence that AP scores influence the choice of colleges by students.

paradoxically suggests that a student is less likely to attend a college if that college offers the student additional credit for a score of 4 over a 3. Combined, the first five columns suggest that there is no evidence that endogenous college enrollment is driving the main results.

As we only can identify a student's choice of major for those students listed with a BA degree in the NSC data, the results in Table 5 could conceivably reflect an effect of AP credit on college graduation rather than on the choice of college major. Column 6 of Table 6 shows small increases in six-year completion rates at the 2/3, 3/4 and 4/5 thresholds, which is consistent with Smith, Hurwitz and Avery (2017).[29] However, when we condition on bachelor's completion (column 7), we find nearly identical point estimates to those shown in Table 5. This provides reassuring evidence that we can isolate the effects of higher AP exam scores on shifting college major from the documented effects on the production of more college majors.

5.3.2. Signal versus College Credit

With the mechanism(s) largely unexplained as of yet, we explore two alternatives: college-specific credit policies that reduce major course requirements, which we label "mechanical," or the behavioral response to higher scores. The behavioral response may be a result of positive affirmation of a student's ability to succeed in a subject, but could be reaffirmed by other actors driving the decision process, such as parents, counselors, or even the college itself. An alternative behavioral response may simply be that students use the high score as a guidepost to in the course selection process, with no impact on self-confidence.

We exploit the rich variety in AP credit policies across postsecondary institutions and compare students on the 4/5 thresholds (for example) who attend institutions where a score of 5 results in additional credit to similar students who attend institutions where no such credit is

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[29] We can only use 2004-2007 in these analyses. Using the full sample and four-year graduation rates, results are consistent with Smith, Hurwitz, and Avery (2017) - strong effects on the 2/3 and 3/4 thresholds, where college credit is often at stake.

offered. Note that students with higher scores at colleges that give credit for those scores may benefit from the mechanical and behavioral impact of higher scores. Students only benefit from the behavioral impact of higher scores if their higher scores do not come with credit and thus, we can compare the relative impacts across sets of institutions.

To separate the behavioral from the mechanical effects, we reproduce in column 1 of Table 7 our main results using only our "policy sample" of 500 largest colleges, for which we collected detailed AP credit policy information. The results mimic those for the full sample in Table 5. The second column then show results for the subsample of colleges that offer additional credit/placement for scores above versus below a particular scaled score threshold, whereas column 3 shows effects at colleges which do not offer credit/placement (henceforth referred to as credit for the sake of brevity). Thus, column 3 represents the pure behavioral effect, whereas the estimated effects reported in Column 2 represent a combination of behavioral and mechanical effects from receiving an increased AP integer score.

We find statistically significant increases in the probability of a matched college major due to the pure behavioral effect at the 3/4 and 4/5 thresholds. The behavioral effect is slightly smaller than the combined behavioral and mechanical effect at the 2/3 and 3/4 thresholds and slightly larger than the combined effect at the 4/5 threshold. The evidence in Table 7 suggests a strong behavioral effect from receiving higher AP integer scores, particularly at the 4/5 threshold where the signal is strongest and changes in credit receipt are uncommon. However, we are unable to rule out completely the possibility that the mechanical effect of receiving a higher AP score plays a small role in influencing a student's choice of college major.

Recall, the main results show no impact on major selection among students of similar exam performance who receive an integer score of 2 rather than 1. This implies that the signaling

effect of a score of 1, as opposed to 2, does not cause students to shy away from majoring in the AP subject. Since there is almost never credit on the line, the impact (or lack thereof) should be considered behavioral and not mechanical. Given the strongest impact on the 4/5 margin and the null impact on the 1/2 margin, students are responding to positive signals and not responding to negative signals.

We further investigate the behavioral and mechanical effects of receiving higher AP integer scores separately for STEM and Non-STEM AP exams. The middle set of columns in Table 7 report the results for STEM AP exams. We find a strong behavioral effect from receiving a score of 5 over a 4 on STEM AP exams. We report the results for non-STEM AP exams on the right of Table 7. In these specifications, we estimate that effects on college major that are of similar magnitudes, regardless of whether or not the higher scaled AP score earns the student more college credit. [30] The consistent similarity between these two sets of estimates suggests that the effect of an increased AP score on the choice of major is primarily behavioral in nature.[31]

5.3.3. Robustness Tests of the Behavioral Effect

As AP policies may have changed over time, we test the robustness of these results by using only the set of colleges and subjects whereby the minimum credit granting AP exam score as reported in ASC in 2004 matches the data we collected from the colleges' websites in 2015.[32] Using the approximately 70% of exams that agree perfectly between the sources, estimates are largely unchanged and can be found in Appendix Table 8.

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[30] We also explore whether STEM and non-STEM students have access to earlier signals via the SAT II subject exams. We do not find results consistent with the idea that SAT II taking students are less susceptible, though results are fairly noisy. We thank the reviewers for this suggestion.

[31] Subject-by-subject results are in Appendix Table 3, but are individually too imprecise to distinguish between these two mechanisms. In general, we find positive effects irrespective of whether the college does or does not have an AP policy at the threshold.

[32] The ASC data contains only the minimum credit-granting thresholds and it is unclear whether colleges interpret that to include instances of placement without credit, which is our approach in collecting data on the policy sample.

We next consider whether the behavioral effect is in fact students responding to higher scores or rather, students responding to college-specific credit policies, even when students are on the cusp of an AP integer margin where there is no difference in credit. As an example, a college may give additional credit for a 3 (over a 2) and 5 (over a 4) in a subject but not a 4 (over a 3). In this setting, does the student infer from the college-specific policy that scores of 3 and 4 represent the same level of preparation in that AP subject? If this scenario played out in the data, we might expect null findings at these colleges for the impact of receiving higher AP scores. Removing students attending these types of colleges from the analyses may expose even larger behavioral responses among students attending colleges where the student is not primed to interpret scores of 3 and 4 (for example) as representing identical ability.

To address this issue, we restrict attention to colleges that have uniform credit policies in two senses (Table 8). First, we look at the subsample of college-exam combinations for which the college does not offer credit for any AP scaled score. Repeating the analysis from Table 5 for this subsample provides a clean test of the behavioral effect described above. Not only is there no mechanical effect from credit, but students cannot infer anything from lack of credit offered at one score versus another.[33] As shown in the first row of Table 8, the estimated effect of an increase in AP score at the 3/4 and 4/5 thresholds is positive and of similar magnitude to our estimated effects from earlier results. However, these coefficients are also imprecisely estimated because of the relatively small subsample for college-exam pairs where there is no possibility of AP credit.

Second, we repeat this analysis, for the subset of college-exam combinations where students receive credit at each of the 3, 4, and 5 thresholds. Once again, as reported in Row 2 of

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[33] This is somewhat rare but the most common exams include AP Environmental Science and AP World History.

Table 8, the estimated effects of increased AP scaled score on choice of college major are positive, generally large in magnitude, but still somewhat imprecisely estimated.

Finally, some colleges have a blanket policy on their credit policies across all subjects, for example, by awarding credit for scoring a 3 on all exams with no additional credits offered at higher integer scores. Assuming students are aware of the blanket policy, they may not infer anything from the absence of credit increases on the other margins. Using only the subsample of colleges that have these blanket policies, we find consistent evidence, as reported in Rows 3 and 4 of Table 8 with the main results. Combined, these analyses provide evidence supporting the general accuracy of our earlier estimates in that students are responding to the positive signal, and this behavioral response is not dampened from the unique college-specific credit policies where they enroll.

6. Additional Results

In this section we examine three sets of additional results pertinent to our findings: heterogeneous results across important demographic groups, how students respond to multiple signals, and overall impacts on STEM degree attainment.

6.1 Heterogeneous Effects of AP Credit

In this subsection we investigate whether AP credits have heterogeneous effects by types of student or college. On the student side, we are especially interested in the effects of AP credits on subgroups, such as women, low-income families, and minority students traditionally underrepresented in STEM fields (Turner & Bowen, 1999; Zafar, 2015). We report the results of our analyses for each of these subgroups in the first eight rows of Table 9. One immediate challenge is that these subgroups of students are underrepresented in our AP samples (as evidenced by the fairly small sample sizes for these groups), thereby limiting the precision of our

estimated effects for each of these subgroups. Subject to this caveat, we find only limited evidence of differential responses for any subgroup of students, regardless of the threshold or field, in the probability of majoring in the AP subject in response to a higher AP score.[34]

We consider separately the possibility of an interaction between SAT score and AP exam score. Specifically, when we split the sample into three SAT score ranges, as reported in Rows 9 through 11 of Table 9, we find similar estimated effects of AP score on college major for each of these subsamples. These results suggest that a change in AP scores has a similar effect on all students, regardless of that student's academic ability (as measured by SAT score).

On the college side, we split the sample by average SAT of all enrolled students at the colleges and report the results in Rows 12 through 14 of Table 9. Once again, we find little evidence of differential effects across the subsamples of colleges. These results suggest that the effects of higher AP scores are not localized to certain types of colleges.

6.2 Multiple Signals

In this section, we address how students shift majors when they receive multiple signals of ability. Students differ substantially in the number of AP exams taken and their performance on these exams, and both of these factors likely influence the extent to which an additional score of 5 (for example) alters student major. In the presence of many other positive signals through high AP exam scores, we hypothesize that receiving an additional AP score of 5 (for example) is less likely to shift a student's major into the focal AP exam subject relative to the effect such a signal might have on the student with no additional AP signals.

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[34] There is some evidence in Table 7 of larger estimated coefficients for "White" students than for other subgroups of students. However, the estimated effects for Asian and other minority students (Black and Hispanic) are also positive and the standard errors are sufficiently larger that it does not seem plausible to conclude that there are differential effects across these groups. Similarly, the estimated effects at the 4/5 scaled score threshold appear to be smaller for students from lowest-income families (less than $50,000 in family income) than for others, but this is not the case at other score thresholds.

In Table 10, we present the results of a pooled regression in which the threshold dummy variable in Equation 1 is interacted with student's average performance on all other AP exams, while including fixed effects that control for the exact combination of AP exams taken by the student. We focus on the 4/5 margin because it is this threshold on which we find the largest effects throughout the paper, and we only include the multiple exam takers in this table. The first column of Table 10 demonstrates that the main effect of receiving a 5 over a 4 is similar in magnitude for multiple-exam takers, compared to the entire sample of students.

Interacting the average of a student's other AP exams with the 4/5 threshold indicator, we find that magnitude of the shift in college major into the focal AP subject is highly sensitive to the average of AP scores on the other exams taken by the student. For ease of interpretation, the average AP score on other exams is centered at three, indicating that a student with an average score of 3.0 on all other exams would be 0.9 percentage points more likely to major in the AP subject with a score of 5 over a 4. Across all exams, the coefficient of -0.0029 in Row 2, Column 2 suggests that each one point increase in average AP score on other AP exams mutes the focal exam's pull by about 0.3 percentage points. So for a student with an average of 4 on all other AP exams, scoring a 5 over a 4 on an additional AP exam would increase the probability that she majors in that subject by about 0.6 percentage points (calculated as 0.0091-0.0029). It is also clear from columns 3 and 4 that high average scores on other non-STEM exams have a notably stronger muting effect than do high average scores on STEM exams.[35]

We used this analytic strategy because of data limitations that come from the recommended approach by Papay et al. (2016), but it comes at the cost of introducing alternative

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[35] Regressions that interact the threshold variable with alternate definitions of alternate AP exam performance, such as counts of the number of exams with scores of 3, 4, or 5, produce similar results.

hypotheses.[36] One leading alternative explanation is that students with multiple positive signals, who are typically high-ability students, have a difficult time interpreting the signals. However, Table 9 shows us that the highest ability students, as measured by SAT, are the most responsive to these positive signals.

6.3. STEM Degree Attainment

Both descriptive statistics in Table 2 and the causal estimates above imply that higher scores increase the likelihood that a student majors in a specific subject. However, major choice is typically a zero sum game – if a student majors in one subject, then she is likely forgoing the opportunity to major in a different subject. This is a key differentiator between this study and Smith et al. (2017), which examined bachelor's degree completion. We show that receiving a higher integer score on the AP Biology exam increases the likelihood of majoring in Biology, but STEM production increases only if the student's counterfactual degree was in a non-STEM field, such as English or social sciences, rather than an alternate STEM degree, such as chemistry. This is important as a shortage of STEM majors is frequently cited as a deficit in our current educational system, and multiple policy levers have been enacted to combat this problem.

Table 11 suggests that, in general, we are unable to conclude that simply receiving a higher integer AP score on a STEM AP exam positively impacts STEM major completion, although we do observe a positive and statistically significant effect in the full sample at the 2/3 threshold. By contrast, we find some suggestive evidence that higher integer scores on non AP STEM exams may draw students away from STEM fields in other non-STEM disciplines. These results show that positive signals of high AP scores alone may not be enough to shift students

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[36] With no data limitations, the preferred analytic strategy would to follow Papay et al. (2014) and test the simultaneous effects of crossing one or two thresholds. This approach is challenging in our context for a number of reasons that severely limit our statistical power. Predominately, many students take three or more exams, requiring higher order interaction terms that increase exponentially, and because interaction effects differ across four different boundaries, rather than only one. Results using the Papay et al. (2014) approach for students taking two AP exams (not shown here) produce noisy estimates that are uninformative.

into STEM fields, as STEM-focused students may enter college with stronger major intentions. Yet it is important to remember that exposure to any subject may have independent effects on majoring in that subject (Fricke, Grogger, and Steinmayr, 2015) and this includes exposure to STEM curriculum in the promotion of STEM degrees, which we cannot test here.

7. Discussion and Conclusion

This paper shows that students incorporate signals of their relative academic performance in determining an important human capital decision: choice of college major. Although high school graduates have received countless sources of feedback over their lifetime, our results suggest that performance labels provided late in secondary school can have large impacts of subsequent educational investment decisions. This paper adds to the growing evidence that educational interventions late in students' high school careers can have significant impacts on their subsequent postsecondary decisions. Although not as consequential towards the immediate college enrollment process as interventions that provide information or structured guidance (e.g., Hoxby and Turner, 2014; Carrell and Sacerdote, 2016), students are using academic information gathered during high school to help make long-term career decisions. Similar to Hoxby and Turner (2014), our results are concentrated among high-performing students, though they are not restricted to specific geographic regions.

We find that the shift in college major is predominately a behavioral response and is strongest when the students have few other competing signals of academic excellence on AP exams. Our strong results may come from the signal salience, as AP exams are nationally recognized and known to be consequential in the college acceptance process and for college course credits. Other studies of academic signaling have produced mixed results. Papay,

Murnane, and Willett (2016) find that students are more likely to attend college when they have a positive label that summarizes their score performance on a standardized test, though they cannot distinguish between the impact of the signal on student attitudes versus how the signal is used by schools as a sorting mechanism that might promote college-going behaviors. As in their paper, we also find the strongest impacts to occur at the highest levels of the test-score distribution. Foote, Schulkind and Shapiro (2015) and Jackson (2015) find no impacts on any relevant college-going measures from signals of college-readiness in high school, perhaps because few students or institutions recognize the signal as particularly consequential or the signals are poorly communicated.[37]

The impacts on student major found in this research, in combination with the decrease in time to degree found in Smith et al. (2017), show that that AP scores affect the postsecondary choices and outcomes of different students in different ways. The earlier study finds that at the minimum credit-granting margin (generally the 2/3 scaled score margin), students receiving the higher integer score, despite otherwise similar performance on that AP exam, are more likely to complete a BA degree in four years, principally because credit receipt generally reduces the minimum credits for BA completion. By contrast, this study finds that the AP integer score primarily influences the choice of college major for students at the higher scaled score cutoff of 4/5 on most exams, when performance on that AP exam is otherwise similar to students who simply fell on the other side of the cut score. Although the magnitudes of these effects are generally less than 1 percentage point per test, they are not negligible by comparison to the cross-sectional correlations between AP score and college major. On average, the signaling effect of the higher score explains approximately 16 percent of the difference in the probability

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[37] Other papers within the broader literature on the effects of positive signals of ability include Diamond and Perrson (2016), Kosfeld & Neckermann (2011), Fryer, Levitt & List (2008) and Steele and Aronson (1995).

of majoring in the subject for students who receive a 5 versus a 4. Also, given the national scope of AP, small magnitudes in parameter estimates translate into thousands of students in each high school cohort.

Our results highlight that timely signals of academic preparation can impact major choice, yet we generally find statistically significant evidence of changes in college major within the broader classifications of "STEM" vs. "Non-STEM", not across these broad classifications. Our estimates of the effect of a higher integer score on an AP STEM exam and the probability of choosing a STEM major are consistently positive (Table 11), even though they lack statistical precision. That is, there may be small positive effects of AP integer scores on the choice of a STEM major that are beyond the power of the tests we can perform on existing data. In addition, we only observe student major when a student graduates from college, as opposed to intended college major at each stage of postsecondary enrollment. Given the evidence that many college students who aspire to complete STEM degrees switch into non-STEM disciplines (Arcidiacono, Aucejo, & Spenner, 2012; Stinebrickner & Stinebrickner, 2014) this may lead us to underestimate the potential impact of these signals on total effort towards STEM majors. Instead, our results are indicative of the power of signals to obtain achievable goals.

Why might we find differences in the effects of ability signals between STEM and non-STEM AP exams? Signaling effects may be weaker for STEM AP takers because these students may have already received many alternate and perhaps competing signals of preparation in that AP subject. For example, STEM AP takers may have received more consistent feedback from frequent tests that use grading standards on which the student might place more weight. In other words, students may perceive their evaluations in these subjects to have greater objectivity. This then suggests that developing skills in rigorous high school courses can help promote STEM

completion. In addition, STEM students tend to take more AP exams, which we show mitigates any one signal, and so it is certainly possible that variations on signal strength and timeliness in STEM fields can have sizable impacts. Stinebrickner and Stinebrickner (2013) find that "students enter school quite optimistic about obtaining a science degree, but that relatively few students end up graduating with a science degree, … [primarily due to] misperceptions about their ability to perform well academically in science." As AP takers enter college amongst the most highly prepared students in the nation, these results underscore the challenge of carrying out a plan to complete a major in a STEM field. Interventions that help students navigate introductory courses, perhaps through counseling or psychological supports (e.g., Walton and Cohen (2011)) may help retain these high-achievers in STEM fields.

Overall, the results in this paper suggest that positive signal of students' ability can change their major, and that timely provision of signals might produce larger shifts in outcomes. For example, providing students similar feedback earlier within their high school careers might increase subsequent effort or spur additional course-taking within desired fields. More research that identifies what aspects of various signals students find salient could help identify ability signals that yield the largest changes in student behavior. This may be a particularly desirable strand of research because these signals are nearly costless as compared to more traditional methods of producing STEM majors, such as outreach activities or financial incentives. As there are many opportunities for individuals and organizations to incentivize strategic goals, such as efforts to increase STEM majors, these results in this paper show promising evidence of low-cost signaling interventions to shift the distribution of college majors.

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Table 1: Summary Statistics

	(1)	(2)	(3)	(4)	(5)
			Threshold		
	Overall	*1/2*	*2/3*	*3/4*	*4/5*
Student Demographics					
White	69.3%	60.9%	69.5%	72.9%	72.4%
Asian	10.7%	12.4%	12.3%	13.2%	15.2%
Black	6.8%	9.8%	5.5%	3.3%	2.1%
Latino/Hispanic	9.2%	12.8%	8.7%	6.8%	6.4%
Male	43.2%	40.4%	42.4%	45.6%	49.2%
Parental Education: Some College	49.6%	45.2%	52.2%	58.8%	63.8%
Income Less Than $50k	13.0%	17.2%	12.9%	10.3%	8.9%
Income $50k-$100k	19.1%	19.9%	20.4%	19.7%	18.5%
Income Great Than $100k	18.0%	16.4%	19.4%	21.9%	23.8%
Exam Scores					
SAT	1207	1147	1203	1265	1324
Number of AP Exams Taken	2.8	3.3	3.6	4.1	4.7
Number of STEM AP Exams Taken	1.0	1.1	1.2	1.4	1.7
Average AP Exam Score	2.7	1.7	2.4	3.2	3.8
College Outcomes					
Attended Barron's Most Competitive	13.4%	8.6%	12.3%	20.4%	32.2%
Graduated within six years	77.8%	74.0%	80.2%	84.5%	87.4%
Majored in STEM field	14.3%	10.9%	14.3%	18.5%	24.0%
N	3,148,598	317,481	519,340	553,804	385,777

Notes: Summary statistics are calculated using de-duplicated, individual-level data. Column 1 includes the full sample includes all students who took one of the 19 most taken AP exams. Columns 2 through 5 include students within five points below the relevant threshold on at least one exam. Some students

Table 2: Probability of Majoring in core CIP code or STEM by AP Exam Subject

AP Score	Major in Core Subject					Major in STEM				
	1	2	3	4	5	1	2	3	4	5
Biology	5.4%	9.5%	13.7%	18.5%	24.6%	8.0%	14.4%	20.9%	28.7%	40.9%
Calculus AB	4.4%	7.1%	9.2%	12.0%	18.4%	11.8%	17.5%	21.3%	26.0%	35.4%
Calculus BC	8.7%	11.7%	14.8%	18.3%	26.4%	20.4%	25.9%	30.8%	35.8%	46.4%
Chemistry	1.9%	3.5%	4.7%	6.5%	9.6%	14.7%	24.6%	32.1%	40.2%	51.7%
English Language & Comp.	1.0%	1.9%	3.4%	5.5%	8.1%	5.6%	10.4%	15.0%	18.3%	20.6%
English Literature & Comp.	0.9%	2.0%	3.8%	6.4%	9.8%	5.6%	10.2%	14.5%	17.4%	18.5%
Environmental Science	2.2%	3.9%	5.5%	7.6%	11.3%	4.6%	7.6%	10.7%	15.7%	26.1%
European History	1.2%	1.9%	3.7%	6.5%	9.8%	7.1%	10.9%	14.4%	18.0%	20.2%
French Language and Culture	2.0%	3.9%	6.4%	9.0%	10.9%	11.4%	15.0%	17.7%	18.3%	18.7%
Macroeconomics	7.0%	9.4%	11.1%	13.0%	16.8%	8.4%	13.6%	17.6%	23.6%	32.4%
Microeconomics	7.9%	10.0%	11.6%	14.5%	17.8%	8.5%	12.3%	16.9%	22.9%	34.3%
Physics B	1.4%	2.3%	3.6%	5.0%	8.7%	15.2%	22.7%	30.4%	38.8%	49.8%
Physics C: Mechanics	1.9%	2.9%	3.8%	5.1%	9.3%	20.9%	31.0%	38.0%	45.2%	55.9%
Psychology	4.6%	5.8%	7.1%	9.1%	11.2%	4.4%	6.8%	9.1%	13.1%	20.3%
Spanish Language	2.1%	4.0%	5.3%	6.4%	7.4%	12.4%	15.1%	15.2%	14.7%	14.4%
Statistics	1.9%	3.6%	6.3%	11.9%	22.4%	5.9%	9.6%	14.8%	24.1%	39.5%
US Gov and Politics	5.0%	8.0%	11.1%	14.7%	18.1%	6.1%	11.1%	16.0%	20.6%	24.9%
US History	0.6%	1.4%	2.5%	4.2%	7.0%	7.0%	12.1%	16.0%	19.9%	23.3%
World History	0.5%	1.1%	2.2%	4.0%	6.5%	6.8%	11.0%	16.0%	20.4%	24.7%

Notes: Each cell indicates the probability of majoring in the two-digit CIP code categorization most closely associated with the AP exam.

Table 3: Probability of Majoring in CIP cody by AP Exam Subject, Student Scoring 3 or Higher

					College Major			
AP Exam	English Language and Literature/Letters	History	Social Sciences	Psychology	Foreign Languages, Literatures, and Linguistics	Biological and Biomedical Sciences	Physical Sciences	Engineering/Mathematics and Statistics
CIP CODE	23	54	45	42	16	26	40	14/27
Biology	2.6%	2.0%	8.7%	4.9%	2.3%	**18.9%**	2.7%	7.8%
Calculus AB	2.0%	1.5%	7.9%	3.6%	2.1%	9.7%	3.1%	**13.4%**
Calculus BC	1.5%	1.4%	9.1%	3.0%	2.1%	11.4%	4.7%	**21.7%**
Chemistry	1.5%	1.4%	7.8%	3.1%	2.0%	14.2%	**6.7%**	18.2%
English Language & Comp.	**4.8%**	2.5%	10.0%	4.9%	2.8%	7.4%	1.9%	6.6%
English Literature & Comp.	**5.4%**	2.7%	10.0%	4.9%	2.8%	7.3%	1.9%	6.0%
Environmental Science	3.2%	2.6%	11.5%	4.5%	2.1%	**7.6%**	1.9%	5.7%
European History	4.5%	**5.7%**	13.5%	4.0%	3.1%	7.0%	2.1%	6.5%
French Language and Culture	4.8%	3.1%	14.3%	4.8%	**7.9%**	8.3%	2.5%	6.5%
Macroeconomics	2.3%	2.4%	**13.4%**	3.3%	2.0%	8.2%	2.4%	11.7%
Microeconomics	2.1%	2.2%	**14.3%**	3.1%	2.0%	7.7%	2.4%	11.8%
Physics B	1.6%	1.4%	7.9%	2.6%	1.7%	9.4%	**5.2%**	20.4%
Physics C: Mechanics	1.1%	1.0%	7.3%	1.7%	1.3%	7.6%	**6.2%**	29.9%
Psychology	3.2%	1.9%	8.5%	**9.2%**	2.2%	7.1%	1.4%	4.9%
Spanish Language	2.9%	1.9%	11.0%	5.0%	**6.3%**	6.9%	1.6%	5.7%
Statistics	2.2%	1.8%	10.0%	4.4%	2.0%	7.8%	2.3%	**11.8%**
US Gov and Politics	3.5%	3.7%	**13.5%**	3.9%	2.4%	7.6%	2.2%	8.2%
US History	4.0%	**4.0%**	12.2%	4.3%	2.8%	7.9%	2.2%	7.8%
World History	3.6%	**3.7%**	11.4%	4.1%	2.7%	7.9%	2.2%	7.9%

Notes: Each cell indicates the probability of majoring in the two-digit CIP code categorization. Bolded and underlined cells are the outcome major used in all regressions.

Table 4: Covariate Balancing Tests

	Male	White	Asian	Black	Hispanic	Parent Educ: Less Than HS	Parent Educ: HS graduate	Parent Educ: BA or higher	Income < $50k	Income $50k-$100k	Income > $100k	Took SAT	SAT Score	High School FRPL	Total AP Within Year	Average AP Score Within Year	Predicted Score
								1/2 Threshold									
Above Threshold	0.0017	-0.0009	0.0015	0.0002	-0.0005	-0.0004	-0.0001	0.0017	0.0002	-0.0014	-0.0004	0.0004	0.1553	-0.0504	0.0028	-0.0054	-0.0032
	(0.0018)	(0.0017)	(0.0012)	(0.0010)	(0.0012)	(0.0011)	(0.0013)	(0.0018)	(0.0013)	(0.0014)	(0.0013)	(0.0014)	(0.5107)	(0.0804)	(0.0038)	(0.0041)	(0.0058)
N	1473612	1473612	1473612	1473612	1473612	1473612	1473612	1473612	1473612	1473612	1473612	1473612	1195599	1223338	1473612	931157	1473612
								2/3 Threshold									
Above Threshold	-0.0010	-0.0020	0.0013	-0.0005	0.0015+	0.0000	0.0028**	-0.0021	0.0011	0.0014	-0.0022*	0.0015	0.7791*	0.1047+	0.0024	-0.0020	-0.0092
	(0.0014)	(0.0013)	(0.0009)	(0.0006)	(0.0008)	(0.0007)	(0.0010)	(0.0014)	(0.0009)	(0.0011)	(0.0011)	(0.0011)	(0.3811)	(0.0569)	(0.0031)	(0.0033)	(0.0066)
N	2383844	2383844	2383844	2383844	2383844	2383844	2383844	2383844	2383844	2383844	2383844	2383844	1972409	1928003	2383844	1623492	2383844
								3/4 Threshold									
Above Threshold	-0.0034*	-0.0035**	0.0017+	-0.0008+	0.0012+	-0.0007	0.0014	0.0010	-0.0006	-0.0003	0.0022+	0.0009	-0.9662**	-0.0266	0.0021	-0.0021	0.0058
	(0.0014)	(0.0012)	(0.0010)	(0.0005)	(0.0007)	(0.0006)	(0.0009)	(0.0013)	(0.0008)	(0.0011)	(0.0012)	(0.0010)	(0.3649)	(0.0516)	(0.0032)	(0.0030)	(0.0063)
N	2472178	2472178	2472178	2472178	2472178	2472178	2472178	2472178	2472178	2472178	2472178	2472178	2113990	1933772	2472178	1848836	2472178
								4/5 Threshold									
Above Threshold	-0.0016	-0.0011	0.0032*	-0.0004	-0.0012	-0.0001	-0.0002	0.0020	-0.0001	0.0016	-0.0003	0.0020+	0.6089	-0.0307	0.0017	0.0020	0.0205
	(0.0016)	(0.0015)	(0.0012)	(0.0005)	(0.0007)	(0.0006)	(0.0009)	(0.0016)	(0.0009)	(0.0013)	(0.0015)	(0.0011)	(0.4268)	(0.0601)	(0.0041)	(0.0033)	(0.0129)
N	1679162	1679162	1679162	1679162	1679162	1679162	1679162	1679162	1679162	1679162	1679162	1679162	1485920	1277910	1679162	1351907	1679162

Notes. $+ p<0.10$, $* p<0.05$, $** p<0.01$, $*** p<0.001$. All students in the sample first attended a four-year college within 180 days of high school graduation. An observation is a student AP exam. Results based on local linear regressions with triangular kernels of bandwidth 10 that include fixed effects for AP exam-year and high school graduation year. Other variables include the Distance from the threshold and the interaction of Distance and Above Threshold. Standard errors clustered by individual.

Table 5: Effect of Attaining Higher AP Exam Scores on Major

Threshold:	Outcome = Majored in Same Subject as AP Exam			
	1/2	2/3	3/4	4/5
	Full Sample			
Above Threshold	-0.0003	0.0018**	0.0038**	0.0064**
	(0.0007)	(0.0006)	(0.0007)	(0.0011)
Mean at Cutoff	4.2%	5.4%	8.1%	12.2%
N	1473612	2383844	2472178	1679162
	Only AP STEM Exams			
Above Threshold	-0.0006	0.0011	0.0022	0.0053**
	(0.0012)	(0.0013)	(0.0015)	(0.0019)
Mean at Cutoff	5.4%	7.5%	10.8%	15.7%
N	626287	770240	803432	635615
	Only AP Non-STEM Exams			
Above Threshold	-0.0001	0.0022**	0.0045**	0.0073**
	(0.0008)	(0.0007)	(0.0008)	(0.0012)
Mean at Cutoff	3.3%	4.4%	6.8%	10.0%
N	847325	1613604	1668746	1043547

Notes. + $p<0.10$, * $p<0.05$, ** $p<0.01$. All students in the sample first attended a four-year college within 180 days of high school graduation. An observation is a student AP exam. Results based on local linear regressions with triangular kernels of bandwidth 10 that include fixed effects for AP exam-year and high school graduation year. Other variables include the Distance from the threshold and the interaction of Distance and Above Threshold. Standard errors clustered by individual. Means at cutoff are based on all students within one point below the designated threshold.

Table 6: Potential Mechanisms for Impacts of Higher AP Exam Scores on College Major

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
			College Choice			College Graduation	
	College's Average SAT	Barrons Most, Highly, or Very Competitive	Major in Subject; Senior Exams Only	Major in Subject; College FE	Schools Offers Credit at Threshold	Bachelor in Six Years	Major in Subject; College Graduates
				1/2 Threshold			
Above Threshold	0.4266	0.0026	-0.0001	-0.0004	--	-0.0037+	-0.0000
	(0.3993)	(0.0017)	(0.0010)	(0.0007)	--	(0.0021)	(0.0010)
Mean At Cutoff	1140	59.0%	5.3%	4.2%	--	75.0%	6.2%
N	1427550	1473612	928304	1473612	--	831234	982436
				2/3 Threshold			
Above Threshold	0.4230	0.0009	0.0013	0.0020**	0.0001	0.0027+	0.0022**
	(0.3131)	(0.0013)	(0.0009)	(0.0006)	(0.0015)	(0.0014)	(0.0008)
Mean At Cutoff	1173	69.4%	6.3%	5.4%	59.3%	82.0%	7.1%
N	2325531	2383844	1475603	2383844	1956213	1386828	1768736
				3/4 Threshold			
Above Threshold	0.6023+	0.0026*	0.0033**	0.0035**	-0.0031*	0.0029*	0.0044**
	(0.3219)	(0.0011)	(0.0010)	(0.0007)	(0.0015)	(0.0013)	(0.0009)
Mean At Cutoff	1213	78.7%	9.1%	8.1%	55.6%	85.7%	10.0%
N	2421632	2472178	1553288	2472178	2045180	1435783	1966483
				4/5 Threshold			
Above Threshold	0.9922*	0.0006	0.0042**	0.0068**	0.0019	0.0032*	0.0076**
	(0.4087)	(0.0012)	(0.0014)	(0.0011)	(0.0014)	(0.0014)	(0.0012)
Mean At Cutoff	1258	85.8%	13.3%	12.2%	20.4%	88.7%	14.5%
N	1650548	1679162	1057689	1679162	1402697	953759	1401213

Notes. + p<0.10, * p<0.05, ** p<0.01. All students in the sample first attended a four-year college within 180 days of high school graduation. An observation is a student AP exam. Results based on local linear regressions with triangular kernels of bandwidth 10 that include fixed effects for AP exam-year and high school graduation year. Other variables include the Distance from the threshold and the interaction of Distance and Above Threshold. Standard errors clustered by individual.

Table 7: Effect of Attaining Higher AP Exam Scores on Major - Credit or Signal?

	Policy Sample			STEM AP Exams			Non-STEM AP Exams		
	All	With AP Policy	Without AP Policy	All	With AP Policy	Without AP Policy	All	With AP Policy	Without AP Policy
	2/3 Threshold								
Above Threshold	0.0021**	0.0028**	0.0012	0.0014	0.0030	-0.0012	0.0025**	0.0026**	0.0022+
	(0.0007)	(0.0009)	(0.0011)	(0.0014)	(0.0018)	(0.0023)	(0.0008)	(0.0010)	(0.0012)
Mean At Threshold	5.4%	5.4%	5.4%	7.6%	7.9%	7.2%	4.3%	4.1%	4.6%
N	1956213	1164325	791888	638044	391487	246557	1318169	772838	545331
	3/4 Threshold								
Above Threshold	0.0036**	0.0042**	0.0028*	0.0019	0.0027	0.0010	0.0044**	0.0049**	0.0037**
	(0.0008)	(0.0011)	(0.0012)	(0.0016)	(0.0022)	(0.0023)	(0.0009)	(0.0012)	(0.0014)
Mean At Threshold	8.1%	8.2%	8.0%	11.1%	11.8%	10.3%	6.7%	6.6%	6.8%
N	2045180	1137975	907205	674183	363711	310472	1370997	774264	596733
	4/5 Threshold								
Above Threshold	0.0068**	0.0053*	0.0072**	0.0069**	0.0024	0.0085**	0.0069**	0.0080*	0.0066**
	(0.0012)	(0.0026)	(0.0013)	(0.0021)	(0.0041)	(0.0024)	(0.0014)	(0.0032)	(0.0015)
Mean At Threshold	12.4%	12.5%	12.4%	16.2%	15.2%	16.6%	9.9%	10.0%	9.9%
N	1402697	277830	1124867	540619	130449	410170	862078	147381	714697

Notes. + $p<0.10$, * $p<0.05$, ** $p<0.01$. All students in the sample first attended a four-year college within 180 days of high school graduation. Policy sample includes 500 colleges where credit policies are collected. Colleges are defined as "with a policy" if there is any alteration in the units or courses offered at the threshold. An observation is a student AP exam. Results based on local linear regressions with triangular kernels of bandwidth 10 that include fixed effects for AP exam-year and high school graduation year. Other variables include the Distance from the threshold and the interaction of Distance and Above Threshold. Standard errors clustered by individual. Means at cutoff are based on all students within one point below the designated threshold.

Table 8: Effect of Attaining Higher AP Exam Scores on Major - Credit or Signal with Uniform Credit Policies

Threshold:	Sample		2/3	3/4	4/5
No Credit Given for Exam at Any Threshold	311 school-exam combinations (106 schools) that give no credit at any threshold. Environmental Science, World History, and European History are 1/2 of the sample.	Above Threshold	-0.0011 (0.0050)	0.0084+ (0.0045)	0.0047 (0.0050)
		N	34048	56323	62216
Credit Given for All Thresholds	435 school-exam combinations (203 schools) that given credit at the 2/3, 3/4, and 4/5 thresholds. Biology, Chemistry, Spanish Language, and French Language are 4/5 of the sample.	Above Threshold	0.0087* (0.0042)	0.0099+ (0.0054)	0.0074 (0.0078)
		N	58256	50920	31721
Uniform Credit Policy Across AP Subjects	71 schools that offer AP credit at either the 2/3 or 3/4 threshold for every exam	Above Threshold	0.0009 (0.0019)	0.0022 (0.0020)	0.0088** (0.0029)
		N	283142	315673	222507
Uniform Credit Policy Across AP Subjects (2/3 Threshold Only)	52 schools that offer AP credit at the 2/3 threshold for every exam	Above Threshold	0.0019 (0.0021)	0.0026 (0.0023)	0.0083* (0.0033)
		N	233759	256960	180238

Notes. + p<0.10, * p<0.05, ** p<0.01. All students in the sample first attended a four-year college within 180 days of high school graduation. Analyses use credit policy sample, whereby policies are collected for 500 colleges. An observation is a student AP exam. Results based on local linear regressions with triangular kernels of bandwidth 10 that include fixed effects for AP exam-year and high school graduation year. Other variables include the Distance from the threshold and the interaction of Distance and Above Threshold. Standard errors clustered by individual.

Table 9: Effect of Attaining Higher AP Exam Scores on Major - Heterogeneity

	All AP Exams			STEM AP Exams			Non-STEM AP Exams		
Threshold:	2/3	3/4	4/5	2/3	3/4	4/5	2/3	3/4	4/5
Male	0.0023*	0.0033**	0.0067**	0.0022	0.0028	0.0055*	0.0022*	0.0037**	0.0078**
	(0.0010)	(0.0011)	(0.0015)	(0.0020)	(0.0021)	(0.0027)	(0.0010)	(0.0012)	(0.0018)
N	1024316	1140410	836630	369339	418061	359260	654977	722349	477370
Female	0.0016*	0.0040**	0.0062**	0.0001	0.0016	0.0050+	0.0022*	0.0050**	0.0068**
	(0.0008)	(0.0010)	(0.0015)	(0.0016)	(0.0019)	(0.0027)	(0.0009)	(0.0011)	(0.0017)
N	1359528	1331768	842532	400901	385371	276355	958627	946397	566177
White	0.0020**	0.0040**	0.0075**	0.0012	0.0026	0.0051*	0.0024**	0.0047**	0.0091**
	(0.0007)	(0.0009)	(0.0013)	(0.0015)	(0.0017)	(0.0023)	(0.0008)	(0.0010)	(0.0015)
N	1656577	1789749	1204179	538372	573035	449550	1118205	1216714	754629
Asian	0.0023	0.0028	0.0029	0.0000	0.0016	0.0040	0.0037*	0.0036+	0.0022
	(0.0017)	(0.0019)	(0.0025)	(0.0034)	(0.0037)	(0.0044)	(0.0018)	(0.0021)	(0.0029)
N	308939	345783	273790	119323	137425	125712	189616	208358	148078
Minority (Black/Hispanic)	0.0023	0.0041+	0.0026	0.0051	-0.0002	0.0026	0.0013	0.0056*	0.0026
	(0.0017)	(0.0023)	(0.0036)	(0.0040)	(0.0053)	(0.0082)	(0.0018)	(0.0025)	(0.0038)
N	323417	239491	134227	83214	63093	36986	240203	176398	97241
Income < $50k	0.0045*	0.0046*	-0.0020	0.0059	0.0031	-0.0047	0.0039*	0.0055*	-0.0003
	(0.0018)	(0.0023)	(0.0036)	(0.0038)	(0.0048)	(0.0068)	(0.0019)	(0.0025)	(0.0041)
N	299503	248206	144763	91086	79173	52964	208417	169033	91799
Income $50k - $100k	0.0017	0.0038*	0.0098**	0.0016	0.0031	0.0137**	0.0018	0.0043*	0.0080**
	(0.0014)	(0.0016)	(0.0025)	(0.0029)	(0.0034)	(0.0046)	(0.0015)	(0.0018)	(0.0029)
N	485175	483721	308762	153935	153702	115658	331240	330019	193104
Income > $100k	0.0001	0.0051**	0.0089**	-0.0008	0.0036	0.0090*	0.0006	0.0058**	0.0090**
	(0.0014)	(0.0015)	(0.0021)	(0.0027)	(0.0030)	(0.0039)	(0.0016)	(0.0017)	(0.0025)
N	474661	557844	409834	157629	179685	151643	317032	378159	258191
Took One AP	-0.0007	0.0035	0.0041	-0.0025	-0.0017	-0.0016	0.0003	0.0070*	0.0090
	(0.0017)	(0.0025)	(0.0047)	(0.0034)	(0.0045)	(0.0075)	(0.0019)	(0.0030)	(0.0057)
N	328563	225638	101150	114393	86042	45804	214170	139596	55346
Took Two or More AP	0.0023**	0.0038**	0.0066**	0.0017	0.0026+	0.0058**	0.0025**	0.0044**	0.0073**
	(0.0007)	(0.0008)	(0.0011)	(0.0014)	(0.0015)	(0.0020)	(0.0007)	(0.0008)	(0.0013)
N	2055281	2246540	1578012	655847	717390	589811	1399434	1529150	988201
Bottom Third SAT	0.0024*	0.0062**	0.0030	0.0033	0.0023	0.0025	0.0021+	0.0080**	0.0033
	(0.0010)	(0.0019)	(0.0041)	(0.0024)	(0.0039)	(0.0084)	(0.0011)	(0.0021)	(0.0045)
N	834173	434741	131157	218393	123701	41141	615780	311040	90016
Middle Third SAT	0.0005	0.0035**	0.0052*	-0.0010	0.0021	0.0019	0.0012	0.0043**	0.0077**
	(0.0011)	(0.0012)	(0.0022)	(0.0021)	(0.0024)	(0.0037)	(0.0012)	(0.0014)	(0.0026)
N	798336	908774	469918	280039	296351	184270	518297	612423	285648
Top Third SAT	-0.0003	0.0016	0.0083**	-0.0014	0.0002	0.0096**	0.0005	0.0023+	0.0076**
	(0.0017)	(0.0012)	(0.0014)	(0.0028)	(0.0024)	(0.0025)	(0.0022)	(0.0014)	(0.0016)
N	339900	770475	884845	143872	265633	331807	196028	504842	553038
Bottom Third College Quality (Avg. SAT)	0.0030**	0.0026*	0.0064**	0.0052*	-0.0011	0.0065	0.0021*	0.0042**	0.0063*
	(0.0009)	(0.0013)	(0.0023)	(0.0021)	(0.0028)	(0.0044)	(0.0009)	(0.0014)	(0.0026)
N	975176	734177	341542	278649	220467	123894	696527	513710	217648
Middle Third College Quality (Avg. SAT)	0.0016	0.0039**	0.0083**	0.0002	0.0037	0.0094*	0.0023*	0.0040**	0.0079**
	(0.0011)	(0.0013)	(0.0020)	(0.0023)	(0.0026)	(0.0037)	(0.0012)	(0.0014)	(0.0023)
N	822881	838322	493909	270060	274458	192741	552821	563864	301168
Top Third College Quality (Avg. SAT)	-0.0001	0.0043**	0.0054**	-0.0025	0.0029	0.0028	0.0014	0.0051**	0.0071**
	(0.0015)	(0.0013)	(0.0015)	(0.0024)	(0.0023)	(0.0027)	(0.0019)	(0.0015)	(0.0018)
N	527474	849133	815097	204439	293389	309072	323035	555744	506025

Notes. + p<0.10, * p<0.05, ** p<0.01. Each estimate is a separate regression that is restricted to the identified sample. All students in the sample first attended a four-year college within 180 days of high school graduation. An observation is a student AP exam. Results based on local linear regressions with triangular kernels of bandwidth 10 that include fixed effects for AP exam-year and high school graduation year. Other variables include the Distance from the threshold and the interaction of Distance and Above Threshold. Standard errors clustered by individual.

Table 10: Impact of Earning Multiple High Scores on AP Exams

	Multiple AP Takers	Other Exam = Average of exam scores (Centered at 3)		
	(1)	(2)	(3)	(4)
Above 4/5 Threshold (Primary Exam)	0.0068***	0.0091***	0.0077***	0.0093***
	(0.0011)	(0.0013)	(0.0014)	(0.0014)
Above 4/5 Threshold (Primary Exam)*Other Exam	--	-0.0029***	--	--
	--	(0.0008)	--	--
Above 4/5 Threshold (Primary Exam)*Other STEM Exam	--	--	-0.0011+	--
	--	--	(0.0007)	--
Above 4/5 Threshold (Primary Exam)*Other Non-STEM Exam	--	--	--	-0.0030***
	--	--	--	(0.0008)
N	1578216	1578012	1256934	1449178

Notes. + $p<0.10$, * $p<0.05$, ** $p<0.01$. All students in the sample first attended a four-year college within 180 days of high school graduation. An observation is a student AP exam but only for students near the 4/5 threshold on at least one exam. Results based on local linear regressions with triangular kernels of bandwidth 10 that include fixed effects for AP exam subject of the forcing variable, AP exam-year and high school graduation year. These regressions also contain fixed effects for the exact set of total AP exams taken by the student. Other variables include the Distance from the threshold and the interaction of Distance and Above Threshold. Standard errors clustered by individual.

Table 11: Effect of Attaining Higher AP Exam Scores on Majoring in Any STEM Field

Threshold:	Outcome = Majored in STEM			
	1/2	2/3	3/4	4/5
	Full Sample			
Above Threshold	-0.0002	0.0021*	0.0001	-0.0021
	(0.0011)	(0.0010)	(0.0011)	(0.0014)
Mean at Cutoff	11.7%	15.8%	20.2%	26.0%
N	1473612	2383844	2472178	1679162
	Only AP STEM Exams			
Above Threshold	-0.0012	0.0028	0.0010	0.0006
	(0.0019)	(0.0019)	(0.0021)	(0.0026)
Mean at Cutoff	15.5%	20.5%	26.7%	34.9%
N	626287	770240	803432	635615
	Only AP Non-STEM Exams			
Above Threshold	0.0005	0.0018	-0.0003	-0.0035*
	(0.0014)	(0.0012)	(0.0013)	(0.0017)
Mean at Cutoff	9.0%	13.5%	17.1%	20.4%
N	847325	1613604	1668746	1043547

Notes. + $p<0.10$, * $p<0.05$, ** $p<0.01$. All students in the sample first attended a four-year college within 180 days of high school graduation. An observation is a student AP exam. Results based on local linear regressions with triangular kernels of bandwidth 10 that include fixed effects for AP exam-year and high school graduation year. Other variables include the Distance from the threshold and the interaction of Distance and Above Threshold. Standard errors clustered by individual. Means at cutoff are based on all students within one point below the designated threshold.

Figure 1: Density of Students Around Thresholds
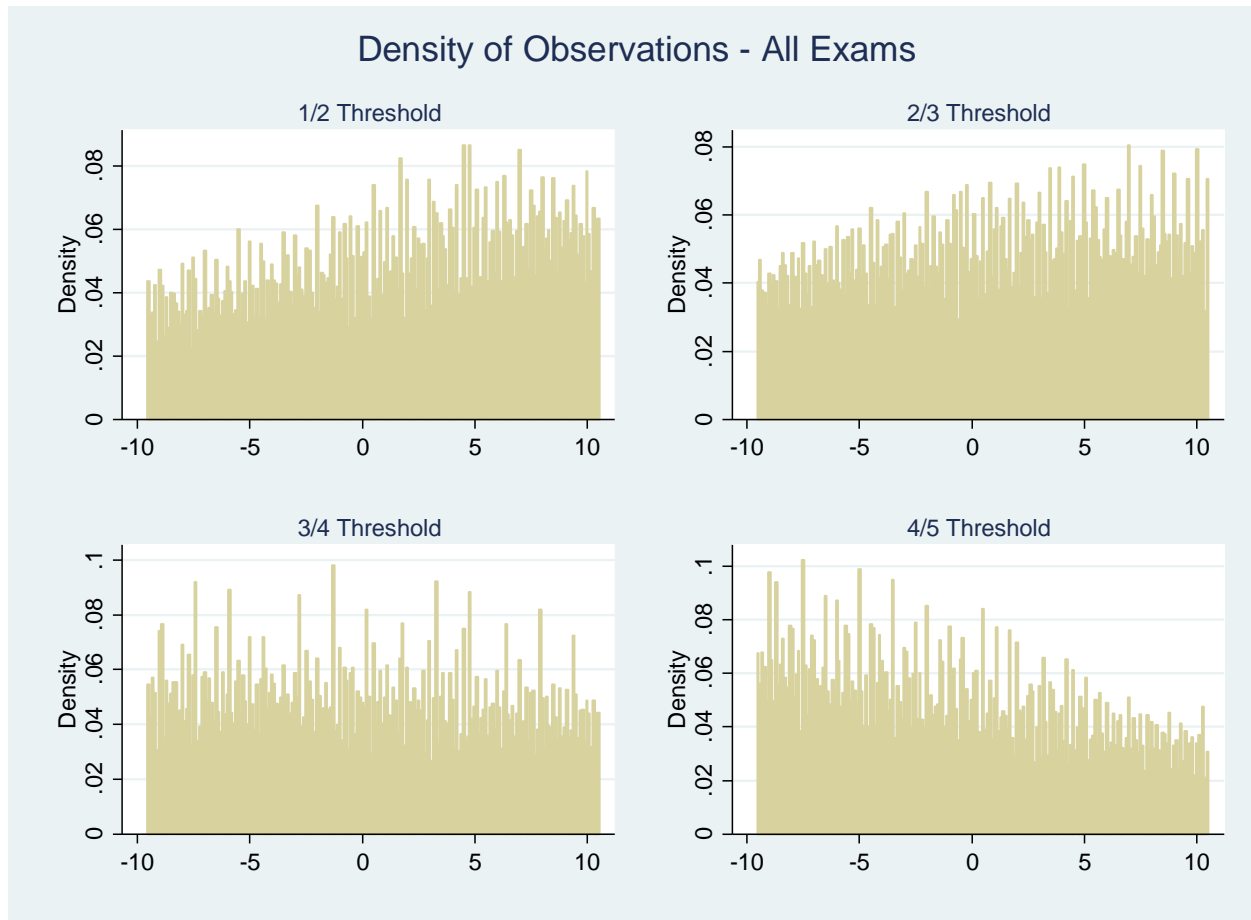
Notes. Figure includes all student-exam observations within 10 points of the integer AP score threshold for the nineteen AP exams listed in Table 2 for the years 2004 through 2009 graduating high school cohorts. Sample sizes for the 1/2, 2/3, 3/4, and 4/5 thresholds are 1,473,612, 2,383,844, 2,472,178, and 1,679,162 observations, respectively.

Figure 2 - Main Results
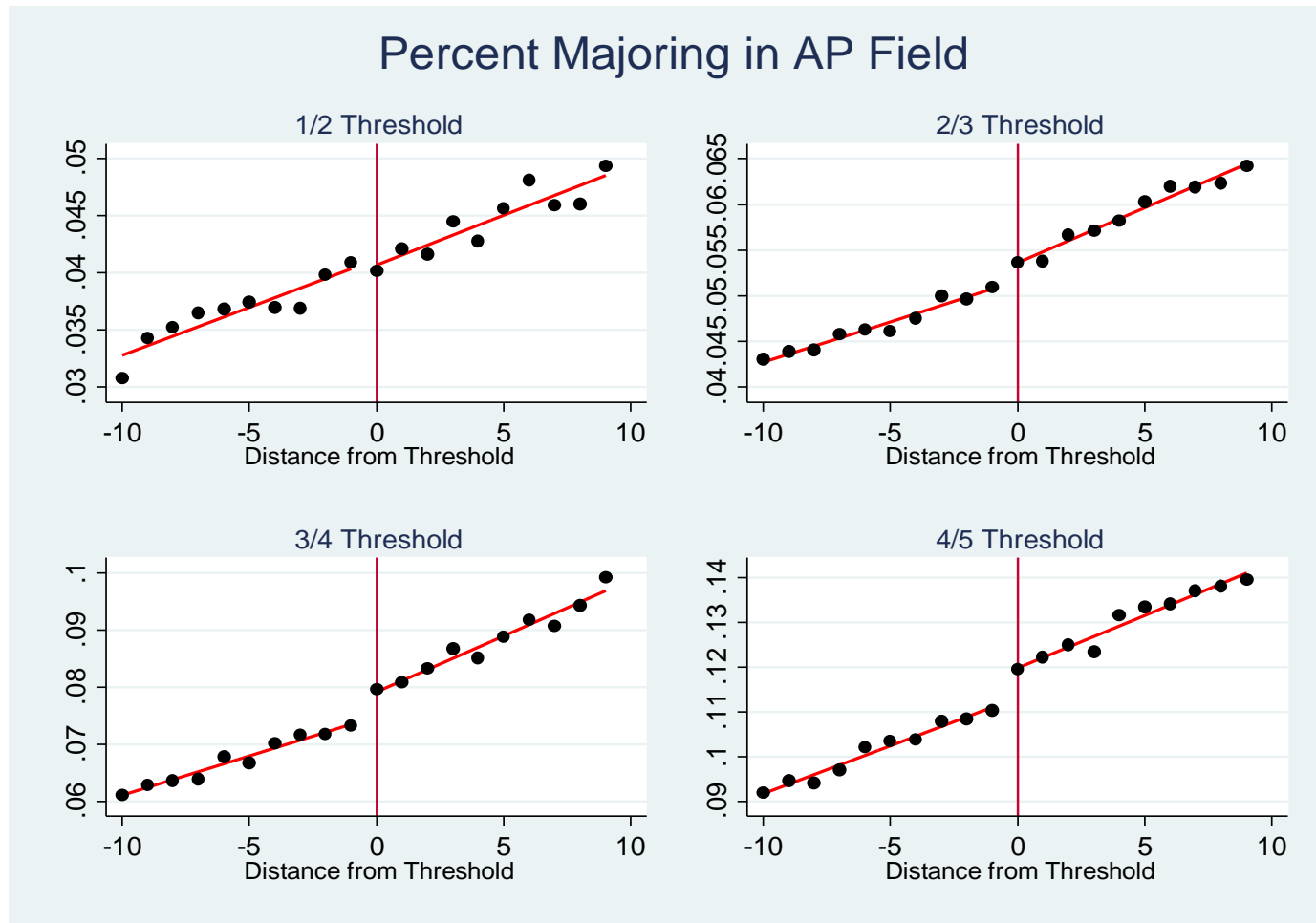
Notes. Figure includes all student-exam observations within 10 points of the integer AP score threshold for the nineteen AP exams listed in Table 2 for the years 2004 through 2009 graduating high school cohorts. Sample sizes for the 1/2, 2/3, 3/4, and 4/5 thresholds are 1,473,612, 2,383,844, 2,472,178, and 1,679,162 observations, respectively.

Figure 3 - Main Results - Stem and Non-STEM Fields
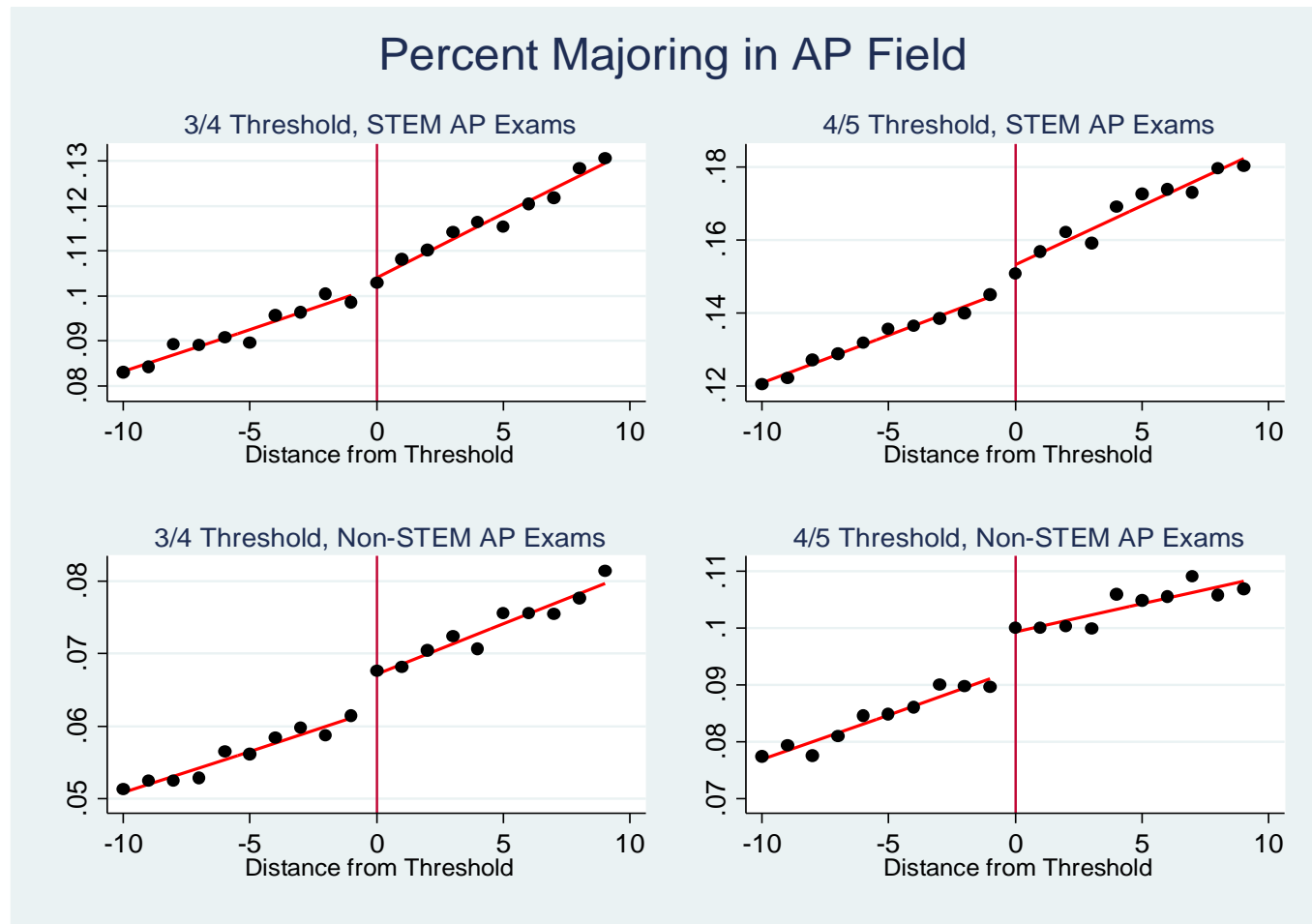
Notes. Figure includes all student-exam observations within 10 points of the integer AP score threshold for the nineteen AP exams listed in Table 2 for the years 2004 through 2009 graduating high school cohorts. Sample sizes for the STEM AP exams at the 3/4 and 4/5 thresholds are 803,432 and 635,615 observations, respectively. Sample sizes for the Non-STEM AP exams at the 3/4 and 4/5 thresholds are 1,668,746 and 1,043,547 observations, respectively.

Figure 4. Subject by Subject Results
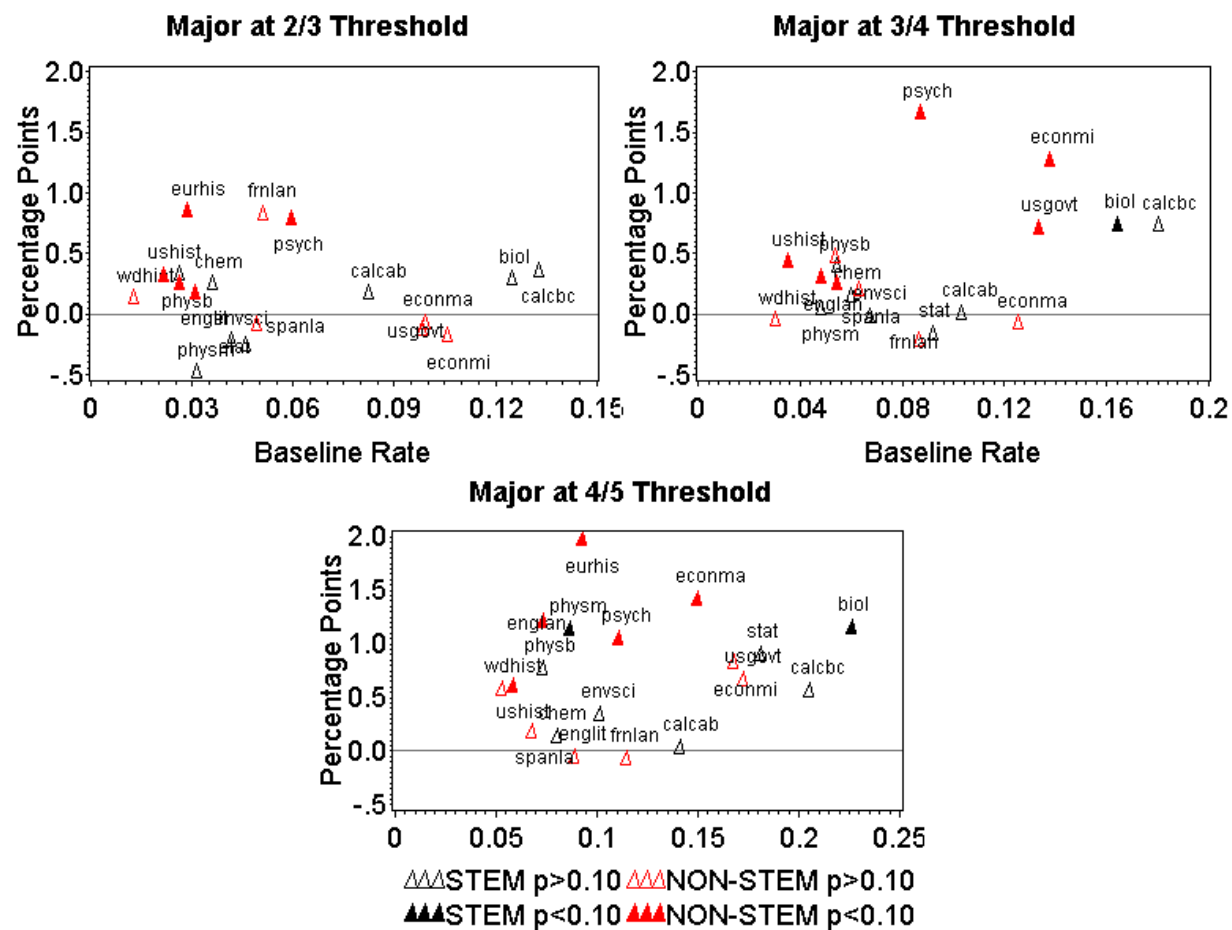
Appendix Table 1: Distribution of Credit-Granting Scores and Test Timing

AP subject	In Sample	STEM exam	Total obs.	Percent distribution of high school years during which exam was				Exists credit policy at score of X, relative to X-1 (for 500 in-sample colleges):		
				Fresh.	Soph.	Jun.	Sen.	3	4	5
English Literature & Comp.	Y	N	1,641,172	0.0	0.1	5.9	94.0	61.3%	55.8%	17.1%
US History	Y	N	1,438,063	0.0	5.9	86.8	7.3	62.9%	47.7%	12.5%
English Language & Comp.	Y	N	1,228,818	0.0	1.0	79.5	19.5	64.7%	52.6%	19.1%
Calculus AB	Y	Y	1,120,442	0.0	0.8	14.8	84.4	71.2%	43.3%	7.3%
US Gov and Politics	Y	N	847,245	0.2	3.2	8.5	88.2	65.7%	31.6%	4.8%
Biology	Y	Y	690,772	0.4	6.4	34.4	58.8	64.3%	59.3%	26.5%
Psychology	Y	N	510,673	0.0	1.7	26.5	71.8	64.9%	33.4%	3.8%
Spanish Language	Y	N	472,437	1.3	8.8	33.8	56.1	76.6%	64.3%	38.6%
Chemistry	Y	Y	444,396	0.0	4.1	48.5	47.3	66.5%	65.1%	32.0%
Statistics	Y	Y	436,090	0.1	2.3	15.6	82.0	69.0%	30.4%	5.9%
European History	Y	N	406,442	0.3	42.3	16.7	40.8	59.8%	44.4%	10.4%
Calculus BC	Y	Y	330,823	0.1	1.2	18.0	80.7	75.5%	52.4%	8.8%
Macroeconomics	Y	N	313,155	0.0	0.7	7.8	91.5	63.3%	35.2%	4.4%
World History	Y	N	305,650	2.7	73.5	13.3	10.5	58.6%	42.3%	11.7%
Physics B	Y	Y	276,199	0.1	1.4	31.4	67.1	62.6%	46.2%	12.3%
Environmental Science	Y	Y	257,417	0.4	2.3	28.4	68.9	60.1%	33.2%	3.8%
Microeconomics	Y	N	192,262	0.1	1.3	10.2	88.4	63.7%	35.0%	4.4%
Physics C: Mechanics	Y	Y	142,707	0.0	0.5	10.8	88.7	58.7%	50.6%	11.0%
French Language and Culture	Y	N	106,032	0.5	3.3	23.8	72.4	76.7%	62.6%	37.0%
Art History	N	--	94,143	0.1	6.3	27.6	66.0			
Human Geography	N	--	80,677	17.9	17.9	18.9	45.3			
Spanish Literature	N	--	76,242	0.4	4.8	26.5	68.2			
Comparative Gov.and Politics	N	--	74,051	0.1	5.1	14.1	80.7			
Computer Science A	N	--	72,446	0.6	11.6	35.9	51.9			
Physics C: E&M	N	--	63,715	0.0	0.6	8.8	90.5			
Studio Art 2-D	N	--	62,215	0.0	0.9	11.8	87.2			
Studio Art Drawing	N	--	61,579	0.0	1.1	14.2	84.7			
Music Theory	N	--	52,425	0.3	5.4	28.1	66.2			
Computer Science AB	N	--	25,564	0.3	8.8	36.0	54.8			
German Language and Culture	N	--	24,368	0.8	4.3	20.9	74.0			
Latin Vergil	N	--	24,040	0.2	5.2	37.4	57.3			
Latin Literature	N	--	18,154	0.1	3.5	37.6	58.7			
Studio Art 3-D	N	--	10,622	0.0	0.9	10.5	88.5			
French Literature	N	--	10,142	0.2	3.3	20.5	76.0			
Chinese	N	--	7,382	0.0	4.2	35.5	60.3			
Italian Language and Culture	N	--	6,467	0.1	0.9	11.1	87.9			
Japanese Lang. and Culture	N	--	3,949	0.0	2.1	20.1	77.9			

Notes: Includes AP exams taken by the 2004-2009 cohorts. On-time students are those who began at a four-year college within 180 days of high school graduation. Credit policies collected from college websites in August and September of 2015 and include any mention of college credit or placement.

Appendix Table 2: AP Subject, Classification of Instructional Program (CIP) Code, Major Crosswalk

AP Subject	CIP Code	Assigned Major
STEM		
Biology	26	Biological Sciences
Calculus AB	14, 15, 27	Engineering / Engineering Technologies / Mathematics
Calculus BC	14, 15, 27	Engineering / Engineering Technologies / Mathematics
Chemistry	40	Physical Sciences
Environmental Science	26	Biological Sciences
Physics (Mechanics)	40	Physical Sciences
Physics B	40	Physical Sciences
Statistics	14, 15, 27	Engineering / Engineering Technologies / Mathematics
Non-STEM		
English Language	23	English Language and Literature/Letters
English Literature	23	English Language and Literature/Letters
European History	54	History
French Language	16	Foreign Languages, Literatures, and Linguistics
Macroeconomics	45	Social Sciences
Microeconomics	45	Social Sciences
Psychology	42	Psychology
Spanish Language	16	Foreign Languages, Literatures, and Linguistics
US Government	45	Social Sciences
US History	54	History
World History	54	History

Notes. CIP categories taken from 2010 NCES categorization (see
https://nces.ed.gov/ipeds/cipcode/browse.aspx?y=55).

Appendix Table 3: Subject-by-Subject Selected Results

| | 2/3 Threshold | | | | 3/4 Threshold | | | | 4/5 Threshold | | | |
| | | Policy Sample | | | | Policy Sample | | | | Policy Sample | | |
	Full Sample	All	With AP Policy	Without AP Policy	Full Sample	All	With AP Policy	Without AP Policy	Full Sample	All	With AP Policy	Without AP Policy
Biology - Above Threshold	0.0030	0.0026	0.0052	-0.0009	0.0075+	0.0072	0.0027	0.0148+	0.0117*	0.0114+	0.0110	0.0122
	(0.0039)	(0.0044)	(0.0057)	(0.0067)	(0.0043)	(0.0048)	(0.0060)	(0.0081)	(0.0055)	(0.0061)	(0.0093)	(0.0080)
N	134134	107805	61950	45855	135445	110575	70435	40140	106010	88085	34771	53314
Calc AB - Above Threshold	0.0018	0.0029	0.0031	0.0027	0.0002	0.0008	0.0031	-0.0011	0.0005	0.0025	-0.0147	0.0056
	(0.0024)	(0.0027)	(0.0034)	(0.0047)	(0.0026)	(0.0030)	(0.0044)	(0.0040)	(0.0033)	(0.0036)	(0.0094)	(0.0039)
N	237829	195003	124721	70282	248500	205351	99448	105903	212499	177148	25939	151209
Calc BC - Above Threshold	0.0037	0.0018	0.0020	0.0017	0.0074	0.0077	0.0170*	-0.0072	0.0058	0.0073	0.0035	0.0089
	(0.0062)	(0.0068)	(0.0082)	(0.0122)	(0.0056)	(0.0061)	(0.0079)	(0.0094)	(0.0057)	(0.0061)	(0.0125)	(0.0070)
N	54462	47121	33031	14090	84679	74005	45483	28522	92320	81275	17391	63884
Chemistry - Above Threshold	0.0026	0.0007	0.0054	-0.0064	0.0016	-0.0003	0.0019	-0.0053	0.0016	0.0053	-0.0055	0.0145*
	(0.0031)	(0.0032)	(0.0042)	(0.0051)	(0.0038)	(0.0039)	(0.0049)	(0.0066)	(0.0051)	(0.0053)	(0.0078)	(0.0071)
N	71210	59320	35555	23765	67984	57690	40629	17061	51440	44526	20100	24426
Env Sci - Above Threshold	-0.0021	-0.0023	-0.0023	-0.0024	-0.0001	0.0008	0.0037	-0.0019	0.0036	0.0057	-0.0207	0.0082
	(0.0040)	(0.0045)	(0.0060)	(0.0067)	(0.0045)	(0.0050)	(0.0072)	(0.0070)	(0.0073)	(0.0080)	(0.0283)	(0.0084)
N	55311	45910	27781	18129	54626	45306	21157	24149	32135	26707	2263	24444
Physics B - Above Threshold	0.0034	0.0057	0.0142**	-0.0038	0.0040	0.0033	0.0026	0.0042	0.0079	0.0089	0.0311*	-0.0002
	(0.0034)	(0.0036)	(0.0052)	(0.0049)	(0.0045)	(0.0046)	(0.0070)	(0.0060)	(0.0068)	(0.0071)	(0.0124)	(0.0086)
N	46392	39111	20730	18381	39348	33608	16740	16868	24366	21135	6478	14657
Physics M - Above Threshold	-0.0047	-0.0047	-0.0021	-0.0066	0.0006	0.0004	-0.0044	0.0055	0.0116*	0.0111*	0.0109	0.0111
	(0.0038)	(0.0039)	(0.0059)	(0.0053)	(0.0040)	(0.0040)	(0.0059)	(0.0054)	(0.0055)	(0.0055)	(0.0081)	(0.0073)
N	42046	36594	16153	20441	47802	42023	21741	20282	38935	34465	12256	22209
Statistics - Above Threshold	-0.0024	-0.0014	-0.0007	-0.0030	-0.0015	-0.0038	-0.0083	-0.0002	0.0092	0.0121+	0.0109	0.0127+
	(0.0025)	(0.0028)	(0.0034)	(0.0049)	(0.0034)	(0.0038)	(0.0057)	(0.0052)	(0.0058)	(0.0063)	(0.0150)	(0.0070)
N	128856	107180	71566	35614	125048	105625	48078	57547	77910	67278	11251	56027
English Language - Above Threshold	0.0026*	0.0026+	0.0023	0.0032	0.0031+	0.0032+	0.0021	0.0047+	0.0123**	0.0103**	0.0090	0.0106**
	(0.0012)	(0.0013)	(0.0017)	(0.0023)	(0.0017)	(0.0018)	(0.0024)	(0.0028)	(0.0027)	(0.0029)	(0.0063)	(0.0033)
N	287384	236258	153217	83041	286089	235356	139639	95717	164779	134770	28218	106552

Appendix Table 3 - Continued : Subject-by-Subject Selected Results

	2/3 Threshold				3/4 Threshold				4/5 Threshold			
		Policy Sample				Policy Sample				Policy Sample		
	Full Sample	All	With AP Policy	Without AP Policy	Full Sample	All	With AP Policy	Without AP Policy	Full Sample	All	With AP Policy	Without AP Policy
English Literature - Above Threshold	0.0019+	0.0025*	0.0029+	0.0019	0.0026+	0.0025	0.0021	0.0032	-0.0004	-0.0016	0.0023	-0.0026
	(0.0011)	(0.0012)	(0.0016)	(0.0019)	(0.0014)	(0.0016)	(0.0020)	(0.0025)	(0.0026)	(0.0029)	(0.0059)	(0.0033)
N	399869	319268	185275	133993	424802	340753	215138	125615	215421	171874	36485	135389
European History - Above Threshold	0.0086**	0.0077**	0.0072+	0.0084+	0.0049	0.0077*	0.0094+	0.0051	0.0199**	0.0202**	0.0231+	0.0196**
	(0.0026)	(0.0029)	(0.0039)	(0.0044)	(0.0035)	(0.0039)	(0.0051)	(0.0058)	(0.0055)	(0.0061)	(0.0134)	(0.0069)
N	68559	55106	30009	25097	76047	61374	35888	25486	48174	38916	7356	31560
French Language - Above Threshold	0.0084	0.0098	0.0128	0.0067	-0.0021	-0.0016	0.0099	-0.0305+	-0.0005	0.0092	0.0321	-0.0088
	(0.0069)	(0.0076)	(0.0105)	(0.0107)	(0.0094)	(0.0105)	(0.0128)	(0.0182)	(0.0127)	(0.0141)	(0.0216)	(0.0186)
N	17678	14038	8261	5777	15946	12601	8960	3641	10597	8505	3810	4695
Macroeconomics - Above Threshold	-0.0006	0.0006	-0.0005	0.0018	-0.0007	-0.0015	-0.0032	0.0002	0.0143*	0.0139*	0.0224	0.0127*
	(0.0046)	(0.0050)	(0.0066)	(0.0075)	(0.0048)	(0.0051)	(0.0070)	(0.0073)	(0.0057)	(0.0060)	(0.0198)	(0.0062)
N	80885	69407	35274	34133	87380	75690	37880	37810	70345	61749	8009	53740
Microeconmics - Above Threshold	-0.0017	-0.0019	-0.0080	0.0031	0.0128*	0.0108+	0.0176+	0.0040	0.0084	0.0110	-0.0280	0.0168*
	(0.0058)	(0.0063)	(0.0076)	(0.0101)	(0.0060)	(0.0064)	(0.0091)	(0.0091)	(0.0075)	(0.0080)	(0.0237)	(0.0083)
N	51006	43268	22744	20524	58488	50329	24771	25558	45786	39964	6176	33788
Psychology - Above Threshold	0.0080*	0.0072+	0.0109*	0.0011	0.0167**	0.0175**	0.0237**	0.0129*	0.0107*	0.0118*	0.0229	0.0108*
	(0.0037)	(0.0041)	(0.0050)	(0.0071)	(0.0037)	(0.0040)	(0.0063)	(0.0053)	(0.0044)	(0.0048)	(0.0187)	(0.0050)
N	83580	68261	43955	24306	103015	85052	36421	48631	91387	76005	5491	70514
Spanish Language - Above Threshold	-0.0008	0.0029	0.0053	-0.0021	0.0021	0.0002	0.0038	-0.0057	0.0020	0.0048	0.0066	0.0039
	(0.0038)	(0.0040)	(0.0049)	(0.0068)	(0.0040)	(0.0043)	(0.0057)	(0.0064)	(0.0046)	(0.0050)	(0.0080)	(0.0064)
N	60926	50185	33774	16411	67221	55441	34892	20549	56173	46388	17651	28737
US Government - Above Threshold	-0.0011	0.0001	0.0008	-0.0015	0.0072*	0.0066+	0.0067	0.0064	0.0069	0.0044	-0.0035	0.0048
	(0.0029)	(0.0031)	(0.0038)	(0.0056)	(0.0032)	(0.0035)	(0.0056)	(0.0044)	(0.0045)	(0.0048)	(0.0230)	(0.0049)
N	200044	167771	106102	61669	204511	172642	72739	99903	132408	112365	6341	106024
US History - Above Threshold	0.0033**	0.0031**	0.0026	0.0036*	0.0044**	0.0041**	0.0039+	0.0044+	0.0063*	0.0064*	0.0128+	0.0051+
	(0.0011)	(0.0012)	(0.0016)	(0.0018)	(0.0015)	(0.0016)	(0.0020)	(0.0026)	(0.0025)	(0.0028)	(0.0069)	(0.0030)
N	290107	233817	124135	109682	274145	222966	134778	88188	159671	130979	21922	109057
World History - Above Threshold	0.0014	0.0001	-0.0007	0.0007	-0.0004	-0.0001	0.0091*	-0.0124**	0.0059	0.0051	0.0075	0.0049
	(0.0018)	(0.0020)	(0.0027)	(0.0030)	(0.0027)	(0.0029)	(0.0040)	(0.0043)	(0.0044)	(0.0047)	(0.0110)	(0.0051)
N	73566	60790	30092	30698	71102	58793	33158	25635	48806	40563	5922	34641

Notes: Notes. + p<0.10, * p<0.05, ** p<0.01. All students in the sample first attended a four-year college within 180 days of high school graduation. Results based on local linear regressions with triangular kernels of bandwidth 10 that include fixed effects for AP exam-year and high school graduation year. Other variables include the Distance from the threshold and the interaction of Distance and Above Threshold. Regressions use heteroskedasticity-consistent standard errors.

Appendix Table 4: Effect of Attaining Higher AP Exam Scores on Majoring in AP Exam Subject - Specification Robustness Tests

Kernel	Tri	Rect	Rect	Tri	Rect	Rect	Tri	Rect	Rect	Tri	Rect	Rect	Tri	Rect	Rect	Tri	Rect	Rect
Functional Form	Linear	Linear	Quad	Linear	Linear	Quad	Linear	Linear	Quad	Linear	Linear	Quad	Linear	Linear	Quad	Linear	Linear	Quad
Bandwidth	5	5	5	5	5	5	10	10	10	10	10	10	15	15	15	15	15	15
Individual Controls	N	N	N	Y	Y	Y	N	N	N	Y	Y	Y	N	N	N	Y	Y	Y
1/2 Threshold	-0.0012	-0.0004	-0.0024+	-0.0012	-0.0004	-0.0025+	-0.0003	-0.0000	-0.0007	-0.0003	-0.0000	-0.0007	0.0002	0.0010+	-0.0009	0.0002	0.0009+	-0.0009
	(0.0010)	(0.0009)	(0.0013)	(0.0010)	(0.0009)	(0.0013)	(0.0007)	(0.0006)	(0.0010)	(0.0007)	(0.0006)	(0.0010)	(0.0006)	(0.0005)	(0.0008)	(0.0006)	(0.0005)	(0.0008)
2/3 Threshold	0.0020*	0.0017*	0.0024*	0.0020*	0.0017*	0.0024*	0.0018**	0.0023***	0.0011	0.0019**	0.0023***	0.0011	0.0024***	0.0030***	0.0014*	0.0024***	0.0030***	0.0014*
	(0.0009)	(0.0008)	(0.0012)	(0.0009)	(0.0008)	(0.0012)	(0.0006)	(0.0006)	(0.0008)	(0.0006)	(0.0006)	(0.0008)	(0.0005)	(0.0005)	(0.0007)	(0.0005)	(0.0005)	(0.0007)
3/4 Threshold	0.0035***	0.0037***	0.0034*	0.0036***	0.0037***	0.0034*	0.0038***	0.0037***	0.0039***	0.0038***	0.0037***	0.0040***	0.0040***	0.0049***	0.0026**	0.0040***	0.0049***	0.0026**
	(0.0010)	(0.0009)	(0.0014)	(0.0010)	(0.0009)	(0.0014)	(0.0007)	(0.0007)	(0.0010)	(0.0007)	(0.0007)	(0.0010)	(0.0006)	(0.0006)	(0.0008)	(0.0006)	(0.0006)	(0.0008)
4/5 Threshold	0.0079***	0.0065***	0.0101***	0.0079***	0.0066***	0.0101***	0.0064***	0.0063***	0.0067***	0.0065***	0.0064***	0.0068***	0.0069***	0.0071***	0.0068***	0.0069***	0.0071***	0.0068***
	(0.0015)	(0.0014)	(0.0020)	(0.0015)	(0.0014)	(0.0020)	(0.0011)	(0.0010)	(0.0015)	(0.0011)	(0.0010)	(0.0015)	(0.0009)	(0.0008)	(0.0012)	(0.0009)	(0.0008)	(0.0012)

Notes. + p<0.10, * p<0.05, ** p<0.01, *** p<0.001. All students in the sample first attended a four-year college within 180 days of high school graduation. An observation is a student AP exam. Results based on local linear regressions with fixed effects for AP exam-year and high school graduation year. Other variables include the Distance from the threshold and the interaction of Distance and Above Threshold. Standard errors clustered by individual.

Appendix Table 5: Effect of Attaining Higher AP Exam Scores on Majoring in AP Exam Subject - Subsample Robustness Tests

	1/2 Threshold	2/3 Threshold	3/4 Threshold	4/5 Threshold
		2005-2007 Cohorts		
Above Threshold	-0.0011	0.0036***	0.0041***	0.0079***
	(0.0011)	(0.0009)	(0.0011)	(0.0016)
	725515	1203950	1241365	822227
		Excluding Manual CIP Codes		
Above Threshold	-0.0003	0.0010+	0.0037***	0.0033***
	(0.0006)	(0.0006)	(0.0006)	(0.0009)
	1367893	2200966	2277760	1547630
		Removed Double Majors		
Above Threshold	0.0001	0.0015*	0.0031***	0.0059***
	(0.0007)	(0.0006)	(0.0007)	(0.0010)
	1458932	2347437	2411761	1619220

Notes. + $p<0.10$, * $p<0.05$, ** $p<0.01$, *** $p<0.001$. All students in the sample first attended a four-year college within 180 days of high school graduation. An observation is a student AP exam. Results based on local linear regressions with triangular kernels of bandwidth 10 that include fixed effects for AP exam-year and high school graduation year. Other variables include the Distance from the threshold and the interaction of Distance and Above Threshold. Standard errors clustered by individual.

Appendix Table 6: Effect of Attaining Higher AP Exam Scores on Major, Heaping Robustness Checks

Threshold:	Outcome = Majored in Same Subject as AP Exam				Outcome = Majored in Same Subject as AP Exam			
	1/2	2/3	3/4	4/5	1/2	2/3	3/4	4/5
Modification:	Removed Observations Within 1 Point of Threshold				Removed Heaps			
	Full Sample				*Full Sample*			
Above Threshold	0.0007	0.0012	0.0039**	0.0055**	-0.0007	0.0019**	0.0034**	0.0077**
	(0.0009)	(0.0008)	(0.0009)	(0.0014)	(0.0008)	(0.0007)	(0.0008)	(0.0012)
Mean at Cutoff	4.2%	5.4%	8.1%	12.2%	4.2%	5.4%	8.1%	12.2%
N	1326522	2138171	2221518	1509418	1261633	2020218	2034736	1394120
	Only AP STEM Exams				*Only AP STEM Exams*			
Above Threshold	0.0008	0.0008	0.0012	0.0072**	-0.0011	0.0016	0.0019	0.0069**
	(0.0015)	(0.0016)	(0.0019)	(0.0024)	(0.0013)	(0.0013)	(0.0015)	(0.0020)
Mean at Cutoff	5.4%	7.5%	10.8%	15.7%	5.4%	7.5%	10.8%	15.7%
N	561622	690701	721249	571855	550989	704004	739665	574712
	Only AP Non-STEM Exams				*Only AP Non-STEM Exams*			
Above Threshold	0.0005	0.0014	0.0052**	0.0046**	-0.0004	0.0021**	0.0043**	0.0081**
	(0.0011)	(0.0009)	(0.0010)	(0.0016)	(0.0009)	(0.0008)	(0.0009)	(0.0014)
Mean at Cutoff	3.3%	4.4%	6.8%	10.0%	3.3%	4.4%	6.8%	10.0%
N	764900	1447470	1500269	937563	710644	1316214	1295071	819408

Notes. + p<0.10, * p<0.05, ** p<0.01. All students in the sample first attended a four-year college within 180 days of high school graduation. An observation is a student AP exam. Results based on local linear regressions with triangular kernels of bandwidth 10 that include fixed effects for AP exam-year and high school graduation year. Other variables include the Distance from the threshold and the interaction of Distance and Above Threshold. Standard errors clustered by individual. Means at cutoff are based on all students within one point below the designated threshold.

Appendix Table 7: Potential Mechanisms for Impacts of Higher AP Exam Scores on College Major, Year of Exam

|	(1)	(2)	(3)		(4)	(5)	(6)
	College Choice (Senior exams)				College Choice (Non-Senior exams)		
	College's Average SAT	Barrons Most, Highly, or Very Competitive	Major in Subject; College FE		College's Average SAT	Barrons Most, Highly, or Very Competitive	Major in Subject; College FE
	1/2 Threshold				*1/2 Threshold*		
Above Threshold	0.1019	0.0024	-0.0001		1.0225	0.0031	-0.0006
	(0.5056)	(0.0022)	(0.0010)		(0.6491)	(0.0029)	(0.0009)
Mean At Cutoff	1131	56.2%	2.3%		1131	56.2%	2.3%
N	900422	928304	928304		527128	545308	545308
	2/3 Threshold				*2/3 Threshold*		
Above Threshold	0.1525	-0.0003	0.0013		0.8923+	0.0028	0.0027**
	(0.3988)	(0.0016)	(0.0009)		(0.5055)	(0.0021)	(0.0008)
Mean At Cutoff	1172	69.1%	3.8%		1172	69.1%	3.8%
N	1439781	1475603	1475603		885750	908241	908241
	3/4 Threshold				*3/4 Threshold*		
Above Threshold	0.1121	0.0006	0.0033**		1.4251**	0.0059**	0.0046**
	(0.4033)	(0.0014)	(0.0010)		(0.5324)	(0.0018)	(0.0010)
Mean At Cutoff	1218	79.8%	6.2%		1218	79.8%	6.2%
N	1521783	1553288	1553288		899849	918890	918890
	4/5 Threshold				*4/5 Threshold*		
Above Threshold	0.7655	0.0003	0.0042**		1.4583*	0.0013	0.0105**
	(0.5088)	(0.0015)	(0.0014)		(0.6827)	(0.0019)	(0.0016)
Mean At Cutoff	1269	87.1%	10.3%		1269	87.1%	10.3%
N	1039529	1057689	1057689		611019	621473	621473

Notes. + p<0.10, * p<0.05, ** p<0.01. All students in the sample first attended a four-year college within 180 days of high school graduation. An observation is a student AP exam. Results based on local linear regressions with triangular kernels of bandwidth 10 that include fixed effects for AP exam-year and high school graduation year. Other variables include the Distance from the threshold and the interaction of Distance and Above Threshold. Standard errors clustered by individual.

Appendix Table 8: Effect of Attaining Higher AP Exam Scores on Major - Credit or Signal Robustness Test Using Alternative Source of Credit Policies

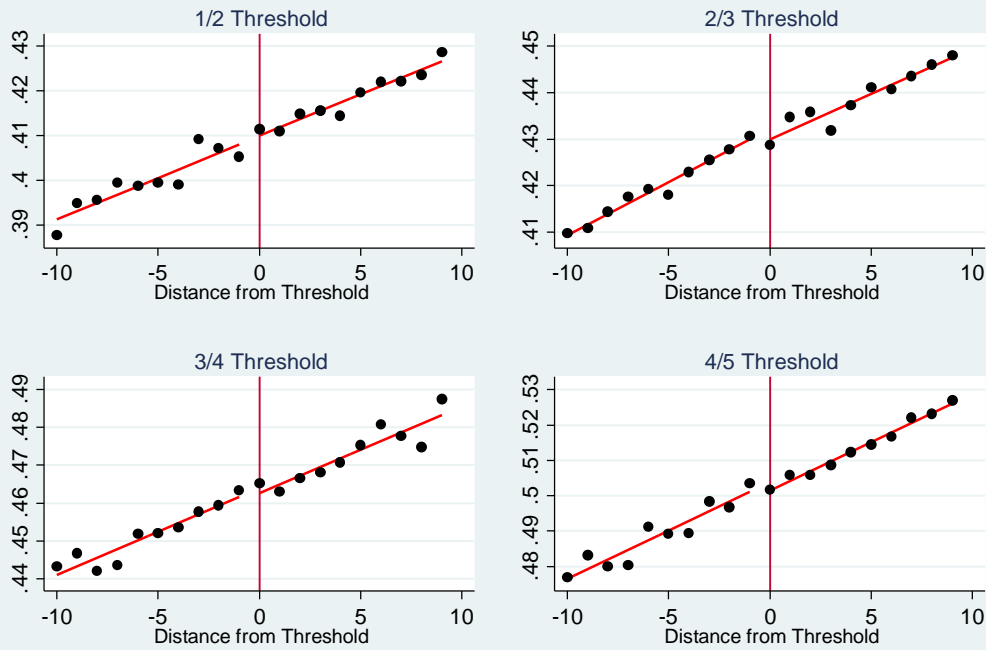|	Full Sample			STEM AP Exams			Non-STEM AP Exams		
	All	With AP Policy	Without AP Policy	All	With AP Policy	Without AP Policy	All	With AP Policy	Without AP Policy
	2/3 Threshold								
Above Threshold	0.0021**	0.0025**	0.0011	0.0010	0.0016	-0.0000	0.0025**	0.0030**	0.0016
	(0.0008)	(0.0010)	(0.0014)	(0.0017)	(0.0020)	(0.0031)	(0.0009)	(0.0010)	(0.0015)
Mean At Threshold	5.6%	5.5%	5.7%	8.0%	8.2%	7.8%	4.5%	4.2%	4.8%
N	1488769	981909	506860	465593	322190	143403	1023176	659719	363457
	3/4 Threshold								
Above Threshold	0.0032**	0.0042**	0.0019	0.0017	0.0035	-0.0001	0.0039**	0.0046**	0.0029+
	(0.0009)	(0.0012)	(0.0014)	(0.0019)	(0.0027)	(0.0027)	(0.0010)	(0.0013)	(0.0016)
Mean At Threshold	8.2%	8.1%	8.2%	11.4%	11.9%	10.7%	6.7%	6.6%	6.9%
N	1540503	834237	706266	485698	248731	236967	1054805	585506	469299
	4/5 Threshold								
Above Threshold	0.0073**	0.0044	0.0079**	0.0101**	0.0069	0.0111**	0.0058**	0.0026	0.0064**
	(0.0014)	(0.0032)	(0.0015)	(0.0025)	(0.0053)	(0.0029)	(0.0016)	(0.0039)	(0.0017)
Mean At Threshold	12.5%	12.1%	12.6%	16.5%	15.2%	16.8%	10.0%	9.5%	10.1%
N	1037245	178498	858747	383588	78861	304727	653657	99637	554020

Notes. + p<0.10, * p<0.05, ** p<0.01. All students in the sample first attended a four-year college within 180 days of high school graduation. Policy sample includes 500 colleges where credit policies are collected. Colleges are defined as "with a policy" if there is any alteration in the units or courses offered at the threshold. An observation is a student AP exam. Results based on local linear regressions with triangular kernels of bandwidth 10 that include fixed effects for AP exam-year and high school graduation year. Other variables include the Distance from the threshold and the interaction of Distance and Above Threshold. Standard errors clustered by individual. Means at cutoff are based on all students within one point below the designated threshold.

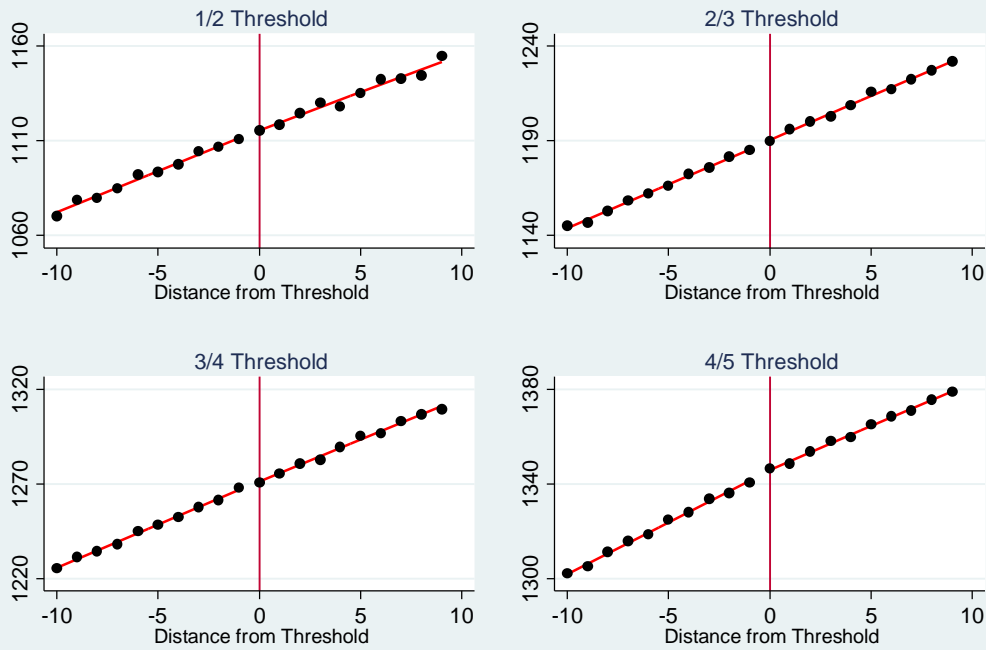**Appendix Figure 1. Covariate Balance at Integer Score Thresholds**
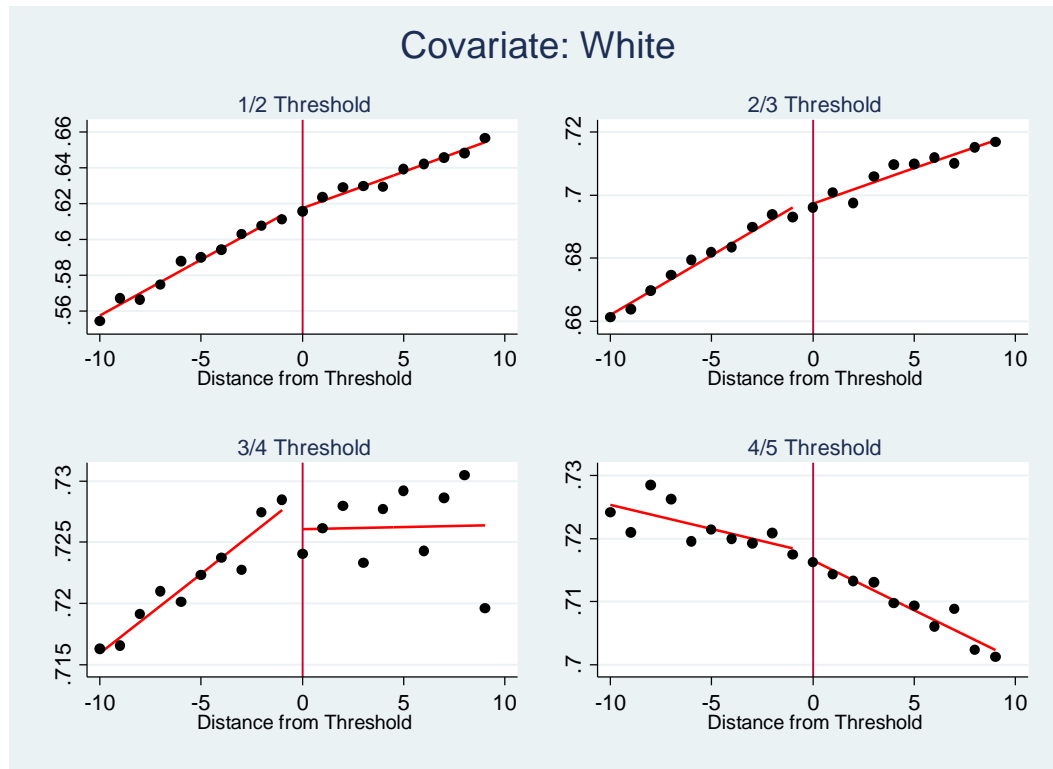
Notes. Figure includes all student-exam observations within 10 points of the integer AP score threshold for the nineteen AP exams listed in Table 2 for the years 2004 through 2009 graduating high school cohorts. Sample sizes for the 1/2, 2/3, 3/4, and 4/5 thresholds are 1,473,612, 2,383,844, 2,472,178, and 1,679,162 observations, respectively.

Covariate: Male

Notes. Figure includes all student-exam observations within 10 points of the integer AP score threshold for the nineteen AP exams listed in Table 2 for the years 2004 through 2009 graduating high school cohorts. Sample sizes for the 1/2, 2/3, 3/4, and 4/5 thresholds are 1,473,612, 2,383,844, 2,472,178, and 1,679,162 observations, respectively.

Notes. Figure includes all student-exam observations within 10 points of the integer AP score threshold for the nineteen AP exams listed in Table 2 for the years 2004 through 2009 graduating high school cohorts. Sample sizes for the 1/2, 2/3, 3/4, and 4/5 thresholds are 1,195,599, 1,972,409, 2,113,990, and 1,485,920 observations, respectively.