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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A Thesis Presented to the Faculty
of the Graduate School of Education of Harvard University
in Partial Fulfillment of the Requirements
for the Degree of Doctor of Education

2012

Acknowledgements

For someone with a near-endless enthusiasm for stories, connections, and relationships to others, an Acknowledgements section at the end of a long graduate school career is a most difficult challenge indeed. While I long to recognize every teacher, friend, colleague, student, and stranger who has aided this work along the way, I know I would still come up short. As such, I wish to explicitly thank those to whom I owe my greatest debts, while carrying with me a deep gratitude for the support and kindness of all not listed here.

This research would not have been possible without the fine people at the Tennessee Higher Education Commission and the Tennessee Board of Regents. David Wright, Chris Brewer, and Greg Schutz provided both the data and the institutional-knowledge necessary to complete this work. I especially thank Greg Schutz for his unwavering willingness to answer my calls and respond to my requests in the midst of countless other deadlines, all of which were undoubtedly more pressing than mine. Part of 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 Grant #DRL-0941014, and as such, the opinions reflect those of the author and not necessarily those of the granting agencies.

My work at the Harvard Graduate School of Education was supported in every sense of the word by the members of my committee. I thank my advisor Bridget Long for her expert guidance throughout the entire six-year process, and am deeply grateful to John Willett and Richard Murnane for helping me to talk through this work and to create a polished and professional finished product. The opportunity to witness both the individual and combined expertise of these three senior scholars was an extraordinarily powerful academic experience for me, and one I will forever credit with my own development as a professional in this field.

Prior to arriving at Harvard, I received invaluable guidance from three scholars without whom I would surely not be here today. My advisor in my Master's program at the University of Michigan, Steve DesJardins, was a most valued sounding board for my future hopes and aspirations (in large part for the fluency with which he spoke Minnesotan). Paul Lingenfelter at the State Higher Education Executive Officers (SHEEO) has generously shared his personal and professional wisdom over the years, and always made me feel as if I had someone rooting for me from the mountains of Colorado. And to Paul Courant, for whom I spent my last year in Ann Arbor working as a research assistant, who let me agonize for months over the decision of where to do my doctoral work before telling me, just as soon as I had decided, what he really thought during a conversation that remains a pivotal turning point in my life.

My colleagues at the Harvard Graduate School of Education have provided the kind of support only fellow graduate students can. I thank Scott Barge, Hanna Rodriguez-Farrar, Kevin Gee, Mike Hurwitz, John Papay, Lindsay Page, Sherry Deckman, and Adela Soliz for fully sharing in this experience with me.

The years I spent at Eliot House at Harvard College have given me more joy and insight than I could have ever imagined. The people I met as a result of this community completed a part of me I didn't know was missing, and I am forever changed from this experience. In addition, Eliot House introduced me to Theresa Lund, my dear friend whose advice and perspective I value beyond words.

No acknowledgements section would be complete without mention of my family and closest friends, and I only wish I could mention them all here. Amy Irene Rodquist-Kodet knows me better than I know myself and has been my single greatest support for the last 15 years. We should all be so fortunate to survive graduate school with a health and wellness coach as our very best friend. I thank David Schofield for magically appearing in the Eliot House courtyard one year ago, and helping me to cross this finish line in the most loving and generous way imaginable. And to my mom, Nancy Boatman, who taught me, through her own example, about sacrifice and commitment, and that goodness on this earth is just as important as greatness. I dedicate my Harvard degree to her.

I conclude by recognizing the four extraordinary women who have served as my mentors. Verna Cornelia Price, June Nobbe, Stella Raudenbush, and Bridget Long have shaped my life in countless and indescribable ways. They gave me professional opportunities beyond measure, and had me attending meetings, teaching classes, and presenting at conferences long before I thought I was ready. But perhaps more importantly, they have also shared their full, rich, holistic lives with me in ways that leave me humbled, grateful, and awash in admiration. Not a day goes by that I don't think of some small act or conversation or gesture related to one of these women. They inspire me to do the very best I can, and to remember that life is short and worth living to the fullest.

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Abstract

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 and helping to prepare them for success in college-level courses. 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 this research, several colleges have redesigned the way in which they offer remedial courses, including mainstreaming students into college-level courses and making greater use of learning-technology to provide individualized modules tailored to students' specific academic needs. However, little research has been done to estimate the causal effects of these redesigns on student academic outcomes, and evaluate how the impact of the new courses compares to that of "traditional" remediation.

Exploiting a statewide cutoff 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 in remediation. Moreover, using data on student outcomes prior to the course redesign, I also test whether the redesigned remedial programs are more effective in preparing students for success in postsecondary education than were the remedial programs they replaced. The effects of enrollment in developmental mathematics are 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 do not persist over time, as I find no statistically significant differences between groups after two years. Furthermore, students exposed to redesigned developmental math courses had more positive outcomes than their peers in non-redesign institutions during the same period and also when compared to students exposed to the previous version of traditional remediation within their institution in prior years. The results of my 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 to best help underprepared students.

Evaluating Institutional Efforts to Streamline Postsecondary Remediation: The Causal Effects of the Tennessee Developmental-Course Redesign Initiative on Early Student Academic Success

Introduction

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 (NCES, 2004; Attewell et al., 2006; Bailey,

[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, Jeong, & Cho, 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.

Jeong, & Cho, 2010), with some postsecondary institutions reporting that nearly six out of ten students enroll in remedial coursework during their college career (Bettinger & Long, 2009; 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). Within developmental education itself, students are most likely to need help in the subject of math (Wirt et al., 2004; Bailey, Jeong, & Cho, 2010).

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, as cited in Bailey, 2009; Collins, 2010).[2] 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 towards a student's overall GPA, but rarely are they counted toward graduation requirements. Furthermore, the social costs of not offering remediation may be even larger 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

[2] Calculating the costs of remediation is likely to become more complicated in the future, 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).

compare samples of remedial students to 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, 2009). 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 uncovered critical questions regarding not only *whether* remedial programs work, on average, to improve student academic outcomes, but also which *types* of programs are most effective. Broadly speaking, colleges still know little about what are the most effective ways to provide remedial and developmental courses to improve students' chances for postsecondary success.

Background and Context on Developmental Education

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 courses may be a worthwhile investment of time and resources (Becker, 1993). By helping students 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, 2009). Additionally, theories of student integration and engagement tell us that the additional academic supports offered commonly in remedial courses may help 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 stay enrolled than those that 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/her skills, it could also increase student academic engagement and improve chances for success indirectly (Astin, 1993; Gray et al., 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 assessment tests that are used to place students into remediation can cause students to become frustrated, leading potentially to increased college drop-out rates (Deil-Amen & Rosenbaum, 2002). Remedial and developmental courses themselves may slow students in their progress toward a degree, given that remedial courses count rarely toward a student's graduation requirements. Factors that lengthen the time to degree could also reduce the probability of degree completion (Bailey, 2009). A recent study by Jenkins & Cho (2012) concluded that students who do not enter a degree program within a year of first entering college have a lower probability of earning a degree or credential ultimately, thereby stressing the importance of students making early progress towards 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, 2007; 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 to 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 of 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 recent studies have used quasi-experimental research designs to attempt to determine if remediation has a causal impact on subsequent student outcomes. Bettinger & Long (2009) applied instrumental-variables estimation to examine differences in remediation-placement policies in Ohio. By exploiting institutional variation in placement policies and using distance from a student's home to the nearest four-year college as an instrument for college choice (and thereby placement), the authors compare academically similar students who had different experiences with remedial courses. They found that, on average, placement into remediation increased the probability of college persistence in comparison to academically-similar peers not required to take remedial courses. Alternatively, Attewell et al. (2006), used propensity-score matching to estimate the effects of remediation on student outcomes. These researchers used national data (NELS:88) to create observationally similar groups of treatment and control students, half of whom had taken remedial courses and half of whom had not. Their results suggest that, on average, it was less probable that students in remedial courses would receive a Bachelor's degree, but no less probable that they would receive an Associate's degree or certificate.

Several studies have addressed the causal question using a regression-discontinuity (RD) design, comparing students who are placed into remedial courses by just failing a remediation-placement examination to similar students who just pass the same examination and then take college-level courses (Calcagno & Long, 2008; Lesik, 2007; Martorell & McFarlin, 2008). 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). Using this strategy combined with discrete-time survival analyses in her study of a large state university in the Northeast, Lesik (2007) concluded that the odds that students on the margins of needing math remediation who did not enroll in these courses would drop out of the university during their first three years were 4.3 times the odds than observationally similar students who did enroll in these remedial courses. In a study of remediation with over 100,000 community college students in Florida, Calcagno & Long (2008) found that assignment to remedial courses appeared to increase persistence to the second year and increase the total number of credits completed, but did not lead to higher probabilities of degree completion, on average, among students with scores near the developmental cutoff on the placement exam. A study of Texas students concluded that remedial courses had little effect on the average number of credits attempted, the probability of receiving a college degree, or future labor-market earnings among students at the cut-off on the forcing variable (Martorell & McFarlin, 2008). The mixed results from these studies suggest that the causal effect of remedial courses on student outcomes is not yet fully understood.

New research has attempted to explore whether the mixed results of prior studies may be explained by differences in students' levels of academic preparation. The vast majority of colleges offer multiple levels of remedial and developmental courses, within a subject area, in an effort to meet the needs of students from a wide range of academic backgrounds. For example,

in Tennessee, the subject of this research, there can be up to three developmental math courses below college-level math: *Developmental Algebra II* for those students just below college-level math and in need of algebraic computational skills, *Developmental Algebra I* for those students needing to learn functions, quadratic equations, and inequalities, and *Remedial Arithmetic* for those students in need of computational arithmetic skills (addition, subtraction, multiplication, division). Most commonly, students must complete their assigned developmental course successfully before moving on to the next course in the sequence. Not surprisingly, students assigned to the higher developmental math courses complete their developmental-course sequence and move on to a college-level math course at higher rates (45 percent) than those students assigned to the lowest-level courses (17 percent) (Bailey, Jeong, & Cho, 2010).[3] Among students assigned to the lowest-level courses (i.e. those in need of remedial courses several levels below college-level), the effects of remediation on persistence, degree completion, and the number of total and college-level credits completed over time appear to be positive in magnitude or have a much smaller negative effect compared to students placed into the upper-level developmental courses (Boatman & Long, 2010). This research provides important evidence to suggest that the effects of remediation may differ depending on individual student need. Like most prior research in this area, however, it focused 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 the traditional model of offering developmental courses may be changing.

Redesigning Developmental Education

[3] This is not surprising given that students assigned to the lowest-level of remedial mathematics, by definition, have more courses in the developmental sequence to complete.

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 the student has already mastered. Many are concerned that this traditional model may prolong the time to degree unnecessarily and increase the probability that students will stop out. Moreover, the method of delivering traditional 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.

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 in the ways that they offer remedial and developmental education (Couturier, 2011; Carnegie Foundation, 2011; Zachry & Schnieder, 2010). Six states are participating currently in the Developmental Education Initiative (DEI), an effort funded by the Bill & Melinda Gates Foundation and Lumina Foundation designed to further advance state-policy work in developmental education.[4] As part of these efforts, DEI states compile information on the structure and assessment of developmental-course innovations across their campuses. In 2005, no state had taken any steps to move away from traditional, semester-length developmental courses, but by 2010 four states reported substantial efforts to do so. Furthermore, from 2007 to 2010, all DEI states reported a dramatic increase in the number of

[4] These six states include Connecticut, Florida, North Carolina, Ohio, Texas, and Virginia, a subset of the 22 states participating in the Achieving the Dream Community College Count initiative funded by the Lumina Foundation.

colleges expressing interest in developing and implementing new developmental courses in reading, writing and math (Couturier, 2011).

Redesigning developmental courses can take on a number of purposes and forms. Rutschow & Schneider (2011) distill 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. Each type of intervention includes a wide range of programs and initiatives, several of which have been evaluated in recent years. For example, in 2004 the California Department of Education and the California State University system developed an innovative new Early-Assessment Program to target students potentially in need of remediation *before* they entered college, with the goal of reducing this need once they enrolled. A key component to the program is a test administered in the 11th grade which provides students, teachers, and parents with information about their students' college readiness. A recent evaluation of the program found that participation in the Early-Assessment Program reduced the a student's probability of needing remediation in college by 6.2 percentage points in English and 4.3 percentage points in math (Howell, Kurlaender, and Grodsky, 2010). An example of a program that combines basic skill attainment with college-level coursework is Washington State's Integrated Basic-Education Skills Training (I-Best) Program. This program has been cited frequently as one example of a highly successful innovation in developmental education. It combines instruction in basic skills with college-level material, all taught jointly by remedial instructors and college-level faculty. Evaluations of this alternative model show

higher rates of credit accumulation among recipients over time, as well as persistence to the second year (Jenkins et al., 2009).

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 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, 2010). 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 the material only offered in a developmental course. 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 theirs peers who did not enroll in a mainstreamed course (Jenkins et al., 2010). In the ALP program, a limited number of students who were assigned initially to the upper-level developmental-English course were allowed to take the college-level composition course instead, along with a special support section. These findings might support moving more students directly into college-level courses, particularly those with placement test scores at or around the cutoff. However, the design of existing research on the ALP program is either solely descriptive or cannot provide evidence that mainstreaming programs actually *cause* positive student-academic outcomes. 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 to students taking traditional developmental courses, yet causal questions about the effects of these programs on

student outcomes remain unanswered (Jenkins et al., 2010; Epper & Baker, 2009; Zachry, 2008; Edgecombe, 2011).

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). Using learning technology in the classroom aims to shorten the 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. Moreover, by using learning technology to tailor course material individually to a student's needs, the psychic costs of these courses may also be reduced, leading potentially to higher rates of persistence. On the other hand, the redesigned courses could have no differential impact or even produce more negative effects due to their reliance on learning technology. Not all students may be comfortable using learning technology as an instructional tool, particularly at the accelerated pace offered in the redesigned courses. For students struggling with the use of computerized modules in the classroom, these courses may lead to an increase in anxiety and frustration and potentially lower performance than a more traditional classroom-learning environment might.

In this research, 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 in the students who are placed into remedial courses versus those who are not. My hope is that such courses will provide students with the skills they need in a more streamlined manner, thereby shortening their pathway to college-level courses and increasing their probability of degree completion (Bailey, 2009).

The Tennessee Higher-Education System and Developmental-Course Redesign Initiative

For the past decade, the Tennessee Board of Regents (TBR) has engaged actively in discussions on how to improve remedial and developmental education across its 13 community colleges and six public universities.[5] In 2005, the Tennessee Board of Regents developed its five-year Strategic Plan, which included the adoption of a "best practice, system-wide, community-college-based remedial/developmental program that is substantially learning technology driven, composed of language arts and mathematics, which allows students to identify and focus on the academic areas where they are deficient". With an average of 65 percent of all students beginning at a community college recommended for at least one developmental course each year, the percent of students in need of remediation has remained relatively steady for the past decade (Tennessee Higher Education Commission, 2012). Among all students attending two-year colleges in Tennessee in the fall of 2009, slightly more than half (54 percent) returned in the fall of 2010.[6] Given that two-thirds of students entering community

[5] Tennessee has a higher education system similar to most other mid-sized states. The Tennessee Higher Education Commission (THEC) coordinates two systems of public higher education in the state: The 3 University of Tennessee institutions governed by the University Of Tennessee Board Of Trustees, and the 6 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.

[6] 54 percent is the average first-to-second year retention rate of fulltime students (57 percent) and part-time students (43 percent) across all 13 community colleges in Tennessee. Nationally, the first-to-second year retention rate

colleges in the state are in need of remediation, and over half of all students do not return for a second year, the TBR decided in the early 2000s to focus increased attention on the process and pipeline of developmental education across the state. Additionally, the high percentage of students in developmental courses was becoming a cost issue for both institutions and students. In the fall of 2005, the TBR estimated it was spending over $25 million per year to offer developmental courses at its institutions, with students paying between $1,300 and $4,100 in additional tuition to cover the cost of these courses (Short, 2009).

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.[7] 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. Starting in the fall 2007, the FIPSE funds were distributed to the National Center for Academic Transformation (NCAT), a non-profit organization with expertise in supporting institutions in the use of learning technology to improve student learning outcomes. Seventeen of the 19 colleges in the TBR system submitted proposals to participate in the pilot to redesign their developmental reading and/or writing and/or mathematics courses. Six proposals were selected as pilot projects designed to last for three semesters- four in math and two in English.[8] In the fall of 2007, NCAT awarded pilot grants totaling $211,668 to the six selected TBR institutions: Austin Peay State

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among all students attending public two-year colleges is 51 percent. The rate for students attending four-year colleges in Tennessee is 73 percent, slightly below the national average of 77 percent (NCEMS, 2012).

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

[8] 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.

University (math), 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).[9] 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.[10] In both cases, instructional and technological aspects of the initial plan were not followed, which led to a revision of the plan mid-way through the three-semester pilot period (Tennessee Developmental Studies Redesign Project, 2008).

In this research, 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.[11] 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 any other subject

[9] The amount each institution received was determined by the budget put forth in their proposal. These budgets were determined by the scope of the project and the projected cost of implementation. Grant money was used for space renovation, the purchase of computers and software, and general administrative costs. $40,000 grants were awarded 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.

[10] The most common problems intuitions faced were correctly estimating the number of sections they would need, training faculty to teach the new courses, and implementing a new registration process that could track students over time. At Chattanooga State, the adoption problem stemmed in part from a difference in opinion between the administration and the math faculty, which some initial resistance to the changes from the faculty (Mills, 2010).

[11] 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 present institutional characteristics for Chattanooga State in Table 2, and included it in early rounds of the analysis, although the results, none of which were statistically significant, are not shown.

(NCES, 2001, as cited in Bettinger & Long, 2007; Bailey, Jeong, & Cho, 2010). However, 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, Rogers, & Santos, 2011; Carnegie Foundation, 2012). The students furthest behind in math are the least likely ever to advance into classes for college credit, with only 10 percent of this group ever completing one college-level course (Bailey, Jeong, & Cho, 2010).

While the specific details of each institution's course-redesign efforts have differed, the overarching goal of all reforms was to decrease the time students spent 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 to the next. Thus, for students in need of multiple remedial courses in the same subject, there could be 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, in and out of the classroom, to enable the students to work at their own pace and 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 of the 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 on-line 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 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 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 pre-test 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 pre-test, 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 pre-test 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 Appendix A, I summarize the specific developmental math redesign efforts implemented at each institution.[12]

Observational research and descriptive summaries suggest these redesigns have been highly successful (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 reduce instructional costs by 36 percent, on average. At Austin Peay 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

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

percent (NCAT, 2009). At Cleveland State Community College, the number of students completing developmental math increased by 47 percent the first semester after implementing redesigned courses and the number of students enrolling in college-level math courses increased by 42 percent after one year. A more rigorous study by Schutz & Tingle (2010) used logistic regression analysis to determine what effects the course redesigns had at Cleveland State Community College, 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. Additionally, course success was not differentiated by gender and race, and it appeared redesigned courses helped to close the gaps in average achievement between developmental and college-level students.

These existing evaluations simply compare the pass rates of students before and after the course redesigns were implemented, while again failing to account for the selection of students into these courses and any unobserved differences between them and their peers who did not take remedial courses. In the current research, I 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. Secondly, I use the same research design to compare the causal effects of enrolling in traditional remedial courses to the effects of enrolling in the newly-redesigned courses, by comparing the average outcomes of students attending the other 16 colleges in Tennessee to those attending "treatment" institutions during the same time period. Finally, I compare cohorts of students at the three treatment institutions before, 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 is more or less effective than enrollment in the traditional remedial courses they replaced.

Specific Research Questions

In this study, I exploit the manner by which students were assigned to developmental math courses in Tennessee, using a regression-discontinuity design to estimate the effects of being just below rather than just above the test score cutoff used to assign students to developmental math (Murnane and Willett, 2011). With this research design, I can obtain consistent estimates of the causal effect of assignment to developmental math on subsequent academic outcomes. 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:

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 with regards to the impact on subsequent student academic outcomes?*
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?*

Research Design

It is the manner in which students were assigned to developmental math courses in Tennessee that 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 which 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 was the ACT Math exam, a subsection of the overall ACT exam.[13] In 2005, the Tennessee Board of Regents adopted the Guideline A-100, which identifies the ACT as the first-line of assessment for remedial education. Other diagnostic assessments were allowable as secondary or challenge assessments. Additionally, the Tennessee Board of Regents Strategic Plan 2005-2010 specified the ACT cut scores, and required students to demonstrate they had addressed deficiencies before proceeding to college-level courses. Among first-time, degree-seeking students, those under 21 years old has to present ACT (or SAT) scores to their institution before enrolling.[14] Community college students under the age of 21 without an ACT score were given a placement test prior to registering for classes. Entering students 21 years and older who did not have an ACT or SAT score also had to take a placement exam.[15] Under the traditional statewide policy, students with scores between 19-36 points on the ACT Math exam were assigned to college-level math,

[13] 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 with a standardized test score (ACT/ SAT) below a predetermined threshold, and/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.

[14] Tennessee currently requires all high school students to 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 3 years prior to the first day of the student's entering term.

students with scores of 17-18 points were 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 compare the sample means of select background characteristics and college enrollment information for those students who took the ACT Math exam to those who did not, between the four years of 2006-07 to 2009-10. In Column 1, I include the sample means and select standard deviations for the full sample of students in the complete dataset, including all first-time students who began at one of the 19 Tennessee Board of Regents public colleges from 2006-07 to 2009-10. In Columns 2 and 3, I divide the sample into those who took an ACT Math exam and those who did not, respectively. 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 fulltime 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 of Table 1) were generally older, with an average age of 28 years old, nearly half were enrolled part 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 illustrate in Column 2 of Table 1, includes primarily students of traditional college-age and with fulltime enrollment status at the start of their first year.

To address my three research questions, I used a regression-discontinuity design to identify the causal effects of enrollment in developmental courses on selected academic

outcomes over the first two years of college, for students at the margins of passing into college-level math as determined by their score on the ACT Math exam. In my second research question, I used an extension of the same analytic approach to compare estimates of the causal impacts of enrolling in a redesigned remedial-education course with similarly obtained estimates of the impacts of remedial-education on student outcomes in comparable institutions offering traditional remedial courses during the same time period of the redesign. Finally, in my third research question, I used this same extension of the original analytic approach to obtain estimates of the impacts of remedial-education on student outcomes in the same institutions *prior* to the redesign (i.e. the traditional model). Given that there was no change in the remedial-assignment policy during the years of this study and assuming no differences in the population of students enrolling in college in Tennessee over the period of the research[16], for my third research question I pooled data that straddled the period pre- and post- the redesign project (2006-07 to 2009-10) for those three institutions and applied a similar regression-discontinuity strategy as in addressing the first research question; however, I also included a post-reform dichotomous cohort variable in my statistical models in order to compare estimates of the impact of remediation pre- and post- the fall 2008 redesign efforts.

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

[16] In Table 3 I compare the sample characteristics of students in the cohorts prior to the redesign to students in the cohorts post-redesign to illustrate that the composition of students in these groups did not change unexpectedly after the fall of 2008. While it may be plausible that student motivations for enrolling in college changed over this period as a result of the economic downturn of 2008, it does not appear that the characteristics of these students differed in any significant way.

the student was enrolled actively 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 cover 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, or the year in which they *first* began at a public two- or four-year college in the state. Given that the developmental education redesign initiatives in Tennessee were fully implemented by the fall of 2008, these data provide access to two student cohorts on either side of the discontinuity in the type of developmental math course provided. 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 am able to work with a sample large enough to detect relatively small effect sizes, at standard levels of Type I error.

I also incorporate data from the *Integrated Postsecondary Education Data System* (IPEDS), an annual, federal survey, which provides institutional-level characteristics, such as the Carnegie classification code, average enrollment, and college-graduation rates for each institution in the study. These data allow 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 fulltime retention rate of first-time students (68 percent at Austin Peay compared to 69% at the other four-year colleges) and the high percent of students receiving any financial aid (95 percent at Austin Peay compared to 94 percent). Compared to the five other four-year colleges in the state, however, Austin Peay has 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), possibly lending to its choice as one of the pilot institutions. Among the two-year colleges, Cleveland State enrolled a greater percentage of white students (89 percent at Cleveland State compared to 77 percent at the other two-year colleges), as well as students with slightly higher ACT Math scores and high school GPAs. It also had the lowest percentage of students recommend for any remedial math course, with 66.8 percent compared to 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 is not much higher at 12 percent. Chattanooga State had the highest percentage of students recommended for any remedial math course, yet was the one institution of the four that was not able to implement a redesigned curriculum successfully in the first semester of the pilot.

Sample

My sample contains those students in Tennessee who attended one of the three institutions that implemented a math course redesign successfully (described above and in Appendix A) 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, my sample size was 8,948

students.[17] Additionally, the sample only included 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 limited the sample to students under the age of 21 in order to isolate the effects to traditional students, and only included 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 & 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.[18] In the cells of Table 3, I present sample means for the smaller group of students that fell within a smaller "bandwidth" – that is, within fewer points on either side of the ACT Math exam cutoff score used to assign

[17] 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.

[18] The baseline covariates for gender, race, age, and high-school GPA should be continuous at the ACT Math exam cutoff used to assign students to developmental or college-level math. To show that the covariates do not differ on either side of the discontinuity, I calculated an impact at the cutoff by projecting the covariate values onto the discontinuity and testing for a difference at this break. The parameter estimates, standard errors, and approximate p-values are found in Appendix B. The only non-continuous variable across the cutoff is found with females, and only when restricting the sample to the pre-reform cohorts (2006-07 and 2007-08).

students to developmental math courses in Tennessee.[19] 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-cohorts. On average, more female and black students are recommended for developmental math than college-level math (as shown by rows 1 and 3 of Table 3). Not surprisingly, students recommended for college-level math had higher high-school grade-point averages (GPAs), on average, than 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 recommended for the course, and over 80 percent of those recommended actually enrolled in the first semester.

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 to 86.6 percent post-reform). This difference is likely being 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).

[19] Later in the paper I describe the analytic procedure used to select this optimal smaller bandwidth. For Table 3, 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.

Measures

Due to the relatively recent implementation of the redesigns (fall 2008), I measured subsequent academic outcomes for students over the short term. Focusing on outcomes in the first two years of college allows 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 research refers to the probability of remaining enrolled in college after the first semester or first year.[20] However, not all students who enrolled full-time in their first semester continued to stay enrolled fulltime in subsequent semesters, and the same was true for part-time students. 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 & 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 (Jenkins & Cho, 2012). While the number of total credits in the second year may be a good indication of student progress toward a

[20] I define persistence to be within the same institution in which a student first enrolled. Future work will examine transfer students and enrollment in other TBR institutions.

degree, it is the number of *college-level* credits completed over time that is most critical to degree attainment. Remedial courses in Tennessee count towards 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 credit 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 credit 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.[21]

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 their subsequent college-level course, however, which results in the majority of students enrolling in their assigned developmental math course within the first semester. From prior research I have done on remediation in Tennessee, I know the majority of those students recommended to

[21] As I do not have individual course grades in the data, I am not able to know if a student did not successfully complete a course due to failure or dropping the course willingly. As such, this measure is a loose proxy for potential early academic difficulty.

remedial courses actually enroll in these courses within the first semester (over 80 percent).[22] In my analysis, I also included a dichotomous predictor that indicates whether the student was enrolled *after* the course redesigns took effect (fall of 2008). 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-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).

Covariates

To increase the precision of my estimates, I also incorporated selected exogenous covariates into my analyses. Including these selected controls into the analysis reduced the residual variation, made the standard errors smaller, and increased the statistical power.

[22] However, it may be that those who delayed enrollment in their remedial courses to a later semester differ in unobserved ways from those who enroll 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 to the results for students who enrolled in a subsequent semester. The results are not statistically different than for those who enroll in remedial education in their first semester.

However, all of these control variables must themselves be exogenous, and so I included only covariates whose values were measured prior to the period in which students were assigned to developmental math. As is typical in these kinds of analyses (Murnane & Willett, 2011), I included student-level covariates describing student gender, race, age, and high school GPA for all students in the sample. High-school GPA was included as it is widely accepted as a very strong predictor of college success (Adelman, 2006). I also included a dummy variable describing whether a student had been assigned to a prior developmental/ remedial reading or writing course. 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. All of these covariates are represented by a vector, Z, in my subsequent statistical models.

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 who were just assigned, versus 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

are 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 classes. Consequently, I used an instrumental-variables (IV) strategy, and two-stage least-squares (2SLS) estimation, to resolve the fuzziness (Murnane & Willett, 2011; Shadish et al., 2002). I treated *assignment to remediation* at the cut-off 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 this fuzziness in the placement policy. Across all 19 public institutions over the four years between 206-07 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.[23] The degree of "fuzziness" is different across each of the three institutions in 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. 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 institutions in the sample, on average, over 80 percent of all students assigned to a developmental math course enrolled in one

[23] 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 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.

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 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 towards 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 the four-year institution in the sample.

In the four panels of Figure 3, I illustrate the distribution of several outcome measures describing persistence and credit accumulation by ACT Math score, with vertical lines representing the cutoff for developmental math. These graphs illustrate general trends in student enrollment and course-taking across the full range of ACT Math scores. The slopes of the trend lines also suggest there may have been differences in these outcomes for students on either side of the cutoff. It appears that the number of total credits did not differ discontinuously at the cutoff, although student persistence and the total number of college-level credits after one year may have differed depending on a student's ACT Math score (and therefore subsequent assignment to developmental or college-level math). These basic plots of bivariate relationships in the raw data foreshadowed possible discontinuities at the cutoff for assignment to remediation.

A common threat in RD designs is that students may be able to manipulate their placement on the forcing variable, or that administrators within each institution may manipulate

the assignment policy. In my research, given that the ACT Math score was used as the tool for placement, it would have been very difficult for a student to manipulate his/ her score in order to fall intentionally just to the left or right of the ACT cutoff.[24] On the other hand, teachers or administrators may have violated the placement policy by assigning students who fell close to, but below, the cutoff to the higher-level course, thus violating the "equal in expectation" assumption immediately on either side of the cutoff prior to treatment. Examining my data, I note high compliance with the cutoff policy, with only a few institutions, not in the sample for this study, deviating from the policy.

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 only to 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 classes, 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:

[24] While a student may know the cutoff score for getting into college-level math and therefore re-take the ACT until s/he scores just above the cutoff, this is not supported with evidence from Tennessee. If this were the case, we would expect to see large clusters of ACT Math scores right around the cutoff, and instead we see an even distribution across the range of scores.

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

for the i^{th} individual and where δ_i is the first-stage residual. Z is the vector of covariates discussed above. 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) $$Y_i = \beta_0 + \beta_1 \left(\hat{DEV}_i \right) + \beta_2 \left(SCORE_i \right) + \beta_3 \left(ASSIGN * SCORE \right) + \beta_4 \left(Z_i \right) + \varepsilon_i$$

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 local 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).

In specifying this second-stage model, I have used generic outcome Y_i to refer to each of the eight outcomes described above. In cases where there are dichotomous outcomes at both the first and second stages, I adopt 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 fit 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 regards 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 which 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 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 the model I also included a dummy predictor, INST, to identify those three institutions which implemented a redesigned developmental math curriculum (INST=1) from those institutions which did not

(INST=0), in the years 2008-09 and 2009-10. I then interacted this predictor with other critical variables in my first-stage model to ensure that the relationship between the take-up of remediation and the forcing variable was allowed to differ between types of institution. 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:

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

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). 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 which 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 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 in 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). I then regressed whether a student enrolled in a remedial course on whether the student was assigned to this course, and included a dummy predictor, POST, to identify those cohorts which began in the years of course redesign efforts (POST=1 for cohorts 2008-09 and 2009-10, and 0 otherwise). Again, I interacted this predictor with other critical variables in my first-stage model to allow for estimates of the impact of the developmental education programs, before and after the remedial course redesign, to differ. Thus, my first-stage model became:

$$(5) \quad \begin{aligned} DEV_i &= \gamma_o + \gamma_1 ASSIGN_i + \gamma_2 SCORE_i + \gamma_3 (ASSIGN * SCORE)_i + \gamma_4 POST_i \\ &+ \gamma_5 (ASSIGN * POST)_i + \gamma_6 (SCORE * POST)_i + \gamma_7 (SCORE * POST * ASSIGN)_i + \gamma_8 Z_i + \delta_i \end{aligned}$$

Again, I take the fitted probability of being assigned to a developmental course obtained from fitting this model into the second-stage statistical model to estimate the causal effect of remediation on generic outcome, Y_i, as follows:

$$
\begin{aligned}
Y_i &= \beta_o + \beta_1 \hat{DEV}_i + \beta_2 SCORE_i + \beta_3 (ASSIGN * SCORE)_i + \beta_4 POST_i \\
&+ \beta_5 (\hat{DEV} * POST)_i + \beta_6 (ASSIGN * POST)_i + \beta_7 (SCORE * POST)_i \\
&+ \beta_8 (SCORE * POST * ASSIGN)_i + \beta_9 Z_i + \varepsilon_i
\end{aligned} \tag{6}
$$

with the usual notation and a suitable correction to the standard errors of the estimates. The parameter of interest in equation (6) is again β_1 as it represents the causal effect of enrollment in remediation across the years 2006-07 to 2009-10 on the outcomes of interest, on average, in the population. Estimating parameter β_5 allowed me to examine how the main effects obtained from β_1 differ as a result of the 2008 course redesign project.

Determining the Bandwidth

A critical component of any RD 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. In an RD specification, the model specification ensures that I project to the cutoff, from the data included on either side, and make inferences only at the cutoff, where individuals can be assumed to be equal in expectation, in the population, prior to treatment. By selecting a smaller bandwidth near the cutoff, I gain 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 statistical power, but also increases the sensitivity of the analysis to the functional form of the outcome/forcing variable relationship (Murnane & Willett, 2011). However, the most serious problem in analyzing data using an RD design is model misspecification, as the estimated treatment effects will only be unbiased if the functional form of the relationship between the outcome variable and the forcing variable is modeled correctly (Schochet, 2008).

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. For each outcome, to estimate the optimal bandwidth around the cutoff, I estimated a separate linear regression function to predict the value of the outcome at each ACT Math exam score point within a range of two to 10 ACT Math exam points on either side of the cutoff. This resulted in estimating eight predicted values of each outcome on the left of the ACT Math exam cutoff point and eight on the right. The residuals from each regression were then estimated and the optimal bandwidth was chosen by selecting the bandwidth that minimized the mean square error of the difference between the predicted and the actual value of the outcome.

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 restrict the lower bound on the forcing variable to two ACT Math exam points, and use the procedure described above to estimate the optimal bandwidth *above* the cutoff score for all outcomes.[25] Within each table of results, I present the optimal bandwidth for each outcome estimate.[26]

[25] I assume 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-estimesd the findings for alternative functional forms to the right of the cutoff by including a quadratic term for my question predictor in equations (2), (4) and (6), and in all cases found that the estimates did not change significantly. While the size of the standard errors increases, these estimates did not differ from those obtained from the local linear specification.

[26] I also tested whether the results were robust when background controls were eliminated, which had no effect on the estimates. Additionally, I tested whether the results were sensitive to the choice of bandwidth by limiting the bandwidth to just two points on either side of the cutoff. I found that the estimates did not differ in any significant way.

Results

In my analysis, I obtain 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 used for placement into developmental math courses. As such, these results are only externally valid for students whose scores on the forcing variable fell close to the discontinuity in the placement scores, and therefore can only be generalized to the population of students *at the margins of passing*.

My 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 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 their peers in non-redesign institutions, on average, during the same period and also when compared to students exposed to the previous version of traditional remediation within their institution in prior years. It appears students enroll and persist at the same rate in the second year, but are taking more college-level courses as a result of the redesign process.

First-Stage Results: Who Are the Students Enrolling in Developmental Math?

Due to the imperfect compliance with the assignment rules for placement into developmental math, I expected the probability of enrollment in these courses to differ by

student characteristics. In the first stage of each of my three analytic models, I estimated the fitted impact of scoring above or below the cutoff for placement into a developmental math course on the probability of enrolling in a developmental math course, as a function of ACT Math score. For illustration of the raw distribution of this "take-up", in Figure 2, I display the average number of students who actually enrolled in a developmental math course within their first year, by ACT Math score. Across the three 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, making assignment to developmental math a strong predictor of enrollment in development math.

In Table 4, I present the first-stage fitted parameters and standard errors for those student characteristics used to predict enrollment in the first stage. These results were obtained by regressing enrollment in a developmental math course on the forcing variable, *SCORE*, and the instrumental variable, *ASSIGN*, and the interaction of the two. As I show in the first row of Table 4, the assignment predictor, *ASSIGN*, predicted enrollment in developmental math in both the pooled sample and in the three individual intuitions, although to differing degrees. The interaction of assignment and the ACT Math exam forcing variable (row 2 of Table 4) also had a statistically significant effect on enrollment in developmental math, but in the reverse direction. Among students with high ACT Math scores, the probability that the student enrolled in a developmental math course decreased as the ACT Math exam score increased.

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

In Table 5, 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 resembled prior research to address research questions on college remediation, as it simply compared the academic outcomes for students enrolling in a developmental math course to similar students enrolled in a college-level math course. In estimating the results in Table 5, I have restricted the sample to include only the three institutions that first implemented redesigned developmental math courses in the fall of 2008, but have pooled both the 2008-09 and 2009-10 cohorts, as the redesigned courses were offered in subsequent semesters.[27]

In the top row of Table 5, 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

[27] 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, I believe including the second cohort of students is more representative of the true effects of these resigned courses than simply focusing on the pilot year.

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 the 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 4, for both the pooled reform institutions and for Cleveland State. In the pooled sample plot on the left, prototypical students enrolling in developmental math completed 1.6 more of their attempted credits than 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. This is the opposite effect seen at Jackson State Community College, where students in developmental math dropped an additional credit at some point in the semester compared to their peers enrolled in college-level math, although this latter effect is not statistically significant.

The effects of the reformed remediation on the dichotomous outcomes describing student persistence (columns 2 and 5) 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 to students in college-level math, as shown in the first row of column 2. This estimate included 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 the pooled or the individual institutions, in the population.

While I would expect that students assigned to developmental math courses would earn fewer college-level credits in the first semester, by the second semester I might hope 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 reformed remedial course on the number of college-level credits completed in the second semester only. Across all three institutions for the the 2008-09 and 2009-10 cohorts, as well as individually within each institution, it appears that both treatment (enrolled in developmental math in the first semester) and control (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 were 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 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

In Table 5, I present the effects of assignment to remediation courses compared to assignment to college-level courses for students enrolled in one of the three institutions which implemented course redesigns in the fall of 2008. However, I also examined the effects across all four and two-year institutions during this same period to allow for a deeper comparison of these effects to the more traditional forms remedial education that were being offered at the other 16 public colleges at the same time. Table 6 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 6 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 to 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-level math; however these results were 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 to their peers in college-level math (column 6).

The interaction term in Table 6 provides the effect for the redesigned institutions compared to 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 to students attending their peer four-year institutions. This result is shown graphically in Figure 7, 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 6, 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 was 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 to students at the other nine community colleges, who completed an average of 1.5 fewer credits than their peers enrolled in college-level math. Table 6 provides interesting results relative to the non-redesigned 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 appeared to differ by institution.

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

While Table 6 suggests that students in developmental math at Austin Peay in the two years post-redesign had stronger academic outcomes than those students enrolled in developmental education at the other four-year colleges in the state during this time, it does not illustrate how the redesign effects compare to the prior traditional model of remedial math education with Austin Peay University. Using data for the two cohorts prior to the developmental math redesigns (fall 2006-07 and fall 2007-08), Table 7 presents the effects of enrollment in developmental math on the academic outcomes for students at the three redesign institutions, but also includes a cohort effect (POST) to allow for a comparison to the more traditional developmental education model that was being used prior to the 2008-09 course redesigns. The outcomes in Table 7 are the same as in prior tables. Plotting the data pre-and post-reform, Figure 6 suggests there may be differences in outcomes after the three sample institutions implemented their reforms, as suggested by an increase in student persistence on the top two graphs and a decrease in the gap in college-level credits after two years shown in the bottom two graphs. Table 7 provides estimates to answer this question.

The top row of each section of Table 7 reports the cumulative effect of assignment to developmental math across all four cohorts in the data. Generally across the three pooled institutions, it appeared that participation in a remedial math course had negative effects on the number of credits attempted but not completed, and the number of college-level credits a student had completed by the end of the first and second year, 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 most interesting results in this table, however, are not the basic comparisons of

students in developmental math to those in college-level math. The interaction term of Table 7 (β_5) illustrates the comparison of redesigned courses to 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 to 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 lead to a 4.3 percentage point increase in the likelihood of being enrolled in the second semester compared to 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. The GLH test presented in the bottom rows of each panel on the Table 7 provides evidence that this difference between the main effect and the interaction was statistically different than zero at the 10% level.

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 so 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 be an improvement from the prior course offerings at two of the three schools. For students at Jackson State, it appears the redesigned courses did not differ in their impact compared to the traditional developmental courses offered

in the earlier years, as we see no statistically significant effects on the coefficients in Table 7. At Jackson State, students in the redesigned math courses proceeded through the required modules at their own pace. Therefore, when one semester ended and another began, students could resume work on any modules not completed, and therefore the traditional definition of "semester" and "course credit" was much looser in this case.

Threats to Validity

In my RD analysis, I included a time-trend predictor to capture any secular trend in student outcomes over time. I also checked that the observable characteristics of students enrolled at these four institutions pre-redesign are similar to the characteristics of students enrolled post-redesign in order to rule out large changes in the composition of the student body during the four years of this study. Additionally, changes in other factors related to the subsequent academic outcomes of remedial students would also threaten my interpretation. For example, it is possible that the push to improve remediation in Tennessee by redesigning courses also affected other policies or efforts to support underprepared students during the same time. If the three colleges that implemented redesigned courses were also implementing other support initiatives during this time, this could challenge the causal interpretation that any differential effects in student outcomes found before and after the change were due solely to the redesign efforts. However, progress reports from people in each of the institutions do not confirm that other large-scale efforts were underway in developmental education within these institutions during the two years post-redesign.

A limitation of the RD design is that it only estimates impacts for those students near the cutoff on the ACT Math exam. Across all three institutions, this averages out to be about 35 percent of all students beginning in each cohort who took the ACT Math exam.

Discussion and Policy Implications

The redesigned remedial courses that took effect in Tennessee in the fall of 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 my research, 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 I have presented here 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, however, students exposed to redesigned developmental math courses had more positive outcomes than their peers in non-redesign institutions during the same period, and also when compared to 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 and Cleveland State Community College.

At Austin Peay University, the four-year college, I find a positive impact of the elimination of developmental math courses on early student persistence. I also saw an increase in the number of college-level credit accumulated by the end of the first and second year when compared to other four-year institutions or to more traditional methods of offering remediation.

This was the only institution of the three which 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 only applies to students at the margin of needing math remediation, and cannot be extrapolated to students far down the ability distribution in which enrollment in a college-level math course could potentially lead to more harmful academic effects than positive ones. These caveats aside, however, these 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 these students showed strong gains when compared to prior years or comparable institutions, it is advised to lower the cutoff to avoid over-placement in remedial courses. A more accurate placement system could lead to a reduction in the number of difficulties that arise with 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. My 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 are a dramatic change from the 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 seeing 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, 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 the reason why 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.

Developmental education is a particular concern in Tennessee today, as the state adopted the Complete College Tennessee Act in 2010 to take effect in the fall of 2012. In the Act, all four-year colleges and universities are prohibited from offering remedial education courses. Students will instead be able to be co-enrolled in four-year colleges and community colleges until they complete their remedial instruction. In addition, the Act requires the development of a strategic plan for higher education and the development of a performance funding model that likely will ultimately include performance measures related to remedial education (Senate Bill 7006/House Bill 7008). It is too early to know the long-term effects of these redesigned courses; however, the adoption of the Complete College Tennessee Act will ensure all the community colleges in the state 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 supports affects students in these institutions.

The redesign efforts in Tennessee 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 intended to address whatever was 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 a curricular burden. Future redesign efforts should continue 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 includes a deeper look at student grades, particularly in college-level math courses. The research needs to move beyond a study of the basic effects of developmental education and into the classroom to discover what is really going on in these courses with respect to teaching and learning, as well as how faculty members can best adapt to these new innovations. Rather than focusing on basic credit accumulation, administrators, policymakers, and students are increasingly more interested in what students need to know to be successful in college-level courses and what skills they most need for the modern workforce. 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 if redesigned remedial courses are helping or hurting students differently. By thinking more creatively about how to respond to a variety of

learning abilities, it is possible to design courses that work well with diverse array of students and institutions, which may ultimately lead to better learning for all.

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Tables and Figures

Table 1: Sample means (and select standard deviations) for all first-time students attending one of the 19 Tennessee Board of Regents public colleges from 2006-07 to 2009-10, comparing students who took the ACT Math exam to 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
Fulltime 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

Table 2: Selected characteristics (raw enrollment data, sample means, and select standard deviations) of institutions that proposed to redesign remediation relative to all Tennessee public colleges of their level, fall semester 2008.

	All TN Four-Year Colleges	Austin Peay State Univ.	All TN Two-Year Colleges	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						
Fulltime (FT) Equivalent Undergraduate Enrollment	51,821	7,772	31,165	2,213	2,900	5,423
Percent of all undergraduates beginning as first-time, fulltime 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 (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 institutional-level data. Notes: Standard deviations, when available, are shown in parentheses. All data reported for the fall term of 2008-09. The Two-Year Colleges column does not include Cleveland State Community College, Jackson State Community College, or Chattanooga State Community College. Likewise, the Four-Year Colleges column does not include Austin Peay State University. Fulltime (FT) students are those enrolled for 12 or more credits per semester. The fulltime retention rate applies to students enrolled fulltime in the fall of 2008 who subsequently enroll fulltime in the fall of 2009.

Table 3: Sample means (and standard deviations) for 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 ACT Math scores within 2 points below the cutoff for assignment to developmental math and 4 points above, 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	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. The total number of developmental credit hours accumulated in the first semester includes credit hours for developmental math, reading, writing, and/or study skills.

Table 4: First-stage fitted parameters (and standard errors) describing enrollment in developmental math for the two post-reform cohorts, fall 2008-09 and 2009-10 for students with ACT Math scores within 2 points below the cutoff for assignment to developmental math and four points above.

	Pooled Sample Estimate	Austin Peay State University	Cleveland State Community College	Jackson State Community College
Instrumental Variables				
Assigned to Developmental Math due to Assignment Policy	0.613**** (0.032)	0.469*** (0.048)	0.601*** (0.051)	0.896*** (0.046)
ACT Math Score* Assigned to Developmental Math	-0.060*** (0.019)	-0.044* (0.029)	-0.158*** (0.032)	-0.059* (0.028)
Other Predictors				
ACT Math Score	0.001 (0.007)	0.001 (0.009)	0.001 (0.014)	0.003 (0.012)
Female	-0.006 (0.013)	-0.021 (0.019)	0.061* (0.024)	0.000 (0.019)
White	-0.024 (0.041)	-0.048 (0.051)	-0.095 (0.071)	-0.021 (0.104)
Black	-0.018 (0.044)	-0.032 (0.055)	-0.059 (0.091)	0.053 (0.106)
Other Race	-0.025 (0.044)	-0.012 (0.055)	-0.040 (0.091)	-0.016 (0.106)
High-School GPA	-0.019 (0.013)	0.023 (0.019)	-0.017 (0.024)	-0.020 (0.020)
Age in first semester	-0.017 (0.012)	-0.021 (0.017)	-0.009 (0.022)	0.020 (0.016)
Constant	0.412* (0.229)	0.361 (0.329)	0.294 (0.435)	-0.302 (0.342)
N	2392	1309	459	624
R^2	0.5697	0.4047	0.7566	0.7897

Notes: Standard errors are shown in parentheses. The sample is limited to students who began at a 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 was chosen to closely resemble the optimal bandwidths used in the statistical analysis of Tables 5-7. $p<0.10$, ** $p<0.05$, *** $p<0.01$.

Table 5: Second-stage IV parameter estimates (and approximate *p*-values) describing the effect of enrollment in developmental math courses on student persistence and the number of credits earned in the first semester, first year, and second year for the two post-reform cohorts, fall 2008-09 and 2009-10 .

	FIRST SEMESTER		FIRST YEAR			SECOND YEAR		
	Credits attempted but not completed Semester1	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	-1.656**	0.105**	0.713	1.876	0.008	1.321	1.027	2.040
Develop. AlgebraII	(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	-1.477	0.093+	0.688	3.782	-0.037	0.866	0.662	3.497
Develop. AlgebraII	(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	-3.333*	0.102	0.614	-0.823	0.007	1.234	1.724	-0.184
Develop. AlgebraII	(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	-0.827	0.148	0.536	1.744	0.029	2.531	1.969	1.688
Develop. AlgebraII	(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, fulltime 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 & Lemiuex (2007). 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 drop out, the number of credits is listed as the number of credits the student had completed when last enrolled. + p<0.15 * p<0.10, ** p<0.05, *** p<0.01.

Table 6: Comparing redesigned remediation courses versus traditional remediation courses at similar institutions in Tennessee. Second-stage IV parameter estimates (and approximate p-values) of the effect of enrollment in developmental math courses on student persistence and the number of credits earned in the first semester, first year, and second year for the two post-reform cohorts, fall 2008-09 and 2009-10).

	FIRST SEMESTER		FIRST YEAR		SECOND YEAR			
	Credits attempted but not completed Semester1	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. AlgII (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≤x≤3	-2≤x≤2	-2≤x≤3	-2≤x≤1	-2≤x≤1	-2≤x≤3	-2≤x≤3	-2≤x≤2
Observations	10996	9595	10996	7845	7845	10996	10996	9595
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. AlgII (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≤x≤3	-2≤x≤3	-2≤x≤2	-2≤x≤3	-2≤x≤3	-2≤x≤2	-2≤x≤2	-2≤x≤3
Observations	9163	9163	8379	9163	9163	8379	8379	9163
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, fulltime 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 one 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<0.15 * p<0.10, ** p<0.05, *** p<0.01.

Table 7: Comparing the second-stage IV parameter estimates (and approximate p-values) for traditional developmental courses offered in 2006-07 and 2007-08 (pre-reform) versus redesigned developmental courses offered in 2008-09 and 2009-10 (post-reform) at Cleveland State Community College, Jackson State Community College, and Austin Peay State University.

	FIRST SEMESTER		FIRST YEAR		SECOND YEAR			
	Credits attempted but not completed Semester1	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. AlgII (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≤x≤3	-2≤x≤2	-2≤x≤2	-2≤x≤3	-2≤x≤1	-2≤x≤3	-2≤x≤3	-2≤x≤3
Observations	4666	4168	4168	4666	3510	4666	4666	4666
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. AlgII (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≤x≤1	-2≤x≤3	-2≤x≤1	-2≤x≤3	-2≤x≤1	-2≤x≤1	-2≤x≤1	-2≤x≤1
Observations	1762	2500	1762	2500	1762	1762	1762	1762
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 Semester1	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. AlgII (β_1)	-0.407	0.154*	0.513	0.549	0.058	-3.909*	-1.431	-1.431
	(1.515)	(0.084)	(1.785)	(3.280)	(0.118)	(2.197)	(2.460)	(2.460)
Post Reform (β_4)	0.465	0.030	-0.496	-0.447	-0.025	-3.826*	-4.104	-4.104
	(0.720)	(0.036)	(0.830)	(1.559)	(0.048)	(1.995)	(3.003)	(3.003)
Assigned * Post Reform (β_5)	-2.084	-0.357**	0.382	-0.651	0.031	6.213+	1.979	1.979
	(1.607)	(0.167)	(2.099)	(3.478)	(0.141)	(3.850)	(2.597)	(2.597)
Fitted value at cutoff	4.06	0.821	11.23	24.02	0.614	13.82	31.626	36.92
Bandwidth	-2≤x≤3	-2≤x≤2	-2≤x≤2	-2≤x≤3	-2≤x≤3	-2≤x≤3	-2≤x≤2	-2≤x≤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. AlgII (β_1)	-0.685	0.113*	0.407	1.170	0.016	2.928	2.102	3.217
	(1.020)	(0.067)	(1.073)	(2.139)	(0.087)	(2.581)	(4.160)	(3.854)
Post Reform (β_4)	-0.873	0.041	0.279	1.740	-0.033	-0.542	-0.087	0.939
	(0.570)	(0.033)	(0.600)	(1.196)	(0.042)	(1.443)	(2.325)	(2.154)
Assigned * Post Reform (β_5)	0.449	-0.055	-0.893	-1.082	0.079	-1.198	-2.534	-3.708
	(1.195)	(0.104)	(1.257)	(2.508)	(0.122)	(3.026)	(4.876)	(4.518)
Fitted value at cutoff	4.18	0.807	10.18	21.49	0.584	12.01	27.79	33.38
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	1280	1280	1280	1280	1280	1280	1280	1280
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, fulltime 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<0.15 * p<0.10, ** p<0.05, *** p<0.01.

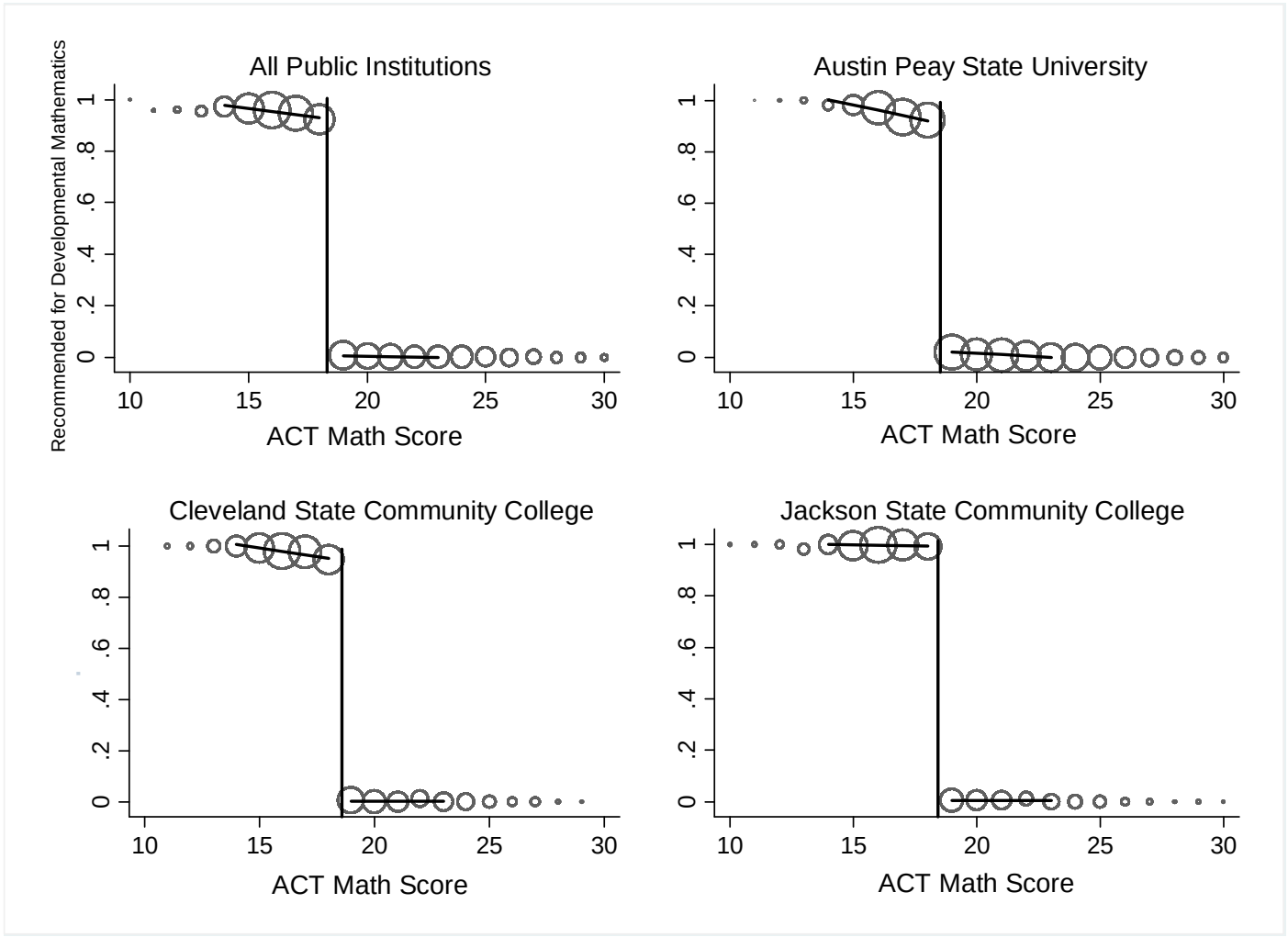

Figure 1: Percent of students assigned to developmental or remedial math by ACT Math Score for all Tennessee Board of Regents Public Colleges, and individually for Austin Peay State University, Cleveland State Community College, and Jackson State Community College, 2006-07 to 2009-10.

Notes: All public institutions includes all 19 public colleges in the Tennessee Board of Regents of 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.

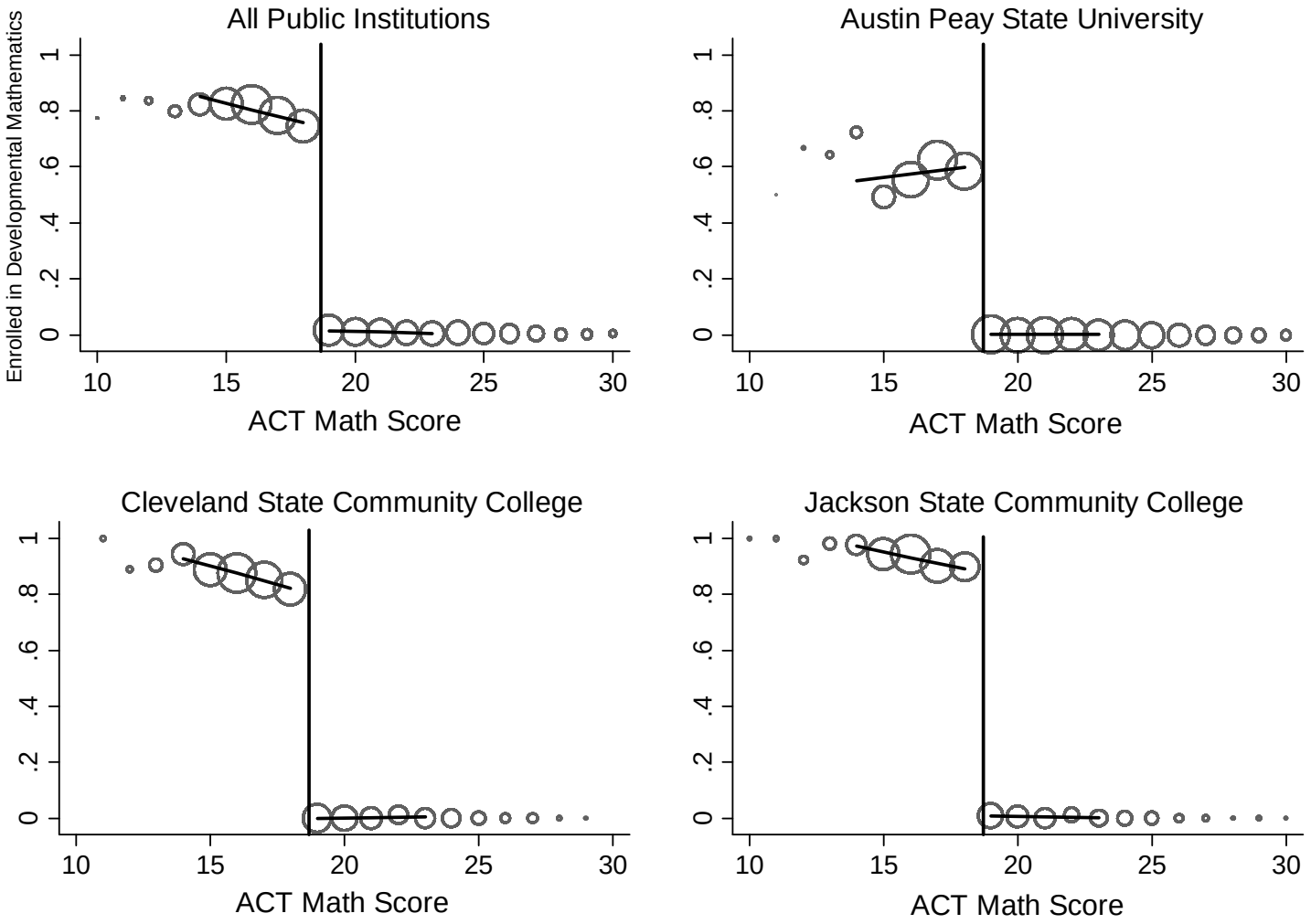

Figure 2: Actual enrollment in developmental or remedial math by ACT Math Score for all Tennessee Board of Regents public colleges, and individually for Austin Peay State University, Cleveland State Community College, and Jackson State Community College, 2006-07 to 2009-10. See Notes for Figure 1.

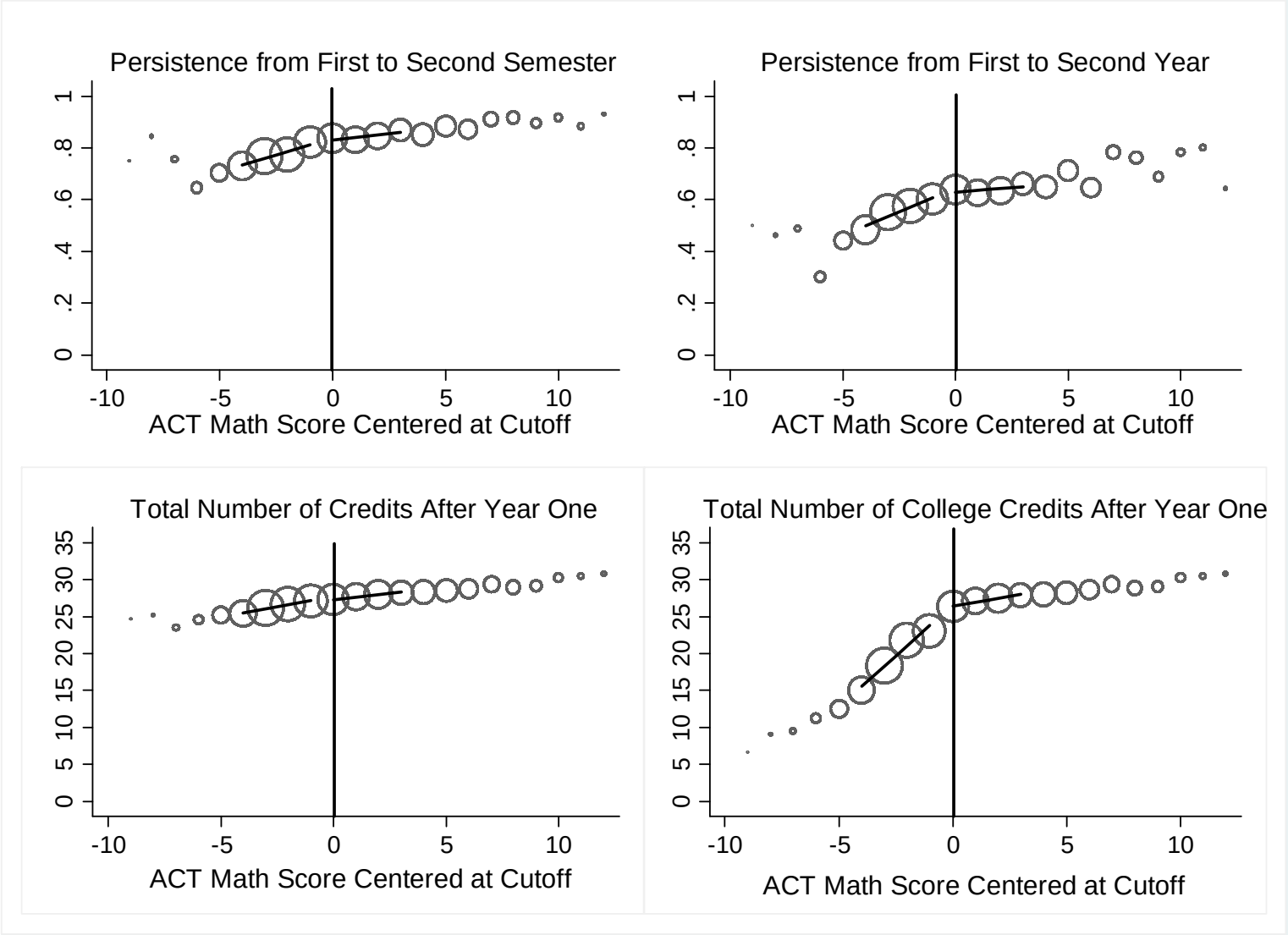

Figure 3: Selected outcomes by ACT Math Score for all first-time, fulltime students with a reported ACT Math score beginning in the fall of 2006-07 to 2009-10 at Austin Peay State University, Cleveland State Community College, and Jackson State Community College with trend lines providing linear predictions across raw means.

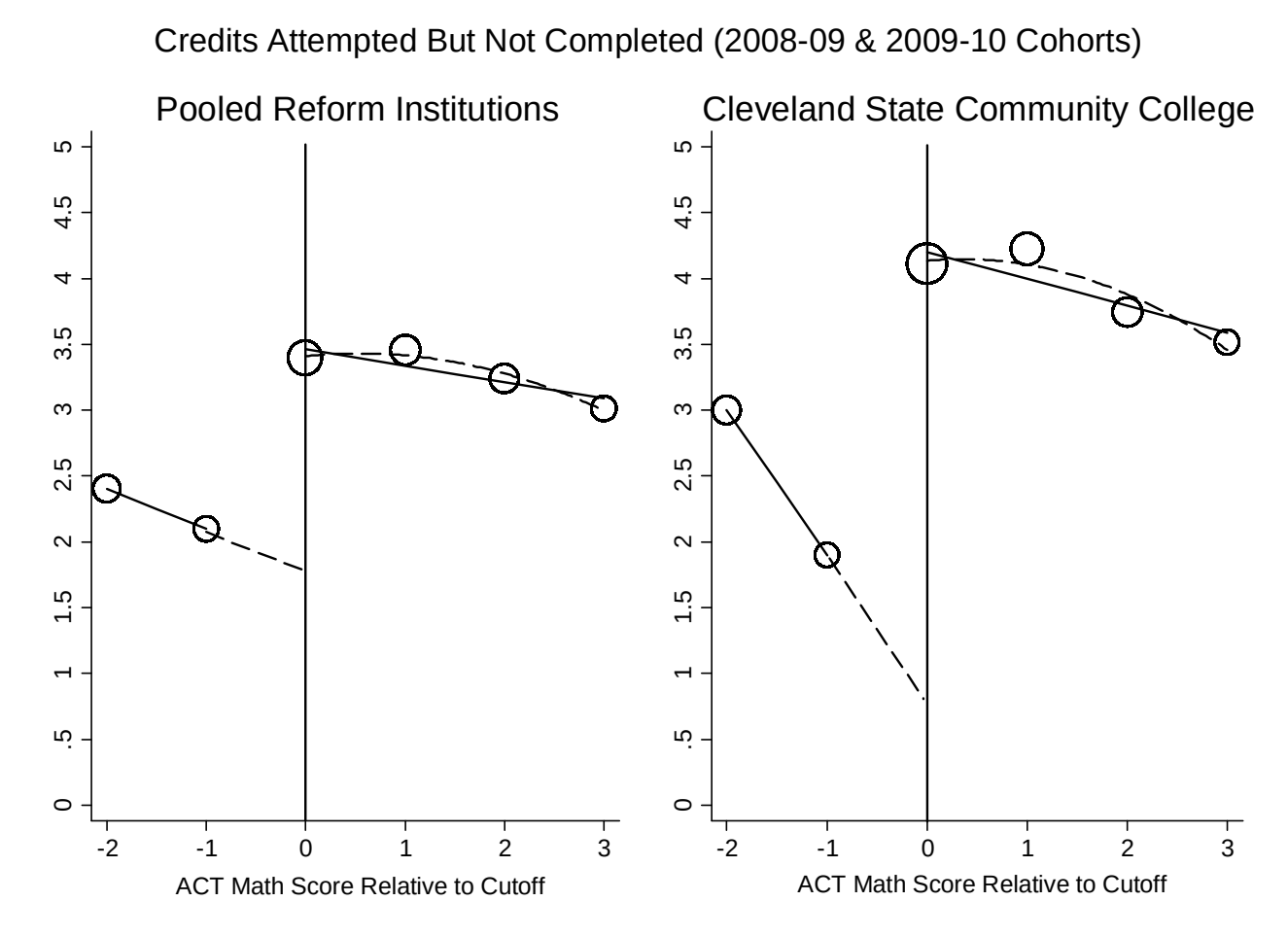

Figure 4: Fitted values estimating enrollment in developmental math on the number of credits attempted but not completed after two years for students beginning in the fall of 2008-09 & 2009-10 (from *Table 5)*

Notes: The sample for the Pooled Reform Institutions includes all first-time, fulltime 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 & Lemiuex (2007).

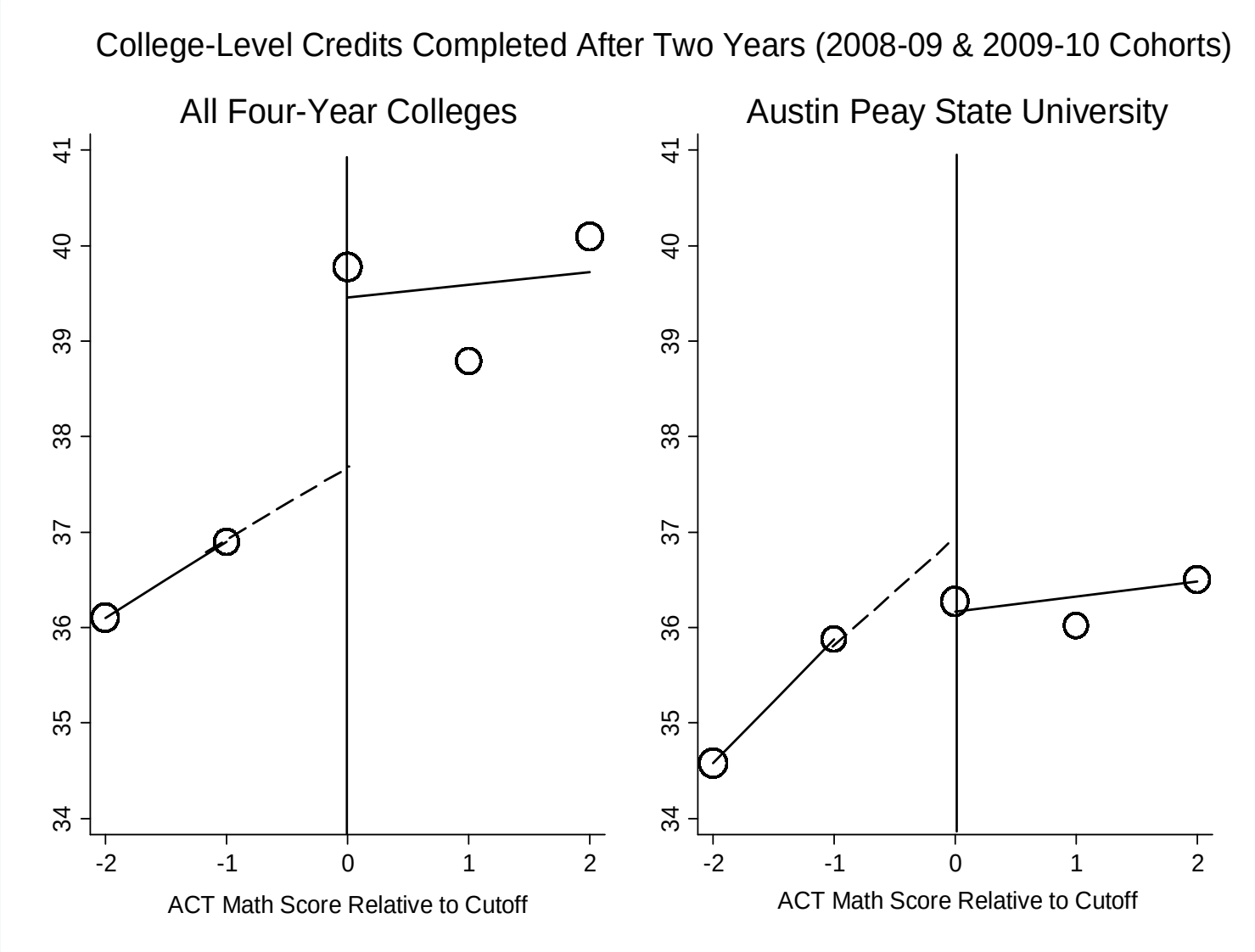

Figure 5: Effects of enrollment in developmental math on the number of college-level credits completed After One Year, Comparing Austin Peay University to other Four-Year Public Colleges, 2008-09 & 2009-10 Cohorts (*from Table 6*). See notes for Figure 4

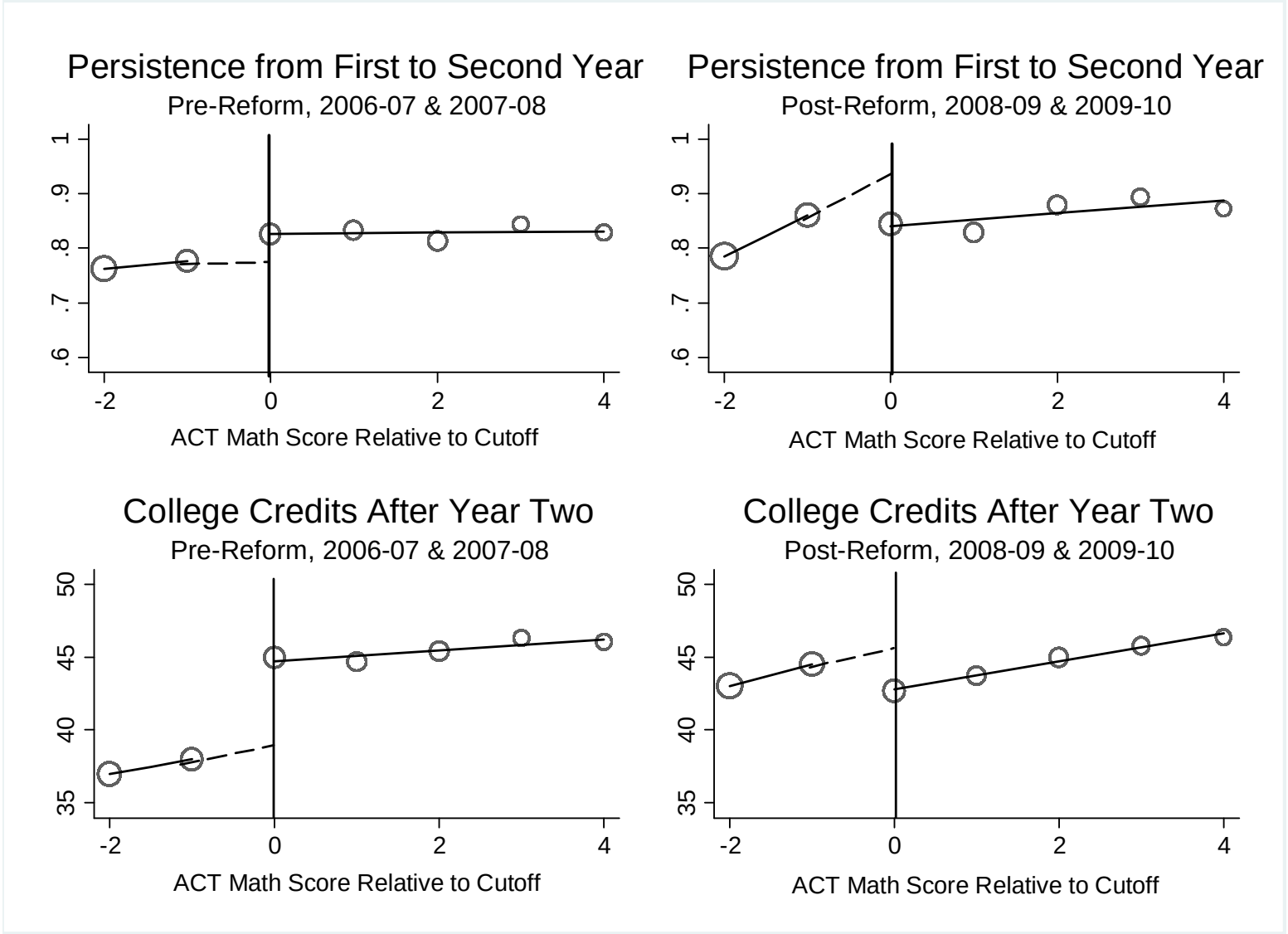

Figure 6: Selected Outcomes Pre- and Post- Reform (Fall 2008) for Students attending Austin Peay State University, Cleveland State Community College, and Jackson State Community College. See notes for Figure 4

Appendix A: 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 the 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 pre-test 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 which will provide a path to achieving the desired learning outcomes. Students will be required to master only the concept deficiencies determined by a pre-test 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/)

Appendix B: Parameter estimates, (standard errors), and approximate p-values testing the stability of key covariates across the discontinuity in ACT Math exam score for 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 by time period of first enrollment

	ALL YEARS (2006-07 to 2009-10 Cohorts)	PRE-REFORM (2006-07 and 2007-08 Cohorts)	POST-REFORM (2008-09 and 2009-10 Cohorts)
Covariates			
Female	-0.048 (0.150)	-0.357* (0.207)	0.283 (0.222)
White	-0.056 (0.159)	-0.221 (0.222)	0.119 (0.231)
Black	0.020 (0.187)	0.148 (0.256)	-0.135 (0.276)
Other Race	0.019 (0.198)	0.134 (0.284)	-0.108 (0.280)
High-School GPA	0.030 (0.058)	-0.060 (0.081)	0.123 (0.084)
Age in first semester	0.072 (0.062)	0.040 (0.085)	0.106 (0.091)
Observations	4713	2291	2422

Notes: The sample is 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.

VITA
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