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HIGH SCHOOL DUAL ENROLLMENT PROGRAMS: ARE WE FAST-TRACKING STUDENTS TOO FAST?

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ABSTRACT

Dual enrollment, an arrangement by which high school students take college courses, is becoming increasingly popular as a mean of improving high school education. However, there is very little rigorous evidence of its impact on student outcomes. To avoid the selection bias that arises because more able students are more likely to take dual enrollment courses, I exploit a statutory mandate in the state of Florida that requires high school students to have a minimum academic standing in order to participate. Using transcript data from two high school cohorts in selected Florida counties and utilizing both general as well as course-specific eligibility requirements, I examine the effect of dual enrollment with two regressions discontinuity designs. For students on the margin of participation eligibility, I find little evidence that dual enrollment significantly improves students' outcomes as measured by high school graduation, college enrollment, and college degree attainment. However, I find that taking one particular challenging dual enrollment course, college algebra, has large and significant effects on the likelihood of obtaining a college degree, with some indication of positive effects on college retention and performance.

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1. Introduction

Roughly one third of high school graduates do not enroll in postsecondary institutions, and a third of those that do are required to first take remedial education to prepare them for college level work (National Center for Education Statistics (NCES) 2003, 2004). One approach to address these problems is Dual Enrollment (hereafter DE), an arrangement by which high school students (typically juniors and seniors) enroll in college courses and earn college credits. DE is based on the notion that participation would promote college enrollment and completion by giving students a stronger preparation and a realistic idea of college academics. However, fast-tracking students through the educational system could potentially discourage students, particularly those academically or emotionally not ready to handle college demands, or might simply not have an effect as long as affects only college-bound students.

While there are no nationwide numbers on the growth of DE programs, two recent reports by the National Center of Education Statistics estimated that about 5% of all high school students (nearly a million students) took a college course during the 2002-03 school year (Kleiner and Lewis 2003), and about 71% of all public high schools offer DE programs (Waits et al. 2005).[1] In Florida, the state analyzed in this paper, DE constitutes the second largest acceleration mechanism with about 14% of high school students taking at least one college course, next to Advanced Placement with 20%.

Despite the popularity and growth of DE programs, there is little evidence of their effectiveness.[2] Two extensive reviews of the literature (Bailey and Karp 2003; Lerner and Brand 2006) conclude that there is no sound evidence showing that DE programs contribute to students' college access and academic success. Assessing their impact is difficult because DE students would likely have better outcomes than non-DE students in the absence of participation. The

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[1] Evidence from growing enrollment of part-time students under the age of 18 at public 2-year colleges— presumably composed mostly by DE students— confirms the perception of a rapid expansion. Between 1995 and 2005, the number of these students enrolled more than doubled (NCES 1998, 2006), while high school enrollment growth was only about 19% over the same time period (NCES 2008).

[2] The literature on the effect of DE is limited and often qualitative in nature. Most of the quantitative evidence available is merely descriptive, simply comparing DE students with non-participants in terms of their educational outcomes (e.g. Windham and Perkins 2001; Adelman 2004; Florida DOE 2004a, 2004b, 2006; Western Interstate Commission for Higher Education 2006). Notably, the empirical available research is overwhelmingly conducted by colleges' office of institutional research or doctoral students as part of their dissertation, with only a few conducted by non-profit research organizations. To my knowledge, there is no quantitative research published in a peer-review journal about the effect of DE on students' outcomes.

selection problem is two-fold: not only students choose to take college courses while in high school based on their academic ability, motivation, and expected gains from participation, but also colleges are allowed to set their own admission requirements to ensure the integrity of their academic programs. In the effort to statistically control for students' differences, a handful of studies have employed a regression framework; though the availability and quality of the data used vary considerably (e.g., Crook 1990; Goodman et al. 2001; Nitzke 2002; Eimers and Mullen 2003; Kim 2006; Karp et al. 2007; Swanson 2008).[3] DE participation has been found to be strongly positively associated to nearly every educational outcome studied. For example, Karp et al. (2007) finds that, compared to non-DE students, DE students in Florida are 17 percentage points more likely to enroll in college and 8 percentage points more likely to initially enroll in a 4-year college, among other positive outcomes, after controlling characteristics that are likely correlated with both DE participation and students' outcomes such as race, gender, academic background, free/reduced price lunch status at school, and school demographics.

While these findings are encouraging, it remains unclear to what extent students' success can be attributed to the program. This paper constitutes the first attempt to use a quasi-experimental method to gauge the causal effect of DE on students' likelihood of high school graduation, college access, and college success. Using a regression discontinuity design, I address the selection problem inherent in DE participation by exploiting a statutory mandate in Florida that restricts enrollment, generating a source of plausible exogenous variation in DE participation. Under Florida's policy, students are mandated to have a minimum grade point average (GPA) in high school in order to take a DE course and, for enrollment in specific courses such as math, to have a minimum score in a college placement test. I exploit both features of the policy to first examine the effect of taking at least one DE course (regardless of its subject area)

[3] Abstracting from the potential failure to properly account for the selection problem, the DE literature suffers from two additional shortcomings—both highlighted by Jackson (2009) in the literature on Advanced Placement. First, all studies control for variables that are determined *after* DE participation, such as HS GPA, college placement scores, or even college choice or enrollment patterns. Controlling for post-treatment variables, potentially affected by DE participation, may induce bias in the estimation of the treatment effect. The second limitation derives from the fact that studies, aiming to uncover the effect of DE on college outcomes, restrict the sample of analysis to college-goers. To the extent that DE affects students' likelihood of going to college, then comparisons of DE and non-DE no longer have a valid causal interpretation (see Angrist and Pischke 2009 for a description of the problem). Both of these shortcomings are often inevitable due to data limitations, since most studies only have access to college transcript files. It is important to note that, even longitudinal datasets such as the NELS: 88/00 that follow students from high school into college, only identify DE courses from the college transcripts, which were collected exclusively for students that enroll in college after high school.

and then the effect of one particular DE course, college-level algebra (MAC 1105), the single most popular DE course after English Composition.

Using both high school and college transcript records for the 2000 and 2001 graduating cohorts of high school students in selected Florida counties, I find little indication that taking dual enrollment (regardless of its subject area) significantly affects students' education progress among students with a high school GPA on the margin of dual enrollment eligibility. The coefficients are generally positive, but often not statistically significant at conventional levels. Drawing from a subsample of students who took Florida's College Placement Test, I find, however, that taking college level algebra as dually enrolled has a substantial influence on students' likelihood of obtaining a college degree, with some indication of positive effects on college persistence and performance. Taken together, these findings suggest that DE have the potential to increase college success but that the quality, subject area, or level of difficulty of the DE experience might be important considerations when assessing the value of DE programs as a policy intervention. It is important to highlight, however, that the RD estimates only speak to the local effect of DE among students on the margin of eligibility, and may not be representative of the gains from participation for students with different academic preparation. In addition, this study is restricted to a small set of counties where there is empirical evidence that the eligibility requirements for participation were binding, limiting the external validity of the results.

The paper is organized as follows. Section 2 provides background on DE programs, the potential mechanisms by which they affects students' outcomes, and Florida's DE policy. Section 3 describes the data for the analysis. Section 4 explains the empirical strategy and its assumptions, and presents the results along with robustness checks. Section 5 concludes the paper.

2. Background

2.1. Dual Enrollment and its Conceptual Framework

DE differs from other so-called 'acceleration mechanisms' which also allow high school students to earn college credits such as Advanced Placement (AP), International Baccalaureate

(IB), or the more recent Advanced International Certificate of Education (AICE).[4] The main difference is that DE consists of a regular college course using an actual college syllabus which grants credits when passing the course. Instead, other programs follow a standardized college-level curriculum and college credits are only obtained with a satisfactory score on an end-of-course examination. Not all DE courses involve a true college experience where high school students are mixed with college students since some courses are taught at the high school campus. Nevertheless, in most states DE instructors must meet the faculty qualifications for an adjunct instructor at a community college.

There are several potential channels by which a DE experience could foster college access and success. First, DE might help students build *human capital* by providing a more rigorous curriculum than traditional high school courses, facilitating the 'academic transition' to the demands of college (Bailey el al. 2002). In addition, the broader scope of curricular options available through DE might also be a more appropriate learning environment to challenge and motivate students with a wide variety of interests. Second, DE could have a *signaling value* for students preparing for admission at selective colleges as it conveys information about students own abilities and motivation, mitigating the information asymmetry in college applications.

Third, DE could potentially give students more accurate *information* about the institutions and their own abilities which translates into better school choices and postsecondary success. Academic-matching between students and colleges is known to significantly affect students' college dropout behavior, persistence, and degree completion (e.g. Light and Strayer 2004). Consistent with the theory of "schooling as an experimentation" (Manski 1989), DE then allows students to 'test the waters' in college and update their prior belief about their academic match with the institution before making their school choice. In addition, simply providing students with information about their own college-readiness early in high school using a college placement test has been found to significantly influence their academic preparation for college (Howell et al. forthcoming). A DE experience might thus be an effective way to provide students with such valuable information, giving an early call to strengthen their skills in particular areas if necessary.

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[4] College Level Examination Program (CLEP) is also considered an acceleration mechanism but, unlike others, it does not involve enrolling in a course and the college credit does not count towards high school graduation.

Last, by *reducing the cost* of college, DE might also foster college access. Students can reduce the time (and forgone earnings) to get a college degree and, in states with subsidized DE programs, the direct cost of a degree. These financial benefits might be a key factor for pursuing a college degree among low-income students (Greenberg 1989). In addition, DE might also overcome other students' barriers to college by helping students make the 'psychological transition' (Bailey et al. 2002). Since DE students get familiar with the college application and enrollment process typically with additional support from the high school counselor or college DE coordinator, the experience might encourage postsecondary enrollment for students who would have otherwise fallen between the cracks in the education system.

While DE can be viewed as a potential tool to increase college access and success, it is not without controversy. A common concern of DE programs is that it might lower students' self-esteem and educational aspirations. It is not clear that students who are marginally successful in high school can do college level work (Bailey and Karp 2003). A course failure might discourage postsecondary education altogether or it might set students on a non-academic path too early in their lives. Given that DE programs are mostly offered through 2-year colleges, the DE experience might also induce students that would have otherwise attended a 4-year college after HS graduation to enroll in community colleges, reducing their educational attainment due to high transfer costs and less emphasis on bachelor's degree, among other barriers. In addition, the ability of DE programs to actually provide college-level curriculum has been questioned (e.g. Johnstone and Del Genio 2001). Allowing high school students into the class could dilute the quality of education at the college campus, and many are skeptical about the quality of DE courses taught by high school teachers in the high school campus. Last but not least, one could also be concerned about the possible general equilibrium effects of DE programs. The possibility of diverting students to college courses might reduce the incentives to improve the level of high school courses available to those that do not participate, thus exacerbating the already existing inequities in postsecondary opportunity (Museus et al. 2007).

2.2. Florida's Dual Enrollment Policy

Florida has been at the forefront of many innovations in educational policy, and DE is not an exception. The state provides students with clear incentives to participate in DE. Florida is one of 6 states that pay for DE courses, while most other states require the school district or the students themselves to pay for them (Western Interstate Commission for Higher Education (WICHE) 2006). This funding provision not only promotes program participation but also enables access for students from low-income households. In addition, Florida funds *both* high schools and colleges for DE courses (Office of Program Policy and Government Accountability (OPPAGA) 2006a), encouraging schools to support students' participation.[5]

Florida is also one of only 15 states that allows students to simultaneously earn *both* a high school credit and a postsecondary credit, *and* guarantees that the credits counts towards high school graduation requirements (WICHE 2006). Successfully completed courses may apply towards the requirements necessary to earn a certificate or degree thereby shortening the time it takes to earn a postsecondary award. Florida has also developed a statewide course numbering system that eases the transfer of credits among the state's public colleges and universities and, beginning in 2006, the legislature requires state colleges to weight DE courses the same as AP, IB, or AICE courses when calculating their own GPA for admissions decisions. This, coupled with the fact that students in Florida are exempt from the payment of registration, tuition, books, and laboratory fees related to the course, makes the DE program an attractive acceleration mechanism.

Florida's strong support for DE has been crystallized in a widespread program, with all 28 community colleges having an articulation agreement in place with its serving district and all school districts taking advantage of such possibility. DE is the second most popular choice among different acceleration mechanisms—the first choice being AP. Overall, about 14% of the high school students in this study took at least one academic DE course, while 20% took AP and 3% IB.

2.2.1 Dual Enrollment Eligibility and Enrollment Process

[5] Despite Florida's "double-dipping" funding formula which pays both the high school and the college for each student, DE has proven to be a cost-saving strategy for the state as well. As any other accelerating mechanism, DE saves tax-payers money by reducing the number of courses and time it takes for a student to get a postsecondary degree. DE is relatively cost-effective even when compared with other acceleration mechanisms because: (a) the rate at which students accumulate college credits is considerably higher in DE than in any other programs (OPPAGA 2006b), (b) DE courses are almost exclusively offered by the relatively low-cost local community college, and (c) other programs have additional performance-based incentive funding (OPPAGA 2006c). OPPAGA (2006a) provides further information on funding for the different acceleration programs.

To be eligible for DE in Florida, students are mandated to have a minimum of 3.0 un-weighted GPA and demonstrate college readiness with the College Placement Test (CPT) (Florida Statute 1007.271).[6] The statute is not specific regarding what portions of the CPT are appropriate for admission into specific courses. However, common practice has been to set the same requirements for both DE and regular college students. In particular, students must pass the math (English) portion of the CPT for math (English) courses, and fulfill any course pre-requisites when required. An important difference is that, unlike regular students, DE students whose placement CPT score is below the state minimum required score for '*college-readiness*' (defined in Rule 6A-10.0315) are not allowed to enroll in remediation (i.e. college preparatory instruction[7]). Remedial courses as well as physical education courses are excluded from the DE program.

With a few exceptions, colleges set their GPA requirements at the minimum 3.0 required by statute, as evidenced by my compilation of DE agreements and college catalogs for the years relevant to this study. Only a few college courses (typically in math, English, or science) have a minimum CPT score requirement. Colleges must follow statewide cutoff scores for placement into certain introductory courses such as intermediate-algebra or freshman English composition, but are free to define the cutoffs for placement into more advanced courses. In particular, students can bypass intermediate algebra (MAT1103) and place directly in college algebra (MAC 1105) provided they meet the college-specific cutoff score.

Florida statute allows districts and colleges to make exceptions to the GPA requirement or set additional admission criteria for DE participation if those are written on their inter-institutional articulation agreement. The exceptions are often granted on a case-by-case basis based on a joint decision between the college DE coordinator and the high school counselor or principal. The most common additional admission requirement is a letter of recommendation from the teacher or counselor (about 65% of the districts according to Florida board of Education 2003), with only a few colleges placing restrictions on students' age or grade level.

[6] The Florida statute also stipulates a minimum of 2.0 un-weighted GPA for DE vocational courses. Vocational DE students are a small and distinct group of DE students, with very few combining both vocational and academic courses. Unfortunately, a separate RD analysis on DE vocational experiences is not feasible due to small sample sizes.

[7] College remedial or developmental courses are designed to help academically unprepared students for college-level work. Remedial credits do not count towards college degree requirements.

A standard DE application process involves close interaction between students and the high school counselor. Based on students' scores and career goals, counselors help students make an appropriate course selection and complete the application form. The form is typically a one-page document with students' information, the course selected, and a statement (often signed by the high school counselor) of the current GPA and CPT scores. Students and parents sign the application and allow the release of students' scores and high school transcript to the college. After the application form is submitted, the student is considered a college student and is subject to the same standards than regular matriculated students.

2. Data

This study uses a unique dataset obtained from the Florida Department of Education which includes all public school students in the 2000-01 and 2001-02 high school senior cohort, and tracks their postsecondary outcomes in the state's public system through summer 2007.[8] These state's administrative records provide transcript information on all the courses taken in high school and college, with a unique identifier for DE courses and their type (academic or vocational). The data contain basic demographic characteristics such as age, gender, race/ethnicity, English language proficiency, and free lunch eligibility, as well as students' 10th grade state standardized test scores (FCAT), college placement test scores, and GPA. In addition, state records on postsecondary enrollment (though not degree attainment) are complemented with the National Student Clearinghouse data, which tracks postsecondary enrollment of students as they enroll in out-of-state colleges or in private institutions.[9] Last, districts characteristics such as median income and urbanicity are obtained from the 2000 Common Core Data and Census.[10]

GPA eligibility requirements for DE are obtained from the inter-institutional articulation agreements between the districts and colleges or directly from the college catalogs for the years

[8] I restrict the sample to students who did the entire high school education in Florida (grades 10th through 12th) for whom I can calculate their cumulative high school GPA to determine dual enrollment eligibility based on their course transcript.

[9] The National Student Clearinghouse tracks more than 92% of college enrollment nationally.

[10] This study uses the same cohort of students as Karp et al. (2009) but employs an augmented dataset that includes pre-DE standardized test scores (10th grade FCAT), college placement tests, and clearinghouse data. In addition, the data in this paper tracks students for two years longer into college, allowing for sufficient time to evaluate the effect of DE on postsecondary degree attainment. I follow, however, different sample restrictions. Specifically, I a) define DE as students who took at least one academic DE (i.e. not including vocational courses), b) identify DE using college transcripts instead of the high school transcript (which match on about 75% of the DE courses), c) restrict to public school students with the entire high school experience in Florida.

relevant for the study.[11] Five out of the 28 colleges could not provide written documentation of the GPA requirements going back that far and the information was collected through personal communication with the DE coordinator at the college. The 3.0 state mandate was assumed for three colleges where the coordinator did not respond to phone and email requests. (Appendix A.1. provides a tally of the different GPA requirements.) The college placement test (CPT) cutoff scores for placement into college algebra (which is the same for DE students as for regular matriculated college students) was obtained from the college catalogs and, when missing, augmented with state documentation on placement scores.[12]

There are some important limitations with the data. First, for the years used in this study the state only kept records of students' highest score on the college placement tests and did not collect information about the date the test was taken. Since highly motivated students who score just below the required cutoff can re-take and pass the test, a natural concern is that students just above and below the cutoff are no longer comparable, violating an assumption of the RD design. By examining the density of the score, I show no evidence of "re-testing bias" being present in the sample analyzed.

An additional challenge comes from the absence of test dates. Given that the CPT math score is used for placement into math courses both for DE and for regular college students, I cannot distinguish students who took the test during high school for DE purposes from those who took it after high school graduation for placement purposes in a community college. While I cannot rule out the possibility that the effect of DE algebra might be confounded with the effect of just taking algebra (regardless whether in high school), I show in that enrollment in algebra as a regular non-DE college course does not change discontinuously at the placement cutoff, suggesting that any observed effect at the cutoff could be reasonably attributed to the DE algebra experience. Though admittedly puzzling, I provide two pieces of evidence that help rationalize this finding: a) most students who fail to meet the cutoff take a lower level math course (pre-algebra) which satisfies the pre-requisites to later enroll in algebra, and b) DE algebra substitutes regular college algebra, depressing overall participation rates in the latter among eligible students.

[11] With the exception of 2 colleges for which only 2002-03 requirements were available through an official document, GPA cutoffs are those valid from the years 2000 through 2002, when the students in the sample were most likely to take dual enrollment.
[12] http://www.fldoe.org/articulation/pdf/acc_102506ada.pdf (retrieved on April 30th, 2009).

A third limitation of the data is that it only provides information about students who made it to the 12th grade, but does not include data on earlier dropouts. To the extent that previous DE experience contributed to early dropout behavior, the estimation of the effect of DE will be biased. However, it is unlikely that at-risk students would be on the margin of eligibility for DE since Florida academic requirements for participation are relatively high.

Another drawback of the data is that college degree attainment and college GPA are only identified for students that enrolled in the state higher education public system. This is because I only have National Student Clearinghouse data on enrollment in private and out-of-state colleges but not on student's outcomes. In order to address this missing data problem, I follow the standard approach of imputing zero when students have no postsecondary records. This approach would induce bias in the estimation if students that barely pass the DE eligibility cutoff were disproportionately more likely to attend college outside Florida or in one of Florida's private institutions than students who barely fail the cutoff. However, I show that the discontinuity in the probability of enrolling outside Florida's public postsecondary sector (i.e. having missing college outcome information) at the threshold of DE eligibility is small and statistically insignificant (Table 3). In addition, the number of students that would be incorrectly classified as not having a college degree is likely to be small since only 7.7% of the students in the full sample went to college outside Florida and 4.5% attended a Florida private institution.

The key variable of interest is whether students took an *academic DE* course.[13] I define "treatment" in two different ways. First, I look at the effect of taking any DE course (regardless of the subject area). Second, I examine the effect of taking one particular DE course, college algebra (MAC 1105), which covers topics such as graphing functions and solving systems of equations and consists on the first course in the math sequence that counts towards the state requirements for an associates degree.[14,15] In both cases, I focus on DE courses taken in 12th

[13] I exclude academic dual enrollment courses taken at the state university system, at special education centers, or taken on a full-time basis (i.e., early enrollments). Only about 0.7% of all dual enrollment courses are not directly offered by a community college and about 2.5% are early enrollments. These courses are typically subject to different eligibility requirements. In addition, I exclude dual enrollment courses with missing enrollment date from the treatment definition.

[14] Florida's Statewide Course Numbering System stipulate the course content to include: functions and functional notations, domains and ranges of functions, graphs of functions and relations, operations on functions, inverse functions, linear functions, quadratic functions, rational functions, absolute value functions, radical functions, exponential and logarithmic properties, exponential and logarithmic functions, exponential and logarithmic equations, systems of equations and inequalities, and applications.

grade since that is when most of the DE experience takes place: 82% of DE students take a DE course in their senior year, and 77% of high school students that take college algebra do so in their senior year.[16]

This paper measures the effect of DE on several academic outcomes. The first outcome of interest is high school graduation, which includes any type of diploma offered in Florida (regular or special education diplomas, certificate of completion, and GED). Second, I examine the effect of DE on college access using two measures: whether students enroll in a postsecondary institution (either 2-year or 4-year) after high school graduation and whether they first enroll in a 4-year institution. College access is observed for all students regardless of their choice of public vs. private or in- vs. out-of-state institution, owing to the National Student Clearinghouse data. While enrollment in higher education is of prime policy interest, it is important to also explore the effect on its type. DE might increase students' likelihood of admissions at 4-year colleges, either through a stronger academic preparation or through a better signal of students' innate unobserved abilities. At the same time, DE might also divert students who would have gone to 4-year institutions into 2-year colleges since it provides a unique opportunity for community colleges to increase their institutional status and recruit higher-income, better prepared students (Morest and Karp 2006). Thus, whether DE fosters 4-year enrollments remains an empirical question.

I also examine the effect of DE on college success, measured by: persistence into second term (non-summer enrollment in term following first enrollment term) and into second year (enrollment in the academic year following first enrollment year), college degree attainment (associate (AA) and bachelors (BA) degree obtained within a 5-6 year window depending on the cohort), and first-year college GPA (cumulated GPA in the first 30 college credits). In order to avoid reverse causality problems by using DE course both as outcome and treatment variable, only non-DE credits were considered in the college GPA calculation.

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[15] Other courses such as college English Composition (ENC 1101) or Intermediate Algebra (MAT 1033) also have CPT score requirements for enrollment. However, the scores that determines placement into these courses are the same used for placement into college remediation, making it impossible to separately identify their effect from any potential effect of college remediation. Instead, the CPT score requirement for placement into college Algebra, the course analyzed in this paper, is above that used for assignment into remediation.

[16] Ideally, one would be interested in separately identify the effect of taking dual enrollment at different times during high school (e.g., junior vs. senior year). However, the current data does not provide enough variation in course taking patterns to identify these dynamic effects. Most of the DE students take DE exclusively in 12th grade (about 67%), with the majority of the remaining students taking both in 11th and 12th grade. DE participation in 11th grade only is very rare (less than 5% of the students).

3 Empirical Strategy and Findings

4.1. Research Design and Estimation

DE is a voluntary program, and participants are very different than non-participants. Table 1 shows the descriptive statistics broken down by participation status using statewide data. DE students are more likely to be female, white, native English speakers, and come from economically advantaged households (as proxied by free/reduced price lunch status) when compared to non-DE students. DE students also have a stronger academic preparation than non-DE students according to their 10th grade standardized scores in both Reading and Math and high school GPA. Perhaps not surprisingly, DE students are more likely to experience positive postsecondary education outcomes than non-DE students. They are about 30 percentage points more likely to enroll in college after high school and 25 percentage points more likely to first enroll in a 4-year institution. DE students also have a lower incidence of college remediation and earn college degrees at significantly higher rates than non-DE students. These statistics provide the motivation to use a quasi-experimental technique to gauge the causal effect of the program.

To avoid the selection bias that arises because more able students are more likely to participate in DE, I exploit a statutory mandate in the state of Florida that requires high school students to have a minimum GPA in order to enroll in college courses and, in specific courses such as college level math, a passing score in the College Placement Exam. This policy creates an ideal setting to estimate the program effect using a Regression Discontinuity (RD) design.

The basic implementation of the RD design identifies the impact of the program by comparing outcomes of students who barely pass with those that barely miss the required GPA (or CPT) cutoff. Arguably, students with a GPA just under a 3.0 cutoff are on average very similar in many relevant respects to students with a score just over the cutoff, but these small differences in the GPA leads to a large difference in DE eligibility and participation. However, not every student above the required cutoff takes a DE course, and not every student below the cutoff is disallowed enrollment since exceptions are allowed on a case-by-case basis with agreement of the high school counselor and the DE college coordinator. This situation, referred to as a “Fuzzy” RD design (Campbell 1969), requires that the difference in average outcomes of students just above and below the cutoff be scaled up by the difference in the probability of enrolling in DE.

Following Imbens and Lemieux (2008), I use a local linear regression to estimate the program effect in a two-stage least square instrumental variable specification of the form:

$$DE_i = \delta_0 + \delta_1 Above_i + \delta_2(Score\_Gap_i * Above_i) + \delta_3(Score\_Gap_i * Below_i) + \mathbf{X}_i\delta + \varepsilon_i \quad (1)$$

$$Y_i = \gamma_0 + \gamma_1 DE_i' + \gamma_2(Score\_Gap_i * Above_i) + \gamma_3(Score\_Gap_i * Below_i) + \mathbf{X}_i\gamma + \varepsilon_i \quad (2)$$

where *i* is the student, DE_i is an indicator that takes the value one if the student *i* took a DE course (or DE algebra) in 12th grade and zero otherwise, $Above_i$ ($Below_i$) is an indicator that the student is above (below) the cutoff, $Score\_Gap_i$ is the un-weighted GPA_{11th} or CPT score centered around the cutoff (thus measuring distance to the minimum requirement), DE_i' is the predicted probability from the first stage in equation (1), and X_i is a vector of covariates including students' gender, race, free/reduced price lunch status, 10th grade standardized scores, and high school level demographics.[17] Because students can only choose to take DE from their local community college, vector X_i also includes community college fixed effects along with cohort fixed effects.[18] The model is estimated locally using data incrementally close to the cutoff following different bandwidths around the cutoff. In all specifications, standard errors are heteroskedasticity-robust and clustered at the score level.[19] The parameter of interest is γ_1 which captures what Angrist, Imbens, and Rubin (1996) call "local average treatment effect" (LATE): the effect of DE participation for those students that were induced to participate because of their eligibility status. This average effect of DE participation is also 'local' in that it is only identified

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[17] Note that controlling for additional covariates is not necessary for identification since the RD strategy is based on the assumption that close to the cutoff participation is "as good as" randomized (i.e. conditional on the score being close to the cutoff, other covariates are independent of participation). However, just like in a pure randomized study, adding controls helps improve the precision of the estimate by reducing residual variation. In most cases, I will report covariate-adjusted estimates but show that adding covariate does not materially affect the results.

[18] A similar specification (not shown) including HS fixed effects do not materially affect the results. This supports the notion that students are students around the cutoff are evenly distributed within schools, consistent with a smooth determination of the high school GPA.

[19] Lee and Card (2008) recommends clustering standard errors when the variable that determines eligibility is discrete such as the CPT. I also report clustered standard errors when using the GPA though the difference is immaterial.

close to the eligibility cutoff. As such, it is not necessarily indicative of the effect for other students.[20]

Not all colleges shared the same 3.0 cutoff requirement, and colleges use different CPT math score cutoffs for taking college algebra, most ranging from 85 to 95 points in a 20-120 test score range. This does not present a challenge for an RD strategy given that students in Florida are required to take DE courses sponsored by their local community college, avoiding concerns about self-selection bias associated with students choosing DE courses at colleges based on their cutoff policies.

There is one important methodological consideration when estimating the effect of DE on postsecondary outcomes. Ideally, one would be interested in measuring the effect of DE on students' probability of going to college and then, conditional on college attendance, the effect of DE on college success outcomes such as the probability of obtaining a bachelors degree. However, to the extent that DE has an effect on college-going, disentangling both effects is methodologically challenging even in a pure-randomized setting. For a randomized study to uncover the causal effect of DE on college success once in college (i.e. conditional on college access) it would have to be the case that all students (both randomized in and out of DE in high school) are forced to go to college— an experiment practically unfeasible.

The standard approach to measure college success outcomes has been to restrict the sample of analysis to students that enroll in college.[21] Given that DE might change the composition of students that go to college, limiting the sample on college-going induces sample selection bias. The direction of this sample selection bias is unclear. Not only might DE students that went to college be different than those DE students who did not, but they might also be different to non-DE students who went to college without the program's help. The approach in this paper is to include in the sample all high school students and impute zero on postsecondary outcomes for students that do not go to college. The effects on these outcomes represent the overall effect of DE— a combination of the effect of DE on the probability of college success given the effect on college-going and given improvements in academic performance.

[20] The binary nature of the treatment variable and some of the outcomes might suggest the use of a probit or logit model instead. However, these models are not well-suited to an instrumental variable strategy. Conventional two-stage least square estimator is consistent regardless of the linearity of the first-stage and captures the local average treatment effect regardless of whether the dependent variable is binary (Angrist 2001; Angrist and Pischke 2009).
[21] A notable exception is Jackson (2009) on the effect of Advanced Placement, whose approach I follow.

4.2. Selected Sample: "GPA sample" and "CPT sample"

A necessary condition for an RD study is that participation in DE does, indeed, change discontinuously at the required cutoff. Figure 1 shows the mean 12th grade DE participation (any course) by the 11th grade cumulative high school GPA, broken down by community college.[22] Similarly, figure 2 shows the mean 12th grade DE participation in college algebra (MAC 1105) by the CPT score. While the probability of DE participation increases monotonically with students' ability measures across all colleges, inspection of figures suggest that compliance with college-specific requirements varies considerably from college to college. Figures 3 and 4 display the formal local linear estimates of the discontinuity in participation at the GPA and CPT cutoff, respectively.[23] Because students in a given district can only take DE from the local community college, the discontinuity is estimated by community college.[24] I restrict the analysis to the subsample of DE programs for which there is a statistically significant discontinuity in participation at the required cutoff of at least 7.5 percentage points (indicated by the thick horizontal line in the figures) though I relax the criteria for robustness checks.[25] Following this criteria, the selected colleges are: Brevard, Indian River, St. Johns River, Lake-City, and Valencia for the DE analysis (any course) (hereafter, "*GPA sample*"); and Gulf-Coast, Lake-

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[22] Since the largest enrollment in dual enrollment courses occurs in the fall semester of students' senior year, I use the cumulative 11th grade GPA up through the summer before the senior year to determine eligibility for 12th grade courses. Given the small number of courses taken during the summer, this GPA is nearly identical to that through the end of the 11th grade spring semester. High schools with non-standard academic calendars were normalized to a three semester calendar (fall, spring, summer) in the calculation of GPA.

[23] I experimented with alternative definitions of dual enrollment and eligibility in the estimation of the discontinuity in dual enrollment participation. Notably, I examined whether there were differences in enforcement of the eligibility requirements by the location of the dual enrollment course (college or high school campus), by cohort of students, and by the proximity of the high school to the colleges (high schools in the same zip-code as a community college campus might have higher dual enrollment participation rate which, conditional on equal enforcement of requirements, makes it easier to detect discontinuities than in high schools with low participation rate). In addition, I explored whether schools were using weighted GPA for eligibility (instead of un-weighted) following the most frequent weighting scheme reported by districts according to the Florida Board of Education study (2003). I also explored using the GPA up through fall of junior year (allowing for delays in high school's grade processing) or the highest GPA of fall and spring semesters (allowing for selective reporting). Last, I examined the discontinuity using the CPT conditional on those that passed the GPA (since college might enforce both cutoffs for enrollment in algebra course). None of these exercises changed the general patterns between scores and participation.

[24] Given the many-to-one partnership between districts and the local community college, the discontinuity in dual enrollment participation could have been estimated at the district or even high school level without loss of generality. However, the sample size becomes too small to get precise estimates at such disaggregated level. It is important to emphasize that each community college has the same dual enrollment application process and requirements for all the districts in its attendance-area.

[25] The CPT sample for the main analysis is selected based on participation in both DE math and English (both of which have eligibility requirements) since this would provide more robust evidence that the college follows the requirements.

Sumter, South Florida, and Valencia for the DE math analysis (hereafter, "*CPT sample*"). Overall, the analyses use data from 8 different colleges (one college is included in both GPA and CPT samples), serving 34% of Florida's 67 school districts and educating about a third of all DE students in the state.[26]

Figures 5 and 6 plots mean DE participation by each value of the score, along with the first stage fitted values from equation (1). Having an eligible GPA at the end of the 11th grade is estimated to increase 12th grade DE take-up by about 10 percentage points off of a base of about 20 percent just below the required cutoff.[27] Having an eligible CPT math score increases the likelihood of enrolling in DE algebra in 12th grade by about 22 percentage points at the required cutoff, with participation gradually tailing off with higher test scores as students can place directly into higher level math courses.[28] In the case of DE algebra, however, participation during both junior and senior year change discontinuously with the same score (shown in Table 3); thus, the effect of taking the course at different times cannot be disentangled.

4.3. Descriptive Statistics on Dual Enrollment in State versus Selected Samples

[26] One plausible explanation for the lack of discontinuity in DE participation in many colleges relates to the severe overcrowding problem that Florida was facing during this time period exacerbated by class-size reduction pressures, later crystallized in a voter-approved amendment of Section 1 of Article IX of the State Constitution in 2002. DE was regarded as an effective strategy to alleviate overpopulated classrooms (Florida Board of Education 2003) and anecdotal evidence suggests that districts and colleges may have waived GPA requirements to rapidly increase DE participation. Another possible explanation for the lack of discontinuity in participation is the low participation rates in some colleges. If DE is not a popular program, even with strict enforcement of the requirements, it is difficult to get precise estimates of small differences in mean participation with limited data.
In the particular case of DE algebra, the lack of discontinuity is likely attributed to two factors. One factor is that students may substitute CPT scores with SAT or ACT scores in their dual enrollment application, and I only focus on the variation in participation generated by the CPT score. It is important to highlight that using the CPT score for students that took multiple tests just creates more "fuzziness" or noise in the estimation of the discontinuity as long as CPT barely failers are not SAT/ACT barely passers or vice-versa. Although conversion of the SAT/ACT into CPT scores is possible thorough College Board rules, it is not appropriate for an RD study since it leads to artificial stacking at certain values of the CPT (Calcagno and Long 2008). In addition, since college catalogs do not typically indicate the CPT equivalents for advanced courses, the exact SAT or ACT cutoff scores for college algebra are unknown. A separate analysis using the SAT and ACT scores (not shown) reveals no noticeable discontinuity in participation at any score for most colleges. The second factor is that college may use additional testing requirement above and beyond the CPT score. In fact, about 40% of the colleges require students to take a College Level Math (CLM) test in addition to the regular CPT math test (which covers only elementary algebra skills) for placement into college algebra course— a score not available in the data. None of the colleges in the selected CPT sample require this additional testing.
[27] DE participation in 11th grade also increases at the cutoff with respect to the cumulative 10th grade GPA, but the discontinuity is about half the size of that in 12th grade.
[28] These discontinuities, despite being arguably small in magnitude, are strong instruments for DE participation. The F-test on the excluded instrument renders a statistics of about 43.5 and 53.3 for DE and DE math, respectively— both well-above the recommended rule-of-thumb of 10 (Stock, Wright, and Yofo 2002).

Table 2 compares DE students in the GPA and CPT samples with the average in the state. While the racial composition of DE participants in the selected samples is quite similar, participants in both samples are slightly less likely to be Black or Hispanic than the average DE student in the state. Notably, DE students in districts selected in the GPA sample are less likely to come from economically disadvantaged households. Instead, DE students in the CPT sample are slightly more likely to be poor; 27% receive free/reduced-price lunch compared to 23% in the entire state and 20% in the GPA sample. This difference is likely explained by the fact that CPT test takers are a selected group of students in any given district, mostly students who are seriously considering community college as an affordable alternative for their postsecondary education. Despite any differences in the race and economic standing, DE students in the selected samples are somewhat similar to the average in the state in terms of their academic ability or preparation; though students in the CPT sample are below average in both Math and Reading standardized scores.

The DE experience in the samples selected for the analysis is considerably different than the average in the state. DE programs in the selected samples are larger than on average: the percentage of high school students taking at least one DE course is 27% in the GPA sample and 51% in the CPT sample; both rates exceed the state average of 14%. Recall that the CPT sample includes only students with a valid CPT score in the districts served by the selected community college. Thus, the disproportionately higher participation rate among these students reflects the CPT requirement in the DE application. A typical DE student takes about 4 DE courses and earns about 10 college credits while in high school (success rate of about 77%), with the averages being slightly higher for the selected samples.

DE algebra (MAC 1105), a course analyzed in this study, is the single most popular course among DE students after DE English composition, with a take-up rate of about 19%. Interestingly, only 5% of DE students take DE courses exclusively at the high school campus. Most students have a DE experience that combines courses taken either at the college and high school campuses (58%) or at the college campus (37%).Compared to the state average, students in the selected sample are substituting away from a DE experience that consists on only courses at the college campus to an experience that combines both high school and the college locations.[29]

4.4. Validity of the Research Design

The fundamental assumption of a RD design is that, with the exception of the treatment, any determinants of the outcome vary "smoothly" around the cutoff.[30] While this assumption is at some level fundamentally non-testable, for validity checks I assess whether (a) students above and below the cutoff are observationally comparable and (b) no other treatment assignment changes discontinuously at the cutoff.

A direct assessment of the comparability of students just above and below the cutoffs is shown in Table 3. The table shows local linear estimates of the discontinuity in pre-determined students' characteristics at the GPA and CPT cutoff using data incrementally close to the cutoff. Overall, there is no evidence that students above the cutoff are statistically significantly different than those below in observable characteristics known to affect students' outcomes (gender, race, English fluency, poverty, and pre-DE English and math test scores). A few characteristics (such as the proportion of Blacks in the GPA sample or the mean 10th grade math test score in the CPT sample) present a significant discontinuity using the larger bandwidth around the cutoff, but become insignificant when using a narrowly defined sample of the data. Only one characteristic- the proportion of Hispanic students in the CPT sample— presents a small significant discontinuity in a small bandwidth around the cutoff but not in the broader sample, suggesting that this difference might be driven by chance alone. In fact, a Chi-square test that all the discontinuities are jointly zero reveals that the data is consistent with no discontinuities for any of the observed covariates in both the GPA and CPT samples for students in a narrow bandwidth around the cutoff.

Given that the cutoff scores for DE are well known, a concern would be that highly motivated students who barely missed the cutoff exert additional effort (or choose their courses

[29] This provides some support to the overcrowding hypothesis that argued that schools that had less pressure to get students out of schools buildings were more likely to enforce dual enrollment participation cutoffs.
[30] The interpretation of the fuzzy RD-IV estimate as causal requires the additional assumption of monotonicity (Imbens and Angrist 1994). In this context, that participation in DE is monotonic in eligibility implies that becoming eligible cannot cause both to take DE and to refuse taking DE (i.e., it rules out the existence of "defiers"— students who would take DE if ineligible but not take DE if eligible).

strategically) to boost their GPA or re-take the CPT exam to become eligible. This type of gaming behavior would render students on either side of the cutoff who are different in unobservable ways, violating the RD assumptions. A diagnostic test for this endogenous sorting of students involves an analysis of the density of the score around the cutoff (McCrary 2008). Figure 7 (top) shows the histogram for the GPA, both for the entire GPA distribution and for values close to the cutoff. A visual inspection of the graphs reveals a bell-shaped density of the GPA with a spike at the number of students with an exact 3.0 GPA. It is important to highlight that while a discontinuous density of the score around the cutoff would be consistent with endogenous sorting of students, it is not necessarily caused by it. I argue that, in this particular context, the discontinuous nature of the GPA is likely a consequence of the GPA determination based on coarse letter grade system.

From a theoretical standpoint, while students certainly influence their scores, it seems difficult that they could control their grade point average perfectly. Course letter grades get converted into a 5-digit number according to a rule defined by statute (Florida Statute 1003.437). A large number of courses define a student's cumulative GPA, making it difficult to accurately predict a strategy to go from a 2.9999 to a 3.0001 GPA. Empirically, the stacking of students does not only occur at the 3.0 cutoff used for eligibility for DE courses, but also at other rounded-values of the GPA such as 1, 2, 2.5, or 4 (Figure 7, bottom graph), suggesting a mechanical property of the GPA determination at play.[31]

Figure 8 shows the density of the CPT score which does not support the idea of students re-testing the exam to become eligible for a college algebra course. The estimated discontinuity in the empirical density is small and statistically insignificant (coefficient of 0.003 with standard error of 0.002), and suggests low stakes consequences of not passing the cutoff for students with such a high CPT score. Students who barely fail the requirements for college algebra can enroll

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[31] McCrary(2008) suggests a formal test to estimate the discontinuity in the density in RD designs. Using McCrary's Stata code (downloaded from his personal website), I obtained a significant discontinuity at the cutoff (log difference in height=0.45, std=0.041). However, as pointed by Martorell and McFarlin (2009), McCrary test assumes a continuous and well-behaved distribution along the support of the variable which might not hold in the GPA (and similarly in the CPT) where the number of students "piled-up" at certain discrete values. If instead of using McCrary framework, I test the discontinuity in the empirical density at the cutoff locally, controlling for a linear term in the GPA on either side of the cutoff along with additional covariates, the estimate of the discontinuity is small (implying a 0.12% point increase in the density) and statistically insignificant. Importantly, even if there is a sizeable discontinuity in the density, it seems unlikely to be driven by students' strategic manipulation.

in a lower level course (intermediate algebra) which also grants college-level credits that counts towards postsecondary degrees— an strategy that many students follow even if eligible.

The second testable implication of the RD assumption rules out the existence of other treatment changing discontinuously at the DE assignment cutoff. A natural concern is that districts may use the same GPA cutoff requirement for DE courses for placement into other advanced courses such as AP, IB, or Honors courses in high school.[32] To the extent that this practice holds, then the effect of DE cannot be disentangled for the effect of other programs. However there is no evidence that districts in the selected GPA sample are using the same DE cutoffs for other courses (Table 3). Similarly, participation in other advanced courses does not change discontinuously at the CPT score but, as indicated before, both 11th and 12th participation in college algebra increase for eligible students. Interestingly, there is a small indication that students with an eligible CPT for college algebra substitute away from AP courses in their senior year, but the effect is not significant.

While a 3.0 high school GPA can be viewed as a milestone for future college enrollment, the 11th grade GPA employed in this analysis is a year before college application and thus is unlikely to position students just above and just below any differently in terms of college applications. In addition, the state merit scholarship with a 3.0 minimum GPA requirement (Florida Medallion Scholars Award which pays 75% of college tuition), uses a different GPA based on selected high school courses and a particular weighting scheme.

The CPT math cutoff score for DE algebra does not determine eligibility for other likely candidates such as college scholarship, college admissions, college remediation, or college algebra enrollment after high school. First, the only state scholarship that requires a CPT score is a vocational scholarship (Florida Gold Seal) but has a 72 score cutoff which is considerably lower than the 85-95 used for placement into algebra. Second, the CPT test is only used in Florida's community college system for placement (not admission) purposes since these are open-admission colleges. Four-year colleges require instead a SAT or ACT for admissions. Third, unlike freshman English composition, the state minimum cutoff score that places students into college remediation is different than the one used for placement in the college algebra

[32] About 32% of the districts in Florida self-reported using the GPA for placement into AP courses, 45% for placement into IB, and 23% into Honors courses (Florida Board of Education 2003).

course, the course studied here.[33] This is shown in figure 9 which displays enrollment patterns in math college remediation and shows that the cutoff used for assignment into remediation (solid line) is lower than the one used for college algebra which is defined by the college (range in dotted lines). Given that students can use the same score for placement in DE or later for placement after high school graduation, the fact that these courses cutoffs are different allows isolating the DE effect form any effect of remediation.

Last, given that the CPT cutoff is used for placement into college algebra course for all students regardless of their DE status, it becomes important to sort out whether the observed effect can be solely attributed to DE versus simply to college algebra. Ideally, we would want to be able to identify those students that took the CPT for DE purposes ("potential DE math takers") and those that took the exam once in the community college as a regular matriculated student ("potential math takers"). Provided these two types of students can be sorted apart, we can compare potential DE students who took the CPT before 12th grade and barely pass the math cutoff with those who barely fail it. Unfortunately, the state of Florida only recorded student's highest score and no information about the test dates, making it difficult to identify students based on the timing of the test.[34] As a result, discontinuities in both participation in math as a DE course and participation as a regular college course might occur at the CPT cutoff score. If so, it becomes hard to know to what extent any effect on college outcomes (not college access) is due to participation in math dual enrollment as opposed to participation as a regular college student.

However, as shown in Figure 10 (top graph), there is *no* evidence of a discontinuity in college algebra participation as a regular college course at the cutoff. This could partially be explained by the fact that students who do not have an eligible CPT score may still take algebra after enrolling and passing intermediate algebra (MAT 1033, a course that counts as elective credit towards a college degree). This is confirmed with Figure 10 (bottom graph) where college students who barely fail the cutoff for college algebra are shown to be more likely to enroll in this pre-requisite course.[35] In addition, since DE is a substitute for the college course, DE algebra depresses overall participation rates in regular college algebra among eligible community college

[33] Two notable studies that have used remedial cutoff scores for identification of the effect of college remediation are Calcagno and Long (2008) and Martorell and McFarlin (2009) using data from Florida and Texas, respectively.
[34] These two types of students are likely to be different. For example, they might have different unobserved academic motivation or a different CPT score since there is an age-effect in test outcomes. Inasmuch as these factors do not induce differential sorting of students around the cutoff (such as older students systematically scoring just above the cutoff), they do not pose a threat to the RD internal validity.
[35] Enrollment in intermediate algebra (MAT 1033) as dual enrollment (not shown) is very rare.

students, further contributing to the lack of discontinuity in non-DE regular college algebra. Thus, having an ineligible CPT for college algebra does not seem to change the likelihood that students eventually take the course, but rather how they get there.[36] Inasmuch as a one-semester delay in taking algebra due to taking intermediate algebra first has an independent effect on the likelihood of completing a degree, then my estimates are confounded. It is however unlikely that postponing taking algebra for one-semester severely distorts students' progress towards a degree since, after all, only two math courses are required for an associate degree. Taken together, these factors seem to suggest that exploiting CPT eligibility requirements in the absence of test-dates does not provide a serious threat to the identification of the effect of DE algebra.

4.5. Effect of Dual Enrollment on Academic Outcomes

Table 4 presents the RD-IV estimates of the effect of taking a DE course in 12th grade. For reference, column (1) shows the mean value of the outcome for students just below the cutoff and column (2) the naïve ordinary least square (OLS) estimates which ignore students' self-selection into DE. The next columns report the reduced form effect which corresponds to the effects graphically displayed in figures 11. Because not every student eligible and some students not eligible take DE, the reduced form effects in column (3) are scaled up by the first-stage (row 1, column 4), to get the RD-IV effect of DE in column (4). The next columns provide robustness checks to additional covariates and alternative bandwidth selection, though additional sensitivity analyses are discussed in Section 4.7.

The first outcome I consider is whether DE increases the likelihood of obtaining a high school diploma. Given that the data consists on students who already made it to 12th grade, there is little variability in this outcome measure. Nevertheless, it is still an interesting outcome to explore since most DE courses are taken in 12th grade. There is no evidence, however, that DE has significant leverage on high school graduation. The next sets of outcomes describe students'

[36] This might not come to a surprise in the light of the evidence showing that college math remediation, a non-credit course taken by students with a CPT lower than that for MAC 1105, has virtually no effect in the likelihood of students completing MAC 1105 (Calcagno and Long 2008). If math remediation does not seem to discourage students from continuing the college-level course sequence, it is reasonable to expect that placement into intermediate algebra would not affect the likelihood of taking college-level algebra. It might still be possible that taking intermediate algebra does not change the likelihood of taking college-level algebra, but it provides a stronger preparation for students on the margin than if they would have placed directly into algebra. This type of bias, however, would work against finding an effect on DE algebra.

postsecondary access: college enrollment (any type) or college enrollment at 4-year institutions (both measured across the private vs. public or in- and out-of-state divide). The point estimates on the effect of DE on postsecondary enrollment is positive (0.095) but highly insignificant, with standard errors of 0.140 (column 4), making it difficult to draw any conclusive answer. There is some indication, however, that despite the relative advantage community colleges may have in attracting DE students after high school graduation (for example, DE students are considered returning students and need not reapply to the college), taking DE courses sponsored by the local community college does not seem to "divert" students toward 2-year institutions. The effect of DE on 4-year enrollment is large— enrollment rate increases by about 22 percentage points (column 4) off of a base of 19 percent just below the cutoff, though is marginally significant at the 10% confidence-level and becomes insignificant (and considerable smaller in size) using a narrower sample of the data around the cutoff (column 7 and 8).

Given the substantial policy interest in finding effective interventions not only to get students into college but also to help them succeed, the final set of outcomes I examine are measures of students' success in college.[37] Relative to students below the cutoff, DE students just above the cutoff are not significantly more likely to persist through the second term or the second year after their first postsecondary enrollment. The estimate for persistence through second year is only significant using a broader bandwidth of the data (column 6), and is not robust in samples incrementally close to the cutoff, despite arguably large sample sizes (column 4, 7, and 8). The effect of DE on AA degree completion is small and insignificant across all discontinuity samples, with the sign of the estimate changing in different samples. The point estimates on baccalaureate attainment are, however, consistent with the evidence in 4-year enrollment across different samples. DE increases BA attainment by about 24 percentage points (column 4) from a low base of 10 percentage points just below the cutoff; a percentage increase that roughly mirrors the 22 percentage points increase observed in 4-year enrollment. Like 4-year enrollment, the effect is however no longer significant at conventional levels in a narrow sample close to the cutoff point, despite arguably large number of observations, with a 95% confidence interval lower bound of -0.12 (column 7), and becomes considerable smaller in size as is estimated with data closer to the cutoff (column 8) . The last outcome refers to the cumulative GPA (0 to 4

[37] Note that, as explained before, college outcomes are defined over the entire population of high students (i.e. not college-going rate. The empirical estimate of the DE impact on college access is, nevertheless, not significantly different than zero.

range) in the first 30 non-DE college credits. To the extent that DE provides students on the margin of eligibility a stronger academic preparation, we might expect improved college performance. However, the standard errors in Table 4 are large and point estimates instable across discontinuity samples to provide empirical support for this.

4.6. The Effect of Dual Enrollment Math on Academic Outcomes

DE, as defined in the previous section, might encompass a wide range of experiences that range from taking courses in life-learning skills to courses in chemistry. While abstracting from the specific subject area or level of difficultly of the DE experience provides a good indication of the effect on average, it might not be entirely informative of the potential effect of DE. This section addresses this issue by examining the impact of taking one challenging course, college algebra, which unlike other DE courses requires a particular score in the CPT math test for enrollment.

It is important to emphasize that students in the CPT sample (those with a CPT score in the selected districts) are *not* representative of all high school students. For example, they are more likely to go to college and to enroll in a community college than the average student, consistent with their choice of taking the CPT— a test used exclusively at community colleges. Perhaps, precisely these characteristics make the evidence from this group of students of particular policy relevance, since these might be the students for which DE might have a decisive impact in their educational outcomes. After all, these are students with a genuine commitment to college but who are, as indicated before in Table 2, “negatively selected” in terms of their demographic characteristics (e.g.. they have lower academic preparation and are more likely to be poor than an average student).

Figure 12 provides a visual preview of the results. It displays the mean outcome variables by the CPT score (centered at each college cutoff), traced by the fitted values of a regression of the outcome on a linear term in the CPT estimated separately on each side of the cutoff. The reduced-form estimates are shown at the top of each graph. Visual inspection of the graph suggests important discontinuities in college degree attainment, with some indication of positive effects in persistence to 2nd year and college GPA.

Table 5 presents the formal RD-IV estimates of taking college algebra (MAC 1105) as DE for students with a CPT score around the cutoff used for placement. Outcome estimates in the first row provides evidence that taking DE math does not significantly affect the likelihood of high school graduation. Next, there is no evidence of a beneficial effect of DE on college access. The estimate is positive but statistically insignificant and fairly instable across most discontinuity samples. Similarly, there is no evidence that taking college algebra has a significant effect on students' choice of college type for their first postsecondary enrollment. The point estimates for college persistence through 2nd semester suggest a positive relationship, though the effects are not statistically significant in any discontinuity sample. Instead, DE algebra is associated with increased college retention through the 2nd year. The effect is large (0.27), statistically significant (column 4), and robust to not controlling for additional variables (column 5) — though doing so increases the standard errors considerably.

The largest effects of DE are found in college degree attainment, both the likelihood of obtaining an AA or BA degree. The effects are substantial; the most conservative coefficients are a 0.44 and 0.36 (column 6 and 5) for AA and BA, respectively, and are significant at conventional levels. The estimates are fairly stable across discontinuity samples; though get highly imprecise when using a small number of observations around the cutoff (column 8). Put it in context, taking college algebra while in high school increase AA attainment by 44 percentage points from a base of 26% just below the cutoff and BA attainment by 36 percentage points from a base of 18%. College algebra is a gatekeeper course and having it out the way at the onset of college helps students make progress towards a degree. One potential explanation for this finding is that students faced with more rigorous curriculum while in high school might be better prepared for college academically and therefore more likely to persist towards obtaining a degree. It is also possible that DE students have a better experience during the course (learn more or have higher passing rate) by taking advantage of the high school support (counselors are supposed to monitor their progress in DE courses) or family environment than in they were to take it once in college. A different hypothesis is that students that have already done college-level algebra start college with higher self-esteem and confidence of their abilities to obtain a degree. The last outcome measured in Table 5 points towards suggestive evidence of an effect of DE math on first-year college GPA, though the standard errors are too large to draw a definitive conclusion.

4.7. Robustness

Table 6 examines the sensitivity of the DE effect (Panel A) and DE math effect (Panel B) to sample selection and model specification. Specifically, I use a discontinuity sample (bandwidth of 0.4 GPA points and 40 CPT points around the cutoff) and examine whether these baseline estimates are robust to an alternative estimation using a low-order polynomial regression, to different sample of students, or to the inclusion of more colleges into the sample. In addition, I explore the heterogeneity of the DE effect across programs offered by different colleges as well as the heterogeneity across cohorts of students. For ease of comparison, the baseline estimates in the main results are restated at the top of each panel. Since the estimates for DE effect are quite sensitive to small changes in bandwidth choice, I report robustness checks using a preferred narrow sample around the cutoff (bandwidth of 0.4 GPA).

An estimation alternative to the local linear regression used in this paper employs polynomials on the score to capture the underlying relationship between the score and the outcome. Because the sample is already close to the cutoff, a quadratic polynomial suffices to fit the data appropriately. The estimates using these polynomial controls are similar in magnitude to my main results (Table 6, Panel A, first and second row) and have comparable statistical power. The next three rows in Panel A, show estimates using different samples of students. First, I exclude students who took a college course while in high school but outside the DE program, either because they were not aware that enrolling as DE was free of charge or did not qualify. These are few students (less than 1.3%) and the estimates are very similar, if anything, slightly larger in magnitude. Second, I exclude students who took DE before 12th grade and then exclude DE math and English courses (which have CPT requirements in addition to the GPA) from the definition of DE student. None of these exercises materially affect the results. The estimates removing students who took DE in 11th grade are similar in magnitude to the baseline. This was expected, given that DE participation in 11th grade does not change discontinuously around the cutoff (shown in table 3). There is, however, a loss in precision when reducing the sample size by 10%. Next, I examine whether the results are robust to the inclusion of other DE programs with small (less than 7.5 percentage points) discontinuities in participation at the cutoff. The point estimates using a larger set of colleges are smaller in general, with some even changing sign, suggesting some heterogeneity across programs. All estimates are, however, not significant at conventional levels. To further explore potential heterogeneity, I test whether there are differences across DE programs within the sample selected for the main analysis and I find support for homogeneity in the effects on 4-year and BA, but not in other outcomes. Last, I cannot reject homogeneity in effects across cohorts in any outcome measure.

Panel B shows the robustness checks for the CPT sample analysis. Given that students are in theory mandated to have an eligible GPA in addition to the CPT score in order to participate, the first sensitivity test estimates the discontinuity in the outcome at the CPT cutoff for those with an eligible GPA. Doing this does not materially affect the results, suggesting that the GPA requirement was not binding in these DE programs. Using a polynomial model renders very similar estimates, and so does adding CPT scores in another subject area. Very few students had the DE-math type of experience but not officially registered for the course as dually enrolled, so excluding them from the analysis does not change the estimates. The next sensitivity test addresses the fact that participation during both junior and senior years changes discontinuously with the same score. Since students that took the course in 11^{th} grade would be considered non-DE in 12^{th} grade, I explore whether the findings are robust to excluding these students from the analysis. The results remain mostly unchanged, which was expected since only a small proportion of students take this course in 11^{th} grade.

The following robustness checks include a larger sample of colleges by relaxing the criteria used in this paper for selecting colleges. First, I include colleges with a sizeable discontinuity in DE participation in algebra only (as opposed to DE algebra and English composition). The main conclusion still holds in this sample, though the significant effects are about 25% smaller in size in 2^{nd} year persistence and AA attainment and 34% smaller for BA completion. Notably, there is some indication of an effect on postsecondary enrollment (marginal significant at 10%) in this sample, indicating that DE programs might vary in their effects, though the effect becomes insignificant when not controlling for additional covariates (not shown). This heterogeneity is confirmed using a broader set of colleges with a discontinuity in DE math of any size (an addition of 5 colleges and 2.5 times the number students), where the effects on degree attainment (both AA and BA) are even larger than baseline estimates and the effect on persistence is half the size and no longer significant. Despite variability in the DE effectiveness across colleges outside the main sample of analysis, the consistency on positive and significant effects on degree outcomes across different sample of colleges is reassuring. The last two row estimates the heterogeneity of the effects among colleges in the selected sample used in the main analysis. Overall, there is no evidence of significant heterogeneity within these colleges at 5 % level in any outcome or, with the exception of AA degree and GPA, across cohorts of students.

5. Conclusions

In the presence of gloomy statistics on postsecondary enrollment and attainment, there is a growing need to find effective ways to help high school students in their transition to higher education. There is a large body of literature indicating that a rigorous high school curriculum is a key determinant of students' educational progress, such as the likelihood of pursuing and obtaining a college degree. To this end, policymakers are increasingly viewing dual enrollment programs— which allow students to take college courses while in high school— an appropriate intervention. This enthusiasm with dual enrollment has been accompanied by remarkable growth in state legislation that governs their structure and funding. While 23 states had dual enrollment legislation in 2000 (Frazier 2000), 42 states had passed one by the end of 2005 (WICHE 2006). As the program continues to expand, it is important to understand its impact on students' academic progress.

This paper provides empirical evidence of the effect of dual enrollment using data from Florida; a state with a well-developed, highly regulated, and fully-funded dual enrollment program. Florida provides a unique opportunity to assess the effect of dual enrollment participation since participation requirements are set forth by the state. In particular, students are required to have a minimum 3.0 high school GPA in order to take an academic dual enrollment course and, for courses such as math, a minimum proficiency in a college placement test. This feature of the program allows using a regression discontinuity design to estimate its causal impact. Using data from the 2000 and 2001 high school graduating cohorts in selected Florida counties, I find little evidence that taking dual enrollment significantly increases students' likelihood of high school graduation, college enrollment or college success for students who are on the margin of Florida's minimum grade point average eligibility cutoff. However, dual enrollment participation conceals important variation in course experience. Based on a sample of students who took Florida's college placement test (CPT), I find that taking one popular challenging course as dual enrollment, college algebra, significantly increases students' likelihood of obtaining an associate and a bachelor degree, with some indication of positive effects on second year retention and college performance.

In contrast to the prior research, I do not find conclusive evidence of a significant effect of dual enrollment on college access. However, the average treatment effect using a regression discontinuity design is only locally identified at the cutoff for eligibility. This might suggest that students close to the 3.0 high school GPA or with a math academic preparation well-above the minimum necessary for an entry level college math course are not the marginal college-going student for whom a dual enrollment experience can have a decisive impact.

This research presents the first attempt to use a quasi-experimental method to examine the causal effect of participation in an academic DE program. From a policy perspective, it provides credible evidence that dual enrollment programs can play a significant role in improving students' college success. It also highlights that factors such as the subject area, quality, or level of difficulty of the dual enrollment experience should be taken into account when expanding these programs with the objective of addressing the needs of high school students as they transition to postsecondary education.

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Appendix

A.1 GPA requirement for Academic Dual Enrollment

	Freq	%
Un-weighted 3.0 GPA [a]	19	67.9%
Weighted GPA and/or cutoff other than 3.0 [b]	6	21.4%
Missing	3	10.7%
N Colleges	28	100%

Source: Author's compilation of Inter-Institutional Articulation Agreements (IAA) between colleges and districts, college catalogs, and personal communication with colleges' dual enrollment coordinators.

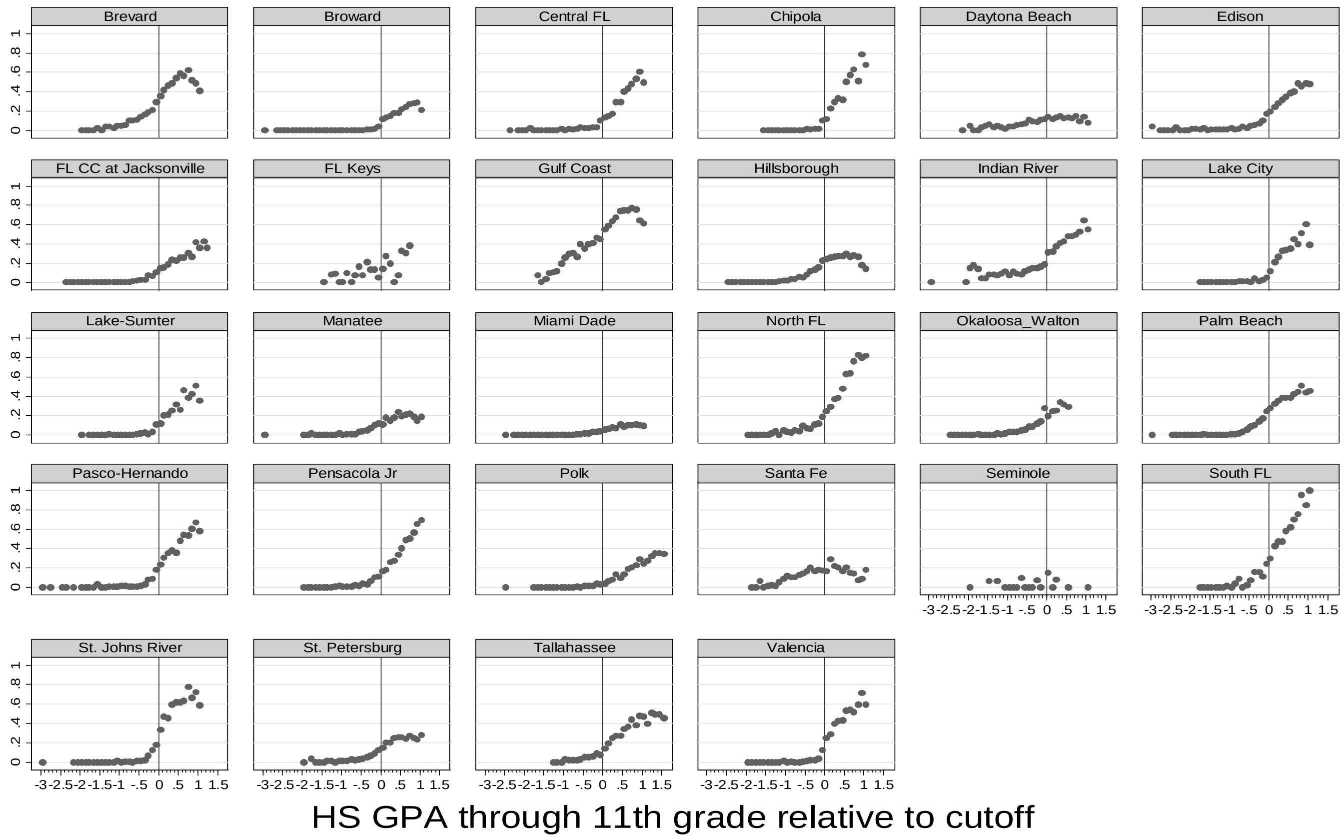
Notes: Un-weighted 3.0 GPA is the minimum GPA requirement set by the Florida statue, but colleges can set a higher standard.

[a] Includes a college with no specification of weights in the GPA calculation. The requirements for 5 of these colleges were obtained through personal communication with dual enrollment coordinators

[b] The breakout is as follows: one college with GPA cutoff < 3.0, two with cutoff < 3.0 that allowed for weights, one with cutoff > 3.0 that allowed for weights, and two allowed for weights in the GPA calculation.

Figure 1

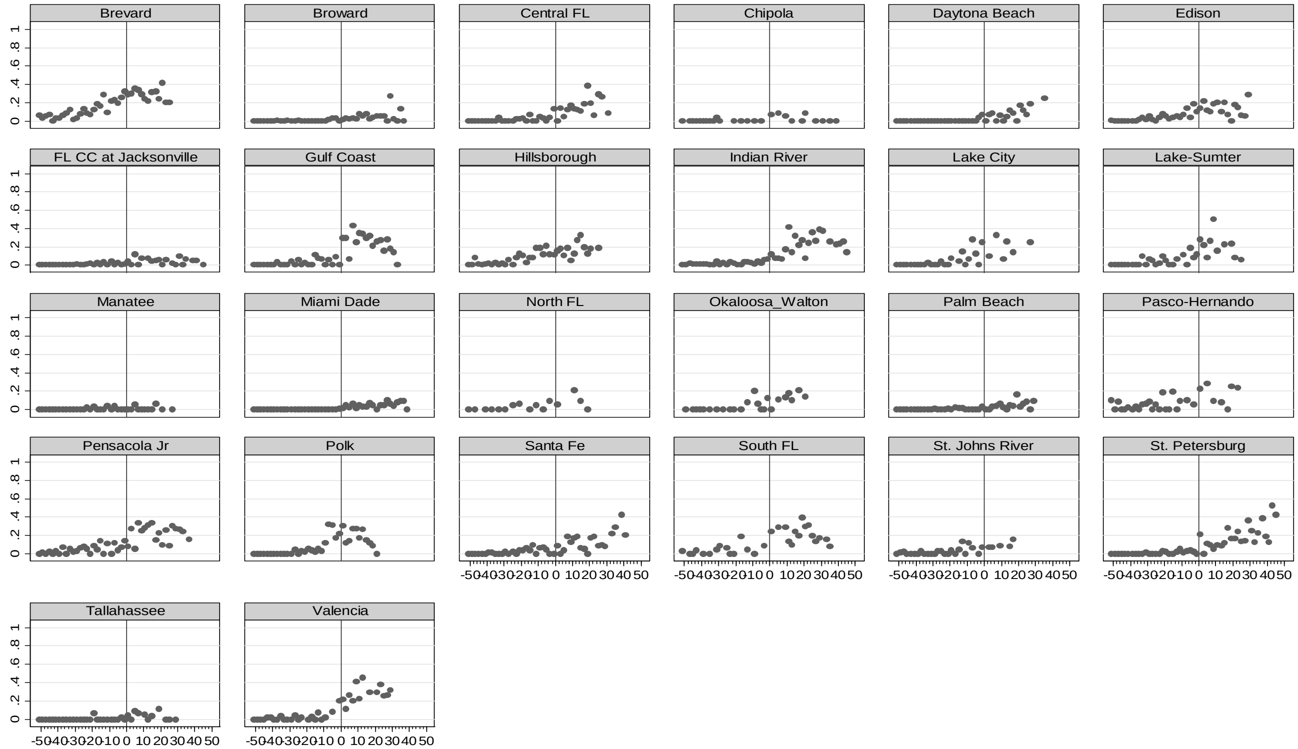
Dual Enrollment participation in 12th grade by community college



Notes: GPA bins are 0.1 points wide on either side of the cutoff. The state-mandated cutoff (un-weighted 3.0) was assumed for 3 colleges (Indian River, Manatee, and Gulf Coast) whose official requirements could not be obtained. Values with less than 10 observations are not displayed in the graph.

Figure 2

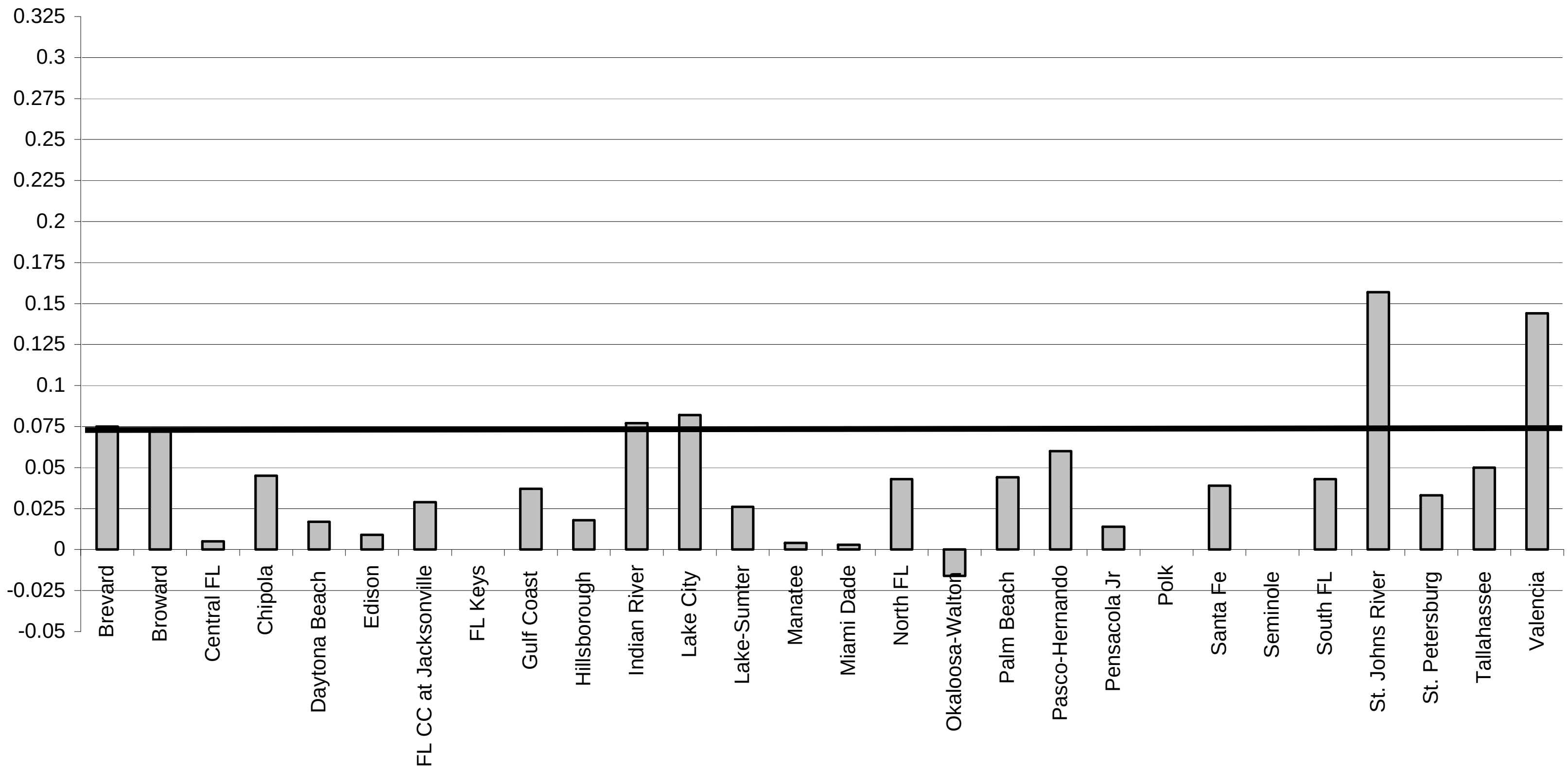
Dual Enrollment College-level Math (MAC 1105) participation in 12th grade by community college



CPT Math relative to cutoff

Notes: CPT bins are 2 scale scores points wide on either side of the cutoff. Points with less than 10 observations are not displayed in the graph.

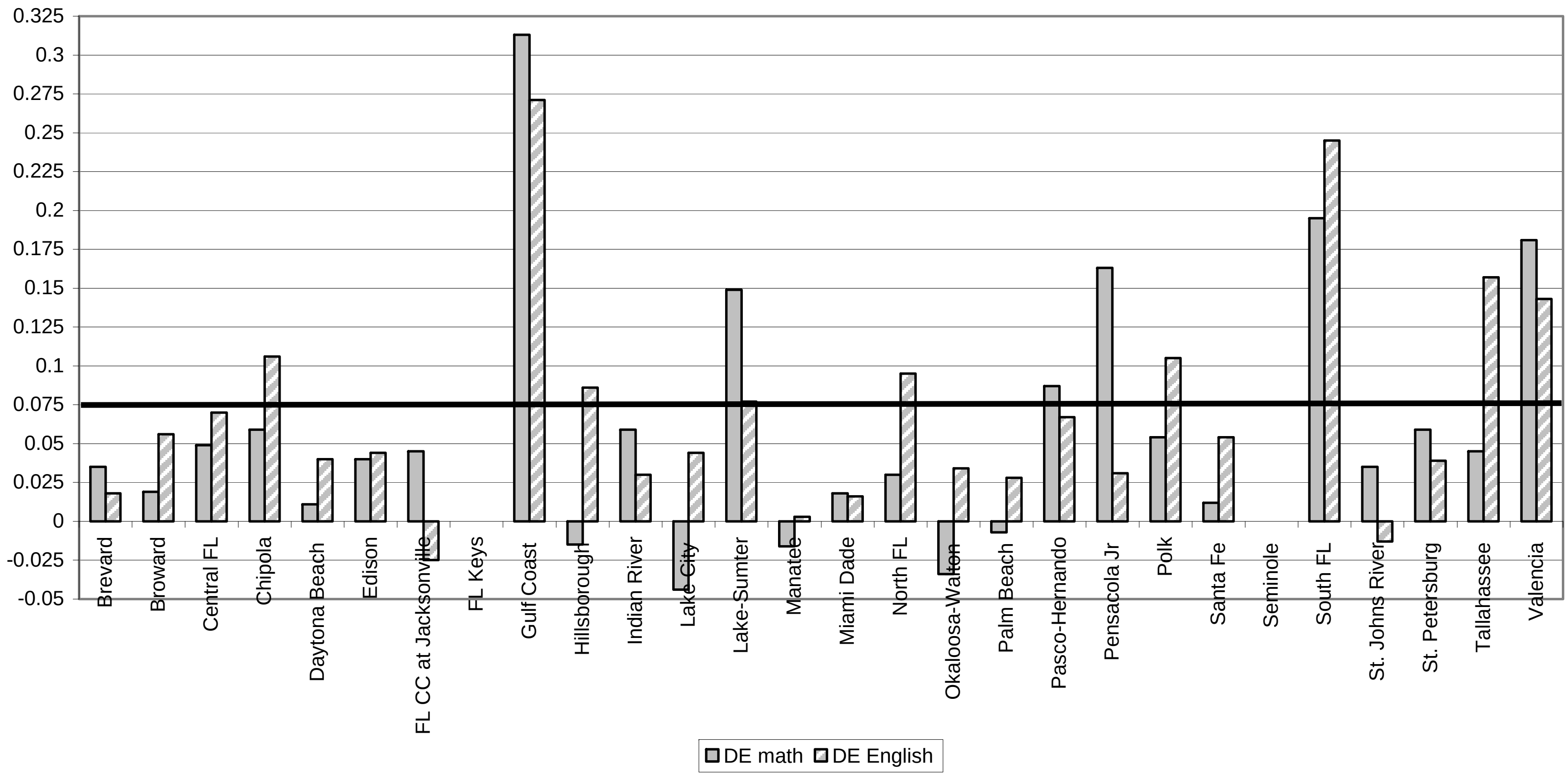
Figure 3
Discontinuity in DE 12th grade participation
(First Stage Coefficient on Eligibility based on HS GPA through 11th grade)



Notes: The state-mandated cutoff (un-weighted 3.0) was assumed for 3 colleges (Indian River, Manatee, and Gulf Coast) whose official requirements could not be obtained. The discontinuity is estimated using local linear regression within a 0.5 GPA points bandwidth at each side of the cutoff and controls for additional covariates as described in the text. Discontinuity for Polk was estimated to be zero. Discontinuities for FL Keys and Seminole (set to zero) cannot be estimated reliably due to small sizes. Colleges were selected based on a statistically significant (at 5% level) discontinuity at the cutoff of 7.5 percentage points (indicated by the thick horizontal line). Significance levels are as follows: FL CC at Jacksonville and Pasco-Hernando are significant at 10 percent; Brevard, and Palm Beach at 5 percent; Broward, Indian River, Lake City, St. Johns River, Tallahassee, and Valencia at 1%. Discontinuities are not significantly different than zero at other colleges.

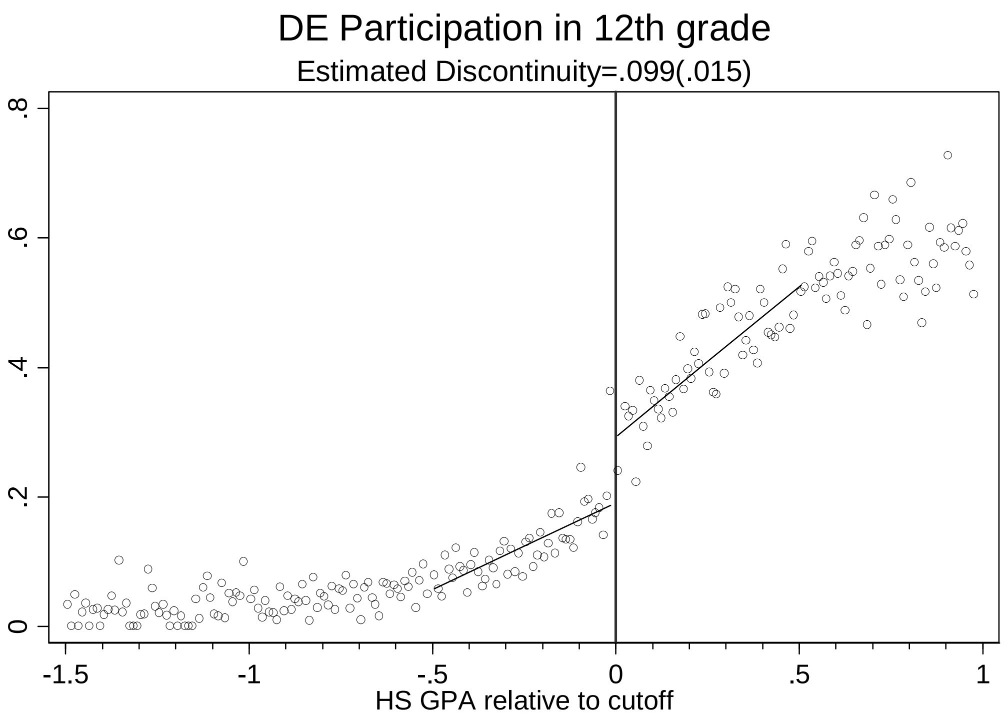
Figure 4

Discontinuity in 12th grade DE Algebra (Math) and Freshman Composition (English) participation
(First Stage Coefficient on Eligibility based on Math/Reading CPT scores)



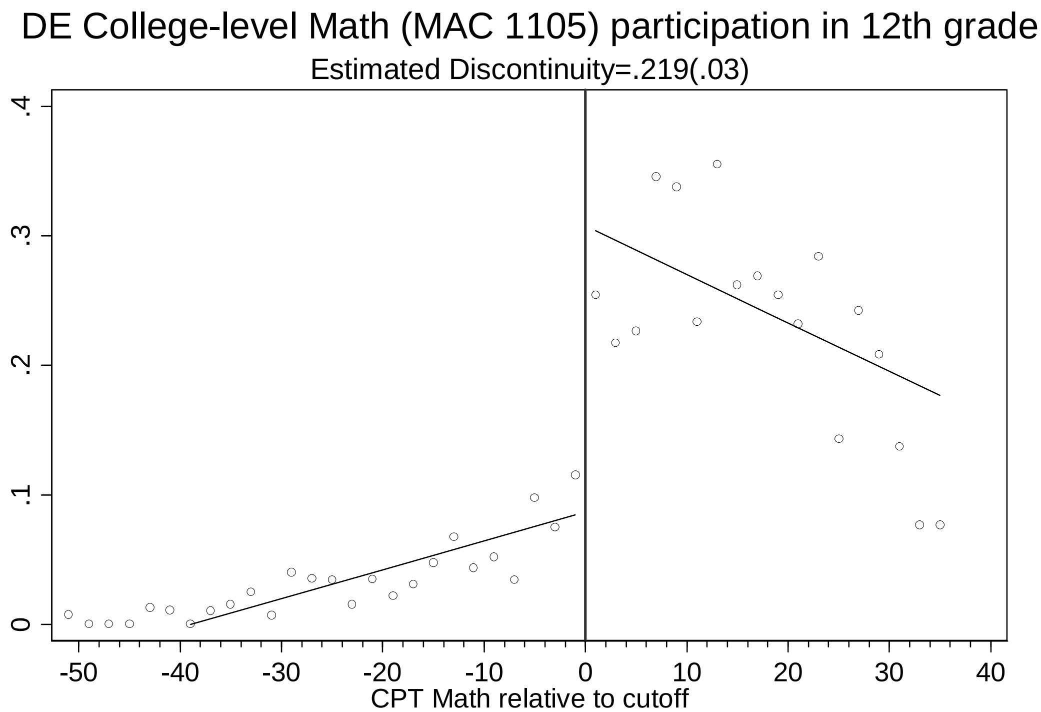
Notes: The discontinuity at the college-specific cutoff scores is estimated using local linear regression within a 40 CPT points bandwidth at each side of the cutoff and controls for additional covariates as described in the text. Colleges were selected based on a statistically significant (at 5 percent level) discontinuity at the cutoff of 7.5 percentage points in both dual enrollment math and English (indicated by the thick horizontal line). Discontinuities for FL Keys and Seminole cannot be estimated due to small sizes. Significance levels in math are as follows: Broward and Central FL are significant at 10 percent; FL CC at Jacksonville and Miami Dade at 5 percent; Gulf Coast, Indian River, Lake-Sumter, Pensacola Jr., South FL, Tallahassee, and Valencia at 1%. Discontinuities are not significantly different than zero at other colleges. With the exception of Pensacola Jr, all collages with large discontinuities in DE math have also sizeable discontinuity in DE English (Gulf Coast, South FL, and Valencia at 1%; Lake-Sumter at 5%).

Figure 5



Notes: GPA is displayed in bins 0.01 points wide on either side of the cutoff. Circles are cell means at each GPA value. The solid lines are fitted values of a local linear regression estimated within a 0.5 GPA points bandwidth on either side of the cutoff, controlling for additional covariates as described in the text.

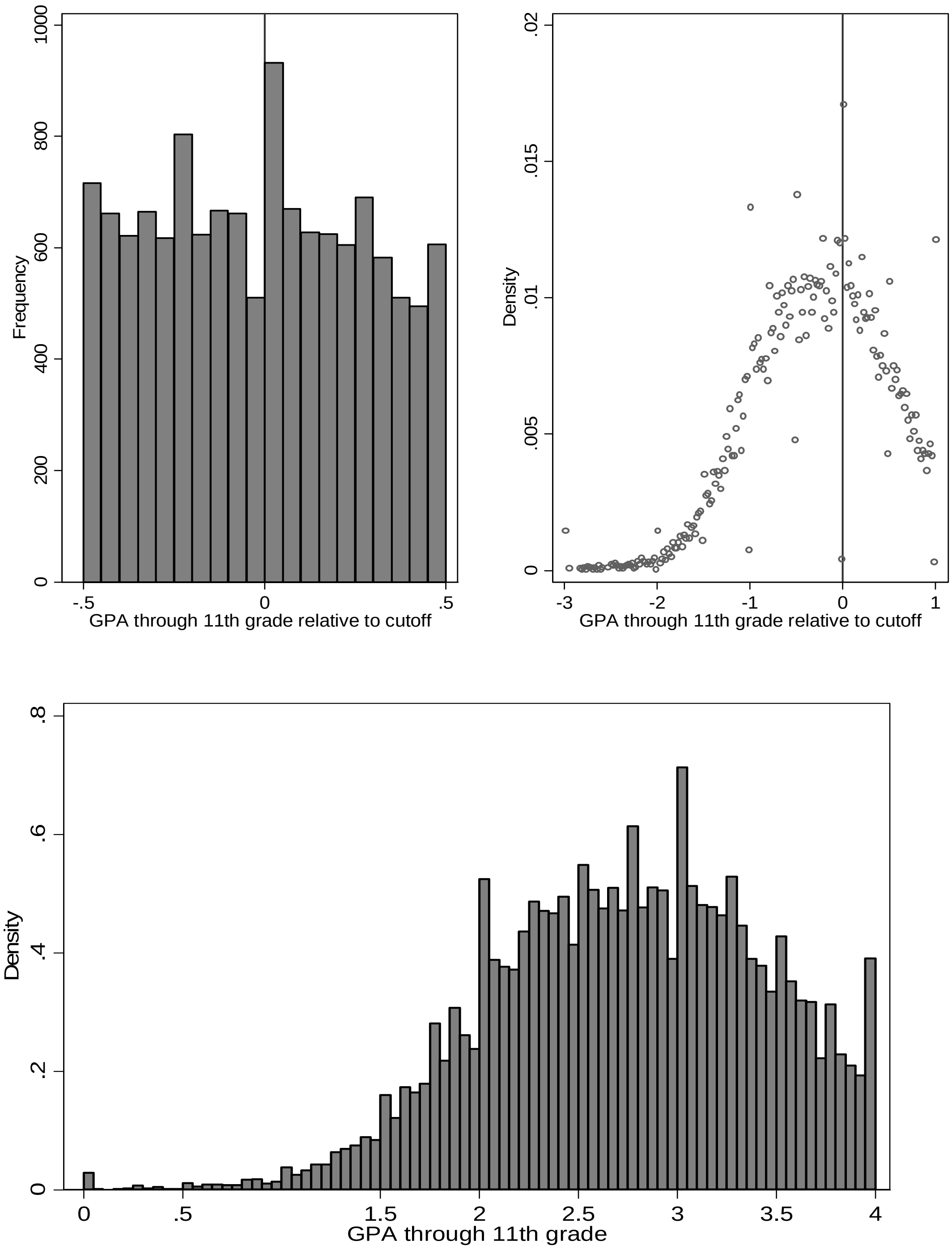
Figure 6



Notes: CPT is displayed in bins 2 scale score wide on either side of the cutoff. Circles are cell means at each CPT math scale score. The solid lines are fitted values of a local linear regression estimated within a 40 points bandwidth on either side of the cutoff, controlling for additional covariates as described in the text.

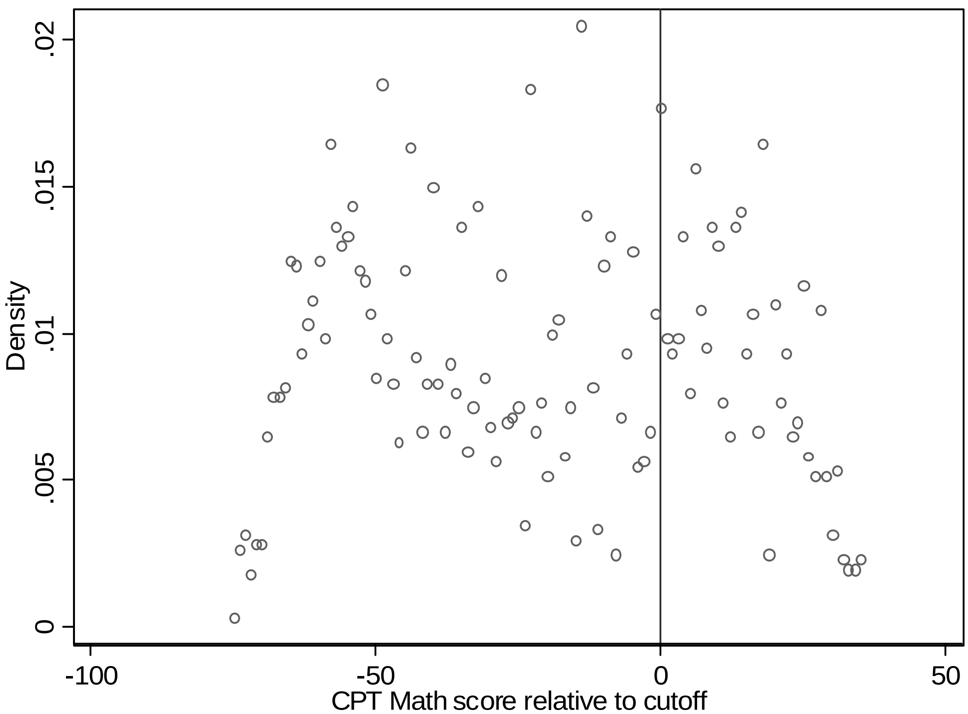
Figure 7

Distribution of the 11th grade High School GPA



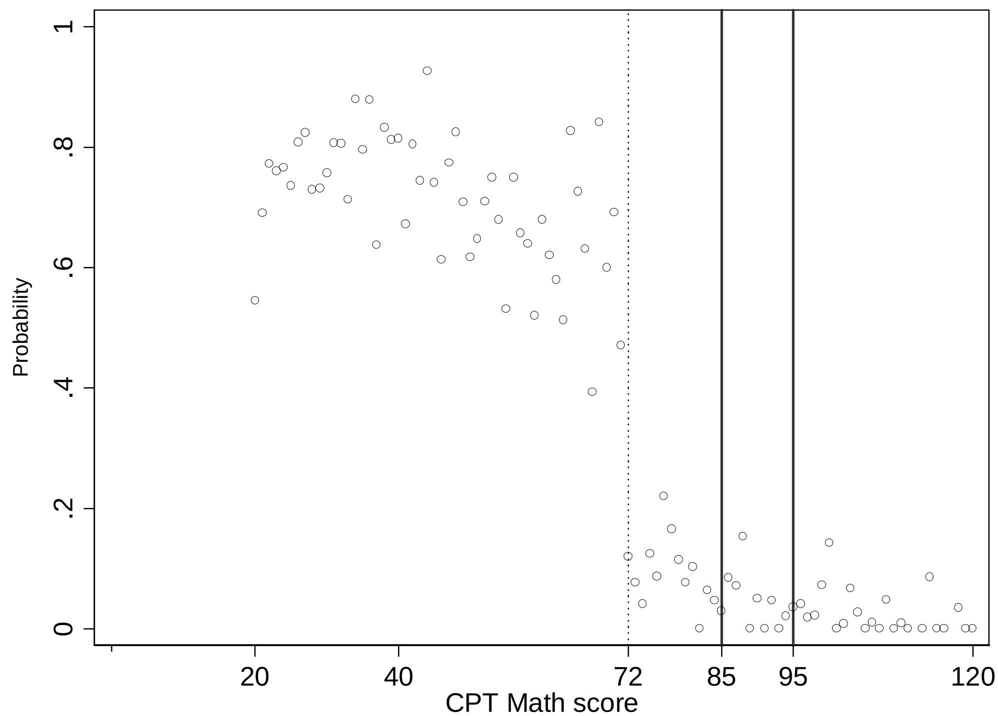
Notes: Left figure (top panel) shows the frequency distribution for GPA values close to the eligibility cutoff (indicated by zero). GPA is displayed in bins 0.05 points wide. Right figure (top panel) shows the density on the entire GPA spectrum. Circles are cell means at each GPA value, displayed in bins 0.02 points wide on either side of the cutoff. Bottom figure shows the full (un-centered) GPA histogram in bins 0.05 points wide.

Figure 8
Distribution of CPT Math score



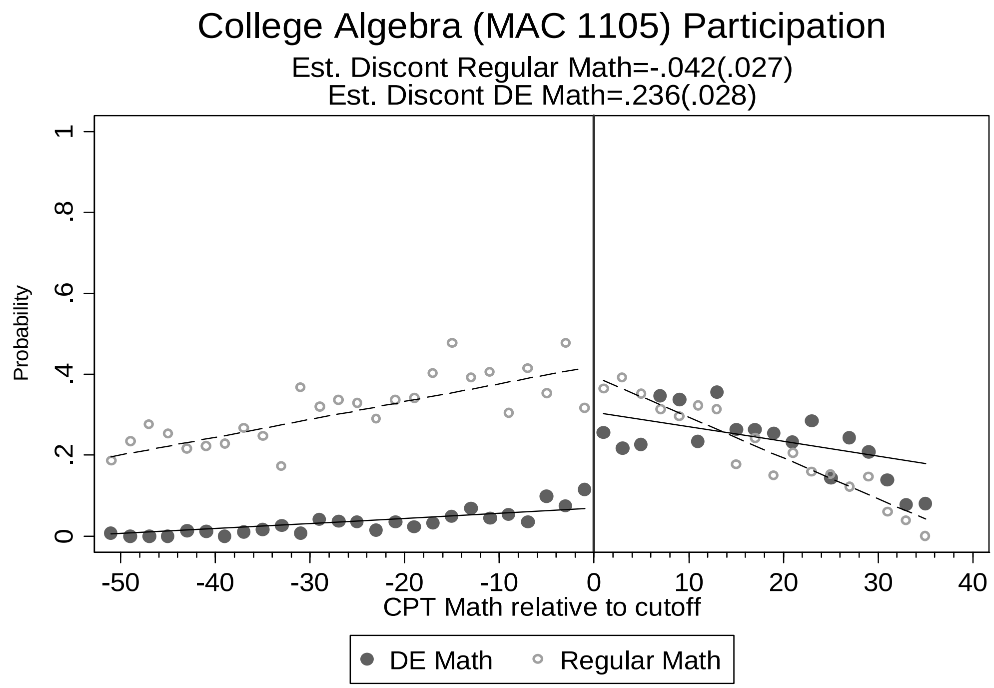
Note: Circles are cell means at each CPT math score centered at the eligibility cutoff.

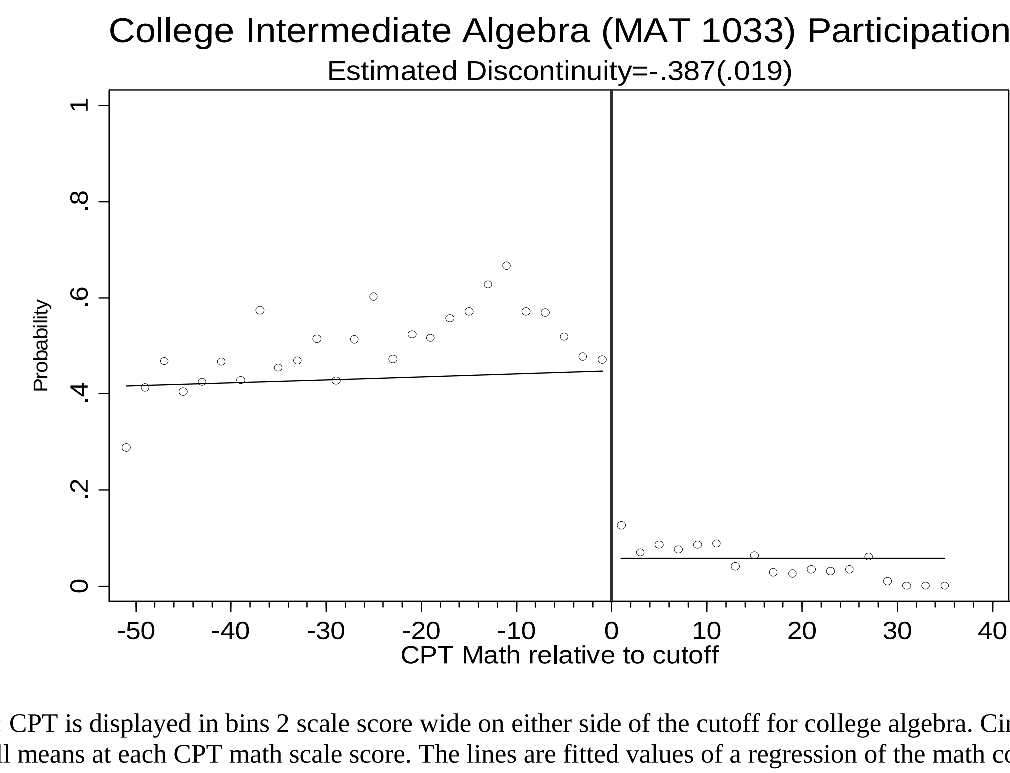
Figure 9
Probability of Math College Remediation



Notes: Circles are cell means at each CPT score for students selected in the CPT sample. Dotted line indicates the state-wide cutoff used for assignment into college remediation. Solid lines demark the range of cutoffs used by different colleges for placement into college algebra (MAC 1105).

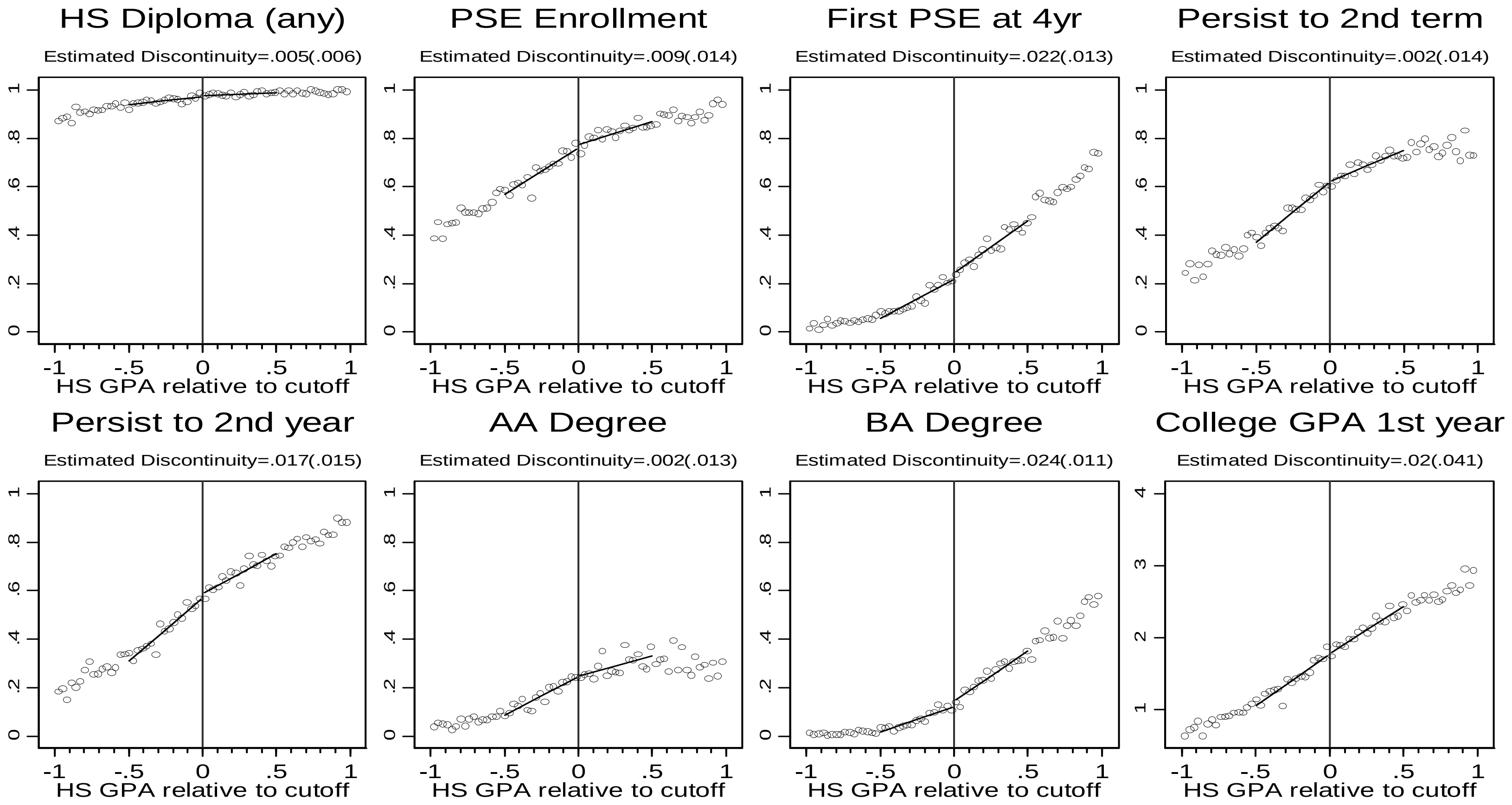
Figure 10





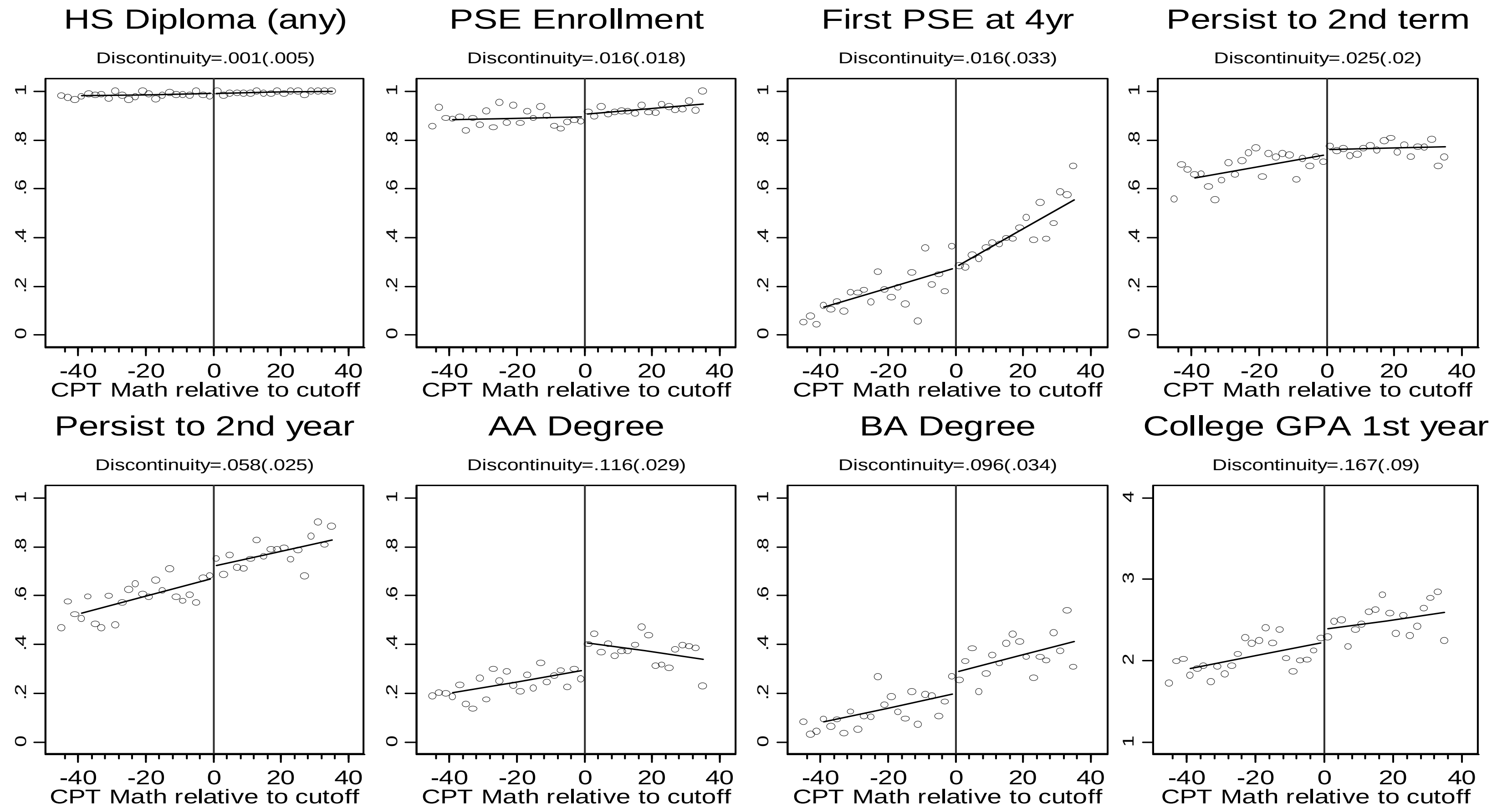
Notes: CPT is displayed in bins 2 scale score wide on either side of the cutoff for college algebra. Circles are cell means at each CPT math scale score. The lines are fitted values of a regression of the math course attempted at a community college on a dummy indicating eligible score controlling for a linear term on the CPT (allowed to vary on either side of the cutoff) and additional covariates as described in the text.

Figure 11
Outcomes by 11th grade High School GPA



Notes: GPA is displayed in bins 0.03 points wide on either side of the cutoff. Vertical line indicates the cutoff. Circles are cell means at each GPA value. The solid lines are fitted values of a local linear regression estimated within a 0.5 GPA points bandwidth on either side of the cutoff, controlling for additional covariates as described in the text.

Figure 12
Outcomes by CPT Math Score



Notes: CPT is displayed in bins 2 scale score wide on either side of the cutoff. Vertical line indicates the cutoff. Circles are cell means at each CPT scale score. The solid lines are fitted values of a local linear regression estimated within a 40 points bandwidth on either side of the cutoff, controlling for additional covariates as described in the text. Only students within the 40 points bandwidth are displayed.

Table 1: Descriptive statistics of Dual enrollment participants and non-participants

Variable	All Students	DE	Non-DE
Student characteristics			
Female	51.3%	62.4%	49.4%
White	55.7%	77.7%	52.0%
Black	24.1%	10.6%	26.3%
Hispanic	17.2%	7.4%	18.9%
Limited English Proficient	3.0%	0.5%	3.5%
Economically disadvantaged	42.8%	22.8%	46.3%
FCAT Reading score, 10^{th} grade	304.3	334.5	298.4
FCAT Math score, 10^{th} grade	313.9	344.2	308.0
HS GPA	2.67	3.26	2.58
Outcomes			
HS diploma	90.6%	98.1%	89.3%
PSE enrollment after HS (in or out of state)	61.8%	88.3%	57.4%
PSE enrollment at 4yr-institution (in or out of state)	39.5%	59.0%	34.4%
Persistence to 2^{nd} term (in or out of state)	76.1%	83.0%	74.3%
Persistence to 2^{nd} year (in or out of state)	72.6%	84.4%	69.6%
Remedial Reading enrollment	23.3%	5.8%	27.8%
Remedial English enrollment	18.1%	3.8%	21.8%
Remedial Math enrollment	33.0%	11.4%	38.5%
Freshman college GPA (including DE courses)	2.43	2.95	2.30
Associate degree	21.5%	32.0%	18.8%
Bachelors degree	23.2%	42.6%	18.2%
Observations	**229,904**	**32,980**	**196,924**
%	**100%**	**14%**	**86%**

Source: Florida K-20 Education Data Warehouse & National Clearinghouse data (extracted April, 2008).
Notes: DE denotes students who took at least one dual enrollment (academic) course.

Table 2: Descriptive statistics for dual enrollment participants

	All Colleges	GPA sample	CPT sample
DE Student characteristics			
Female	62.4%	62.6%	61.9%
White	77.7%	83.2%	80.0%
Black	10.6%	7.9%	8.7%
Hispanic	7.4%	5.2%	7.3%
Limited English Proficient	0.5%	0.3%	0.5%
Economically disadvantaged	22.8%	19.8%	27.3%
FCAT Reading score, 10th grade	334.5	332.7	328.1
	(32.2)	(33)	(31.2)
FCAT Math score, 10th grade	344.2	341.7	337.7
	(31.6)	(32.7)	(29.8)
HS GPA	3.26	3.26	3.29
	(0.47)	(0.49)	(0.45)
DE experience			
Participation rate	14.3%	27.2%	50.7%
Participation rate of high ability students (11th grade GPA ≥ 3)	33.0%	52.4%	71.2%
Average Total DE courses attempted	3.7	4.5	4.7
	(3.2)	(3.8)	(3.3)
Average Total DE courses attempted in 12th grade	2.9	3.6	3.3
	(2.1)	(2.5)	(2.4)
Average Total DE credits attempted	11.0	13.6	14.1
	(9.7)	(11.2)	(10.5)
Average Total DE credits earned	9.9	12.2	11.9
	(8.9)	(10.1)	(9.1)
DE success rate (passing course with grade C or higher)	77.0%	81.1%	68.7%
DE 12th grade English success rate	83.1%	85.6%	86.5%
DE 12th grade Math success rate	77.7%	78.7%	69.7%
Percent students take college course while HS outside DE program	1.4%	1.2%	0.5%
Percent taking DE college level math (MAC 1105) in 12th grade	18.3%	24.7%	18.7%
Percent taking DE college level English (ENC 1101) in 12th grade	29.5%	26.2%	38.1%
Percent taking DE on a full-time basis (i.e. Early Admission)	2.3%	2.5%	0.7%
DE location			
Percent DE courses at Community College campus only	37.3%	25.1%	26.6%
Percent DE courses at High School campus only	4.9%	4.6%	1.3%
Percent DE courses at both Community College & High School campuses	57.8%	70.3%	72.1%
Schools in college attendance area			
Total senior enrollment (both cohorts)	229,904	26,118	6,003
Percent of total senior enrollment (both cohorts)	100%	11.4%	2.6%
Number of dual enrollment students	**32,980**	**7,095**	**3,046**
Number of districts	**67**	**15**	**10**
Number of colleges	**28**	**5**	**4**

Notes: Standard deviations for continuous variables are shown in parenthesis. Statistics are based on students who took at least one academic dual enrollment course sponsored by a community college. Only academic courses are considered. Students that only took dual enrollment as a full-time basis (i.e. early admission) are not included. GPA sample consists on all HS senior students in districts assigned to Brevard, Indian River, St. Johns River, Lake-City, and Valencia community college. CPT sample consists on all HS senior students who took the CPT test in districts assigned to: Gulf Coast, Lake-Sumter, South Florida, and Valencia community college.

Table 3: Discontinuity in baseline characteristics and other high school programs

	GPA sample			CPT Sample		
	Discontinuity Sample			Discontinuity Sample		
	± 0.5	**± 0.4**	**± 0.2**	**± 60**	**± 40**	**± 20**
Female	-0.015	-0.019	-0.009	0.012	0.031	0.048
	(0.017)	(0.019)	(0.027)	(0.023)	(0.025)	(0.035)
Black	0.026	0.018	0.015	-0.007	0.001	0.021
	(0.011)**	(0.011)	(0.016)	(0.017)	(0.021)	(0.032)
Hispanic	0.010	0.015	0.015	0.012	0.026	0.055
	(0.010)	(0.011)	(0.015)	(0.024)	(0.025)	(0.026)**
English Learner	0.002	0.005	0.015	-0.003	-0.007	0.008
	(0.007)	(0.008)	(0.010)	(0.013)	(0.015)	(0.014)
Free or Reduced lunch	0.008	-0.003	-0.010	0.039	0.058	0.043
	(0.014)	(0.016)	(0.022)	(0.028)	(0.032)*	(0.042)
FCAT Reading (10th grade)	1.093	0.607	2.474	-3.358	-3.133	-2.574
	(1.108)	(1.245)	(1.828)	(2.205)	(2.465)	(3.392)
FCAT Math (10th grade)	1.434	1.269	1.595	-5.195	-4.056	-4.935
	(1.158)	(1.261)	(1.776)	(2.142)**	(2.510)	(3.070)
AP 12th grade	0.005	0.004	0.019	-0.017	-0.036	-0.059
	(0.012)	(0.013)	(0.018)	(0.035)	(0.040)	(0.052)
IB 12th grade	0.003	0.003	0.005	0.007	0.008	0.006
	(0.005)	(0.005)	(0.007)	(0.006)	(0.006)	(0.005)
Honors 12th grade	0.032	0.016	0.023	-0.023	-0.007	0.024
	(0.019)*	(0.021)	(0.030)	(0.038)	(0.044)	(0.056)
DE 11th grade	0.036	0.026	0.007	0.012	0.009	0.032
	(0.014)**	(0.015)*	(0.021)	(0.037)	(0.041)	(0.048)
DE math (MAC 1105) 11th grade	0.001	0.003	0.002	0.124	0.119	0.122
	(0.003)	(0.003)	(0.004)	(0.019)**	(0.019)**	(0.022)**
DE English (ENC 1101) 11th grade	0.005	0.001	-0.003	-0.004	0.001	0.004
	(0.006)	(0.007)	(0.010)	(0.017)	(0.019)	(0.024)
Prob. enrolling outside Florida public postsecondary system	0.006	0.007	0.017	-0.006	-0.008	0.002
	(0.007)	(0.008)	(0.011)	(0.017)	(0.019)	(0.025)
Chi2 test that all discontinuities (up to DE take-up) are jointly	15.64	9.07	7.68	22.15	17.99	15.70
zero, *[p-value]*	[0.110]	[0.525]	[0.660]	[0.014]	[0.055]	[0.109]
Number of students	**12,888**	**10,409**	**5,316**	**5,406**	**4,014**	**2,420**
Number of colleges	**5**	**5**	**5**	**4**	**4**	**4**

Notes: Standard errors (in parenthesis) are clustered at the GPA or CPT math score. * significant at 10% ** significant at 5%
Each cell represents the estimated discontinuity in the covariate from a linear probability model on a dummy indicating GPA or CPT score above the respective cutoff for each institution and a linear term on the score allowed to vary on either side of the cutoff. Chi2 test was performed using seemingly unrelated regression estimation where each equation represents a different baseline covariate.

Table 4: Regression discontinuity estimates of the effect of dual enrollment on student outcomes, GPA Sample

	Mean below cutoff (std)	OLS	Reduced Form	RD-IV				
Bandwidth Choice	**-0.2**	**± 0.5**	**± 0.5**	**± 0.5**		**± 0.6**	**± 0.4**	**± 0.3**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variable								
Dual enrollment in any subject (First Stage)				0.099	0.100	0.109	0.088	0.074
				(0.015)**	(0.018)**	(0.014)**	(0.017)**	(0.019)**
Outcomes								
HS diploma (any)	0.96	0.007	0.005	0.052	0.044	0.051	0.101	0.131
	(0.19)	(0.003)**	(0.006)	(0.060)	(0.063)	(0.048)	(0.073)	(0.097)
Postsecondary Enroll	0.72	0.115	0.009	0.095	0.081	0.138	0.031	0.135
	(0.45)	(0.009)**	(0.014)	(0.140)	(0.194)	(0.114)	(0.182)	(0.243)
First Enroll 4yr institution	0.19	0.094	0.022	0.217	0.238	0.191	0.122	0.153
	(0.39)	(0.010)**	(0.013)*	(0.131)*	(0.136)*	(0.114)*	(0.164)	(0.219)
Persistence through 2nd term	0.57	0.127	0.002	0.024	-0.011	0.146	0.045	0.208
	(0.50)	(0.010)**	(0.014)	(0.141)	(0.178)	(0.117)	(0.177)	(0.232)
Persistence through 2nd year	0.52	0.130	0.017	0.169	0.136	0.262	0.150	0.331
	(0.50)	(0.011)**	(0.015)	(0.143)	(0.173)	(0.120)**	(0.177)	(0.241)
Associate degree	0.22	0.119	0.002	0.024	-0.012	0.120	-0.033	0.040
	(0.41)	(0.011)**	(0.013)	(0.134)	(0.146)	(0.114)	(0.178)	(0.238)
Bachelor degree	0.1	0.108	0.024	0.239	0.206	0.261	0.163	0.058
	(0.3)	(0.009)**	(0.011)**	(0.112)**	(0.117)*	(0.093)**	(0.139)	(0.185)
College GPA Y1 (non-DE courses)	1.62	0.339	0.020	0.197	0.071	0.366	-0.027	-0.133
	(1.35)	(0.026)**	(0.041)	(0.406)	(0.529)	(0.334)	(0.533)	(0.736)
Number students	**2,462**	**12,883**	**12,883**	**12,883**	**12,883**	**14,923**	**10,406**	**8,029**
Additional controls		√	√	√		√	√	√
GPA controls		cubic	LLR	LLR	LLR	LLR	LLR	LLR
Number of colleges in GPA Sample	5	5	5	5	5	5	5	5

Notes: standard errors (in parenthesis) are clustered at the 11th grade HS GPA. * significant at 10%; ** significant at 5%
Mean outcome values are calculated with students whose 11th grade HS GPA is below the cutoff but not lower than 0.2 points away from the cutoff.
Each cell in the remaining columns represents a separate regression. Dependent variable is defined as taking dual enrollment in any subject area. OLS coefficients in column (2) are regression estimates that do not account for selection into participation, controlling for a cubic polinomial on the score and additional controls. The remaining columns are RD-IV estimates using a local linear regression (LLR) specification. Additional controls include: gender, race dummies, English learner, free or reduced lunch status, FCAT 10th grade standardized score in Reading and Math, cohort and college fixed effect, HS-level demographics (race, ELs, low SES, FCAT 10th grade scores, and total enrollment), districts' median-income and urbanicity.

Table 5: Regression discontinuity estimates of the effect of dual enrollment algebra (math) on student outcomes, CPT sample

	below cutoff (std)	**OLS**	**Reduced Form**	**RD-IV**				
Bandwidth Choice	**-10**	**± 40**	**± 40**	**± 40**		**± 60**	**± 20**	**± 10**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variable								
Dual enrollment algebra (MAC 1105) [First Stage]				0.219	0.216	0.231	0.176	0.135
				(0.030)**	(0.032)**	(0.028)**	(0.038)**	(0.052)**
Outcomes								
HS diploma (any)	0.99	0.008	0.001	0.006	0.005	0.019	0.015	0.055
	(0.11)	(0.002)**	(0.005)	(0.023)	(0.024)	(0.020)	(0.041)	(0.064)
Postsecondary Enroll	0.87	0.023	0.016	0.072	0.072	0.023	0.232	0.168
	(0.34)	(0.012)*	(0.018)	(0.082)	(0.103)	(0.072)	(0.127)*	(0.217)
First Enroll 4yr institution	0.29	0.118	0.016	0.072	-0.081	0.075	-0.020	0.430
	(0.45)	(0.022)**	(0.033)	(0.149)	(0.245)	(0.131)	(0.231)	(0.442)
Persistence through 2nd term	0.69	0.067	0.025	0.112	0.126	0.037	0.221	0.146
	(0.46)	(0.020)**	(0.020)	(0.093)	(0.119)	(0.091)	(0.143)	(0.230)
Persistence through 2nd year	0.61	0.065	0.058	0.266	0.233	0.203	0.448	0.353
	(0.49)	(0.019)**	(0.025)**	(0.118)**	(0.148)	(0.099)**	(0.187)**	(0.254)
Associate degree	0.26	0.042	0.116	0.527	0.518	0.442	0.683	1.171
	(0.44)	(0.020)**	(0.029)**	(0.152)**	(0.156)**	(0.122)**	(0.273)**	(0.675)*
Bachelor degree	0.18	0.080	0.096	0.438	0.364	0.440	0.446	0.788
	(0.39)	(0.025)**	(0.034)**	(0.183)**	(0.188)*	(0.157)**	(0.327)	(0.706)
College GPA Y1 (non-DE courses)	2.03	0.106	0.167	0.763	0.591	0.669	1.751	0.721
	(1.27)	(0.063)*	(0.090)*	(0.442)*	(0.482)	(0.361)*	(0.836)**	(1.275)
Number students	**516**	**4,009**	**4,009**	**4,009**	**4,009**	**5,401**	**2,418**	**1,300**
Additional controls		√	√	√		√	√	√
CPT controls		Cubic	LLR	LLR	LLR	LLR	LLR	LLR
Number of colleges in CPT sample	4	4	4	4	4	4	4	4

Notes: Standard errors (in parenthesis) are clustered at the CPT score. * significant at 10%; ** significant at 5%
Mean outcome values are calculated with students whose CPT score is below the cutoff but not lower than 10 points away from the cutoff.
Each cell in the remaining columns represents a separate regression. Dependent variable is defined as taking dual enrollment algebra (MAC 1105). OLS coefficients in column (2) are regression estimates that do not account for selection into participation, controlling for a cubic polinomial on the score and additional controls. The remaining columns are RD-IV estimates using a local linear regression (LLR) specification. Additional controls include: gender, race dummies, English learner, free or reduced lunch status, FCAT 10th grade standardized score in Reading and Math, cohort and college fixed effect, HS-level demographics (race, ELs, low SES, FCAT 10th grade scores, and total enrollment), districts' median-income and urbanicity.

Table 6: Sensitivity of dual enrollment effect to sample selection and model specification

	HS diploma (any)	**Postsecondary Enroll**	**First Enroll 4yr institution**	**Persist through 2nd term**	**Persist through 2nd year**	**Associate degree**	**Bachelor degree**	**College GPA Y1 (non-DE courses)**
Panel A: ***Effect of dual enrollment (any course)***								
Baseline (Table 4 column 7)	0.101	0.031	0.122	0.045	0.150	-0.033	0.163	-0.027
	(0.073)	(0.182)	(0.164)	(0.177)	(0.177)	(0.178)	(0.139)	(0.533)
Polynomial estimation (2nd order control on the GPA)	0.110	0.055	0.114	0.070	0.173	-0.010	0.136	0.007
	(0.073)	(0.178)	(0.166)	(0.177)	(0.178)	(0.178)	(0.147)	(0.539)
Excluding students who took a college course while in HS outside the DE program	0.099	0.059	0.144	0.065	0.152	-0.030	0.167	0.047
	(0.072)	(0.171)	(0.165)	(0.173)	(0.175)	(0.175)	(0.138)	(0.519)
Excluding students who took DE before 12th grade	0.076	0.034	0.149	0.009	0.212	-0.141	0.168	0.029
	(0.087)	(0.229)	(0.194)	(0.217)	(0.214)	(0.212)	(0.161)	(0.669)
Re-defining DE as students who took any DE course except DE math or english courses	0.115	0.036	0.139	0.052	0.170	-0.038	0.186	-0.031
	(0.083)	(0.208)	(0.187)	(0.202)	(0.203)	(0.203)	(0.159)	(0.607)
Including a larger set of colleges with significant discontinuities in DE participation of any magnitude (8 colleges), First Stage=0.062(0.008)	-0.092	0.007	0.011	-0.124	-0.063	-0.060	0.101	-0.089
	(0.083)	(0.156)	(0.164)	(0.173)	(0.174)	(0.133)	(0.168)	(0.526)
F-Tests								
F-test of homogeneity of effect by college (df = 4) (no additional covariates),	4.25	3.84	1.36	3.64	3.24	3.76	0.37	4.40
[p-value]	[0.00]	[0.00]	[0.25]	[0.01]	[0.01]	[0.00]	[0.83]	[0.00]
F-test of homogeneity of effect by cohort (df = 1) (no additional covariates),	2.43	0.48	1.49	0.67	0.06	0.15	0.12	0.48
[p-value]	[0.12]	[0.49]	[0.22]	[0.41]	[0.81]	[0.70]	[0.73]	[0.49]
Panel B: ***Effect of dual enrollment math (MAC 1105)***								
Baseline (Table 5 column 4)	0.006	0.072	0.072	0.112	0.266	0.527	0.438	0.763
	(0.023)	(0.082)	(0.149)	(0.093)	(0.118)**	(0.152)**	(0.183)**	(0.442)*
Students with GPA above cutoff	-0.003	0.092	0.026	0.202	0.337	0.620	0.389	0.985
	(0.016)	(0.104)	(0.162)	(0.130)	(0.162)**	(0.188)**	(0.203)*	(0.536)*
Polynomial estimation (2nd order control on the CPT)	0.005	0.072	0.037	0.131	0.268	0.538	0.419	0.773
	(0.021)	(0.079)	(0.141)	(0.088)	(0.113)**	(0.146)**	(0.180)**	(0.433)*
Adding linear term in the CPT reading score	0.003	0.054	0.100	0.066	0.279	0.450	0.450	0.749
	(0.022)	(0.084)	(0.164)	(0.097)	(0.137)**	(0.156)**	(0.181)**	(0.459)
Excluding students who took a college course while in HS outside the DE program	0.006	0.081	0.069	0.111	0.253	0.521	0.435	0.754
	(0.023)	(0.083)	(0.151)	(0.090)	(0.116)**	(0.156)**	(0.184)**	(0.442)*
Excluding students who took DE math before 12 grade	0.005	0.087	0.035	0.137	0.260	0.496	0.427	0.792
	(0.023)	(0.083)	(0.146)	(0.093)	(0.117)**	(0.149)**	(0.175)**	(0.433)*
Including a larger set of colleges with large discontinuities in DE algebra only (5 colleges), First Stage= 0.197(0.025)	0.035	0.144	0.052	0.124	0.203	0.409	0.292	0.627
	(0.021)	(0.074)*	(0.123)	(0.098)	(0.117)*	(0.131)**	(0.160)*	(0.397)
Including a larger set of colleges with significant discontinuities in DE algebra only of any magnitude (9 colleges), First Stage=0.097(0.013)	0.040	0.107	0.123	0.156	0.131	0.616	0.397	1.041
	(0.039)	(0.065)	(0.162)	(0.123)	(0.120)	(0.130)**	(0.132)**	(0.364)**
F-tests								
F-test of homogeneity of effect by college (df = 3) (no additional covariates),	1.36	0.42	0.14	2.30	0.50	0.73	2.30	1.17
[p-value]	[0.26]	[0.74]	[0.94]	[0.08]	[0.68]	[0.54]	[0.08]	[0.33]
F-test of homogeneity of effect by cohort (df = 1) (no additional covariates),	3.50	2.42	0.02	3.13	2.36	4.33	0.24	8.42
[p-value]	[0.07]	[0.12]	[0.88]	[0.08]	[0.13]	[0.04]	[0.62]	[0.00]

Notes: standard errors (in parenthesis) are clustered at the 11th grade HS GPA. * significant at 10%; ** significant at 5%
Panel A uses data within 0.4 GPA points around the cutoff and Panel B uses data within 40 points in the CPT math score. The number of observations varies depending on the sample restriction. Estimates are based on a local linear regression discontinuity specification and control for additional covariates described in the text unless indicated otherwise.