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How college credit in high school impacts postsecondary course-taking: the role of AP exams

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Abstract: This paper uses Advanced Placement (AP) exams to examine how receiving college credit in high school alters students' subsequent human capital investment. Using data from one large state, I link high school students to postsecondary transcripts from in-state, public institutions and estimate causal impacts using a regression discontinuity that compares students with essentially identical AP performance but who receive different offers of college credit. I find that female students who earn credit from STEM exams take higher-level STEM courses, significantly increasing their depth of study, with no observed impacts for males. As a result, the male-female gap in STEM courses taken shrinks by roughly one-third to two-thirds, depending on the outcome studied. Earning non-STEM AP credit increases overall coursework in non-STEM courses and increases the breadth of study across departments. Early credit policies help assist colleges to produce graduates whose skills aligns with commonly cited social or economic priorities, such as developing STEM graduates with stronger skills, particularly among traditionally underrepresented groups.

Introduction

The typical United States citizen spends at least a dozen years in formal presecondary schooling, developing skills in preparation for college and the labor force. As states and districts have incredible latitude in preparing students for adulthood, this raises the question of how to improve the efficiency of our current educational system. One option is to provide more opportunities for rigorous, "college-level" work during high school. Exposing students to a college-level curriculum can have multiple benefits: preparing students for the academic rigor of college; increasing students' knowledge of or confidence about college-readiness; and learning about potential college majors or career choices.

I examine how early college coursework alters students' subsequent human capital investment in the context of Advanced Placement (AP) exams. AP courses are a nationally recognized college-level curriculum, and high performance on AP exams can impact college pathways by allowing students to receive college credit for introductory courses, as well as providing students a signal of their academic preparedness. Prior work has shown both effects, as earning college credit reduces time to degree, whereas higher integer scores can independently shift students' college major through a signaling effect (Avery, Gurantz, Hurwitz, & Smith, 2018; Evans, forthcoming; Mattern, Shaw, & Ewing, 2011; J. Smith, Hurwitz, & Avery, 2017).

This paper focuses on an alternate outcome, estimating the impact of AP performance on students' postsecondary curricular choices, and how these impacts vary by student gender. I estimate the causal impact of higher AP integer scores using a regression discontinuity design that compares students in one large state with essentially identical academic performance but who receive different integer exam scores (e.g., a 3 versus a 2); as a result, some students receive different signals of their academic performance and are provided the opportunity to skip introductory college courses. In addition to graduating earlier or altering the choice of major, students can use AP credit to deepen their study by taking more courses within their preferred discipline, or conversely broadening the scope of their exposure to different disciplines. Knowing more about which courses students take is key to understanding the impact of early credit opportunities, as the types of skills developed in school may matter as much as the degree obtained (Altonji & Pierret, 2001; Arteaga, 2018; Goodman, forthcoming). Postsecondary enrollment is inherently driven by tradeoffs in course-taking, as many colleges promote the holistic benefits of a broad liberal arts curriculum against the need to delve deeply into coursework that will serve as the basis of a future career.[1]

I find that receiving college credit from an AP exam in science or mathematics ("STEM") increases the depth of study within STEM departments, at the cost of slightly reducing the breadth of study across departments. Earning STEM credit leads students to take higher level courses within that same AP field and additional STEM courses outside of the AP field more generally. Receiving college credit from a non-STEM AP exam increases the number of non-STEM courses taken, though the strongest evidence points to this occurring outside of the discipline of the AP exam (i.e., earning English credit does not increase the number of English courses taken).

[1] There are three other mechanisms where AP scores impact postsecondary investments. One is that stronger academic preparation shifts students' course decisions (K. Smith, Jagesic, Wyatt, & Ewing, 2018; Wyatt, Jagesic, & Godfrey, 2018), but the use of a regression discontinuity (RD) design (described below) eliminates that issue in this context. The other is if AP exams lead students to attend more selective institutions, but this has been shown not to be the case in a narrowly tailored RD framework (J. Smith et al., 2017). A third is if AP credits increase the likelihood of double-majoring. Both Evans (forthcoming) and Ewing, Jagesic, and Wyatt (2018) find positive impacts on double majors after comparing students who take or pass AP to those who do not, after applying a rich set of controls. In an RD framework similar to this paper, Avery et al. (2018) find no impacts on double-majors, though this was not reported in published versions.

The results point to the actual credit received as the key mechanism, as achieving a higher integer score at a threshold that does not offer credit has no effect on courses taken.[2] These results are not driven by changes in college major; prior work found that AP exams shift students across STEM fields but do not increase overall STEM completion (Avery et al., 2018), and the estimated magnitude on those effects, which are corroborated in this paper, are not large enough to account for the observed differences in course-taking.

I analyze gender differences in course-taking patterns, given abundant evidence on lower levels of female participation and success in STEM in the postsecondary sector. I find that females are significantly more likely than males to use the college credit to progress deeper within STEM disciplines. As a result, the male-female gap in STEM courses taken shrinks by roughly one-third to two-thirds, depending on the outcome studied. Previous work has repeatedly shown that women are less likely to earn STEM degrees or participate in STEM-related careers, though debate continues as to the role that variation in preferences, academic preparation, discrimination, and other factors drives these differences (Niederle, 2016). Although results based on individual AP exams are noisy, I find larger effects on higher-level STEM courses when females earn higher AP scores in traditional – and typically optional – Science courses (Biology, Chemistry, Physics) than on math exams, which are more frequently required for graduation. This work shows that providing female high school students the opportunity to delve more quickly into higher-level STEM courses increases overall STEM participation, potentially improving later career decisions and performance.

[2] These results align with prior work that found time to degree effects predominately at credit granting thresholds, with meaningful but much smaller signaling effects irrespective of credit offerings.

This paper provides rigorous causal evidence that earning STEM credit increases the level of human capital investment within STEM disciplines, whereas earning non-STEM credit appears to free up students to broaden their curriculum. This result adds to our understanding of how students promote their own human capital development in secondary and postsecondary education. Although high school exposure to a college-level curriculum has been shown to improve college-going and completion (Edmunds et al., 2012; Haxton et al., 2016), this paper adds to our knowledge of how students use earned credit to shape postsecondary pathways. Shifts towards STEM courses may be particularly beneficial for students, as increasing human capital investment in even lower-level math improves long-run labor force outcomes (Goodman, forthcoming). The results also highlight one pathway that promotes equitable outcomes for females in college-level STEM coursework.

The paper proceeds as follows. Section 2 describes the literature on Advanced Placement and issues in STEM participation, section 3 provides context for the sample of AP participants, section 4 describes the methodology, section 5 provides results, and section 6 discusses implications.

Literature Review

The strongest correlate of college success is a student's level of academic preparation.[3] Raising curricular standards or the amount of time spent in rigorous courses has been shown to increase short-term academic and long-term labor market outcomes (Cortes, Goodman, & Nomi, 2015; Edmunds et al., 2012; Goodman, forthcoming; Haxton et al., 2016; Taylor, 2014). A number of papers have shown how AP exams in particular impact student outcomes. First, being induced to take an AP exam improved college preparatory behaviors, leading to increases in degree

[3] Obviously, academic preparation is correlated with other factors such as family income or wealth, but these are often not well-captured in traditional administrative datasets.

attainment and earnings (Jackson, 2010, 2014). Receiving a higher AP score increases on-time bachelor's degree completion when the exam is linked to college credit (J. Smith et al., 2017). Students who participate in AP STEM fields are more likely to major in those disciplines (K. Smith et al., 2018), and some portion of this shift in major is causal (Avery et al., 2018). Students are more likely to major in the AP discipline as they exhibit a behavioral response from the signal of receiving a higher AP integer score, but college credit had no independent impact on this shift in major; in addition, the signal was much stronger for students receiving a 5 (instead of a 4), compared to students receiving a 3 (instead of a 2).

Evans (forthcoming) uses the Beginning Postsecondary Survey to examine linkages between AP credits and a variety of postsecondary outcomes, and serves as a good companion study to this paper. He uses a nationally representative study and a strong set of controls to minimize bias typically found in correlational studies. This approach allows him to examine not just graduation and courses taken, but a broader set of outcomes such as hours worked, debt, and graduate school enrollment. In contrast, my study uses a regression discontinuity design (described below) that makes a stronger causal claim to comparing essentially identical students, though at the cost of being unable to make broader generalizations about, as just one example, students who took multiple APs to those who took few or none. Discussed below, both papers find strong evidence of increased math and science course-taking, though differ along a few dimensions: my more narrowly tailored question shows no impacts on credits earned in the first-year or overall, and prior national-level work using a similar methodology finds no impacts on enrollment in four-year colleges enrollment or bachelor's degree completion after six years (J. Smith et al., 2017).[4]

[4] Evans (forthcoming) also find increases in first-year GPA but I show below that students with AP credit generally skip the introductory course, so it is challenging to determine whether this is due to AP causally improving academic performance or simply shifting students into classes with different grade distributions. Wyatt et al. (2018) also find

Policymakers continue to focus on STEM education as vital for preparing the workforce of the future, given the importance of technological innovation for economic growth (Mokyr, Vickers, & Ziebarth, 2015). Although many students enter college with a desire to major in a STEM discipline, attritions rates are high, particularly for females and minority students (Arcidiacono, Aucejo, & Spenner, 2012; Morgan, Gelbgiser, & Weeden, 2013; Stinebrickner & Stinebrickner, 2014). The large returns to a STEM degree should serve as a natural motivation, but heterogeneous tastes dominate the preference for particular majors (Carnevale, Cheah, & Hanson, 2015; Carnevale, Rose, & Cheah, 2011; Wiswall & Zafar, 2015). These results suggest that we need more information about which types of interventions are needed to increase STEM degrees. For example, financial aid and incentives may help students overcome short-term credit constraints and invest more in their schooling, whereas tying aid eligibility to college GPA may increase the likelihood that students drop out of these more challenging courses (Castleman, Long, & Mabel, 2018; Dee & Jackson, 1999; Denning & Turley, 2017).

Who might benefit most from the "intervention" – eliminating introductory courses and receiving a signal of higher skills – described in this paper? Among relatively higher-achieving students, research consistently finds lower STEM attainment among females, in part due to differences in educational opportunities, how math or other science skills are socialized, or the importance of having same gender role models (Ellison & Swanson, 2010; Kofoed & mcGovney, 2017; Lim & Meer, 2017; Mansour, Rees, Rintala, & Wozny, 2018; Niederle & Vesterlund, 2010).[5] One explanation for male STEM success is overconfidence (relative to one's own skills), suggesting

similar or stronger performance in higher-level college courses when comparing AP students who skipped the introductory course versus non-AP students who passed the introductory course.

[5] Female academic attainment has increased significantly over the past few decades and numerous studies find strong intervention impacts among males, but these are often focused on students at the lower end of the ability distribution.

that the signaling value of higher AP scores – an external signal of their readiness – could be more valuable for females (Huang & Kisgen, 2013; Reuben, Wiswall, & Zafar, 2017). Additionally, female students may gain more from skipping introductory "gateway" courses, which are typically large courses that – intentionally or not – create a broad distribution of grades through difficult examinations. Research has found that female students are more likely to exit STEM disciplines after receiving a poor grade (e.g., Buser and Yuan (forthcoming)), and the combination of removing a course requirement while eliminating the potential for a negative course grade "shock" may be particularly valuable for women. This is consistent with prior work finding that females may be especially prone to benefiting from an academically rich environment at the high school or college level (Deming, Hastings, Kane, & Staiger, 2014; Dynarski, Libassi, Michelmore, & Owen, 2018).

In sum, the AP "intervention" in this paper attempts to differentiate between two types of treatments. There is a signaling effect from receiving a higher score, which can be analogously compared to an "informational" intervention, which occurs at all thresholds. There is an additional more intensive intervention at only some thresholds that provide the student college credit that eliminates an administrative hurdle towards graduation. While both types of interventions have been shown to work in different contexts, interventions that eliminate an administrative or logistical barrier are typically found to be more effective. For example, providing students information about the FAFSA had essentially no impact, whereas helping them complete the form increased college attendance; similar results were also found for elderly individuals eligible for SNAP receipt (Bettinger, Long, Oreopoulos, & Sanbonmatsu, 2012; Finkelstein & Notowidigdo, 2018). In another context, providing students a signal of their high ability had little independent impact on college-going behaviors or outcomes, except when paired with college outreach and financial aid (Gurantz, Hurwitz, & Smith, 2017). Comparing impacts across these two types of thresholds provides an independent impact of the "informational" versus "administrative" support in pushing students into higher-level courses.

Data

Background context

Data come from all AP exam takers who graduated from one large state in 2004, 2005, and 2006. Students in an AP course but who did not attempt an exam are unobserved in our data. For privacy reasons I cannot identify the state that shared the postsecondary transcripts. During this time period this state was a proponent of "accelerated courses", with the number of AP exams taken rising faster than other large states. One way this occurred was through funding incentives that: covered AP exam fees for all students, whereas most states only subsidized low-income students; small teacher bonuses for each student that passed an AP exam, and; extra funding for teachers in "low ranked" schools.

I focus on students who took one of the ten largest AP exams during this time period. I split these exams into two groups: STEM exams (Biology, Calculus AB/BC, Chemistry, Physics B, Statistics) and non-STEM exams (English Language, English Literature, Psychology, U.S. Government, World History). Students who take AP exams receive an integer score between 1 (the lowest score) and 5 (highest). Nationwide, many colleges offer college credit for specific AP exam scores – in some cases colleges offer students the opportunity to skip a particular class (e.g., a student who scores a 3 on the Calculus AB exam can skip the first semester of introductory Calculus) whereas in others a student could earn general credit that is not tied to a specific course. Earning a score of 3 or higher often considered "passing" and frequently translates into one of these two benefits, though many schools offer additional credit for higher scores (e.g., a student who scores a 5 on the Calculus AB exam could skip a full year of introductory Calculus). In some cases, particularly at more selective schools, students might need to earn a 4 or 5 to earn basic credit, or may not be eligible for credit at all.

For the purposes of this study, and during the time period under review, the state's public colleges offered essentially uniform AP policies across postsecondary institutions. (These results are summarized in Appendix Table 1.) First, each college offered AP credit – meaning the student was obviated from having to take a specific introductory course – for earning a 3 on any of the ten subjects used in this study. In seven of the ten subjects students who earned a 4 could earn credit explicitly tied to a second course (Biology, Calculus BC, Chemistry, Physics B, English Language, English Literature, World History). Only two STEM exams (Chemistry, Biology) offered students the right to skip an additional course for scoring a 5. In all cases the college credit was linked to the ability to skip an additional specified course. All of the courses also met general education requirements for earning a bachelor's degree. Biology and Chemistry differ from other disciplines as students who want to major in these fields must take two semesters of "bundled" introductory coursework, where earning a 4 or 5 allows students to skip either one or both semesters, respectively; students earning a 3 met the general education requirement for science, but would have to take higher-level courses to earn the major. From archival records it appears that the state's two-year colleges followed similar guidelines as in-state four-year colleges

College Board data

Students who take AP exams receive an integer score between 1 (the lowest score) and 5 (highest), but underlying each AP exam is a continuous metric that generally runs between 0 and 150 points and is unobserved by the student. The continuous score is a composite that takes into account performance on both multiple choice and free response sections, extends for four decimal places, and are collapsed into scaled integer scores using the modified Angoff method (Angoff, 1971). Psychometricians determine cut points that differentiate integer scores (i.e., a minimum score to earn a 2, 3, 4, or 5) prior to the exam being offered, but individual exam graders are unable to manipulate scores by offering enough credit to surpass specific thresholds.

My data contain both raw (unobserved) and integer (observed) AP scores, in addition to demographic characteristics (gender, ethnicity, high school attended) and information derived from other College Board services (e.g., SAT participation).

AP exam takers were linked to postsecondary transcript files from in-state public two- and four-year colleges. Two-thirds of in-state, four-year attendees enrolled in the three largest public four-year colleges, but community college enrollment was much more broadly split across colleges. Transcript data are provided by the state and follow each cohort for four years of postsecondary attendance. Transcripts identify courses taken, their associated department and number of units, and the grade received. The transcript data do not contain fields on whether a student graduated, so I utilize National Student Clearinghouse (NSC) data to identify those who earned a degree and their major.

Table 1 provides descriptive statistics for the full sample of AP exam takers. The first column shows that of the 70,770 unique students, 64.2% and 25.9% attended an in-state four-year or two-year college, with most of the remaining students attending in-state private or out of state schools for which I do not have transcripts. Roughly 60% of the sample were female and 60% white. Socio-economic status is significantly higher than national averages, with 57% of families having a college-educated parent and 19% earning $100,000 or more in income (both statistics are student self-reports). Roughly 90% of students attended an in-state four- or two-year college, with about 60% earning a bachelor's degree within six years and 8% earning a STEM degree.[6] The second column of Table 1 more closely matches the later analytic sample by restricting to students who attend an in-state public college and earned at least one 3 on an AP exam. Compared to the full sample, these students are more likely to be white and have higher socio-economic status, earn higher SAT scores, and take on average almost 5 AP exams.

Columns 3 and 4 of Table 1 describe large differences in characteristics between students who took at least one STEM exam or no STEM exams, respectively. STEM exam students are less likely to be African-American or Hispanic and more likely to be Asian. STEM exam takers have SAT math scores that are almost 70 points higher, even though they have relatively similar SAT verbal scores. Students who took a STEM AP exam were roughly four times as likely to earn a STEM degree (15.6% versus 3.7%). This suggests that early exposure to college-level STEM courses is a key precursor to earning a STEM degree, even though this cannot be interpreted as a causal impact due to strong observable – and likely unobservable – differences between these two groups.

I create two sets of outcome measures to examine students' curricular choices. The first is based on total courses attempted in three broad categories: (1) higher-level courses within the AP exam field (e.g., does passing AP Biology lead students to take Biology courses that are a higher level than the AP-relevant course?); (2) total STEM units outside the AP field; and (3) total non-STEM

[6] STEM degree is defined as a major whose first two-digits of the CIP code is 11 (Computer and Information Sciences), 14 (Engineering), 15 (Engineering Technologies and Related Fields), 26 (Biological and Biomedical Sciences), 27 (Mathematics and Statistics), or 40 (Physical Sciences).

units.[7] The second set of outcome measures attempt to examine student tradeoffs in curricular breadth and depth. Curricular breadth is the count of each student's total number of departments they participate in, and whether they took just one course or two or more courses within that department. An increase (decrease) in this number then indicates a broader (narrower) set of courses. For depth I create a metric which identifies units that are most closely aligned with the relevant AP field, relying on college course transcripts as a guide. To do so I follow the following process: (1) identify all students who majored in a specific field; (2) aggregate their total units attempted within each of the many possible departments, and (3) identify departments that have the highest average unit totals.[8] This process then uses the transcript data, rather than human attribution, to identify key departments linked to a specific major.[9] My primary outcome defines depth as taking more units within the top three departments related to the major.

Methodology

I employ a regression discontinuity design to compare students with essentially identical continuous AP scores who receive different AP exam integer scores. As a result of these minor

[7] To account for different AP exam types I alter the STEM and non-STEM definition to exclude courses directly related to that field. For example, if the AP exam is Biology then STEM courses means all courses not in the Biology department. If the AP exam is English, then non-STEM courses means all courses not in the English department.
[8] College major is defined using the two-digit CIP code in the NSC data. Most AP exams link easily to a specific major (e.g., AP English matches to English) but there are three exceptions: (1) Chemistry and Physics both link to the CIP code for "Physical Sciences"; (2) Calculus and Statistics are linked to both Math and Engineering, given that Engineering is the most popular major choice beyond the relatively few Math majors, and (3) AP U.S. Government is linked to the broad Social Sciences CIP code.
[9] As an illustrative example, students who take AP Chemistry are linked to the Chemistry college major, whose top three departments are (in order): Chemistry, Physics, and Process Biology Genetics (PBG). For example, Chemistry majors take 20.5% of their courses in Chemistry, 12.9% in Physics, and 3.4% in PBG. I could alternately estimate the departments that constitute 30% (or 40%, etc.) of all major-specific units, which would then include just Chemistry and Physics (as these three listed above combined to 33.5% of all units). These two alternate formulations provide similar results, particularly as I vary the number of top departments or percentage totals in robustness checks. Appendix Table 6 shows the top ten departments and associated percentages for each AP exam major used in the paper.

differences in exam performance, students either do or do not receive AP credit that gives them the choice of skipping introductory courses.

As each AP exam contains multiple thresholds, the preferred estimation strategy is as follows. First, I stack the 2/3, 3/4, and 4/5 thresholds, thus estimating the combined effect of crossing any integer threshold. (I omit the 1/2 threshold as no college offers credit at that point but discuss these results below). In order to avoid using the same students multiple times (e.g., someone above a score of 3 could also be considered below a 4), I restrict to relatively short bandwidths around each discontinuity. In the sample, restricting to six point bandwidths produces results without overlap; for comparison, using 7 and 10 point bandwidths results in overlap rates of 1.5% and 16.7%, respectively.[10] Finally, estimated results include only thresholds where there is differential credit offered by in-state public colleges. This approach has two virtues. First, thresholds that offer no specific college credit serve as an alternative test of whether course taking patterns are impacted just by signaling, and I later show that there are no large impacts at these points. Second, this approach maximizes power by focusing results only on credit-granting thresholds and concentrating on students relatively close to these boundaries.

This leads to the following estimating equation:

$$Y_{irty} = \beta_0 + \beta_1 * f(score_{irty}) + \beta_2 * Threshold_{irty} + \beta_3 * Threshold_{irty} * f(score_{irty}) + \theta_{rty} + X_{irty} + \varepsilon_{irty} \quad (1)$$

[10] Among the tests used in this study average gap between thresholds is approximately 20 points, but varies anywhere from 12 to 30. In robustness tests that vary bandwidth I randomly assign students in these overlap regions to one side of the discontinuity, such that someone halfway between 3 and 4 will in some cases be considered "above three" and in other cases "below four").

In this model Y_{irty} is the outcome of interest (e.g., courses attempted) for student i taking exam r at threshold t in year y, $f(score_{irty})$ is a function that indicates an individual's distance from the year- and exam-specific threshold centered at the eligibility cutoff, θ_{rty} is a set of year-exam-threshold fixed effects, and X_{irty} is a vector of baseline observable characteristics that are only included in results as robustness checks. $Threshold_{irty}$ is a variable that equals one if a student scores above an AP threshold, and so identifies β_2 as the causal reduced form parameter of being offered AP credit on later outcomes. Results rely on linear specifications with rectangular kernels and utilize robust standard errors.

The validity of the research design depends on no sorting near the AP integer thresholds that invalidates the assumption of no differences between students. Theoretically this appears evident, as students are unaware and unable to manipulate their continuous score to precisely score above these benchmarks. Cut scores are determined prior to AP scoring, so are not set by natural breaks that might idiosyncratically occur in a given year.

Empirically, I follow the standard approach to testing equality by examining the continuity of the density of observations and students' baseline characteristics near the threshold. Given that I can only observe transcripts for students who attend in-state public colleges, any evidence that AP performance shifts students towards private or out-of-state colleges might invalidate the research design. The top panel of Appendix Table 2 presents results that show students are not more likely to attend an in-state four- or two-year public college from receiving a higher integer score. In addition, Appendix Table 2 shows that earning a higher integer score has no impact on a student persisting in all four years of the transcript data. Thus my reliance on using only students with transcripts does not invalidate the research design.

I restrict to only those students with transcripts and examine a variety of individual-level covariates theoretically unassociated with AP performance: gender, ethnicity, taking the SAT, SAT performance, total AP exams taken, parent education, and reported income. Appendix Table 3 shows no evidence that any of these values change discontinuously at the threshold, providing more evidence that the reseach design is valid.[11] A standard McCrary test and finds no evidence of a discontinuity in observations at the thresholds.[12]

Results

Impacts of AP credit on participation in introductory courses

Table 2 examines to what extent students decrease their participation in introductory courses when offered AP credit. (All tables in the Results section employ a regression discontinuity design using student-by-exam observations within six points of the 2/3, 3/4, and 4/5 AP integer thresholds, adding AP test-by-year and cohort fixed effects; design decisions are discussed in the Methodology section above). The first column shows that students are 35, 23, and 26 percentage points less likely to take the corresponding course when offered credit at the 2/3, 3/4, and 4/5 thresholds, respectively. This corresponds to a decline of 73%, 64%, and 45% over baseline rates of students who are below the threshold and choose to take the course. As expected, most students offered credit opt out of the course, but a non-trivial portion of students choose to retake the same material. Close to 20% of students offered STEM credit retake the course, with a little over 10% retake rate in non-STEM exams; scatterplots for the 2/3 threshold are shown in Figure 1.

[11] I follow the standard approach of estimating discontinuities by putting covariates on the left-hand side of equation (2). Only 86% and 62% of students report any value for parental education income, so these baseline values are not representative of the full population.

[12] McCrary test shown in Appendix Figure 1. Regression estimates for the McCrary test using a six point bandwidth are a statistically insignificant 0.032 with a standard error of 0.023. McCrary tests using longer bandwidths that randomly assign students to being above or below the threshold also produce statistically insignificant results.

Table 2 shows two potential reasons students might retake a course for which they have already earned credit.[13] The first reason is that some students may desire a stronger signal of their academic performance before they feel ready to skip the college material. This can be seen in the second column of Table 2, where some students who are eligible to skip a course by earning a 3 will wait until they earn a 4 before doing so. At the 3/4 threshold, only 7.4% of students earning a 3 still retake the course, but this drops by 4.1 percentage points (55%) for identical students earning an AP score of 4. (It bears noting that these are students with a very strong 3, even though they do not observe their exact raw score). The second reason appears related to course "bundling", where two courses are part of a multi-course sequence, and students choose to skip only when they receive credit for both courses (e.g,. Biology 1A and 1B). We can observe this at the 4/5 threshold, where students who earn a 4 or 5 can skip either one or both semesters, respectively, of the introductory courses required for Biology or Chemistry majors.[14] The data show that students earning a 5 are roughly 25 percentage points less likely to take both the first and second semester of Biology/Chemistry when offered the opportunity. Thus some students are making the choice to skip the entire sequence or not, rather than considering individual courses in isolation.[15]

A final finding, not shown in the tables, is that earning credit at the 2/3 threshold in either Calculus or Statistics reduces the likelihood that students take lower-level, remedial math courses by roughly 15 percentage points.[16] The most plausible reason is that students are often required to

[13] In general it is not recommended to compare the magnitude of the impact estimates across different thresholds, as there are a number of changes in which students are represented, the types of institutions attended, and other factors that could all weight into the decision to skip or retake a course.
[14] Students who earn a 3 on Biology or Chemistry are offered credit for a course that meets general education science graduation requirements but is not part of the major sequence.
[15] Another way to see this is through the high retake rates, where 47.8% of students who scored a 4 and earned credit for the first semester of Biology/Chemistry are still retaking the first semester, and 57.4% of these students at some point also take the second semester; thus there is little difference in retake rates between these two courses for those scoring a very strong AP exam score of 4.
[16] I define remedial math courses as those with Pre-Calculus, Trigonometry, or Algebra in their title.

take math placement exams but the presence of AP credit can serve as a substitute accountability method that reduces the likelihood students perform poorly and are misplaced (Scott-Clayton & Rodriguez, 2015). I find no statistically significant or meaningful results on taking lower-level English courses for students at the margins of earning AP English Language or Literature exams, though this could be due to differences in the accuracy or utilization of the specific placement policies.

Impacts of AP credit on subsequent course-taking

Table 3 examines the total number of courses taken by students after one and four years of postsecondary enrollment, with graphical results presented in Figure 2. Overall, students who are offered STEM credit are significantly more likely to take additional STEM (non-STEM) courses when passing a STEM (non-STEM) AP exam. Subsequent tables show this is not due to signaling or other alternative explanations, and is drive solely by allowing students the opportunity to skip introductory courses.

The first two columns of Table 3 focus on STEM involvement. First, students take an additional 0.10 (19%) higher-level courses during the first year that are within the AP discipline (e.g., skipping introductory Biology allows students to take higher-level and upper-division Biology courses). (All outcome measures are described above in the Data section above). Students also take 0.23 (8%) more STEM courses outside of the immediate AP exam field during the first year of study. After four years, the estimated impacts on courses in the AP exam subject and total STEM courses are similar in magnitude, but either retain marginal significance or lose significance given the increased dispersion of students' course-taking choices. Graphical results presented in Appendix Figure 2 shows regression estimates across bandwidths and support the finding of consistent positive results on taking higher-level AP field and STEM courses, with some estimates on four-year impacts reaching marginal levels of statistical significance. Receiving STEM credit has no impact on non-STEM units taken.

Students earning non-STEM credit use this opportunity to take more non-STEM courses, averaging an additional 0.25 (5%) and 0.48 (2%) courses after one and four years, respectively (Table 3, columns 3 and 4). There are no impacts on STEM courses taken. In contrast to STEM, earning non-STEM credit leads students to take fewer courses within the AP discipline in the long-run. After four years, students offered non-STEM credit are 3.2 percentage points (7%) more likely to have taken no courses in that discipline, indicating that they avoid this subject area entirely in favor of taking courses in alternative departments.

Impact estimates are not due to functional form or measurement issues. Appendix Figure 2 confirms results for STEM exam takers over bandwidths from three to nine points, with covariate-adjusted results producing similar results. Appendix Figure 3 does the same for non-STEM exams. Alternate measures of course-taking that examine total units attempted or passed, rather than courses, also finds similar results (omitted for brevity).

Distinguishing between college credit or alternative explanations

Although these course-taking shifts could indicate that students are finishing college with increased investment or specialization within specific disciplines, there may be alternative explanations. First, I eliminate the possibility that increased courses taken comes from students on either side of the threshold staying shorter or longer periods of time due to early graduation (as in J. Smith et al. (2017)), dropout, or transfer rates. Early exits are not a concern as there are no impacts of AP thresholds on remaining in an in-state public college for four years, as previously shown in the top panel of Appendix Table 2, and results are identical when using only students who attend for at least four years (results omitted for brevity). A separate concern is that the AP induces on-time graduation, such that the increase in units attempted does not represent increased depth of study in the long run. The bottom panel of Appendix Table 2 confirms J. Smith et al. (2017), and does find small increases in four-year bachelor's degree completion. Nonetheless, these impacts are statistically insignificant at the credit thresholds, and too small in magnitude to explain the shifts in course-taking documented in this study.[17] In particular, the estimated impact on earning a STEM degree is a statistically insignificant 0.3%, suggesting that increases in STEM courses represents real human capital investment gains, and do not arise from shifts in college major.

An alternate explanation is that these gains arise from the signal that students internalize from receiving a higher AP score, rather than college credit. It first bears noting that this would contradict the two prior papers that use a similar methodology: (1) gains in on-time degree completion were driven by credit-granting thresholds; (2) signaling effects at non-credit thresholds are too small to explain the effects observed here, and in previous work did not produce additional STEM majors, instead shifting STEM majors across specific disciplines. Appendix Table 4 reproduces Table 3 but uses only the AP thresholds where students are not offered any course credit. As the results show, there are no significant results for any AP STEM results and only one

[17] If we assume AP increases four-year degree completion by two percentage points, which is the upper limit of previously estimated impacts, and STEM courses increase by 0.38 (coefficients 0.14 and 0.24 from rows two and six from Table 3), then we can only think of this impact coming from "new" majors (rather than in-depth study among existing majors) if the induced majors took 19 additional STEM courses then they would have otherwise.

significant finding for non-STEM after one year, highlighting that these gains occur from the credit increases rather than the positive signal associated with the integer score itself.[18]

Finally, observed gains in course-taking might not necessarily indicative of increased depth within the curriculum, if the gains are relatively unconnected to the relevant discipline. As described in the Data section above, I test additional metrics for depth and breadth designed to proxy for these curricular values, using only students who persisted for four years. Appendix Table 5 finds that STEM credit increases depth as students take 0.24 more courses (11%) in the top three departments most directly related to that AP major. This comes at the expense of curricular breadth, with students taking courses in 0.43 fewer total departments. For non-STEM students the results are quite different, as students take more 0.4 more courses in departments that are not considered essential to the AP-specific major, with no evidence that students focus more narrowly on the AP-related non-STEM major. Results are identical when using alternate thresholds (e.g., the top five departments) or metrics (e.g., departments as the total percentage of courses).

Gender differences in the impacts of AP credit on subsequent course-taking

Table 4 examines gender differences in the responsiveness to college credit, and shows that females are more likely than males to shift their course-taking patterns.[19] After four years, STEM credit increases female investment by 0.17 AP exam subject courses (12%) and 0.76 STEM courses (9%). Males take essentially no additional higher-level STEM courses, with female-male

[18] Additional results at the 1/2 threshold, which offer no credit but could induce signaling, are also null and omitted for brevity.

[19] Although there are additional heterogeneity outcomes one might investigate, the results are weakly powered and favor attempts that split the sample relatively equally. Ethnic differences are challenging given that relatively few students fall into traditional categories underrepresented in AP, such as African-American and Hispanic students.

differences in taking more courses in the AP discipline or total STEM courses statistically different at the $p<0.1$ level.[20]

The point estimates suggest that earning AP credit shrinks roughly one-half of the male-female gap in STEM participation. This derives from the fact that baseline values – shown underneath the point estimates in Table 4 – indicate that females take 1.4 AP exam subject courses and 8.6 STEM courses, whereas male control means are 1.7 and 10.5, respectively. Thus even the highest-performing high school students – those who are taking and passing AP STEM exams – continue to exhibit large differences in subsequent STEM participation, and receiving early college credit helps ameliorate this issue.[21]

Differences across required and optional college courses

General education requirements for earning a bachelor's degree lead to a fundamental difference between AP exams. Math (i.e., Calculus and Statistics) and English AP exams eliminate a course requirement that is essentially required for all students, such that students who do not pass these exams must repeat them. In contrast, the other STEM and non-STEM exams can be satisfied by many different general education courses, so a student who earns a 2 on AP Psychology, as one example, may take any number of other social science courses to earn their degree.[22]

Table 5 probes whether there are differences in outcomes across AP exams and whether these vary by gender. As each exam is individually underpowered, I combine exams into four categories that

[20] Male-female differences after one year also show larger increases in female STEM participation than for males, but are omitted for brevity.
[21] Differences could arise if males are more likely to score at higher or lower AP levels and these weighted differences are driving differences in effects or control means. Alternate analysis focused only on students at the 2/3 threshold are identical and suggest this is not the case.
[22] Some colleges offer alternative math or English courses but most students within a university retake the course associated with AP college credit. Many students who earn a 2 still choose to retake the same course for which they did not earn credit, likely in part as this is easier than passing an entirely new course.

are "required" (English; math) and "not required" (Biology, Chemistry, and Physics; U.S. Government, History, and Psychology). I find that the largest impacts on STEM courses taken are among females passing these "not required" STEM exams. Thus, female students whose AP scores make them eligible to skip core Science courses leads them to additional STEM courses (outside the AP exam field). The results point to the idea that offering and encouraging participation in more Science focused courses in high school can encourage increased depth of STEM study for female college students. Although female students take an additional 1.2 STEM courses, implying roughly a one for one substitution effect, all estimates are quite noisy at this level of disaggregation and should be considered general trends in behavior rather than precise estimates. The increase in higher level STEM courses appears to come from a shift out of non-STEM courses.

I find no strong positive effects when examining non-STEM exams, though again results are statistically imprecise. Being offered college credit does not appear to lead to substantially different results when comparing English exams versus other social sciences such as World History, U.S Government, or Psychology, with all exhibiting positive but statistically insignificant impacts on additional non-STEM courses. There is some weak evidence that female students who are offered credit on these "not required" social science exams are less likely to take higher-level courses in these disciplines.

Discussion

This study uses AP exam takers to show the impact of early college credit on postsecondary pathways. For all students, I find that being offered course credit leads to large reductions in the likelihood they take introductory college courses, though how they use their newfound freedom varies by exam type and gender. Female students who earn STEM credit increase their curricular depth by taking higher-level science courses in areas both directly and indirectly related to the AP exam, with no observable impacts for males. Students who earn AP credit in non-STEM disciplines diversify the breadth of their curriculum, taking more courses in departments not directly tied to their major. It bears repeating that the increases in courses taken do not arise from large changes in STEM or non-STEM majors, which are too small in magnitude to account for these shifts; thus the results should be considered a comparison of two identical STEM or non-STEM majors who make different decisions in their allocation of courses taken.

There are large differences in how often students major in the AP field that may explain the different patterns between STEM and non-STEM exams. For example, students who take AP Biology are much more likely to major in Biology than students who take AP History major in History (specific rates are given in Avery et al. (2018)). Thus STEM exam takers may be more focused on their field and shift more effort into STEM courses than might be observed in non-STEM areas. On the other hand, non-STEM disciplines may be more interdisciplinary in nature, with History majors benefitting more from insights in other fields (e.g., Economics or Sociology). Unfortunately, even when using one very large state with multiple years of data and a causal design that produces large changes in introductory course taking, there is so much variation in curricular patterns that I am underpowered to investigate some of these possibilities.

Although there are some concerns that students are not using their scores to waive out of college credit, I observe large changes in student participation in introductory courses, with retake rates roughly 10% in non-STEM and 20% in STEM disciplines. Retake rates in STEM disciplines are higher in part due to “bundled” courses, where students prefer to use their credit only when they can eliminate the entire first-year sequence of introductory Science courses. If we would like to discourage retaking, one option may be to provide students a more nuanced picture of their true

AP performance. This could include some details of their raw scores as additional information, given that consumers might be overly responsive to broad grading programs (Anderson & Magruder, 2012; Figlio & Lucas, 2004).

Earning college-level credit in high school leads females to increase their human capital investment in STEM, producing stronger college graduates. Although this paper cannot answer why females are more responsive to the credit offering, I offer a few thoughts. An important contextual point is that these shifts in STEM participation substantially shrink but do not eliminate female-male gaps in STEM participation, even though we are implicitly conditioning on the AP score. Thus the impacts are in part explained by the fact that females with equal academic performance on AP STEM exams take fewer STEM courses in college. Prior research has analyzed how women are more likely to avoid competitive environments, even when they have the requisite ability to perform well, and large introductory courses might be a particularly challenging environment for some female STEM students, leading them to shift some of their future coursework into the areas (Niederle, 2016; Niederle & Vesterlund, 2007). The results cannot be drive entirely by signaling effects – where women might be more responsive to external markers of their ability due to underrepresentation in STEM disciplines – because I find no impacts at thresholds that do not grant credit. Nonetheless there might be some particular benefit to females from the combination of the signal and credit, as an earlier start in higher-level coursework might constitute a large personal boost in their momentum towards the degree or could result in females receiving extra mentoring from professors that encourages them to take additional coursework.

One implication of this study is that encouraging credit policies assists colleges to produce graduates whose skills aligns with commonly cited social or economic priorities. Yet there is an open question about how best to meet this goal, with one claim that too much rigorous coursework at an early level might negatively impact outcomes for some students (Pope, Brown, & Miles, 2015). Some colleges have suggested that introductory courses serve an important purpose in socializing students to their new environment, and students might benefit from the unique experiences of college faculty (Bettinger & Long, 2005; Figlio, Schapiro, & Soter, 2013). Although worthy goals, states subsidize much of the cost of postsecondary enrollment, and this paper shows that they might want to promote these programs to support broader societal goals, such as developing STEM graduates with stronger skills (Webber, 2017). Although balancing these competing demands is a complex issue, states and districts are engaged in numerous efforts to increase early credit opportunities, through avenues such as Advanced Placement exams, International Baccalaureate programs, early college high schools, or traditional dual-enrollment in public two- and four-year colleges. Although there are many potential benefits to engaging in these programs, their ultimate utility will be limited if students' early college credit is not recognized when they enroll in college.

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Table 1. Summary Statistics

	(1)	(2)	(3)	(4)
		Attended in-state public and at least one AP exam>=3		
	All students	All	Took STEM	No STEM
N	70770	30887	21448	9439
Student demographics				
Female	59.8%	56.3%	51.7%	66.6%
African-American	10.9%	5.7%	5.3%	6.5%
Asian	6.5%	6.8%	8.3%	3.6%
Hispanic	18.1%	15.0%	14.4%	16.4%
White	60.9%	69.3%	69.1%	69.8%
One parent has a bachelor's degree	57.3%	64.1%	66.2%	59.1%
Student reported family income >= $100K	18.9%	22.4%	23.8%	19.4%
Exam scores				
Took SAT	91.8%	95.5%	96.9%	92.4%
Final verbal score	553	599	601	594
Final math score	555	597	617	549
Total AP	3.6	4.6	5.4	3.0
Total STEM	1.0	1.4	2.0	0.0
Total Non-STEM	2.6	3.3	3.4	3.0
College outcomes				
Attend in-state four-year college	64.2%	84.3%	89.1%	73.2%
Attend in-state two-year college	25.9%	15.7%	10.9%	26.8%
Six-year bachelor's degree completion	59.4%	71.8%	75.9%	62.5%
STEM degree	8.1%	12.0%	15.6%	3.7%

Notes. All students graduated from a Florida high school between 2004 and 2006. All values are based on unique student observations. Demographics are based on student self-reports, Exam scores are based on College Board data, and College outcomes are based on National Student Clearinghouse data.

Table 2. Impacts of crossing AP threshold on taking AP relevant course within four years

Student achieved an AP integer score of:	N	Took college course that corresponded to credit offered at AP threshold	Took college course that corresponded to credit offered at lower-level AP threshold
3	25971	-0.346**	
		(0.010)	
Baseline value		47.6%	
4	11344	-0.229**	-0.041**
		(0.015)	(0.009)
Baseline value		35.8%	7.4%
5	659	-0.258**	-0.231**
		(0.074)	(0.071)
Baseline value		57.4%	47.8%

Notes. + p<0.1, * p<0.05, ** p<0.01. All students in the sample graduated from a Florida high school and attended an in-state public college. Estimates derive from equation (1) in the text, which provides a regression discontinuity estimate using a linear specification over a bandwidth of six AP points and includes test-by-year and cohort fixed effects. An observation is a unique student-by-test observation, with standard errors clustered by student. Baseline values include all students within two points below the threshold.

Table 3. Impacts of crossing AP threshold on courses attempted, credit-granting thresholds only

	(1)	(2)	(3)	(4)
	STEM		Non-STEM	
	1 year	4 years	1 year	4 years
Total courses	0.077	-0.211	0.016	-0.161
	(0.105)	(0.399)	(0.067)	(0.257)
	9.5	36.0	9.1	34.1
Total courses in AP subject above AP exam	0.095**	0.141+	-0.003	-0.034
	(0.034)	(0.078)	(0.012)	(0.036)
	0.5	1.6	0.3	0.9
Took zero courses (%)	-0.067***	-0.036+	0.013	0.032**
	(0.019)	(0.019)	(0.010)	(0.011)
	68.8%	42.2%	70.0%	48.6%
Took one course (%)	0.047**	0.017	-0.022*	-0.010
	(0.016)	(0.015)	(0.010)	(0.011)
	18.7%	20.2%	27.3%	32.0%
Took two or more courses (%)	0.020	0.019	0.010*	-0.022*
	(0.013)	(0.020)	(0.004)	(0.009)
	12.5%	37.6%	2.7%	19.4%
STEM courses	0.234**	0.244	0.039	-0.258
	(0.084)	(0.289)	(0.056)	(0.181)
	2.9	9.5	3.0	9.0
Non-STEM courses	0.015	-0.129	0.249***	0.477*
	(0.096)	(0.380)	(0.059)	(0.237)
	5.5	23.9	5.4	23.8
	9801		28159	

Notes. + p<0.1, * p<0.05, ** p<0.01. All students in the sample graduated from a Florida high school and attended an in-state public college. Estimates derive from equation (1) in the text, which provides a regression discontinuity estimate using a linear specification over a bandwidth of six AP points and includes test-by-year and cohort fixed effects. An observation is a unique student-by-test observation, with standard errors clustered by student. Baseline values are listed below the regression estimates and standard error, and include all students within two points below the threshold.

Table 4. Gender differences in impacts of crossing AP threshold on courses attempted within four years

	(1)	(2)		(3)	(4)	
	STEM			NON-STEM		
	Female	Male	p-value	Female	Male	p-value
Total courses	-0.334	0.075	0.60	-0.089	-0.368	0.60
	(0.535)	(0.582)		(0.323)	(0.420)	
	37.3	34.8		34.8	33.1	
Total courses in AP subject above AP exam	0.172+	0.032	0.36	-0.028	-0.042	0.84
	(0.104)	(0.113)		(0.049)	(0.050)	
	1.4	1.7		1.0	0.8	
Took zero courses (%)	-0.064*	0.004	0.07	0.031*	0.028+	0.88
	(0.027)	(0.026)		(0.014)	(0.017)	
	44.9%	39.2%		46.5%	51.8%	
Took one course (%)	0.039+	0.001	0.22	-0.007	-0.007	1.00
	(0.023)	(0.021)		(0.014)	(0.017)	
	22.1%	18.6%		32.4%	31.4%	
Took two or more courses (%)	0.025	-0.005	0.43	-0.024*	-0.021	0.86
	(0.026)	(0.028)		(0.012)	(0.013)	
	33.0%	42.2%		21.1%	16.7%	
STEM courses	0.759+	-0.263	0.08	-0.105	-0.391	0.45
	(0.421)	(0.394)		(0.221)	(0.305)	
	8.6	10.5		8.2	10.2	
Non-STEM courses	-0.828	0.765	0.03	0.424	0.361	0.90
	(0.537)	(0.510)		(0.302)	(0.370)	
	26.3	21.6		25.1	21.7	
	4809	4991		17140	11019	

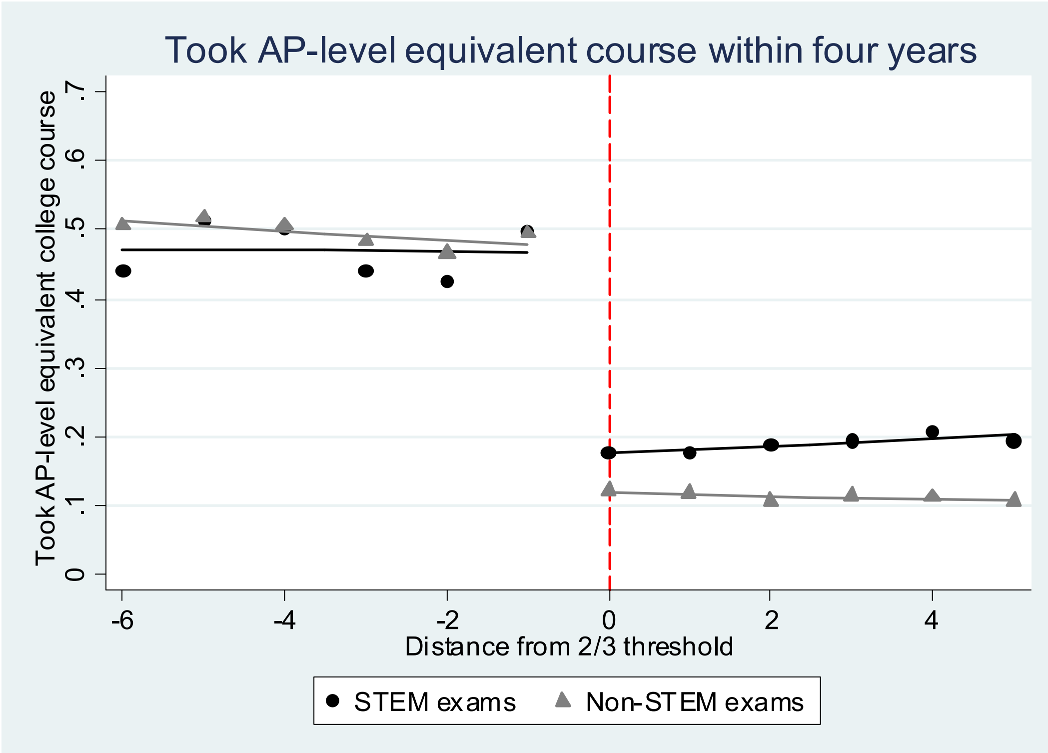
Notes. + p<0.1, * p<0.05, ** p<0.01. All students in the sample graduated from a Florida high school and attended an in-state public college. Estimates derive from equation (1) in the text, which provides a regression discontinuity estimate using a linear specification over a bandwidth of six AP points and includes test-by-year and cohort fixed effects. An observation is a unique student-by-test observation, with standard errors clustered by student. Baseline values are listed below the regression estimates and standard error, and include all students within two points below the threshold.

Table 5. Gender differences in impacts of crossing AP threshold on courses attempted within four years, by exam type

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Calculus/Statistics		Biology/Chemistry/Physics		English Language/Literature		History/Gov't/Psychology	
	Female	Male	Female	Male	Female	Male	Female	Male
Total courses in AP subject	0.212+	0.170	0.172	-0.016	-0.004	-0.037	-0.085*	-0.053
above AP exam	(0.108)	(0.141)	(0.182)	(0.176)	(0.068)	(0.077)	(0.042)	(0.045)
	1.08	1.76	1.67	1.71	1.28	1.19	0.32	0.30
STEM courses	0.294	-0.188	1.226*	-0.376	0.110	-0.473	-0.591	-0.251
	(0.589)	(0.575)	(0.595)	(0.554)	(0.264)	(0.388)	(0.403)	(0.488)
	8.05	9.35	9.19	11.60	8.09	10.32	8.32	9.92
Non-STEM courses	-0.173	0.747	-1.492+	0.813	0.264	0.528	0.794	0.082
	(0.744)	(0.745)	(0.767)	(0.717)	(0.361)	(0.475)	(0.546)	(0.594)
	26.75	21.95	25.81	21.20	24.82	21.24	25.88	22.35
N	2470	2526	2341	2466	11999	6679	5141	4340

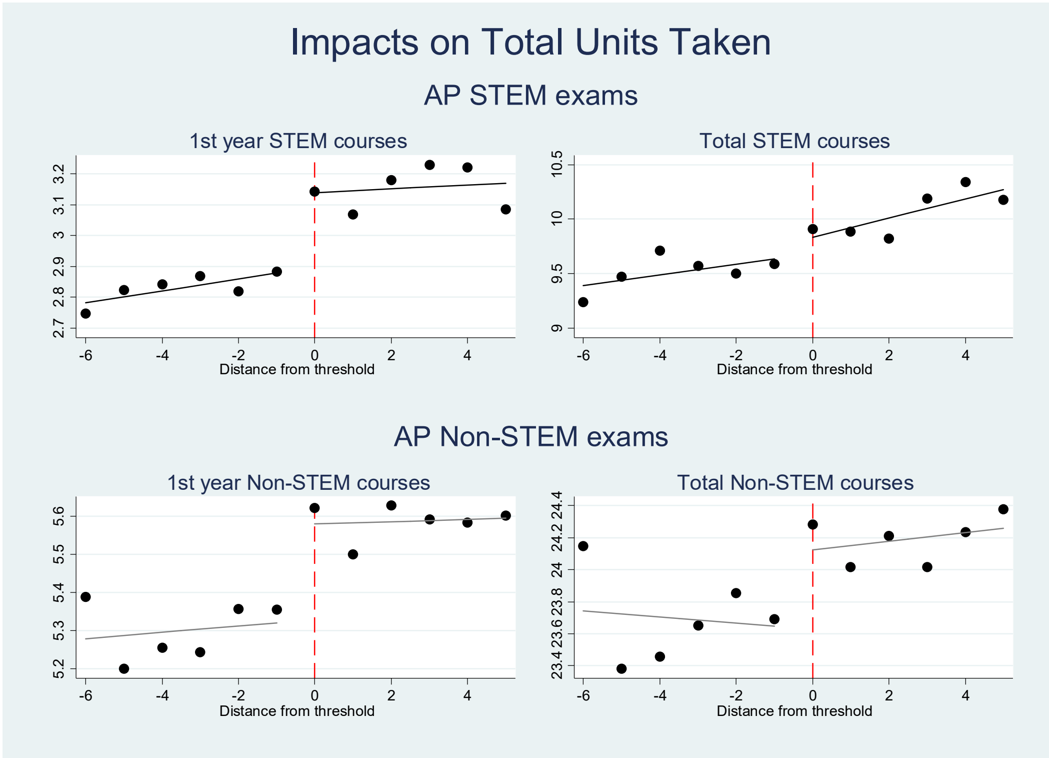
Notes. + p<0.1, * p<0.05, ** p<0.01. All students in the sample took an AP exam, graduated from high school in one large state between 2004 and 2006, and attended an in-state public college. Estimates derive from equation (1) in the text, which provides a regression discontinuity estimate using a linear specification over a bandwidth of six AP points and includes test-by-year and cohort fixed effects. An observation is a unique student-by-test observation, with standard errors clustered by student. Baseline values are listed below the regression estimates and standard error, and include all students within two points below the threshold.

Figure 1. Impacts of college-credit on taking introductory courses associated with AP exams



Notes. Figure includes all student-by-exam observations within 6 points of integer AP score thresholds that provide college credit. Sample includes all high school graduates from 2004 to 2006 in one large state who attended in-state public colleges.

Figure 2. Impact of college-credit on one- and four-year course-taking patterns



Notes. Figure includes all student-by-exam observations within 6 points of integer AP score thresholds that provide college credit. Sample includes all high school graduates from 2004 to 2006 in one large state who attended in-state public colleges.

Appendix Table 1. AP credit offerings, Florida public colleges

	AP integer threshold		
	2/3	3/4	4/5
STEM exams			
Biology	√	√	√
Calculus AB	√		
Calculus BC	√	√	
Chemisty	√	√	√
Physics B	√	√	
Statistics	√		
Non-STEM exams			
English Language	√	√	
English Literature	√	√	
Psychology	√		
U.S. Government	√		
World History	√	√	

Notes. Course credit indicates the elimination of a specific course requirement. No Florida college offers AP credit at the 1/2 threshold.

Appendix Table 2. Impacts of AP thresholds on overall attendance and completion

	All Students	Credit-thresholds	Non-credit thresholds
Attendance in Florida colleges			
Four-year public	0.009	0.013	-0.005
	(0.007)	(0.008)	(0.013)
	75.9%	74.3%	80.3%
Community college	-0.003	-0.006	0.011
	(0.005)	(0.007)	(0.009)
	12.6%	14.3%	7.8%
Any public college	0.006	0.007	0.006
	(0.005)	(0.006)	(0.011)
	88.5%	88.6%	88.1%
	0.004	0.003	0.006
Any public college for four years	(0.006)	(0.007)	(0.012)
	82.9%	82.5%	84.1%
Completion in Florida colleges			
Bachelor in four years	0.024*	0.016	0.027*
	(0.010)	(0.020)	(0.012)
	44.6%	47.4%	43.7%
Same major as AP exam	0.009*	0.013	0.008+
	(0.004)	(0.010)	(0.004)
	4.1%	6.8%	3.2%
STEM major in four years	0.003	0.003	0.004
	(0.005)	(0.012)	(0.005)
	5.8%	9.4%	4.6%
N	57728	42650	15078

Notes. + p<0.1, * p<0.05, ** p<0.01. All students in the sample graduated from a Florida high school between 2004 and 2006. Estimates derive from equation (1) in the text, which provides a regression discontinuity estimate using a linear specification over a bandwidth of six AP points and includes test-by-year and cohort fixed effects. An observation is a unique student-by-test observation, with standard errors clustered by student. Baseline values are listed below the regression estimates and standard error, and include all students within two points below the threshold.

Appendix Table 3. Impacts of AP threshold on individual-level covariates

	All Students	Credit-granting thresholds	Non-credit thresholds
Female	0.009	0.011	0.006
	(0.009)	(0.010)	(0.017)
	55.5%	57.9%	48.9%
African-American	-0.003	-0.004	0.001
	(0.004)	(0.005)	(0.006)
	5.5%	6.2%	3.8%
Asian	-0.002	0.001	-0.011
	(0.005)	(0.005)	(0.009)
	7.5%	7.4%	7.7%
Hispanic	0.009	0.012	0.003
	(0.006)	(0.007)	(0.012)
	14.7%	15.4%	12.6%
White	-0.005	-0.007	-0.002
	(0.008)	(0.010)	(0.015)
	69.4%	68.0%	73.3%
Took SAT	-0.002	0.002	-0.014*
	(0.003)	(0.004)	(0.006)
	96.1%	95.7%	97.3%
SAT score	2.404	3.873	-3.530
	(2.313)	(2.583)	(4.125)
	1205	1183	1262
Total AP exams taken	0.009	0.038	-0.095
	(0.030)	(0.034)	(0.062)
	3.5	3.4	3.8
Parent Education: High	-0.015+	-0.015	-0.018
	(0.009)	(0.010)	(0.017)
	57.5%	56.2%	61.2%
Income: High	-0.005	-0.001	-0.018
	(0.006)	(0.007)	(0.013)
	14.8%	14.2%	16.3%
N	51251	37975	13276

Notes. + p<0.1, * p<0.05, ** p<0.01. All students in the sample graduated from a Florida high school and attended an in-state public college. Estimates derive from equation (1) in the text, which provides a regression discontinuity estimate using a linear specification over a bandwidth of six AP points and includes test-by-year and cohort fixed effects. An observation is a unique student-by-test observation, with standard errors clustered by student. Baseline values are listed below the regression estimates and standard error, and include all students within two points below the threshold.

Appendix Table 4. Impacts of crossing AP threshold on courses attempted at non-credit thresholds

	(1)	(2)	(3)	(4)
	STEM		Non-STEM	
	1 year	4 years	1 year	4 years
Total courses	-0.032	0.163	-0.010	0.009
	(0.135)	(0.500)	(0.122)	(0.445)
Total courses in AP subject above AP exam	-0.016	-0.016	0.011	0.031
	(0.039)	(0.093)	(0.012)	(0.053)
Took zero courses (%)	0.005	0.014	-0.007	-0.010
	(0.026)	(0.025)	(0.010)	(0.017)
Took one course (%)	0.006	0.016	0.004	-0.006
	(0.024)	(0.023)	(0.009)	(0.013)
Took two or more courses (%)	-0.011	-0.031	0.003	0.016
	(0.017)	(0.025)	(0.004)	(0.013)
STEM courses	-0.073	0.241	-0.254*	-0.288
	(0.114)	(0.396)	(0.117)	(0.365)
Non-STEM courses	0.025	-0.076	0.207+	0.188
	(0.121)	(0.469)	(0.117)	(0.420)

Notes. + p<0.1, * p<0.05, ** p<0.01. All students in the sample graduated from a Florida high school and attended an in-state public college. Estimates derive from equation (1) in the text, which provides a regression discontinuity estimate using a linear specification over a bandwidth of six AP points and includes test-by-year and cohort fixed effects. An observation is a unique student-by-test observation, with standard errors clustered by student. Baseline values are listed below the regression estimates and standard error, and include all students within two points below the threshold. STEM and non-STEM regressions utilize 5,758 and 7,533 observations, respectively.

Appendix Table 5. Impacts of crossing AP threshold on concentration of depth vs. breadth of courses taken, four-year persisters

	(1)	(2)
	STEM	Non-STEM
Depth		
Top 3 departments associated with AP exam major	0.237+	0.007
	(0.135)	(0.036)
	2.1	0.7
Departments less associated with AP exam major	-0.274	0.412*
	(0.347)	(0.208)
	28.3	29.3
Breadth		
Number of departments	-0.428*	-0.088
	(0.189)	(0.120)
	19.4	20.0
Number of departments taking one course	-0.357*	0.011
	(0.174)	(0.109)
	12.5	13.2
Number of departments taking two or more courses	-0.070	-0.099+
	(0.085)	(0.056)
	6.9	6.8

Notes. + p<0.1, * p<0.05, ** p<0.01. All students in the sample graduated from a Florida high school and attended an in-state public college. Estimates derive from equation (1) in the text, which provides a regression discontinuity estimate using a linear specification over a bandwidth of six AP points and includes test-by-year and cohort fixed effects. An observation is a unique student-by-test observation, with standard errors clustered by student. Baseline values are listed below the regression estimates and standard error, and include all students within two points below the threshold. STEM and non-STEM regressions utilize 8,825 and 24,557 observations, respectively.

Appendix Table 6. Most commonly attempted departments by major, STEM exams

	Biology			Calculus AB			Calculus BC		
Order	Dept.	%	Cum. %	Dept.	%	Cum. %	Dept.	%	Cum. %
1	Chemistry	15.3%	15.3%	Physics	14.4%	14.4%	Physics	14.3%	14.3%
2	Process Biology Genetics	13.5%	28.8%	Engineering: General	10.4%	24.8%	Engineering: General	8.4%	22.7%
3	Microbiology	6.7%	35.5%	Electrical and Computer Engineerir	3.9%	28.6%	Electrical and Computer Engineerir	4.9%	27.6%
4	Biological Science	5.0%	40.4%	Mathematics: Calculus & Precalcul	3.8%	32.4%	Mathematics: Calculus & Precalcul	4.0%	31.5%
5	Health Science	3.9%	44.3%	Mathematics: Applied	3.4%	35.8%	Mechanical Engineering	3.7%	35.3%
6	Interdisciplinary Honors	3.3%	47.7%	Mechanical Engineering	3.0%	38.8%	Mathematics: Applied	3.7%	38.9%
7	Physics	3.3%	51.0%	Computer and Information Science	3.0%	41.8%	Chemistry	3.4%	42.4%
8	Zoology	2.9%	53.8%	Civil and Coastal Engineering	2.8%	44.6%	English Composition	3.0%	45.4%
9	Spanish	2.6%	56.4%	Economics	2.8%	47.4%	Civil and Coastal Engineering	2.8%	48.2%
10	Anthopology	2.0%	58.4%	English Composition	2.6%	50.0%	Statistics	2.7%	50.9%

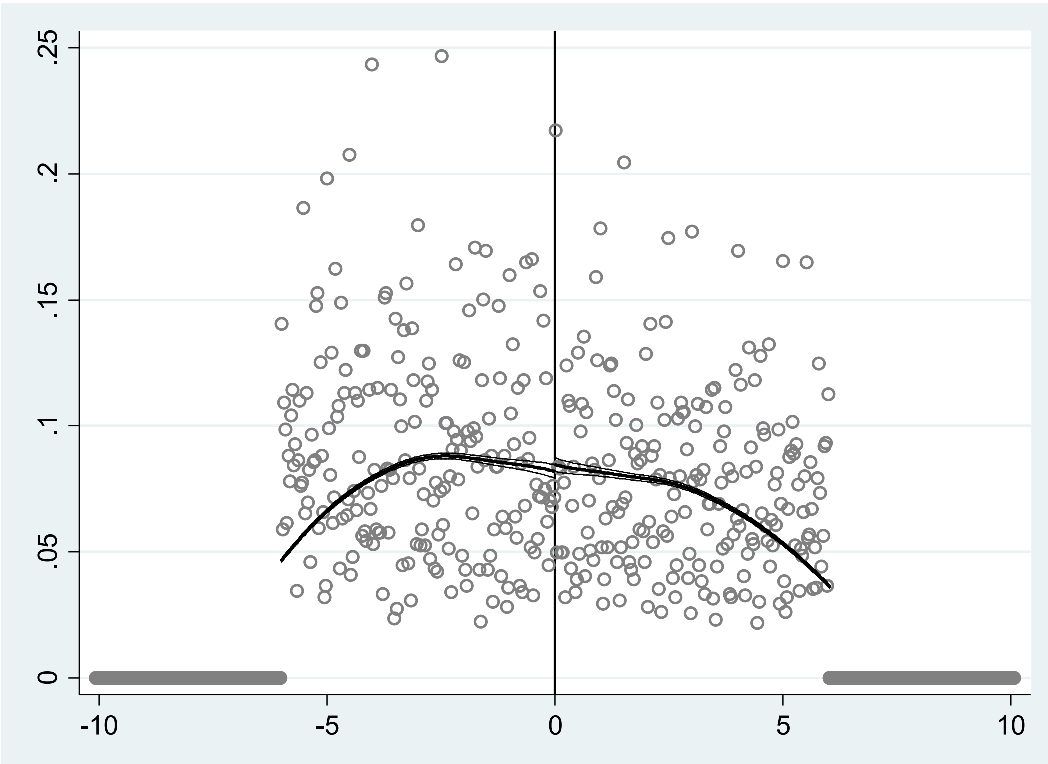
	Chemistry			Physics B			Statistics		
Order	Dept.	%	Cum. %	Dept.	%	Cum. %	Dept.	%	Cum. %
1	Chemistry	20.5%	20.5%	Physics	16.5%	16.5%	Physics	13.6%	13.6%
2	Physics	12.9%	33.5%	Chemistry	14.1%	30.5%	Engineering: General	10.6%	24.2%
3	Process Biology Genetics	3.4%	36.9%	Mathematics: Calculus & Precalcul	3.5%	34.1%	Mathematics: Calculus & Precalcul	3.9%	28.1%
4	Mathematics: Calculus & Precalc	2.8%	39.7%	Interdisciplinary Honors	2.7%	36.7%	Electrical and Computer Engineerir	3.6%	31.6%
5	Interdisciplinary Honors	2.6%	42.3%	Mathematics: Applied	2.6%	39.3%	Mathematics: Applied	3.5%	35.1%
6	Spanish	2.5%	44.8%	Spanish	2.4%	41.7%	Computer and Information Science	3.1%	38.2%
7	Microbiology	2.3%	47.1%	Process Biology Genetics	2.4%	44.1%	Mechanical Engineering	3.0%	41.1%
8	Economics	2.0%	49.1%	Mathematics: Algebraic Structures	2.3%	46.4%	Economics	2.9%	44.0%
9	Anthopology	1.8%	51.0%	Economics	2.0%	48.4%	Chemistry	2.7%	46.7%
10	Biological Science	1.5%	52.5%	Microbiology	2.0%	50.4%	English Composition	2.6%	49.3%

Appendix Table 6. Most commonly attempted departments by major, Non-STEM exams

	US Government			US History			English Language		
Order	Dept.	%	Cum. %	Dept.	%	Cum. %	Dept.	%	Cum. %
1	Anthopology	6.2%	6.2%	European History	8.1%	8.1%	Literature	6.1%	6.1%
2	Political Science	5.6%	11.8%	American History	6.7%	14.8%	English Literature	5.9%	12.0%
3	Economics	5.4%	17.2%	History	4.5%	19.3%	American Literature	4.6%	16.6%
4	International Relations	4.7%	21.9%	Spanish	3.6%	22.9%	Creative Writing	4.5%	21.1%
5	Comparative Politics	3.2%	25.1%	Anthopology	3.4%	26.3%	Spanish	3.9%	25.0%
6	Spanish	3.1%	28.2%	Economics	2.4%	28.6%	English	3.8%	28.8%
7	Sociology, General	2.2%	30.4%	Political Science	2.4%	31.0%	Speech Communication	3.1%	31.9%
8	Religion	2.0%	32.4%	Mathematics: General & Finite	2.2%	33.3%	English Composition	2.9%	34.8%
9	Philosophy	2.0%	34.4%	International Relations	2.2%	35.4%	Mathematics: General & Finite	2.6%	37.4%
10	Mathematics: General & Finite	1.7%	36.1%	Religion	2.1%	37.5%	Anthopology	2.5%	39.9%

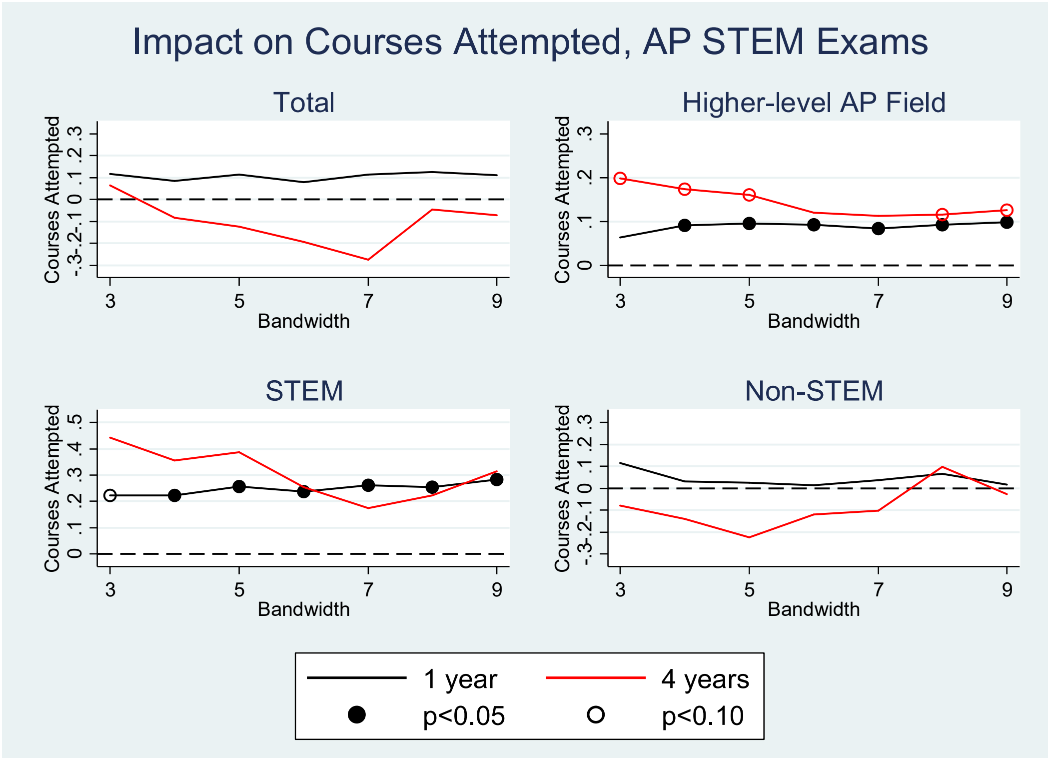
	English Literature			Psychology		
Order	Dept.	%	Cum. %	Dept.	%	Cum. %
1	Literature	6.4%	6.4%	Psychology	7.2%	7.2%
2	English Literature	6.2%	12.6%	Social Psychology	5.9%	13.1%
3	American Literature	4.7%	17.3%	Clinical Psychology	5.7%	18.8%
4	Creative Writing	4.6%	21.9%	Experimental Psychology	4.4%	23.2%
5	Spanish	3.9%	25.8%	Developmental Psychology	4.3%	27.5%
6	English	3.7%	29.4%	Spanish	3.8%	31.4%
7	English Composition	3.1%	32.5%	Psychobiology	3.0%	34.4%
8	Mathematics: General & Finite	2.8%	35.3%	Anthopology	2.6%	36.9%
9	Speech Communication	2.7%	38.0%	Sociology, General	2.5%	39.4%
10	Anthopology	2.6%	40.6%	Personality	2.4%	41.9%

Appendix Figure 1. McCrary test for continuity of observations at threshold



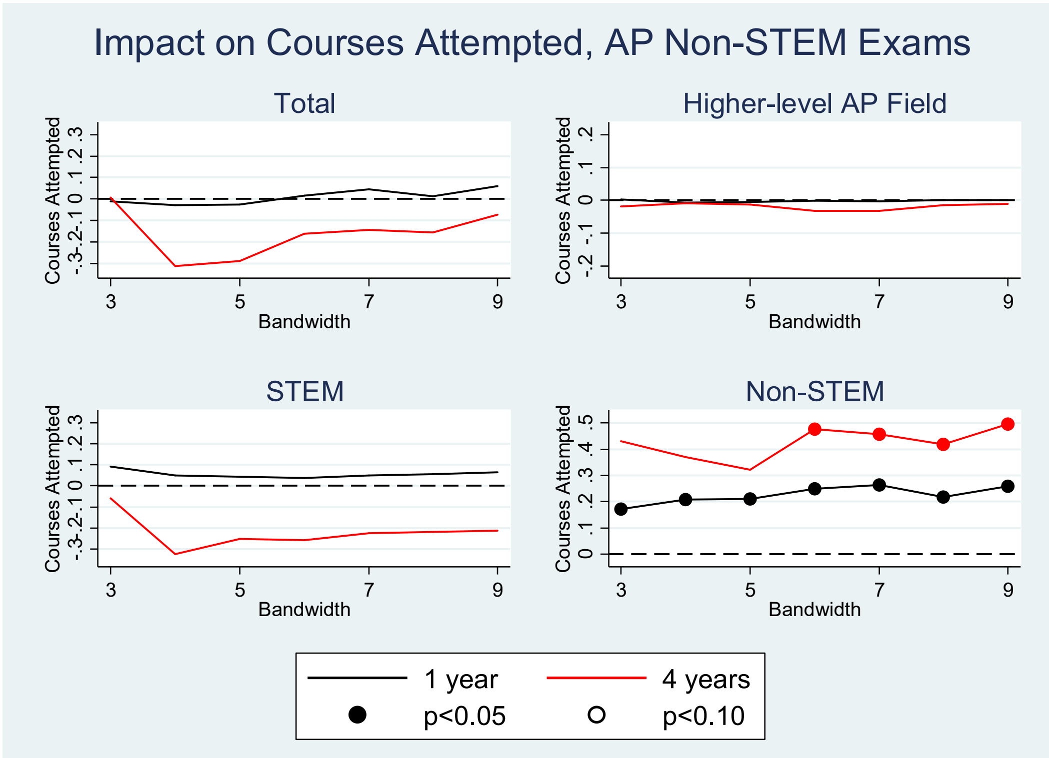
Notes. Figure includes all student-by-exam observations within 6 points of integer AP score thresholds. Sample includes all Florida high school graduates from 2004 to 2006 who attended in-state public colleges. McCrary test utilizes Stata 'dcdensity' command.

Appendix Figure 2. Impacts of crossing AP STEM thresholds on courses attempted, robustness to bandwidth



Notes. Sample includes all high school graduates from 2004 to 2006 in one large state who attended in-state public colleges. Each point estimate derives from equation (1) in the text, which constitutes a regression discontinuity estimate using a linear specification over a bandwidth that varies from 3 to 10 points. Results that are statistically significant at the $p<0.05$ and $p<0.10$ level are denoted by solid and hollow circles, respectively.

Appendix Figure 3. Impacts of crossing AP Non-STEM thresholds on courses attempted, robustness to bandwidth



Notes. Sample includes all high school graduates from 2004 to 2006 in one large state who attended in-state public colleges. Each point estimate derives from equation (1) in the text, which constitutes a regression discontinuity estimate using a linear specification over a bandwidth that varies from 3 to 10 points. Results that are statistically significant at the $p<0.05$ and $p<0.10$ level are denoted by solid and hollow circles, respectively.