First, Do No Harm. But Can We Do Better? An Evaluation of a Statewide Developmental Education Reform

Zeyu Xu
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Zeyu Xu
American Institutes for Research / CALDER

Ben Backes
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1400 Crystal Drive 10th Floor, Arlington, VA 22202

202-403-5796 • www.caldercenter.org

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Abstract

Research shows that the corequisite developmental education (DE) model outperforms the prerequisite model, largely by mitigating the negative effects of prerequisites on student outcomes. While this is an important first step, evidence is limited on whether corequisite DE has added value when compared to not requiring DE and, in math, whether the corequisite "effect" is in fact driven by pathway reforms that have typically accompanied the transition toward corequisite DE. We use data from the Kentucky Community and Technical College System (KCTCS) to describe a complex set of support options available to students depending on their academic readiness levels and chosen math pathways and, using a regression discontinuity approach, estimate the effects of having such support on first-year college outcomes. For students with very low initial skills in math and English, requiring a prerequisite course in addition to corequisites produces null or negative effects compared to corequisite DE alone. However, students with very low math skills benefit from taking corequisite non-college algebra courses, and students with relatively high initial English skills benefit from corequisite English. The corequisite benefits in math are concentrated among female students who took advantage of the pathway reforms to take and pass non-college algebra math courses, while the English benefits are more pronounced among male and part-time students.

1. Introduction

Community colleges play a vital role in expanding the college-educated workforce. According to a Community College Research Center analysis,[1] community colleges enrolled more students than any other types of higher education institution before the COVID-19 pandemic. Nearly half of bachelor's degree recipients enrolled at a community college at some point (National Student Clearinghouse, 2017). Even after a steep drop during the pandemic, enrollment at community colleges accounted for 37% of all undergraduate enrollment in fall 2023, nearly as large as the enrollment at public 4-year colleges.

A consequence of providing broad access to postsecondary education is that community colleges enroll students with a wide range of precollege skills. It is estimated that about two-thirds of community college students arrive unprepared for college-level courses (Bailey & Jaggars, 2016). The percentage of students who are unprepared for college math is even higher (Holzer & Xu, 2021). In Kentucky, the site of this study, 83% of students who enrolled in the community college system entered with ACT math scores below college readiness benchmarks. Research suggests that precollege skills can explain at least two-thirds of the disparities in college graduation rate (Arcidiacono & Koedel, 2014). It is therefore not surprising that community college graduation rate has stagnated at around 40% for over two decades. In the science, technology, engineering, and math (STEM) fields, only 19% of community college students attain a STEM credential within six years (van Noy & Zeidenberg, 2014). How to balance the mission of democratizing access to postsecondary education and making sure the time and resources invested in a community college education are well spent will be an ongoing

[1] https://public.tableau.com/app/profile/john.fink/viz/UndergraduateEnrollmentTrendsbySector/Summary.

challenge. Improving how we help academically underprepared community college students achieve their goals must be a key part of the solution to the puzzle.

The traditional policy response to college readiness deficiency has been prerequisite developmental education (DE). It requires students deemed not ready for college courses to take a sequence of non-credit-bearing courses (prerequisites) before enrolling in credit-bearing college courses. But it has become clear that prerequisite DE is not working as intended. Despite billions of dollars in annual spending (Scott-Clayton & Rodriguez, 2015), students participating in DE still struggle in college. According to Jaggars and Stacey (2014), among students who are referred to three or more prerequisite courses, 11% eventually pass a gateway course in math and 29% pass a gateway course in English. A meta-analysis of 11 rigorous impact studies concludes that prerequisite DE has negative, statistically significant, and substantively large effects on key college outcomes such as progressing through college gateway courses (Valentine et al., 2017).

In response to the ineffectiveness of the prerequisite model, many community college systems across the country have implemented a suite of DE reforms. These often include corequisite DE and math pathway reforms in conjunction. Under the corequisite model, students who are deemed not ready for college-level coursework are allowed to directly enroll in a credit-bearing, college-level course combined with paired developmental support. Corequisite DE has been touted as a major reconceptualization for how to best support underprepared college students academically (Bailey & Jaggars, 2016). Following Baltimore County Community College's implementation of its Accelerated Learning Program (ALP) in 2007, Tennessee became the first state to implement the corequisite model statewide in 2015. As of 2023, more than 77% of community colleges around the country were offering corequisites (Litschwartz et al., 2023). In addition, pathway reforms in math now allow students to graduate without first passing college algebra, with non-college algebra courses such as applied statistics being used to meet graduation requirements for some majors.

There is fairly consistent evidence that moving away from prerequisite DE is a step in the right direction. For example, descriptive statistics show that passing rates of introductory college courses improved substantially after replacing prerequisite DE with corequisite DE.[2] In addition, as we will discuss in the next section, rigorous, causal research evidence consistently supports the conclusion that corequisite DE (along with reforms to math pathways) leads to better early college outcomes *relative to prerequisite DE*, probably by mitigating the negative impact of prerequisites (Ran & Lin, 2022).

While doing no harm to academically underprepared students is an important first step, it is natural to ask whether corequisite and math pathway reforms are better than *not requiring DE at all or making DE optional*.[3] Emerging evidence suggests that corequisite and math pathway reforms do not appreciably improve student skills and knowledge when compared to no DE support. In particular, the combined effect of the reforms in math relative to prerequisite DE is largely driven by math pathway reforms (Ran & Lin, 2022). This means recent DE reforms may not be addressing the skills deficiencies in math and English that are one of the key reasons why graduation rates in community colleges are persistently low. Given the high cost of implementing these new DE strategies (Belfield et al., 2013; Dong et al., 2025), the answer to this question will have important implications for resource allocation.

Relatedly, even when compared to prerequisite DE, it is unclear whether corequisite and math pathway reforms are the better choice for *all* students. Existing evidence on the efficacy of

[2] For example, in Tennessee, the passing rate of college math among community college students increased from 12% to 51% and from 31% to 59% for writing after replacing prerequisite DE with corequisite DE (Denley, 2016).
[3] For example, DE has been optional in Florida since 2013.

recent DE reforms typically focuses on students who are close to being college ready. But most students who are not college ready tend to be far below readiness benchmarks. For example, among students who scored below the ACT college readiness cutoffs, 88% missed the benchmark by 3 or more points[4] in math and 76% in English (ACT, 2019). Because corequisite DE requires students to simultaneously enroll in college-level courses and catch up on knowledge that is necessary for college-level instruction, it could be more demanding than prerequisite DE (Boylan & Trawick, 2015). Whether it is the right choice for students with very weak initial skills is far from clear. The only existing evidence of which we are aware – also based on the Tennessee experience – suggests that the effect of corequisite DE does vary by students' initial skills (Ran & Lee, 2025). Conversely, although prerequisite DE has adverse impacts on students who are close to being college ready, it may benefit students with lower levels of academic preparation (Boatman & Long, 2017).

Using data from the Kentucky Community and Technical College System (KCTCS), our study aims to expand the sparse evidence base on the effect of recent DE reforms centered around corequisite DE delivery and multiple math pathways relative to no developmental support and how the impact of these reforms varies by students' initial achievement level. At KCTCS, corequisite DE replaced prerequisite DE across all 16 colleges in the 2019-20 school year. While its DE reform shares core features with recent reforms in other colleges (such as providing precollege- and college-level instructions in the same semester and multiple pathways in math), a distinctive feature of KCTCS' DE reform is the existence of multiple placement cutoff points for math and English. Students at or above the higher cutoff (an ACT score of 22 in math and 18 in English) can enroll in college-level math and English without supplemental support. Students

[4] Equivalent to about 0.7 standard deviations in math and 0.5 standard deviations in English.

below the higher cutoff can enroll in college math and English with paired corequisite courses. However, students with very low initial proficiencies (below 19 in ACT math and 14 in ACT English) enroll in a hybrid DE sequence that requires the completion of one prerequisite course followed by college-level courses with paired corequisites. This design allows us to evaluate the effectiveness of various DE strategies at two distinct margins.

Specifically, we seek evidence on the efficacy of corequisite DE relative to no DE support (at the higher cutoff) and the extent to which hybrid DE helps students with very low initial skills in math and English (at the lower cutoff). The study focuses on four early momentum measures that are shown to be strong predictors of college completion (Jenkins & Bailey, 2017): college-level math and English course enrollment and completion within the first year, persistence to the second year, and the number of completed credits during the first year. Because ACT is mandatory for all Kentucky public high school juniors, ACT test scores are available for placement decisions for most recent high school graduates, and we use a regression discontinuity (RD) design to address these research questions.

Our study makes several contributions to the literature on developmental education reform. First, we provide causal evidence on the effectiveness of corequisite DE relative to *no* developmental support, a comparison that has received far less attention than the corequisite-versus-prerequisite contrast that dominates the existing literature. Second, we evaluate a DE policy that features *two* placement cutoffs rather than one, allowing us to separately identify the effects of corequisite DE at different points in the readiness distribution and, critically, to assess whether hybrid DE (prerequisite followed by corequisite) adds value for students with the lowest initial skills — a population largely absent from prior causal work. Third, we disentangle the math pathway reform effect from the corequisite effect by leveraging major-based pathway assignments, contributing to an emerging debate about whether reported corequisite gains in math are driven by instructional support or by course substitution toward lower-level gateway courses. Finally, we document meaningful heterogeneity in corequisite effects by gender and enrollment intensity, findings that carry direct implications for targeted advising and support.

We find that, despite the intention to provide extra support for students with the lowest initial skills, adding prerequisites on top of corequisites reduces first-year enrollment rates in college algebra and English courses by 3 and 6 percentage points respectively. The efficacy of corequisite DE relative to no DE support, on the other hand, is mixed. Corequisites in English improve the likelihood that students take and complete college English (by 4-5 percentage points), increase the total credits earned in the first year (by 0.78 credits), and raise the GPA in English (by 0.15 on a 4.0 scale). In math, corequisites appear to help students take and succeed in non-college algebra courses like applied statistics (by 2 percentage points) but not in college algebra or higher-level math courses. The positive effects of corequisites in English are stronger among men and part-time students, whereas the positive effects of corequisites on non-college algebra outcomes are concentrated among women. Overall, we observe substitution away from college algebra towards more applied math courses that results in no overall change in the likelihood of taking or passing a college-level math course by the end of the first year in college.

In the rest of this paper, we first review the related literature on prerequisite and corequisite DE. This is followed by a description of the current DE model at KCTCS. Study design, including sample and data, sample characteristics and empirical strategies, is presented in Section 4. Section 5 reports study findings, and Section 6 concludes.

2. Theory and Empirical Evidence

2.1 Why Corequisite DE Might Work Better Than Prerequisite DE

Researchers have proposed several explanations for why prerequisite DE has not been working as intended. Students assigned to prerequisite DE on average take at least three remedial courses (Chen, 2016).[5] And a lengthy prerequisite sequence can add confusion and cost to underprepared students, leading many developmental students to quit before reaching college-level courses (Bailey, et al., 2010; Bailey & Jaggars, 2016). Students required to take prerequisite courses may also be disappointed and discouraged by the realization that completing a high school diploma does not prepare them adequately for the next step in their education (Bettinger & Long, 2009). Such stigma may be the reason why nearly 30% of students referred to prerequisite DE never start the DE sequence (Scott-Clayton & Stacey, 2015). And finally, prerequisite courses may be perceived by students as having limited relevance and usefulness because those courses are often taught with a "drill and practice" pedagogical style (Boatman, 2012; Grubb, 2013). In short, prerequisite DE is viewed as producing limited benefits while imposing unnecessary financial, psychological, and opportunity costs on academically underprepared students, thus reducing student engagement and motivation (McPartland, 1993).

Corequisite DE is designed to lower these costs by accelerating students' exposure to college-level contents and instruction.[6] By placing developmental students directly in college-level courses (also known as "mainstreaming"), corequisite DE could in theory allow these students to observe and learn from their more advanced peers. This could include not just academic content but also important college navigation behaviors such as study habits, when to seek help, and time-management techniques (Moss et al., 2014; Sacerdote, 2001, 2011). In

[5] Underrepresented minority (URM) students take even more. For example, Black and Hispanic students take an average of 3.5 and 4 courses, respectively, compared to an average of 2.4 courses for White students.
[6] Other forms of DE acceleration include the "paired courses" model (e.g., Denver's FastStart math) which combines two sequential developmental courses into one semester while keeping the same credit hours, and the "compressed sequences" models (e.g., CUNY, Chabot) which reduces the number of required credit hours.

addition to the potential benefits of mainstreaming, corequisite reforms are almost invariably accompanied by math pathway reforms in which college algebra is no longer required for all majors. Students can opt to take courses like applied statistics to meet their college graduation requirements. The diversification of math pathways adds a second mechanism that could further increase the relevance of coursework and hence encourage student engagement and completion (Hayward et al., 2014; Yamada, 2014).

2.2 Comparing Corequisite and Prerequisite DE in Controlled Settings

Compared to prerequisite DE, corequisite DE has been found to improve gateway course completion in both math and English during the first year in college substantially. However, these findings are applicable to students who were close to college readiness benchmarks, and most studies found no statistically significant improvement in other student outcomes such as persistence, credit accumulation, transfer to a 4-year college, or college completion.

In English, Cho et al. (2012) and Jaggars et al. (2015) evaluated the English corequisite model implemented among 1,800 students in the Community College of Baltimore County using regressions and propensity score matching. Compared to students taking the highest level of prerequisite English, students taking the corequisite option were found to be 36 percentage points more likely to complete a gateway English course by the end of the first year and more likely to persist to the second year in college. Similarly, a randomized controlled trial (RCT) conducted among 1,200 students in 5 large urban community colleges in Texas found stronger student outcomes among students assigned to corequisite English than students assigned to the highest level of prerequisite English (Miller et al., 2021). Corequisite English students were 21 percentage points more likely to pass gateway English within the first year in college and 6.4

percentage points more likely to complete English II by Year 2. However, there was no detectable effect on persistence.

In math, the reported "corequisite effects" are typically the combined effects of corequisite and math pathway reforms. Logue et al. (2016) and Logue et al. (2019) conducted an RCT among about 900 first time freshmen who planned to major in disciplines that did not require College Algebra at 3 City University of New York (CUNY) colleges. Compared to students assigned to take prerequisite Elementary Algebra, students assigned to corequisite College Statistics were 17 percentage points more likely to pass gateway math and 8 percentage points more likely to graduate or transfer to 4-year universities. A recent follow-up study found further evidence of long-term benefits in terms of bachelor's degree completion within 5 years and earnings in years 5 to 7 (Douglas et al., 2023). The CUNY RCT is the only study that found positive effects on longer-run student outcomes. Using data from 8 community colleges in Texas and an RD design, Meiselman and Schudde (2022) found that corequisite math course placement (not necessarily enrollment) increased the passing rate of gateway math by 13 percentage points, but no statistically significant effect on degree attainment or transfer to 4-year colleges was detected.

These studies were conducted among institutions that *elected* to participate and to offer corequisite options. The participating colleges represent only a small portion of the total number of colleges within each respective college system for the studies (e.g., Texas has over 80 community colleges and CUNY has 25). And the voluntary nature of study participation raises questions about self-selection at the college level.[7] As we have learned from Baltimore's ALP

[7] There are also potential self-selection concerns at the student level in the two math studies. In the CUNY RCT, students who were assigned to corequisite statistics would have to start over in a prerequisite algebra course had they failed to receive a passing grade in statistics. Given this condition, it is plausible that students who were willing to participate in the experiment had higher-than-average level of confidence in passing college statistics. In the

program and more broadly, reforms during the "completion agenda" era such as Achieving the Dream and the Developmental Education Initiative, positive outcomes observed in pilot reforms or under controlled conditions rarely scale because the intensity and quality of program implementation cannot realistically be matched during scaling up (Adam & McKusick, 2014; Bailey, 2012).

2.3 Evidence from a Statewide Corequisite Model and Emerging Nuances

The first study on the effect of corequisite DE implemented statewide was conducted by Ran and Lin (2022) in Tennessee. Using an RD design, they largely confirmed the findings generated from experimental and voluntary settings. Relative to prerequisite DE, being *placed* (i.e., the intent-to-treat effect) into corequisite DE increased the likelihood of gateway course completion during the first year in college by 15 and 18 percentage points in math and English, respectively. These effects dissipate over time, but they remain statistically significant for English by the end of Year 3 in college. Corequisite DE generally has no statistically significant effect on other college outcomes like credits attempted or earned, persistence, and transfer to 4-year colleges.

In addition to confirming the findings reported in earlier studies conducted in controlled settings, evidence from Tennessee adds important nuances to the existing evidence on corequisite DE. First, Ran and Lin (2022) found that the positive effect of corequisite DE relative to prerequisite DE was almost entirely driven by corequisite DE mitigating the negative impact of prerequisite DE. Corequisite DE placement does not have statistically significant effects on

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Texas RD study, half of the students in the participating colleges had no Texas Success Initiative (TSI) assessment score. Missingness of TSI scores is not random; only students who met other criteria (such as having taken prior college coursework or having high scores on the ACT, SAT or the state's standardized tests) are exempt from the TSI assessment. Because the TSI score is the running variable, students lacking TSI scores were excluded from the study. This raises the concern about the representativeness of those students included in the study.

gateway course completion *compared to no DE*. Second, evidence suggests that the most likely driver of the corequisite impact (relative to prerequisite DE) in math is the expansion of math pathways rather than replacing prerequisite DE with corequisite DE. That is, students were more likely to pass gateway courses like applied statistics than college algebra, but for students in majors that required college algebra, neither corequisite nor prerequisite placement increased their chances of passing the course.

These findings have helped move the field beyond comparing corequisite and prerequisite DE in aggregate, but more evidence is needed. For example, a study from Texas (Austin et al., 2024) found that corequisite DE benefited students even when compared to no DE support, contradicting a key finding from Tennessee. Additionally, a deeper dive into the same Tennessee model discovered that while higher-scoring developmental students benefited more from corequisite DE in math than lower-scoring students, the reverse is true for English for unknown reasons (Ran & Lee, 2025). Heterogeneity in corequisite effects echoes findings from the California Community College system (Ngo & Melguizo, 2025). Taken together, the latest empirical evidence suggests that we do not have all the answers to DE reforms yet.

3. Developmental Education at KCTCS

3.1 The General Education Core Curriculum

KCTCS students who aim to earn associate degrees, diplomas and certificates are required to complete KCTCS' general education core curriculum at the level that corresponds to the credential. The curriculum encompasses six competencies, all of which are required for associate degrees. Although the number of required credits and course selection for each competency vary by degree type, all associate degree programs require students be college ready in math and English to enroll in those courses. By comparison, students seeking diplomas and certificates only need 6 and 3 general education credits, and they do not necessarily need to demonstrate college readiness to enroll in the lowest level of courses[8] that can meet those requirements. For this reason, DE has the highest stakes for degree-seeking students who have not yet met college readiness benchmarks, and our study focuses on associate degree program students only (including those who were undecided about their major). According to Holzer and Xu (2021), degree-seeking students account for about 83% of credential-seeking students at KCTCS.

3.2 Corequisite DE at KCTCS

Historically, DE at KCTCS was provided in the form of prerequisite courses. Each course was typically 3 credit hours, but they were not counted as college credits. Students with very low initial academic skills in math and English could be required to take up to three terms of prerequisite courses. Under the prerequisite DE model, only 16.3% of KCTCS students who did not meet statewide college readiness standards would go on to complete a gatekeeper course by the end of the freshman year (Council for Postsecondary Education [CPE], 2019). Recognizing the barriers confronting students facing a long sequence of developmental courses, CPE introduced the corequisite model to accelerate the timetable for students to earn college credits in areas in which they are not yet college ready. After several years of preparation and experimentation, including offering a limited set of corequisite options for students, corequisite DE was implemented systemwide in fall 2019.

Under KCTCS's new corequisite model, developmental support is primarily delivered in the format of corequisite math and English courses.[9] Each corequisite course is typically 1–2 credit hours (compared to 3 credits in Tennessee) that count toward college credits. Each course

[8] For example, OST 108 – Editing Skills for Office Professionals and OST 213 – Business Calculations for The Office Professional.
[9] We interviewed two faculty representatives from each of the 16 KCTCS colleges and conducted document reviews to understand the implementation of corequisite DE in KCTCS.

is paired with a college-level course, and developmental students are required to take both simultaneously. A typical college-level course meets twice a week, and its paired corequisite course meets once or twice a week. Both college-level and corequisite courses span 16 weeks, although in some cases the corequisite course lasts just 12 weeks and may start a few weeks before or after the paired college-level course starts. Typically, paired courses are taught by the same instructor, and both college-ready and non-ready students enroll in the same college course sections without any target student mix ratio. However, paired courses can sometimes have different instructors, and college-ready and non-ready students could be asked to register for different sections of the same college-level course. These decisions appear to be driven by the demand and supply of certain courses rather than predetermined policies.

Corequisite instructors typically use their lesson time to provide on-demand support rather than follow any systematically designed developmental curricula. For example, corequisite classes are often used to address questions from the previous college-level class and preview the upcoming college-level class. In addition to corequisite courses, developmental students also receive help from teaching assistants for the college-level courses, instructor office hours, tutoring services provided through KCTCS's Academic Center for Excellence, and online tutoring support via NetTutor in Blackboard. However, these resources are accessible to all KCTCS students. We do not have information about the extent to which these resources have been used more or less frequently by developmental students than their peers.

3.3 Math Pathway Reforms and Gateway Courses

Corequisite DE reforms are often accompanied by math pathway reforms, and KCTCS is no exception. Recognizing that not all fields of study need college algebra, which is the traditional gateway math course, KCTCS now offers multiple math pathways to students depending on the math skills that their programs and future jobs are likely to require. These primarily include the Quantitative Reasoning (QR) and College Algebra (CA) pathways. When classifying majors into pathways based on the most-commonly taken math course in the major, about 20% of students take majors in the QR pathway and 79% in the CA pathway.[10] Students in associate in applied science (AAS) degree programs like computer and information technologies can take the QR pathway. Students in associate in arts (AA) and associate in science (AS) degree programs like medical sonography can take the CA pathway. The addition of the QR pathway has expanded the course options that students could take to meet the graduation requirement for math. The gatekeeper courses for the QR pathway include STA 151 – Introduction to Applied Statistics), MAT 141 – Liberal Arts Mathematics, and PHI 250 – Symbolic Logic.

3.4 Multiple Tiers of College Readiness and Course Placement

College readiness benchmarks in math and English,[11] established by CPE, are used to determine course placement. KCTCS primarily relies on ACT subject test scores to measure college readiness because the ACT is mandatory for all high school juniors in Kentucky public schools. Other measures that colleges could use to determine students' college readiness include the high school GPA (as of 2020-21), ACCUPLACER, ALEKS, EdReady, KYOTE, and the SAT.

Adding to the complexity of KCTCS's assessment and placement policies is the existence of multiple tiers of college readiness. Two cutoffs divide college readiness into three main tiers for each subject (Table 1). In English, the two cutoffs are 18 and 14 on ACT English. Students with a score of 18 or higher can enroll in college English directly. Students who missed the

[10] About 1% of students choose majors where no students are observed in math courses during the first year.
[11] There are also college-readiness benchmarks for reading. However, students are considered college ready in reading if they complete 12 or more credits in any general education courses. Because an associate degree requires at least 15 general education credits, demonstrating college readiness in reading does not impose an extra burden for students who are on track to degree completion.

higher cutoff but scored at least 14 can enroll in college English courses with paired corequisites. Students who missed the lower cutoff are required to complete a prerequisite English course before taking college-level English with paired corequisite support.

In math, the two cutoffs are 22 and 19 on ACT math. Math course placement is determined by these cutoffs in conjunction with math pathways discussed above (Table 1). Students scoring 22 or higher are exempt from any form of DE. Students with scores between the higher and lower cutoffs are considered ready for the QR pathway, but not for the CA pathway. As a result, students in this score range could either enroll directly in college-level QR math courses or take college algebra with its paired corequisite. Finally, students who missed the lower cutoff must enroll in QR math courses with paired corequisite courses or complete a prerequisite math course before enrolling in a CA pathway math course with corequisite support.[12]

4. Study Design

4.1 Data and Sample

We use student-level administrative records obtained from the Kentucky Center for Statistics. These data cover all students newly enrolled in KCTCS between 2019-20 and 2023-24 school years and include information on student characteristics such as gender, race/ethnicity, full/part-time status and age; enrollment data such as college, year, credential type, and field of study; transcript data such as enrolled and completed courses, course grades and credits, and uniform course codes. For recent high school graduates (2015 and later), their data are also linked with high school records which include additional background information such as school

[12] Reflecting the diversity of community college students, even lower cutoffs exist for both math (16) and English (12). Students who missed these cutoffs are generally considered in the pre-algebra domain and not meeting early high school standards. Fundamentally different strategies are likely needed to help those students.

lunch status, whether English was used at home, special education status, and ACT test scores from the 11th grade.

Our study focuses on all first-time freshmen enrolled in a KCTCS degree program between 2019–20 and 2023–24 who have ACT scores. These students account for 73% of all degree-seeking students in KCTCS. Students who are excluded from our study tend to be older, which is likely the reason why they do not have ACT scores on file. Compared to the study sample, students in the excluded sample are more likely to be at least 24 years old (59% vs. 7% in the study sample), attend part-time (55% vs 34%), and not be White (68% vs 76% White) (Table 2). Excluded students also tend to have weaker first year outcomes with fewer completed credits and lower persistence rates than students in the study sample.

Based on the counts of students in each ACT score range at the bottom of Table 2, only 17% of students in the study sample are considered fully college ready (i.e., at or above the higher cutoff) in math and 49% in English. Approximately 69% and 21% of students have ACT scores below the lower cutoff in math and English, respectively. As measured by ACT scores, college readiness poses a far greater challenge in math than in English for community college students in Kentucky.

URM and disadvantaged students are overrepresented among the lowest scoring group in both subjects, but this pattern is more pronounced in English than in math. For example, although Black students represent only 10% of all students in the study sample, they account for 12% of students scoring below the lower cutoff in math and 21% in English. Similarly, although students who are eligible for free or reduced-priced lunch represent 74% of students in the study sample, they account for 79% of the lowest-performing group in math and 87% in English.

Finally, a higher percentage of male students are in the highest-scoring math group (55% vs. 42% in the overall study sample) but not in English.

4.2 Descriptive Statistics of Course Taking Sequence and First Year Outcomes

The "throughput" of math and English course-taking in the first year of college, by ACT test score range, is depicted in Figure 1. Detailed summary statistics can be found in Table 2. An often-overlooked point of leakage is that around 40% of students, including among those deemed college ready, did not take any math or English courses during the first year (Panel IV, Table 2). In fact, students who scored at or above the higher ACT cutoff for math were less likely to take any math course than students who scored below the lower cutoff (52% vs. 59%). Thirty-nine percent of these college-ready students passed college-level math by the end of the first year, suggesting a course success rate of 75%. The course success rate is similar in English among students who scored above the higher ACT cutoff, with 60% taking English courses and 45% passing them in the first year.

For students with ACT scores below the higher cutoff, not all were expected to take developmental courses. Many students simply did not take any math or English courses in the first year. Additionally, students could place out of developmental courses by using alternative college readiness metrics other than ACT scores. Finally, in math, students with scores between the higher and lower ACT cutoffs could enroll directly in college-level math courses for the QR pathway instead of taking corequisite college algebra.

Among students whose ACT math scores fell between the higher and lower cutoffs, about the same proportion began with college-level QR math (16%) as with corequisite college algebra (17%) (see Panel III, Table 2). Another 18% enrolled in college algebra directly. Overall, by the end of the first year, 55% of students with ACT math scores in this mid-range took college-level math and 39% passed a college-level math course, suggesting a course success rate of 71%.

Among students who scored below the lower cutoff, 25% started with prerequisite math (which is only necessary for students who plan to take college algebra later) and 8% started with corequisite QR math. About 6% of students in this lowest ACT math score range directly enrolled in corequisite college algebra and 18% directly enrolled in college-level math courses (Panel III, Table 2). By the end of the first year, 39% of these took a college-level math course and 24% passed, implying a course success rate of 62%.

There are fewer course options for students who are not fully college ready in English. For those whose English ACT scores fell between the higher and lower cutoffs, 36% placed out of DE and enrolled in college-level English directly, 24% took corequisite English and 6% took prerequisite English (Panel III, Table 2). By the end of the first year, 61% of them took college English courses and 41% passed with a course success rate of 67%. Among students who scored below the lower cutoff on ACT English, 24% enrolled in college English directly, 19% took corequisite English, and 17% took prerequisite English. About 46% of students in this group took college English by the end of the first year and 27% passed, suggesting a course success rate of 59%.

4.3 Empirical Strategies

We address the research questions in a regression discontinuity (RD) framework. Let S_i denote the difference between the score of student i on the ACT and the corresponding cutoff so that negative values would indicate scores below the cutoff. $T_i = 1(S_i < 0)$ is an indicator for those identified to receive treatment. A parametric representation would then become:

$$Y_i = \alpha + \beta T_i + k(S_i) + \gamma T_i k(S_i) + \epsilon_i, \qquad (1)$$

where Y_i is the outcome of interest and $k(S_i)$ is a function of the cutoff-centered ACT score of student i. As described in the previous section, not all students below the ACT cutoffs are expected to take developmental courses in either the prerequisite or corequisite format. As a result, the coefficient β represents the intent-to-treat (ITT) effect. Because the running variable, the ACT test score, is discrete and therefore does not include values arbitrarily close to the cutoff, the assumption required for nonparametric identification—that bandwidth shrinking to zero as the sample grows—does not hold. As pointed out in Lee & Card (2008), this limitation necessitates adopting a parametric specification. Following their insight, we estimate β parametrically. Methods recommended by Calonico et al. (2017) suggest that the optimal bandwidth is approximately 2-3 points around the cutoff, which is consistent with previous RD studies on DE policies that use the ACT score as the running variable (e.g., Ran & Lin, 2022; Boatman, 2012).[13] Due to the small bandwidth, $k(S)$ is specified as a linear function. We use Eicker-Huber-White (EHW) heteroskedasticity-robust standard errors for statistical inference based on evidence presented in Kolesár & Rothe (2018). In Section 5.3 below, we examine the sensitivity of the main findings to specification errors using the *rdhonest* approach proposed by Kolesár and Rothe (2018).

β will yield unbiased estimates of the causal effect of the treatment provided that several key assumptions are met. We first examine the integrity of the running variable. Manipulation of ACT scores is very unlikely to occur because the ACT is assessed without any teacher, student, or school involvement. Because the ACT is mandatory in Kentucky, self-selection in ACT participation is not an issue. However, in theory students could retake the ACT after the initial attempt in the 11th grade and therefore the final ACT scores recorded by KCTCS may confound

[13] As shown in Appendix Table A2, results are robust to other choices of bandwidth.

variation in student ability with effort. In practice, however, students who enroll in KCTCS rarely (less than 10%) retake the ACT, and all results are nearly identical regardless of which ACT scores (initial scores or college-recorded scores) are used as the running variable. In Figure 2, the distributions of the final ACT scores reported by KCTCS and the initial 11th -grade ACT scores are presented as panels I and II. There are no signs of abrupt bunching of scores above or below the cutoffs except for a jump in the density of English scores at the low cutoff.[14] But a similar-sized jump is present in both versions of the ACT score, and so it is unlikely to be the result of retesting attempts by some students to meet the lower benchmark.[15] Because using KCTCS-recorded ACT scores results in a sample that is about 11% larger than using the 11th-grade scores, we use the KCTCS recorded scores as the running variable for the main results.

Another assumption of RD is that in the absence of treatment, the relationship between the outcome and the running variable is smooth through the cutoff. Although this cannot be definitively proven, smoothness of student attributes through the cutoff would provide suggestive support for this assumption. The outcome variable in Equation 4 is replaced with observed student attributes and high school GPA, and the estimated discontinuity at the low and high cutoffs for math and English are reported in Table 3. None of the differences in student characteristics around the higher cutoff for either subject are statistically significant, and only a few are marginally significant (at the 0.10 level) at the lower cutoff for English. We see more statistically significant differences at the 0.05 level at the lower cutoff for math. Compared to

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[14] Results from the Cattaneo–Jansson–Ma (2018) density discontinuity test reject the null hypothesis that the distribution of test scores is continuous at the cutoffs. However, the null hypothesis is rejected at all other pseudo "cutoffs" where no test score manipulation is expected.

[15] In Appendix Figure A1, we directly examine the relationship between the probability of ACT retake and students' initial ACT scores, with solid lines representing the estimated Equation (1) using whether a student retook the ACT as the outcome and the 11th-grade ACT scores as the running variable. There is no clear pattern of retaking: although students just below the low cutoff in English are somewhat more likely (by 3.1 percentage points) to retake the ACT, students just below the high cutoff in English are less likely to retake (by 2.4 percentage points). In math, there is no detectable difference in test retaking at either cutoff.

students who scored just above the lower math cutoff, students just below the cutoff are more likely to be White or speak English at home, but less likely to be Black, to be part-time, or to have received special education classification in high school. In other words, students below the lower math cutoff appear to be *less* disadvantaged. Similar covariate imbalance exists when we use the 11th -grade ACT score as the running variable (Appendix Table A1), suggesting that differential test retaking behavior is unlikely to be the cause.

While there is no evidence that test score manipulation is an issue, there still can be nonrandom sample selection at the cutoffs (especially at the lower cutoffs) if college enrollment is dependent on students' ACT scores. Specifically, DE requirements may deter some students from enrolling in KCTCS. This, in turn, may result in positive self-selection among those who decided to register for KCTCS courses despite very low initial skills. The discontinuities in ACT score density at the lower English cutoff and in student characteristics at the lower math cutoff are both consistent with this hypothesis. Unfortunately, this hypothesis cannot be directly verified because students who did not enroll in KCTCS are not observed in our data. We evaluate the sensitivity of RD estimates to the inclusion of observable student attributes. Moreover, we contend that plausible positive self-selection would reinforce null or negative results.

5. Results

5.1 Treatment-comparison contrast

As outlined in Table 1 earlier, the existence of two cutoff points in each subject, combined with the availability of multiple pathways in math, complicates the treatment-comparison contrasts around the cutoffs. We quantify these contrasts by estimating discontinuities in students' initial course placements in math and English (i.e., the likelihood of beginning their math and English course sequence with a particular type of course) using the regression discontinuity design described by Equation 1. These estimates are reported in Table 4 and presented in graphical form in Figure 3.

Relative to students who scored just above the higher cutoff in math, students who scored just below the higher cutoff were 14 percentage points more likely to take corequisite college algebra along with their first math course and 5 percentage points more likely to start with a math course in the QR pathway. The higher likelihood of enrollment in these courses is almost entirely offset by an 18-percentage point drop in the likelihood of enrolling in college algebra directly. These estimates suggest that estimated effects at the higher cutoff in math can be interpreted as the aggregate impact of corequisite college algebra and alternative math pathway (i.e., college-level QR math courses) relative to direct enrollment in college algebra without DE support.

Compared to students who scored just above the lower cutoff in math, students who scored just below the low cutoff were 7 percentage points more likely to start with prerequisite math courses and 4 percentage points more likely to start with corequisite math courses for the QR pathway. On the other hand, students just above the lower cutoff in math were 6 percentage points more likely to start with corequisite college algebra and 2 percentage points more likely to enroll in QR pathway math courses directly. Given these estimates, the effects estimated at the lower cutoff can be interpreted as the aggregate impact of corequisite QR math (*vs*. QR math without DE support) and hybrid DE (i.e., prerequisite + corequisite) for college algebra (*vs*. corequisite college algebra).

These aggregate impact estimates provide important insights into what DE placement policies that combine corequisite and math pathway reforms could realistically expect in an authentic setting. It would also be useful to disaggregate the combined effects by math pathway to isolate the corequisite effect. Unfortunately, math pathway-specific estimates would be conditional on the level of math sequence that students choose to take. Because pathway choices are endogenous, treatment assignments near the cutoffs (conditional on ACT scores) should no longer be treated as random. For example, students who scored just below the higher cutoff but chose the longer CA pathway instead of the QR pathway may be more determined than other CA pathway students who scored just above the higher cutoff. If determination is positively correlated with future student outcomes, the estimated corequisite effect for students who chose the CA pathway is likely upwardly biased. However, if the estimated effects turned out to be null or negative in spite of the likely upward bias, such results would strongly suggest that corequisite DE did not help students who needed to pass college algebra. In other words, a pathway-specific effect can generate useful qualitative information when the estimate and the bias go in opposing directions. We return to this point in section 5.3 after presenting the main results.

Due to the lack of multiple pathways in English, placement options are more straightforward in English (Panel II, Table 3). Compared to students with ACT English scores just above the higher cutoff, students with scores just below the cutoff were 15 percentage points more likely to enroll in corequisite English. Effects estimated at the higher cutoff for English would be driven by corequisite DE relative to no developmental support at all. At the lower cutoff for English, students with scores just below the cutoff were 9 percentage points more likely to enroll in prerequisite English courses and 7 percentage points less likely to enroll in corequisite English courses. Effects that can be detected at the lower cutoff for English reflect the impact of hybrid DE relative to corequisite DE.

5.2 Main Student Outcome Results

The estimated impacts on first year college outcomes are presented in Table 5, with the corresponding regression discontinuity plots displayed in Figure 4. For students just below the higher cutoff for math, the availability of the QR math pathway and corequisites increased the likelihood that students take QR pathway math courses from 11% at the cutoff to 16% and the likelihood that they pass those courses from 7% to 11%. These positive effects are offset by a 4-percentage point decrease in the likelihood that students take college algebra or higher-level college math courses (from a baseline at the cutoff of 42%) and a 2-percentage point decrease (albeit statistically insignificant) in the likelihood of passing those courses (from a baseline of 30%). These estimates are consistent with the treatment-comparison contrast described in the previous section (Table 4), and they suggest a substitution away from CA toward QR pathway math courses that results in no overall change in the likelihood of taking or passing a college-level math course. The number of credits earned in math during the first year of college increased slightly by 0.21 credit under KCTCS's placement policy for students just below the higher cutoff.

The pattern is similar for students near the lower math cutoff, although the interpretation is somewhat different. Here, for students just below the cutoff, we also observe an increased likelihood of taking and passing QR pathway math courses (both by 2 percentage points from baselines of 19% and 12%, respectively) being offset by a decreased likelihood of taking college algebra or higher-level math (by 3 percentage points from a baseline of 38%) and passing those courses (by a statistically insignificant 1 percentage point with a baseline of 27%). Because enrollment in prerequisite (necessary for the CA pathway for this score range) and corequisite (for QR math) both increased among students just below the lower cutoff (Table 4), these contrasting impact estimates do not merely reflect a course substitution effect. Instead, they suggest that requiring a prerequisite on top of a corequisite reduces the chance that students reach college algebra courses. The lack of statistically significant drop in the overall passing rate of college algebra courses may suggest higher chances of success for those who managed to reach those courses, but overall, prerequisites do not appear to have added value for those choosing the CA pathway compared to requiring a corequisite only. By comparison, for students who chose the QR pathway, corequisites help them succeed in QR math courses compared to providing no DE support. Overall, KCTCS's placement policies for students near the low cutoff increased their likelihood of earning at least 15 credits in the first year by 4 percentage points and improved their college GPA by 0.22 (roughly equivalent to moving from a B to a B+).

For English, students just below the higher cutoff were 4 percentage points more likely to take college English (baseline: 62%), 5 percentage points more likely to pass college English (baseline: 45%), earned 0.39 more credits in English (baseline: 1.79) and 0.78 more credits in total (baseline: 13.23) by the end of the first year, and had 0.15 higher GPA (baseline: 2.16). These effects suggest that corequisite English has short-term benefits compared to no DE support, although there is no evidence of improved persistence to a second year in KCTCS. By comparison, students just below the lower cutoff were about 6 percentage points less likely to enroll in a college-level English course (baseline: 58%). While point estimates for passing a college-level English course, credit accumulation, and advancing to the second year are all negative, none are statistically significant. The negative and null effects suggest that providing extra support in the form of prerequisites was not working as intended.

5.3 Robustness checks

We display robustness of the main findings to the inclusion of student-level covariates and different choices of bandwidth in Appendix Table A2. Results are quite consistent across specifications, with the exception of the lower cutoff in math for some outcomes. In particular, using a bandwidth of 2 (instead of 3 or 4), we no longer detect any positive effects at the lower math cutoff on the likelihood of students taking or completing non-college algebra math courses in the first year. One possibility is that the sample size limitations from a smaller bandwidth introduce more noise in the estimates. On the other hand, controlling for student characteristics leads to minimal changes to the estimated effects around the low math cutoff where our earlier covariate balance check raised some concerns (Table 3).

In Appendix Table A3, we examine the sensitivity of the main findings to specification errors using the *rdhonest* approach proposed by Kolesár and Rothe (2018). This approach estimates confidence intervals that account for model specification uncertainty in addition to sampling uncertainty. The level of misspecification is reflected in the smoothness constant (M), where higher values imply stronger curvature and higher deviation from the linearity assumption of our main model. The main findings about KCTCS' DE policies at the higher math cutoff and the lower English cutoff are robust to small misspecification errors (M=0.01). At the lower math cutoff, we no longer see significant positive effects on any outcomes, and some of the null results have become significantly negative (e.g., the likelihood of taking college-level math courses and the total credits earned in math). In other words, accounting for small misspecification errors accentuates the main finding that adding prerequisites to corequisites did not help students with very low initial math skills. At the higher English cutoff, the positive effects on taking and passing college-level English courses are fragile to small misspecification, and they are no longer statistically significant. However, the positive effects of English corequisite on the number of completed credits in the first year, the total number of earned credits in English and the weighted college GPA in English remain robust.

Finally, in Appendix Table A4, we report the main results when using Grade 11 ACT scores as the running variable. While using these scores carries the advantage of being unsusceptible to systematic score manipulation through ACT retakes, we do not prefer these as our main estimates because we only observe them for students who attended a public school in Kentucky in Grade 11 and thus lead to reduced sample sizes. Nevertheless, results are very similar when using Grade 11 ACT scores.

5.4 Pathway-specific effects

As discussed in 5.1, grouping students into math pathways based on the actual courses they took will result in biased estimates due to endogenous course selection. We instead assign students to pathways based on the requirements of their majors. This method cannot fully eliminate self-selection because students could strategically choose majors based on the programs' math requirements and their own initial math skills, but it mitigates self-selection conditional on major choices. We use a data-driven approach following Ran & Lin (2022) and rely on introductory math courses that were most frequently taken by students in each major to infer the pathway requirement for that major. If students in a major (identified by 6-digit CIP codes) most frequently start with College Algebra (or higher-level math courses), all students in that major would be assigned to the CA pathway. Otherwise, students would be assigned to the QR pathway. Based on this approach, about 80% of degree-seeking students at KCTCS are in the CA pathway and 20% are in the QR pathway.

With this limitation in mind, we divide students by math pathway and estimate the effects at the higher and lower cutoffs for each subsample separately. These results are reported in Table 6. For students in the CA pathway, DE support—hybrid *vs*. corequisite for students just below the lower cutoff and corequisite *vs*. no support for students just below the higher cutoff—has null or negative effects on taking or passing college algebra. Because positive self-selection is plausible among students who chose majors that require the more demanding CA pathway despite missing the readiness cutoffs, these results strongly suggest that neither hybrid nor corequisite DE helps students whose majors require college algebra meet their needs. Although DE support significantly improves non-college algebra math outcomes, those outcomes are not adequate for majors that require college algebra. For students in the QR pathway, we do not expect any effects at the higher cutoff because students on both sides of the cutoff could enroll directly in QR pathway math courses. At the lower cutoff, corequisite DE appears to increase the likelihood that students take QR math courses by 2 percentage points and pass those courses by 4 percentage points relative to no DE support. These effects are not statistically significant, but we could only rule out effects of 6 percentage points or more due to the smaller sample size for this analysis.

5.5 Heterogeneity Analyses for Student Subgroups

College major choices tend to differ systematically by gender. For example, a recent study of college pathways among KCTCS students found that men disproportionately chose STEM majors, whereas women were substantially more likely to choose health fields (Holzer & Xu, 2021). Because math requirements vary by major, we might expect to observe different impacts of the reforms to math pathways and DE by gender. We explore this possibility in Table 7 by obtaining the main results from Table 5 separately for males and females.[16] Near the lower cutoff in math, positive results are concentrated among female students. In particular, female students were 3 percentage points more likely to take a non-college algebra math course and 4 percentage points more likely to pass the course. These improvements are sizeable relative to a

[16] To help interpret the results, we estimate the first stage by gender separately to demonstrate the treatment-comparison contrasts (Appendix Table A5). These contrasts are not appreciably different between gender.

baseline enrollment rate of 15% at the cutoff and a baseline pass rate of 11%. Female students just below the lower math cutoff were also more likely to earn at least 15 credits in the first year (by 4 percentage points relative to a baseline of 73%), accumulate more college credits (by 0.78 relative to a baseline of 15.81 credits), have higher GPA (by 0.29 relative to a baseline of 2.15), and remain in KCTCS for a second year (by 5 percentage points relative to a baseline of 65%). None of these outcomes are statistically significant for male students. Thus, it appears that the benefits of KCTCS's new DE policies at the lower math cutoff were concentrated among female students who took advantage of the pathway reforms to take and pass non-college algebra math courses. At the higher math cutoff, on the other hand, there is less evidence of differences across subgroups.

In English, by comparison, the benefits of corequisite DE are more apparent for male students. While corequisite DE increased the likelihood of passing college English for both genders (6 percentage points for males and 4 percentage points for females), it was achieved primarily by raising the enrollment rate in college English for male students by 6 percentages points compared to a statistically insignificant 1 percentage point for female students.

In addition to gender, we also examine student subgroups by enrollment and URM status as community colleges tend to enroll a higher percentage of part-time and URM students than 4-year institutions. These results are reported in Appendix Tables A6 and A7. We do not observe meaningful differences across these subgroups in general, although there are sample size challenges for some groups, especially URM students. However, there are a few notable between-group contrasts. For example, the positive effects of corequisite DE for college English at the higher cutoff are concentrated among part-time students (a 7-8 percentage point increase in course enrollment and completion compared to a 2-3 percentage point increase for full-time students). The negative effect of hybrid DE in English on the likelihood that students take college-level English courses in the first year is more pronounced for non-URM students (a decrease of 8 percentage points) than for URM students (a 2-percentage point decrease).

6. Discussion

While proponents of corequisite DE acknowledge that some questions remain about which version of the corequisite model is more or less effective at supporting students, they believe that those are primarily implementation questions and that the general effectiveness of the corequisite model is supported by numerous studies (e.g., Complete College America, 2021). Our review of the literature suggests that rigorous causal evidence is not as extensive as one might expect, and much of it is generated in controlled settings with voluntary institutional and student participants. Critically, the view that the corequisite model is effective often ignores what the model is compared to: in particular, the prerequisite model that has been shown to negatively affect student outcomes. In math, the view also ignores that much of the reported corequisite effect may be driven by students switching from college algebra to lower-level college math courses.

Our study shows that concluding the corequisite model is uniformly effective may be an oversimplification. In practice, community college DE policies provide a wide range of support options to address varying degrees of academic preparedness of students and, in math, accommodate the specific quantitative competencies required by different fields of study. As demonstrated in this study, DE policies are more complex than what corequisite impact research has mostly focused on so far. Our findings reaffirm that delaying student access to college-level instruction, in the form of prerequisites, is counterproductive even for the less prepared among non-college ready students. The answer to whether corequisite DE has added benefits compared to no DE support at all, on the other hand, is more nuanced.

Overall, we find that corequisite DE has positive effects on English outcomes for students just below the higher English cutoff and on QR math outcomes for students just below the lower math cutoff. Compared to the baseline course completion rates at the cutoffs, these effects represent an improvement of 11% in college English and 17% in non-college algebra math courses. The benefits of corequisite English are stronger among men and part-time students, and the benefits of corequisite math on QR math are concentrated among women.

However, we find no evidence that corequisite math helps students take or pass college algebra. How to help students succeed in these more rigorous college algebra courses remains a challenge. Because more than half of students in KCTCS chose the college algebra pathway even though other more applied math courses were available, this challenge is amplified by the continued interest in and demand for college algebra courses. The degree to which the lack of an effective college algebra strategy is a problem varies by college systems. In Tennessee, for example, most students switched to the QR pathway after it became available and only 1 in 5 students took the CA pathway (Ran & Lin, 2022). Students in Texas community colleges, on the other hand, demonstrated continued interest in college algebra, a pattern similar to that found among KCTCS students (Meiselman & Schudde, 2022).

A limitation of our study is its focus on first year outcomes. This decision was made so that we could include more cohorts of first-time freshmen to maximize statistical power. The tradeoff of this decision is that early momentum in college often does not always translate into improved attainment later. Even though these early momentum measures have been identified by previous research as the strongest predictors of college graduation, their predictive power remains relatively weak. For example, doubling the number of credits earned in the first year from 15 to 30 credits increases likelihood of attaining a credential within 3 years by 10-15 percentage points (Belfield et al., 2019). This means that the positive effects of corequisite DE on first year outcomes are unlikely to result in substantial improvements in college graduation rates in community colleges. This would be consistent with the empirical evidence we reviewed earlier, which shows that, with the exception of the CUNY studies, corequisite DE produces no longer-term benefits even when compared to prerequisite DE.

While the search for more effective ways to academically support underprepared students succeed in college continues, it is important to seek other areas that have potentially large scopes for improvement. For example, our investigation on what courses students take to begin the math and English sequences found that 40-60% of first-time freshmen did not take any math or English courses in the first year. A potential explanation is that procedural barriers and administrative complexity lead students who have applied for community colleges to drop out of registered classes before the census date, which is a few weeks into a term when class enrollment is officially recorded (Karam et al., 2025). Such loss accounts for 10-15% of community college applicants based on data from Kentucky as well as California and Texas. Although we did not find this to be an issue with our study sample—nearly all students in our sample, including those who did not take any courses in math or English, were recorded as taking some college courses in the first year—policies that support and incentivize students to begin math and English course sequences early could be as important to improving community college completion rates as delivering effective developmental academic support.

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Tables and Figures

Table 1. Course Placement, By Cutoff, Subject and Math Pathway

	< Low cut	[Low cut, High cut)	≥ High Cut
CA pathway	Prerequisite	CA math corequisite	CA or QR math
QR pathway	QR math corequisite	QR math	CA or QR math
English	Prerequisite	Corequisite	College English

Note: Low cut = an ACT score of 19 (math) and 14 (English). High cut = an ACT score of 22 (math) and 18 (English). CA and QR refer to the college algebra and quantitative reasoning math pathways, respectively. CA math courses include MAT 150 (college algebra) or higher, and QR math courses include MAT 151 (applied statistics) and introductory college math courses below MAT 150 (e.g., MAT 126 and MAT 146).

Table 2. Summary Statistics of College Readiness, Student Characteristics, and First-Year Courses and Outcomes in College: 2020–2024

Student characteristics and outcomes	Excluded sample	Study sample	Math			English		
			<Low cut	[Low, High)	≥High cut	<Low cut	[Low, High)	≥High cut
I. Precollege skills								
ACT Math	–	17.77	15.76	19.83	24.34	15.00	16.54	19.71
ACT English	–	17.76	15.91	20.25	23.28	11.22	15.39	22.01
II. Student demographics								
White	0.68***	0.76	0.72	0.83	0.86	0.61	0.73	0.84
Black	0.14***	0.10	0.12	0.04	0.02	0.21	0.11	0.04
Hispanic	0.12***	0.09	0.10	0.07	0.06	0.12	0.10	0.07
Asian	0.03***	0.02	0.02	0.01	0.01	0.03	0.02	0.01
Other race	0.04	0.04	0.05	0.04	0.04	0.04	0.05	0.04
Male	0.42	0.41	0.37	0.45	0.55	0.42	0.41	0.41
Part-Time	0.55***	0.34	0.37	0.27	0.25	0.47	0.35	0.27
Age ≥24	0.59***	0.07	0.09	0.05	0.04	0.11	0.08	0.05
Free/reduced-priced lunch	0.78***	0.74	0.79	0.66	0.59	0.87	0.78	0.66
English spoken at home	0.94***	0.92	0.91	0.95	0.97	0.84	0.92	0.97
Special education in HS	0.12***	0.09	0.12	0.04	0.05	0.21	0.09	0.05
III. 1^{st} course taken in subject								
Prerequisite	–	–	0.26	0.03	0.01	0.17	0.06	0.00
Corequisite	–	–	0.14	0.18	0.02	0.19	0.24	0.02
QR corequisite	–	–	0.08	0.01	0.00	–	–	–
CA corequisite	–	–	0.06	0.17	0.01	–	–	–
Gateway without DE	–	–				0.24	0.36	0.57
QR gateway without DE	–	–	0.09	0.16	0.09	–	–	–
CA gateway without DE	–	–	0.09	0.18	0.31	–	–	–

IV. Year 1 college outcomes								
Take any course in math	0.49***	0.58	0.59	0.57	0.52	–	–	–
Take any course in English	0.56***	0.61	–	–	–	0.59	0.65	0.60
Take college-level subject	–	–	0.39	0.55	0.51	0.46	0.61	0.59
Pass college-level subject	–	–	0.24	0.39	0.38	0.27	0.41	0.45
Credits earned in subject	–	–	0.97	1.56	1.44	1.17	1.86	1.82
College GPA in subject	–	–	1.76	2.16	2.34	1.64	2.00	2.43
Total year 1 credits earned	9.65***	12.95	11.15	16.03	17.74	8.08	11.67	15.80
Took >=15 credits 1st year	0.54***	0.67	0.63	0.73	0.77	0.55	0.65	0.74
Advance to 2nd year	0.51***	0.58	0.54	0.63	0.68	0.46	0.54	0.64
Number of observations	15,758	43,632	30,111	6,260	7,261	8,968	13,363	21,301

– Not applicable

Note: Low cut = an ACT score of 19 (math) and 14 (English). High cut = an ACT score of 22 (math) and 18 (English). QR = Quantitative Reasoning math pathway. CA = College Algebra math pathway. *, **, and *** denote that the characteristic of the study sample is statistically different from that of the excluded sample at the 0.10, 0.05, and 0.01 levels.

Table 3. Covariate Balance Check

	Math		English	
Student characteristic	Low cut	High cut	Low cut	High cut
White	0.023**	-0.007	0.006	0.005
	(0.011)	(0.016)	(0.017)	(0.014)
Black	-0.020***	0.002	-0.018	-0.005
	(0.007)	(0.008)	(0.013)	(0.009)
Hispanic	-0.007	0.002	0.015	0.004
	(0.008)	(0.008)	(0.012)	(0.010)
Asian	-0.002	0.004	0.010*	0.002
	(0.003)	(0.004)	(0.006)	(0.004)
Other race	0.006	-0.002	-0.013*	-0.006
	(0.006)	(0.009)	(0.008)	(0.007)
Male	0.009	-0.007	0.013	0.003
	(0.014)	(0.021)	(0.018)	(0.017)
Part-time	-0.035***	-0.001	0.019	-0.005
	(0.013)	(0.019)	(0.018)	(0.016)
Age >= 24	0.006	-0.001	-0.020*	0.005
	(0.007)	(0.019)	(0.010)	(0.009)
Free/reduced-priced lunch	0.005	0.012	-0.000	-0.001
	(0.013)	(0.021)	(0.014)	(0.015)
English spoken at home	0.025***	0.002	-0.019	-0.003
	(0.007)	(0.009)	(0.013)	(0.009)
Special education in HS	-0.017**	0.002	-0.003	-0.000
	(0.007)	(0.009)	(0.014)	(0.009)

Note: Each student characteristic is an outcome of an RD model. Estimated discontinuities at various cutoffs are reported. KCTCS recorded ACT scores are used as the running variable. *, **, *** denote statistical significance at the 0.10, 0.05 and 0.01 levels, respectively. Eicker-Huber-White standard errors are in parentheses. Low cut = an ACT score of 19 (math) and 14 (English). High cut = an ACT score of 22 (math) and 18 (English).

Table 4. Treatment-Comparison Contrast at the Cutoffs

1st Course in subject	Low cut	High cut
I. Math		
Prerequisite math	0.07***	0.01
	(0.01)	(0.01)
	[0.03]	[0.01]
Corequisite math	-0.02*	0.14***
	(0.01)	(0.01)
	[0.18]	[0.02]
QR corequisite	0.04***	0.00
	(0.01)	(0.00)
	[0.01]	[0.00]
CA corequisite	-0.06***	0.14***
	(0.01)	(0.01)
	[0.17]	[0.02]
QR gateway math without DE	-0.02**	0.05***
	(0.01)	(0.02)
	[0.17]	[0.10]
CA gateway math without DE	0.00	-0.18**
	(0.01)	(0.02)
	[0.17]	[0.34]
Number of observations	23,625	10,407
II. English		
Prerequisite English	0.09***	-0.01**
	(0.01)	(0.01)
	[0.08]	[0.02]
Corequisite English	-0.07***	0.15***
	(0.01)	(0.01)
	[0.25]	[0.05]
College English without DE	-0.03*	-0.10***
	(0.02)	(0.02)
	[0.31]	[0.57]
Number of observations	16,745	17,736

Note: *, **, *** denote statistical significance at the 0.10, 0.05 and 0.01 levels, respectively. Eicker-Huber-White standard errors are in parentheses, and the means at the cutoffs are in square brackets. Corequisite courses for English include IRW 100 and ENG 100. English prerequisite courses include ENC 91, IRW 085, IRW 095, and ENG courses lower than 100. Corequisite courses for math include MAT 100 and courses with course numbers suffixed with “s”.

Table 5. Estimated Effects on First-Year Student Outcomes

	Math		English	
First-year outcome	Low cut	High cut	Low cut	High cut
Take college-level course	-0.01	0.00	-0.06***	0.04**
	(0.01)	(0.02)	(0.02)	(0.02)
	[0.56]	[0.53]	[0.58]	[0.62]
College Algebra or above	-0.03**	-0.04**	–	–
	(0.01)	(0.02)	–	–
	[0.38]	[0.42]		
Below College Algebra	0.02*	0.05***	–	–
	(0.01)	(0.02)	–	–
	[0.19]	[0.11]		
Pass college-level course	0.01	0.02	-0.01	0.05***
	(0.01)	(0.02)	(0.02)	(0.02)
	[0.40]	[0.38]	[0.36]	[0.45]
College Algebra or above	-0.01	-0.02	–	–
	(0.01)	(0.02)	–	–
	[0.27]	[0.30]		
Below College Algebra	0.02**	0.04***	–	–
	(0.01)	(0.01)	–	–
	[0.12]	[0.07]		
15 or more credits	0.04***	0.01	-0.02	0.01
	(0.01)	(0.02)	(0.02)	(0.02)
	[0.72]	[0.75]	[0.62]	[0.69]
Year 1 credits earned	0.57*	0.01	-0.03	0.78**
	(0.31)	(0.02)	(0.35)	(0.36)
	[15.70]	[17.00]	[10.31]	[13.23]
Total credits earned in subject	0.00	0.21**	-0.06	0.39***
	(0.06)	(0.09)	(0.08)	(0.08)
	[1.59]	[1.34]	[1.63]	[1.79]
Weighted college GPA in subject	0.22***	0.12	0.17**	0.15**
	(0.06)	(0.09)	(0.08)	(0.07)
	[2.11]	[2.20]	[1.82]	[2.16]
Advance to 2^{nd} Year	0.03**	0.01	-0.01	0.01
	(0.02)	(0.02)	(0.02)	(0.02)
	[0.63]	[0.66]	[0.52]	[0.56]
Number of observations	23,625	10,407	16,745	17,736

Note: – Not applicable. *, **, *** denote statistical significance at the 0.10, 0.05 and 0.01 levels, respectively. Eicker-Huber-White standard errors are in parentheses, and the means at the cutoffs are in square brackets. Observation numbers are smaller for the last two outcomes. Counts for Weighted GPA are 11,044 (math low cut), 5,522 (math high cut), 9,339 (English low cut) and 11,011 (English high cut) because Pass/Fail courses do not have a numeric grade. Counts for persistence are 19,909 (math low cut), 8,907 (math high cut), 13,761 (English low cut) and 14,962 (English high cut) because second year enrollment data are not available for the 2024 freshmen cohort.

Table 6. Estimated Effects on First-Year Student Outcomes, by Math Pathway

	CA pathway		QR pathway	
First-year outcome	Low cut	High cut	Low cut	High cut
Take college-level course	-0.01	0.01	-0.01	-0.02
	(0.02)	(0.02)	(0.03)	(0.05)
	[0.58]	[0.54]	[0.50]	[0.49]
College Algebra or above	-0.03*	-0.02	-0.03*	-0.05
	(0.02)	(0.02)	(0.02)	(0.03)
	[0.45]	[0.48]	[0.09]	[0.16]
Below College Algebra	0.02*	0.04***	0.02	0.02
	(0.01)	(0.01)	(0.03)	(0.03)
	[0.14]	[0.07]	[0.41]	[0.33]
Pass college-level course	0.01	0.03	0.01	-0.03
	(0.02)	(0.02)	(0.03)	(0.05)
	[0.40]	[0.39]	[0.38]	[0.36]
College Algebra or above	-0.01	-0.00	-0.05	-0.04
	(0.01)	(0.02)	(0.03)	(0.03)
	[0.32]	[0.34]	[0.06]	[0.09]
Below College Algebra	0.02**	0.04***	0.04	0.01
	(0.01)	(0.01)	(0.03)	(0.05)
	[0.09]	[0.05]	[0.32]	[0.27]
15 or more credits	0.05***	0.01	-0.02	0.04
	(0.01)	(0.02)	(0.03)	(0.04)
	[0.71]	[0.75]	[0.77]	[0.76]
Year 1 credits earned	0.90***	0.14	-0.48	0.21
	(0.34)	(0.51)	(0.81)	(1.24)
	[14.85]	[16.52]	[19.22]	[19.32]
Total credits earned in subject	-0.00	0.31***	0.08	-0.10
	(0.07)	(0.10)	(0.11)	(0.16)
	[1.68]	[1.39]	[1.26]	[1.14]
Weighted college GPA in subject	0.22***	0.15	0.25	-0.10
	(0.07)	(0.10)	(0.16)	(0.24)
	[2.06]	[2.17]	[2.33]	[2.38]
Advance to 2^{nd} Year	0.05***	0.00	-0.04	0.04
	(0.02)	(0.02)	(0.04)	(0.06)
	[0.62]	[0.66]	[0.63]	[0.65]
Number of observations	18,986	8,477	4,306	1,759

Note: *, **, *** denote statistical significance at the 0.10, 0.05 and 0.01 levels, respectively. Eicker-Huber-White standard errors are in parentheses, and the means at the cutoffs are in square brackets. Observation numbers (available upon request) are smaller for Weighted GPA because Pass/Fail courses do not have a numeric grade, and for persistence because second year enrollment data are not available for the 2024 freshmen cohort. Students are classified into pathways based on their major and the math course most frequently taken by students in that major.

Table 7. Estimated Effects on First-Year Student Outcomes, by Gender

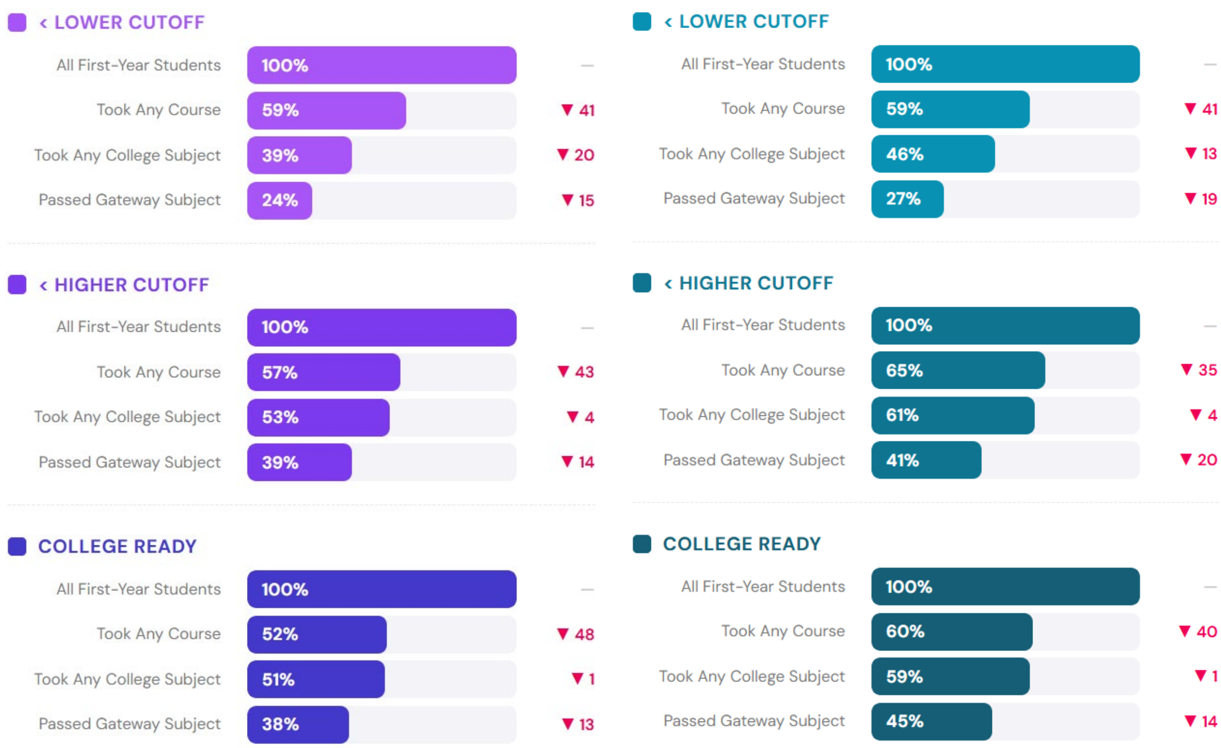
	Female		Male	
First-year outcome	Low cut	High cut	Low cut	High cut
I. Math				
Take college-level course	0.00	0.03	-0.03	-0.04
	(0.02)	(0.03)	(0.02)	(0.03)
	[0.55]	[0.53]	[0.57]	[0.53]
College Algebra or above	-0.02	-0.03	-0.04**	-0.05
	(0.02)	(0.03)	(0.02)	(0.03)
	[0.41]	[0.45]	[0.35]	[0.40]
Below College Algebra	0.03**	0.07***	0.01	0.03
	(0.01)	(0.02)	(0.02)	(0.02)
	[0.15]	[0.09]	[0.23]	[0.14]
Pass college-level course	0.04**	0.04	-0.02	-0.02
	(0.02)	(0.03)	(0.02)	(0.03)
	[0.39]	[0.41]	[0.40]	[0.35]
College Algebra or above	0.00	-0.01	-0.03*	-0.03
	(0.02)	(0.03)	(0.02)	(0.03)
	[0.29]	[0.35]	[0.24]	[0.25]
Below College Algebra	0.04***	-0.03	0.01	0.02
	(0.01)	(0.03)	(0.02)	(0.02)
	[0.11]	[0.06]	[0.17]	[0.10]
15 or more credits	0.04**	0.00	0.03	0.02
	(0.02)	(0.03)	(0.02)	(0.03)
	[0.73]	[0.77]	[0.71]	[0.74]
Year 1 credits earned	0.78*	-0.31	0.25	0.51
	(0.40)	(0.63)	(0.51)	(0.71)
	[15.81]	[17.96]	[15.56]	[15.99]
Total credits earned in subject	0.10	0.31***	-0.13	0.10
	(0.08)	(0.12)	(0.09)	(0.13)
	[1.58]	[1.40]	[1.62]	[1.28]
Weighted college GPA in subject	0.29***	0.13	0.09	0.08
	(0.08)	(0.12)	(0.10)	(0.13)
	[2.15]	[2.44]	[2.06]	[1.96]
Advance to 2nd Year	0.05**	0.01	0.01	0.00
	(0.02)	(0.03)	(0.02)	(0.03)
	[0.65]	[0.69]	[0.60]	[0.62]
Number of observations	14,154	5,471	9,471	4,936
II. English				
Take college-level course	-0.05*	0.01	-0.08***	0.06**
	(0.02)	(0.02)	(0.03)	(0.03)

	[0.62]	[0.66]	[0.53]	[0.58]
Pass college-level course	0.01	0.04*	-0.05**	0.06**
	(0.02)	(0.02)	(0.03)	(0.03)
	[0.38]	[0.48]	[0.34]	[0.41]
15 or more credits	-0.00	0.00	-0.04	0.01
	(0.02)	(0.02)	(0.03)	(0.03)
	[0.61]	[0.70]	[0.63]	[0.68]
Year 1 credits earned	0.24	0.54	-0.45	1.07*
	(0.43)	(0.45)	(0.60)	(0.60)
	[9.39]	[13.07]	[11.61]	[13.47]
total credits earned in subject	0.03	0.38***	-0.19	0.40***
	(0.11)	(0.11)	(0.12)	(0.12)
	[1.76]	[1.91]	[1.46]	[1.61]
Weighted college GPA in subject	0.24**	0.20**	0.05	0.08
	(0.10)	(0.09)	(0.13)	(0.11)
	[1.83]	[2.19]	[1.82]	[2.11]
Advance to 2^{nd} year	0.01	-0.00	-0.04	0.03
	(0.03)	(0.02)	(0.03)	(0.03)
	[0.51]	[0.58]	[0.54]	[0.53]
Number of observations	9,812	10,488	6,933	7,248

Note: *, **, *** denote statistical significance at the 0.10, 0.05 and 0.01 levels, respectively. Eicker-Huber-White standard errors are in parentheses, and the means at the cutoffs are in square brackets. Observation numbers (available upon request) are smaller for Weighted GPA because Pass/Fail courses do not have a numeric grade, and for persistence because second year enrollment data are not available for the 2024 freshmen cohort.

Figure 1. First Year Course Taking Sequence and Throughput in Math and English, by ACT Score Range

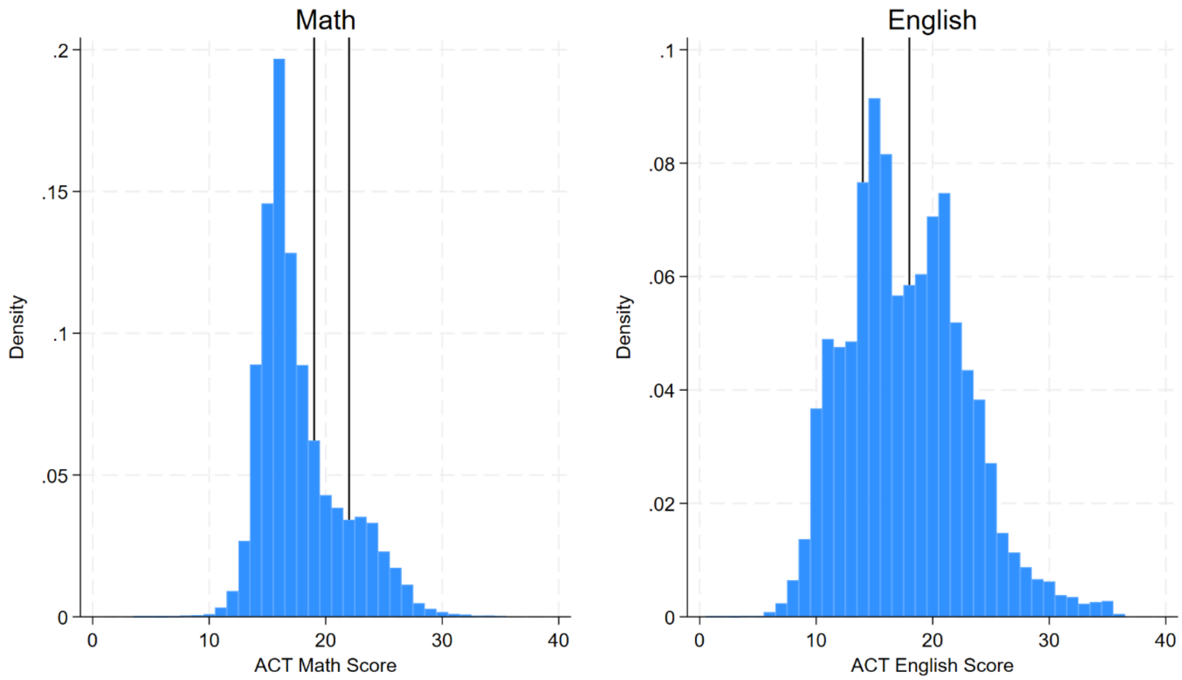
I. Math **II. English**



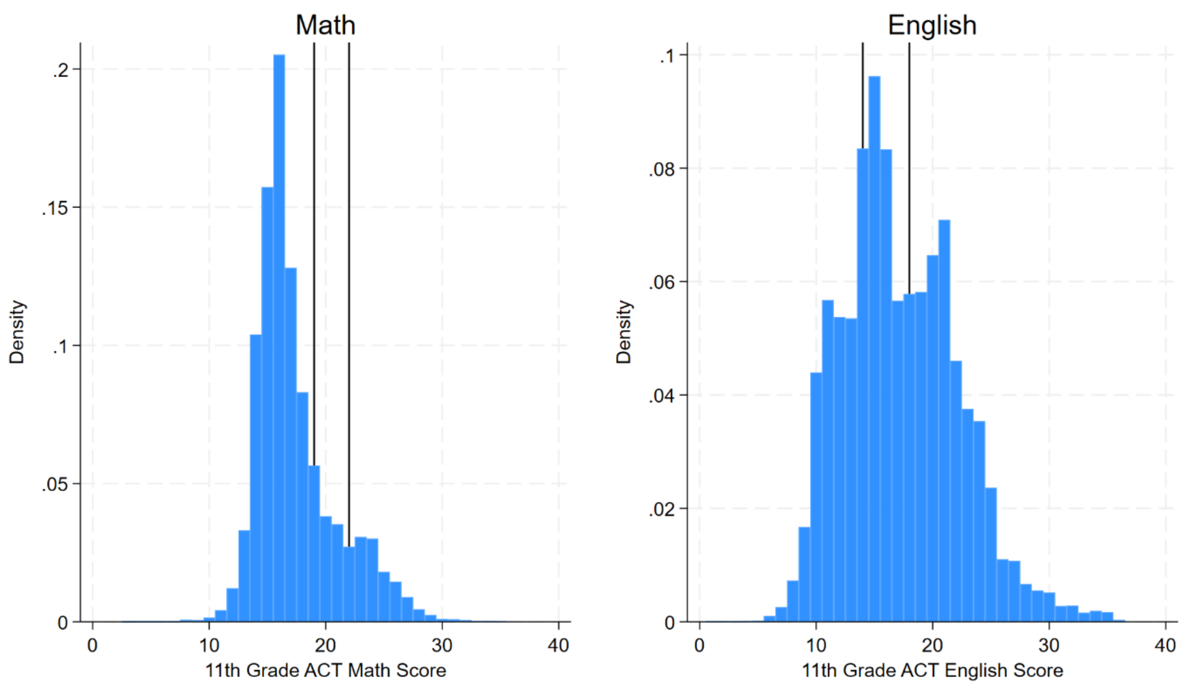
Note: Lower cutoff = an ACT score of 19 (math) and 14 (English). Higher cutoff = an ACT score of 22 (math) and 18 (English). Charts generated with assistance from claude.ai.

Figure 2. Distribution of ACT Scores Among First-Time Freshmen Enrolled in Degree Programs, 2020–2024

I. KCTCS recorded ACT scores



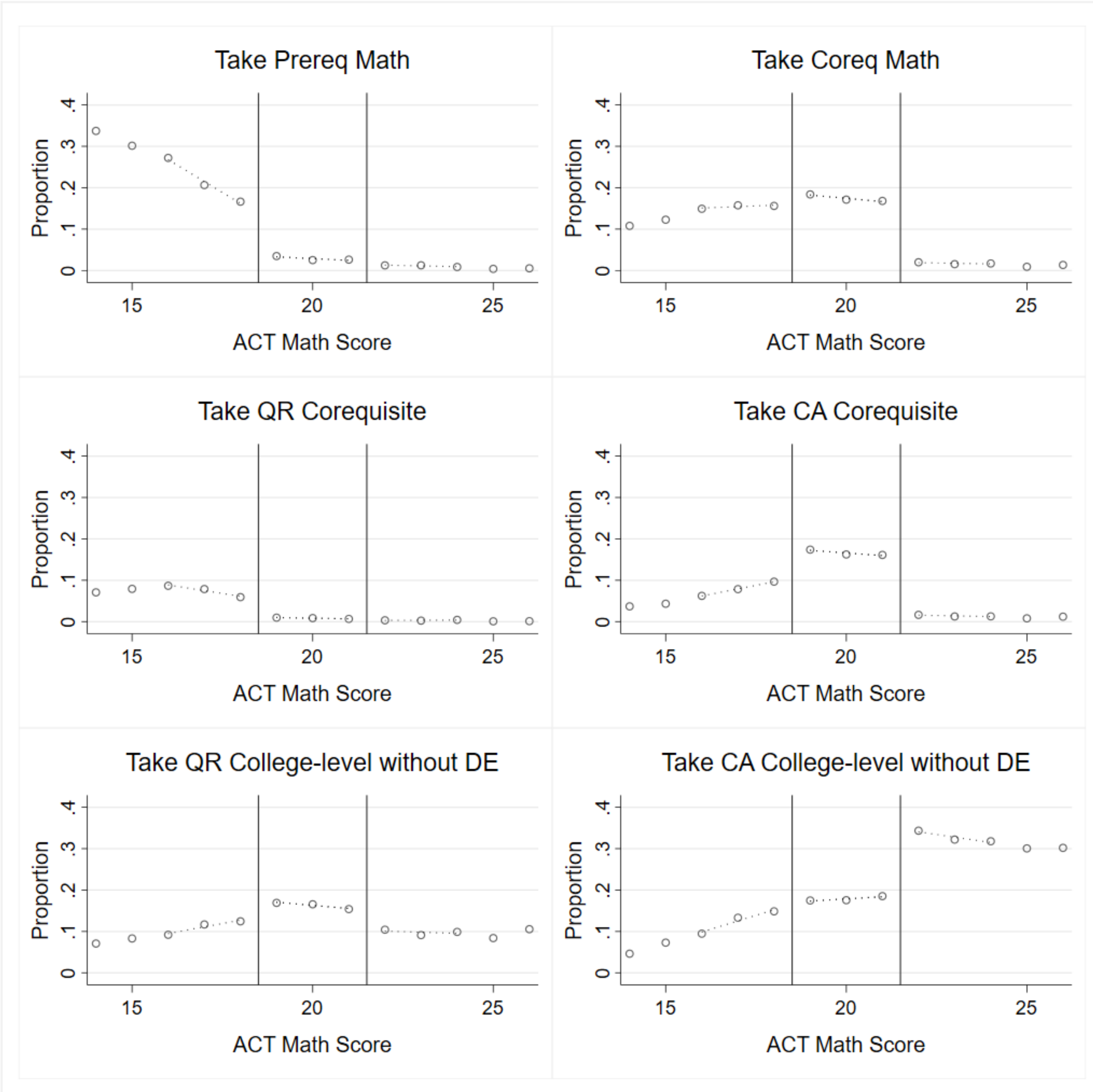
II. 11th -grade ACT scores



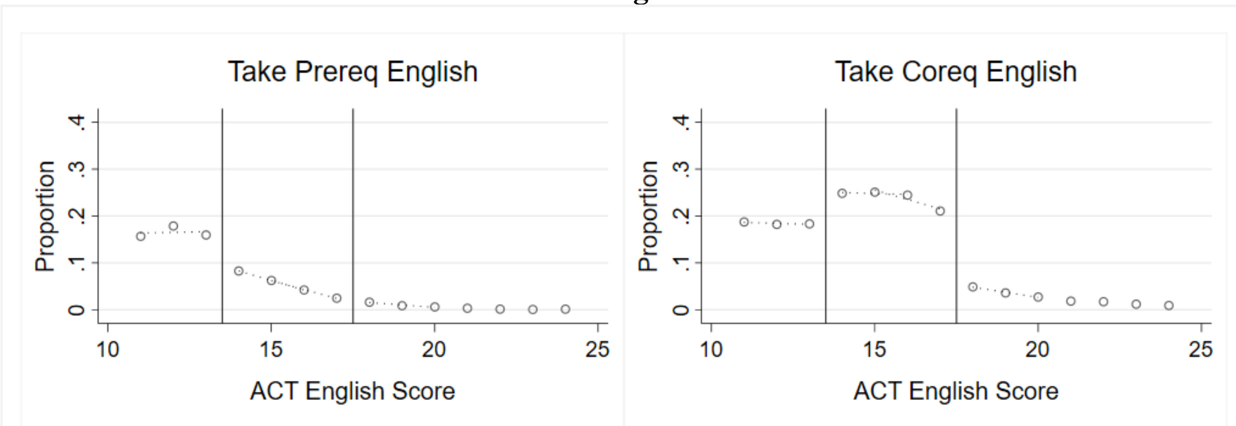
Note: Vertical lines represent the high and low cutoffs for each subject.

Figure 3. First Course Taken in Math and English, by ACT Score

I. Math



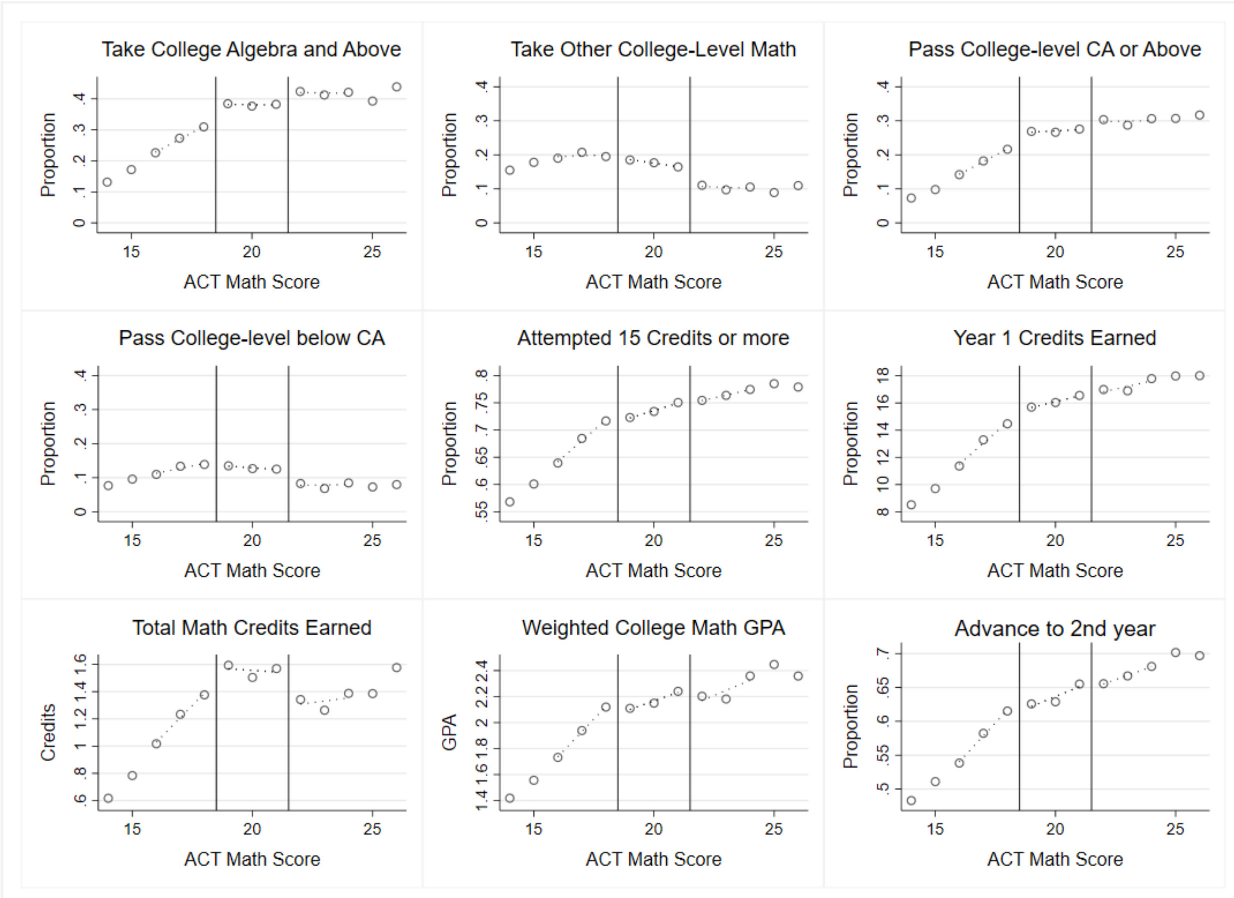
II. English



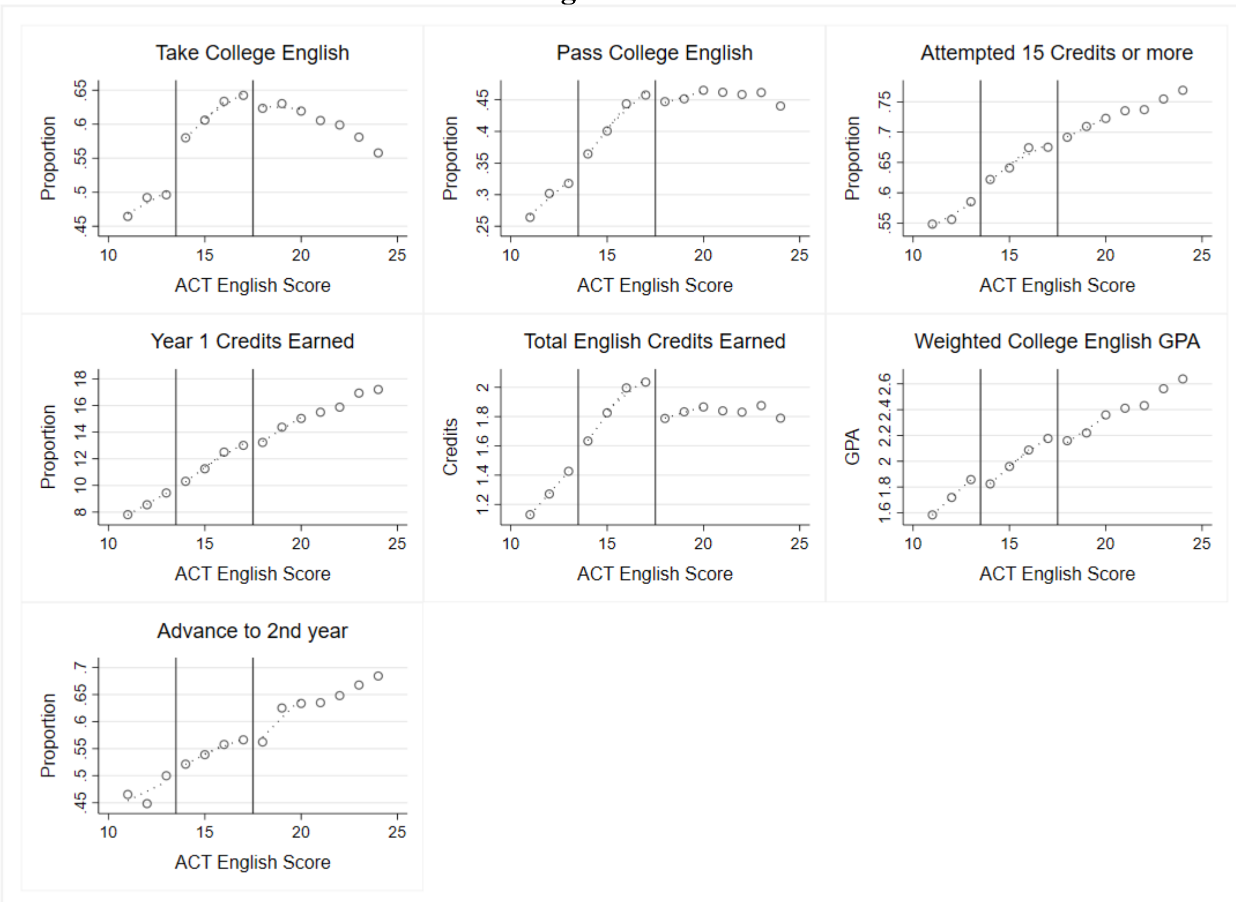
Note: Vertical lines represent the high and low cutoffs for each subject.

Figure 4. First Year Outcomes by ACT Score

I. Math Outcomes



II. English Outcomes



Notes: Displays average outcome by ACT score along with vertical lines denoting college readiness ACT benchmarks of 19 and 22 (math) and 14 and 18 (English). Each figure contains a linear best fit line through three points on either side of the college readiness cutoffs.

Appendix

Supplementary Tables & Figures

Table A1. Covariate Balance Check Using 11th Grade ACT Score

	Math		English	
Student Characteristic	Low cut	High cut	Low cut	High cut
White	0.019	-0.004	-0.009	0.003
	(0.012)	(0.017)	(0.017)	(0.015)
Black	-0.020***	0.009	-0.007	-0.007
	(0.007)	(0.009)	(0.013)	(0.009)
Hispanic	-0.002	-0.005	0.022*	0.006
	(0.008)	(0.012)	(0.012)	(0.010)
Asian	-0.005*	0.005	0.004	0.002
	(0.003)	(0.005)	(0.006)	(0.004)
Other race	0.008	-0.006	-0.009	-0.004
	(0.006)	(0.010)	(0.008)	(0.007)
Male	0.010	-0.051**	0.009	0.013
	(0.016)	(0.024)	(0.018)	(0.018)
Part-time	-0.024*	0.008	0.032*	-0.004
	(0.014)	(0.021)	(0.018)	(0.017)
Age >= 24	0.016**	0.013	-0.011	-0.005
	(0.006)	(0.009)	(0.008)	(0.008)
Free/reduced-priced lunch	-0.014	-0.003	0.020	-0.002
	(0.014)	(0.023)	(0.014)	(0.015)
English spoken at home	0.022***	-0.003	-0.022*	-0.004
	(0.007)	(0.010)	(0.013)	(0.009)
Special education	-0.011	-0.020**	-0.004	0.006
	(0.007)	(0.009)	(0.013)	(0.009)

Note: Each student characteristic is an outcome of an RD model. Estimated discontinuities at various cutoffs are reported. Grade 11 ACT scores are used as the running variable. *, **, *** denote statistical significance at the 0.10, 0.05 and 0.01 levels, respectively. Eicker-Huber-White standard errors are in parentheses. Low cut = an ACT score of 19 (math) and 14 (English). High cut = an ACT score of 22 (math) and 18 (English).

Table A2. Robustness of the Estimated Effects to the Inclusion of Covariates and Alternate Bandwidths

	Math						English					
	Low cut			High cut			Low cut			High cut		
Outcome	Covs	BW - 1	BW + 1	Covs	BW - 1	BW + 1	Covs	BW - 1	BW + 1	Covs	BW - 1	BW + 1
Take college-level course	-0.02	-0.05**	0.00	0.02	0.00	0.05**	-0.07***	-0.08***	-0.05***	0.04**	0.03	0.04***
	(0.02)	(0.02)	(0.01)	(0.02)	(0.03)	(0.02)	(0.02)	(0.03)	(0.02)	(0.02)	(0.02)	(0.01)
College Algebra or above	-0.03*	-0.04**	-0.01	-0.03	-0.04	0.00	–	–	–	–	–	–
	(0.02)	(0.02)	(0.01)	(0.02)	(0.03)	(0.02)	–	–	–	–	–	–
Below College Algebra	0.02	-0.00	0.02**	0.04**	0.04*	0.05***	–	–	–	–	–	–
	(0.01)	(0.02)	(0.01)	(0.02)	(0.02)	(0.01)	–	–	–	–	–	–
Pass college-level course	0.00	-0.01	0.01	0.02	0.02	0.05***	-0.02	-0.03	-0.01	0.05***	0.02	0.05***
	(0.02)	(0.02)	(0.01)	(0.02)	(0.03)	(0.02)	(0.02)	(0.02)	(0.01)	(0.02)	(0.02)	(0.01)
College Algebra or above	-0.02	-0.02	-0.00	-0.01	-0.02	0.01	–	–	–	–	–	–
	(0.01)	(0.02)	(0.01)	(0.02)	(0.03)	(0.02)	–	–	–	–	–	–
Below College Algebra	0.02**	0.01	0.02**	0.04**	0.04**	0.04***	–	–	–	–	–	–
	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.01)	–	–	–	–	–	–
15 or more credits	0.03**	0.03	0.04***	0.01	0.01	0.00	-0.02	-0.01	-0.02	0.00	-0.02	0.01
	(0.01)	(0.02)	(0.01)	(0.02)	(0.03)	(0.02)	(0.02)	(0.03)	(0.02)	(0.02)	(0.02)	(0.01)
Year 1 credits earned	0.16	-0.04	0.66**	-0.13	0.08	0.62	-0.05	0.01	-0.27	0.67*	0.29	0.74**
	(0.33)	(0.43)	(0.27)	(0.50)	(0.66)	(0.39)	(0.35)	(0.50)	(0.30)	(0.38)	(0.51)	(0.30)
Total credits earned in subject	-0.03	-0.07	0.01	0.23**	0.29**	0.36***	-0.08	-0.05	-0.08	0.38***	0.29**	0.43***
	(0.07)	(0.08)	(0.05)	(0.10)	(0.12)	(0.07)	(0.09)	(0.12)	(0.07)	(0.09)	(0.12)	(0.07)
Weighted GPA in subject	0.14**	0.19**	0.20***	0.08	0.13	0.08	0.16*	0.17	0.16**	0.17**	0.11	0.16***
	(0.07)	(0.09)	(0.05)	(0.10)	(0.13)	(0.08)	(0.09)	(0.11)	(0.07)	(0.07)	(0.09)	(0.06)
Advance to 2^{nd} year	0.02	0.02	0.03**	0.01	0.03	0.01	-0.02	0.03	-0.02	0.01	0.01	0.00
	(0.02)	(0.02)	(0.01)	(0.02)	(0.03)	(0.02)	(0.02)	(0.03)	(0.02)	(0.02)	(0.03)	(0.02)

Note: *, ** and *** denote statistical significance at the 0.10, 0.05 and 0.01 levels, respectively. Eicker-Huber-White standard errors in parentheses. The optimal bandwidth (BW) is 3. Covariates include demographic characteristics: race (Black, White, Hispanic, Asian, Other), gender (male), enrollment status (part-time), age above 24, free or reduced-price lunch eligibility, home language (English), and special education status in high school.

Table A3. 95% confidence intervals when assuming various levels of model misspecification

First-year outcome	Smoothness constant (M)	Math		English	
		Low cut	High cut	Low cut	High cut
Take college-level course	0.01	**(-0.11, -0.01)**	(-0.03, 0.09)	(-0.09, 0.00)	(-0.03, 0.07)
	0.05	(-0.20, 0.08)	(-0.12, 0.18)	(-0.18, 0.09)	(-0.12, 0.16)
	0.10	(-0.32, 0.19)	(-0.24, 0.30)	(-0.29, 0.20)	(-0.24, 0.28)
College Algebra or above	0.01	**(-0.12, -0.02)**	(-0.08, 0.04)	–	–
	0.05	(-0.21, 0.07)	(-0.17, 0.13)	–	–
	0.10	(-0.32, 0.19)	(-0.29, 0.25)	–	–
Below College Algebra	0.01	(-0.03, 0.05)	**(0.01, 0.10)**	–	–
	0.05	(-0.13, 0.14)	(-0.08, 0.20)	–	–
	0.10	(-0.24, 0.26)	(-0.20, 0.31)	–	–
Pass college-level course	0.01	(-0.09, 0.01)	(-0.03, 0.09)	(-0.05, 0.05)	(-0.02, 0.08)
	0.05	(-0.18, 0.10)	(-0.12, 0.19)	(-0.13, 0.14)	(-0.11, 0.17)
	0.10	(-0.29, 0.21)	(-0.23, 0.30)	(-0.24, 0.24)	(-0.23, 0.29)
College Algebra or above	0.01	(-0.09, 0.00)	(-0.07, 0.05)	–	–
	0.05	(-0.18, 0.09)	(-0.16, 0.14)	–	–
	0.10	(-0.30, 0.21)	(-0.27, 0.26)	–	–
Below College Algebra	0.01	(-0.04, 0.05)	**(0.00, 0.09)**	–	–
	0.05	(-0.13, 0.14)	(-0.09, 0.18)	–	–
	0.10	(-0.24, 0.25)	(-0.21, 0.30)	–	–
15 or more credits	0.01	(-0.04, 0.06)	(-0.05, 0.06)	(-0.06, 0.04)	(-0.04, 0.06)
	0.05	(-0.13, 0.15)	(-0.14, 0.15)	(-0.15, 0.12)	(-0.14, 0.15)
	0.10	(-0.24, 0.26)	(-0.26, 0.27)	(-0.25, 0.23)	(-0.25, 0.27)
Year 1 credits earned	0.01	(-1.20, 0.06)	(-0.52, 1.15)	(-0.34, 0.74)	**(0.18, 1.41)**
	0.05	(-1.29, 0.15)	(-0.61, 1.24)	(-0.43, 0.83)	**(0.09, 1.50)**
	0.10	(-1.40, 0.26)	(-0.72, 1.36)	(-0.54, 0.94)	(-0.03, 1.62)
Total credits earned in subject	0.01	**(-0.32, -0.04)**	**(0.15, 0.48)**	(-0.17, 0.12)	**(0.19, 0.49)**
	0.05	**(-0.41, -0.07)**	**(0.06, 0.58)**	(-0.26, 0.20)	**(0.10, 0.58)**
	0.10	(-0.53, 0.16)	(-0.06, 0.69)	(-0.37, 0.31)	(-0.02, 0.70)
Weighted college GPA in subject	0.01	(-0.06, 0.22)	(-0.06, 0.29)	**(0.03, 0.29)**	**(0.02, 0.28)**
	0.05	(-0.14, 0.31)	(-0.16, 0.39)	(-0.06, 0.38)	(-0.08, 0.37)
	0.10	(-0.25, 0.42)	(-0.27, 0.50)	(-0.16, 0.49)	(-0.19, 0.49)
Advance to 2nd Year	0.01	(-0.05, 0.06)	(-0.05, 0.07)	(-0.07, 0.03)	(-0.02, 0.09)
	0.05	(-0.14, 0.15)	(-0.15, 0.16)	(-0.15, 0.12)	(-0.11, 0.18)
	0.10	(-0.25, 0.26)	(-0.26, 0.28)	(-0.26, 0.23)	(-0.23, 0.29)

Note: – Not applicable. Bolded confidence intervals are statistically significant at the 95% level. Confidence intervals are estimated using *rdhonest* (Kolesár & Rothe, 2018) with a uniform kernel, Eicker-Huber-White standard errors and a bandwidth of +/-3 to mimic how the main results are estimated. In addition to sampling uncertainty, the confidence intervals here also account for misspecification biases, which increase with the value of the smoothness constant (M).

Table A4. Estimated Effects on First-Year Student Outcomes Using 11th Grade ACT Scores

	Math		English	
First-year Outcome	Low cut	High cut	Low cut	High cut
Take college-level course	-0.00	0.04	-0.05***	0.03*
	(0.02)	(0.02)	(0.02)	(0.02)
College Algebra or above	-0.02	-0.01	–	–
	(0.01)	(0.02)	–	–
Below College Algebra	0.02	0.05***	–	–
	(0.01)	(0.02)	–	–
Pass college-level course	0.03*	0.06**	-0.03*	0.03*
	(0.02)	(0.02)	(0.02)	(0.02)
College Algebra or above	-0.00	0.01	–	–
	(0.01)	(0.02)	–	–
Below College Algebra	0.03***	0.04***	–	–
	(0.01)	(0.01)	–	–
15 or more credits	0.04***	0.02	-0.01	-0.01
	(0.01)	(0.02)	(0.02)	(0.02)
Year 1 credits earned	0.82**	0.26	-0.66*	0.46
	(0.34)	(0.53)	(0.36)	(0.39)
Total credits earned in subject	0.12*	0.31***	-0.10	0.28***
	(0.06)	(0.10)	(0.08)	(0.08)
Weighted college GPA in subject	0.23***	0.18*	-0.04	0.07
	(0.07)	(0.10)	(0.08)	(0.07)
Advance to 2nd year	0.02	0.01	-0.01	0.02
	(0.02)	(0.03)	(0.02)	(0.02)
Number of observations	20,816	8,298	16,303	15,861

Note: – Not applicable. *, **, *** denote statistical significance at the 0.10, 0.05 and 0.01 levels, respectively. Eicker-Huber-White standard errors are in parentheses. Observation numbers are smaller for the last two outcomes. Counts for Weighted GPA are 9,682 (math low cut), 4,264 (math high cut), 9,281 (English low cut) and 9,717 (English high cut) because Pass/Fail courses do not have a numeric grade. Counts for persistence are 17,231 (math low cut), 7,020 (math high cut), 13,060 (English low cut) and 13,034 (English high cut) because second year enrollment data are not available for the 2024 freshmen cohort.

Table A5. Treatment-Comparison Contrast at the Cutoffs, by Gender

	Female		Male	
First-year outcome	Low cut	High cut	Low cut	High cut
I. Math				
Prerequisite math	0.07***	0.00	0.07***	0.01
	(0.01)	(0.01)	(0.01)	(0.01)
	[0.03]	[0.01]	[0.04]	[0.01]
Corequisite math	-0.02	0.15***	-0.02	0.13***
	(0.01)	(0.02)	(0.02)	(0.02)
	[0.19]	[0.02]	[0.18]	[0.02]
QR corequisite	0.04***	0.00	0.04***	0.00
	(0.01)	(0.00)	(0.01)	(0.01)
	[0.01]	[0.00]	[0.01]	[0.00]
CA corequisite	-0.06***	0.15***	-0.06***	0.13***
	(0.01)	(0.02)	(0.01)	(0.02)
	[0.18]	[0.01]	[0.17]	[0.02]
QR gateway math without DE	-0.02	0.07***	-0.03**	0.02
	(0.01)	(0.02)	(0.02)	(0.02)
	[0.14]	[0.08]	[0.21]	[0.13]
CA gateway math without DE	0.01	-0.14***	0.01	0.02
	(0.01)	(0.03)	(0.01)	(0.02)
	[0.20]	[0.37]	[0.14]	[0.32]
Number of observations	14,154	5,471	9,471	4,936
II. English				
Prerequisite English	0.08***	-0.01	0.10***	-0.01
	(0.02)	(0.01)	(0.02)	(0.01)
	[0.08]	[0.02]	[0.08]	[0.02]
Corequisite English	-0.07***	0.14***	-0.07***	0.17***
	(0.02)	(0.02)	(0.02)	(0.02)
	[0.27]	[0.05]	[0.22]	[0.05]
Number of observations	9,812	10,488	6,933	7,248

Note: *, **, *** denote statistical significance at the 0.10, 0.05 and 0.01 levels, respectively. Eicker-Huber-White standard errors are in parentheses, and the means at the cutoffs are in square brackets. Corequisite courses for English include IRW 100 and ENG 100. English prerequisite courses include ENC 91, IRW 085, IRW 095, and ENG courses lower than 100. Corequisite courses for math include MAT 100 and courses with course numbers suffixed with “s”.

Table A6. Estimated Effects on First-Year Student Outcomes, by Full- and Part-Time Status

	Full Time		Part Time	
First-year outcome	Low cut	High cut	Low cut	High cut
I. Math				
Take college-level course	-0.02	0.01	-0.02	-0.02
	(0.02)	(0.02)	(0.03)	(0.04)
College Algebra or above	-0.03*	-0.04*	-0.04	-0.04
	(0.02)	(0.02)	(0.02)	(0.04)
Below College Algebra	0.02	0.04***	0.02	0.02
	(0.01)	(0.02)	(0.02)	(0.03)
Pass college-level course	0.01	0.02	-0.01	-0.01
	(0.02)	(0.02)	(0.02)	(0.04)
College Algebra or above	-0.01	-0.02	-0.02	-0.04
	(0.02)	(0.02)	(0.02)	(0.04)
Below College Algebra	0.03**	0.04***	0.02	0.03
	(0.01)	(0.02)	(0.02)	(0.02)
15 or more credits	0.04***	0.02	0.00	-0.02
	(0.01)	(0.02)	(0.03)	(0.04)
Year 1 credits earned	0.43	0.43	0.23	-1.02
	(0.37)	(0.53)	(0.49)	(0.84)
Total credits earned in subject	0.01	0.24**	-0.07	0.12
	(0.07)	(0.10)	(0.10)	(0.16)
Weighted college GPA in subject	0.21***	0.16	0.20	-0.03
	(0.07)	(0.10)	(0.14)	(0.21)
Advance to 2nd year	0.04**	0.02	0.00	-0.03
	(0.02)	(0.03)	(0.03)	(0.05)
Number of observations	16,381	7,748	7,244	2,659
II. English				
Take college-level course	-0.06**	0.02	-0.06**	0.07**
	(0.02)	(0.02)	(0.03)	(0.03)
Pass college-level course	0.00	0.03	-0.03	0.08***
	(0.02)	(0.02)	(0.02)	(0.03)
15 or more credits	0.02	0.01	-0.05*	-0.01
	(0.02)	(0.02)	(0.03)	(0.03)
Year 1 credits earned	0.61	0.62	-0.60	0.83
	(0.50)	(0.44)	(0.39)	(0.53)
Total credits earned in subject	0.00	0.33***	-0.12	0.45***
	(0.12)	(0.10)	(0.11)	(0.13)
Weighted college GPA in subject	0.22**	0.09	0.06	0.32**
	(0.10)	(0.08)	(0.14)	(0.14)
Advance to 2nd Year	-0.02	0.01	0.00	-0.00

	(0.03)	(0.02)	(0.03)	(0.03)
Number of observations	10,330	12,193	6,415	5,543

Note: *, **, *** denote statistical significance at the 0.10, 0.05 and 0.01 levels, respectively. Eicker-Huber-White standard errors are in parentheses. Observation numbers (available upon request) are smaller for Weighted GPA because Pass/Fail courses do not have a numeric grade, and for persistence because second year enrollment data are not available for the 2024 freshmen cohort.

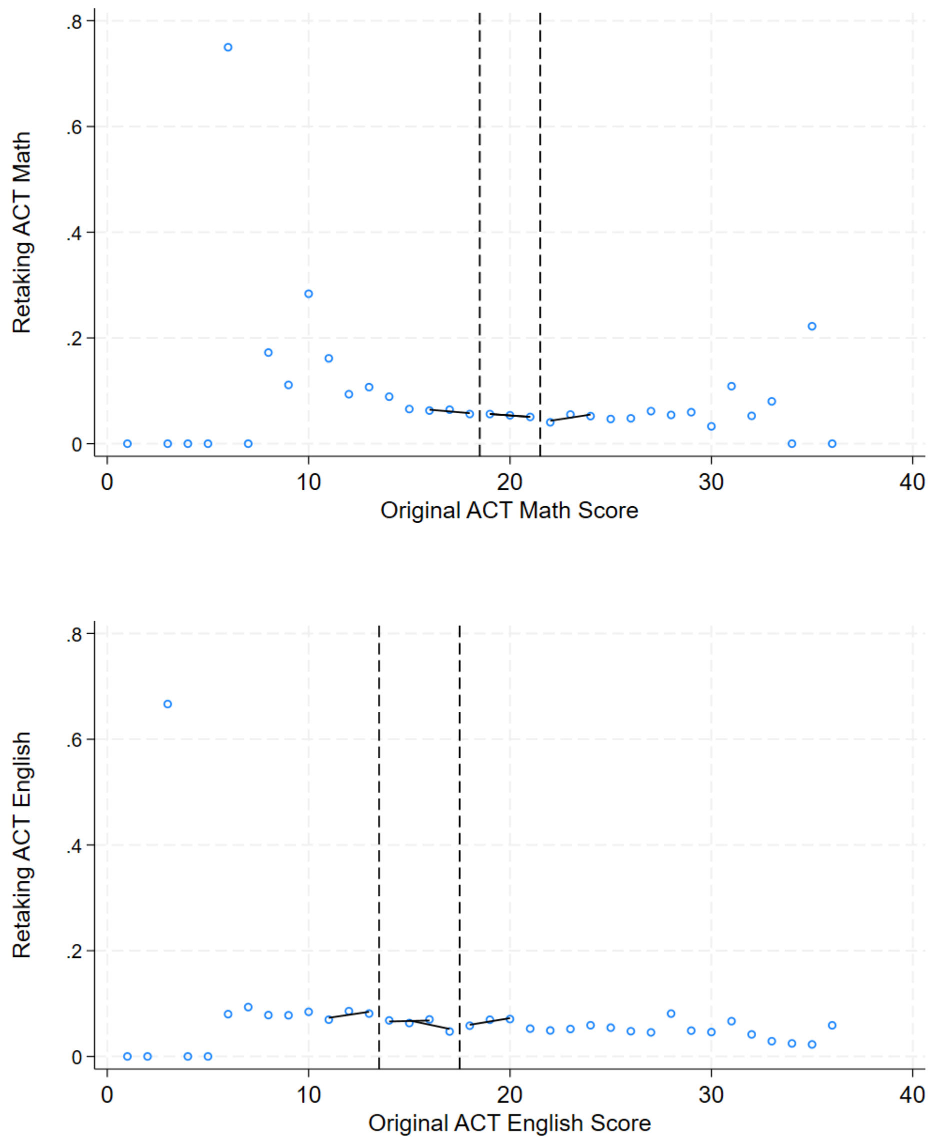
Table A7. Estimated Effects on First-Year Student Outcomes, by Underrepresented Minority (URM) Student Status

	URM		Non-URM	
First-year Outcome	Low cut	High cut	Low cut	High cut
I. Math				
Take college-level course	-0.01	-0.03	-0.02	0.00
	(0.04)	(0.07)	(0.02)	(0.02)
College Algebra or above	-0.00	-0.02	-0.04**	-0.05**
	(0.04)	(0.07)	(0.01)	(0.02)
Below College Algebra	0.00	0.01	0.02*	0.05***
	(0.03)	(0.04)	(0.01)	(0.02)
Pass college-level course	0.02	-0.03	0.01	0.01
	(0.04)	(0.07)	(0.02)	(0.02)
College Algebra or above	0.02	0.01	-0.02	-0.02
	(0.03)	(0.06)	(0.01)	(0.02)
Below College Algebra	0.01	0.03	0.03**	0.04***
	(0.02)	(0.04)	(0.01)	(0.01)
15 or more credits	0.08**	0.09	0.03**	-0.00
	(0.04)	(0.06)	(0.01)	(0.02)
Year 1 credits earned	2.22***	3.84***	0.21	-0.34
	(0.78)	(1.43)	(0.34)	(0.50)
Total credits earned in subject	0.11	0.48*	-0.03	0.18*
	(0.15)	(0.27)	(0.06)	(0.09)
Weighted college GPA in subject	0.32*	0.35	0.19***	0.10
	(0.18)	(0.29)	(0.07)	(0.10)
Advance to 2nd year	0.06	0.06	0.03*	0.00
	(0.04)	(0.07)	(0.02)	(0.02)
Number of observations	3,921	1,121	19,704	9,286
II. English				
Take college-level course	-0.02	0.05	-0.08***	0.04**
	(0.03)	(0.04)	(0.02)	(0.02)
Pass college-level course	0.01	0.04	-0.02	0.05***
	(0.03)	(0.04)	(0.02)	(0.02)
15 or more credits	-0.00	0.02	-0.03	0.01
	(0.03)	(0.04)	(0.02)	(0.02)
Year 1 credits earned	0.44	0.61	-0.24	0.82**
	(0.59)	(0.81)	(0.43)	(0.40)
Total credits earned in subject	0.05	0.58***	-0.10	0.34***
	(0.15)	(0.21)	(0.10)	(0.09)
Weighted college GPA in subject	0.10	0.16	-0.10	0.14*
	(0.15)	(0.17)	(0.10)	(0.07)

Advance to 2nd Year	-0.01	-0.02	-0.01	0.02
	(0.04)	(0.05)	(0.02)	(0.02)
Number of observations	4,198	2,973	12,547	14,763

Note: *, **, *** denote statistical significance at the 0.10, 0.05 and 0.01 levels, respectively. Eicker-Huber-White standard errors are in parentheses. Observation numbers (available upon request) are smaller for Weighted GPA because Pass/Fail courses do not have a numeric grade, and for persistence because second year enrollment data are not available for the 2024 freshmen cohort.

Figure A1. Probability of ACT Retake by 11th-Grade ACT Score



Notes: Displays average probability of ACT retake by 11th-grade ACT score along with vertical lines denoting college readiness ACT benchmarks of 19 and 22 (math) and 14 and 18 (English). Each figure contains a linear best fit line through three points on either side of the college readiness cutoffs.