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Are Four-Year Public Colleges Engines for Economic Mobility? Evidence from Statewide Admissions Thresholds

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Four-year public colleges may play an important role in supporting intergenerational mobility by providing an accessible path to a bachelor's degree and increasing students' earnings. Leveraging a midsize state's GPA- and SAT-based admissions thresholds for the four-year public sector, I use a regression discontinuity design to estimate the effect of four-year public college admissions on earnings and college costs. For low-income students and Black, Hispanic, or Native American students, admission to four-year public colleges increases mean annual earnings by almost $8,000 eight to fourteen years after applying without increasing the private costs of college. The state recovers the cost of an additional four-year public college admission through increased lifetime tax revenue. Expanding access to four-year public colleges may be a particularly effective way to improve the economic outcomes of low-income students and Black, Hispanic, or Native American students.

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Are Four-Year Public Colleges Engines for Economic Mobility? Evidence from Statewide Admissions Thresholds

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Abstract

Four-year public colleges may play an important role in supporting intergenerational mobility by providing an accessible path to a bachelor's degree and increasing students' earnings. Leveraging a midsize state's GPA- and SAT-based admissions thresholds for the four-year public sector, I use a regression discontinuity design to estimate the effect of four-year public college admissions on earnings and college costs. For low-income students and Black, Hispanic, or Native American students, admission to four-year public colleges increases mean annual earnings by almost $8,000 eight to fourteen years after applying without increasing the private costs of college. The state recovers the cost of an additional four-year public college admission through increased lifetime tax revenue. Expanding access to four-year public colleges may be a particularly effective way to improve the economic outcomes of low-income students and Black, Hispanic, or Native American students.

JEL Codes: I20, I23, I24, I26, I28, J24

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I. Introduction

As the college wage premium has grown since the 1980s, a bachelor's degree has become a gatekeeper to a higher quality of life and a path to mobility for those coming from disadvantaged backgrounds (Goldin & Katz, 2008; Kochhar & Sechopoulos, 2022). However, the cost of four-year college is high and rising in real dollars and can present a substantial barrier to access for students (Ma et al., 2018). Two-year public colleges help promote access to college at a lower price, but only 13 percent of community college entrants complete a bachelor's degree within six years (Shapiro et al, 2017). In this context, four-year public colleges may play a uniquely important role in promoting access to a bachelor's degree for disadvantaged students and enabling economic mobility.

A nationwide descriptive study of colleges' effects on intergenerational income mobility found that the institutions with the highest bottom-to-top income quintile mobility rates were mid-tier public institutions, as these institutions enroll a large share of students from the bottom quintile of the family income distribution (Chetty et al., 2017). However, there is relatively little long-term, causal evidence of the effects of college choice on earnings and the costs of college. This is an important question for four-year public colleges, which receive a substantial portion of support from the government and were founded in part with a social mission of expanding access to non-wealthy students. As state appropriations per student have declined at four-year public colleges over the last twenty years, understanding the value of these investments is important for state policymakers (Mitchell et al., 2017).

Identifying the causal effect of four-year public colleges on students' long-run earnings is challenging because there are large differences in the types of students attending four-year public colleges in terms of academic preparation and financial resources. Separating the causal effect from the effects of non-random student sorting across colleges requires identifying an exogenous source of variation in where students enroll. In this study, I use a regression discontinuity design to estimate the causal effect of access to the four-year public college sector on earnings and costs for students on the margin of qualifying for admission. To do so, I leverage the sliding admission scale for four-year public colleges in Massachusetts, which is based on high school grade point average (GPA) and SAT scores. Nationwide, one-fifth of four-year institutions report using test scores to define an admissions threshold (Briggs, 2009), and in the public sector, many states including Georgia, Florida, and Texas set minimum thresholds based on test scores, grade point average (GPA), or class rank to determine admission to public four-year colleges. While there is a large research base examining the effects of loosening financial constraints on college enrollment, completion, and earnings (e.g., Kane, 2003; Deming & Dynarski, 2010; Castleman & Long, 2016; Denning et al., 2019; Scott-Clayton & Zafar, 2019; Bettinger, Gurantz, et al., 2019), there is much less research on the effects of admissions thresholds in constraining access to colleges.

Since the admissions thresholds are public information, one concern with this design is that students might behave strategically to move above the admissions threshold by retaking the SAT or lobbying a teacher for a higher grade to raise their GPA, or that they may be less inclined to apply if they were below the threshold. As shown in Figure A1, students from advantaged backgrounds appear to engage in this behavior, while low-income students and Black, Hispanic, or Native American (BHN) students do not, most likely because of differences in the resources and information available to these students. Prior work has shown that Black, Hispanic, and Native American students and lower-income students are less likely to retake the SAT (Goodman, et al., 2020) and that low-cost interventions to support these students can help them to enroll in college at higher rates (Bettinger, et al., 2012; Castleman & Page, 2015) or enroll in more selective colleges (Hoxby & Turner, 2013; Pallais, 2015). Since the regression discontinuity design relies on students not manipulating the running variable, I focus on low-income and BHN students.

Regression discontinuity estimates show that a student's probability of admission to a four-year public college increases by 25 percentage points at the threshold. Admission increases a student's likelihood of enrolling in a four-year public college by 58 percentage points for students who would have otherwise enrolled in a two-year college (19 pp), four-year private college (13 pp), or no college at all (18 pp). It also increases bachelor's degree attainment by 15 percentage points, in part by shifting students away from associate or certificate degrees. Eight to fourteen years following their application to college, admission to a four-year public college raises students' average annual earnings by $7,950 (as measured in 2018 dollars), a 26% increase in earnings relative to the comparison group. The large gains for low-income and BHN students are concentrated among males and students with persistently low family income. Although admission to a four-year public college causes students to enroll in a four-year college for an additional year, there is no increase in the private costs of college on average, which appears to be driven by the large cost savings from some students switching from four-year private colleges to four-year public colleges. The additional investment the state makes in admitting students to four-year public college pays for itself in increased tax revenues within twenty years.

This study is the first paper to estimate the long-run effects of admission to a state's four-year public college sector on applicants' earnings and college costs. Two prior studies have used regression discontinuity designs to examine the effect of access to a particular university in the United States on earnings, finding positive effects of access to a state flagship university

(Hoekstra, 2009) or a less selective four-year public university in Florida (Zimmerman, 2014). From international contexts, Kirkeboen et al. (2016) and Hastings et al. (2013) leverage data from centralized postsecondary admissions systems in Norway and Chile, respectively, to estimate the effects of college choices on earnings. The closest work from a U.S. context examines the effects of access to a state's four-year public sector in Georgia using minimum SAT admissions thresholds. Goodman et al. (2017) find positive effects of access to four-year public colleges on bachelor's degree attainment rates for students who would have primarily otherwise attended a two-year college. A recent working paper extending this work finds large positive effects of access on students' estimated household income at age 30 for students who take the SAT too late to retake the test before applying (Goodman et al., 2020). Similar to my analysis sample, this group is disproportionately composed of students who come from low-income high schools and historically underrepresented groups. My paper complements this work by using applicants' true earnings rather than estimated income and focuses explicitly on applicants' wages rather than household income, which includes spousal income.

To estimate the returns to admission, I use student-level college cost and aid data, rather than relying on institutional average costs (Zimmerman, 2014; Goodman et al., 2020). This is an important advancement because aid packages can differ substantially across students within institutions, particularly for low-income students, which will affect estimates of the returns to college. In addition to using the student-level earnings and cost data to estimate private returns to the student, I also estimate the returns to the state government for admitting an additional student at the admissions threshold to a four-year public college. This is important because it directly addresses the question of whether the state can recover the additional investment of granting admission to students on the margin of being admitted. It follows an approach similar in spirit to

Denning et al. (2019), which estimate how quickly the federal government recovers the additional costs of the Pell Grant through tax revenues, and Bettinger, Kremer, et al. (2019) which estimate whether the government of Colombia can recover the cost of administering private secondary school scholarships.

The paper proceeds as follows. Section II reviews the state policy context and the data I use. Section III presents the empirical methods, validity checks, and the analysis sample. Section IV reviews the first stage and main results, including effects on enrollment, graduation, earnings, costs, and aid, while Section V presents the cost-benefit analysis. I conclude with a discussion of policy implications in Section VI.

II. State Context & Data

A. State Context

The public higher education system in Massachusetts consists of fifteen community colleges, nine state universities, and four research universities within the University of Massachusetts (UMass) system. The nine state universities include six comprehensive universities and three specialized colleges with a particular focus on liberal arts, art and design, or the maritime industry. Approximately half of all graduating seniors in Massachusetts who enroll in college enrolled in the MA public sector, with just over half enrolling in four-year public colleges and the remainder in two-year public colleges.[1]

The Massachusetts Board of Higher Education (BHE) sets a minimum threshold for admission to four-year public universities in the state (Massachusetts DHE, 2013). To qualify for admission to the four-year colleges, students must have a combined SAT (math plus verbal)

[1] Author's calculation from graduating high school cohorts of 2002 to 2010. Enrollments are measured by the fall after graduating from high school.

score and high school grade point average (GPA) that meet a set of criteria on the sliding scale. Because the Board has a higher set of thresholds for the UMass institutions, I focus on the state university thresholds, as these pose the binding constraint on access to the state's four-year public college system. Figure 1 plots combined SAT scores and high school GPAs for all applicants to the state universities in the 2004-2010 application cohorts with a white line denoting the application threshold. Students on the white line or to the right of it meet the minimum qualifications for admission while those under the line do not. It is clear from the figure that the minimum thresholds affect a substantial portion of applicants.

Exemptions to the minimum admissions thresholds can be granted to at least 10% of students who enroll in a given cohort. The largest exemption is for special admissions applicants who have demonstrated their "potential for success in a four-year program" through other means. Examples include students who have "steadily improving high school grades, a high class rank, special talents, and/or strong recommendations" (MA DHE, 2013).

The Board of Higher Education also has a policy for how universities are expected to calculate the weighted GPA used in admissions decisions (MA DHE, 2013). The GPA is based on a set of sixteen required courses in English, math, science, social sciences, foreign languages, and electives. An additional 0.5 points are granted for honors courses and an additional 1.0 point for AP/IP/Dual Enrollment courses.[2] In practice, there is wide variation in how the same student's weighted GPA is calculated across institutions, suggesting that universities make different judgments when determining which courses to include and which weights to use when calculating GPAs from students' transcripts.

[2] Some students will have not yet completed all the courses when they apply, in which case the GPA is calculated without those courses.

Table A1 compares the state universities to the UMass universities and community colleges for the 2004-05 academic year. On average, the state universities are less expensive to attend than the UMass universities and more expensive than the community colleges. Education-related expenditures are higher at the state universities than the community colleges, but less than in the UMass system. For first-time enrollees, 76% of full-time students return the following year, and 48% earn a bachelor's degree within six years. This is slightly lower than the national bachelor's degree attainment rate for first-time enrollees at public four-year institutions of 53%.[3]

B. Data

I use student-level data from the Massachusetts's Department of Higher Education (DHE) on applicants to the comprehensive four-year public universities who applied to enroll for the 2004-05 to 2010-11 academic years.[4] For each applicant, I have the math and verbal SAT score used in the admissions decision, demographics (race/ethnicity, gender, age) and a weighted high school GPA which was calculated by the four-year colleges' admissions departments from student transcripts.[5] I also have 10th grade standardized test scores in math and English and additional demographics (e.g. free and reduced price lunch status, limited English proficient (LEP) status) from the Department of Elementary and Secondary Education (DESE).[6]

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[3] National Center for Education Statistics, 2010. Table 343. From the Beginning Postsecondary Students Longitudinal Survey (1996/01), which follows the cohort beginning postsecondary education in 1995-96 through 2001.

[4] MA high school graduates from the 2006-07 school year are omitted from the data because the National Student Clearinghouse records were unavailable for this cohort in the sample linked to earnings data.

[5] The four-year public colleges submit the SAT scores used in the admissions decision. It is not clear what decision rule is used to determine the relevant SAT if multiple are submitted, as I do not observe multiple SAT scores for those who took the test multiple times.

[6] Test scores are standardized within subject and year relative to the state mean and standard deviation to facilitate comparison of students within cohorts.

To track college enrollments and degree attainment, I combine this with data from the National Student Clearinghouse (NSC). The NSC collects information on students' enrollment in postsecondary education in the U.S. nationally. In Massachusetts, NSC covered 95% of all undergraduate enrollments in the state as of 2011 and about 90% of enrollments in other states (Dynarski et al., 2015). The NSC data allow me to identify where students enroll in the fall term following their spring application (e.g. four-year public, four-year private, two-year college, or no college), whether and when they earn a degree and from what type of institution they earn a degree (e.g. four-year private, four-year public, or two-year public).

I also construct two measures of college characteristics. Traditional measures of peer achievement at postsecondary institutions consist of measures based on ACT or SAT scores. However, two-year institutions often do not collect or report this information. Smith and Stange (2016) take the mean PSAT score of students enrolled at a given college to construct a measure of peer ability for two-year and four-year institutions. I use a similar approach with Massachusetts's high school exit exam scores (the 10^{th} grade MCAS) for the graduating high school classes of 2002 to 2010.

Another challenge with measuring student outcomes for two-year institutions is that traditional measures of degree attainment reported in IPEDS do not follow students over time to examine bachelor's degree receipt or transfer rates. Following Goodman, et al. (2017), I use the Massachusetts high school graduating classes of 2002 to 2010 to estimate the mean 8-year degree completion rates for each college from students who enroll at that college within one year of graduating from high school. For applicants who do not enroll in any college by the fall after applying, I assign the mean eight-year graduation rate or the mean MCAS score, respectively, for applicants in this group.[7]

For all students who enroll in any college (public or private) within the state of Massachusetts, I also use data from the Department of Higher Education on students' costs of attending college and their total financial aid package including total grants from all federal, state, institutional, or outside sources for each year that they are enrolled from 2004-05 to 2016-17. The data cover all student who either apply for or receive any financial aid award from federal, state, or institutional sources. (The vast majority apply for FAFSA but there are also a small number of students who did not submit FAFSA but received an award.) For all students who are enrolled in an institution in a given term but are not in the financial aid data, I assign the student zero federal, state, and institutional aid, as they would have been present in the financial aid data had they received any aid. I also estimate tuition and fees for these students by calculating the average tuition and fees for students who enroll in an institution in a given year with the same enrollment intensity (i.e. the same terms and the same enrollment status [part-time or full-time] in each term) and received financial aid.[8]

Students who enroll out-of-state are missing from the data. For these students, I use data from IPEDS (Integrated Postsecondary Education Data System) assembled by the Delta Cost Project to estimate costs and aid.[9] I calculate the FTE (full-time equivalent) enrollment for each student in each institution in each year and multiply this by the listed tuition and fees for an FTE student. To estimate aid, I subtract net tuition revenue from gross tuition and fee revenue and

[7] The mean eight-year graduation rate for applicants to state universities who do not enroll in college by the fall after applying is 0.103 and the mean combined MCAS score is -0.142.
[8] For those with aid, the correlation between these estimates and observed tuition fees is 0.98. This suggests that the imputed tuition and fees for students that are not in the financial aid data are likely quite accurate estimates.
[9] Since Delta Cost data is not available after 2014-15, I use IPEDS to reconstruct the Delta Cost variables for 2015-16 and 2016-17.

divide this by FTE enrollment. I then calculate an estimate of average aid for each student by multiplying this by each student's FTE enrollment at an institution in a given year. (See Appendix C for details regarding financial aid variables.)

Lastly, I combine this with records from the Massachusetts Department of Unemployment Assistance (DUA) that include quarterly earnings starting in the first quarter of 2010 through the last quarter of 2018. I convert all earnings, costs, and aid to 2018 dollars using the CPI-U. The analysis sample is limited to applicants who graduated from a Massachusetts high school between 2001-02 and 2010-11, as this is the sample that I am able to match to the labor data.

III. Empirical Methods, Validity, and Sample

A. Empirical Methods

The key challenge to identifying the causal effect of attending a four-year public college on students' outcomes is finding an exogenous source of variation in a students' likelihood of attending one. In this study, I leverage the sliding scale admissions thresholds used to determine access to four-year state universities in Massachusetts. For students near the admissions thresholds, those just above the cutoff for admission are more likely to be admitted to four-year public institutions, while those just beneath are less likely to be admitted. However, other characteristics of the students which might affect their outcomes should be continuous through the cutoff. This provides an opportunity to estimate the effect of attending a four-year public college on a range of outcomes using a regression discontinuity design.

I begin by estimating the effect of being just above the cutoff for admission on college enrollment using the following local linear regression on the sample of students near the admissions cutoff:

$$(1)\ Y_{its} = \beta_0 + \beta_1 Above_{its} + \beta_2 Distance_{its} + \beta_3 Above_{its} * Distance_{its} + \delta_t + \phi_s + \epsilon_{its}$$

Y_{its} represents the outcome of interest for student i applying to enroll in the fall of year t in SAT bin s. SAT bins are defined for all students based on the GPA cutoff that binds for students with their combined SAT score (math + verbal). For example, a student with a 1020 combined SAT score would be in the SAT bin for students scoring at or above 1000 and below 1040, as all of these students are required to have a high school GPA at 2.31 or higher to be admitted. All students are sorted into one of seven bins based on their SAT score. $Distance_{its}$ is the distance a student's weighted high school GPA is from the relevant GPA threshold for a student in their SAT bin. Continuing the prior example, a student with a 1020 SAT score would have a high school GPA centered at 2.31, as this is the binding threshold for students in their SAT bin. $Above_{its}$ is an indicator for whether a student i has a high school GPA that is above the relevant threshold for her given SAT bin s. Year fixed effects (δ_t) are included to absorb any year-to-year variations in the cohort of applicants to four-year institutions. SAT bin fixed effects (ϕ_s) are also included to absorb differences between students across SAT bins. The causal effect of being just above the minimum cutoff for admission is β_1.

First, I use the reduced form model from equation (1) to estimate the first stage effects on admission to a state university. Then, I use the same general model to instrument for admission to a four-year public college with an indicator for being above the relevant GPA threshold in a fuzzy regression discontinuity design. To do so, I first estimate the following model where $Admit_{its}$ is an indicator for admission to a four-year public college in the state.

$$(2)\ \ Admit_{its} = \alpha_0 + \alpha_1 Above_{its} + \alpha_2 Distance_{its} + \alpha_3 Above_{its} * Distance_{its} + \gamma_t + \tau_s + u_{its}$$

I then calculate the predicted values of $Admit_{its}$ from that regression to estimate the following second stage equation:

$$(3)\ \ Y_{its} = \lambda_0 + \lambda_1 \widehat{Admit}_{its} + \lambda_2 Distance_{its} + \lambda_3 Above_{its} * Distance_{its} + \psi_t + \pi_s + e_{its}$$

In this model, λ_1 is the effect of admission to a four-year public college on an outcome, Y_{its}, for students who would be admitted in a four-year public institution because they were just above the cutoff for admission and for students who would not be admitted if they were just below the cutoff. I estimate the effect of admission to a four-year public college on enrollment, degree attainment, earnings 8-14 years following admission, and costs and aid. Standard errors are clustered at the distance to the GPA threshold as recommended by Lee and Card (2008). The optimal bandwidths proposed by Calonico, Cattaneo, and Titiunik (2014) for the main outcomes of interest (degree attainment, earnings, and costs) vary between 0.5 and 0.6 GPA points. For each outcome, I use the optimal bandwidth for the main specifications, but also show robustness to alternative bandwidths that are wider and narrower.

B. Validity of Research Design

One assumption for regression discontinuity estimates to be valid is that students cannot systematically sort themselves above or below the cutoff. In this case, the cutoffs for admission to a four-year state university are publicly known. This presents two potentials problems. First, students may not apply to four-year public colleges at all (and therefore would not appear in my sample) if they knew that they would not be able to pass the GPA and SAT thresholds for admission. Second, students may try to adjust their GPA if they were just below the relevant GPA threshold in order to pass the cutoff or may retake the SAT to get into an SAT bin where their GPA would be above the minimum threshold.

To address these concerns, it is useful to consider what a student would need to know and when in order to manipulate their status relative to the cutpoint. First, students would need to be aware of the minimum thresholds in order to respond. To change their GPA, they would need to be aware of the cutoffs before their senior year, as most students apply in the fall of their senior year before senior-year grades appear on their transcripts. However, changing one's SAT score is something a student could do relatively late, such as when they are applying to college their senior year, if they had the resources to retake the SAT. Students would also need to be aware of how the state universities were using their transcripts to calculate weighted GPAs. The formula is available online, but there appears to be significant discretion involved in which courses are used to calculate the GPA and which weights each course receives. Across colleges I observe substantial variation in the calculation of weighted GPAs for the same applicant. Three-quarters of students who apply to multiple public four-year institutions have different high school GPAs, with a mean difference of 0.14 points for these students. This uncertainty makes it harder for students to respond strategically to the cutoffs.

Another source of uncertainty comes from exemptions to the standards. The state publicly indicates that students can be exempt from the minimum thresholds by showing potential through other means, such as class rank or steadily increasing high school grades (MA

DHE, 2013). This would give students just under the cutoffs for admission a compelling reason to still apply.

Although there is some uncertainty in the process that makes it harder to respond strategically to the cutoffs, students still have a strong incentive to do so when applying to college. I conduct two empirical tests to check for evidence that students are responding strategically to the cutoffs. First, following McCrary (2008), I test if the density of students is smooth through the admissions threshold. In Figure A1, I split the sample into two groups: those who are low-income or BHN students and those who are not.[10] Two features stand out in the histogram for the advantaged students. First, the density is consistently higher to the right of the cutoff compared to the left even away from the cutoff itself. This is consistent with a situation in which students are more likely to apply if they are above the cutoffs than if they are below or are engaging in other behaviors to raise their SAT scores or GPAs to get above the cutoff. However, there is no increase in density to the right of the cutoff for low-income and BHN students. These students appear to be either less aware of or less able to respond to the cutoffs for admission at the state universities. The second salient feature of Figure A1 that is present in both the upper and lower histograms is an increase in density immediately at the cutoff for admission. Although this may look like manipulation, grade point averages tend to cluster at specific values, particularly whole numbers, due to how they are calculated (Barreca et al., 2016: Ost et al., 2018). In this context, the most common GPA that is binding for students is a 3.0, which could be causing the increased density right at the cutoff.

To demonstrate this issue, I conduct a placebo test in which I take all students who are in an SAT bin that is not bound by a GPA cutoff of 3.0, but center them at 3.0 as if they were

[10] Low-income students are defined as those who ever qualified for free-and-reduced price lunch (FRPL) in high school.

bound by that cutoff. The histogram of this placebo test in Figure A2 also has a large increase in values immediately at the cutoff.[11] This suggests that the heaping observed in the original density plot is not being driven by manipulation. However, Barreca et al. (2016) show that a heap like this can lead to bias in estimates even if it is not driven by manipulation. Therefore, I show a donut specification in all the tables that leaves out observations at the cutoff to address this issue.

Lastly, I conduct a covariate balance test to see if any covariates are discontinuous through the cutoff, which would suggest that the composition of the students on either side of the cutoff was different. To do so, I estimate equation (1) using a range of student characteristics as the outcomes of interest. As shown in Table A2 and Figure A3, I find no consistently significant differences in demographic characteristics such as gender, race, FRPL and LEP (limited English proficiency) status in high school, years of FRPL in high school, or age at entry into college.[12] I also find no differences in prior achievement on high school standardized 10th grade test scores (known as the MCAS), nor any differences in SAT scores. Lastly, I predict earnings 8 to 14 years after application and bachelor's degree attainment after eight years using all of the demographic and achievement test variables I have noted and find no difference in predicted earnings or bachelor's degree attainment rates at the cutoff. Together, these tests suggest that low-income and BHN students are not systematically sorting in a way that could bias the results of the regression discontinuity design.

C. Sample

[11] There is also a visible heap at -1, which corresponds with a 2.0 GPA, another whole number value.
[12] One variable – FRPL – is statistically different at the 10% level in one of four specifications. No other variable has any statistically significant differences across all four specifications.

The full sample consists of all applicants to the four-year comprehensive state universities in Massachusetts starting in the fall of 2004 through fall of 2010 for whom there is a recorded SAT and GPA in the application (83% of all students).[13] For students with multiple application years, I use the first year, as the later years may be endogenous. For students with multiple applications within one year, I use the application with the highest high school GPA, as a student need only pass the threshold for admission at one institution to be admitted to a state university. The sample is limited to students who graduated from an MA high school in 2002 to 2010, as this is the sample for whom earnings data were available.[14]

As shown in Table 1, the sample of all applicants consists of 65,600 people, 18,712 of whom are low-income or BHN. This group is 82% white, 7% black, and 6% Hispanic. About one-fourth of students qualified for free and reduced price lunch in high school. The average high school GPA was 2.93 and the average math and verbal SAT scores were approximately 500 and 490, which are below the national median of 510 in math and verbal for college bound seniors in 2004.[15] The average 10th grade MCAS scores in ELA and math are just over the mean for high school graduates in the state (0.16 standard deviations in ELA and 0.14 in math). One third of all applicants enrolled in a state university within one year of applying, and 23% enrolled in a private four-year college. Only 11% enrolled in a two-year college. Students enrolled for an average of 8.14 terms, which is equivalent to about four academic years of college. Within eight years, 59% had earned a bachelor's degree. Eight to twelve years following application, 85% of students were in the labor force in Massachusetts, earning an average of $35,764 per year. (Note

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[13] The National Student Clearinghouse data that was matched to the earnings data was not available for students graduating from high school in 2007, so these students are omitted from the sample.
[14] One comprehensive state university only collects GPA for admitted students, so it was dropped from the analysis.
[15] Source: https://secure-media.collegeboard.com/digitalServices/pdf/research/cb-seniors-2004-CBSNR_total_group.pdf

that this average includes zero wages for students who are not in the labor force. The average for those in the labor force is approximately $42,000 per year.)

In column 2, the sample is restricted to students who are low-income or BHN. In high school, 88% of students in this sample were FRPL-eligible and 17% qualified as having limited English proficiency (LEP). Half of the sample is black or Hispanic. SAT math and verbal scores are 40 points lower than for the full sample, while 10^{th} grade MCAS scores are about 0.1 standard deviations below the state mean in ELA and math. The average high school GPA is 0.08 points lower than the mean for the full sample. Low-income and BHN students are slightly less likely than students in the full sample to enroll in a state university (29%) or a four-year private college (21%) and are slightly more likely to enroll in a community college (15%). The eight-year bachelor's degree attainment rate is substantially lower for these students at 46%. While low-income and BHN students participate in the labor force at a similar rate to the full sample, they earn approximately $3,600 (or 10%) less per year.

The last column restricts the analysis sample to those within 0.6 GPA points above or below the threshold for admission for their SAT bin. This group is similar on average to the full analysis sample in demographic characteristics, college enrollment patterns, labor force participation, and earnings. However, their academic achievement is slightly lower, with SAT scores about 20 points lower in math and verbal, MCAS scores 0.1 standard deviations lower, and high school GPA 0.11 points lower.

IV. Results

A. Admission, Enrollment, and Degree Attainment

Table 2 presents the regression discontinuity estimates of the effects on admission using the reduced form estimates in row 1 and then instrumenting with admission to a four-year public in all subsequent rows. Column 1 uses the main model with a bandwidth of 0.6 GPA points. Column 2 adds demographic controls. Columns 3-5 show robustness checks, including a donut specification that drops observations immediately at the cutoff and estimates using a smaller bandwidth (0.5 GPA points) and a larger bandwidth (0.7 GPA points).

As shown in Figure 2, students just above the cutoff for admission are 25 percentage points more likely to be admitted to an MA state university. Admission to a state university increases enrollment in a state university by the fall after applying by 58 percentage points. The increase in state university enrollment is offset by a decrease in students' enrollment in four-year private colleges by 13 percentage points, two-year public colleges by 19 percentage points, and no college by 18 percentage points. There is no statistically significant change in a student's likelihood of enrolling in a UMass institution or in an out-of-state four-year public college. Admission to a state university also changes the characteristics of the colleges students enroll in, causing students to enroll in colleges with bachelor's degree attainment rates that are 19 percentage points higher and peer MCAS scores that are 0.25 standard deviations higher.

In total, admission causes students to enroll in a state university for an additional 2.5 terms (just over a year of college) and increases enrollment in any four-year college for an additional 1.9 terms (almost a full-year of college). This increase is in part offset by students enrolling 1 fewer term in a two-year public college. There is little change in the terms enrolled in private four-year colleges, suggesting that students induced to attend a four-year private college as a result of being below the admission threshold for the state universities do not stay enrolled in four-year private college for very long.

As shown in Table 3, admission to a state university also causes a 15 percentage point increase in a student's likelihood of earning bachelor's degree, though these estimates are somewhat noisy. This change is driven entirely by students earning bachelor's degrees from state universities, with no change in students' probability of earning a bachelor's degree from a private or other public institution. The gains in bachelor's degree attainment are in part offset by a 12 percentage point decrease in associate or certificate completion. Together, these results suggest that admission to a four-year public college could affect earnings through at least three channels: expanding bachelor's degree completion, expanding the total years enrolled in a four-year college, and increasing the selectivity of the colleges in which students enroll.

B. Earnings

In order to pool estimates across all cohorts, I use average earnings 8-14 years following a student's application to estimate effects on earnings. To the extent that there are any employment effects, I impute zeros for those missing earnings to take this into account. Figure 3 plots mean annual earnings 8-14 years after application as a function of GPA distance to the threshold. As estimated in Table 4, at the cutoff for admission there is a large increase in annual earnings of $1,960, which corresponds with a $7,950 increase in annual earnings due to admission to a state university. The estimates are robust to adding controls for demographics and prior achievement (column 2), removing observations at the cutoff from the sample (column 3), and using either a smaller (0.5) or wider (0.7) bandwidth (columns 4-5). The increase in earnings is approximately 26% of the mean earnings for the comparison group just below the admissions threshold. This estimate is comparable with Zimmerman (2014), which found a

$8,175 increase in annual earnings (in 2018 dollars) for the average marginal student admitted to Florida International University.[16]

To examine how effects on earnings change over time, I plot the instrumental variable estimates of access to four-year public institutions on annual earnings by year. As shown in Figure 4, there is a clear upward trajectory in effects on earnings, which would be consistent with a growing wage premium with experience. One caveat with this figure is that the panel is unbalanced, since I can only follow cohorts through the end of 2018. This causes the estimates to become noisier over time as cohorts drop from the sample and also means estimates conflate cohort effects with effects on earnings over time.

One concern with using state unemployment insurance (UI) data is that students who move out of state or work in an industry not covered by UI data will be counted as having zero earnings.[17] If admission to a four-year public college affects the probability of appearing in the UI data, then estimates of the effect of four-year public college admission could be biased. I address this concern using two approaches. First, following Denning et al. (2019), I define students as residing in-state if they are attending an in-state institution or appear in the UI data with wages in a given year. I then estimate the effect on being in-state for each year in which I have wage data using the main regression discontinuity model. The coefficients from this exercise are shown in Figure A4. The point estimates are small and positive, but never statistically significant. The effect in year eight is the closest to being almost statistically significant so I conduct an additional robustness check in which I only estimate effects on

[16] Zimmerman (2014) finds an effect of admission on quarterly earnings (in 2005 dollars) of a $1,593. Converting to annual earnings yields an effect of $6372 in 2005 dollars. Converting to 2018 dollars using the CPI-U, this is $8,175.

[17] UI records cover all employers who have at least one employee working on a permanent, part-time, or temporary basis one or more days in 13 weeks during a calendar year or employers who pay more than $1500 in wages in any quarter of a calendar year. Agricultural employers have higher thresholds. Source: https://www.mass.gov/service-details/employers-subject-to-unemployment-insurance-ui-contributions

earnings for years 9-14 following application. As shown in Table A3, the effects are slightly larger in magnitude and statistically significant, though the sample size decreases slightly as one cohort is no longer in the sample.

Second, I conduct a bounding exercise following Lee (2009). I use the point estimates from Figure A4 to identify the (statistically insignificant) increase at the cutoff in the percentage of students who are in-state in a given year. For each year post application, I then order students above the cutoff by their earnings and trim the percentage of top earning applicants denoted by the point estimate for that year. I then construct the mean annual earnings for years 8-14 using this trimmed earnings data and re-estimate the models. This exercise provides a lower bound estimate of the effects on earnings under the extreme assumption that all of the difference in the percentage of students who are in-state in a given year can be attributed to differential selection, whereby the highest earning students beneath the cutoff all leave the state (or go into an industry that is not covered in the UI data). The estimates (shown in Table A4) are only slightly attenuated and are substantively unchanged.[18]

C. Heterogeneity in Effects

Table 5 shows the main effects separated by gender, race and ethnicity, and FRPL intensity in high school. Average effects on earnings vary substantially by gender, with men experiencing large gains in earnings. Admission increases men's earnings by $12,441 annually at the threshold, while women's earnings increase by only $5,342 and are not statistically significant. Students who persistently qualify for FRPL in high school also have quite large

[18] The total sample size in these regressions is the same as in the main specifications because a student who is in the trimmed earnings range in one year is present in at least one year in which he is not trimmed. Removing a high-earning year or years from a student's average earnings in years 8-14 does little to change the overall estimate.

positive effects, as admission increases these students' earnings by $14,938.[19] Effects on earnings are also particularly large and positive for black students, though this estimate is not statistically significant.

The groups with the largest effects on earnings tend to be the groups with the largest effects on bachelor's degree attainment, with the exception of Hispanic applicants. Admission to state universities makes men 29 percentage points more likely to earn a bachelor's degree. Black students and those who are persistently FRPL-eligible also have large positive effects on bachelor's degree attainment, although they are not statistically significant.

D. Costs

On average, students above the cutoff are substituting away from enrolling in four-year private colleges, two-year public colleges, or no college. The additional cost of a four-year private college compared to a four-year public college tends to be larger than the cost savings from attending a two-year college instead of a four-year college. This would suggest students might save money as a result of admission to a state university. However, admission to four-year public colleges is also causing student to enroll in more terms of four-year college. This makes it unclear what the net effect will be on costs. Further complicating predictions is the fact that aid varies within institutions across students. Given that low-income and BHN students are more likely to qualify for aid, it is not clear how admission to a four-year public college will affect costs.

Table 6 shows the results of estimating effects on tuition and fees, aid, and net tuition and fees for students enrolled in college through 2016-17. Regression discontinuity estimates

[19] Michelmore & Dynarski (2017) show that years of FRPL-eligibility is a proxy for family income.

indicate no statistically significant effect on tuition and fees, total grant aid, or net tuition and fees. However, there is a positive effect on the amount of aid students receive from federal sources, though this is somewhat sensitive to specification. This positive effect is likely due to the fact that many students are Pell-eligible and are enrolling in a four-year college for longer. Effects on state aid are positive, but not consistently statistically significant. Institutional sources of aid appear to be mostly unchanged. Although they are not statistically significant differences, the point estimates suggest that students pay slightly lower sticker prices for tuition and fees, receive slightly more aid in total, and pay lower net tuition and fees. These effects are encouraging given that students are staying in four-year college for an additional year.

One limitation of the financial aid data I use is that any out-of-state enrollments rely on average costs and aid amounts, scaled for each student's intensity of enrollment. To the extent that low-income and BHN students receive different amounts of aid than the average student, this could bias the estimates. Although there is not a statistically significant difference in whether a student enrolled out of state or the quantity of terms a student enrolled out of state, I test whether dropping students who ever enroll out of state affects the estimates of the effects on tuition and fees, aid, and net tuition and fees and find a similar pattern of results (See Table A5).

V. Cost-Benefit Analysis

While low-income and BHN students experience large earnings gains from admission to a four-year public college, the costs to taxpayers also increase, as students are induced to stay in four-year college for additional years and shift from private colleges to four-year public colleges or from two-year public colleges to four-year public colleges. Although the results from the prior section show that individual students experience no increase in average college costs on the margin, they may also face indirect costs in foregone earnings as they invest in additional years of four-year college. To identify if this shift is on net beneficial for students, society, and the state, I calculate the net present value of a marginal admission from all three perspectives.

Starting with the private returns to the student, I first estimate the effect of admitting an additional student to a four-year public college on net tuition and fees and earnings in each year one through twelve (or, for net tuition and fees, nine) following a student's application to college (Figure 4 & Figure A5).[20] I then calculate the present value of the costs and the earnings through year twelve using a discount rate of 5%, and difference these figures to get the net present value. The results of this exercise are shown in Table 7. For an individual, the private costs of college are simply the present value of the effects on net tuition and fees each year one through twelve, while the present value of earnings captures both foregone earnings in the years immediately following application and the earnings gains in the later years. On net, admission to a four-year public college has a net present value of $44,008 within twelve years following a student's application to college. In the lower panel, I assume the boost in earnings in year twelve stays constant through an individual's lifetime (through approximately age 65). Over the course of an individual's working life, admission is worth an additional $208,201. This is likely an understatement of the true effects on earnings, given that the returns to an additional year of education typically rise over an individual's lifetime.

Next, I examine the social net present value of a marginal admission. The benefits from the perspective of a social planner are the same as for the individual, but the costs take into

[20] The estimates for the effects on earnings in each year become very noisy in the later years (year 13 and year 14 post-application), as I can only follow one to two cohorts to this point. I stop at year twelve to get more precise estimates. Note that, if anything, this decision would modestly understate the positive returns to four-year public college, since the point estimates in years 13 and 14 are higher than those in year 12. The estimates for the effects on net tuition and fees stop at year nine because practically no students are enrolled in college after year 9.

account the effect on all educational costs, which includes the net tuition and fees paid by the student as well as other costs of educating the students which are typically covered through state, federal, or local funds. I define direct educational costs by using the education-related expenditure for each institution from the Delta Cost Project divided by its FTE enrollment for each year. For each student in each year, I calculate their FTE enrollment in each institution and calculate the social cost of that enrollment by multiplying the education-related expenditures per FTE enrollment by a student's FTE enrollment. I then estimate the effect of a marginal admission on social costs in each year one through twelve and calculate the present value of these costs. As shown in Table 7, the social net present value through year twelve is $30,171. This is smaller than the private net present value but still large and positive. Through an individual's lifetime, the social value is $194,364, an investment with an internal rate of return of 34%. However, this could overstate the social returns to the extent that the tax revenues used to pay for the educational costs which are not covered by net tuition and fees must be collected through tax revenues. The results in column 3 take into account the deadweight loss of taxation (estimated at 30%, per Feldstein (1999)) by multiplying all education-related expenditures per FTE enrollment that are not covered by net tuition and fees by 1.3. Even after taking into account the deadweight loss, the returns are still large and positive.

While the private and social returns to admitting an additional student to four-year public colleges are high, the returns for the state are less clear. Admission to four-year public colleges on the margin draws students away from otherwise enrolling in four-year private colleges, two-year public colleges, or no college. The state incurs no direct cost from students enrolling in private colleges or when students do not enroll in college and incurs smaller costs per full-time enrollment for public two-year colleges. Drawing students from these alternatives unambiguously raises the state's costs. However, because students experience a substantial earnings boost from four-year public college admission, the state may be able to recover the costs through increased income tax revenue.

I define direct costs for the state by taking the state appropriations for each public institution and dividing by full-time equivalent (FTE) enrollment for each year from 2004-05 through 2016-17. For each student in each academic year at each public institution, I calculate their FTE enrollment and multiply this by the state appropriation per FTE enrollment. I then estimate effects on state costs in each year post-application. As shown in Table 7, the state would earn approximately $2,142 in additional tax revenue, breaking even on the additional costs approximately 20 years after a student first applied to college. The internal rate of return on admitting a marginal student is 9% over an individual's working life. Even taking into account that all state appropriations must be collected through taxes which carry a deadweight loss, the return is still positive at 7%. These estimates likely understate the total financial benefits to the state, in that they do not take into account any other positive effects of increased college enrollment and bachelor's degree attainment, such as reduced spending on social welfare programs.[21]

VI. Discussion

Admission to in-state four-year public colleges causes a large increase in earnings with no increase in the private costs of college for low-income and BHN students on the margin of qualifying for admission. The earnings gains are likely driven by a combination of increased

[21] Research suggests that additional education has positive effects on other aspects of people's lives, e.g. improving health, lowering crime, etc., which are likely to reduce the need for state spending on health programs, the justice system, and the social safety net (Lochner, 2011).

bachelor's degree attainment, increased college selectivity, and additional years of four-year college. In addition to giving student's a large private return, the state recovers the additional educational spending for these students through increased tax revenues within twenty years. These results are consistent with Hendren & Sprung-Keyser (2019) which find that programs that invest in youth, including interventions supporting college access and financing, often have long-term benefits that far outweigh the costs to the government of providing them.

These results suggest that the four-year public sector is uniquely valuable to low-income and BHN students. The large returns to admission demonstrate that students are not able to substitute to colleges that produce similar results in terms of earnings gains relative to costs. Although they have more resources per student, the four-year private colleges are substantially more expensive, even net of aid. While two-year colleges are less expensive, they have fewer resources per student, and prior research suggests that students who attend two-year college are less likely to earn a bachelor's degree than if they had otherwise attended a four-year institution (Goodman et al., 2017; Long & Kurlaender, 2009; Reynolds, 2012).

This study has two important implications for state policy. First, states are currently limiting access to four-year public colleges through the admissions thresholds they set. For example, large public college systems in Georgia, Florida, California, and Texas set minimum thresholds based on test scores, grade point average (GPA), and/or class rank to determine admission to public four-year colleges. I find substantial welfare gains for low-income and BHN students and even a modest gain to the state of expanding access at these admissions thresholds.

The second contribution of this paper to state policy is that it identifies the important role that the four-year public college sector plays in promoting mobility. With widening inequality, promoting access to and success in these institutions is important. Instead, state funding for higher education has gone in the opposite direction. State appropriations for higher education were cut by approximately $2,000 per student following the Great Recession, and as of fiscal year 2018, remain about $1,000 per student below their prior level (SHEEO, 2019). As states consider funding priorities moving forward, this research provides clear evidence of the value of investing in higher education to reduce inequality.

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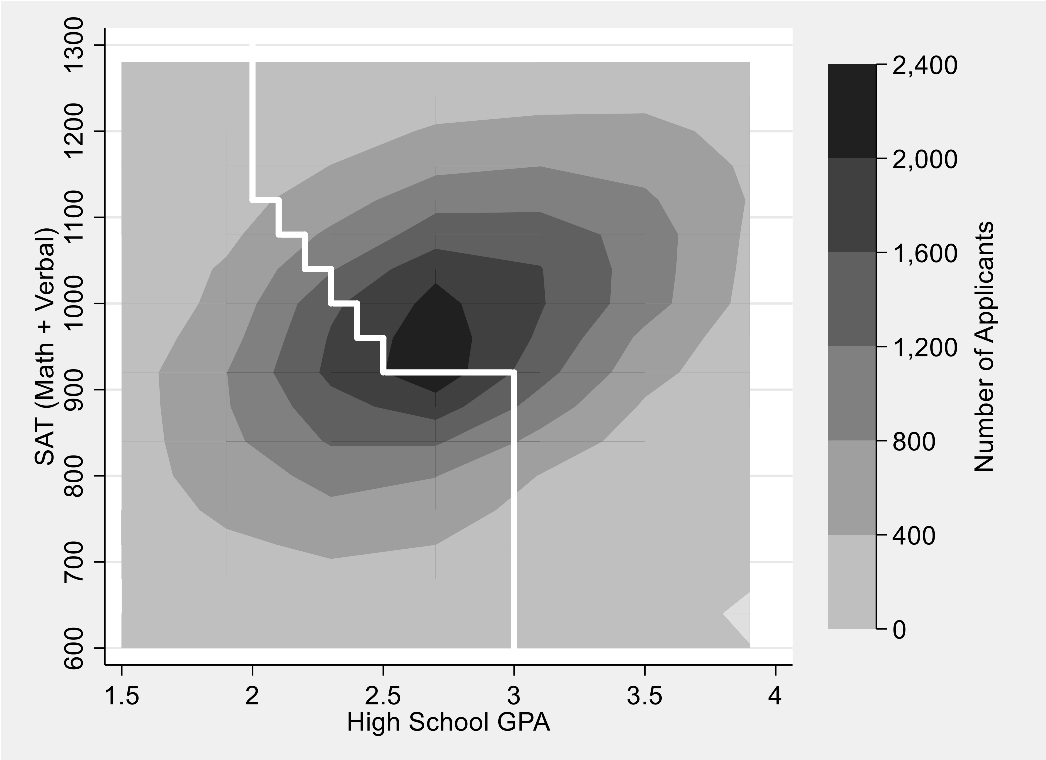
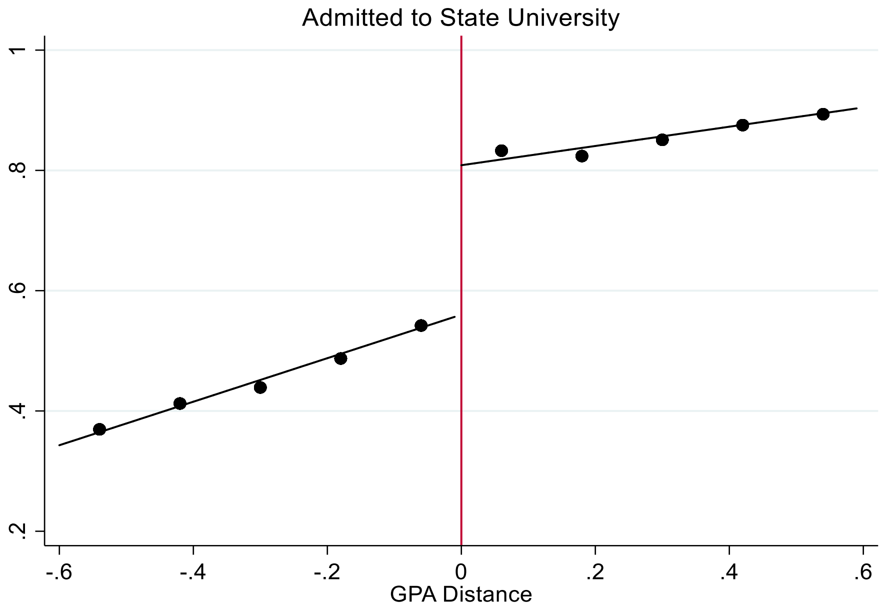
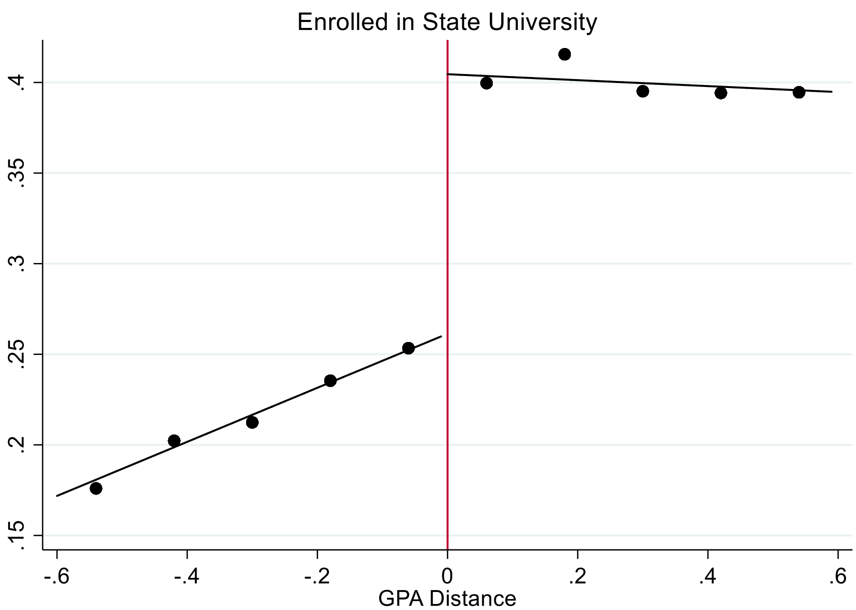
Figure 1. Admissions Threshold Contour Plot for All Applicants



Notes: This contour plot uses shading to show the number of applications corresponding with each SAT score and high school GPA bin (Bin size for SAT scores is 40 points, while bin size for high school GPA is 0.4 points). The white line indicates the admissions threshold for the state universities. Students on the white line or to the right of the white line qualify for admission. Sample includes all applicants to state universities. Approximately 3% of observations lie outside the depicted region in each plot.

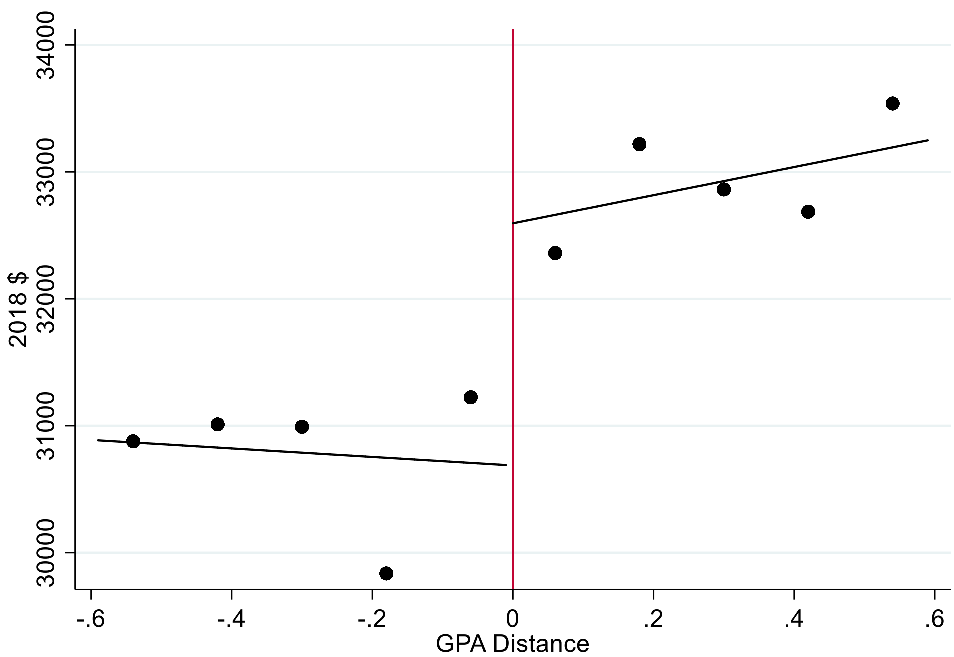
Figure 2. Effects on Admissions and Enrollment in State Universities





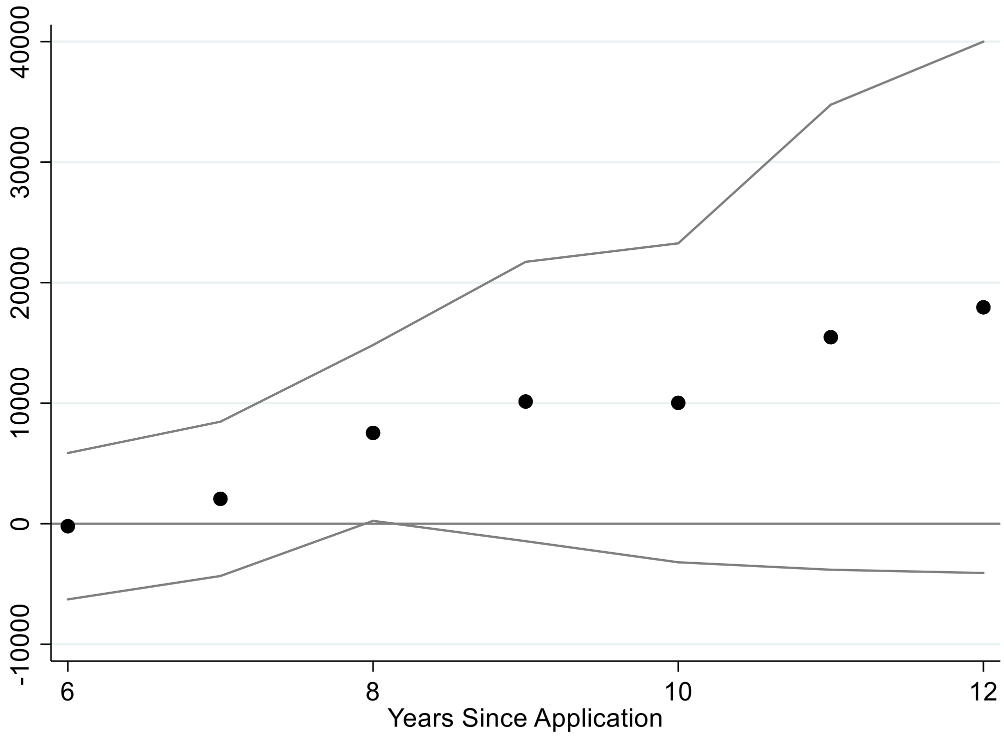
Notes: This figure shows the fraction of students admitted to a state university (top) or enrolling in a state university (bottom) by the fall after applying as a function of the distance to the admissions threshold in GPA points. The figures also include fitted regression lines from the main specification using a bandwidth of 0.6.

Figure 3. Mean Annual Earnings 8-14 Years After Application



Notes: The figure shows the mean annual earnings in 2018 dollars for students 8-14 years after applying to a state university as a function of the distance to the admissions threshold in GPA points. The figures also include fitted regression lines from the main specification and a bandwidth of 0.6 GPA points.

Figure 4. Effects on Annual Earnings For Each Year Since Application



Notes: This figure plots the instrumental variables estimates of the effects on annual earnings each year 6-12 years after a student's first application to a state university (The last two years are trimmed due to noise). Each estimate comes from the main model specification with controls and uses a bandwidth of 0.6 GPA points. The dots indicate point estimates and the top and bottom lines indicate the confidence interval for each estimate.

Table 1. Summary Statistics

	All Applicants	Low-income and/or BHN applicants	RD Sample
A. Demographics			
Female	0.60	0.63	0.62
Black	0.07	0.25	0.28
Hispanic	0.06	0.22	0.24
White	0.82	0.41	0.38
FRPL in High School	0.25	0.88	0.89
LEP in High School	0.05	0.17	0.19
Years FRPL in High School	0.59	2.08	2.14
B. Test Scores & GPA			
SAT Math	498	463	445
SAT Verbal	489	451	433
10th Grade MCAS ELA	0.16	-0.09	-0.24
10th Grade MCAS Math	0.14	-0.08	-0.22
High School GPA	2.93	2.85	2.74
C. College Outcomes			
Enrolled in State University	0.34	0.29	0.31
Enrolled in 4-Year Private	0.23	0.21	0.20
Enrolled in 2-Year	0.11	0.15	0.15
Terms Enrolled	8.14	7.65	7.57
Earn BA in 8 Years	0.59	0.46	0.42
D. Earnings & Employment			
Mean Annual Earnings 8-14 Years	35,764	32,156	32,884
In MA Labor Force 8-14 Years	0.85	0.85	0.86
Number of applicants (N)	65,600	18,712	9,602

Notes: This table shows the mean values of variables for each sample of interest. Column 1 shows all applicants to state universities in the application cohorts of 2004-2010 (omitting 2007 high school graduates) who graduated from an MA high school after 2002 and have an SAT and GPA attached to their application. Column 2 limits the sample to students who qualify for free-and-reduced-price lunch (FRPL) status in high school or are Black, Hispanic/Latino, or Native American (BHN). The RD sample limits the low-income and BHN analysis sample to applicants within a 0.6 point bandwidth of the application threshold. In Panel B, a small number of students are missing MCAS scores (less than 2 percent in each column). In Panel C, enrollment is determined by the fall of the school year after a student applies to attend a state university. Mean annual earnings and employment are measured 8-14 years after the applicant's application year.

Table 2. Effects on Admission & Enrollment

	Main	Controls	Donut	BW: 0.5	BW: 0.7	Control Mean
First Stage						
Accepted at a State Univ.	0.245***	0.243***	0.249***	0.240***	0.259***	0.52
	(0.018)	(0.018)	(0.018)	(0.020)	(0.018)	
IV Estimates						
A. Enrollment						
Enroll in State University	0.580***	0.573***	0.595***	0.588***	0.594***	0.37
	(0.070)	(0.070)	(0.072)	(0.079)	(0.064)	
Enroll in Public 2-Yr	-0.192***	-0.189***	-0.187***	-0.199***	-0.202***	0.15
	(0.051)	(0.051)	(0.053)	(0.055)	(0.043)	
Enroll in Private 4-Yr	-0.130**	-0.127**	-0.141**	-0.134**	-0.166***	0.20
	(0.058)	(0.058)	(0.059)	(0.067)	(0.050)	
Enroll in a UMass Univ.	-0.047	-0.044	-0.046	-0.044	-0.015	0.07
	(0.045)	(0.044)	(0.047)	(0.046)	(0.039)	
Enroll in Non-MA Public 4-Yr	-0.034	-0.036	-0.037	-0.025	-0.038*	0.06
	(0.025)	(0.026)	(0.028)	(0.029)	(0.022)	
Do Not Enroll	-0.179***	-0.178***	-0.183**	-0.189**	-0.176***	0.14
	(0.067)	(0.067)	(0.071)	(0.075)	(0.056)	
B. IV Estimates on Institutional Characteristics						
Peer MCAS Scores	0.250***	0.241***	0.225***	0.222***	0.262***	-0.05
	(0.062)	(0.061)	(0.062)	(0.065)	(0.052)	
Peer BA Attainment	0.188***	0.184***	0.177***	0.189***	0.190***	0.43
	(0.040)	(0.038)	(0.040)	(0.043)	(0.032)	
C. IV Estimates on Terms Enrolled						
Terms in State U.	2.515***	2.437***	2.764***	2.489***	2.524***	2.14
	(0.671)	(0.682)	(0.649)	(0.768)	(0.598)	
Terms in Any 4-Yr	1.942***	1.910***	2.026***	2.271***	2.000***	5.53
	(0.620)	(0.618)	(0.635)	(0.704)	(0.527)	
Terms in Private 4-Yr	-0.030	0.002	-0.144	0.019	-0.360	1.83
	(0.497)	(0.504)	(0.512)	(0.518)	(0.442)	
Terms in Public 2-Yr	-1.007***	-0.906**	-0.948***	-0.822**	-0.995***	1.89
	(0.339)	(0.352)	(0.367)	(0.373)	(0.313)	
Terms in Any College	0.682	0.739	0.766	1.256*	0.774	7.54
	(0.575)	(0.566)	(0.589)	(0.649)	(0.480)	
Observations	9,602	9,602	9,474	8,129	10,992	

Notes: This table presents estimates of the discontinuity at the admissions threshold from equation (1). The main specification uses a bandwidth of 0.6 GPA points. Controls include indicators for gender and race, SAT scores, FRPL status in high school, LEP status in high school, and age at entry. The donut specification is the same as the main specification but drops observations that are at the cutoff. BW5 and BW7 use the main specification with a bandwidth of 0.5 and 0.7 GPA points respectively. Standard errors are shown in parentheses and are clustered by distance to the admissions threshold. Institutional characteristics refers to the mean value (either MCAS scores or BA attainment rates) of the college each student enrolled in the fall after application. Terms enrolled refers to all fall and spring terms enrolled between the application year and 2018. Significance levels are the following: $^{*}p<0.1$, $^{**}p<0.05$, $^{***}p<0.01$.

Table 3. Effects on Degree Attainment

	RF	IV					
	Main	Main	Controls	Donut	BW: 0.4	BW: 0.6	Control Means
Earn BA	0.036*	0.151*	0.148	0.176*	0.069	0.147*	0.39
	(0.020)	(0.089)	(0.091)	(0.094)	(0.095)	(0.082)	
Earn BA from State Univ.	0.038**	0.159*	0.159*	0.200**	0.103	0.129*	0.24
	(0.019)	(0.081)	(0.083)	(0.081)	(0.087)	(0.074)	
Earn BA from 4-Yr Private	0.000	0.000	-0.001	-0.007	0.005	0.046	0.14
	(0.014)	(0.056)	(0.057)	(0.061)	(0.063)	(0.055)	
Earn BA from Other 4-Yr Public	-0.006	-0.024	-0.024	-0.038	-0.019	0.024	0.13
	(0.014)	(0.055)	(0.057)	(0.059)	(0.062)	(0.054)	
Earn AA or Certificate	-0.029**	-0.120**	-0.112**	-0.130**	-0.083	-0.115**	0.12
	(0.013)	(0.054)	(0.054)	(0.054)	(0.062)	(0.049)	
	8,129	8,129	8,129	8,001	6,640	9,602	

Notes: This table presents estimates of the discontinuity at the admissions threshold from equation (1). The first column reports the reduced form estimates. All other columns report instrumental variable (IV) estimates using admission to a state university as the instrument. The main specification uses a bandwidth of 0.5 GPA points. Controls include indicators for gender, race, SAT scores, FRPL status in high school, LEP status in high school, years of FRPL status in high school, and age at entry. The donut specification is the same as the main specification but drops observations that are exactly at the cutoff. BW4 and BW6 use the main specification with a bandwidth of 0.4 and 0.6 GPA points respectively. Standard errors are shown in parentheses and are clustered by distance to the admissions threshold. Significance levels are the following: *p<0.1, **p<0.05, ***p<0.01.

Table 4. Effects on Earnings and Employment 8-14 Years After Application

	RF	IV					
	Main	Main	Controls	Donut	BW: 0.4	BW: 0.6	Control Means
Mean Earnings 8-14 Years After App.	1953**	7986**	8391**	8112*	7852*	6021*	30,838
	(971)	(3931)	(3969)	(4186)	(4415)	(3452)	
Observations	9,602	9,602	9,602	9,474	8,129	10,992	

Notes: This table presents estimates of the discontinuity at the admissions threshold from equation (1). The first column reports the reduced form estimates. All other columns report instrumental variable (IV) estimates using admission to a state university as the instrument. The main specification uses a bandwidth of 0.6 GPA points. Controls include indicators for gender, race, SAT scores, FRPL status in high school, LEP status in high school, years of FRPL status in high school, and age at entry. The donut specification is the same as the main specification but drops observations that are exactly at the cutoff. BW5 and BW7 use the main specification with a bandwidth of 0.5 and 0.7 GPA points respectively. Standard errors are shown in parentheses and are clustered by distance to the admissions threshold. Significance levels are the following: *p<0.1, **p<0.05, ***p<0.01.

Table 5. Heterogeneity by Demographic Group

	Male	Female	Black	Hispanic	White	Always FRPL
A. First Stage						
Admitted to State University	0.253***	0.236***	0.191***	0.205***	0.328***	0.212***
	(0.031)	(0.021)	(0.031)	(0.029)	(0.029)	(0.030)
B. IV Estimates						
Enroll in a State University	0.561***	0.580***	0.409***	0.356**	0.654***	0.443***
	(0.123)	(0.093)	(0.145)	(0.173)	(0.089)	(0.109)
Enroll in a Public 2-Year	-0.274***	-0.125**	-0.091	0.022	-0.335***	0.021
	(0.080)	(0.063)	(0.114)	(0.137)	(0.074)	(0.116)
Enroll in a Private 4-Year	-0.089	-0.156**	-0.157	-0.295**	-0.039	-0.175
	(0.098)	(0.074)	(0.183)	(0.143)	(0.074)	(0.129)
Do Not Enroll	-0.220**	-0.155*	-0.147	-0.031	-0.182**	-0.235*
	(0.103)	(0.081)	(0.141)	(0.167)	(0.077)	(0.126)
Earn BA	0.289**	0.068	0.259	0.326*	-0.024	0.178
	(0.120)	(0.099)	(0.160)	(0.198)	(0.098)	(0.197)
Earn AA/Certificate	-0.090	-0.130**	-0.139	-0.076	-0.152***	-0.021
	(0.074)	(0.061)	(0.109)	(0.139)	(0.055)	(0.111)
Mean Annual Earnings	12441*	5342	13232	3161	5776	14938*
	(6625)	(6030)	(10578)	(11652)	(4794)	(8633)
Observations	3,653	5,949	2,646	2,302	3,639	2,993

Notes: This table presents estimates of the discontinuity at the admissions threshold limiting the sample to the group noted in the column heading and using a bandwidth of 0.6 GPA points. Panel A reports the reduced form estimates. Panel B reports instrumental variable (IV) estimates using admission to a state university as the instrument. Standard errors are shown in parentheses and are clustered by distance to the admissions threshold. Always FRPL students qualify for free-and-reduced price lunch for all four years of high school. Degree attainment is measured 8 years after applying to college. Mean annual earnings denotes mean annual earnings 8-14 years after application. Significance levels are the following: *p<0.1, **p<0.05, ***p<0.01.

Table 6. Costs and Aid

	RF	IV					
	Main	Main	Controls	Donut	BW: 0.4	BW: 0.6	Control Means
Total Tuition & Fees	-92	-382	-260	-1905	-2772	-829	41,962
	(1381)	(5693)	(5728)	(5795)	(6289)	(5474)	
Total Aid	396	1646	3271	4140	2216	2908	23,297
	(1025)	(4241)	(4017)	(4248)	(4453)	(3815)	
Net Tuition & Fees	-293	-1218	-2618	-5427	-3299	-2949	17,865
	(1336)	(5502)	(5009)	(4563)	(5612)	(4378)	
State Aid in MA	314	1304	1640	2136*	1255	1175	3,919
	(312)	(1286)	(1210)	(1185)	(1397)	(1068)	
Federal Aid in MA	539	2237	3385*	3763**	3246	3124**	9,298
	(509)	(2073)	(1787)	(1862)	(2018)	(1594)	
Institutional Aid in MA	-13	-56	229	399	25	380	6,788
	(659)	(2719)	(2729)	(2921)	(3065)	(2577)	
Observations	8,129	8,129	8,129	8,001	6,640	9,602	

Notes: This table presents estimates of the discontinuity at the admissions threshold. The first column reports the reduced form estimates. All other columns report instrumental variable (IV) estimates using admission to a state university as the instrument. The main specification uses a bandwidth of 0.5 GPA points. Controls include indicators for gender, race, SAT scores, FRPL status in high school, LEP status in high school, years of FRPL status in high school, and age at entry. The donut specification is the same as the main specification but drops observations that are exactly at the cutoff. BW4 and BW6 use the main specification with a bandwidth of 0.4 and 0.6 GPA points respectively. Standard errors are shown in parentheses and are clustered by distance to the admissions threshold. The variables that break down different sources of grant aid (e.g. State aid, Federal aid, and Institutional Aid) are only available for students enrolled in MA institutions. Significance levels are the following: *p<0.1, **p<0.05, ***p<0.01.

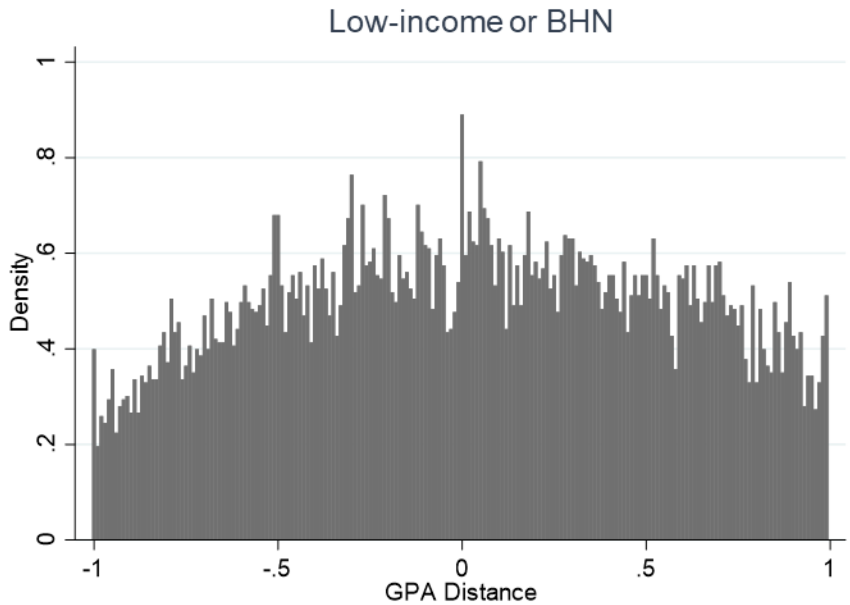
Table 7. Net Present Value of a Marginal Admission from Private, Social, and State Perspectives

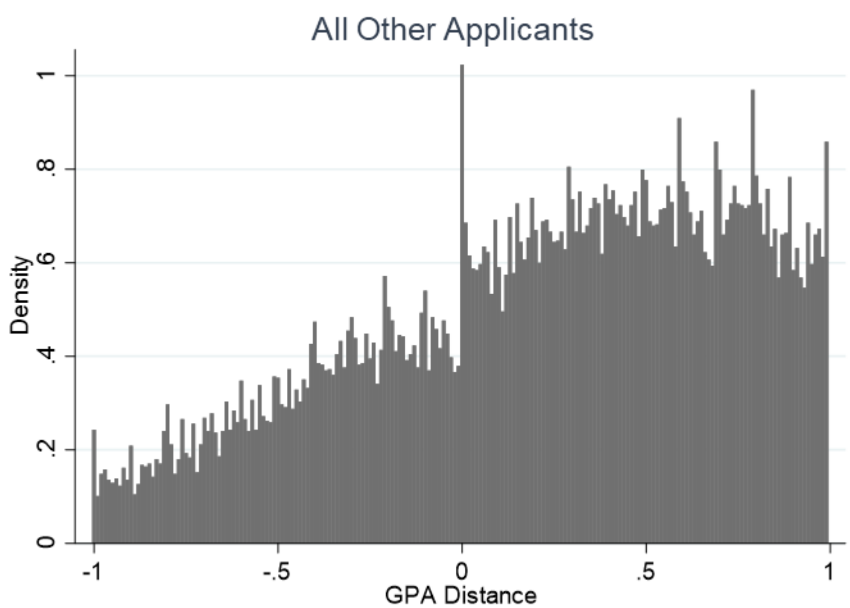
	Private	Social	Social with DWL	State	State with DWL
Through 12 Years After Application					
Education Costs	-2,000	11,837	17,290	5,370	6,982
Earnings	42,009	42,009	42,009	2,142	2,142
Net	44,008	30,171	24,719	-3,228	-4,839
Through Lifetime					
Education Costs	-2,000	11,837	17,290	5,370	6,982
Earnings	206,201	206,201	206,201	10,516	10,516
Net	208,201	194,364	188,912	5,146	3,535
IRR Through 12 Years	∞	28%	20%	-9%	-13%
IRR Through Lifetime	∞	34%	28%	9%	7%

Notes: This table shows the net present value of admitting an additional student on the margin of admission to a four-year public colleges from the perspective of the private, social, and state perspectives. Lifetime estimates assume the effects observed in year 12 stay constant through an additional 47 years following application, which corresponds to an approximate age of 65. DWL indicates the net present value calculations take into account deadweight loss by multiplying social costs by 1.3 and state costs by 1.3 respectively.

Appendix A. Additional Tables and Figures

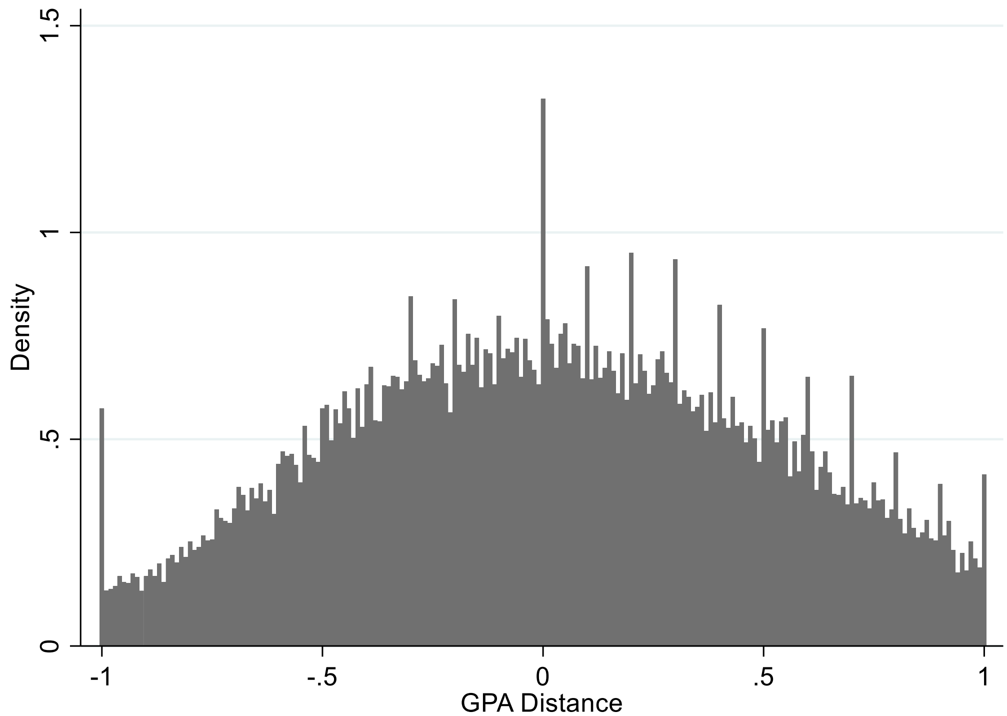
Figure A1. Density of Students by Distance to Admissions Threshold





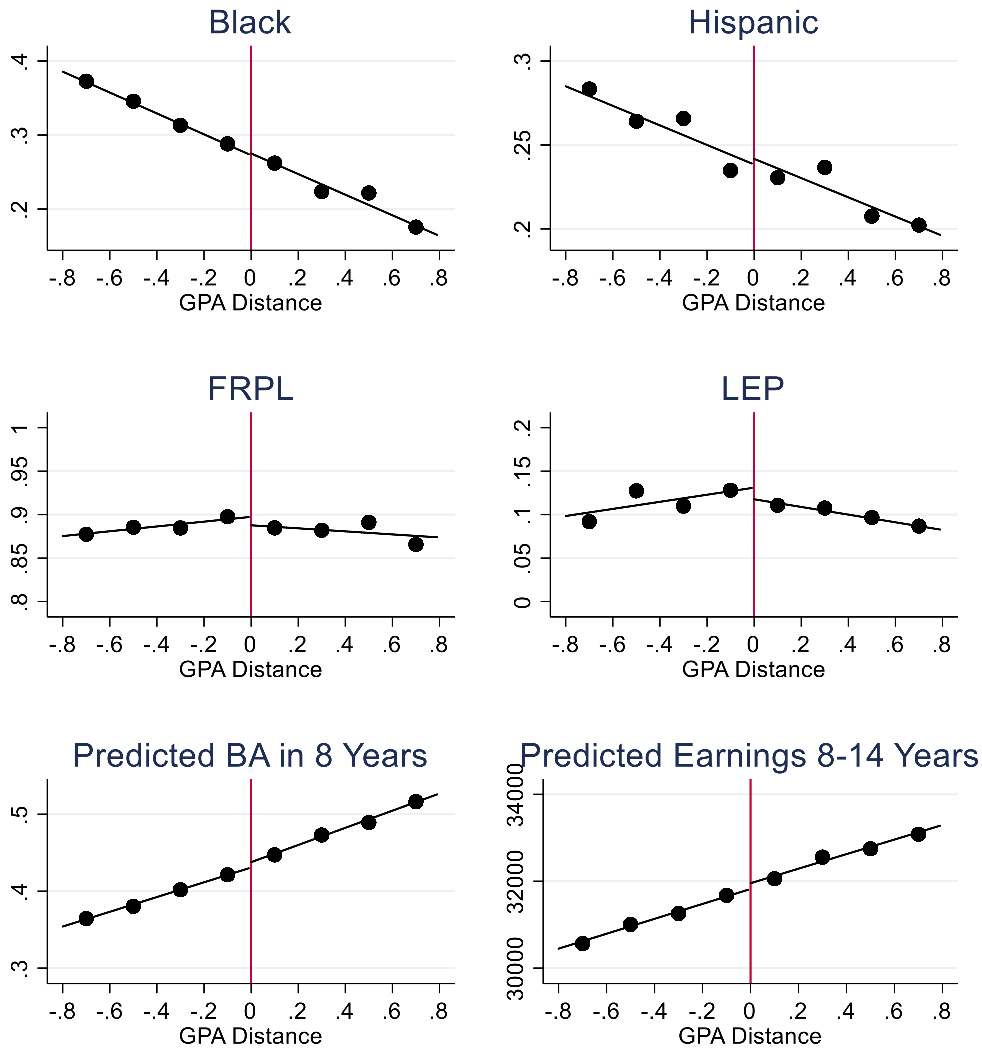
Notes: Histograms of distance to the admissions threshold in GPA points. Top panel includes all applicants who are low-income (defined as qualifying for free-and-reduced price lunch in high school) or Black, Hispanic/Latino, or Native American (BHN) and bottom panel includes all other applicants.

Figure A2. Placebo Density Test



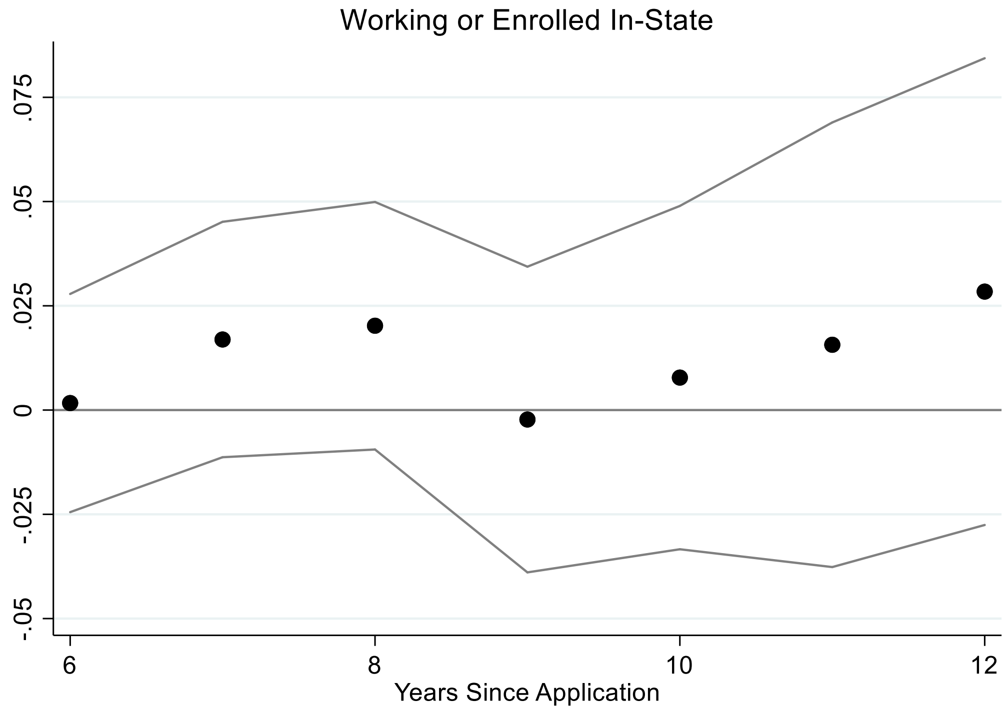
Notes: This figure uses a high school GPA that is centered at a cutoff of 3.0 and plots all applicants who are not bound by a cutoff of 3.0. The increase in density at the threshold suggests for this group indicates that 3.0 is more likely to occur in the GPA distribution even in cases where students are not facing an admissions threshold of 3.0.

Figure A3. Covariate Balance Checks



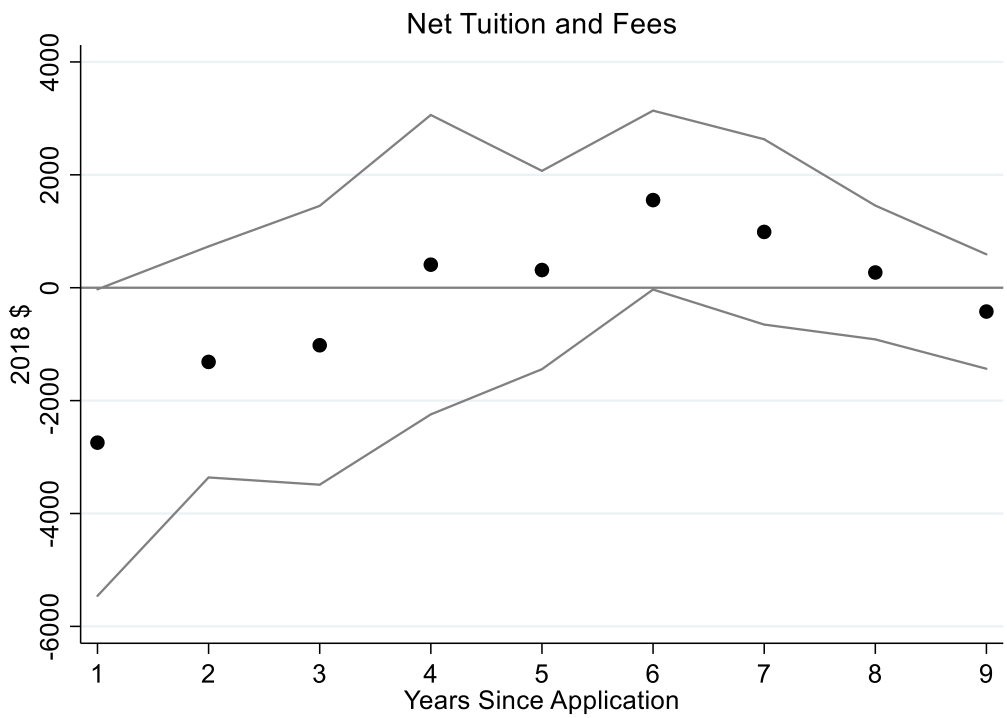
Notes: These panels plot the mean value for each variable as a function of distance from the cutoff for admission. For the bottom two panels, predictions are based on regressions that include the following independent variables: math and ELA MCAS scores, SAT math and verbal scores, gender, race, and individual indicators for FRPL and LEP status in high school. Fitted regression lines are also included from the main specification without fixed effects with a bandwidth of 0.8 GPA points.

Figure A4. Effects on Working or Being Enrolled In-State



Notes: This figure plots the discontinuity estimates of the effects on residing in-state 6-12 years after a student's first application to a state university. Each estimate comes from the main model specification in equation (1) with controls and uses a bandwidth of 0.6 GPA points. The dots indicate point estimates and the top and bottom lines indicate the confidence interval for each estimate.

Figure A5. Effects on Net Tuition and Fees Over Time



Notes: This figure plots the discontinuity estimates of the effects on net tuition and fees each year for 1-9 years after a student's first application to a state university. Each estimate comes from the main model specification with controls and uses a bandwidth of 0.5 GPA points (as this is the median optimal bandwidth from Calonico, et al (2014) across regressions for all years). The dots indicate point estimates and the top and bottom lines indicate the confidence interval for each estimate.

Table A1. MA Public College Characteristics

	Total FTE Enrollment	Tuition & Fees	Net Tuition & Fees	Educational Exp. per FTE	Graduation Rate (150% Time)
UMass Universities	46,216	9,639	8,748	15,238	0.57
State Universities	36,305	5,665	4,674	11,100	0.48
A. Comprehensive					
Bridgewater State University	7,863	6,107	5,249	10,079	0.48
Fitchburg State University	4,001	4,998	4,106	10,848	0.55
Framingham State University	4,152	4,988	4,476	10,378	0.42
Salem State University	7,334	5,616	4,451	10,984	0.40
Westfield State University	4,632	4,782	3,725	9,213	0.53
Worcester State University	4,164	5,365	4,316	9,666	0.43
B. Specialized					
MA College of Art & Design	1,718	8,458	6,772	16,379	0.62
MA College of Liberal Arts	1,472	6,730	5,363	16,778	0.47
MA Maritime Academy	969	7,037	6,205	21,600	0.70
Community Colleges	49,612	3,810	2,103	9,347	0.17

Notes: Data come from the 2004-05 academic year from IPEDS. The UMass, state university, and community college rows present FTE enrollment-weighted averages across institutions (except for total FTE enrollment, which is the sum across institutions). Total FTE enrollment is fall full-time equivalent enrollment. Tuition and fees are total revenue from tuition and fees (as calculated by the Delta Cost Project) divided by FTE enrollment. Net tuition and fees are net student tuition and fees (as calculated by the Delta Cost Project) divided by FTE enrollment. Educational expenditures per FTE are total spending on direct education costs (as calculated by the Delta Cost Project) divided by FTE enrollment. Graduation rate in 150% time are the fraction of students graduating within 150% of normal time (6-years are four-year colleges, 3 at two-year colleges).

Table A2. Covariate Balance Check

	Main	Donut	BW: 0.5	BW: 0.7
Predicted BA in 8 Years	0.001	0.001	0.001	-0.000
	(0.003)	(0.003)	(0.004)	(0.003)
Predicted Earnings 8-14 Years After App.	48.69	85.26	-76.68	15.03
	(105.94)	(106.24)	(115.60)	(100.86)
MCAS Combined	0.029	0.028	0.022	0.022
	(0.027)	(0.029)	(0.030)	(0.025)
SAT Combined	2.35	1.64	2.25	1.02
	(2.49)	(2.52)	(2.77)	(2.44)
Female	-0.022	-0.023	-0.007	-0.013
	(0.015)	(0.016)	(0.016)	(0.014)
White	0.001	-0.004	0.007	0.007
	(0.019)	(0.019)	(0.020)	(0.017)
Asian	-0.008	-0.005	-0.014	-0.014
	(0.010)	(0.010)	(0.011)	(0.010)
Hispanic	0.009	0.017	0.012	0.012
	(0.017)	(0.016)	(0.019)	(0.016)
Black	-0.001	-0.005	-0.005	0.001
	(0.018)	(0.019)	(0.020)	(0.017)
Ever FRPL	-0.026	-0.024	-0.034*	-0.019
	(0.016)	(0.017)	(0.018)	(0.014)
Ever LEP	-0.000	0.003	-0.008	-0.003
	(0.011)	(0.011)	(0.012)	(0.010)
Years FRPL	-0.100	-0.087	-0.124	-0.079
	(0.069)	(0.071)	(0.080)	(0.064)
Age at Entry	-0.012	-0.020	-0.010	-0.008
	(0.023)	(0.024)	(0.027)	(0.021)
Observations	9,602	9,474	8,129	10,992

Notes: This table presents estimates of the discontinuity at the admissions threshold from equation (1) with a bandwidth of 0.6 GPA points. All specifications present reduced form estimates. The donut specification drops observations that are exactly at the cutoff. BW5 and BW7 use the main specification with a bandwidth of 0.5 and 0.7 GPA points respectively. Standard errors are shown in parentheses and are clustered by distance to the admissions threshold. Significance levels are the following: *p<0.1, **p<0.05, ***p<0.01.

Table A3. Robustness Check: Effects on Mean Earnings 9-14 Years After Application

	RF	IV					
	Main	Main	Controls	Donut	BW: 0.4	BW: 0.6	Control Means
Mean Earnings 9-14 Years After	2095*	10040*	10740*	10113*	10919*	8943*	32,087
	(1200)	(5742)	(5740)	(6060)	(6458)	(4811)	
	7,610	7,610	7,610	7,500	6,457	8,727	

Notes: The first column reports the reduced form estimates. All other columns report instrumental variable (IV) estimates using admission to a state university as the instrument. The main specification uses a bandwidth of 0.6 GPA points. Controls include indicators for gender, race, SAT scores, FRPL status in high school, LEP status in high school, years of FRPL status in high school, and age at entry. The donut specification is the same as the main specification but drops observations that are exactly at the cutoff. BW5 and BW7 use the main specification with a bandwidth of 0.5 and 0.7 GPA points respectively. Standard errors are shown in parentheses and are clustered by distance to the admissions threshold. Significance levels are the following: *p<0.1, **p<0.05, ***p<0.01.

Table A4. Effects on Mean Annual Earnings When Trimming With Lee Bounds

	RF	IV				
	Main	Main	Controls	Donut	BW: 0.4	BW: 0.6
Mean Earnings 8-14 Yrs. After Application	1803*	7385*	7797*	7575*	7188	5403
	(982)	(4000)	(4025)	(4257)	(4498)	(3492)
	9,565	9,565	9,565	9,439	8,096	10,955

Notes: The first column reports the reduced form estimates. All other columns report instrumental variable (IV) estimates using admission to a state university as the instrument. The main specification uses a bandwidth of 0.6 GPA points. Controls include indicators for gender, race, SAT scores, FRPL status in high school, LEP status in high school, years of FRPL status in high school, and age at entry. The donut specification is the same as the main specification but drops observations that are exactly at the cutoff. BW5 and BW7 use the main specification with a bandwidth of 0.5 and 0.7 GPA points respectively. Standard errors are shown in parentheses and are clustered by distance to the admissions threshold. Mean earnings 8-14 years after application is constructed after removing the top earners above the cutoff in each year 8-14, with the percentage of top earners trimmed corresponding to the effect on residing in-state for each year 8-14. Significance levels are the following: *p<0.1, **p<0.05, ***p<0.01.

Table A5. Cost and Aid Robustness Check, Dropping Out of State Enrollees

	RF	IV				
	Main	Main	Controls	Donut	BW: 0.4	BW: 0.6
Total Tuition & Fees	-850	-3552	-3497	-3940	-4180	-3035
	(1432)	(5903)	(6070)	(6452)	(6418)	(5735)
Total Aid	-123	-514	897	2007	508	1156
	(1273)	(5286)	(5042)	(5249)	(5636)	(4757)
Net Tuition & Fees	-728	-3041	-4394	-5943	-4800	-4096
	(1208)	(4982)	(4403)	(4495)	(4773)	(3884)
MA State Aid	234	976	1272	1814	854	543
	(368)	(1539)	(1493)	(1488)	(1682)	(1320)
Federal Aid in MA	284	1186	2078	2384	2349	2038
	(606)	(2512)	(2206)	(2325)	(2528)	(2046)
Institutional Aid in MA	-290	-1212	-1043	-984	-866	-594
	(784)	(3250)	(3280)	(3486)	(3630)	(3084)
Observations	6,248	6,248	6,248	6,156	5,120	7,358

Notes: This table is the same as Table 2.6, except that it drops all students who ever enroll out of state. It presents estimates of the discontinuity at the admissions threshold from equation (1). The first column reports the reduced form estimates. All other columns report instrumental variable (IV) estimates using admission to a state university as the instrument. The main specification uses a bandwidth of 0.5 GPA points. Controls include indicators for gender, race, SAT scores, FRPL status in high school, LEP status in high school, years of FRPL status in high school, and age at entry. The donut specification is the same as the main specification but drops observations that are exactly at the cutoff. BW4 and BW6 use the main specification with a bandwidth of 0.4 and 0.6 GPA points respectively. Standard errors are shown in parentheses and are clustered by distance to the admissions threshold. The variables that breakdown different sources of grant aid (e.g. State aid, Federal aid, and Institutional Aid) are only available for students enrolled in MA institutions. Significance levels are the following: *p<0.1, **p<0.05, ***p<0.01.

Appendix B. Calculating Private Costs of College

To calculate costs, I first use the National Student Clearinghouse to identify all undergraduate enrollment spells in any institution between the fall that an applicant would have begun college (e.g. 2004 for the 2004 cohort) and the end of the 2016-17 academic year. I classify all terms in which a student is enrolled in October, or November as a fall term, and all terms in which a student is enrolled in February or March as a spring term. I drop all terms that occur outside these month ranges or are less than one month in duration. (Including winter and summer terms in the "terms enrolled" variable yielded substantively similar results when calculating effects on total terms enrolled, so these are dropped to simplify cost calculations). I also drop any graduate school enrollments, since these are not covered in the state's financial aid data.[22] Lastly, I use the enrollment status variable indicating full-time, part-time, or less than part-time status to identify full-time equivalent (FTE) enrollments for each institution-year a student is enrolled. (For example, a student enrolled full-time in the fall and full-time in the spring has an FTE enrollment of 1, while a student enrolled full-time just one semester has an FTE enrollment of 0.5). I drop all terms in which a student is enrolled less than part-time as these are only 3.4% of term-level enrollments and represent a very small proportion of total costs. In cases where enrollment status is missing and a student has financial aid data, I use the number of registered credits in the financial aid file to impute full-time (12 or more credits), part-time (greater than 6 credits but less than 12), or less than part-time (less than 6 credits). In the remaining 10% of cases where enrollment status is missing, I impute full-time status, as this was the imputed value in 92% of cases where registered credits was available in the financial aid file.

After calculating FTE enrollments at the student-institution-year level, I then merge in financial aid data. For in-state enrollments, students who are not in the financial aid file did not apply for or receive aid and are given a zero for all forms of aid. To identify the tuition and fees paid by these students, I use the average tuition and fees paid by students who enroll in an institution in a given year with the same FTE enrollment intensity. For these calculations, I merge all graduates of MA high schools from 2002 to 2010 with the financial aid file to get these estimates. This improves the precision of the estimates for each college, since there are some cases where only a small number of state university applicants attend a college, but a larger number of high school graduates attend. For those with financial aid data, the correlation between estimated tuition and observed tuition and fees is 0.98.

For students who enroll out-of-state, I use data from IPEDS (Integrated Postsecondary Education Data System) assembled by the Delta Cost Project to construct estimates for tuition and fees and aid.[23] Tuition and fee information is available for each institution in each year for full-time undergraduates (The relevant variable is *tuitionfee02_tf* for in-state tuition and fees and *tuitionfee03_tf* for out of state tuition and fees).[24] I calculated the FTE (full-time equivalent) enrollment for each student and multiply this by the full-time tuition and fee estimates in IPEDS.

[22] Graduate school enrollments are identified as any enrollment that occurs after earning a bachelor's degree or at a college that requires a bachelor's degree to enroll.
[23] Since Delta Cost data is not available after 2014-15, I use IPEDS to reconstruct the Delta Cost variables for 2015-16 and 2016-17.
[24] IPEDS data was available for all but 0.7% of out-of-state enrollment spells. These spells were dropped, as cost data was not available.

Institutions in CT, NY, VT, NH, and ME offer discounted tuition to MA residents through the New England Board of Higher Education Tuition Break program. Because the discounted tuition and fee rate is not available in IPEDS, I use the in-state tuition and fee figures, as these are much closer to the rate students would pay than the out-of-state rate. For all other states, I use the out-of-state tuition and fee figures. To estimate aid, I subtract net tuition revenue from gross tuition and fee revenue and divide this by FTE enrollment (The relevant variables are *tuition03*, *net student_tuition*, and *fte_count*). I then calculate an estimate of average aid for each student by multiplying this by each student's FTE enrollment at an institution in a given year. To calculate net tuition and fees, I subtract aid from tuition and fees.

In a very small number of cases (0.017%), the tuition and fees listed in the state's financial aid data were missing or, in the case of one institution in one year, impossibly large. In these cases, aid estimates were imputed from IPEDS. Also, in 7% of student-institution-year observations, the tuition and fees from the state's financial aid file appear to be input at the year-level, rather than the term-level as the codebook indicates they should be. I identified these cases by comparing reported tuition and fees to the predicted IPEDS tuition and fees estimates. In cases were the tuition and fees were over 1.75 times the predicted tuition and fees, I used the IPEDS predicted tuition and fees.

Lastly, all tuition and fee and aid figures were converted to 2018 dollars to facilitate comparison with the labor market data.