An NCPR Working Paper

Evaluating Institutional Efforts to Streamline Postsecondary Remediation:

The Causal Effects of the Tennessee Developmental Course Redesign Initiative on Early Student Academic Success

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June 2012

National Center for Postsecondary Research
www.PostsecondaryResearch.org

The National Center for Postsecondary Education is a partnership of the Community College Research Center, Teachers College, Columbia University; MDRC; the Curry School of Education at the University of Virginia; and faculty at Harvard University.

This research was supported by a grant from the American Educational Research Association, which receives funds for its AERA Grants Program from the National Science Foundation under NSF Grant No. DRL-0941014. The contents of this paper were also developed under a grant (R305A060010) from the Institute of Education Sciences, U.S. Department of Education. However, those contents do not necessarily represent the policy of the Institute or the U.S. Department of Education, and you should not assume endorsement of the federal government. Opinions reflect those of the author and do not necessarily reflect those of the granting agencies.

Abstract

Exploiting a statewide cutoff point on the placement examination used to assign students to remedial courses in Tennessee, this study employs a regression discontinuity research design to provide causal estimates of the effects on student outcomes of recently redesigned remedial courses at three Tennessee colleges. Moreover, using data on student outcomes prior to the course redesigns, the study also tests whether the redesigned remedial programs were more effective in preparing students for success in postsecondary education than the remedial programs they replaced. The findings indicate that, among students on the margins of the cutoff score, the effects of enrollment in developmental mathematics were positive and statistically significant on early student persistence as well as on the number of credits attempted but not completed in the first semester. However, these effects did not persist over time, as the results show no statistically significant differences between groups after two years. Yet the study also finds that students who were exposed to redesigned developmental math courses had more positive outcomes than did their peers in non-redesign institutions during the same period and also when compared with students who were exposed to the previous version of traditional remediation within their institution in prior years. Students appear to have benefited from redesigned courses at two of the three institutions. The results of this analysis provide insight into the extent to which the particular instruction and delivery methods of remedial courses affect subsequent student academic outcomes, thus informing administrators and policymakers as to how best to help underprepared students.

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1. Introduction

Large numbers of students who attend college each year are required to enroll in remedial programs aimed at enhancing their weak reading, writing, and/or mathematical skills to better prepare them for success in college-level courses (Attewell, Lavin, Domina, & Levey, 2006; Bailey, Jeong, & Cho, 2010). Recently, a host of new course innovations have surfaced that are intended to move students through remediation more efficiently and effectively. In Tennessee, the focus of the research described in this paper, several colleges have redesigned the way in which they offer remedial courses, including mainstreaming students into college-level courses and making greater use of technology to provide individualized modules that are tailored to students' specific academic needs. Yet little research has been conducted to estimate the causal effects of course redesigns on student academic outcomes and to evaluate how the impact of the new courses compares with that of "traditional" remediation. In the current study, I address this gap in the literature by evaluating the causal effects on students' early academic success of recent remedial mathematics course redesign efforts implemented at three different colleges in Tennessee.

Exploiting a statewide cutoff point on the placement examination used to assign students to remedial courses, I employ a regression discontinuity research design to provide causal estimates of the effects of the redesigned courses on the subsequent academic outcomes of students placed in math remediation. Using data on student outcomes prior to the course redesign, I also test whether the redesigned remedial programs were more effective in preparing such students for success in postsecondary education than were the remedial programs they replaced.

Due to the relatively recent adoption of these reform efforts, I focus on the early academic outcomes of students, including persistence from the first to the second semester and from the first to the second year, the number of credits attempted but not completed in the first semester, and the number of credits (both cumulative and college-level) attained in the first two years. I ask the following specific questions: (1) Does participation in redesigned remedial courses improve subsequent academic outcomes for students at the margins of passing the placement test?; (2) Is participation in redesigned remedial courses more effective than participation in traditional remedial courses offered at similar institutions during the same time period?; and (3) Is participation in redesigned remedial courses more effective than participation in the traditional model of remediation at the same institution prior to the implementation of these new courses?

Findings from this study indicate that, among students on the margins of the cutoff score, the effects of enrollment in developmental mathematics were positive and statistically significant on early student persistence as well as on the number of credits attempted but not completed in the first semester. Although these effects did not persist over time, as I find no statistically significant differences between groups after two years, students exposed to redesigned developmental math courses had more positive outcomes than did their peers in non-redesign institutions during the same period and also when compared with students exposed to the previous version of traditional remediation within their institution in prior years. Students appear to have benefited from redesigned courses at two of the three institutions.

2. Background and Context

The Problem of Underprepared Students

Increasing numbers of American students are enrolling in college unprepared for college-level work (Greene & Forster, 2003; Attewell et al., 2006; Strong American Schools, 2008). In an effort to help these students develop the skills needed to succeed in college-level courses, postsecondary institutions offer a range of remedial and developmental courses in reading, writing, and mathematics designed to bridge the gap between high school and college-level material. Remedial and developmental courses, which fall under the general umbrella term of remediation, are designed specifically for students with lower level skills or those in need of material below college-level. While the terms *developmental* and *remedial* are frequently used interchangeably in this literature, developmental courses often refer to those courses just below college-level (e.g., Algebra II), while remedial courses offer material considerably below college-level (e.g., basic arithmetic).[1]

Such courses, and the costs and benefits associated with their delivery, are of growing concern to students, taxpayers, and higher-education policymakers at all levels, and for good reason: the magnitude and scope of college remediation in the United States is immense. Currently, it is estimated that nearly *half* of all students enrolled in postsecondary institutions are in need of at least one high school–level course (U.S. Department of Education, National Center for Education Statistics, 2004; Attewell et al., 2006; Bailey et al., 2010), with some postsecondary institutions reporting that nearly six out of 10 students enroll in remedial coursework during their college career (Bettinger & Long, 2009b; Bailey, 2009). Statistics from Tennessee show that 73.3 percent of all recent high school graduates enrolling in a community college for the first time in the fall of 2010 were in need of at least one remedial or developmental course (Tennessee Higher Education Commission, 2010).[2] Within developmental education itself, students are most likely to need help in the subject of math (U.S. Department of Education, National Center for Education Statistics, 2004; Bailey et al., 2010).

[1] In an effort to avoid possible negative connotations associated with the term *remedial*, practitioners tend to use the term *developmental education* to describe the courses and services offered to students below college-level (Bailey et al., 2010). In this paper I refer primarily to *developmental* mathematics courses as those courses just below college-level. Additionally, I occasionally use the term *remediation* to refer to acts or efforts designed to bring students up to college-level courses.

[2] Seventy-three percent is a decrease from 20 years earlier, when 85 percent of all freshman entering community colleges in Tennessee required at least one remedial course (Van Allen & Belew, 1992).

A recent study estimated the annual cost of remediation at $1.9 to $2.3 billion at community colleges and another $500 million at four-year colleges, while several states cited costs of tens to hundreds of millions of dollars annually to support remedial programs (Strong American Schools, 2008; Collins, 2009).[3] Additionally, students must shoulder the tuition costs of the courses. In most postsecondary institutions, remedial and developmental courses are typically offered for credit and will count toward a student's overall GPA, but rarely are they counted toward graduation requirements. Yet it is also true that the social costs of not offering remediation may be even greater than the institutional costs of the programs and the direct costs to students combined. Unskilled individuals incur expenses, including unemployment costs, government dependency, and crime (Long, forthcoming, 2011). As the nation's economy increasingly demands a more skilled workforce, educational institutions are pushed to develop more effective ways to train their workers.

A growing body of research is emerging on both the scope and effectiveness of college remediation. Existing research, however, does not provide clear-cut evidence of the benefits of remediation for students. Many previous studies are strictly descriptive in nature and simply compare samples of remedial students with their peers, ignoring the fact that students in need of remediation may be different from their more academically prepared peers in both their observed and unobserved background characteristics. Comparing these two very different types of students while ignoring the problem of unobserved selection can lead to biased estimates of the impact of remediation on subsequent academic outcomes (Bettinger & Long, 2009b). Until recently, there has been little research on the causal effects of remediation on student outcomes, and existing studies have produced inconsistent findings. This research has nonetheless uncovered critical questions about whether remedial programs work, on average, to improve student academic outcomes and about which types of programs are most effective. Broadly speaking, colleges still know little about the most effective ways to provide remedial and developmental courses to improve students' chances for postsecondary success.

The Effectiveness of Remediation

The primary purpose of remediation has always been to integrate into college-level courses students who may not be ready for college-level work. Two common hypotheses have surfaced as to the potential effects of college remediation. On one hand, if remedial courses do indeed provide students with the skills they need to be successful academically at college and in the labor market afterward, then according to human capital theory, these

[3] Calculating the costs of remediation is likely to become more complicated as postsecondary institutions begin to explore alternative methods of offering such courses that do not fit into a traditional, semester-long funding formula (Fulton, 2010).

courses may be a worthwhile investment of time and resources (Becker, 1993). By helping students to develop essential skills, remediation may enable them to succeed in college-level courses and persist to graduation more effectively than they otherwise would have (Bettinger & Long, 2009b). Additionally, theories of student integration and engagement tell us that the additional academic supports offered commonly in remedial courses may help to integrate students into their academic environment in important ways, leading to higher rates of persistence and completion of their degrees. Students who feel connected to their institution (either academically, socially, or both) are more likely to remain enrolled than those who feel disconnected (Tinto, 1975; Kuh et al., 1991; Astin, 1993). If access to, and involvement in, college remediation allows a student an opportunity to develop confidence in his or her skills, it could also increase student academic engagement and improve chances for success indirectly (Astin, 1993; Gray-Barnett, 1999).

On the other hand, required participation in remedial education may not increase the probability that students will succeed in postsecondary education. Discouraging results obtained on the impacts of the assessment tests that are used to place students into remediation indicate that such tests can cause students to become frustrated, leading potentially to increased college drop-out rates (Deil-Amen & Rosenbaum, 2002). Furthermore, remedial and developmental courses themselves may slow students in their progress toward a degree, given that remedial courses rarely count toward a student's graduation requirements, and given that factors that lengthen the time to degree can reduce the probability of degree completion (Bailey, 2009). A recent study by Jenkins and Cho (2012) concluded that students who do not enter a degree program within a year of first entering college have a lower probability of eventually earning a degree or credential, thereby stressing the importance of students making early progress toward a degree as an important factor in college persistence. Remediation may also have attached stigma, as taking remedial courses may lead ultimately to lower self-esteem, higher frustration, and higher drop-out rates (Bettinger & Long, 2009a; Jacob & Lefgren, 2004).

Determining the causal impact of remediation on student outcomes is difficult due to the observed and unobserved differences in the students assigned to remediation, as compared with students assigned to college-level courses. Simply contrasting the average outcomes of these two different groups ignores the problem of selection and tells us nothing about whether differences in student outcomes were actually *caused* by students' enrollment in remedial classes, or whether these differences are instead explained by lower levels of academic preparation prior to ever enrolling in remedial courses. Several studies have addressed the causal question using a regression discontinuity (RD) design, comparing students who were placed into remedial courses by narrowly failing a remediation-placement examination with similar students who narrowly passed the same examination and then enrolled in college-level courses (Calcagno & Long, 2008; Lesik, 2007; Martorell

& McFarlin, 2011). In RD designs, students who score below a specified cutoff score on the mandatory remedial placement exam are assigned to a remedial-level course, and students scoring above this cutoff are assigned to a college-level course. Assuming that students who score just above and below the placement cutoff are equal in expectation prior to treatment, one can obtain an unbiased estimate of the causal effect of taking remedial courses on subsequent student outcomes for these students at the margins of passing (Shadish, Cook & Campbell, 2002; Imbens & Lemieux, 2008). The mixed results from prior research suggest that the causal effect of remedial courses on student outcomes is not yet fully understood.[4] Furthermore, most prior research in this area focuses only on evaluating the causal impact of participation in traditional, semester-long remedial courses. Recent innovations in community colleges and four-year institutions across the country suggest that the traditional model of developmental education may be changing.

Redesigning Developmental Education

Traditional remedial courses are generally structured in a 15-week, semester-long format in which a student takes one remedial course in a given subject before moving on to the next course in the sequence. Depending on the student's prior academic background and specific needs, some of these remedial and developmental courses may contain material that the student has already mastered. Many are concerned that this traditional model may unnecessarily prolong the time to degree and thus increase the probability that students will stop out. Moreover, the traditional method of delivering remedial courses often mirrors the way students were taught these same subjects in high school. Repeatedly exposing students to the same material taught in the same manner may not produce large enough learning gains if the instructional format is itself part of the reason for their lack of mastery.

Redesigning developmental courses can take on a number of purposes and forms. Rutschow and Schneider (2011) distilled the multitude of redesign efforts into four types of interventions: (a) strategies targeted to students *before* they enter college, (b) interventions that shorten the timing or content of remedial courses, (c) programs that combine basic skill attainment with college-level coursework, and (d) supplemental programs such as tutoring, advising, or participation in targeted sections outside of class.[5] The process of eliminating the developmental courses, which carry no university credit, is referred to commonly as *mainstreaming*. If the method used to assign students to developmental courses is flawed or

[4] New research has also attempted to explore whether the mixed results of prior studies may be explained by differences in students' levels of academic preparation (Bailey et al., 2010; Boatman & Long, 2010). This research provides important evidence that suggests that the effects of remediation may differ according to individual student need.
[5] For examples of recent evaluations of developmental education interventions, see Howell, Kurlaender, and Grodsky (2010) and Jenkins, Zeidenberg, and Kienzl (2009).

unreliable, it very well may be that students near the cutoff for assignment to these courses would succeed in college-level courses if given the opportunity (Hughes & Scott-Clayton, 2011).[6] Alternatively, if these assessments are accurate in their placement of students into remedial courses, then the process of mainstreaming may deny students the opportunity to learn material that is only offered in a developmental course. Additional research on other types of specific programs suggests that students enrolled in condensed courses, self-paced courses, and/or mainstreamed developmental courses do show higher rates of persistence subsequently when compared with students taking traditional developmental courses, yet causal questions about the effects of these programs on student outcomes remain unanswered (Jenkins, Speroni, Belfield, Jaggars, & Edgecombe, 2010; Epper & Baker, 2009; Zachry, 2008; Edgecombe, 2011).

In the last several years, a host of states and individual institutions have received financial support from government and private sources to provide incentives for redesigning and assessing alternative approaches to the ways that they offer remedial and developmental education (Couturier, 2011; Carnegie Foundation, 2012; Zachry & Schneider, 2010).[7] An increasing number of redesign efforts now incorporate the innovative use of learning technology into the classroom. These newer models of remediation attempt to better target students' academic needs through improved instructional practice, often through the use of learning technology such as self-directed learning labs, online-learning models, and the use of high-tech classrooms (Epper & Baker, 2009; Karnjanaprakorn, 2012). Such use of learning technology could potentially have both positive and negative effects. For example, the use of learning technology in the classroom is aimed at shortening the amount of time that students spend in developmental courses, thus enabling them to move more quickly into their college-level courses while also creating efficiencies in the delivery of developmental education. According to the human capital model, by reducing the amount of time spent in remediation, the redesigned courses could produce better student outcomes due to reducing the direct (tuition) and indirect (foregone earnings) costs of the courses. On the other hand, however, the redesigned courses could have no differential impact or could even produce more negative effects due to an overreliance on learning technology. Not all

[6] In one study of the Community College of Baltimore County's Accelerated Learning Program (ALP), researchers from the Community College Research Center determined that students participating in a mainstreamed English program had higher pass rates in their subsequent college-level courses than did their peers who did not enroll in a mainstreamed course (Jenkins et al., 2010).

[7] Six states (Connecticut, Florida, North Carolina, Ohio, Texas, and Virginia) are currently participating in the Developmental Education Initiative (DEI), an effort funded by the Bill & Melinda Gates Foundation and Lumina Foundation for Education, designed to further advance state policy work in developmental education. These states are a subset of the 22 states participating in the Achieving the Dream: Community Colleges Count initiative funded by Lumina Foundation for Education and other funders.

students may be comfortable using learning technology as an instructional tool, particularly at the accelerated pace offered in the redesigned courses.

In this paper, I evaluate three recent efforts to reform developmental math instruction at three different colleges in Tennessee. I test the aforementioned hypotheses using quasi-experimental methods designed to account for unobserved differences among the students who are placed into remedial courses versus those who are not. The courses are designed to provide students with the skills they need in a more streamlined manner, thereby shortening their pathways to college-level courses and increasing their probabilities of degree completion (Bailey, 2009).

The Tennessee Higher Education System and the Developmental Course Redesign Initiative

For the past decade, the Tennessee Board of Regents (TBR) has actively engaged in discussions on how to improve remedial and developmental education across its 13 community colleges and six public universities.[8] In October 2006, the TBR and the Education Commission of the States (ECS) received a three-year grant from the Fund for the Improvement of Postsecondary Education (FIPSE) through the U.S. Department of Education to implement the Developmental Studies Redesign Project.[9] The project aimed to help individual institutions develop and implement a more efficient delivery system for remedial and developmental courses with the hope of improving their effectiveness and of serving more students better and at less cost (Short, 2009). Starting in the fall 2007, the FIPSE funds were distributed to the National Center for Academic Transformation (NCAT), a nonprofit organization with expertise in supporting institutions in the use of learning technology to improve student learning outcomes. Six proposals out of 17 were selected as pilot projects designed to last for three semesters, with four proposals focused on math and two on English.[10] In the fall of 2007, NCAT awarded pilot grants totaling $211,668 to the six selected TBR institutions: Austin Peay State University (math),

[8] Tennessee has a higher education system that is similar to most other mid-sized states. The Tennessee Higher Education Commission (THEC) coordinates two systems of public higher education in the state: the three University of Tennessee institutions governed by the University of Tennessee Board of Trustees, and the six state universities and 13 community colleges governed by the Tennessee Board of Regents. Together these two systems served over 256,000 students in the fall of 2010 (Tennessee Higher Education Commission, 2010). The 19 TBR colleges do not include the five campuses of the University of Tennessee system: Knoxville, Chattanooga, Martin, Tullahoma, and Memphis.

[9] For more information on the Developmental Studies Redesign Project, see http://tnredesign.org/about.html#

[10] The selection of the pilot sites was determined by both the quality and feasibility of the proposal. Institutions had to demonstrate baseline administrative capacity for making curricular changes and the redesign efforts had to be notably different than the existing developmental course structure.

Cleveland State Community College (math), Jackson State Community College (math), Chattanooga State Community College (math), Columbia State Community College (reading/writing), and Northeast State Community College (reading).[11] These six institutions then took the fall term of 2007 to plan for the implementation of their proposed redesign. The technology was installed and tested in the spring of 2008, and full implementation of the six pilot sites continued in the fall of 2008, with four colleges reporting successful implementation after the first semester. While all of the institutions faced some unanticipated problems during implementation, for Columbia State Community College and Chattanooga State Community College, these challenges prohibited their ability to implement their redesign plans successfully in the first semester of the pilot year. In both cases, instructional and technological aspects of the initial plan were not followed, which led to a revision of the plan midway through the three-semester pilot period (Tennessee Developmental Studies Redesign Project, 2008).

In this paper, I focus on the three institutions that were able to implement reforms in their developmental math courses: Austin Peay State University, Cleveland State Community College, and Jackson State Community College.[12] Math literacy is perhaps the most important need in the nation's effort to remain competitive in the global economy (Epper & Baker, 2009). Yet, of all subject areas, more students enroll in developmental math than in any other subject (NCES 2001, as cited in Bettinger & Long, 2009a; Bailey et al., 2010). Furthermore, students are more likely to fail developmental math than any other course in higher education (Le, Rogers, & Santos, 2011). Students who fail developmental math are also the least likely to ever earn a degree or credential (Le et al., 2011; Carnegie Foundation for the Advancement of Teaching, 2012).

While the specific details of each institution's course redesign efforts have differed, the overarching goal of all reforms has been to decrease the time students spend in developmental math courses. Prior to the Developmental Studies Redesign Initiative, developmental courses at the 19 TBR institutions had been taught in much the same way for the past 20 years. Courses were offered in traditional 16-week, semester-long formats at three levels: *basic remedial*, *basic developmental*, and *intermediate developmental* (Twigg, 2009). Students in need of remediation were placed into one of these levels for reading, writing, and/or math, and were required to complete their assigned course before moving on

[11] NCAT awarded $40,000 in grants each to Austin Peay State University, Jackson State Community College, Chattanooga State Community College, and Northeast State Community College. Cleveland State Community College received $15,000 and Columbia State Community College received $36,668.

[12] Due to the incomplete implementation of the mathematics course redesign effort at Chattanooga State Community College, this institution is not presented in the final analysis. I do, however, present institutional characteristics for Chattanooga State in Table 2 and include it in early rounds of the analysis, although the results, none of which were statistically significant, are not shown.

to the next. Thus, for students in need of multiple remedial courses in the same subject, this could mean over a year of course-taking before their remedial requirements were fulfilled.

The redesigned courses offered innovative structural and instructional changes. Chief among these changes was a shift to using learning technology, both in and out of the classroom, to enable the students to work at their own pace and to focus their attention specifically on the particular skills in which they were deficient. Each of the three institutions in the pilot redesigned their courses to better tailor the remedial material to the students' specific needs and academic deficiencies.

The details of each institution's redesign efforts differed considerably across institutions. At Austin Peay State University, both developmental math courses (Algebra I and Algebra II) were eliminated entirely, and enhanced sections of the two core college-level courses, Fundamentals of Mathematics and Elements of Statistics, were created for students whose ACT exam scores placed them in developmental math. These college-level courses were linked to Structured Learning Assistance (SLA) workshops in which students received additional tutoring and assistance for any course material with which they were struggling. Learning technology in the form of computer labs and online tutorials were used in the SLA workshops to help bring students up to speed in the college-level material. Due to its elimination of the developmental math courses, the Austin Peay model of reform is referred to as an example of *mainstreaming* in the literature.

Cleveland State Community College adopted an *acceleration* approach to its redesign. Students who completed a developmental math course successfully before the end of the term were allowed to begin the next developmental course immediately. Furthermore, each developmental course was divided into a smaller number of modules containing subsections of the course material. Students met for one hour in class and for two hours in a large computer lab, which allowed them to work online, while instructors provided individual student assistance and reviewed student progress. When students completed one module, they were allowed to move on to the next, and once they had completed all of the modules, they could begin the next course in the developmental sequence. This redesign, therefore, required that registration in remedial courses be made more flexible, as students were encouraged to complete one developmental course and immediately begin another, often in the midst of the semester.

At Jackson State Community College, all three developmental math courses were divided into 12 modules, with modules 1–3 replacing Basic Arithmetic, modules 4–7 replacing Developmental Algebra I, and modules 8–12 replacing Developmental Algebra II. A pretest was given to each student at the beginning of the semester to determine which specific skills students would need to gain for competency in their majors. After the pretest, each student received an individualized learning contract that provided guidance through the developmental education pathway. Students were only required to master the concept deficiencies determined by the pretest and those that were relevant to their career goals. The course content modules were offered in a learning center that also offered video lectures, online homework, and weekly testing, as well as immediate assistance from instructors and tutors. Students were encouraged to work at their own pace, and weekly assessments provided alerts for students who were not grasping the material. For further information, in the Appendix I summarize the specific developmental math redesign efforts implemented at each institution.[13]

Observational research and descriptive summaries suggest that these redesigns have been highly successful (National Center for Academic Transformation [NCAT], 2009), yet research to estimate the causal effects of participating in these redesigned courses on subsequent educational outcomes has been notably absent. Descriptively, enrolling in one of the three math course redesigns was found to improve subsequent college-level course completion rates (as measured by a final grade of C or better), as well as to reduce instructional costs by 36 percent, on average. At Austin Peay State University, eliminating two levels of developmental math and enrolling underprepared students into college-level math courses with supplemental instruction resulted in an increase in the overall pass rate of underprepared students who required both developmental courses from 17 percent to 76 percent (NCAT, 2009). At Cleveland State Community College, a study by Schutz and Tingle (2010) used logistic regression analysis to determine what effects the course redesigns had on student academic outcomes, and the results were similar to those in previous studies: strong positive effects were found for next-course success, including the next course in both developmental math and college-level math.

These existing evaluations simply compare the pass rates of students before and after the course redesigns were implemented, while failing to account for the selection of students into these courses and for any unobserved differences between them and their peers who did not take remedial courses. In the research described in this paper, I first use a regression discontinuity design to examine how participation in these redesigned courses affected the subsequent academic outcomes of target students at the margins of passing the placement test. Second, I use the same research design to compare the causal effects of enrolling in traditional remedial courses with the effects of enrolling in the newly redesigned courses; I do this by comparing the average outcomes of students attending the other 16 colleges in Tennessee with those attending "treatment" institutions during the same time period. Finally, I compare cohorts of students at the three treatment institutions before

[13] I include Chattanooga State Community College in the table, although these efforts were not implemented fully during the period of the pilot redesigns.

and after the curriculum change to further estimate the effects of redesigned courses (versus traditional courses) on student academic outcomes. Thus I can determine whether enrollment in the recently redesigned courses was more or less effective than enrollment in the traditional remedial courses they replaced.

3. Research Design

The manner in which students are assigned to developmental math courses in Tennessee provided me with an opportunity to obtain an unbiased estimate of the causal effects of enrollment in developmental math courses on students' subsequent academic success. Tennessee is one of several states that use a statewide placement system to assign students to remedial courses when they enter college. Since 2005, the primary instrument used to assign students to developmental math courses at the public two- and four-year colleges has been the ACT Math exam, a subsection of the overall ACT exam.[14] Other diagnostic assessments are allowable as secondary or challenge assessments. Community college students under the age of 21 without an ACT score are given a placement test prior to registering for classes. Entering students 21 years and older who do not have an ACT or SAT score also have to take a placement exam.[15] Under the traditional statewide policy in place during the years of this study, students with scores between 19–36 points on the ACT Math exam are assigned to college-level math, students with scores of 17–18 points are assigned to Developmental Algebra II, scores of 15–16 points to Developmental Algebra I, and scores below 14 points to Remedial Arithmetic.

Given that the ACT Math exam is the primary assessment tool used to place students into remedial and developmental courses, it is important to examine the differences between those who took the ACT and those who did not. In Table 1, I present the sample means of select background characteristics and college enrollment information for those students who took the ACT Math exam and for those who did not, across the four years of 2006–07 to 2009–10. Across all 19 TBR institutions over these four cohorts, 82.4 percent of all students took the ACT Math exam. Among those students, 98.5 percent were under 21 years old, with the average age being 18 years old. Eighty-eight percent were enrolled as full-time students (registered for a minimum of 12 credit hours per semester) at the start of their first year, and these students were enrolled evenly across two- and four-year institutions. Conversely, the students who did not take the ACT Math exam (column 3) were generally older, with an average age of 28 years old, nearly half were enrolled part

[14] Prior to 2005, the state relied on a mathematics placement exam in addition to the ACT to assign students to developmental courses. This exam, known as COMPASS (Computerized Adaptive Placement Assessment and Support Systems) was administered to students who had a standardized test score (ACT/SAT) below a predetermined threshold or to students who did not take the ACT or SAT. The COMPASS exam was then used as the primary took for assigning students to developmental and college-level courses. In the fall of 2005, the state began using the ACT as the primary assignment tool. Over 85 percent of students in Tennessee take the ACT.

[15] These placements exams are most commonly the COMPASS or ASSET (Assessment of Skills for Successful Entry and Transfer). Any scores used for initial assessment must have been earned within three years prior to the first day of the student's entering term.

time, and the majority attended two-year colleges. In this study, I restricted my sample to only those students who took the ACT Math exam, which, as I i llustrate in column 2, includes primarily students of traditional college age and with full-time enrollment status at the start of their first year.

Table 1

Comparing Students Who Took the ACT Math Exam with Those Who Did Not

	Full sample (1)	Took ACT Math (2)	Did not take ACT Math (3)
Background Characteristics			
Female	0.565	0.554	0.615
White	0.706	0.713	0.672
Black	0.216	0.210	0.242
Other race	0.057	0.055	0.063
High school GPA	2.98 (0.55)	3.01 (0.60)	2.78 (0.69)
Average year of high school graduation	2005 (4.83)	2007 (1.52)	1999 (8.22)
College Enrollment Information			
Age in first semester	20.12 (5.25)	18.23 (0.90)	28.37 (8.25)
Percent under 21	0.830	0.985	0.102
Full-time student	0.822	0.882	0.543
Attend two-year colleges	0.578	0.517	0.860
Recommend any remedial math course	0.548	0.483	0.850
Enrolled any remedial math course	0.448	0.408	0.633
Observations	111,546	91,914	19,632

Data

The Tennessee Higher Education Commission (THEC) and Tennessee Board of Regents (TBR) provided the necessary data for this study. THEC and TBR collect basic enrollment information and transcript data on each student, including courses taken and grades for any term during which the student was actively enrolled at any Tennessee public institution. Select information is also available on students' demographic characteristics, high school background, and test scores. Key to my analysis, the dataset also includes the ACT Math exam scores for all students and a record of their subsequent assignment into remedial, developmental, or college-level courses based on this exam. The THEC and TBR data to which I have access covers each term (fall, spring, and summer) from the fall of 2006 through the spring of 2011. I assigned all students in the dataset to a cohort according to the year in which they *first* began at a public two- or four-year college in the state. By using two cohorts before the policy change (students beginning in the fall of 2006 and the fall of 2007) and two cohorts after (students beginning in the fall of 2008 and the fall of 2009), I was able to work with a sample large enough to detect relatively small effect sizes, at standard levels of Type I error.

I also incorporated data from the Integrated Postsecondary Education Data System (IPEDS), an annual, federal survey that provides institutional-level characteristics, such as the Carnegie classification code, average enrollment, and college graduation rates for each institution in the study. These data allowed me to observe potential differences across the institutions that may influence student enrollment and course-taking behavior. In Table 2, I show the sample means for student background characteristics and raw enrollment data at the institutional level for the four colleges initially receiving FIPSE funds to redesign their developmental math curriculum, as well as aggregate measures for all two-year and four-year public colleges in the TBR system for the fall of 2008. Austin Peay State University, the only four-year college in the sample, is similar to the other five public four-year TBR institutions in the state in terms of the full-time retention rate of first-time students (68 percent at Austin Peay, compared with 69 percent at the other four-year colleges) and the highest percentage of students receiving any financial aid (95 percent at Austin Peay, compared with 94 percent at the other four-year colleges). Compared with the five other four-year colleges in the state, however, Austin Peay had a higher number of students recommended for any remedial math course (45.6 percent versus 35.2 percent, respectively) and a lower six-year graduation rate (32 percent versus 41 percent). Among the two-year colleges, Cleveland State enrolled a greater percentage of White students (89 percent at Cleveland State compared with 77 percent at the other two-year colleges), as well as students with slightly higher ACT Math scores and high school GPAs. Cleveland State also had the lowest percentage of students recommended for any remedial math course, with

Table 2

Select Institutional Characteristics, Fall 2008

	All TN four-year colleges[a]	Austin Peay State Univ.	All TN two-year colleges[b]	Cleveland State CC	Jackson State CC	Chattanooga State CC
Student Characteristics						
Female (%)	58.3 (5.1)	63.1	62.5 (5.8)	61.4	67.2	61.7
Black (%)	26.0 (29.3)	17.2	14.3 (17.5)	5.1	17.4	18.8
White (%)	65.0 (27.3)	62.1	77.2 (17.9)	89.0	78.3	78.7
Age over 25 (%)	13.2 (3.7)	24.4	16.5 (5.3)	21.3	14.6	17.7
Average high school GPA	3.21 (0.51)	3.14 (0.53)	2.83 (0.64)	2.94 (0.60)	2.85 (0.57)	2.83 (0.64)
Average ACT math score	20.97 (4.28)	20.07 (3.75)	17.92 (3.34)	18.20 (3.34)	18.19 (3.23)	17.65 (3.07)
ACT math 75th percentile score	22.0 (2.77)	23.0	19.0 (1.62)	20.0	19.0	19.0
Student Enrollment Information						
Full-time (FT)[c] equivalent undergraduate enrollment	51,821	7,772	31,165	2,213	2,900	5,423
Percent of all undergraduates beginning as first-time, full-time degree-seeking students	25.2 (13.5)	28.7	52.4 (11.2)	42.4	44.3	42.8
Institutional Characteristics						
FT undergraduates receiving any financial aid (%)	94.0 (2.49)	95.0	78.0 (5.44)	81.0	77.0	79.0
Recommended for any remedial math course within the 1st year	35.2	45.6	68.0	66.8	70.1	74.5
Enrolled in any remedial math course in the 1st year	24.4	19.3	56.7	60.8	65.5	61.1
FT retention rate[d] (students enrolled fall 2008 returning fall 2009) (%)	69.0 (5.2)	68.0	52.0 (3.6)	56.0	49.0	53.0
Received any degree within 6 years (%)	41.0 (4.6)	32.0	12.0 (4.5)	13.0	8.0	8.0

SOURCE: Integrated Postsecondary Education Data System (IPEDS), NCES, and author's calculations using THEC and TBR institution-level data.

NOTES: Standard deviations, when available, are shown in parentheses. All data reported for the fall term of 2008–09.

[a]The four-year colleges column does not include Austin Peay State University.

[b]The two-year colleges column does not include Cleveland State Community College, Jackson State Community College, or Chattanooga State Community College.

[c]Full-time (FT) students are those enrolled for 12 or more credits per semester.

[d]The full-time retention rate applies to students enrolled full time in the fall of 2008 who subsequently enroll full time in the fall of 2009.

66.8 percent compared with 70.1 percent at Jackson State and 74.5 percent at Chattanooga State. Jackson State and Chattanooga State more closely resembled the other 11 two-year colleges in Tennessee on race/ethnicity and age characteristics. Both institutions had a low six-year graduation rate at 8 percent of the entering cohort, although the average among two-year institutions was not much higher at 12 percent.

Sample

The sample used in this study contains those students in Tennessee who attended one of the three institutions that implemented a math course redesign successfully (described above and in the Appendix) and who also took the ACT Math exam. When pooled across all four cohorts (two pre-2008 and two post-2008) among these three institutions, the sample size is 8,948 students.[16] Additionally, the sample only includes students who began as full-time students so that I am better able to compare credit accumulation throughout the early years of college. I define *full time* as taking a minimum of 12 credit hours in the entering term. The vast majority of students in the sample (89 percent) began as full-time students, making this a weak restriction. I also limit the sample to students under the age of 21 in order to isolate the effects to traditional students, and only include those students for whom I have complete information on gender, race, high school grade point average, and postsecondary institution enrollment information.

In Table 3, I report the sample means and standard deviations for student characteristics, including gender, race, high school GPA, and age, as well as the means for college-enrollment variables for both the pre-reform (2006–07 and 2007–08) and post-reform (2008–09 and 2009–10) cohorts. In doing so, I provide descriptive statistics of the sample, and also check that the observable characteristics of students enrolled at the three sample institutions pre-2008 were similar to the characteristics of students enrolled post-2008 in order to rule out large changes in the composition of the student body during the four years of this study. Inferential statistics from accompanying *t*-tests indicate the extent to which the sample means of each variable differ, in the population, between the pre- and post-reform cohorts. On average, more female and Black students were recommended for developmental math than for college-level math (as shown by rows 1 and 3). Not surprisingly, students recommended for college-level math had higher high school grade point averages (GPAs) on average than did students recommended for Developmental Algebra II, as well as higher average ACT Composite and Math exam scores. Across all four cohorts, very few students enrolled in Developmental Algebra II who were not

[16] This sample size provides sufficient statistical power (0.90) to detect small treatment effects (0.1 standard deviations) at the usual levels of Type I error, while still remaining chronologically close to the dates of the policy change.

recommended for the course, and over 80 percent of those recommended actually did enroll in the first semester.

Table 3

Sample Characteristics by Level of Course and Time Period of First Enrollment

	RECOMMENDED DEVELOPMENTAL ALGEBRA II			RECOMMENDED COLLEGE-LEVEL		
	Pre-reform (2006–07 & 2007–08)	Post-reform (2008–09 & 2009–10)	*t*-test	Pre-reform (2006–07 & 2007–08)	Post-reform (2008–09 & 2009–10)	*t*-test
Female	0.621	0.653	1.504	0.523	0.588	1.998
White	0.725	0.722	1.636	0.767	0.760	0.011
Black	0.156	0.162	0.369	0.099	0.093	0.446
Other race	0.089	0.120	1.961	0.107	0.118	0.663
High school GPA	2.92 (0.50)	2.96 (0.49)	1.686	3.08 (0.50)	3.15 (0.48)	2.660
Age in 1st semester	18.07 (0.56)	18.13 (0.55)	2.167	18.05 (0.47)	18.09 (0.46)	1.649
ACT composite score	19.32 (2.12)	19.41 (2.11)	0.964	20.62 (1.98)	21.13 (1.96)	5.263
ACT math score	17.44 (0.49)	17.49 (0.61)	2.000	20.12 (1.14)	20.18 (1.14)	1.032
Enroll in any developmental math course	0.866	0.740	7.104	0.004	0.002	0.006
Total number of developmental credit hours in 1st semester[a]	4.28 (3.42)	3.16 (3.73)	6.928	1.02 (2.07)	0.89 (1.77)	1.980
College credit hours in 1st semester	9.59 (4.11)	10.18 (4.26)	3.217	13.34 (2.82)	13.20 (2.39)	1.054
Observations	945	1014		741	921	

NOTES: The sample is limited to students who began at Cleveland State Community College, Jackson State Community College, or Austin Peay State University in the fall of 2006–07 to 2009–10 with complete information on gender, race, age, high school grade point average, and postsecondary institution enrollment information.

The sample is also limited to students under the age of 21 who began full time. The bandwidth on either side of the cutoff ($-2 \leq x \leq 3$ points) was chosen to closely resemble the optimal bandwidths used in the statistical analysis of Tables 5–7.

[a]The total number of developmental credit hours accumulated in the first semester includes credit hours for developmental math, reading, writing, and/or study skills.

Among those students recommended for Developmental Algebra II, fewer students enrolled in any developmental math course post-reform than pre-reform (74 percent pre-reform compared with 86.6 percent post-reform). This difference is likely driven by the reform efforts implemented by Austin Peay State University, which eliminated their upper two developmental math courses as part of their redesign efforts. Therefore, students assigned to these courses instead enrolled in college-level math. This policy change also explains the observed differences across the pre- and post-cohorts in the number of developmental credit hours and the number of college-credit hours attained in the first semester. Among students recommended for college-level courses, I only observed statistically significant differences between the pre- and post-reform cohorts in the average high school GPA and ACT composite score. Both measures increased in the latter two years for students recommended to college-level math, although the increases are substantially quite small (0.07 GPA points and 0.51 ACT points).

Measures

Due to the relatively recent implementation of the redesigns, I measured subsequent academic outcomes for students over the short term. Focusing on outcomes in the first two years of college allowed me to explore a critical period in the persistence trajectory of an undergraduate, as academic performance in the early years is highly predictive of future academic success (Bettinger, 2004; Adelman, 2006). Of particular interest in evaluations of college remediation efforts is whether assignment to remedial courses slows students down in their early progress toward a degree so much so that they become discouraged and stop out of college. *Early persistence* in this paper refers to the probability of remaining enrolled in college after the first semester or first year.[17] Given that the sample includes only those students who began full time (enrolling for 12 or more credits in their first semester), I included in my analysis outcomes for *any* enrollment in the second semester and year, not conditional on prior enrollment.

I also explored the impact that enrollment in developmental math had on the number of both cumulative credits and college-level credits a student had accumulated during the first and second year. In recent research, Jenkins and Cho (2012) found it more probable that those students who completed nine semester credits, or approximately three college courses, in a specific program of study will earn a college credential. This measure of "early momentum" in postsecondary education can help predict future success in their postsecondary education (Jenkins & Cho, 2012). While the number of total credits in the second year may be a good indication of student progress toward a degree, it is the number

[17] I define *persistence* as occurring within the same institution in which a student first enrolled. Future work will examine transfer students and enrollment in other TBR institutions.

of *college-level* credits completed over time that is most critical to degree attainment. Remedial courses in Tennessee count toward a student's cumulative number of credits, but because *college-level* credit accumulation is the most direct path toward degree completion, these are perhaps more important outcomes to consider in the early college years. As such, I included as outcome measures the total number of college-level credits completed in the second semester, in the second year, and over the first two years. I intentionally excluded the first semester when examining the number of college-level credits completed, as we would naturally expect to see students assigned to developmental math taking fewer college-level credits in the first semester. For students who dropped out, both total credits and college credits were imputed as the number of credits when last enrolled. Finally, I also included as an outcome a measure of the number of credits a student attempted in the first semester but did not complete successfully. This outcome serves as an early measure of potential student academic difficulty, as students are generally expected to successfully complete all of the courses they begin.

My principal question predictor was a dichotomous variable that indicates take-up of the assignment, or whether a student actually enrolled in a redesigned remedial or developmental course (1 = enrolled, 0 = otherwise) within the first semester. In Tennessee, students are encouraged to begin their remedial courses immediately upon enrollment, although they are not required to do so. Students must have completed their remedial course before they can enroll in the subsequent college-level course, however, which results in the majority of students enrolling in their assigned developmental math course within the first semester. The majority of students recommended to remedial courses actually enrolled in these courses within the first semester (over 80 percent did so).[18] In my analysis, I also included a dichotomous predictor that indicates whether the student was enrolled *after* the course redesigns took effect. In addition, my forcing variable was a continuous measure of a student's score on the ACT Math exam centered on the cutoff, with scores of 19 and above placing a student into college-level math and scores of 17–18 placing a student into developmental math. I centered its values on the requisite cutoff scores that designate assignment to remediation.

To estimate the impact of the take-up of remediation on the academic outcomes (rather than the impact of the offer of remediation), I used assignment to a developmental math course at one of the three redesign schools as an instrumental variable in my first-

[18] However, it may be that those who delayed enrollment in their remedial courses to a later semester differ in unobserved ways from those who enrolled in their first semester. To check this, I conducted sensitivity analyses, comparing the results only for students who enrolled in their assigned remedial course in their first semester with the results for students who enrolled in a subsequent semester. The results were not statistically different from the results for those who enrolled in remedial education in their first semester.

stage analyses for each of my research questions. This dichotomous predictor took on a value of one if students scored a 17 or 18 on the ACT Math exam (the forcing variable), indicating that they would be assigned to a remedial course, and zero otherwise. The assignment policy is a good choice for an instrument, as it was strongly correlated with enrollment in remedial courses, the potentially endogenous question predictor, but was determined exogenously by state policy (Calcagno & Long, 2008; Bloom, 2009).

Analytic Strategy

All students in this study were assigned to remedial and developmental courses using the placement of their ACT Math score with respect to an exogenously defined statewide cutoff. Thus, I was able to use a regression discontinuity approach to compare the subsequent academic outcomes of students at the margins of passing — those near the cutoff who were assigned to the redesigned courses and those near the cutoff who were not assigned to the redesigned courses — and thereby obtain an unbiased estimate of the causal effect of enrollment in these courses for students at the cutoff (Shadish et al., 2002; DesJardins & McCall, 2007; Murnane & Willett, 2011). My causal inferences assume that, other than placement into a higher or lower level course, students immediately on either side of the cutoff were equal in expectation (i.e., the same, on average, in the population in all other respects, both observed and unobserved) prior to treatment.

However, due to imperfect compliance with the statewide cutoff policy, this discontinuity in assignment to remedial classes was *fuzzy*, in that some students who were assigned to remediation did not receive it, and some who were not assigned subsequently enrolled in remedial courses. Consequently, I used an instrumental variables (IV) strategy and a two-stage least-squares (2SLS) estimation to resolve the fuzziness (Murnane & Willett, 2011; Shadish et al., 2002). I treated *assignment to remediation* at the cutoff on the placement score forcing variable as my instrument for the potentially endogenous enrollment, or take-up, in these remedial courses, and thus obtained an unbiased estimate of the causal impact of actual enrollment in a remedial class on subsequent student outcomes.

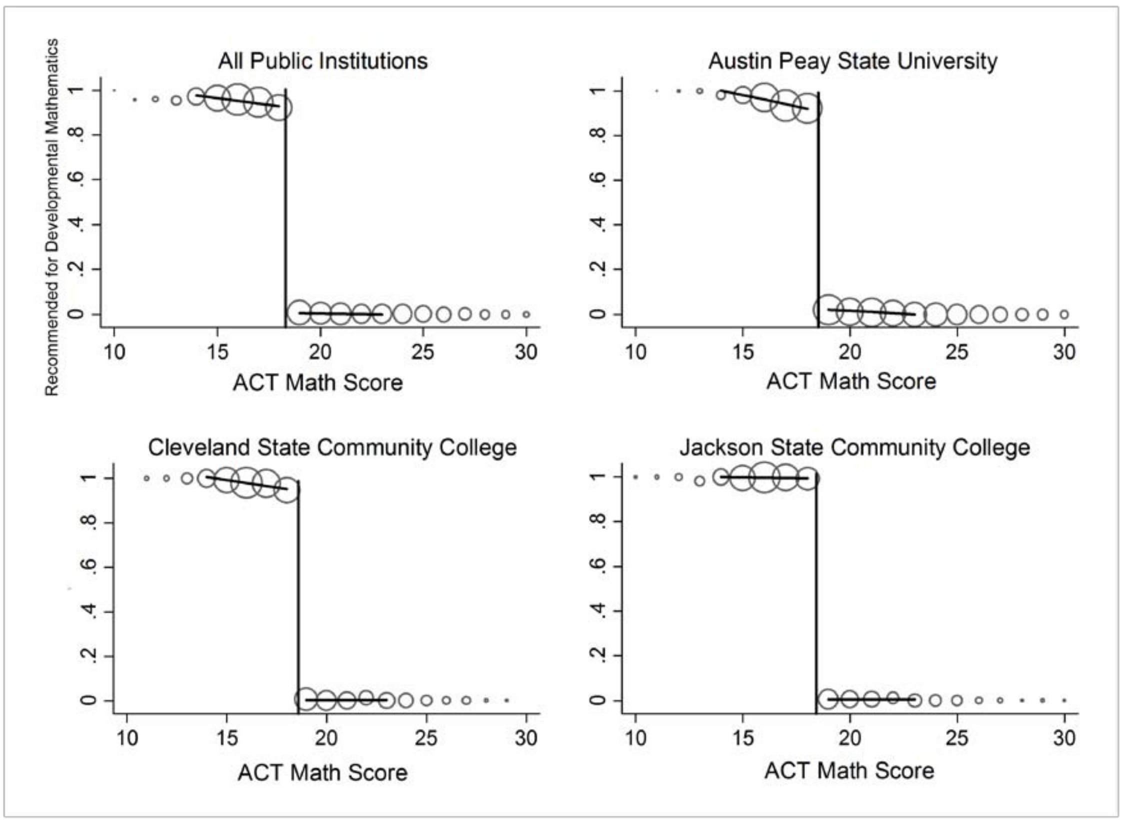
In Figure 1, I illustrate the fuzziness in the placement policy. Across all 19 public institutions over the four years between 2006–07 and 2009–10, as well as at each of the individual institutions in the sample, all students scoring above a 19 on the ACT Math exam were *not* recommended for developmental math, but not 100 percent of the students scoring below a 19 were.[19] The degree of fuzziness differed across each of the three institutions in

[19] While all institutions are supposed to assign students to developmental courses based on students' scores on the ACT Math exam, discussions with officials in Tennessee indicate that exceptions to this assignment policy are sometimes made on an individual basis, most commonly as a result of particularly

the sample as well. Austin Peay demonstrated the greatest deviation from the placement policy, although for students below the cutoff, the assignment rate was still over 85 percent.

Figure 1

Percent of Students Assigned to Developmental or Remedial Math by ACT Math Score, 2006–07 to 2009–10



NOTES: *All public institutions* includes all 19 public colleges in the Tennessee Board of Regents system from 2006–07 to 2009–10. Each circle represents the percent of students placed into a developmental or remedial math course. The size of the circle represents the relative number of students reporting an ACT Math score in the fall of their first year. The vertical lines are drawn at an ACT Math score of 19, the statewide cutoff for placement into college-level math.

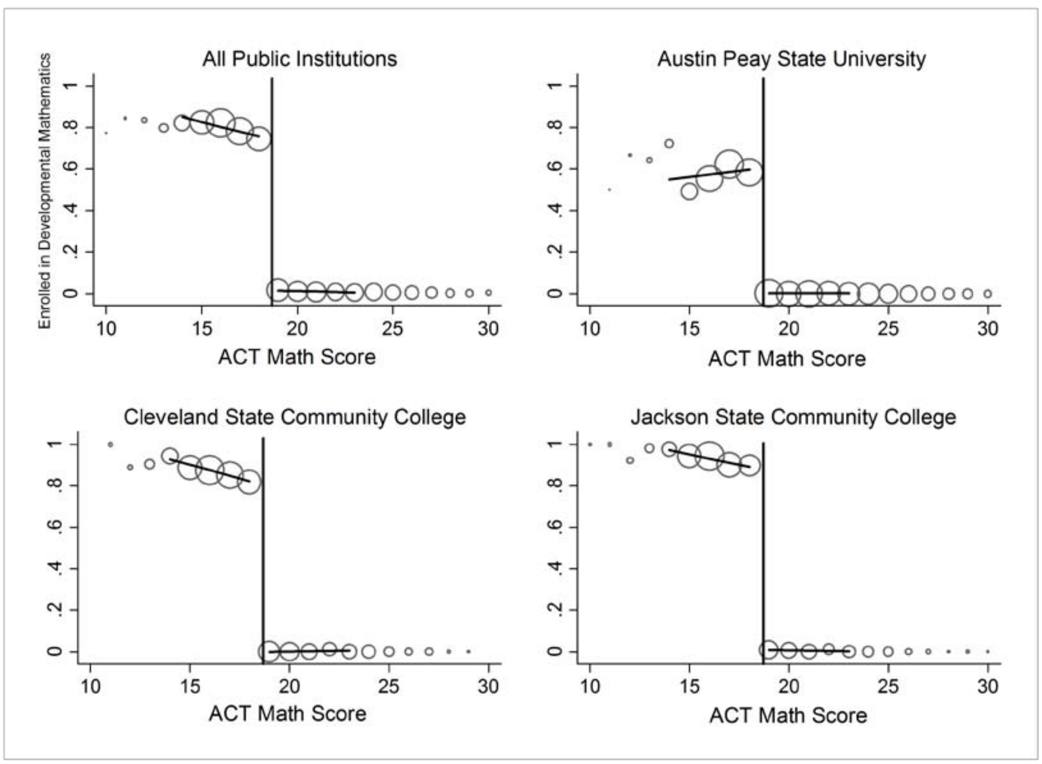
In Figure 2, I present the actual enrollment in developmental math versus ACT Math score, or the take-up of assignment across all four years in the study. Across the three

strong high school grades or special student circumstances. These exceptions do not appear to be uniform across institutions, nor do they appear to be particularly common.

institutions in the sample, on average, over 80 percent of all students assigned to a developmental math course enrolled in one of these courses within the first year. In the case of the two community colleges in the sample, the enrollment distribution looks similar to the assignment distribution shown in Figure 1. For Austin Peay, however, the actual take-up of assignment was much lower, at an average of about 60 percent. While this may suggest that students were less likely to comply with their assignment after the course redesigns took effect, this difference is in part explained by the structure of the redesign itself. Austin Peay State University eliminated Developmental Algebra I and II and instead enrolled students with ACT Math scores below the cutoff into one of two core college-level courses, Fundamentals of Math or Elements of Statistics, depending on which course would count toward a student's expected major. As a result, it may appear that fewer students enrolled in a developmental math course after 2008, but much of this difference was being driven by an elimination of the developmental math course options at this institution.

Figure 2

Actual Enrollment in Developmental or Remedial Math by ACT Math Score, 2006–07 to 2009–10



Research Question 1: Does participation in redesigned remedial courses improve subsequent academic outcomes for students at the margins of passing the placement test?

To address my first research question, I restricted my sample to only those students attending institutions in which remedial course redesign occurred in the fall of 2008 and 2009 in order to estimate the causal effect of enrollment in a redesigned remedial course (the treatment group) versus no enrollment in these courses (and subsequent unhindered enrollment in college-level college courses, the control group). Then, in the first stage of my instrumental variables estimation, I fitted the following hypothesized linear probability model (Angrist & Pischke, 2009) in which I regressed whether a student enrolled in a remedial course on whether a student was assigned to this course based on his/her ACT Math exam score centered at the cutoff as follows:

$$(1) \qquad DEV_i = \gamma_o + \gamma_1 ASSIGN_i + \gamma_2 SCORE_i + \gamma_3 (ASSIGN * SCORE) + \gamma_4 Z_i + \delta_i$$

for the i^{th} individual and where δ_i is the first-stage residual. *Z* includes exogenous covariates describing student gender, race, age, high school GPA, and whether a student had also been assigned to a developmental/remedial reading or writing course.[20] I then introduced the fitted probability of being enrolled in developmental courses (from fitting the model specified in Equation 1) as the critical question predictor in the following second-stage statistical model to estimate the causal effect of the take-up of remediation on outcome, Y_i, as follows:

$$(2) \qquad Y_i = \beta_0 + \beta_1\left(\hat{DEV}_i\right) + \beta_2\left(SCORE_i\right) + \beta_3\left(ASSIGN * SCORE\right) + \beta_4\left(Z_i\right) + \varepsilon_i$$

with a suitable adjustment to the standard errors of the estimates, and where ε_i is the second-stage residual. The estimates I obtained from fitting the model in Equation 2 provided the Local Average Treatment Effect (LATE) of the new remediation approach and captured only the variation in the outcome that was affected by take-up of the offer of developmental math. These results do not provide any information about students whose enrollment or non-enrollment in remediation was not influenced by the ACT Math exam used for developmental course assignment. Furthermore, these estimates apply only locally to the cutoff, and do not apply to students with scores further away from the cutoff than is designated by the optimal bandwidth (explained below).

[20] Across all 19 public institutions in the state in the fall of 2008, among those recommended for any developmental math course, 42.2 percent were also recommended for a developmental reading course and 51.8 percent were recommended for a developmental writing course. Twenty-nine percent of all students were recommended to enroll in developmental courses in all three subjects.

In specifying this second-stage model, I used generic outcome Y_i to refer to each of the eight outcomes described above. In cases where there were dichotomous outcomes at both the first and second stages, I adopted a bivariate probit model at both stages, estimating marginal effects evaluated at the sample mean to summarize the effects that enrollment in developmental education had on the probability that a student was enrolled in the second semester and/or the second year. For continuous outcomes, I fitted linear regression models using OLS methods. The parameter of interest in Equation 2 is β_1, representing the difference in outcome between treatment and control students, at the discontinuity, on average in the population.

Research Question 2: Is participation in redesigned remedial courses more effective than participation in traditional remedial courses offered at similar institutions during the same time period with regard to the impact on subsequent student academic outcomes?

I am also interested in whether the impact of enrollment in developmental math at the three sample institutions differed from the impact of enrollment in developmental math at similar types of institutions in Tennessee that offered traditional remedial courses during the same time period. A plausible hypothesis might be that, among students enrolled in two-year schools, enrollment in developmental math has a greater impact on those attending colleges that implemented a redesign. Incorporating data from the other 16 colleges in Tennessee in the years 2008–09 and 2009–10 (for the post-reform cohorts) allowed me to answer my second research question.

To answer this question, I again used a fuzzy regression discontinuity design, but this time I included data from all 19 public TBR institutions in the analysis and incorporated in the statistical model a two-way interaction term between the instrumental variable, *ASSIGN*, and whether or not a student attended an institution that implemented a redesign, hereafter known as a *reform institution*. As before, in my first-stage model, I regressed whether a student enrolled in a remedial course on whether the student was assigned to this course based on his or her position with respect to the cutoff on the ACT Math exam, as in Equation 1, but in this model I also included a dummy predictor, *INST*, to identify those three institutions that implemented a redesigned developmental math curriculum (*INST* = 1) from those institutions that did not (*INST* = 0), in the years 2008–09 and 2009–10. Thus, my first-stage model then becomes:

$$(3)\quad \begin{aligned} DEV_i &= \gamma_o + \gamma_1 ASSIGN_i + \gamma_2 SCORE_i + \gamma_3 (ASSIGN * SCORE)_i + \gamma_4 INST_i \\ &+ \gamma_5 (ASSIGN * INST)_i + \gamma_6 (SCORE * INST)_i + \gamma_7 (SCORE * INST * ASSIGN)_i + \gamma_8 Z_i + \delta_i \end{aligned}$$

for the i^{th} individual and where δ_i is the first-stage residual. Z is the same vector of covariates as in Equation 1. I again introduced the fitted probability of enrolling in developmental courses as the critical question predictor in the second-stage statistical model to estimate the causal effect of the take-up of remediation on outcome Y_i as follows:

$$
\begin{aligned}
& Y_i = \beta_o + \beta_1 \hat{DEV}_i + \beta_2 SCORE_i + \beta_3 (ASSIGN * SCORE)_i + \beta_4 INST_i \\
(4) \quad & + \beta_5 (\hat{DEV} * INST)_i + \beta_6 (ASSIGN * INST)_i + \beta_7 (SCORE * INST)_i \\
& + \beta_8 (SCORE * INST * ASSIGN)_i + \beta_9 Z_i + \varepsilon_i
\end{aligned}
$$

with the usual notation and a suitable correction to the standard errors of the estimates. Equation 4 contains two parameters of interest: β_1 represents the causal effect of enrollment in remediation on the outcomes of interest within all four-year and two-year TBR colleges during the post-reform years (2008–09 and 2009–10) and β_5 provides an estimate of how the main effects captured in β_1 differ as a result of being enrolled in one of the three reform institutions.

Research Question 3: Is participation in redesigned remedial courses more effective than participation in the traditional model of remediation at the same institution prior to the implementation of these new courses?

The results from my second research question provide a comparison of the impacts on outcomes of redesigned remedial courses to traditional remedial courses using similar institutions across Tennessee in the same time period. This strategy, however, does not account for the fact that the three reform institutions may be different in unobservable ways from other seemingly similar institutions across the state. It may be that the three institutions that applied for and received funding to implement course redesigns already had a culture of innovation or an infrastructure to support institutional reforms. If this were the case, comparing these institutions to their peers in the same sector (four year vs. two year) would overestimate the effects of these redesign efforts. To address this concern, I used an IV estimation similar to that described above for Research Question 2; however, I restricted the sample to include only the three institutions that implemented a course redesign as with Research Question 1, but I also included data from the two cohorts of students entering these institutions prior to the redesign (2006–07 and 2007–08). Consequently, I included in the analysis a two-way interaction term between the instrumental variable, *ASSIGN*, and whether or not a student enrolled in their institution post-redesign (*POST*).

Determining the Bandwidth

A critical component of any regression discontinuity analysis is the selection of a bandwidth around the cutoff score on the forcing variable within which data are included in the sample and the statistical models fitted. By selecting a smaller bandwidth near the cutoff, one gains more confidence in the linearity of the outcome/forcing variable relationship that is driving the regression discontinuity projection. Alternatively, increasing the bandwidth increases the sample size and thus the statistical power of the analysis, but doing so also increases the sensitivity of the analysis to the functional form of the outcome/forcing variable relationship (Murnane & Willett, 2011). In what follows, I examined the sensitivity of my findings to bandwidth size empirically, using a cross-validation procedure developed by Imbens and Lemiuex (2008) to estimate the optimal bandwidth. I determined that the preferred bandwidth obtained using this procedure could not be greater than two points to the left of the cutoff, given the multi-tiered placement policy in Tennessee. Students scoring more than two points below the cutoff are traditionally no longer assigned to the first developmental course below college-level, but to the second or third. For this reason, I restricted the lower bound on the forcing variable to two ACT Math exam points, and used the procedure described above to estimate the optimal bandwidth *above* the cutoff score for all outcomes.[21] Within each table of results, I present the optimal bandwidth for each outcome estimate.

[21] I assumed that the functional form to the left of the cutoff was linear, while I permitted the functional form to right of the cutoff to differ, according to the data. As a sensitivity check, I re-estimated the findings for alternative functional forms to the right of the cutoff by including a quadratic term for my question predictor in Equations 2 and 4, and in all cases found that the estimates did not change significantly. While the size of the standard errors increased, these estimates did not differ from those obtained from the local linear specification.

4. Results

In my analysis, I obtained consistent estimates of the causal impact of enrolling in developmental courses on subsequent outcomes for students *on the margins* of scoring above the cutoff on the ACT Math exam that is used for placement into developmental math courses. As such, these results are externally valid only for students whose scores on the forcing variable fell close to the discontinuity in the placement scores. The results can therefore be generalized only to the population of students *at the margins of passing*.

The results offer important evidence as to the potential power and influence of redesigning developmental math courses. Overall, I found that students who enrolled in developmental math courses had higher first-to-second semester persistence rates than did their peers enrolling in college-level courses after the first and second year; however, these effects tended to diminish over time. While there did appear to be some early gains in student persistence from the first to the second semester, these effects were no longer confirmed from the first to the second year. Interestingly, however, students exposed to redesigned developmental math courses had more positive outcomes than did their peers in non-redesign institutions, on average, during the same period and also when compared with students exposed to the previous version of traditional remediation within their institution in prior years. It appears that students enroll and persist at the same rate in the second year, but take more college-level courses as a result of the redesign process.

Estimated Effects of Redesigned Remediation Courses, Fall 2008–09 and 2009–10 Cohorts

In Table 4, I present instrumental-variables estimates from the fitted two-stage least-squares models specified in Equations 1 and 2. These estimates summarize the causal effects of the redesigned developmental math courses on subsequent academic outcomes for students beginning in one of the three sample institutions in the fall of 2008–09 and 2009–10, at the margins of passing the placement test. This analysis most closely resembles prior research that sought to address research questions on college remediation, as it simply compares the academic outcomes for students enrolling in a developmental math course with outcomes for similar students enrolled in a college-level math course. I restricted the sample to include only the three institutions that had first implemented redesigned developmental math courses in the fall of 2008, but pooled both the 2008–09 and 2009–10

Table 4

Estimated Effects of Redesigned Remediation Courses, Fall 2008–09 and 2009–10 Cohorts

	FIRST SEMESTER		FIRST YEAR		SECOND YEAR			
	Credits attempted but not completed in 1st semester	1st to 2nd semester persistence	College-level credits completed in 2nd semester	Total credits completed after 1 year	Still enrolled in year 2	College-level credits completed in year 2	College-level credits completed after 2 years	Total credits completed after 2 years
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
REFORM INSTITUTIONS: POOLED DATA								
Assigned to Develop. Algebra II	−1.656**	0.105**	0.713	1.876	0.008	1.321	1.027	2.040
	(0.802)	(0.047)	(0.859)	(1.695)	(0.085)	(2.276)	(3.748)	(3.270)
Fitted value at cutoff	3.40	0.864	11.59	24.81	0.647	14.81	33.56	39.02
Bandwidth	−2 ≤ x ≤ 3	−2 ≤ x ≤ 3	−2 ≤ x ≤ 3	−2 ≤ x ≤ 3	−2 ≤ x ≤ 2	−2 ≤ x ≤ 1	−2 ≤ x ≤ 1	−2 ≤ x ≤ 2
Observations	2392	2392	2392	2392	2135	1804	1804	2135
AUSTIN PEAY STATE UNIVERSITY								
Assigned to Develop. Algebra II	−1.477	0.093+	0.688	3.782	−0.037	0.866	0.662	3.497
	(1.443)	(0.060)	(1.521)	(2.998)	(0.155)	(2.276)	(7.098)	(6.106)
Fitted value at cutoff	3.08	0.892	12.41	26.36	0.697	17.18	37.92	42.88
Bandwidth	−2 ≤ x ≤ 3	−2 ≤ x ≤ 3	−2 ≤ x ≤ 3	−2 ≤ x ≤ 3	−2 ≤ x ≤ 2	−2 ≤ x ≤ 1	−2 ≤ x ≤ 1	−2 ≤ x ≤ 1
Observations	1309	1309	1309	1309	1137	928	928	928
CLEVELAND STATE COMMUNITY COLLEGE								
Assigned to Develop. Algebra II	−3.333*	0.102	0.614	−0.823	0.007	1.234	1.724	−0.184
	(1.762)	(0.491)	(1.839)	(3.602)	(0.186)	(2.523)	(2.305)	(3.485)
Fitted value at cutoff	4.22	0.813	10.65	23.02	0.573	12.15	28.41	34.31
Bandwidth	−2 ≤ x ≤ 3	−2 ≤ x ≤ 3	−2 ≤ x ≤ 3	−2 ≤ x ≤ 3	−2 ≤ x ≤ 3	−2 ≤ x ≤ 4	−2 ≤ x ≤ 4	−2 ≤ x ≤ 3
Observations	459	459	459	459	459	489	489	459
JACKSON STATE COMMUNITY COLLEGE								
Assigned to Develop. Algebra II	−0.827	0.148	0.536	1.744	0.029	2.531	1.969	1.688
	(1.074)	(0.847)	(1.106)	(2.272)	(0.803)	(2.748)	(2.424)	(2.007)
Fitted value at cutoff	3.38	0.849	10.71	23.10	0.605	12.17	28.89	35.01
Bandwidth	−2 ≤ x ≤ 3	−2 ≤ x ≤ 3	−2 ≤ x ≤ 3	−2 ≤ x ≤ 3	−2 ≤ x ≤ 3	−2 ≤ x ≤ 3	−2 ≤ x ≤ 3	−2 ≤ x ≤ 3
Observations	624	624	624	624	624	624	624	624

NOTES: Robust standard errors are shown in parentheses. The pooled data sample includes all first-time, full-time students under the age of 21 with a reported ACT Math Score at Austin Peay State University, Cleveland State Community College, and Jackson State Community College in the fall of 2008 or the fall of 2009. For the four binary persistence outcomes, the marginal effects and standard deviations are reported. Control variables include gender, race/ethnicity, age, high school GPA, and a dummy variable for whether a student was assigned to a developmental/remedial reading or writing course.

The bandwidth on either side of the cutoff is calculated individually for each outcome using the cross-validation procedure developed by Imbens and Lemiuex (2008). The statewide cutoff policy used to assign students to developmental math courses is used as an instrument for enrollment in developmental math. For students who dropped out, the number of credits is listed as the number of credits the student had completed when last enrolled.

+$p < .15$. *$p < .10$. **$p < .05$. ***$p < .01$.

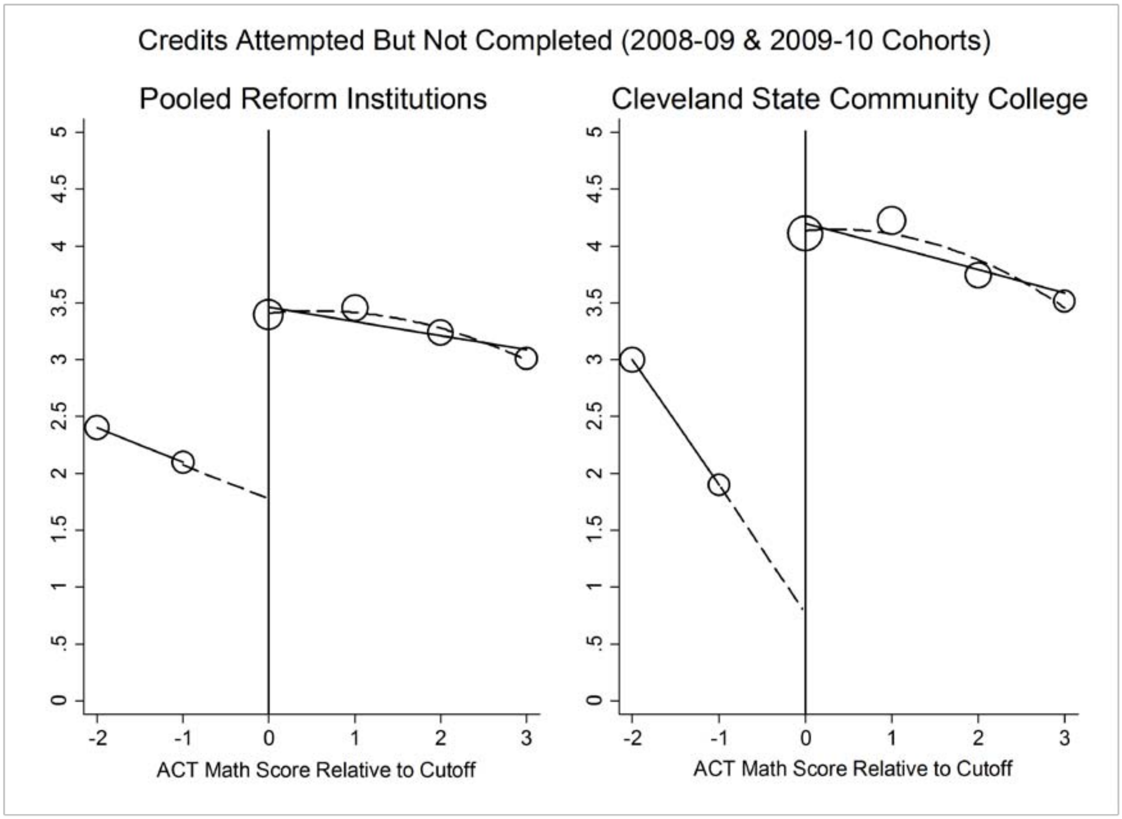
cohorts, as the redesigned courses were offered in subsequent semesters.[22] In the top row of Table 4, I present estimated effects pooled across all three institutions and in the subsequent rows break out the findings by individual institution. The outcomes are ordered chronologically, with first-semester outcomes in columns 1–2, first-year outcomes in columns 3–4, and second-year outcomes in columns 5–8. Additionally, I provide the fitted value of each outcome at the cutoff (when *SCORE* = 0) as a reference point for the size of the main effect found in the first row of each section of the table. I also list the optimal bandwidth for each outcome within each institution, as well as the number of observations within this bandwidth.

An early measure of potential student academic difficulty can be gauged by the number of credits a student attempts in the first semester but does not complete. In column 1, I show the effects of enrollment in developmental math on the number of credits attempted but not completed in the first semester. At Cleveland State, for example, the number of credits attempted but not completed for students just above the cutoff for assignment to developmental math was 4.22 credits, which includes those students who completed all of the credits they attempted (and thus have a value of zero for this outcome). Among those enrolled in developmental math, however, students completed an average of 3.3 credits *more* of their attempted credits (or an average of one course) than their peers assigned to college-level math. For Cleveland State, it appears that enrollment in developmental math had a positive effect on the number of credits attempted but not completed in the first semester. I present these results graphically in Figure 3 for both the pooled reform institutions and for Cleveland State. In the pooled sample plot on the left, on average, students enrolling in developmental math completed 1.6 more of their attempted credits than did their peers who enrolled in college-level math. This gap is even wider among students at Cleveland State, shown on the right. For the fitted values to the right of the vertical cutoff on both graphs, I present both the linear specification and a quadratic specification to illustrate that the results do not differ by the choice in the functional form of the outcome/forcing variable relationship.

[22] Students attending one of the three sample institutions in the fall 2009–10 cohort would have been exposed to the same basic redesigned developmental mathematics courses as their peers beginning in the fall 2008. However, it may likely be the case that the delivery and instruction of these courses improved over the course of a year from the pilot year in 2008, in which case pooling both cohorts may result in a slight overestimation of the effects that would have otherwise been observed if examining only the pilot year. Arguably, given the many challenges that accompany implementing any pilot program, including the second cohort of students is more representative of the true effects of these resigned courses than simply focusing on the pilot year.

Figure 3

Fitted Values Estimating Enrollment in Developmental Math on the Number of Credits Attempted but Not Completed After Two Years for Students Beginning in the Fall of 2008–09 and 2009–10 (from Table 4)



NOTES: The sample for the Pooled Reform Institutions includes all first-time, full-time students under the age of 21 with a reported ACT Math score at Austin Peay State University, Cleveland State Community College, and Jackson State Community College. Each circle represents the sample mean of the dependent variable for students with a given ACT Math score, with the vertical line representing the statewide cutoff for placement into college-level math. The dashed lines represent the fitted values for the outcome on the assignment to treatment variable by ACT Math score. Control variables include gender, race/ethnicity, age, high school GPA, and a dummy variable for whether a student was assigned to a developmental/remedial reading or writing course. The bandwidth on either side of the cutoff is estimated individually for each outcome using the cross-validation procedure developed by Imbens and Lemiuex (2008).

The effects of the redesigned remediation on the dichotomous outcomes describing student persistence (columns 2 and 5 of Table 4) are estimated using a bivariate probit model, estimating marginal effects at the sample mean. Across the three institutions in the sample, for students at the margins of placing into a college-level math course, enrolling in

Developmental Algebra II increased the probability of persisting from the first to the second semester by 10.5 percentage points compared with students in college-level math, as shown in the first row of column 2. This estimate includes students who enrolled full time in the fall of their first semester but subsequently enrolled either full or part time in the following spring. The statistically significant effects on persistence from the first to the second semester, however, do not hold up when examining the effects on persistence from the first to the second year (column 5), as none of the coefficients on persistence can be distinguished from zero, across either the pooled or the individual institutions, in the population.

While one would expect that students assigned to developmental math courses would earn fewer college-level credits in the first semester, by the second semester one might speculate that these students would be enrolling in college-level courses at the same level as their peers who did not enroll in developmental math in the first semester. In column 3, I present estimates of the effect of enrollment in a redesigned remedial course on the number of college-level credits completed in the second semester only. Across all three institutions for the 2008–09 and 2009–10 cohorts, as well as individually within each institution, it appears that both treatment students (who enrolled in developmental math in the first semester) and control students (who enrolled in college-level math in the first semester) took a similar number of college-level credits in the second semester. The same is true for the number of college-level credits completed in the second year, as well as cumulatively after two years (columns 6 and 7), although these estimates are not statistically significant by the end of year two. Similarly, students enrolled in developmental math did not accumulate any more or less total credits than did their peers enrolled in college-level math after the first or second year.

Estimated Effects of Redesigned Remediation Courses Versus Traditional Remediation Courses at Other Two- and Four-Year Institutions, Fall 2008–09 and 2009–10 Cohorts

Table 5 presents the effects of remediation for the three redesign institutions, but now relative to the other public institutions in the same sector. The top row in both the four-year and two-year panels of Table 5 displays the effect of assignment to developmental math across all four-year and two-year institutions in the state, respectively. Across all four-year colleges, students who enrolled in a developmental math course completed 0.5 fewer college-level credits in the second semester compared with their peers enrolling in college-level math, and this gap jumped to two credits after two years (both significant at the 10 percent level). Column 8 suggests that students who enrolled in developmental math had nearly three fewer total credits by the end of two years than their peers enrolling in college-

Table 5

Comparing Redesigned Remediation Courses with Traditional Remediation Courses at Other Two and Four-Year Institutions, Fall 2008–09 and 2009–10 Cohorts

	FIRST SEMESTER		FIRST YEAR		SECOND YEAR			
	Credits attempted but not completed in 1st semester	1st to 2nd semester persistence	College-level credits completed in 2nd semester	Total credits completed after 1 year	Still enrolled in year 2	College-level credits completed in year 2	College-level credits completed after 2 years	Total credits completed after 2 years
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ALL FOUR YEAR COLLEGES (Redesigned Remediation = Austin Peay State University)								
Assigned to Develop. Alg. II (β_1)	−0.578	0.025	−0.492*	−1.146	0.019	−0.399	−1.972*	−2.873
	(0.471)	(0.021)	(0.185)	(1.009)	(0.036)	(1.400)	(2.317)	(1.987)
Redesigned Remediation (β_4)	−0.261	−0.007	0.026	−0.488	0.007	−0.532	−0.739	−0.803
	(0.174)	(0.012)	(0.179)	(0.501)	(0.017)	(0.517)	(0.856)	(0.734)
Assigned * Redesigned Remediation (β_5)	0.115	−0.013	−0.698*	0.077	−0.006	1.145	2.694*	0.949
	(0.517)	(0.027)	(0.331)	(1.238)	(0.038)	(1.534)	(1.539)	(2.177)
Fitted value at cutoff	3.02	0.904	12.90	27.26	0.707	17.94	39.77	44.69
Bandwidth	$-2 \le x \le 3$	$-2 \le x \le 2$	$-2 \le x \le 3$	$-2 \le x \le 1$	$-2 \le x \le 1$	$-2 \le x \le 3$	$-2 \le x \le 3$	$-2 \le x \le 2$
Observations	10,996	9,595	10,996	7,845	7,845	10,996	10,996	9,595
H_0: $\beta_1 + \beta_5 = 0$	0.540	0.567	0.095	0.525	0.833	0.740	0.086	0.546
ALL TWO YEAR COLLEGES (Redesigned Remediation = Cleveland State and Jackson State Community Colleges)								
Assigned to Develop. Alg. II (β_1)	−0.378	0.004	−0.442	−1.515*	0.076*	2.069*	−0.612	−0.612
	(0.453)	(0.033)	(0.493)	(0.864)	(0.043)	(1.228)	(1.754)	(1.754)
Redesigned Remediation (β_4)	0.147	−0.005	0.038	0.203	−0.064***	−1.552**	−1.125	−1.125
	(0.218)	(0.019)	(0.255)	(0.463)	(0.023)	(0.635)	(0.842)	(0.842)
Assigned * Redesigned Remediation (β_5)	0.143	−0.012	−0.145	0.466	−0.014	0.072	−1.035	−0.035
	(0.378)	(0.031)	(0.424)	(0.804)	(0.038)	(1.056)	(1.462)	(1.462)
Fitted value at cutoff	3.77	0.821	10.58	22.55	0.613	13.07	29.70	34.95
Bandwidth	$-2 \le x \le 3$	$-2 \le x \le 3$	$-2 \le x \le 2$	$-2 \le x \le 3$	$-2 \le x \le 3$	$-2 \le x \le 2$	$-2 \le x \le 2$	$-2 \le x \le 3$
Observations	9,163	9,163	8,379	9,163	9,163	8,379	8,379	9,163
H_0: $\beta_1 + \beta_5 = 0$	0.613	0.908	0.252	0.103	0.258	0.093	0.089	0.719

NOTES: See notes for Table 5. Robust standard errors are shown in parentheses. The pooled data sample includes all first-time, full-time students under the age of 21 with a reported ACT Math Score at Austin Peay State University, Cleveland State Community College, and Jackson State Community College in the fall of 2008 or the fall of 2009. Redesigned remediation is equal to 1 when a student attends either Austin Peay University among the four-year institutions, or Cleveland State or Jackson State among the two-year institutions.

+$p < .15$. *$p < .10$. **$p < .05$. ***$p < .01$.

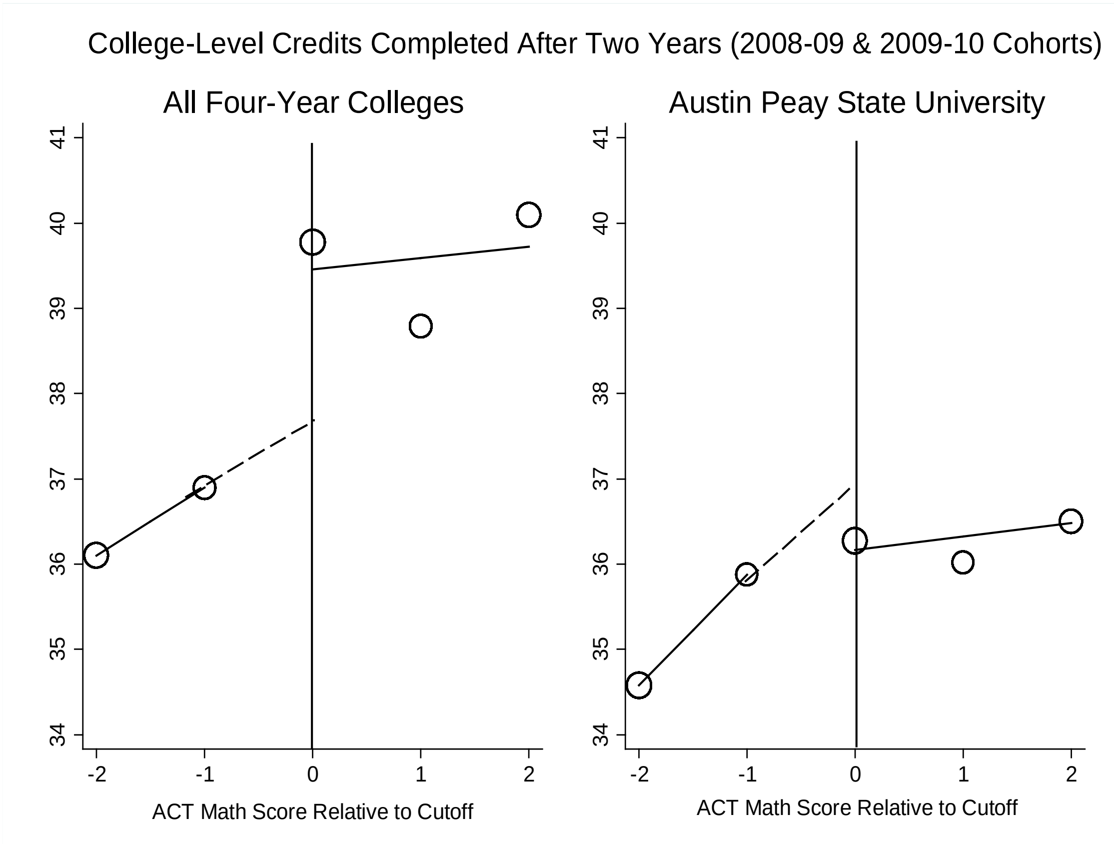
level math; however, these results are not statistically significant. Within the two-year colleges, students assigned to developmental math completed an average of two additional college-level credits in their second year compared with their peers in college-level math (column 6).

The interaction term in Table 5 provides the effect for the redesign institutions compared with the other public four-and two-year colleges in the state during the time period post-reform (2008–09 and 2009–10). Relative to other four-year institutions, students in developmental math at Austin Peay completed 2.7 more college-level credits than their peers after two years. Given the details of the Austin Peay redesign, this is not surprising. Whereas other students who enrolled in developmental math at the other five four-year colleges did not receive college-level credits for these courses, students at Austin Peay were mainstreamed into college-level math classes and thus received college-level credit. Therefore, these students had more college-level credits after one and two years compared with students attending their peer four-year institutions. This result is shown graphically in Figure 4, with the gap in the number of college-level credits between remedial and college-level students at all four-year colleges shrinking considerably for students attending Austin Peay State University. On Table 5, I also include the results from a general linear hypothesis (GLH) test to test if the sum of the β_1 and β_5 is zero. For the number of college-level credits completed after two years, the 0.722 difference in credits between Austin Peay and the other four-year colleges in the state is statistically different than zero, as shown by the last row of column 7.

Within the two-year colleges, the effects at Cleveland State and Jackson State did not differ in most cases from the overall effects of remediation within the two-year colleges. For the number of total credits completed after one year, students who attended one of the two redesigned math courses completed an average of 0.5 more total credits compared with students at the other nine community colleges, who completed an average of 1.5 fewer credits than did their peers enrolled in college-level math. Table 5 provides interesting results relative to the non-redesign institutions. These findings confirm that assignment to a newly designed remedial program had a causal effect on students' subsequent academic outcomes among students at the margins of passing, and that these effects differ by institution.

Figure 4

Effects of Enrollment in Developmental Math on the Number of College-Level Credits Completed After One Year, Comparing Austin Peay University with Other Four-Year Public Colleges, 2008–09 and 2009–10 Cohorts (from Table 5)



Estimated Effects of Traditional Versus Redesigned Remediation Courses at the Redesign Institutions

Using data for the two cohorts prior to the developmental math redesigns (fall 2006–07 and fall 2007–08), Table 6 presents the effects of enrollment in developmental math on the academic outcomes for students at the three reform institutions, but also includes a cohort effect (*POST*) to allow for a comparison with the more traditional developmental education model that was being used prior to the 2008–09 course redesigns. The outcomes in Table 6 are the same as in prior tables.

Table 6

Estimated Effects of Traditional Versus Redesigned Remediation Courses at the Reform Institutions

	FIRST SEMESTER		FIRST YEAR		SECOND YEAR			
	Credits attempted but not completed in 1st semester	1st to 2nd semester persistence	College-level credits completed in 2nd semester	Total credits completed after 1 year	Still enrolled in year 2	College-level credits completed in year 2	College-level credits completed after 2 years	Total credits completed after 2 years
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
REFORM INSTITUTIONS: POOLED DATA								
Assigned to Develop. Alg. II (β_1)	0.481*	0.038*	−1.181	−0.955	−0.063	−1.985	−5.189*	−3.919+
	(0.244)	(0.018)	(0.752)	(1.370)	(0.056)	(1.772)	(2.933)	(2.630)
Post Reform (β_4)	−0.182	0.039**	−0.094	0.695	−0.016	−1.361*	−1.684	−1.330
	(0.293)	(0.016)	(0.335)	(0.624)	(0.026)	(0.807)	(1.337)	(1.198)
Assigned * Post Reform (β_5)	−1.336*	0.033*	1.651*	1.539	0.041	3.387*	5.971*	4.907+
	(0.732)	(0.015)	(0.937)	(1.556)	(0.062)	(2.012)	(3.332)	(2.987)
Fitted value at cutoff	3.72	0.850	11.54	24.37	0.646	15.30	34.19	39.32
Bandwidth	$-2 \le x \le 3$	$-2 \le x \le 2$	$-2 \le x \le 2$	$-2 \le x \le 3$	$-2 \le x \le 1$	$-2 \le x \le 3$	$-2 \le x \le 3$	$-2 \le x \le 3$
Observations	4,666	4,168	4,168	4,666	3,510	4,666	4,666	4,666
H_0: $\beta_1 + \beta_5 = 0$	0.094	0.079	0.568	0.702	0.918	0.147	0.811	0.086
AUSTIN PEAY STATE UNIVERSITY								
Assigned to Develop. Alg. II (β_1)	1.559	−0.043*	−2.216*	−3.252	−0.165*	−6.211*	−6.189**	−4.832**
	(1.192)	(0.021)	(1.273)	(2.051)	(0.087)	(3.339)	(2.960)	(1.922)
Post Reform (β_4)	0.060	0.037**	−0.039	0.574	−0.001	−1.371	−1.768	−2.335
	(0.416)	(0.018)	(0.444)	(0.805)	(0.034)	(1.165)	(1.941)	(1.718)
Assigned * Post Reform (β_5)	−2.305	0.076+	2.609	4.071	0.147*	6.063	2.475*	5.781*
	(1.783)	(0.044)	(1.904)	(2.523)	(0.076)	(4.995)	(1.318)	(2.963)
Fitted value at cutoff	3.34	0.883	12.35	25.99	0.690	17.57	38.50	43.34
Bandwidth	$-2 \le x \le 1$	$-2 \le x \le 3$	$-2 \le x \le 1$	$-2 \le x \le 3$	$-2 \le x \le 1$	$-2 \le x \le 1$	$-2 \le x \le 1$	$-2 \le x \le 1$
Observations	1,762	2,500	1,762	2,500	1,762	1,762	1,762	1,762
H_0: $\beta_1 + \beta_5 = 0$	0.619	0.100	0.806	0.765	0.403	0.972	0.119	0.178

	FIRST SEMESTER		FIRST YEAR		SECOND YEAR			
	Credits attempted but not completed in 1st semester	1st to 2nd semester persistence	College-level credits completed in 2nd semester	Total credits completed after 1 year	Still enrolled in year 2	College-level credits completed in year 2	College-level credits completed after 2 years	Total credits completed after 2 years
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
CLEVELAND STATE COMMUNITY COLLEGE								
Assigned to Develop. Alg II (β_1)	−0.407 (1.515)	0.154* (0.084)	0.513 (1.785)	0.549 (3.280)	0.058 (0.118)	−3.909* (2.197)	−1.431 (2.460)	−1.431 (2.460)
Post Reform (β_4)	0.465 (0.720)	0.030 (0.036)	−0.496 (0.830)	−0.447 (1.559)	−0.025 (0.048)	−3.826* (1.995)	−4.104 (3.003)	−4.104 (3.003)
Assigned * Post Reform (β_5)	−2.084 (1.607)	−0.357** (0.167)	0.382 (2.099)	−0.651 (3.478)	0.031 (0.141)	6.213+ (3.850)	1.979 (2.597)	1.979 (2.597)
Fitted value at cutoff	4.06	0.821	11.23	24.02	0.614	13.82	31.626	36.92
Bandwidth	$-2 \le x \le 3$	$-2 \le x \le 2$	$-2 \le x \le 2$	$-2 \le x \le 3$	$-2 \le x \le 3$	$-2 \le x \le 3$	$-2 \le x \le 2$	$-2 \le x \le 2$
Observations	886	808	808	886	886	886	808	808
H_0: $\beta_1 + \beta_5 = 0$	0.089	0.201	0.597	0.975	0.616	0.140	0.929	0.929
JACKSON STATE COMMUNITY COLLEGE								
Assigned to Develop. Alg II (β_1)	−0.685 (1.020)	0.113* (0.067)	0.407 (1.073)	1.170 (2.139)	0.016 (0.087)	2.928 (2.581)	2.102 (4.160)	3.217 (3.854)
Post Reform (β_4)	−0.873 (0.570)	0.041 (0.033)	0.279 (0.600)	1.740 (1.196)	−0.033 (0.042)	−0.542 (1.443)	−0.087 (2.325)	0.939 (2.154)
Assigned * Post Reform (β_5)	0.449 (1.195)	−0.055 (0.104)	−0.893 (1.257)	-1.082 (2.508)	0.079 (0.122)	−1.198 (3.026)	−2.534 (4.876)	−3.708 (4.518)
Fitted value at cutoff	4.18	0.807	10.18	21.49	0.584	12.01	27.79	33.38
Bandwidth	$-2 \le x \le 3$	$-2 \le x \le 3$	$-2 \le x \le 3$	$-2 \le x \le 3$	$-2 \le x \le 3$	$-2 \le x \le 3$	$-2 \le x \le 3$	$-2 \le x \le 3$
Observations	1,280	1,280	1,280	1,280	1,280	1,280	1,280	1,280
H_0: $\beta_1 + \beta_5 = 0$	0.815	0.139	0.647	0.967	0.956	0.498	0.916	0.897

NOTES: See notes for Table 5. Robust standard errors are shown in parentheses. The pooled data sample includes all first-time, full-time students under the age of 21 with a reported ACT Math Score at Austin Peay State University, Cleveland State Community College, and Jackson State Community College.

POST = 1 for those cohorts beginning in 2008–09 and 2009–10 and *POST* = 0 for those cohorts beginning in 2006–07 and 2007–08.

+$p < .15$. *$p < .10$. **$p < .05$. ***$p < .01$.

The top row of each section of Table 6 reports the cumulative effect of assignment to developmental math across all four cohorts in the data. Generally across the three pooled institutions, it appears that participation in a remedial math course had negative effects on the number of credits attempted but not completed and on the number of college-level credits a student had completed by the end of the first and second years, with the greatest deficit in the number of college-level credits (six by the end of the second year) observed at Austin Peay State University. The more interesting results in this table, however, are not the basic comparisons of students in developmental math with those in college-level math. The interaction term of Table 6 (β_5) illustrates the comparison of redesigned courses with the prior traditional version of developmental courses. The coefficient on the interaction term provides the estimate of the impacts of enrollment in a redesigned developmental math course compared with enrollment in a traditional developmental math course for students within the same institution, pre- and post-redesign. For example, for students at Austin Peay University between 2006–07 and 2009–10, the overall effect of enrollment in a developmental math course led to a 4.3 percentage point increase in the likelihood of being enrolled in the second semester compared with students assigned to a college-level course. For students who entered in the latter two cohorts (those with redesigned developmental courses), however, the likelihood of being enrolled in the second semester was 7.6 percentage points *higher* than it was previously. The overall effect on student persistence is the sum of the coefficient on the main effect plus the coefficient on the interaction term.

At Cleveland State, the redesigned courses led to more college-level credits after two years. Given that Cleveland State adopted an acceleration model by which students could move to the next course as soon as they had completed the prior, these are encouraging results. One would think that those who refused to take remediation might be the better students; thus one might expect, all else equal, that remediation would have worse effects. That does not appear to be the case here, however. Overall, the redesign appears to have been an improvement from the prior course offerings at two of the three schools. For students at Jackson State, it appears that the redesigned courses did not differ in their impact compared with the traditional developmental courses offered in the earlier years, as we see no statistically significant effects on the coefficients in Table 6. At Jackson State, students in the redesigned math courses proceeded through the required modules at their own pace. When one semester ended and another began, students could resume work on any modules not completed, and therefore the traditional definitions of *semester* and *course credit* are much looser in this case.

5. Conclusion and Implications

The redesigned remedial courses that took effect in Tennessee in 2008 provided a natural experiment for estimating the causal effects of different models of instruction and delivery for these courses on student persistence and course-taking behavior. In this study, I investigated not only whether remediation helped to improve students' college outcomes, but also what role course design played in determining student success.

The results of the study offer important evidence as to the potential power and influence of redesigning developmental math courses. Overall, I found that students in developmental math courses completed more of their attempted credits and had higher rates of persistence from the first to the second semester; however, these effects tended to disappear by the second year. Interestingly, students exposed to redesigned developmental math courses had more positive outcomes than did their peers in non-redesign institutions during the same period, and also when compared with students exposed to the previous version of traditional remediation within their institution in prior years. Students appeared to benefit the most from redesigned courses at Austin Peay State University and Cleveland State Community College.

At Austin Peay State University, the four-year college, I found that the elimination of developmental math courses had a positive impact on early student persistence. I also found an increase in the number of college-level credits accumulated by the end of the first and second years when compared with other four-year institutions or with more traditional methods of offering remediation. This was the only institution of the three that implemented mainstreaming, or the elimination of developmental math courses in lieu of placing students into college-level courses with special outside supports. With strong positive results relative to their prior methods of teaching remedial math, the case could be made for endorsing mainstreaming remedial education more broadly. However, it is important to remember that we cannot separate out the particular culture of the institution from the impact of the redesign model. It may very well be the case that the institution and its students and educators aided in the adoption of this mainstreaming approach in such a way that the effects seen here would not translate universally to all institutions. Furthermore, this result applies only to students at the margins of needing math remediation and therefore cannot be extrapolated to students far down the ability distribution, in which case enrollment in a college-level math course could potentially lead to more harmful academic effects than positive ones. These caveats aside, however, the results do seem to provide a strong endorsement of the notion that far too many students are placed in developmental courses at this institution. Given that students on the margins of needing developmental math were allowed to enroll directly in college-level math and that these students showed strong gains when compared with prior years or with comparable institutions, it would be worthwhile to consider lowering the cutoff to avoid overplacement in remedial courses. A more accurate placement system could lead to a reduction in the number of difficulties that arise from improper placement.

A common component of each of the redesign efforts was the use of technology in the assessment and delivery of the course material. The study's results support the notion that, at the very least, the adoption of such technologies does not have a negative effect on student outcomes, even in institutions where such new developments represent a dramatic change from prior methods of offering such courses. Increased modularization and assessments should enable institutions to continue to customize remediation to best suit individual student needs. Additionally, in progress reports provided from the three institutions in the study, all three indicated that they were witnessing a more positive attitude toward the use of technology and the possibilities it created for future redesign efforts (NCAT, 2009).

Colleges and universities should also focus their efforts on helping students assigned to remedial courses to make continued progress toward their degrees. While taking remedial courses may not have large effects on short-term persistence, as shown in this study, it does significantly affect the number of college-level credits a student has completed by the end of the second year. Credit accumulation may be one reason why some students in need of remediation obtain degrees at rates lower than their peers. For this reason, it is important to consider ways in which students can complete their remedial requirements, yet not be deterred from taking additional courses. The acceleration model implemented by Cleveland State Community College and the modules developed by Jackson State Community College are two examples of institutional efforts to encourage credit accumulation among their students. As students complete one course and/or module, they are encouraged to begin the next step in the sequence immediately, which allows students the opportunity to move on to their college-level courses more quickly. These efforts may prove to have positive long-term effects on student persistence and degree attainment if college-level credit accumulation is indeed one of the key barriers to student success.

Developmental education is a particular concern in Tennessee today. In 2010 the state adopted the Complete College Tennessee Act, which will take effect in the fall of 2012. Under this act, all four-year colleges and universities will be prohibited from offering remedial education courses. Students will instead be able to co-enroll in four-year colleges and community colleges until they complete their remedial instruction. In addition, this act requires the development of a strategic plan for higher education and the development of a performance funding model that will likely include performance measures related to remedial education (Senate Bill 7006/House Bill 7008). It is too early to know what the long-term effects of these redesigned courses will be; however, the adoption of the Complete College Tennessee Act will ensure that all the community colleges in the state will begin to focus on the adoption of newly designed programs of their own. Given that the largest positive findings in this study were from the four-year institution, policymakers in Tennessee are encouraged to pay close attention to the ways in which eliminating developmental education affects students at these institutions.

The redesigns in Tennessee also raise awareness that remediation efforts need not focus solely on the skills students did not learn in the past, but can instead attempt to identify and provide the skills students will need for a future career or academic major. Traditionally, developmental education has been intended to address whatever skills may have been missed in high school (Education Commission of the States, 2012). The ways in which these three redesign efforts attempted to more closely identify the areas in which students most need improvement helps to redefine developmental education more as an academic support than as a curricular burden. Future redesign efforts should consider continuing this focus on differentiated delivery based on student skill and placement level as more institutions look to customize instruction to address specific student deficiencies.

Further research in this area ought to include a deeper look at student grades, particularly in college-level math courses. Ideally the research needs to move beyond a study of the basic effects of developmental education; it should delve into the classroom to discover what is really going on in these courses with respect to teaching and learning and to examine how faculty members can best adapt these new innovations. Rather than focusing on basic credit accumulation, administrators, policymakers, and students are increasingly interested in what students need to know to be successful in college-level courses and what skills they most need for the contemporary workplace. Scaling up successful programs is a continued challenge, particularly given evidence that developmental courses may affect students differently. Further work in Tennessee will explore this heterogeneity among subgroups to determine whether redesigned remedial courses are helping or hurting students differently. By thinking more creatively about how to respond to a variety of learning abilities, it may be possible to design courses that work well with a diverse array of students and institutions, which may ultimately lead to better learning for all.

Appendix

Table A.1

Summarizing Course Redesign at Each Campus

Institution	Remedial Courses Redesigned	Redesign Model	Details of Redesign	Approx. Savings to Institution
Austin Peay State University	Elementary Algebra and Intermediate Algebra	"Mainstreaming" Eliminate the developmental courses, which carry no university credit	Enhanced sections of t he two core college-level courses, Fundamentals of Math and Elements of Statistics, will be created for students whose test scores place them in developmental math. These college-level courses will not change in content but will be linked to Structured Learning Assistance (SLA) workshops. Only the deficiencies which are deemed necessary for success in the core math course will be addressed during the workshops.	Decrease instructional costs from $402,804 to $193,556.
Cleveland State Community College	Sequence of 3 developmental math courses: Basic Math, Elementary Algebra and Intermediate Algebra	"Acceleration" Students who complete a developmental math course before the end of the term will be allowed to begin the next developmental course immediately	Each course consists of 10–12 modules. Students will meet one hour in class and two hours in a large computer lab. The one-hour class meetings will be held in small computer labs to allow students to work online; instructors will provide individual student assistance and review student progress. The large computer lab will be available 54 hours per week to allow students to work at their convenience. Course material will be organized into modules, which students will complete at the rate of one or more each week. All homework and testing will be done online.	The traditional cost-per-student ranging from $236–$208 in the three courses will decrease to a range of $184 to $167, or 19%.
Jackson State Community College	Three developmental math courses	"Modules" Combine three developmental studies math courses into one course broken up into 12 modules	A pretest on an established set of competencies will determine what concepts students will be required to master for their majors. Following this assessment, each student will receive an individualized learning contract based on academic background, learning preferences, identified gaps and educational goals that will provide a path to achieving the desired learning outcomes. Students will be required to master only the concept deficiencies determined by a pretest and those that are relevant to their career goals. Modules 1–3 replaced Basic Arithmetic, Modules 4–7 replaced Developmental Algebra I and Modules 8–12 replaced Developmental Algebra II.	The redesigned course will reduce the cost-per-student from $177 to $141, or 20%.
Chattanooga State Community College (*not successfully implemented in fall 2008*)	Three developmental math courses	Students will spend 2 hours in class and 2 hours in a computer lab staffed by faculty and professional tutors each week	Students in this active learning environment will be able to progress at their own rate, receiving immediate feedback from the software and one-on-one assistance in the lab. When the redesign is fully implemented, students who fail a module will be able to pick up where they left off and not have to repeat the entire course. Students also may take challenge tests for module placement.	Reducing the number of sections from 162 to 40 annually will reduce cost-per-student from $191 to $164 in the redesign (annual savings, $10,000).

SOURCE: Compiled from the National Center for Academic Transformation (http://www.thencat.org/)

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