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Does Corequisite Remediation Work for Everyone? An Exploration of Heterogeneous Effects and Mechanisms

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Does Corequisite Remediation Work for Everyone?

An Exploration of Heterogeneous Effects and Mechanisms

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Abstract

The landscape of developmental education has experienced significant shifts over the last decade nationwide, as more than 20 states and higher education systems have transitioned from the traditional prerequisite model to corequisite remediation. Drawing on administrative data from Tennessee community colleges from 2010 to 2020, this study examined the heterogeneous effects of corequisite reform for remediation-eligible students with varying levels of academic preparation. Using difference-in-differences and event study designs, we found that corequisite remediation significantly improved gateway and subsequent college-level course completion for students in all placement test score groups below the college-level threshold. For math, the positive effects on college-level course completion were stronger for higher-scoring remedial students than for those with lower placement test scores, whereas the pattern was reversed for English. However, since the corequisite reform, students requiring remediation were more likely to drop out of the public college system, and those with the lowest scores were less likely to earn short-term certificates.

I. Introduction

Academic under-preparation is one of the main non-financial barriers to college access and success (Dynarski et al., 2022). Of the 2019 graduating class—the last high school cohort who did not experience disruptions of the Covid pandemic—an estimated one in every three graduates did not meet the college-readiness benchmarks in any subject tested (ACT, 2019). Because of the open-door policy of community colleges and other broad-access postsecondary institutions, developmental education (or remediation),[1] a program designed to bring underprepared students up to an adequate level for college study, should be instrumental in ensuring mass postsecondary education. Since Black and Hispanic students and students from low-income backgrounds disproportionately enroll in developmental courses (Chen et al., 2020), this program should also play an important role in mitigating racial and income gaps in college enrollment and completion.

However, the landscape of developmental education has experienced significant shifts across the nation in the last decade, mainly because the traditional remediation model did not achieve its intended goals. The traditional prerequisite approach typically required students below college-ready thresholds to pass a sequence of remedial courses before enrolling in college-level coursework. However, this approach had a few problems, including inaccurate placement (Scott-Clayton et al., 2014), high attrition rates (Bailey et al., 2010), and disconnected content covered in remedial and college-level courses (Cullinane & Treisman, 2010). In the past few years, more than 20 states have adopted corequisite models, allowing remedial students—and in many cases, mandating everyone regardless of their level of readiness—to take college-level courses with concurrent academic support upon initial enrollment (Education Commission

[1] In this paper, we use developmental education and remediation interchangeably.

of the States, 2021). Such reforms led to significant improvements in the completion rates of the first college-level courses, especially for students who just missed college thresholds by a few points (e.g., Meiselman & Schudde, 2022; Ran & Lin, 2022).

The gap in understanding of corequisite reform is its implications for students who are far below the college-readiness threshold. These students were typically excluded from previous literature examining the effects of developmental education, as most previous research relied on regression discontinuity (RD) designs using students just above and below the college-ready threshold to establish causality. Two studies did extend their analyses to lower-scoring students, but what they examined was the "local" effects of a shorter vs. a longer prerequisite sequence, not the effects of mainstreaming all remedial students into college-level classrooms (Boatman & Long, 2018; Xu & Dadgar, 2018). Despite a few randomized control trials showing overall positive impacts (Logue et al., 2016; Logue et al., 2019; Miller et al., 2022), researchers and higher education practitioners need more causal evidence of the heterogeneous impacts of removing standalone prerequisite sequences.

This study closes this gap in the literature by examining the heterogeneous effects of corequisite versus prerequisite remediation on college success and unpacking the mechanisms of how corequisite remediation affects students with different levels of college readiness. To do so, we obtained administrative data from the Tennessee Board of Regents (TBR) between 2010-11 and 2019-20. TBR provides a great context for this study, as it was the first higher education system in the nation to replace the standalone prerequisite sequence with the corequisite models for all incoming students since 2015. We used difference-in-differences (DID) and event study strategies to compare the outcomes of remedial students with similar placement scores before and after the corequisite implementation, using changes in the outcomes of college-ready students during the same time period to control for general time trends or shocks from other policy changes.[2] To account for slight variations in corequisite implementation timelines across colleges, we also used heterogeneity-robust estimators for our DID and event study models as robustness checks (Callaway & Sant'Anna, 2021; Sun & Abraham, 2021).

Overall, we found that students placed into corequisite remediation were up to 20.4 percentage points (or 77%) more likely to pass gateway math and 22.8 percentage points (or 42%) more likely to pass gateway English within one year of enrollment compared with otherwise similar students placed into prerequisite remedial courses. However, corequisite reform had null effects on the number of college-level credits earned or the likelihood of transfer to a public four-year university by the end of the third year. Since the corequisite reform, students placed below the college-readiness threshold were 4.3 percentage points (or 8.1%) less likely to continue enrolling in the state's public college system and 3.0 percentage points (or 28.8%) less likely to earn a credential (mostly certificates) within three years of the initial enrollment. While the effects on gateway course completion were positive across the full spectrum of placement test score distributions, the negative effects on enrollment persistence and credential completion were primarily driven by students coming in with the lowest scores.

We make three distinctive contributions to developmental education research and policymaking. First, we provided new empirical evidence on the effects of the developmental education reform for students who were not present in the previous literature, primarily using RD methods. As shown in Table A1, the analytic samples in the previous literature include students within a few points above and below the college-readiness threshold, typically between the 40th and 50th percentiles, if converted to ACT. In contrast, our study included students on the entire

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[2] In this study, we use remedial students and college-ready students to refer to students based solely on their placement exam scores.

spectrum of placement score distribution, with ACT composite scores ranging from 1 to 34. By including these students, our sample covers a higher proportion of underrepresented minorities, which represents approximately 55% of the lowest scoring group. Researchers have repeatedly shown that students at the lower end of standardized test score distributions are more likely to come from low-income backgrounds or live in poverty (e.g., Dixon-Román, Everson, & McArdle, 2013). Evidence of the effects of the corequisite reform for students in these demographic groups is crucial to understanding the potential of one of the most extensive interventions targeting academic under-preparation in closing racial and socioeconomic gaps in college success.

Second, we articulated a conceptual framework of how corequisite remediation leads to changes in college outcomes, built on theoretical frameworks developed by Scott-Clayton and Rodriguez (2015) and Kane et al. (2019). We found that the positive effects on gateway course completion were driven by providing direct access and reducing delays to college-level courses. Since students in the lowest-scoring group used to go through the longest prerequisite sequence, they experienced the largest improvement in gateway course enrollment among all remedial students. However, not all students were able to pass the gateway and more advanced college-level courses. The total instruction time on developmental content significantly reduced since the reform, almost cut in half for students with lower scores. In addition, corequisite models also produced de-tracking effects, making college-level classrooms more heterogeneous in terms of students' academic readiness. We found that a 10-percentage-point increase in on-level peers was associated with a 2.7-percentage-point decrease in gateway math completion rates and a 3.3-percentage-point decrease in English.

Lastly, these results can inform ongoing reforms across more than twenty states and systems. The heterogeneous effects that corequisite reform produced for students from different test score groups as well as for different subjects suggest that there is no one-size-fits-all corequisite model. For students who are severely underprepared for college-level studies, colleges need to consider ways to provide enhanced support such as tutoring and academic counseling. This support may need to continue after students move beyond their first college-level math and English, as our results indicated that many lower-scoring remedial students were not able to pass advanced college-level courses even after they successfully completed gateway courses. The more sequential nature of math skill development compared with English means that colleges may experiment with alternative structures of corequisite learning support for different subjects. Some colleges and systems have been adopting corequisite models that use the first half of the semester to cover fundamental skills and move to college-level materials in the second half. Colleges may also consider designating certain gateway course sections exclusively for students with a greater need for support, and adapting the course pace accordingly.

II. Literature Review and Conceptual Framework

A. Previous literature on developmental education

Traditional prerequisite developmental education (DE) is essentially a tracking system that affects student outcomes in three ways: skill *development* that prepares students with remedial needs for future college-level courses, a *delay* that postpones enrollment in college-level courses, and a *diversion* that places remedial and college-ready students into separate courses and reduces heterogeneity within classrooms (Kane et al., 2019; Scott-Clayton & Rodriguez, 2015). Ideally, students should be placed in the appropriate track to develop skills that satisfy their needs. The positive developmental boost has to be large enough to offset the delay or diversion from college-level coursework for developmental education to provide an overall positive effect on college outcomes.

As shown in Panel A of Table A1, the majority of prior literature found null to negative effects of prerequisite DE on early college outcomes. The prerequisite nature of the support created multiple exit points before many students getting into the college-level study: as Bailey, Jeong, and Cho (2010) estimated, up to one third of students referred to DE exited the prerequisite sequence before completing the sequence. Many of them could have passed college-level courses without any remediation, as they were misplaced into DE by a single standardized test score (Scott-Clayton et al., 2014). These students suffered from the adverse consequences of delay, with little or no developmental benefit. Recent randomized trial evidence found that compared to single measures alone, multiple measures that combined high school GPA, standardized test scores, and other measures for placement purposes were much more predictive of future performance (Barnett et al., 2020; Bergman et al., 2021).

Another problem with the traditional DE was its instructional approaches and curriculum designs. Many community college students did not understand basic algebra concepts or have the literacy skills to read college-level textbooks. Traditional DE courses did not provide enough developmental benefits for students truly in need of academic support to succeed in college-level courses because of decontextualized instruction and poor alignment between remedial and college-level courses (Jaggars & Bickerstaff, 2018). To improve college outcomes, remedial students also need a more effective curriculum and pedagogy to garner skill development.

The emerging evidence in general showed that corequisite approaches were more effective than the traditional DE in helping students pass the first college-level English and math courses (Panel B of Table A1). Except for two randomized control trials with smaller sample sizes (Logue et al., 2019; Miller et al., 2022), studies on corequisite DE have focused on the around-the-cutoff population. To inform the current waves of corequisite DE reforms across the nation, researchers and practitioners need to better understand the following areas: (1) the effects of corequisite DE for students at the lower end of skill distribution, (2) the ways in which corequisite DE affects the curriculum and total instructional time for students with different levels of preparedness, and (3) whether corequisite DE works similarly for different subject areas.

B. Conceptual framework of the effects of corequisite DE

Corequisite DE leads to changes in all the three mechanisms described above. First and foremost a structural reform, corequisite remediation is premised on reducing the delay effect by allowing all incoming students to enroll in college-level study immediately upon enrollment. This would also lead to more students enrolling in college-level courses, as this approach helps students avoid exiting points before college-level courses. In addition, with the corequisite approach, college-ready and remedial-eligible students are mixed in college-level classrooms, which changes peer dynamics and may result in differences in learning outcomes for both on-level and remedial students after the corequisite reform.

As for the "skill development" mechanism, we hypothesized that corequisite DE leads to changes in the timing, content, and intensity of developmental support. Corequisite DE provides "just in time" support to remedial students, rather than asking them to build the required skills in a prerequisite sequence before they arrive at college-level classrooms. Due to the contemporaneous nature of the support, many colleges use corequisite reform as an opportunity to align the content and curriculum of developmental support with college-level courses. One example is that incorporating alternative math pathways and content in developmental math no longer focuses solely on algebra. Colleges offer corequisite learning support for statistics, quantitative reasoning, and math for liberal arts to pair with the gateway math courses required by students' program of study. Finally, the corequisite approach typically compresses the total instructional time for remediation by combining two or more developmental courses into a single one-semester experience (Edgecombe, Cormier et al., 2013).

Both the structure and quality of implementation would determine how the skill development mechanism works for corequisite remediation. Originating from Accelerated Learning Programs for English (Cho et al., 2012), the premise of corequisite learning is that contemporaneous support can help students build and refresh skills in meaningful contexts before they fade out. However, curricular and skill development may be more sequential in certain subjects than in others. Students with lower placement test scores arrive at community colleges lacking proficiency in fractions, decimals, and applications of algebra skills in word problem solving (Ngo, 2019). When these students are enrolled in a college algebra or statistics course, just-in-time support may not guarantee work.

In addition, while this study primarily focuses on the structural perspective of the corequisite reform, we must not overlook the crucial role of instructors in teaching learning support courses and the pedagogical practices employed in these courses, as they heavily influence the extent to which corequisite remediation benefits students' skill development. One challenge in replacing standalone DE with corequisites is the shortage of faculty with credentials to teach college-level coursework, especially if colleges want to staff a common instructor for the corequisite and college-level sections (Daugherty et al., 2018). This problem may be more pronounced for math than for English, as it is harder for STEM fields to recruit high-quality instructors when earnings and job opportunities in alternative industries are more competitive for individuals with STEM degrees (Xu & Ran, 2022). These factors may contribute to the different effects of corequisite DE across different subject areas.

These three mechanisms may function differently for students with different levels of preparedness. Students with lower placement test scores experienced the longest delay from the traditional DE, as they were assigned to longer DE sequences. Corequisite DE may benefit them the most in terms of college-level credit accumulation, by giving them direct access to these courses. The effects of mixing remedial and on-level students in college-level classrooms depend on the peer composition of course sections. Previous literature provides a strong theoretical and empirical basis for the existence of peer effects in higher education (e.g., Sacerdote, 2011; Winston & Zimmerman, 2004), but it is unclear whether underprepared students could benefit more from higher-achieving students because of the transfer of specific knowledge and general academic know-how (Griffith & Rask, 2014) or from similar-ability students as instructors could teach to their level. The development component under corequisite models may work better for higher-scoring remedial students, as previous studies have shown that the lowest-placed remedial students benefit from an intensive focus on building basic numeracy and literacy skills before matriculating (Scrivener et al., 2018).

III. Context & Data

A. State & institutional context.

Remediation placement. The placement policy for developmental education in Tennessee did not undergo any major changes during the study period. Scores from the mandatory standardized tests in 11th grade, mainly ACT, were the sole determinant for remediation at TBR community colleges until the fall of 2020. The ACT scores to satisfy direct placement in college-level remained as a score of 19 for math, 18 for writing, and 19 for reading between 2010 fall to 2020 spring. Since the majority of TBR community colleges set minimum scores for both writing and reading for direct placement into college-level English, we used the minimum scores of the two subjects to determine students' placement status for English. It is possible for students to re-take the ACT during high school or take other types of standardized tests (such as ACCUPLACER, ASSET, or COMPASS) after arriving at college to waive remediation requirements. In our data, around 6% of the entering cohorts between 2010 and 2018 reported multiple test scores. As students who challenged their remediation status by retesting might be systematically different from others, we used students' earliest available scores on records for the analyses.

Corequisite implementation. During Fall 2014 and Spring 2015, the TBR started to pilot corequisite remediation across nine colleges (Denley, 2015).[3] We found that 11 out of the 13 community colleges fully scaled corequisite implementation in academic year 2015-16, with virtually no students taking standalone prerequisite remedial courses afterward, while the remaining two colleges did so by 2017-18. Before the corequisite reform, remedial students were placed into a developmental sequence consisting of different levels and numbers of courses based on their placement test scores. Our analyses of student transcript data suggest that the number of prerequisite remedial credits enrolled ranged from one course for those just below the college threshold, to up to three courses for those with the lowest ACT scores. After the reform, while TBR's policy allowed colleges to offer varying levels of corequisite learning support, the

[3] In math, 1,019 students in nine colleges participated in the pilot; close to 1,000 students across seven colleges participated in the pilot for writing.

system's internal report showed that colleges rarely tailored the learning support experience based on a student's academic preparation.[4] Most corequisite courses are semester-long experiences for all remedial students. TBR does not require a standard format for learning support courses. We found some variations in the delivery methods, with three colleges offering the vast majority of their corequisite courses through online courses. We did not see systematic changes in corequisite implementation in TBR's policy documents until 2020 Fall, when the system started a pilot to add high school GPA as a method for placement alongside traditional measures such as ACT scores.[5]

Other policies aimed at improving college success. During the same period of the corequisite implementation, the public education system in Tennessee enacted a few other policy changes to improve college access and success. First, public high schools in Tennessee launched the Seamless Alignment and Integrated Learning Support (SAILS) program in 2012, which aimed to help students complete math remediation in high school and was scaled to around 250 high schools in 2015. Kane et al. (2021) showed that completing SAILS boosted enrollment in college-level math for the college entering cohort of 2014-15, but after the corequisite policy took effect, SAILS no longer produced any additional effects. To separate the possible influence of SAILS, we conducted robustness checks using a subsample of students who graduated from high schools and were unlikely to be affected by SAILS. The Tennessee Promise Scholarship was launched in 2015. It provides Tennessee high school graduates attending community colleges full-time with last-dollar scholarships to cover tuition and fees. As discussed in more detail in the Empirical Strategy section below, this would not bias our results as long as the

4 Information retrieved from https://www.tbr.edu/sites/default/files/media/2022/01/8.VaryingLevels.pdf

5 Information retrieved from https://www.tn.gov/content/dam/tn/stateboardofeducation/documents/education-recovery-and-innovation-commission/2020-report/2020_December_Student%20Access%20and%20Success%20Data.pdf

Promise Program affects students above and below the college readiness threshold in a similar way.

B. Data Description.

Table A2 presents the sample restriction process and how summary statistics change across different samples. Our raw data came from 407,193 students enrolled at one of the 13 community colleges in TBR at any time since the fall of 2010. Given our focus on the heterogeneous effects of corequisite remediation across test score distributions, we restricted our analyses to first-time-in-college students who had at least one set of standardized test scores on record. We also excluded students who entered TBR later than the fall of 2018 to allow a sufficient tracking period for enrollment and attainment outcomes. This restriction dropped around half of the students in the raw data, leaving us a sample of 194,524 students who were much younger at college entry (19.5-year-old vs. 24.0-year old). Next, we restricted our sample to first-time-in-college (FTIC, hereafter) students who entered TBR community colleges during the fall semester immediately after high school. We implemented this restriction for two reasons. First, this is to mitigate possible changes in students' age composition across cohorts due to the introduction of the Promise Scholarship in 2015, as students must apply for Promise during their senior year in high school. In addition, the recent high school graduate fall entrant sample was significantly less prone to data quality issues. Only 2% of the students in this sample did not report a 4.0-scale high school GPA (because of missing or non-standard format high school GPA), whereas 11% of the FTIC sample and close to half of the students in the raw data did not have valid high school GPA records. The caveat of these sample restrictions is that compared to the general student population that TBR community colleges serve, students in our final analytic sample were much younger and had slightly lower test scores and high school GPAs. We need to be cautious about generalizing the results of this study to older students who have longer gaps between high school and community college enrollment.

The final analytic sample consists of 91,511 students. Table 1 contains descriptive statistics for all background and outcome variables for students in our analytic sample by prerequisite and corequisite cohorts. In general, students' demographic characteristics remained fairly consistent across cohorts. On average, 75% of students were assigned to remediation for at least one subject, and the proportions of students referred to remediation remained consistent for students entering TBR during prerequisite and corequisite regimes. On the other hand, changes in outcome variables between the prerequisite and the corequisite cohorts are noticeable. Corequisite cohorts were more likely to complete gateway courses by the end of the first year, by 14 percentage points for math and 9 percentage points for English. In addition, corequisite cohorts were more likely to enroll and complete additional college-level math or English courses. However, the differences in college-level credit accumulation between the corequisite and the prerequisite cohorts diminished by the end of year three. No clear patterns emerged for persistence and credential completion outcomes: the likelihood of stopping enrollment at community colleges and public universities in Tennessee increased by 10 percentage points for the corequisite cohorts, but credential completion rates also increased by 5 percentage points.

To assess the heterogeneous effects of corequisite versus prerequisite remediation by readiness, we separated students below the college-readiness threshold into three subgroups based on placement test scores converted to ACT scales. Group 1 contained students with the lowest scores, who scored six or more points below the college readiness threshold (15% of the analytic sample). Group 2 included students scoring three to five points below the cutoff (38% of the analytic sample), and Group 3 was the highest-scoring remedial students who scored one or two points below the college-readiness cutoff (23% of the analytic sample). The rationale for test score grouping is as follows. A previous study on corequisite reform in Tennessee examined the effects of corequisite versus no remediation for Group 3 students using the regression discontinuity (RD) method (Ran & Lin, 2022). These students were virtually identical to students right above college-level thresholds in terms of demographic and high school academic measures. Groups 1 and 2 contained students with weaker academic preparation, as reflected by their lower placement test scores and lower average high-school GPA. We chose the six-points-from-cutoff threshold to separate Groups 1 and 2 because most students (> 98%) below this threshold were referred to corequisite learning support for *all* three subjects. It takes 18 credit hours to complete three gateway courses paired with learning support sections. Since most full-time students register for four courses (or 12 credit hours) in one semester, it is very difficult for students in Group 1 to fulfill the corequisite requirements within the first semester.

IV. Empirical Strategy

A. Identification strategy

We applied a difference-in-differences (DID) approach to estimate the impacts of corequisite remediation on a set of college success outcomes, compared with traditional prerequisite remediation. Exploiting that any changes in remediation policy should affect only students below college level, we compared the outcomes of remedial-eligible students before and after the implementation of the corequisite reform, using college-ready students as the control group to adjust for any general time trends or policy changes (such as Promise Scholarship) that potentially affected all students. Specifically, we estimated the following equation:

$$Y_{ijt} = \beta_0 + \beta_1 (Below_i * Post_{tj}) + \beta_2 Below_i + \phi_t + \lambda_j + \beta_n X_{itj} + \epsilon_{itj} \qquad (1)$$

Here, Y_{ijt} is the outcome of student *i* of entering cohort *t* in college *j*. $Below_i$ is a student-level indicator for placing below college-level cutoff scores. For the student-level analyses, such as enrollment persistence or credential completion, we used minimum scores across all three subjects to define placement into remediation.[6] $Post_{tj}$ is an indicator for post-corequisite cohorts, which varies across colleges. The coefficient β_1 captures the intent-to-treat (ITT) estimates of the effects of placement into corequisite remediation versus the prerequisite model. In this model, we also controlled for any general time trends through cohort fixed effects (ϕ_t) and any systematic differences in student outcomes across institutions through college fixed effects (λ_j). The vector X_{itj} contains a set of student covariates including gender, age at college entry, race, international student status, placement test scores, high school GPA, and high school fixed effects. Standard errors were three-way clustered at college-, high school-, and cohort-level.

To capture the heterogeneous effects of corequisite remediation by academic preparedness, we further estimated the following model:

$$Y_{itj} = \gamma_0 + \gamma_k(Scorebin_i * Post_{tj}) + \gamma_n(Scorebin_i) + \phi_t + \lambda_j + \beta_n X_{itj} + \epsilon_{itj} \quad (2)$$

where $Scorebin_i$ represents the indicators for the three groups of placement test score bins described above, and the coefficient γ_k captures the effects of placing into corequisite versus prerequisite remediation for students within each bin. The reference group consisted of students above the college-ready threshold.

Because not all remedial-eligible students enrolled in the remedial courses they were referred to, we can obtain the enrollment effects of corequisite versus prerequisite remediation

[6] We also conducted robustness checks using the average scores of all three subjects to define placement status. The results are consistent with those presented in the article. These results are available upon request.

(i.e., treatment on the treated) by instrumenting a student's enrollment in remedial courses using their placement status. The classic exclusion restriction assumption in the instrumental variable framework requires that a student's remedial placement status does not affect her outcomes in ways other than enrollment in remedial courses. Since we can only observe students already enrolled in community colleges in our sample, it requires that remedial designation did not have a direct impact on students' decisions to attend college. Martorell et al. (2015) provided evidence that the effects on college enrollment were insignificant for students around the college-level threshold, although it is not clear whether such conclusions can be generalized to students further away from the college-level threshold. Therefore, in this paper, we focus on the reduced-form estimates of placement effects as our main results.

We also used event study models to examine the effects of corequisite remediation over time. The regression model used for the analysis is as follows:

$$Y_{itj} = \phi_t + \lambda_j + \sum_{\tau=-4}^{-1} \gamma_\tau Below_{itj} + \sum_{\delta=0}^{3} \gamma_\delta Below_{itj} + \beta_n X_{itj} + \epsilon_{itj} \qquad (3)$$

The coefficients γ_τ and γ_δ measure the differences in trajectories of outcomes between remedial and college-ready students relative to the corequisite implementation timeline after controlling for time fixed-effects (ϕ_t) and college fixed-effects (λ_j). Across all specifications, we used five years before the corequisite implementation as the reference year to estimate γ_τ and γ_δ.

B. Validity of DID estimates

Our setting includes college-ready students who were never treated by corequisite remediation and remedial students treated by the reform that started at different time points across colleges. As Goodman-Bacon (2021) showed, the traditional two-way fixed effects (TWFE) estimator described in Equation (1) is a weighted average of all potential canonical 2x2

DID estimates where weights are based on group sizes and variance in treatment. With a staggered treatment timing setting, the following assumptions were required:

The first is the variance-weighted common trends. This is similar to the parallel trend assumption in the canonical DID settings.[7] In other words, the trajectories of outcomes for remedial and college-level students would have been the same if corequisite remediation had not been implemented. We examined whether remedial students were already on a different trajectory before the implementation of corequisite remediation by testing whether γ_τ in Equation (3) was statistically significant. The results in Figure A1 suggest that, compared with five years before the corequisite reform, the effects of placing below the college-readiness threshold were insignificant for two to four years before the reform, and as expected, gateway completion rates started to increase one year before full implementation during the pilot period. These event study estimates provided evidence supporting the parallel trends assumption, as they suggested that the outcomes of remedial and college-ready students had similar trajectories before the reform.

To isolate the effects of corequisite remediation, another important assumption is that the characteristics of students in the treatment and comparison groups did not undergo differential changes during the study period. To test this, we conducted a series of covariate balance tests using our main difference-in-differences specifications with student covariates as outcomes. In these tests, the coefficients of below college-readiness cutoff tell us about the overall differences in covariates between college-ready and remedial students. Meanwhile, the coefficients of post corequisite reform show how student characteristics change over time in general. The coefficients of the interaction terms between below the cutoff and post-reform are the parameters of interest here: they show whether student characteristics were significantly different for

[7] As Goodman-Bacon (2021) showed, this is actually a weaker assumption compared with identical trends, because the weights can make the trends hold even without exact parallel trends.

students below the college readiness cutoff after the reform. The results reported in Table A3 suggest that changes in all but one covariate (the proportion of black students) were balanced across the treatment and control groups. We further conducted subgroup covariate balance tests to examine whether changes in student characteristics systematically differed across remedial students in the different test score groups. The results in Panel B of Table A3 show that the lowest test score group contained fewer underrepresented minority students than before the reform. In addition to the small changes in racial composition, the three groups of remedial students and college-ready students did not experience systematic differences in student demographic characteristics and academic attributes.

This assumption also requires that the corequisite reform or other policies during the same period, such as SAILS, did not affect college-going decisions or alternate characteristics of college enrollees over time. While we cannot directly conduct a test on this, as our data only contain students already enrolled in TBR colleges, Kane and coauthors provided evidence that SAILS did not affect enrollment in community colleges by the spring of 1st year after high school graduation (Table 3 of Kane et al. [2019]). Taken together, compositional changes in the comparison group are unlikely to be an alternative explanation for the findings presented below.

The next assumption is the constant treatment effects within groups over time. As discussed in Goodman-Bacon (2018), TWFE estimates could yield biased results when the composition of the comparison group is changing (representing a shifting mix of not-yet-implementers and previous-implementers) if the treatment effects change over time within groups. To assess whether the effects of the corequisite reform changed over time, we conducted F-tests to examine whether the coefficients of placing below the college-readiness threshold were equal across the corequisite implementation timeline. The F-statistics were 1.51 for the completion of gateway math by year one and 0.88 for English. We cannot reject the null hypothesis of homogeneous effects over time. Nevertheless, we further examined whether our results were robust in the case of varying effects between early and late adopters. We compared the estimates from the original TWFE models with two different heterogeneous-robust estimators recently developed by Callaway and Sant'Anna (2021) and Sun and Abraham (2021), as shown in Columns 3 and 4 of Table 2. Figure A1 illustrates comparisons of these estimators. The fairly consistent results across the models suggest that the TWFE specifications are robust in our setting.

V. Results

A. Effects of corequisite remediation

Gateway course completion. Table 2 shows the effects of corequisite versus prerequisite remediation on first-year gateway math and English completion rates for all students in our analytic sample. Based on the TWFE estimates, students placed into corequisite remediation were 20.4 percentage points more likely to complete gateway math by the end of year one, compared with otherwise similar students placed into prerequisite remediation. This represents a 76% improvement from the baseline average of the prerequisite cohorts. The effect for English was 22.8 percentage points (41% increase from the baseline mean). The event study estimates (Table 2 Panel B) show how the effects of placement into remediation changed relative to the corequisite implementation timeline, using five years before the reform as the reference group. As discussed in the previous section, we take the insignificant coefficients for two to four years before the corequisite pilot and reform as evidence for the parallel trends assumption, as they suggested that there were few changes in remedial students' outcomes before the reform. The heterogeneity-robust estimates reported in Columns 3 and 4 in Table 2 are consistent with the TWFE estimates. Because the computational package producing TWFE estimates allows for more flexible covariate controls and multi-way clustering of standard errors, we hereafter use TWFE specifications as our preferred model.[8]

One of our main goals is to examine the effects by student preparedness; in Table 3, we report the heterogeneous DID estimates by placement scores. As described in the Context and Data section, Group 1 contained students scoring six or more points below the cutoff, Group 2 included students scoring three to five points below the cutoff, and Group 3 was the highest-scoring remedial students, within two points below the college-ready threshold. These results suggest that, compared with prerequisite remediation, corequisite remediation had significant positive effects on first-year gateway completion rates for remedial students in *all test score groups below the college-ready threshold*. For math, the effect was strongest for the highest-scoring remedial students. Students who scored within two points of the college-level cutoff experienced a 21-percentage-point improvement in the first-year gateway completion rate, while the lowest-scoring remedial students had a 15-percentage-point improvement in the first-year gateway completion rate. For English, the pattern was reversed. The lowest-scoring students experienced the greatest improvement in first-year gateway English completion rate (up to 33 percentage points).

[8] We used Stata packages *csdid* and *eventstudyinteract* to obtain heterogeneity-robust estimators, which require a perfectly-balanced panel. Because each college in our sample had different numbers of remedial and college-ready students, we reconfigured the data to college-cohort-remedial status level to get heterogeneity-robust estimators. Any student-level variations within each college-cohort-remedial status level were eliminated during this process. In addition, the package *csdid* does not allow inclusion of covariates, making these estimators less precise compared with TWFE estimators. This is reflected by the wider confidence intervals of Callaway and Sant'Anna estimators shown in Panel A.

Subsequent college-level courses. Next, we examined the effects of corequisite versus prerequisite remediation on subsequent college-level course enrollment and performance. Table 4 presents the results. For both math and English, students in the corequisite cohorts were significantly more likely to enroll in and pass a second college-level course in math and English by the end of year two. Interestingly, the grades in subsequent college-level courses were significantly lower after the corequisite implementation. This does not necessarily mean that corequisite remediation had negative effects on course performance in subsequent college-level courses, because these analyses were conditional on students enrolling in a second college-level course. During the prerequisite era, students who managed to do that—note that they had to fulfill remedial sequence requirements and pass the gateway course before that—were likely to be systematically different from students who got to second college-level courses under the corequisite policy. However, this result highlights the challenge of implementing corequisite remediation. Since every student can enroll in college-level courses under corequisite models, community colleges must either increase course offerings or increase enrollment caps for college-level course sections. In the TBR, community colleges kept enrollment sizes in college-level courses stable over time, but the number of course sections for college-level math increased by more than 30% between the fall of 2014 and the fall of 2015. How to schedule the additional course sections, staff faculty with credentials to teach them, and provide quality instruction to all students are key issues.

Again, the subgroup analyses (Table 4, Panel B) showed reversed patterns for math and English. The positive effects on enrollment in and completion of subsequent college-level math courses were mainly driven by higher-scoring remedial students. Students who scored within two points of the college-level cut-off were six percentage points (or 52%) more likely to enroll in and five percentage points (or 43%) more likely to complete a second college-level math course during the corequisite era than the prerequisite cohorts, while the effects for the lowest-scoring remedial math students were insignificant. For English, it was the lowest-scoring group that experienced the strongest improvement, by 15 percentage points (93%) for enrollment and 9 percentage points (73%) for passing a second college-level English course.

Longer-term outcomes. To assess the effects of corequisite remediation on long-term outcomes, we conducted analyses on a set of outcomes related to credit accumulation, enrollment, and completion tracked over three years after initial enrollment. For credit accumulation, corequisite remediation led to 1.5 fewer total credit enrollments, but 2.5 more *college-level* credits enrolled; the effects on total college-level credits earned were insignificant (Columns 1 to 4 of Table 5). As for persistence and completion outcomes, the general effects of corequisite remediation tended to be negative: remedial students under the corequisite regime were 4.3 percentage points more likely to drop out of college, defined as stopping enrolling in any TBR community college or public four-year university before earning a credential, at the end of year three. They were also three percentage points less likely to complete any credential by that time (Columns 5 to 7 of Table 5). The heterogeneous analyses (Table 5 Panel B) suggest that the effects on the number and composition of credit accumulation came from a reduction in the total number of credits attained, mostly driven by enrolling and earning fewer developmental courses, for the highest-scoring remedial students (2.1 credits or close to one course) and more college-level credits enrolled for the lowest-scoring remedial students (5.1 credits or close to two courses). The negative effects on enrollment at community colleges and public universities in Tennessee were consistent across all test score groups, but the negative effects on credential completion mostly came from lower-scoring remedial students. This was primarily driven by the lower likelihood of earning short-term certificates: more than 70% of the credentials earned by the lowest-scoring students within three years were short-term certificates, and the proportion of students earning degrees at the associate level or higher did not change significantly before and after the corequisite reform.

Robustness checks. We conducted the following analyses to assess the robustness of the main results. First, we ran analyses excluding the data from the academic year 2019-20 to rule out the possible influence of the Covid-19 pandemic. The results showing the effects on gateway course completion and long-term outcomes are presented in Tables A4 and A5, respectively, and are consistent with the main results discussed above. In addition, since the SAILS program serves a purpose similar to corequisite reform, we conducted a robustness check excluding students attending high schools where SAILS was introduced during their senior year. Since SAILS eventually reached most public high schools within the state, this analysis excluded more than half of the students who entered TBR after the academic year 2016-17.

As shown in Table A6, the results for gateway courses, enrollment persistence, and credential attainment are similar between models with and without high schools that have introduced the SAILS program. The most noticeable disparities between the two sets of analyses are for outcomes related to credit accumulation by the third year. For the sample that excludes students from high schools with a heavy SAILS presence, the effects of the corequisite policy on the total number of credits attained were insignificant, and the effects on college-level credits enrolled and earned were significantly positive. The discrepancies are likely due to the corequisite reform muting any boost in college credits resulting from completing SAILS, aligning with the findings of Kane et al. (2021).

B. Implications of corequisite reform effects

The effects of corequisite remediation on gateway course completion and long-term outcomes can be interpreted from two perspectives*:* (1) Does corequisite remediation help students finish courses count towards a degree, and (2) is corequisite remediation—or developmental reforms in general—enough to move the needle to improve college completion? From the first perspective, the answer appears to be yes. Under the corequisite models, students were able to earn similar amounts of college-level credits while enrolling in fewer courses. Credits from developmental courses cannot be applied to a degree; in themselves, these courses, especially developmental math, even have negative labor market returns (Hodara & Xu, 2016). Overall, spending valuable time and financial aid resources at college-level rather than remedial courses was a more efficient way to allocate resources. This is perhaps why a metric called "throughput," defined as the completion rate of college- or transfer-level English and math among a cohort, is the primary yardstick to measure the success of DE legislation, such as AB705 in California and Senate Bill 1720 in Florida (Melguizo et al., 2021; Zhao et al., 2022).

However, our results suggest that colleges need to think beyond what throughput rates measure and place DE reforms in the context of the broader sets of institutional support to help students complete a postsecondary degree, as replacing prerequisite remediation with corequisite models alone was not enough to solve the completion problem. Mainstreaming every student in a college-level course presents new challenges. The average grades in college-level math (including both gateway and more advanced courses) for remedial students went from 1.91 in the prerequisite era to 1.50 for the corequisite cohorts, and the proportion of those who failed any of these courses increased from 36.9% to 50.2%. Early course failures often lead to discouragement or disinterest. Failing college-level courses may also have financial consequences. Many need-based financial aid programs, including Pell Grants and the Tennessee Promise, require students to maintain a certain level of GPA at the end of each academic year. In this new context, institutions need to provide more proactive advising, academic counseling, and other support to students who are unable to meet the expectations of more challenging college-level courses.

C. Exploration of effects mechanisms

In this section, we examine the potential mechanisms through which the corequisite reform worked. In Table 6, we show the timing of remedial students enrolled in their first gateway courses before and after the corequisite reform by placement test score groups. For math, it was common to start enrolling in gateway courses until the third or fourth term during the prerequisite regime, and most remedial students (more than 70% of the lowest-scoring group) did not enroll in gateway math courses during the tracking period. After the corequisite reform, the majority of remedial students enrolled in gateway math, and most students managed to enroll during the first two terms. This reduction in delay was even more substantial in English. While the proportion of students enrolled in gateway English in their first two terms ranged from 28.5% for the lowest-scoring group to 72.2% for the highest-scoring group in the prerequisite era, close to 80% of corequisite students enrolled in gateway English in the first term.

We then examined other factors contributing to how corequisite remediation helps students develop skills, including how the intensity and content of remedial courses changed through corequisite models. The results in Table 7 suggest that the total instructional time for developmental education has decreased since the corequisite reform, especially for those with lower placement scores. Since the reform, the total number of remedial credits enrolled decreased from 13.6 to 7.2 by the end of the third year for the lowest scoring group. It would be a challenge for instructors to cover the content and skills needed to be successful in college-level studies when the instruction time almost halved. This could contribute to the patterns in grades of gateway courses and more advanced college-level courses after the corequisite reform.

In addition to the compression of the development course sequence, the developmental math curriculum also underwent major changes. Before the corequisite reform, the developmental math sequence typically started with a Foundation of Math or Basic math for the lowest-scoring students, an Algebra I course for moderately scoring students, and an Intermediate Algebra course for the highest-scoring remedial students. After the reform, the content of the learning support courses was aligned with that of math gateway courses. Consequently, Corequisite Statistics has become the most popular math learning support course since 2015. Across all test score groups, more than 40% of the remedial students took this course as a companion of gateway math on the statistics pathway. Based on the archive of the course catalog, prerequisite developmental math courses designed for lowest-scoring students covered topics including addition, subtraction, division, multiplication, metric notation, factions, and formulation solving. Our results on remedial students' performance in college-level courses suggest that when students needed refresh of these basic skills, contemporaneous support was insufficient to improve downstream college outcomes.

Next, we examined how de-tracking influenced the outcomes for remedial and college-level students, as corequisite remediation mixes students with all levels of readiness together in college-level courses. Figure 1 presents the proportion of on-level students who were above the college threshold or had completed remedial requirements in gateway course sections by academic year. Indeed, since 2015, the proportion of on-level students has decreased significantly in both math and English gateway course sections. Table 8 shows the associations between the proportion of on-level peers and the first-year gateway course completion rates. These results have two main implications. First, students experienced better gateway course outcomes when their sections had more high-ability (on level) students. Overall, a 10-percentage-point increase in on-level peers in the section was associated with a 3-percentage-point increase in gateway math completion rates and a 2-percentage-point increase in gateway English. Second, perhaps because gateway classrooms became more heterogeneous after the corequisite reform, remedial students had higher gateway completion rates when they studied with more similar-ability (remedial) students since the reform. For students placed into corequisite remediation, a 10-percentage-point increase in on-level peers was associated with a 2.7-percentage-point decrease in gateway math completion rates. The patterns were similar for English, except that the results were entirely driven by remedial students, as the outcomes for college-ready students in gateway English courses were not influenced by their peer composition.

VI. Conclusion & Discussion

The results of this study add to prior evidence on the effects of corequisite remediation reforms in Tennessee (Ran & Lin, 2022), Texas (Meiselman & Schudde, 2022; Miller et al., 2022), and City University of New York (Logue et al., 2019). While most of the existing evidence focuses on higher-scoring remedial students, we expand the evidence to include students with lower placement test scores. We found that although the magnitudes of the effects vary, placement into corequisite remediation led to substantially higher gateway course completion rates—a 76% improvement from prerequisite cohorts for math and a 40% improvement for English—for students across the placement test score distributions.

These positive effects on college-level credit accumulation were primarily the result of structural changes under the corequisite system. Corequisite remediation reduced the delay caused by lengthy prerequisite sequences, and students with lower test scores benefited the most from the mainstreaming effects. In addition, the structural reform also had diversionary effects: it replaced enrollment in remedial sequences with college-level courses. After the corequisite reform, remedial students accumulated similar amounts of college-level credits while enrolling in fewer courses overall, making the allocation of time and financial aid resources more efficient.

However, these positive effects on early college-level credit accumulation did not lead to improved downstream outcomes. We found that remedial students, particularly those with lower placement scores, were more likely to drop out and were less likely to earn short-term certificates. With more than 20 states and higher education systems in the nation adopting corequisite remediation, colleges need to continue identifying effective curriculum designs and pedagogical practices to help students with remedial needs succeed in college-level courses. The fact that college-level course pass rates and average grades became lower for corequisite cohorts than for prerequisite cohorts indicates that the concurrent academic learning support was still not enough for some remedial students to succeed in college-level courses. In addition, with both on-level and remedial students, college-level classrooms have become more heterogeneous learning environments. These changes present new challenges for faculty to accommodate students with a wider range of academic needs.

A broader question for the field is whether remediation reform alone is expected to improve college completion. A series of recent studies found that remedial reforms focusing on structural changes had little impact on enrollment persistence or completion outcomes (Meiselman & Schudde, 2022; Miller et al., 2022; Ran & Lin, 2022). Together with similar results from the initiative to move remediation to high school (Kane et al., 2021), the literature in this area provided emerging evidence that the problems with traditional remediation models were *not* the primary drivers of low college completion rates. Interventions that showed positive effects on attainment outcomes incorporated components of curriculum reforms (Logue et al., 2019) or a holistic set of academic and financial support (Scrivener et al., 2015). Students may need ongoing academic and nonacademic support to translate the momentum gained from additional college-level coursetaking into improved persistence and completion outcomes.

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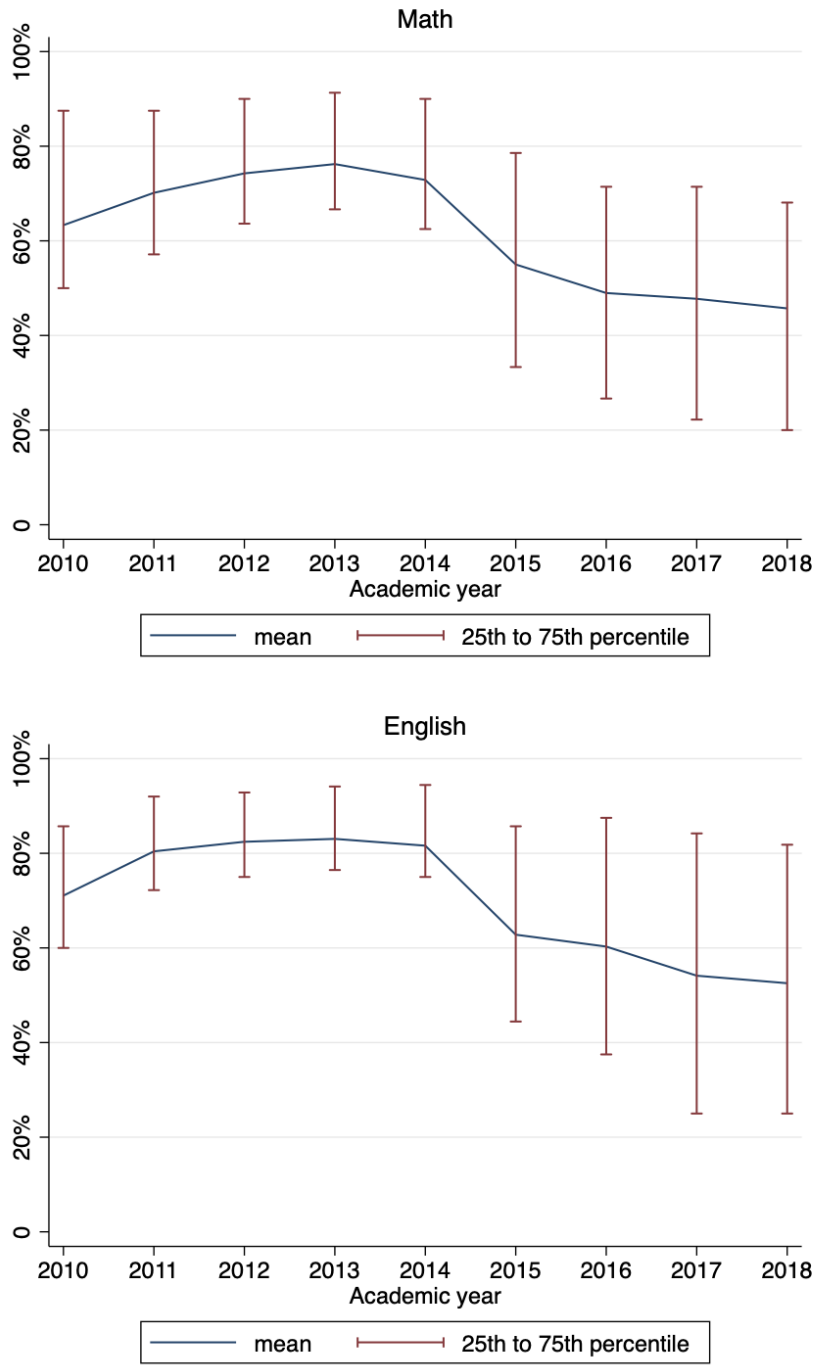
Figures and Tables

Figure1. Proportions of on-level peers in gateway course sections by academic year



Notes: These graphs show the average proportions of on-level peers in gateway course sections along with the 25 to 75 percentile ranges, by academic year. We define on-level peers as the students, other than oneself, who were placed into a gateway course section directly or had completed required remedial courses before enrolling in a gateway course section.

Table 1. Summary Statistics (2010-11 to 2018-19 Cohorts)

	Total	Prerequisite cohort	Corequisite cohort
Panel A. Background variables			
Female	0.543	0.551	0.536
Age at college entry	18.486	18.546	18.432
Race			
White	0.705	0.724	0.687
Black	0.195	0.198	0.192
Hispanic	0.053	0.039	0.066
Other race	0.047	0.039	0.054
International students	0.002	0.003	0.002
High school GPA	2.769	2.873	2.677
ACT score – math	17.882	17.793	17.960
ACT score – English	18.645	18.729	18.570
ACT score – reading	19.444	19.398	19.485
Referred to remediation	0.754	0.755	0.753
Panel B. Outcome variables			
Gateway courses outcomes by Y1			
Completed gateway Math	0.343	0.269	0.408
Completed gateway English	0.608	0.563	0.648
Second college-level courses in math and English by Y2			
Enrolled in a second math course	0.161	0.145	0.174
Completed a second math course	0.134	0.124	0.143
Enrolled in a second English course	0.465	0.438	0.488
Completed a second English course	0.382	0.369	0.394
College-level credit accumulation by Y3*			
# of credits enrolled	39.165	38.868	39.505
# of credits earned	29.647	29.700	29.586
Persistence, transfer, and credential completion by Y3*			
Dropout	0.575	0.530	0.626
Transfer to TN 4-year college	0.096	0.097	0.095
Earned any credential	0.129	0.104	0.158
N	91,511	42,904	48,607

Notes: Descriptive statistics were based on students entering TBR community colleges during fall semesters in the year of high school graduation.

*Calculations for three-year outcomes were based on the 2010-11 to 2017-18 cohorts. The numbers of observations are 80,446 for the full analytic sample and 37,542 for the corequisite sample.

Table 2. Effects of corequisite remediation on first-year gateway course completion

	(1)	(2)	(3)	(4)
Panel A. DID estimates	Two-way fixed-effects estimates		Heterogeneity-robust estimates	
	Math	English	Math	English
Below cutoff * coreq	0.204***	0.228***	0.183***	0.236***
	(0.019)	(0.030)	(0.033)	(0.040)
Baseline mean	0.269	0.563	0.269	0.563
(Baseline SD)	(0.443)	(0.496)	(0.443)	(0.496)
N	91,511	91,511	341	341
Panel B. Event study estimates	Two-way fixed-effects estimates		Heterogeneity-robust estimates	
	Math	English	Math	English
Pre4 * below cutoff	0.002	0.003	-0.032	-0.032*
	(0.014)	(0.018)	(0.029)	(0.014)
Pre3 * below cutoff	0.003	0.023	-0.019	-0.010
	(0.016)	(0.019)	(0.025)	(0.018)
Pre2 * below cutoff	0.002	0.025	-0.010	-0.022
	(0.019)	(0.033)	(0.030)	(0.017)
Pre1 * below cutoff	0.098***	0.066	0.082**	0.008
	(0.015)	(0.029)	(0.027)	(0.011)
Pre0 * below cutoff	0.240***	0.239***	0.222***	0.201***
	(0.020)	(0.016)	(0.029)	(0.014)
Post1 * below cutoff	0.236***	0.247***	0.224***	0.214***
	(0.022)	(0.024)	(0.032)	(0.027)
Post2 * below cutoff	0.211***	0.252***	0.218***	0.256***
	(0.013)	(0.023)	(0.026)	(0.029)
Post3 * below cutoff	0.216***	0.269***	0.238***	0.280***
	(0.015)	(0.014)	(0.030)	(0.028)
N	91,511	91,511	91,511	91,511

Notes: The TWFE models controlled for students' demographic and pre-college academic characteristics in Table 1 Panel A, college fixed-effects, cohort fixed-effects, and high school fixed-effects. The heterogeneity-robust DID model was conducted at college-cohort-remedial status level since Stata packages *csdid* requires perfectly balanced panel. Standard errors are clustered at college-, cohort-, and high school-level. Robust standard errors are shown in parentheses.

Pre-periods stand for the years before the corequisite implementation, and post-periods stand for the years after the implementation. Pre0 represents the year of the corequisite reform.

We used pre5 as the reference group for all event-study specifications.

*** p < 0.01, ** p <0.05, * p < 0.1

Table 3. Effects of corequisite remediation on first-year gateway course completion by placement test scores

	(1)	(2)	(3)	(4)
	Math		English	
	Complete	Baseline Mean	Complete	Baseline Mean
Group 1	0.150***	0.025	0.326***	0.178
	(0.023)	(0.156)	(0.049)	(0.382)
Group2	0.198***	0.092	0.232***	0.400
	(0.021)	(0.289)	(0.024)	(0.490)
Group3	0.209***	0.238	0.136***	0.543
	(0.020)	(0.426)	(0.023)	(0.498)
N	91,511		91,511	

Notes: Results in this table are effects of placing into corequisite remediation for students by groups of placement test scores. All models controlled for students' demographic and pre-college academic characteristics shown in Table 1 Panel A, college fixed-effects, cohort fixed-effects, and high school fixed-effects. Standard errors are clustered at college-, cohort-, and high school-level. Robust standard errors are shown in parentheses.
Group 1 (lowest scoring DE group) is defined as students whose ACT scores were 6 or more points below the cutoff. Group 2 represents students whose ACT scores were 3 to 5 points below the cutoff. Group 3 (highest scoring DE group) includes students whose scores were 1 or 2 points less than the college-ready criteria. Group 4, the reference group, includes students whose scores were at or above the cutoff. We used students' minimum test scores of writing and reading to define the test score subgroup for English.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 4. Effects of corequisite remediation on subsequent college-level course outcomes (by end of Y2)

	(1)	(2)	(3)	(4)	(5)	(6)
	Math			English		
Panel A	All Students					
	Enroll	Complete	Grades	Enroll	Complete	Grades
Below cutoff * coreq	0.056**	0.040*	-0.174**	0.123***	0.076***	-0.193***
	(0.015)	(0.012)	(0.047)	(0.012)	(0.011)	(0.035)
Baseline mean	0.145	0.124	2.412	0.438	0.368	2.431
(Baseline SD)	(0.352)	(0.329)	(1.372)	(0.496)	(0.482)	(1.336)
N	91,511	91,511	13,234	91,511	91,511	40,180
Panel B	Subgroup Analysis					
	Enroll	Complete	Grades	Enroll	Complete	Grades
.						
Group 1 * coreq	0.040	0.029	-0.424	0.151***	0.093**	-0.282**
	(0.020)	(0.016)	(0.269)	(0.020)	(0.019)	(0.069)
Group2 * coreq	0.050**	0.035*	-0.179*	0.123***	0.076***	-0.165**
	(0.015)	(0.011)	(0.076)	(0.011)	(0.009)	(0.042)
Group3 * coreq	0.064**	0.046*	-0.165**	0.098***	0.059***	-0.188***
	(0.017)	(0.014)	(0.042)	(0.012)	(0.011)	(0.035)
Baseline mean & SD						
Group 1	0.022	0.018	2.261	0.162	0.127	2.083
	(0.147)	(0.134)	(1.453)	(0.369)	(0.333)	(1.312)
Group 2	0.058	0.048	2.154	0.304	0.244	2.137
	(0.234)	(0.214)	(1.321)	(0.460)	(0.429)	(1.306)
Group 3	0.124	0.106	2.383	0.395	0.329	2.322
	(0.329)	(0.308)	(1.324)	(0.489)	(0.470)	(1.305)
N	91,511	91,511	13,234	91,511	91,511	40,180

Notes: All models controlled for students' demographic and pre-college academic characteristics shown in Table 1 Panel A, college fixed-effects, cohort fixed-effects, and high school fixed-effects. Standard errors are clustered at college-, cohort-, and high school-level. Robust standard errors are shown in parentheses.
Group 1 (lowest scoring DE group) is defined as students whose ACT scores were 6 or more points below the cutoff. Group 2 represents students whose ACT scores were 3 to 5 points below the cutoff. Group 3 (highest scoring DE group) includes students whose scores were 1 or 2 points less than the college-ready criteria. Group 4, the reference group, includes students whose scores were at or above the cutoff. We used students' minimum test scores of writing and reading to define the test score subgroup for English.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 5. Effects of corequisite remediation on credit accumulation, persistence, transfer and completion (by end of Y3)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Total number of credits		College-level credits		Enrollment		Credential
	Enrolled	Earned	Enrolled	Earned	Left TN public college system	Transfer to 4yr inst	Earned any credential
Panel A				All Students			
Below cutoff * coreq	-1.417**	-1.610**	2.512*	0.712	0.043**	-0.028	-0.030*
	(0.356)	(0.399)	(0.751)	(0.485)	(0.010)	(0.012)	(0.009)
Baseline mean & SD	45.292	33.554	38.868	29.700	0.530	0.097	0.104
	(22.747)	(25.028)	(24.056)	(24.706)	(0.499)	(0.296)	(0.305)
N	80,446	80,446	80,446	80,446	80,446	80,446	80,446
Panel B				Subgroup Analysis			
.							
Group 1 * coreq	-1.131	-1.383	5.055**	1.865	0.039*	-0.044*	-0.061**
	(0.706)	(0.665)	(1.219)	(0.800)	(0.011)	(0.017)	(0.015)
Group2 * coreq	-1.329**	-1.433**	2.735**	0.952*	0.047**	-0.030	-0.031*
	(0.352)	(0.340)	(0.598)	(0.346)	(0.011)	(0.013)	(0.009)
Group3 * coreq	-1.822**	-2.144**	0.304	-0.618	0.041**	-0.016	-0.011
	(0.462)	(0.420)	(0.549)	(0.440)	(0.008)	(0.009)	(0.006)
Baseline mean & SD							
Group 1	37.580	22.893	23.945	15.844	0.656	0.043	0.024
	(21.722)	(22.116)	(21.226)	(19.278)	(0.475)	(0.204)	(0.152)
Group 2	43.570	30.827	34.707	25.387	0.556	0.075	0.060
	(22.667)	(24.256)	(22.995)	(22.851)	(0.497)	(0.263)	(0.238)
Group 3	47.950	37.145	43.439	33.940	0.491	0.108	0.119
	(22.523)	(25.137)	(22.726)	(24.502)	(0.500)	(0.310)	(0.324)
N	80,446	80,446	80,446	80,446	80,446	80,446	80,446

Notes: Results are based on analyses for students from 2010-11 to 2017-18 cohorts. All outcomes are tracked up to three years since initial term enrolled at TBR. All models controlled for students' demographic and pre-college academic characteristics shown in Table 1 Panel A, college fixed-effects, cohort fixed-effects, and high school fixed-effects. Standard errors are clustered at college-, cohort-, and high school-level. Robust standard errors are shown in parentheses.

Group 1 (lowest scoring DE group) is defined as students whose ACT scores were 6 or more points below the cutoff. Group 2 represents students whose ACT scores were 3 to 5 points below the cutoff. Group 3 (highest scoring DE group) includes students whose scores were 1 or 2 points less than the college-ready criteria. Group 4, the reference group, includes students whose scores were at or above the cutoff. We used students' minimum test scores of writing and reading to define the test score subgroup for English.

*** p < 0.01, ** p <0.05, * p < 0.1

Table 6. Timing of first gateway course enrollment before and after corequisite reform by test score group

	Math		English	
	Prerequisite	Corequisite	Prerequisite	Corequisite
Panel A: Group 1 (6 points below the college-readiness threshold)				
Term 1	<3%	24.12%	5.26%	75.62%
Term 2	4.98%	26.38%	23.22%	10.93%
Term 3	6.45%	3.79%	12.54%	<3%
Term 4	6.45%	<3%	7.56%	<3%
Did not enroll by term 4	81.29%	43.00%	51.42%	11.24%
N	1,085	1,107	5,556	7,066
Panel B: Group 2 (3-5 points below the college- readiness threshold)				
Term 1	4.01%	33.06%	12.96%	79.37%
Term 2	11.27%	25.45%	43.35%	11.81%
Term 3	12.70%	4.95%	9.52%	<3%
Term 4	10.03%	<3%	4.07%	<3%
Did not enroll by term 4	62.00%	32.06%	29.55%	7.28%
N	17,438	18,655	9,682	11,141
Panel C: Group 3 (1-2 points below the college- readiness threshold)				
Term 1	8.57%	45.09%	26.58%	80.19%
Term 2	25.50%	23.47%	45.64%	12.00%
Term 3	10.32%	5.35%	6.33%	<3%
Term 4	9.5%	3.04%	<3%	<3%
Did not enroll by term 4	42.38%	23.05%	19.09%	6.59%
N	11,198	13,361	6,543	7,718

Notes: Group 1 (lowest scoring DE group) is defined as students whose ACT scores were 6 or more points below the cutoff. Group 2 represents students whose ACT scores were 3 to 5 points below the cutoff. Group 3 (highest scoring DE group) includes students whose scores were 1 or 2 points less than the college-ready criteria. Students whose placement test scores were above college-readiness threshold are not included in this table.

Table 7. Number of developmental credits enrolled and earned before and after corequisite reform by test score group

Panel A: Prerequisite students

	Enrolled remedial credits			Earned remedial credits		
	By end of Y1	By end of Y2	By end of Y3	By end of Y1	By end of Y2	By end of Y3
Group 1	11.768	13.348	13.634	6.218	6.918	7.048
Group 2	7.880	8.699	8.853	4.968	5.362	5.437
Group 3	4.109	4.441	4.516	2.970	3.156	3.203

Panel B: Corequisite students

	Enrolled remedial credits			Earned remedial credits		
	By end of Y1	By end of Y2	By end of Y3	By end of Y1	By end of Y2	By end of Y3
Group 1	6.603	7.163	7.230	3.374	3.628	3.660
Group 2	4.553	4.846	4.885	2.913	3.078	3.102
Group 3	2.387	2.521	2.541	1.705	1.785	1.797

Notes: Calculations were based on students whose placement test scores were below college-readiness threshold. We imputed zero developmental credits enrolled for students who were placed into but did not enroll in any remedial courses and students who left TBR community colleges.

Group 1 (lowest scoring DE group) is defined as students whose ACT scores were 6 or more points below the cutoff. Group 2 represents students whose ACT scores were 3 to 5 points below the cutoff. Group 3 (highest scoring DE group) includes students whose scores were 1 or 2 points less than the college-ready criteria.

Table 8. Associations between proportion of on-level peers and first-year gateway course completion rates

	(1)	(2)	(3)	(4)	(5)	(6)
	Math			English		
	All gateway enrollees	Enrollees above college-level cutoff	Enrollees below college-level cutoff	All gateway enrollees	Enrollees above college-level cutoff	Enrollees below college-level cutoff
Post corequisite cohorts	0.247***	0.076	0.241***	0.179*	0.053	0.171*
	(0.042)	(0.098)	(0.035)	(0.091)	(0.080)	(0.084)
% on-level students	0.302**	0.337**	0.221**	0.221*	0.160	0.273**
	(0.104)	(0.146)	(0.091)	(0.118)	(0.088)	(0.113)
Post * % on-level	-0.351***	-0.201	-0.267**	-0.268*	-0.038	-0.330**
	(0.099)	(0.149)	(0.100)	(0.128)	(0.094)	(0.120)
N	49,161	21,579	27,582	77,590	41,856	35,734

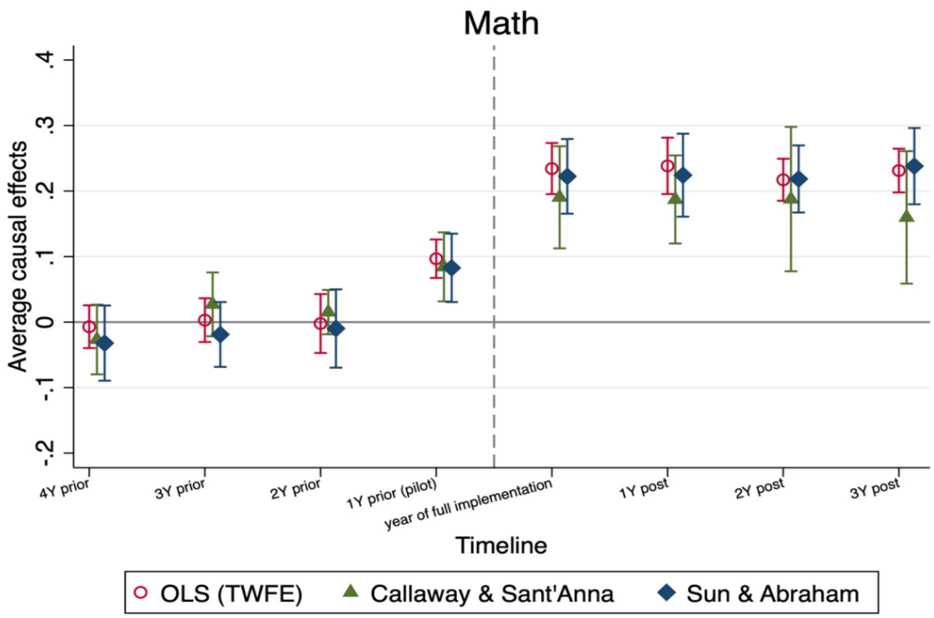
Notes: Each column presents results from a regression using a difference-in-differences set up, where the main predictors include an indicator for post-corequisite cohorts, proportion of on-level students in the gateway course section, and the interaction term between them. The models also controlled for students' demographic and pre-college academic characteristics shown in Table 1 Panel A, college fixed-effects, cohort fixed-effects, and high school fixed-effects. Standard errors are clustered at college-, cohort-, and high school-level. Robust standard errors are shown in parentheses.

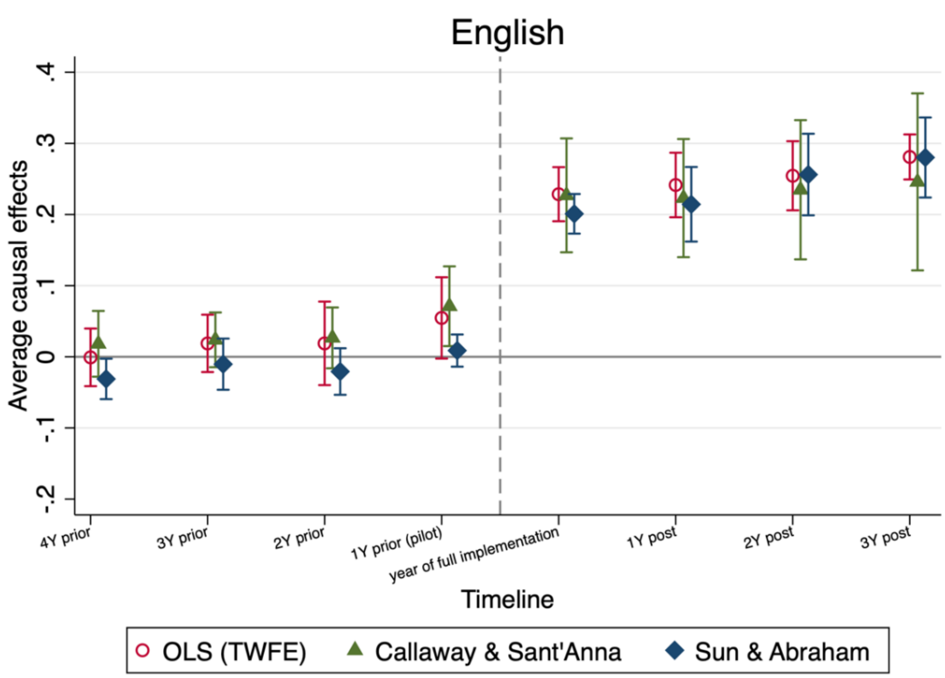
Columns 1 and 4 are results for all students who enrolled in gateway courses during the first year, columns 2 and 5 are results for students whose placement test scores were above college-level cutoff, and columns 3 and 6 are results for students who tested below college-level.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Appendix

Figure A1. Event study estimators comparison: effects on first-year gateway completion





Notes: These graphs show the point estimates and 95% confidence intervals for effects on first-year gateway completion rates from three models. Outcomes five years prior to the corequisite reform were used as the reference for estimates in these plots. Estimates from two-way fixed-effects models are in red, heterogeneity-robust estimates using method developed by Callaway and Sant'Anna (2021) are in green, and heterogeneity-robust estimates using methods by Sun & Abraham (2021) are in deep blue.

Table A1. Evidence on the Effects of Traditional and Corequisite Developmental Education

Panel A. Treatment: traditional (prerequisite) developmental programs

Authors	Method	Sample size & test score range	Data source	Direction of impacts on key outcomes
Bettinger & Long (2009)	IV	No restriction of test score range Observations: 28,376	Ohio Board of Regents	Persistence ↔, credential or transfer ↔ (↑ for math)
Boatman & Long (2018)	Fuzzy RD	*College-level vs. upper DE:* Bandwidth: up to +/-7 of college cutoff (COMPASS) Observations: ~1,800 *Upper vs. lower DE:* Bandwidth: up to +/-7 of upper DE cutoff, Observations: ~1,700	Tennessee Board of Regents (TBR), Tennessee Higher Education Commission (THEC)	*College-level vs. upper DE:* persistence ↓, grade in college-level course ↔, earned college-level credits & credential or transfer ↔ or ↓ *Upper vs. lower DE:* persistence ↔, grade in college-level course ↔ (writing ↑), earned college-level credits & credential or transfer ↔ or ↓
Calcagno & Long (2008)	Fuzzy RD	Bandwidth: up to +/-10 (Florida College Entry Level Placement Test) Observations: 98,370	Florida Department of Education	Persistence ↑, total number of credits completed ↑, college-level credits completed ↔, degree completion ↔
Clotfelter et al. (2015)	IV	No restriction of test score range Observations: ~14,000	North Carolina Education Research Data Center	Short-run persistence ↔, enrollment & performance in college-level courses ↓, transfer & degree completion ↓
Dadgar (2012)	Fuzzy RD	Bandwidth: up to +/-10 (COMPASS) Observations: 24,664	Virginia Community College System (VCCS)	Passed college-level math ↔, earned any credential ↓
De Paola & Scoppa (2014)	Fuzzy RD	Bandwidth: up to +/-10 (U of Calabria placement test) Observations: 4,019	University of Calabria	Earned credits by 2nd year ↑, drop out ↓

Martorell & McFarlin (2011)	Fuzzy RD	Bandwidth: +/-10 (Texas Academic Skills Program) Observations: 255,878 (2-year), 197,502 (4-year)	Texas Schools Microdata Panel, Texas Higher Education Coordinating Board	Persistence & credential or transfer ↔
Melguizo et al. (2016)	RD	Bandwidth: optimal bandwidth for each college, up to +/-14.9 (COMPASS or ACCUPLACER) Observations: 16,553	Large urban community college district in California	Enroll & completion of college-level math courses ↓
Scott-Clayton & Rodriguez (2015)	RD	Bandwidth: +/-6 (COMPASS & in-house exam) Observations: 100,250	Six colleges in large urban community college system	College enrollment ↔, persistence ↔ (misplaced students ↓), take and pass college-level courses ↓, transfer or degree completion ↔
Xu (2016)	fuzzy RD	Bandwidth: up to +/-10 (COMPASS) Observations: 5,146	VCCS	Dropout ↔, enroll & complete gatekeeper course ↔, total credits earned in 5yrs ↔, total college-level credits in 5yrs ↔ , transfer or degree completion ↓
Xu & Dadgar (2018)	fuzzy RD	Bandwidth: +/-8 (COMPASS) Observations: 24,664	VCCS	Passed gatekeeper math ↔, credential completion ↓

Panel B. Treatment: corequisite remediation

Authors	Method	Sample size & test score range	Data source	Direction of impacts on key outcomes
Boatman (2012)	Fuzzy RD	Bandwidth: +/-2 (ACT) Observations: 8,948	THEC, TBR, IPEDS	Persistence ↑, credits attempted ↑
Boatman et al. (2021)	RD	Bandwidth: +/-11.95 (Duoc UC diagnostic test) Observations: 33,075	Departmento Universitario Oberero Campesino, Universidad Catolica (Duoc UC)	Dropout ↓, earned college-level credits by Y1 ↔, first-term GPA ↑, grade in college algebra ↑
Duchini (2017)	RD	Bandwidth: up to +/-5 (an unidentified test) Observations: 2,785	An anonymous university in north Italy	Persistence ↔, passing college-level exam in remediation subjects ↔, earned credits ↔

Logue et al. (2016)	RCT	No restriction of test score range Observations: 717	Three universities in the CUNY system	Credits accumulated ↑, pass college-level statistics ↑
Logue et al. (2019)	RCT, PSM	No restriction of test score range Observations: 594	Three universities in the CUNY system	Quantitative course pass rates ↑, graduation rate ↑
Meiselman & Schudde (2022)	Fuzzy RD	Bandwidth: +/-5 (Texas Success Initiative test) Observations: 16,405	Texas Education Research Center (ERC), THECB	Completion of math requirement ↑, degree completion ↔
Miller et al. (2022)	RCT	No restriction of test score range Observations: 1,482	Five community colleges in Texas	Complete gateway English ↑, credit accumulation ↑, persistence ↔
Ran & Lin (2022)	DiRD, RD	Bandwidth: +/-2 (ACT) Observations: 52,036	TBR	Complete gateway courses ↑, enroll & complete subsequent college-level courses ↑, persistence and transfer ↔

Notes: DID = difference in differences, DiRD = difference in regression discontinuity, IV = instrumental variable, PSM = propensity score matching, RCT = randomized control trial, RD = regression discontinuity, ↑ = significant positive effects at 5% level, ↓ = significant negative effects at 5% level, ↔ = insignificant results at 5% level.

Table A2. Summary statistics of different samples

	Raw data	FTIC sample	Recent HS graduate fall entrants sample (final analytic sample)
Panel A: All students			
Female	0.578	0.572	0.543
Age at college entry	23.995	19.544	18.486
Race/Ethnicity			
White	0.713	0.715	0.705
Black	0.190	0.191	0.195
Hispanic	0.048	0.049	0.053
Other race	0.050	0.045	0.047
International Students	0.009	0.004	0.002
High school GPA	2.774	2.843	2.769
ACT test scores			
Math	18.478	18.372	17.882
English	20.100	19.706	18.645
Reading	20.601	20.414	19.444
N	407,193	194,524	91,511
Panel B: Prerequisite students			
Female	0.583	0.580	0.551
Age at college entry	24.689	20.154	18.546
Race/Ethnicity			
White	0.720	0.717	0.724
Black	0.201	0.205	0.198
Hispanic	0.036	0.039	0.039
Other race	0.043	0.039	0.039
International Students	0.009	0.005	0.003
High school GPA	2.871	2.906	2.873
ACT test scores			
Math	18.226	18.080	17.793

English	20.199	19.647	18.729
Reading	20.534	20.265	19.398
N	231,238	109,747	42,904
Panel C: Corequisite students			
Female	0.570	0.562	0.536
Age at college entry	23.084	18.755	18.432
Race/Ethnicity			
White	0.705	0.711	0.687
Black	0.176	0.174	0.192
Hispanic	0.062	0.061	0.066
Other race	0.058	0.053	0.054
International Students	0.008	0.003	0.002
High school GPA	2.656	2.762	2.677
ACT test scores			
Math	18.805	18.751	17.96
English	19.969	19.783	18.57
Reading	20.687	20.607	19.485
N	175,955	84,777	48,607

Notes: The raw data include any students who had enrollment records at TBR community colleges since 2010 fall. The FTIC sample includes first-time-in college students who started at TBR between 2010 fall and 2018 fall. We exclude students who were dual enrollment students during high school. Recent HS graduate fall entrants' sample (the analytic sample for this study) further excludes students who did not enter TBR community colleges during the fall semesters during the year of high school graduation.
We imputed any missing data with school-cohort mean.

Table A3. Covariate balance test

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Female	Black	Hispanic	Other race	No HS diploma	GED	Age at first term	HS GPA
				Panel A. All Students				
Below cutoff	0.112***	0.099***	0.008*	0.007**	-0.003	0.002	0.175*	-0.379***
	(0.010)	(0.016)	(0.003)	(0.002)	(0.005)	(0.003)	(0.059)	(0.015)
Post coreq	-0.002	0.013*	0.000	-0.009*	-0.027*	0.007	0.050	-0.030
	(0.003)	(0.004)	(0.005)	(0.004)	(0.011)	(0.004)	(0.034)	(0.025)
Below cutoff * post coreq	-0.006	-0.012*	0.006	-0.004	0.005	-0.002	-0.074	-0.011
	(0.009)	(0.003)	(0.005)	(0.003)	(0.006)	(0.003)	(0.047)	(0.015)
				Panel B. Test score subgroup				
Group 1 * post coreq	-0.010	-0.031**	0.004	-0.010*	0.011	-0.003	-0.178	-0.049
	(0.009)	(0.009)	(0.007)	(0.003)	(0.010)	(0.004)	(0.100)	(0.027)
Group2 * post coreq	-0.009	-0.017*	0.005	-0.002	0.008	-0.003	-0.084	-0.006
	(0.010)	(0.006)	(0.005)	(0.003)	(0.007)	(0.003)	(0.060)	(0.020)
Group3 * post coreq	0.005	0.001	0.007	-0.003	-0.002	-0.000	-0.005	0.021
	(0.013)	(0.007)	(0.004)	(0.005)	(0.004)	(0.001)	(0.016)	(0.013)
N	91,511	91,511	91,511	91,511	91,511	91,511	91,511	91,511

Notes: Estimates use the student covariate in each column as the dependent variable, controlling for college fixed-effects, cohort-fixed effects, and high school fixed-effects. We used the difference-in-differences specifications without other student covariates in the model to provide more conservative results. Standard errors are clustered at college-, cohort-, and high school-level. Robust standard errors are shown in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table A4. Effects of corequisite remediation on first-year gateway course completion: robustness check (excluding data from academic year 2019-20)

	(1)	(2)	(3)	(4)
Panel A. DID estimates	Two-way fixed-effects estimates		Heterogeneity-robust estimates	
	Math	English	Math	English
Below cutoff * coreq	0.205***	0.223***	0.193***	0.238***
	(0.019)	(0.031)	(0.039)	(0.039)
Baseline mean	0.337	0.604	0.337	0.604
(Baseline SD)	(0.472)	(0.489)	(0.472)	(0.489)
N	80,447	80,447	304	304
Panel B. Event study estimates	Two-way fixed-effects estimates		Heterogeneity-robust estimates	
	Math	English	Math	English
Pre4 * below cutoff	0.002	0.003	-0.027	-0.030*
	(0.013)	(0.016)	(0.026)	(0.015)
Pre3 * below cutoff	0.003	0.023	-0.014	-0.009
	(0.016)	(0.018)	(0.021)	(0.019)
Pre2 * below cutoff	0.002	0.024	-0.005	-0.021
	(0.019)	(0.034)	(0.027)	(0.016)
Pre1 * below cutoff	0.098***	0.067	0.087**	0.010
	(0.014)	(0.031)	(0.023)	(0.011)
Pre0 * below cutoff	0.239***	0.234***	0.227***	0.199***
	(0.020)	(0.016)	(0.026)	(0.015)
Post1 * below cutoff	0.235***	0.247***	0.229***	0.216***
	(0.022)	(0.030)	(0.029)	(0.025)
Post2 * below cutoff	0.205***	0.256***	0.224***	0.262***
	(0.012)	(0.022)	(0.024)	(0.033)
N	80,447	80,447	80,447	80,447

Notes: Results are based on analyses for students from 2010-11 to 2017-18 cohorts. Gateway course outcomes are tracked up to one academic year since the initial term enrolled at TBR. The TWFE models controlled for students' demographic and pre-college academic characteristics shown in Table 1 Panel A, college fixed-effects, cohort fixed-effects, and high school fixed-effects. The heterogeneity-robust DID model was conducted at college-cohort-remedial status level.

Standard errors are clustered at college-, cohort-, and high school-level. Robust standard errors are shown in parentheses.

Pre-periods stand for the years before the corequisite implementation, and post-periods stand for the years after the implementation. Pre0 represents the year of corequisite reform.

We used pre5 as the reference group for all event study specifications.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0$.

Table A5. Effects of corequisite remediation on credit accumulation, persistence, transfer and completion by end of Y3: robustness check (excluding data from academic year 2019-20)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Total number of credits		College-level credits		Enrollment		Credential
	Enrolled	Earned	Enrolled	Earned	Left TN public college system	Transfer to 4yr inst	Earned any credential
Panel A				All Students			
Below cutoff * coreq	-1.346**	-1.398**	2.474*	0.804	0.041**	-0.014**	-0.025**
	(0.349)	(0.302)	(0.722)	(0.412)	(0.008)	(0.003)	(0.006)
Baseline mean & SD	44.587	33.001	39.251	29.773	0.560	0.097	0.122
	(23.044)	(25.417)	(24.057)	(25.080)	(0.496)	(0.296)	(0.328)
N	68,091	68,091	68,091	68,091	68,091	68,091	68,091
Panel B				Subgroup Analysis			
.							
Group 1 * coreq	-1.402	-1.271	4.685**	1.855	0.044*	-0.024**	-0.054**
	(0.870)	(0.784)	(1.329)	(0.911)	(0.014)	(0.006)	(0.011)
Group2 * coreq	-1.390*	-1.345**	2.604**	0.928*	0.045**	-0.016*	-0.027**
	(0.419)	(0.384)	(0.631)	(0.316)	(0.011)	(0.005)	(0.005)
Group3 * coreq	-1.354**	-1.679***	0.685	-0.247	0.034***	-0.006	-0.008
	(0.316)	(0.281)	(0.442)	(0.353)	(0.004)	(0.005)	(0.006)
Baseline mean & SD							
Group 1	36.396	21.840	25.060	15.996	0.697	0.039	0.027
	(21.732)	(22.208)	(21.179)	(19.638)	(0.460)	(0.194)	(0.163)
Group 2	42.733	30.154	35.327	25.528	0.591	0.072	0.076
	(22.987)	(24.626)	(23.187)	(23.364)	(0.492)	(0.258)	(0.264)
Group 3	47.159	36.440	43.416	33.777	0.523	0.110	0.143
	(22.927)	(25.544)	(23.050)	(24.959)	(0.499)	(0.312)	(0.350)
N	68,091	68,091	68,091	68,091	68,091	68,091	68,091

Notes: Results are based on analyses for students from 2010-11 to 2016-17 cohorts. All outcomes are tracked up to three years since the initial term enrolled at TBR. All models controlled for students' demographic and pre-college academic characteristics shown in Table 1 Panel A, college fixed-effects, cohort fixed-effects, and high school fixed-effects. Standard errors are clustered at college-, cohort-, and high school-level. Robust standard errors are shown in parentheses.

Group 1 (lowest scoring DE group) is defined as students whose ACT scores were 6 or more points below the cutoff. Group 2 represents students whose ACT scores were 3 to 5 points below the cutoff. Group 3 (highest scoring DE group) includes students whose scores were 1 or 2 points less than the college-ready criteria. Group 4, the reference group, includes students whose scores were at or above the cutoff. We used students' minimum test scores of writing and reading to define the test score subgroup for English.

*** p < 0.01, ** p <0.05, * p < 0.1

Table A6. Effects of corequisite remediation on gateway course completion and downstream outcomes: robustness check (excluding students from high schools with SAILS program)

	(1)
Outcomes	Below cutoff * post corequisite reform
Complete gateway math by year one	0.236***
	(0.018)
Complete gateway English by year one	0.243***
	(0.033)
Number of credits enrolled by y3	-0.369
	(0.505)
Number of credits earned by y3	-0.504
	(0.480)
Number of college-level credits enrolled by Y3	3.330**
	(0.803)
Number of college-level credits earned by Y3	1.643*
	(0.558)
Left TN community colleges and public university systems by Y3	0.027*
	(0.012)
Transfer to a four-year university by Y3	-0.021
	(0.012)
Earned any credential by Y3	-0.020*
	(0.006)
N	59,686

Notes: Results are based on students entering TBR between 2010-11 to 2017-18 academic years, excluding students graduated from high school implemented SAILS program during their senior year. The sample restriction represented 1% of students of 2013-14 cohort, 16% of 2014-15 cohort, 34% of 2015-16 cohort, 51% of 2016-17 cohort, and 57% of 2017-18 cohort.

Each row presents the DID estimates of corequisite remediation effect on a separate outcome. All models controlled for students' demographic and pre-college academic characteristics shown in Table 1 Panel A, college fixed-effects, cohort fixed-effects, and high school fixed-effects. Standard errors are clustered at college-, cohort-, and high school-level. Robust standard errors are shown in parentheses.

*** p < 0.01, ** p <0.05, * p < 0.1