



HARVARD Kennedy School
JOHN F. KENNEDY SCHOOL OF GOVERNMENT

Shifting College Majors in Response to Advanced Placement Exam Scores

Faculty Research Working Paper Series

Christopher Avery
Harvard Kennedy School

Oded Gurantz
Stanford University

Michael Hurwitz
College Board

Jonathan Smith
College Board

December 2016

RWP16-058

Visit the **HKS Faculty Research Working Paper Series** at:
<https://research.hks.harvard.edu/publications/workingpapers/Index.aspx>

The views expressed in the **HKS Faculty Research Working Paper Series** are those of the author(s) and do not necessarily reflect those of the John F. Kennedy School of Government or of Harvard University. Faculty Research Working Papers have not undergone formal review and approval. Such papers are included in this series to elicit feedback and to encourage debate on important public policy challenges. Copyright belongs to the author(s). Papers may be downloaded for personal use only.

Shifting College Majors in Response to Advanced Placement Exam Scores*

Christopher Avery, Harvard University
Oded Gurantz, Stanford University
Michael Hurwitz, College Board
Jonathan Smith, College Board

October 2016

Abstract

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.

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, and Zimmerman, 2013; Kirkebøen, Leuven, and 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 majors in specific fields, or because they enter college with inadequate academic preparation for a preferred major (Betts, 1996; Oreopoulos and Dunn, 2013; R. Stinebrickner and Stinebrickner, 2012; Wiswall and 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

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)

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

While 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 (2015) 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

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 complete 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 time to degree completion (Smith, Hurwitz, and Avery, 2015), 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 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 analysis compares two essentially identical students who have both elected to take an AP, but does not 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 score barely received them a 5 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 difference in integer score.

Along with our above primary result, we also find 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 5 is attenuated 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., 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

In order to receive credit, course exemption and placement, students must submit AP scores to the institutions at which they enroll. There exists enormous variation in how AP exam scores are treated, both across postsecondary institutions and across exams within postsecondary

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.

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, Mattern, 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 strategy.

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

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 (Mattern, Marini, & Shaw, 2013), and college completion (Dougherty, Mellor, & Jian, 2006; Hargrove, Godin, & Dodd, 2008; 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).

exam taking have relied on a selection on observables research design (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, forthcoming) 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, 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,

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).

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,

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 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

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.

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.

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

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

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.

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>

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 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

¹⁷ Note that we use the word “credit” but in some instances it is only placement with no credit.

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

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 had a parent who attended at least some college. On average, students earned an 1176 on the SAT, took almost 3 AP exams, and scored an average of 2.7 on the exams. As shown in Smith, Hurwitz and Avery (2016), student demographics vary by AP exam.

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

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

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, 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

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

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.

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 (forthcoming). Each student i on AP exam j receives a continuous score C_{ij} . This continuous score maps into the scaled score, T_{ij} as follows²⁰:

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

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:

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

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

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.

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

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. Still, as reported in Section 5.1, we perform empirical tests to discount these threats, verifying that the density of raw scores is continuous in the vicinity of the thresholds. We also run covariate balancing tests with similar specifications to

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).

equation (1), but using a covariate as the outcome, once again finding no indication of manipulation of raw scores near scaled score thresholds.

5. Main Results

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 52 separate covariate balancing tests shown in this table, 7 yield statistically significant (at the 0.05 level) parameter estimates, and these 7 precisely estimated differences are extremely small in magnitude.²³

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

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 The covariates are highly correlated with one another, which contributes to the number that are not balanced. Running a seemingly unrelated regression to jointly test for balance shows similarly 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.

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 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). Appendix Table 7 reports the results of analyses using different rules for inclusion and exclusion of students from the sample, restricting analysis in turn 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 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.

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 graduation; 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 strategic college enrollment results from the receipt of a higher AP score despite similar performance to students with a lower AP score. The first two columns show little evidence of such trivial differences in student performance shifting college choice, with small and often insignificant effects on school quality, as measured by average SAT or Barron's ranking.²⁴ 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. 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.

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 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.

²⁴ 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., forthcoming) studies this possibility in more detail and similarly finds no evidence that AP scores influence the choice of colleges by students.

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 (forthcoming).²⁵ 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 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

²⁵ 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 (forthcoming) - strong effects on the 2/3 and 3/4 thresholds, where college credit is often at stake.

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 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. 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.²⁶

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 2015.²⁷ Using the approximately 70% of exams that agree perfectly between the sources, estimates are largely unchanged and can be found in Appendix Table 6.

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

²⁶ 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.

²⁷ 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.

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. 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.²⁸ 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 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

²⁸ This is somewhat rare but the most common exams include AP Environmental Science and AP World History.

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, 2011). 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.²⁹

²⁹ 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

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.

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

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.

effects throughout the rest of 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.³⁰

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 our previous study, 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

³⁰ 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.

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 AP score on a STEM AP exam, while having similar exam performance to students who received the adjacent, lower AP exam integer score, 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 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. We find that this is predominately a behavioral response and is strongest when the students have few other competing signals of academic

excellence on AP exams. This result is consistent with recent research by Papay, Willett, and Murnane (forthcoming), who find that students are more likely to attend college when they have a positive label that summarizes their score performance on a standardized test, as well as with the broader literature on the effects of positive signals of ability.³¹

The impacts on student major found in this research, in combination with the decrease in time to degree found in our previous study, show that that AP scores affect the postsecondary choices and outcomes of different students in different ways. Our 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 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

³¹ See for example, Diamond and Perrson (2016), Foote, Schulkind and Shapiro (2015), Jackson (2015), Kosfeld & Neckermann (2011), Fryer, Levitt & List (2008) and Steele and Aronson (1995).

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.

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.

References

- Altonji, J. G., Arcidiacono, P., & Maurel, A. (2015). The Analysis of Field Choice in College and Graduate School: Determinants and Wage Effects *Handbook of the Economics of Education Volume 5, Chapter 7*.
- Arcidiacono, P., Hotz, V. J., & Kang, S. (2012). Modeling college major choices using elicited measures of expectations and counterfactuals. *Journal of Econometrics*, 166(1), 3-16.
doi:<http://dx.doi.org/10.1016/j.jeconom.2011.06.002>
- Beffy, M., Fougère, D., & Maurel, A. (2011). Choosing the Field of Study in Postsecondary Education: Do Expected Earnings Matter? *Review of Economics and Statistics*, 94(1), 334-347.
doi:10.1162/REST_a_00212
- Betts, J. R. (1996). What do students know about wages? Evidence from a survey of undergraduates. *Journal of Human Resources*, 31(1), 27-56.
- Calonico, S., Cattaneo, M. D., & Titiunik, R. (2014). Robust Data-Driven Inference in the Regression-Discontinuity Design. *Stata Journal*, 14(4), 909-946.

- Carnevale, A., Cheah, B., & Hanson, A. (2015). *The Economic Value of College Majors*. Retrieved from Washington DC: <https://cew.georgetown.edu/report/whats-it-worth-the-economic-value-of-college-majors/>
- Castleman, B. L., Long, B. T., & Mabel, Z. A. (2015). *Financial barriers to studying STEM in college: Causal effect estimates of need-based grants on the pursuit and completion of courses and degrees in STEM fields*.
- Chajewski, M., Mattern, K., & Shaw, E. J. (2011). Examining the role of Advanced Placement exam participation in 4-year college enrollment. *Education Measurement: Issues and Practice*, 30, 16-27.
- Denning, J. T., & Turley, P. (forthcoming). Was That SMART? Institutional Financial Incentives and Field of Study. *Journal of Human Resources*.
- Diamond, R. and P. Perrson (2016). "The Long-Term Consequences of Teacher Discretion in Grading of High-Stakes Tests," SIEPER Discussion Paper No. 16-003.
- Dodd, B. G., Fitzpatrick, S. J., De Ayala, R. J., & Jennings, J. A. (2002). *An investigation of the validity of AP grades of 3 and a comparison of AP and non-AP student groups (College Board Research Report No. 2002-9)*. Retrieved from New York, NY: http://apcentral.collegeboard.com/apc/public/repository/ap05_research_validit_49428.pdf
- Dougherty, C., Mellor, L., & Jian, S. (2006). The relationship between Advanced Placement and college graduation. *Education*, 501, 1-35.
- Dynarski, S. M., Hemelt, S. W., & Hyman, J. M. (2015). The missing manual: Using National Student Clearinghouse data to track postsecondary outcomes. *Educational Evaluation and Policy Analysis*, 37, 535-795.
- Evans, B. (2013). How do college students use Advanced Placement credit?
- Evans, B. (2015). *SMART Money: Do Financial Incentives Encourage College Students to Study Science?*
- Foote, A., Schulkind, L., & Shapiro, T. M. (2015). Missed signals: The effect of ACT college-readiness measures on post-secondary decisions. *Economics of Education Review*, 46, 39-51.
- Frandsen, B. R. (2014). *Party Bias in Union Representation Elections: Testing for Manipulation in the Regression Discontinuity Design When the Running Variable is Discrete*.
- Fricke, H., Grogger, J., & Steinmayr, A. (2015). *Does exposure to economics bring new majors to the field? Evidence from a natural experiment (NBER Working Paper 21130)*. National Bureau of Economic Research. Cambridge, MA.
- Fryer, R. G., Jr., Levitt, S. D., & List, J. A. (2008). Exploring the Impact of Financial Incentives on Stereotype Threat: Evidence from a Pilot Study. *American Economic Review*, 98(2), 370-375. doi:doi: 10.1257/aer.98.2.370
- Goldin, C. (2015). *Gender and the Undergraduate Economics Major: Notes on the Undergraduate Economics Major at a Highly Selective Liberal Arts College*. Retrieved from Harvard University.
- Hargrove, L., Godin, D., & Dodd, B. (2008). *College outcomes comparisons by AP and non-AP high school experiences. Higher Education. (Research Rep. No. 2008-3)*. Retrieved from New York, NY: <https://research.collegeboard.org/sites/default/files/publications/2012/7/researchreport-2008-3-college-outcomes-ap-non-ap-high-school-experiences.pdf>
- Hastings, J. S., Neilson, C. A., & Zimmerman, S. D. (2013). *Are Some Degrees Worth More Than Others? Evidence from College Admission Cutoffs in Chile, NBER Working Paper No. 19241*. Retrieved from National Bureau of Economic Research:
- Imbens, G. W., & Kalyanaram, K. (2012). Optimal bandwidth choice for the regression discontinuity estimator. *Review of Economic Studies*, 142(2), 615-635.
- Jackson, K. (2010). A little now for a lot later: An evaluation of a Texas Advanced Placement incentive program. *Journal of Human Resources*, 45(3), 591-639.

- Jackson, J. S. (2015). Does an Early College Readiness Signal Discourage College Application and Enrollment? *Journal of Research on Educational Effectiveness*, 8(3), 380-399.
- Karp, M. M., Calcagno, J. C., Hughes, K. L., Jeong, D. W., & Bailey, T. (2007). *The postsecondary achievement of participants in dual enrollment: An analysis of student outcomes in two states*. Retrieved from St. Paul, MN: <http://ccrc.tc.columbia.edu/publications/dual-enrollment-student-outcomes.html>
- Keng, L., & Dodd, B. G. (2008). *A comparison of college performances of AP and non-AP student groups in 10 subject areas (College Board Research Report 2008-7)*. Retrieved from New York, NY: <http://research.collegeboard.org/publications/content/2012/05/comparison-college-performances-ap-and-non-ap-student-groups-10-subject>
- Kirkebøen, L., Leuven, E., & Mogstad, M. (forthcoming). Field of Study, Earnings, and Self-Selection. *Quarterly Journal of Economics*.
- Kosfeld, M., & Neckermann, S. (2011). Getting More Work for Nothing? Symbolic Awards and Worker Performance. *American Economic Journal: Microeconomics*, 3(3), 86-99.
- Long, M. C., Conger, D., & Iatarola, P. (2012). Effects of high school course-taking on secondary and postsecondary success. *American Educational Research Journal*, 49(2), 285-322.
- Long, M. C., Conger, D., & McGhee, R. J. (2014). *Evaluation of the Sustainability and Effectiveness of Inquiry-Based Advanced Placement Science Courses: Evidence from an In-Depth Formative Evaluation & Randomized Controlled Study*.
- Long, M. C., Goldhaber, D., & Huntington-Klein, N. (2015). Do Completed College Majors Respond to Changes in Wages? *Economics of Education Review*, 49, 1-14.
- Mattern, K., E. Shaw, & Ewing, M. (2011). *Advanced Placement Exam Participation: Is AP Exam Participation and Performance Related to Choice of College Major? (College Board Research Report 2011-6)*. Retrieved from New York, NY: <https://research.collegeboard.org/sites/default/files/publications/2012/7/researchreport-2011-6-ap-participation-performance-major-choice.pdf>
- Mattern, K. D., Marini, J. P., & Shaw, E. J. (2013). *Are AP students more likely to graduate from college on time (College Board Research Report 2013-5)*. Retrieved from New York, NY: <https://research.collegeboard.org/sites/default/files/publications/2014/1/research-report-2013-5-are-ap-students-more-likely-graduate-college.pdf>
- McCrary, J. (2008). Manipulation of the running variable in the regression discontinuity design: A density test. *Journal of Econometrics*, 142(2), 698-714.
- Morgan, S. L., Gelbgiser, D., & Weeden, K. A. (2013). Feeding the pipeline: Gender, occupational plans, and college major selection. *Social Science Research*, 42(4), 989-1005.
- Morgan, R., & Klaric, J. (2007). *AP students in college : An analysis of five-year academic careers (College Board Research Report 2007-4)*. Retrieved from New York, NY: <https://research.collegeboard.org/sites/default/files/publications/2012/7/researchreport-2007-4-ap-students-college-analysis-five-year-academic-careers.pdf>
- Murphy, D., & Dodd, B. G. (2009). *A Comparison of college performance of matched AP and non-AP student groups (College Board Research Report No. 2009-6)*. Retrieved from New York, NY: <https://research.collegeboard.org/sites/default/files/publications/2012/7/researchreport-2009-6-comparision-college-performance-matched-ap-non-ap-student-groups.pdf>
- Oreopoulos, P., & Dunn, R. (2013). Information and College Access: Evidence from a Randomized Field Experiment. *The Scandinavian Journal of Economics*, 115(1), 3-26.
- Ost, B. (2010). The Role of Peers and Grades in Determining Major Persistence in the Sciences. *Economics of Education Review*, 29(6), 923-934.

- Papay, J. P., Willett, J. B., & Murnane, R. J. (forthcoming). How performance information affects human-capital investment decisions: The impact of test-score labels on educational outcomes. *Journal of Human Resources*.
- Patterson, B. F., & Ewing, M. (2013). *Validating the use of AP exam scores for college course placement (Research Rep. No. 2013-2)*. Retrieved from New York, NY: <https://research.collegeboard.org/sites/default/files/publications/2013/7/researchreport-2013-2-validating-AP-exam-scores-college-course-placement.pdf>
- Rogers, T., & Feller, A. (2016). Discouraged by Peer Excellence: Exposure to Exemplary Peer Performance Causes Quitting. *Psychological Science*, 27(3), 365-374. doi:10.1177/0956797615623770
- Shu, P. (2013). *Are the 'Best and Brightest' Going into Finance? Career Choice and Skill Development of MIT Graduates*.
- Smith, J., Hurwitz, M., & Avery, C. (forthcoming). Giving Credit Where it is Due: Advanced Placement Exam Scores and College Outcomes. *Journal of Labor Economics*.
- Stange, K. (2015). Differential Pricing in Undergraduate Education: Effects on Degree Production by Field. *Journal of Policy Analysis and Management*, 34(1), 107-135.
- Steele, C. M., & Aronson, J. (1995). Stereotype threat and the intellectual test performance of African Americans. *Journal of Personality and Social Psychology*, 69(5), 797-811. doi:<http://dx.doi.org/10.1037/0022-3514.69.5.797>
- Stinebrickner, R., & Stinebrickner, T. R. (2012). Learning about Academic Ability and the College Dropout Decision. *Journal of Labor Economics*, 30(4), 707-748.
- Stinebrickner, T., & Stinebrickner, R. (2013). A Major in Science? Initial Beliefs and Final Outcomes for College Major and Dropout. *Review of Economic Studies*, 81(1), 426-472.
- Tai, R. H., Liu, C. Q., Almarode, J. T., & Fan, X. (2010). Advanced placement course enrollment and long-range educational outcomes. In P. M Sadler, G. Sonnert, R. H. Tai, & K. Klopfenstein (Eds.), *AP: A critical examination of the Advance Placement program* (pp. 109-118). Cambridge, MA: Harvard Education Press.
- Theokas, C., & Saaris, R. (2013). *Finding America's Missing AP and IB Students*. Retrieved from <http://edtrust.org/resource/finding-americas-missing-ap-and-ib-students>
- Turner, S., & Bowen, W. (1999). Choice of Major: The Changing (Unchanging) Gender Gap. *Industrial and Labor Relations Review*, 59(2), 289-313.
- Walton, G. M., & Cohen, G. L. (2011). A Brief Social-Belonging Intervention Improves Academic and Health Outcomes of Minority Students. *Science*, 331(6023), 1447-1451. doi:10.1126/science.1198364
- Wiswall, M., & Zafar, B. (2015a). Determinants of College Major Choice: Identification using an Information Experiment. *Review of Economic Studies*, 82, 791-824.
- Wiswall, M., & Zafar, B. (2015b). How Do College Students Respond to Public Information about Earnings? *Journal of Human Capital*, 9(2), 117-169.
- Zafar, B. (2011). How do College Students Form Expectations? *Journal of Labor Economics*, 29(2), 301-348.

Table 1: Summary Statistics

	<u>Mean</u>	<u>Std. Dev.</u>	<u>Min</u>	<u>Max</u>
<i>Student Demographics</i>				
White	69.3%	0.46	0	1
Asian	10.7%	0.31	0	1
Black	6.8%	0.25	0	1
Latino/Hispanic	9.2%	0.29	0	1
Male	43.2%	0.50	0	1
Parental Education (0: HS; 1: Some college)	49.6%	0.50	0	1
Income Less Than \$50k	13.0%	0.34	0	1
Income \$50k-\$100k	19.1%	0.39	0	1
Income Great Than \$100k	18.0%	0.38	0	1
<i>Exam Scores</i>				
SAT	1176	173	400	1600
Number of AP Exams Taken	2.8	2.0	1	18
Number of STEM AP Exams Taken	1.0	1.0	0	8
Average AP Exam Score	2.7	1.1	1	5
Average Raw Score	59.2	28.6	0	179.3
N	3,148,598			

Notes: Summary statistics are calculated using de-duplicated, individual-level data. Full sample includes all students who took one of the 19 most taken AP exams. Some students do not provide demographics.

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

AP Score	Major in Core Subject					Major in STEM				
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>
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 code by AP Exam Subject, Student Scoring 3 or Higher

AP Exam	College Major							
	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%	<u>18.9%</u>	2.7%	7.8%
Calculus AB	2.0%	1.5%	7.9%	3.6%	2.1%	9.7%	3.1%	<u>13.4%</u>
Calculus BC	1.5%	1.4%	9.1%	3.0%	2.1%	11.4%	4.7%	<u>21.7%</u>
Chemistry	1.5%	1.4%	7.8%	3.1%	2.0%	14.2%	<u>6.7%</u>	18.2%
English Language & Comp.	<u>4.8%</u>	2.5%	10.0%	4.9%	2.8%	7.4%	1.9%	6.6%
English Literature & Comp.	<u>5.4%</u>	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%	<u>7.6%</u>	1.9%	5.7%
European History	4.5%	<u>5.7%</u>	13.5%	4.0%	3.1%	7.0%	2.1%	6.5%
French Language and Culture	4.8%	3.1%	14.3%	4.8%	<u>7.9%</u>	8.3%	2.5%	6.5%
Macroeconomics	2.3%	2.4%	<u>13.4%</u>	3.3%	2.0%	8.2%	2.4%	11.7%
Microeconomics	2.1%	2.2%	<u>14.3%</u>	3.1%	2.0%	7.7%	2.4%	11.8%
Physics B	1.6%	1.4%	7.9%	2.6%	1.7%	9.4%	<u>5.2%</u>	20.4%
Physics C: Mechanics	1.1%	1.0%	7.3%	1.7%	1.3%	7.6%	<u>6.2%</u>	29.9%
Psychology	3.2%	1.9%	8.5%	<u>9.2%</u>	2.2%	7.1%	1.4%	4.9%
Spanish Language	2.9%	1.9%	11.0%	5.0%	<u>6.3%</u>	6.9%	1.6%	5.7%
Statistics	2.2%	1.8%	10.0%	4.4%	2.0%	7.8%	2.3%	<u>11.8%</u>
US Gov and Politics	3.5%	3.7%	<u>13.5%</u>	3.9%	2.4%	7.6%	2.2%	8.2%
US History	4.0%	<u>4.0%</u>	12.2%	4.3%	2.8%	7.9%	2.2%	7.8%
World History	3.6%	<u>3.7%</u>	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

	<u>Male</u>	<u>White</u>	<u>Asian</u>	<u>Black</u>	<u>Hispanic</u>	<u>Parent Educ: Less Than HS</u>	<u>Parent Educ: HS graduate</u>	<u>Parent Educ: BA or higher</u>	<u>Income < \$50k</u>	<u>Income \$50k- \$100k</u>	<u>Income > \$100k</u>	<u>Took SAT</u>	<u>SAT Score</u>
<i>1/2 Threshold</i>													
Above Threshold	0.0017 (0.0018)	-0.0009 (0.0017)	0.0015 (0.0012)	0.0002 (0.0010)	-0.0005 (0.0012)	-0.0004 (0.0011)	-0.0001 (0.0013)	0.0017 (0.0018)	0.0002 (0.0013)	-0.0014 (0.0014)	-0.0004 (0.0013)	0.0004 (0.0014)	0.1553 (0.5107)
N	1473612	1473612	1473612	1473612	1473612	1473612	1473612	1473612	1473612	1473612	1473612	1473612	1195599
<i>2/3 Threshold</i>													
Above Threshold	-0.0010 (0.0014)	-0.0020 (0.0013)	0.0013 (0.0009)	-0.0005 (0.0006)	0.0015+ (0.0008)	0.0000 (0.0007)	0.0028** (0.0010)	-0.0021 (0.0014)	0.0011 (0.0009)	0.0014 (0.0011)	-0.0022* (0.0011)	0.0015 (0.0011)	0.7791* (0.3811)
N	2383844	2383844	2383844	2383844	2383844	2383844	2383844	2383844	2383844	2383844	2383844	2383844	1972409
<i>3/4 Threshold</i>													
Above Threshold	-0.0034* (0.0014)	-0.0035** (0.0012)	0.0017+ (0.0010)	-0.0008+ (0.0005)	0.0012+ (0.0007)	-0.0007 (0.0006)	0.0014 (0.0009)	0.0010 (0.0013)	-0.0006 (0.0008)	-0.0003 (0.0011)	0.0022+ (0.0012)	0.0009 (0.0010)	-0.9662** (0.3649)
N	2472178	2472178	2472178	2472178	2472178	2472178	2472178	2472178	2472178	2472178	2472178	2472178	2113990
<i>4/5 Threshold</i>													
Above Threshold	-0.0016 (0.0016)	-0.0011 (0.0015)	0.0032* (0.0012)	-0.0004 (0.0005)	-0.0012 (0.0007)	-0.0001 (0.0006)	-0.0002 (0.0009)	0.0020 (0.0016)	-0.0001 (0.0009)	0.0016 (0.0013)	-0.0003 (0.0015)	0.0020+ (0.0011)	0.6089 (0.4268)
N	1679162	1679162	1679162	1679162	1679162	1679162	1679162	1679162	1679162	1679162	1679162	1679162	1485920

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			
	<u>1/2</u>	<u>2/3</u>	<u>3/4</u>	<u>4/5</u>
	<i>Full Sample</i>			
Above Threshold	-0.0003 (0.0007)	0.0018** (0.0006)	0.0038** (0.0007)	0.0064** (0.0011)
Mean at Cutoff	4.2%	5.4%	8.1%	12.2%
N	1473612	2383844	2472178	1679162
	<i>Only AP STEM Exams</i>			
Above Threshold	-0.0006 (0.0012)	0.0011 (0.0013)	0.0022 (0.0015)	0.0053** (0.0019)
Mean at Cutoff	5.4%	7.5%	10.8%	15.7%
N	626287	770240	803432	635615
	<i>Only AP Non-STEM Exams</i>			
Above Threshold	-0.0001 (0.0008)	0.0022** (0.0007)	0.0045** (0.0008)	0.0073** (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
	<i>1/2 Threshold</i>						
Above Threshold	0.4266 (0.3993)	0.0026 (0.0017)	-0.0001 (0.0010)	-0.0004 (0.0007)	--	-0.0037+ (0.0021)	-0.0000 (0.0010)
Mean At Cutoff	1140	59.0%	5.3%	4.2%	--	75.0%	6.2%
N	1427550	1473612	928304	1473612	--	831234	982436
	<i>2/3 Threshold</i>						
Above Threshold	0.4230 (0.3131)	0.0009 (0.0013)	0.0013 (0.0009)	0.0020** (0.0006)	0.0001 (0.0015)	0.0027+ (0.0014)	0.0022** (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
	<i>3/4 Threshold</i>						
Above Threshold	0.6023+ (0.3219)	0.0026* (0.0011)	0.0033** (0.0010)	0.0035** (0.0007)	-0.0031* (0.0015)	0.0029* (0.0013)	0.0044** (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
	<i>4/5 Threshold</i>						
Above Threshold	0.9922* (0.4087)	0.0006 (0.0012)	0.0042** (0.0014)	0.0068** (0.0011)	0.0019 (0.0014)	0.0032* (0.0014)	0.0076** (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
<i>2/3 Threshold</i>									
Above Threshold	0.0021** (0.0007)	0.0028** (0.0009)	0.0012 (0.0011)	0.0014 (0.0014)	0.0030 (0.0018)	-0.0012 (0.0023)	0.0025** (0.0008)	0.0026** (0.0010)	0.0022+ (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
<i>3/4 Threshold</i>									
Above Threshold	0.0036** (0.0008)	0.0042** (0.0011)	0.0028* (0.0012)	0.0019 (0.0016)	0.0027 (0.0022)	0.0010 (0.0023)	0.0044** (0.0009)	0.0049** (0.0012)	0.0037** (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
<i>4/5 Threshold</i>									
Above Threshold	0.0068** (0.0012)	0.0053* (0.0026)	0.0072** (0.0013)	0.0069** (0.0021)	0.0024 (0.0041)	0.0085** (0.0024)	0.0069** (0.0014)	0.0080* (0.0032)	0.0066** (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

<u>Threshold:</u>	<u>Sample</u>		<u>2/3</u>	<u>3/4</u>	<u>4/5</u>
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

Threshold:	All AP Exams			STEM AP Exams			Non-STEM AP Exams		
	2/3	3/4	4/5	2/3	3/4	4/5	2/3	3/4	4/5
Male	0.0023* (0.0010)	0.0033** (0.0011)	0.0067** (0.0015)	0.0022 (0.0020)	0.0028 (0.0021)	0.0055* (0.0027)	0.0022* (0.0010)	0.0037** (0.0012)	0.0078** (0.0018)
N	1024316	1140410	836630	369339	418061	359260	654977	722349	477370
Female	0.0016* (0.0008)	0.0040** (0.0010)	0.0062** (0.0015)	0.0001 (0.0016)	0.0016 (0.0019)	0.0050+ (0.0027)	0.0022* (0.0009)	0.0050** (0.0011)	0.0068** (0.0017)
N	1359528	1331768	842532	400901	385371	276355	958627	946397	566177
White	0.0020** (0.0007)	0.0040** (0.0009)	0.0075** (0.0013)	0.0012 (0.0015)	0.0026 (0.0017)	0.0051* (0.0023)	0.0024** (0.0008)	0.0047** (0.0010)	0.0091** (0.0015)
N	1656577	1789749	1204179	538372	573035	449550	1118205	1216714	754629
Asian	0.0023 (0.0017)	0.0028 (0.0019)	0.0029 (0.0025)	0.0000 (0.0034)	0.0016 (0.0037)	0.0040 (0.0044)	0.0037* (0.0018)	0.0036+ (0.0021)	0.0022 (0.0029)
N	308939	345783	273790	119323	137425	125712	189616	208358	148078
Minority (Black/Hispanic)	0.0023 (0.0017)	0.0041+ (0.0023)	0.0026 (0.0036)	0.0051 (0.0040)	-0.0002 (0.0053)	0.0026 (0.0082)	0.0013 (0.0018)	0.0056* (0.0025)	0.0026 (0.0038)
N	323417	239491	134227	83214	63093	36986	240203	176398	97241
Income < \$50k	0.0045* (0.0018)	0.0046* (0.0023)	-0.0020 (0.0036)	0.0059 (0.0038)	0.0031 (0.0048)	-0.0047 (0.0068)	0.0039* (0.0019)	0.0055* (0.0025)	-0.0003 (0.0041)
N	299503	248206	144763	91086	79173	52964	208417	169033	91799
Income \$50k - \$100k	0.0017 (0.0014)	0.0038* (0.0016)	0.0098** (0.0025)	0.0016 (0.0029)	0.0031 (0.0034)	0.0137** (0.0046)	0.0018 (0.0015)	0.0043* (0.0018)	0.0080** (0.0029)
N	485175	483721	308762	153935	153702	115658	331240	330019	193104
Income > \$100k	0.0001 (0.0014)	0.0051** (0.0015)	0.0089** (0.0021)	-0.0008 (0.0027)	0.0036 (0.0030)	0.0090* (0.0039)	0.0006 (0.0016)	0.0058** (0.0017)	0.0090** (0.0025)
N	474661	557844	409834	157629	179685	151643	317032	378159	258191
Took One AP	-0.0007 (0.0017)	0.0035 (0.0025)	0.0041 (0.0047)	-0.0025 (0.0034)	-0.0017 (0.0045)	-0.0016 (0.0075)	0.0003 (0.0019)	0.0070* (0.0030)	0.0090 (0.0057)
N	328563	225638	101150	114393	86042	45804	214170	139596	55346
Took Two or More AP	0.0023** (0.0007)	0.0038** (0.0008)	0.0066** (0.0011)	0.0017 (0.0014)	0.0026+ (0.0015)	0.0058** (0.0020)	0.0025** (0.0007)	0.0044** (0.0008)	0.0073** (0.0013)
N	2055281	2246540	1578012	655847	717390	589811	1399434	1529150	988201
Bottom Third SAT	0.0024* (0.0010)	0.0062** (0.0019)	0.0030 (0.0041)	0.0033 (0.0024)	0.0023 (0.0039)	0.0025 (0.0084)	0.0021+ (0.0011)	0.0080** (0.0021)	0.0033 (0.0045)
N	834173	434741	131157	218393	123701	41141	615780	311040	90016
Middle Third SAT	0.0005 (0.0011)	0.0035** (0.0012)	0.0052* (0.0022)	-0.0010 (0.0021)	0.0021 (0.0024)	0.0019 (0.0037)	0.0012 (0.0012)	0.0043** (0.0014)	0.0077** (0.0026)
N	798336	908774	469918	280039	296351	184270	518297	612423	285648
Top Third SAT	-0.0003 (0.0017)	0.0016 (0.0012)	0.0083** (0.0014)	-0.0014 (0.0028)	0.0002 (0.0024)	0.0096** (0.0025)	0.0005 (0.0022)	0.0023+ (0.0014)	0.0076** (0.0016)
N	339900	770475	884845	143872	265633	331807	196028	504842	553038
Bottom Third College Quality (Avg. SAT)	0.0030** (0.0009)	0.0026* (0.0013)	0.0064** (0.0023)	0.0052* (0.0021)	-0.0011 (0.0028)	0.0065 (0.0044)	0.0021* (0.0009)	0.0042** (0.0014)	0.0063* (0.0026)
N	975176	734177	341542	278649	220467	123894	696527	513710	217648
Middle Third College Quality (Avg. SAT)	0.0016 (0.0011)	0.0039** (0.0013)	0.0083** (0.0020)	0.0002 (0.0023)	0.0037 (0.0026)	0.0094* (0.0037)	0.0023* (0.0012)	0.0040** (0.0014)	0.0079** (0.0023)
N	822881	838322	493909	270060	274458	192741	552821	563864	301168
Top Third College Quality (Avg. SAT)	-0.0001 (0.0015)	0.0043** (0.0013)	0.0054** (0.0015)	-0.0025 (0.0024)	0.0029 (0.0023)	0.0028 (0.0027)	0.0014 (0.0019)	0.0051** (0.0015)	0.0071** (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	Other Exam = Average of exam scores		
	Takers	(Centered at 3)		
	(1)	(2)	(3)	(4)
Above 4/5 Threshold (Primary Exam)	0.0068*** (0.0011)	0.0091*** (0.0013)	0.0077*** (0.0014)	0.0093*** (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			
	<u>1/2</u>	<u>2/3</u>	<u>3/4</u>	<u>4/5</u>
	<i>Full Sample</i>			
Above Threshold	-0.0002 (0.0011)	0.0021* (0.0010)	0.0001 (0.0011)	-0.0021 (0.0014)
Mean at Cutoff	11.7%	15.8%	20.2%	26.0%
N	1473612	2383844	2472178	1679162
	<i>Only AP STEM Exams</i>			
Above Threshold	-0.0012 (0.0019)	0.0028 (0.0019)	0.0010 (0.0021)	0.0006 (0.0026)
Mean at Cutoff	15.5%	20.5%	26.7%	34.9%
N	626287	770240	803432	635615
	<i>Only AP Non-STEM Exams</i>			
Above Threshold	0.0005 (0.0014)	0.0018 (0.0012)	-0.0003 (0.0013)	-0.0035* (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

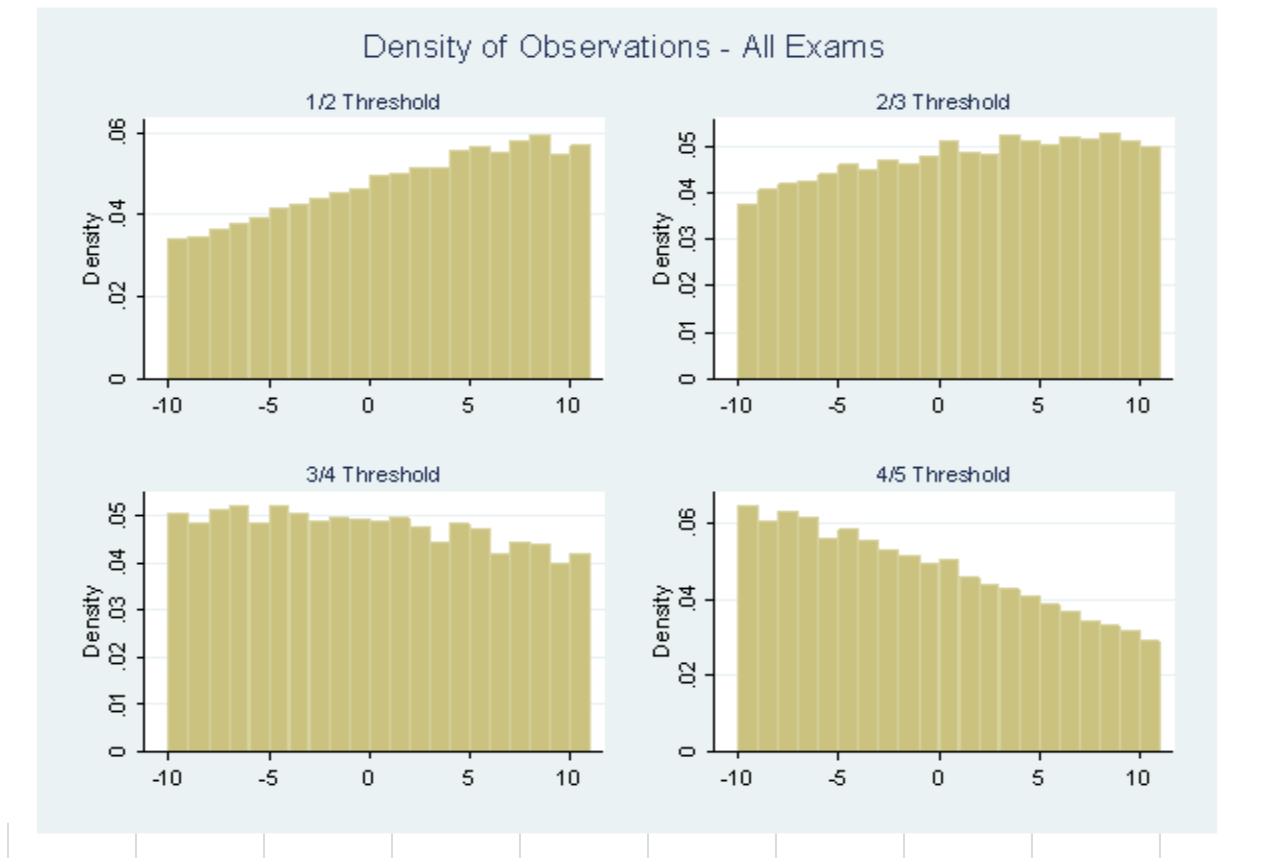


Figure 2 - Main Results

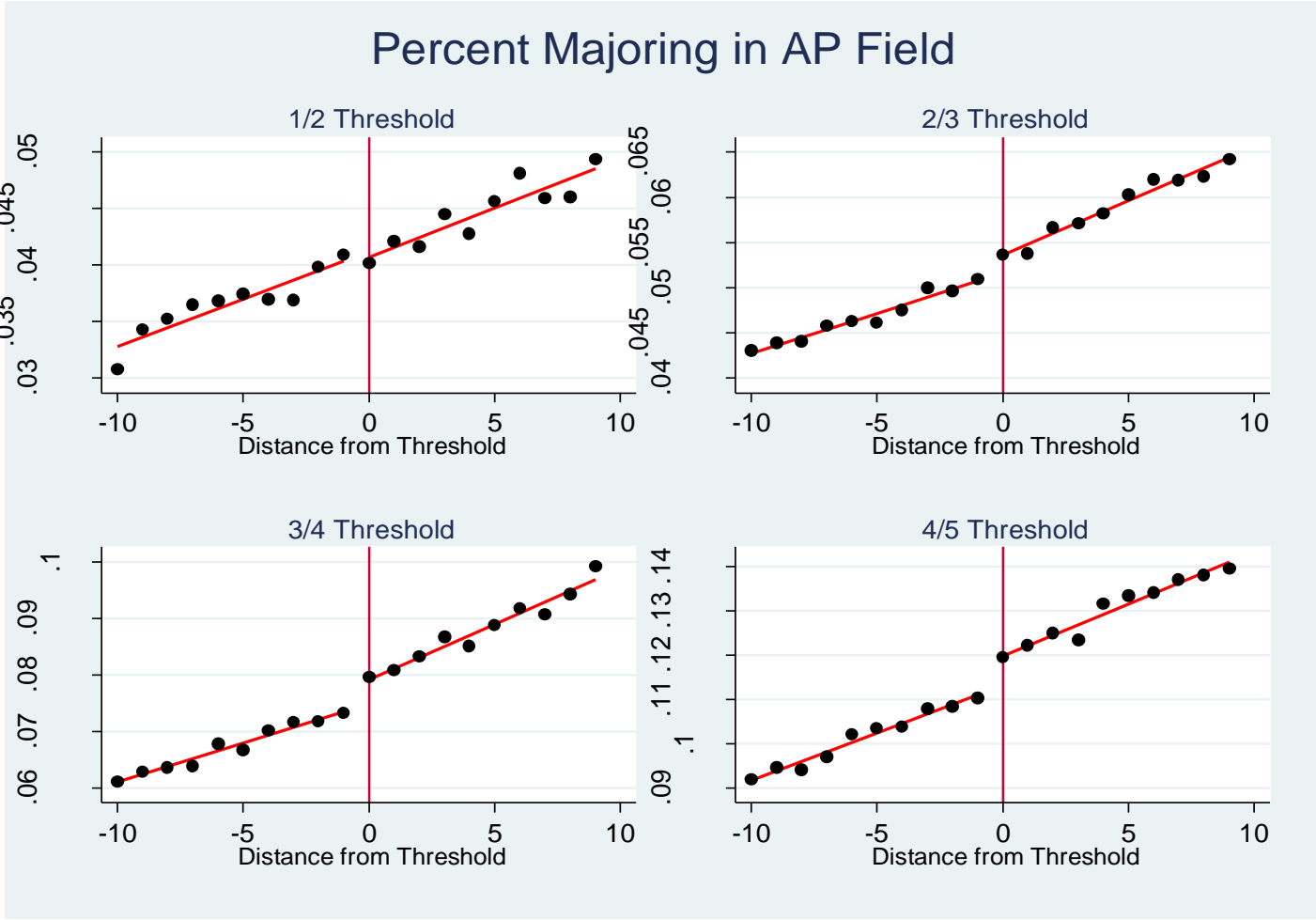


Figure 3 - Main Results - Stem and Non-STEM Fields

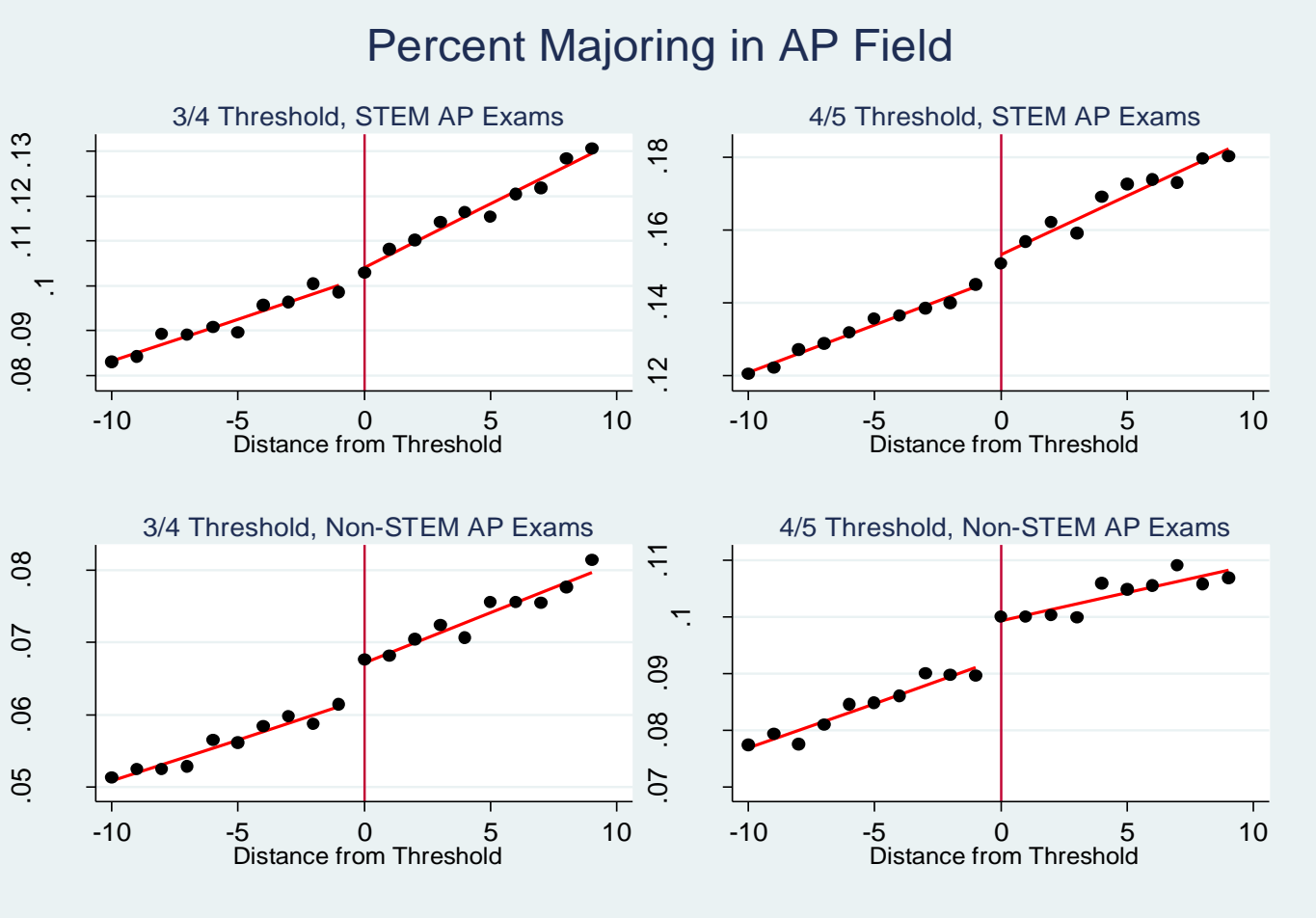
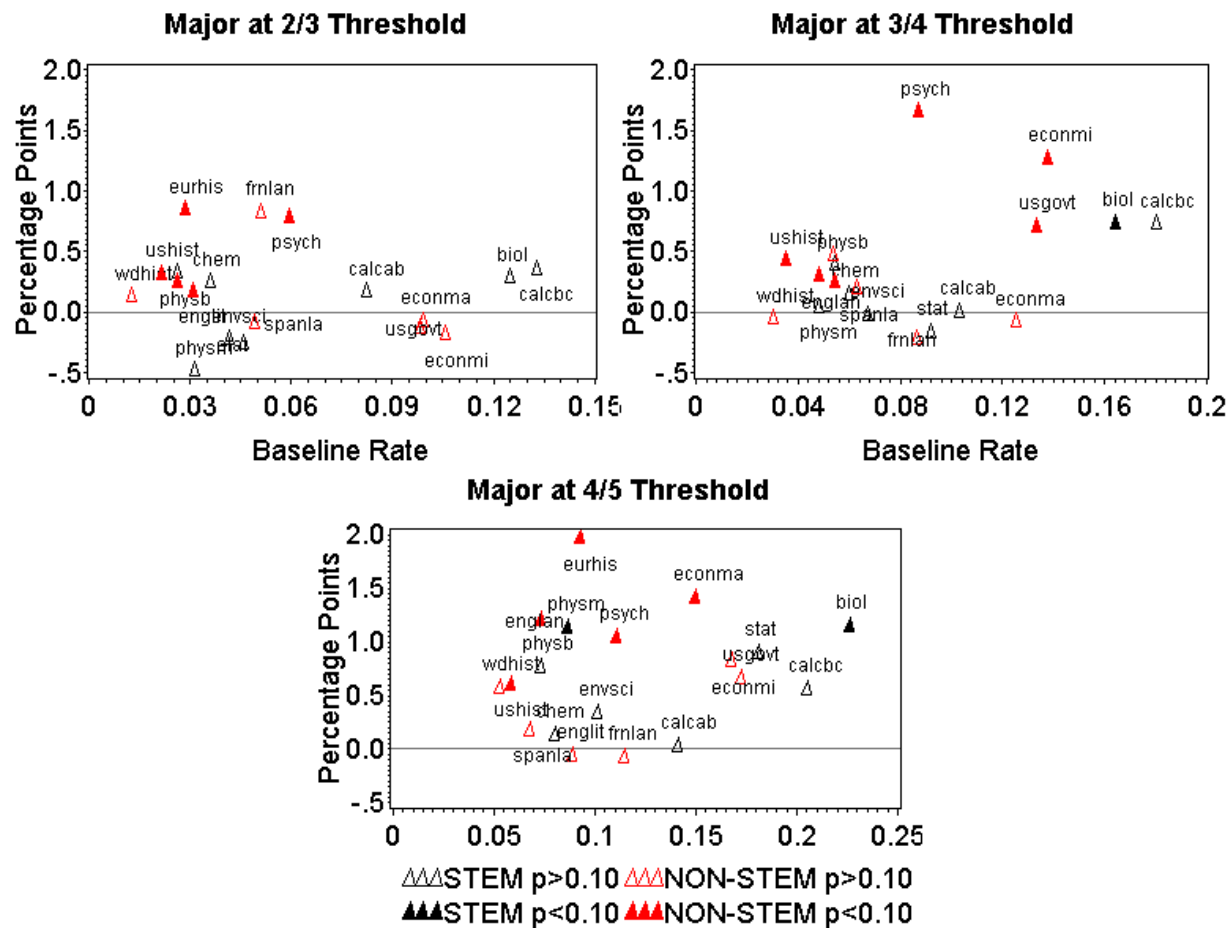


Figure 4. Subject by Subject Results



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
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

<u>AP Subject</u>	<u>CIP Code</u>	<u>Assigned Major</u>
<i>STEM</i>		
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
<i>Non-STEM</i>		
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 (0.0039)	0.0005 (0.0051)	0.0021 (0.0065)	-0.0024 (0.0083)	0.0075+ (0.0043)	0.0088 (0.0056)	0.0012 (0.0071)	0.0199* (0.0091)	0.0117* (0.0055)	0.0121+ (0.0070)	0.0116 (0.0106)	0.0125 (0.0093)
N	134134	80581	49144	31437	135445	83983	51320	32663	106010	67529	27174	40355
Calc AB - Above Threshold	0.0018 (0.0024)	0.0011 (0.0031)	0.0006 (0.0037)	0.0020 (0.0057)	0.0002 (0.0026)	-0.0005 (0.0034)	0.0018 (0.0052)	-0.0023 (0.0045)	0.0005 (0.0033)	0.0016 (0.0042)	-0.0114 (0.0107)	0.0039 (0.0045)
N	237829	149948	101561	48387	248500	158875	71515	87360	212499	137322	20192	117130
Calc BC - Above Threshold	0.0037 (0.0062)	0.0022 (0.0078)	-0.0015 (0.0091)	0.0130 (0.0148)	0.0074 (0.0056)	0.0075 (0.0069)	0.0210* (0.0091)	-0.0128 (0.0103)	0.0058 (0.0057)	0.0060 (0.0070)	0.0033 (0.0136)	0.0076 (0.0081)
N	54462	37673	28015	9658	84679	59438	35721	23717	92320	64962	14343	50619
Chemistry - Above Threshold	0.0026 (0.0031)	0.0026 (0.0035)	0.0055 (0.0044)	-0.0028 (0.0060)	0.0016 (0.0038)	0.0042 (0.0043)	0.0081 (0.0053)	-0.0042 (0.0070)	0.0016 (0.0051)	0.0048 (0.0057)	-0.0024 (0.0088)	0.0107 (0.0074)
N	71210	46168	30244	15924	67984	45137	31261	13876	51440	34437	15270	19167
Env Sci - Above Threshold	-0.0021 (0.0040)	-0.0004 (0.0053)	-0.0025 (0.0067)	0.0038 (0.0083)	-0.0001 (0.0045)	0.0009 (0.0058)	0.0050 (0.0082)	-0.0026 (0.0081)	0.0036 (0.0073)	0.0085 (0.0092)	-0.0242 (0.0330)	0.0120 (0.0096)
N	55311	35475	22925	12550	54626	35282	16429	18853	32135	21072	1793	19279
Physics B - Above Threshold	0.0034 (0.0094)	0.0064+ (0.0039)	0.0120* (0.0054)	-0.0009 (0.0060)	0.0040 (0.0045)	0.0041 (0.0050)	0.0015 (0.0078)	0.0071 (0.0065)	0.0079 (0.0068)	-0.0005 (0.0078)	0.0214 (0.0139)	-0.0092 (0.0093)
N	46392	30617	17230	13387	39348	26216	12810	13406	24366	16377	4801	11576
Physics M - Above Threshold	-0.0047 (0.0038)	-0.0065 (0.0043)	-0.0022 (0.0061)	-0.0103+ (0.0062)	0.0006 (0.0040)	0.0004 (0.0043)	-0.0048 (0.0065)	0.0051 (0.0058)	0.0116* (0.0055)	0.0112+ (0.0061)	0.0115 (0.0092)	0.0108 (0.0079)
N	42046	29294	14264	15030	47802	33141	16070	17071	38935	26654	8978	17676
Statistics - Above Threshold	-0.0024 (0.0025)	0.0004 (0.0033)	-0.0006 (0.0039)	0.0028 (0.0063)	-0.0015 (0.0034)	-0.0040 (0.0044)	-0.0088 (0.0065)	-0.0002 (0.0059)	0.0092 (0.0058)	0.0096 (0.0072)	0.0093 (0.0163)	0.0105 (0.0080)
N	128856	82484	58776	23708	125048	82731	36474	46257	77910	53016	8934	44082
English Language - Above Threshold	0.0026* (0.0012)	0.0021 (0.0015)	0.0023 (0.0018)	0.0016 (0.0027)	0.0031+ (0.0017)	0.0052** (0.0020)	0.0056* (0.0027)	0.0046 (0.0030)	0.0123*** (0.0027)	0.0102** (0.0033)	0.0188* (0.0075)	0.0080* (0.0037)
N	287384	182430	123737	58693	286089	182845	103810	79035	164779	103346	20382	82964
English Literature - Above Threshold	0.0019+ (0.0011)	0.0025+ (0.0014)	0.0027 (0.0018)	0.0022 (0.0023)	0.0026+ (0.0014)	0.0048** (0.0018)	0.0044+ (0.0023)	0.0053+ (0.0028)	-0.0004 (0.0026)	0.0003 (0.0033)	0.0040 (0.0069)	-0.0005 (0.0037)
N	399869	238691	144829	93862	424802	257878	158042	99836	215421	129039	25445	103594
European History - Above Threshold	0.0086*** (0.0026)	0.0068* (0.0032)	0.0070+ (0.0041)	0.0067 (0.0052)	0.0049 (0.0035)	0.0104* (0.0044)	0.0121* (0.0057)	0.0078 (0.0067)	0.0199*** (0.0055)	0.0223** (0.0070)	0.0096 (0.0166)	0.0251** (0.0078)
N	68559	41297	23966	17331	76047	46254	27710	18544	48174	29187	4958	24229
French Language - Above Threshold	0.0084 (0.0069)	0.0081 (0.0088)	0.0088 (0.0114)	0.0083 (0.0133)	-0.0021 (0.0094)	-0.0116 (0.0118)	-0.0016 (0.0145)	-0.0338+ (0.0200)	-0.0005 (0.0127)	0.0217 (0.0169)	0.0428 (0.0261)	0.0034 (0.0222)
N	17678	10529	6881	3648	15946	9334	6391	2943	10597	6077	2729	3348
Macroeconomics - Above Threshold	-0.0006 (0.0046)	-0.0048 (0.0055)	-0.0039 (0.0073)	-0.0058 (0.0085)	-0.0007 (0.0048)	-0.0038 (0.0057)	-0.0038 (0.0080)	-0.0037 (0.0081)	0.0143* (0.0057)	0.0171* (0.0067)	0.0482+ (0.0253)	0.0132+ (0.0068)
N	80885	55219	30164	25055	87380	60333	28721	31612	70345	49151	5316	43835
Microeconomics - Above Threshold	-0.0017 (0.0058)	0.0029 (0.0071)	-0.0090 (0.0087)	0.0174 (0.0116)	0.0128* (0.0060)	0.0062 (0.0073)	0.0174+ (0.0105)	-0.0044 (0.0102)	0.0084 (0.0075)	0.0031 (0.0089)	-0.0217 (0.0294)	0.0065 (0.0091)
N	51006	33799	19009	14790	58488	39471	18692	20779	45786	31416	4104	27312
Psychology - Above Threshold	0.0080* (0.0037)	0.0086+ (0.0048)	0.0118* (0.0058)	0.0032 (0.0085)	0.0167*** (0.0037)	0.0156*** (0.0047)	0.0186* (0.0072)	0.0135* (0.0062)	0.0107* (0.0044)	0.0130* (0.0055)	0.0242 (0.0229)	0.0121* (0.0057)
N	83580	50085	32411	17674	103015	63917	27692	36225	91387	58467	3904	54563
Spanish Language - Above Threshold	-0.0008 (0.0038)	0.0048 (0.0045)	0.0071 (0.0053)	-0.0014 (0.0087)	0.0021 (0.0040)	0.0043 (0.0048)	0.0082 (0.0068)	-0.0007 (0.0067)	0.0020 (0.0046)	0.0029 (0.0056)	0.0029 (0.0091)	0.0030 (0.0070)
N	60926	38487	28214	10273	67221	43086	25237	17849	56173	36208	14065	22143
US Government - Above Threshold	-0.0011 (0.0029)	0.0031 (0.0035)	0.0013 (0.0042)	0.0065 (0.0066)	0.0072* (0.0032)	0.0052 (0.0039)	0.0036 (0.0065)	0.0061 (0.0049)	0.0069 (0.0045)	0.0049 (0.0054)	-0.0276 (0.0359)	0.0057 (0.0055)
N	200044	132652	88512	44140	204511	136311	54090	82221	132408	87792	2800	84992
US History - Above Threshold	0.0033** (0.0011)	0.0024+ (0.0014)	0.0035+ (0.0019)	0.0010 (0.0021)	0.0044** (0.0015)	0.0053** (0.0018)	0.0059** (0.0023)	0.0043 (0.0029)	0.0063* (0.0021)	0.0050 (0.0032)	0.0138 (0.0090)	0.0035 (0.0034)
N	290107	175986	96438	79548	274145	169615	103444	66171	159671	99425	13855	85570
World History - Above Threshold	0.0014 (0.0018)	0.0008 (0.0022)	-0.0010 (0.0029)	0.0025 (0.0034)	-0.0004 (0.0027)	0.0015 (0.0033)	0.0075+ (0.0044)	-0.0068 (0.0049)	0.0059 (0.0044)	0.0047 (0.0053)	0.0190 (0.0138)	0.0032 (0.0057)
N	73566	46974	24451	22523	71102	45798	26187	19611	48806	31080	3632	27448

Notes: 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. 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

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

	<u>1/2 Threshold</u>	<u>2/3 Threshold</u>	<u>3/4 Threshold</u>	<u>4/5 Threshold</u>
<i>2005-2007 Cohorts</i>				
Above Threshold	-0.0011 (0.0011) 725515	0.0036*** (0.0009) 1203950	0.0041*** (0.0011) 1241365	0.0079*** (0.0016) 822227
<i>Excluding Manual CIP Codes</i>				
Above Threshold	-0.0003 (0.0006) 1367893	0.0010+ (0.0006) 2200966	0.0037*** (0.0006) 2277760	0.0033*** (0.0009) 1547630
<i>Removed Double Majors</i>				
Above Threshold	0.0001 (0.0007) 1458932	0.0015* (0.0006) 2347437	0.0031*** (0.0007) 2411761	0.0059*** (0.0010) 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 - 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
<i>2/3 Threshold</i>									
Above Threshold	0.0021** (0.0008)	0.0025** (0.0010)	0.0011 (0.0014)	0.0010 (0.0017)	0.0016 (0.0020)	-0.0000 (0.0031)	0.0025** (0.0009)	0.0030** (0.0010)	0.0016 (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
<i>3/4 Threshold</i>									
Above Threshold	0.0032** (0.0009)	0.0042** (0.0012)	0.0019 (0.0014)	0.0017 (0.0019)	0.0035 (0.0027)	-0.0001 (0.0027)	0.0039** (0.0010)	0.0046** (0.0013)	0.0029+ (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
<i>4/5 Threshold</i>									
Above Threshold	0.0073** (0.0014)	0.0044 (0.0032)	0.0079** (0.0015)	0.0101** (0.0025)	0.0069 (0.0053)	0.0111** (0.0029)	0.0058** (0.0016)	0.0026 (0.0039)	0.0064** (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.