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Who merits financial aid?: Massachusetts' Adams Scholarship ☆

Joshua Goodman *

Economics Department, Columbia University, 1022 International Affairs Building, 420 W. 118th St., New York, NY 10027, USA

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ABSTRACT

Most states now fund merit-based financial aid programs, the effects of which depend on how strongly students react to changes in college costs. I estimate such reactions using quasi-experimental aspects of a recent Massachusetts merit scholarship program intended to attract talented students to the state's public colleges. Despite its small monetary value, the Adams Scholarship induced 6% of winners to choose four-year public colleges instead of four-year private colleges, suggesting an elasticity of demand for public college enrollment above unity. Nonetheless, most funds flowed to students who would have enrolled in public colleges absent the scholarship and the aid had no effect on winners' overall college enrollment rate, which already exceeded 90%. Regression discontinuity estimates are larger than those from difference-in-difference specifications because winners with relatively low academic skill, and thus nearest the treatment threshold, reacted much more strongly to the price change than did highly skilled winners. Conditional on academic skill, low-income winners reacted similarly to their higher income peers, suggesting that previous research may have mistaken income heterogeneity for skill heterogeneity.

1. Previous literature

College costs in most industrialized countries have increased rapidly in recent years, presenting a serious public policy dilemma given most governments' stated goals of improving access to higher education. Many of these countries have experimented with various forms of student support in an attempt to improve access while targeting aid toward students for whom such aid might bring a high return on public investment. Germany has, for example, loosened the income limits for aid eligibility and tried transforming student loans into grants, though Baumgartner and Steiner (2006) find these reforms had no impact on the eligible low-income students. Australia, along with Great Britain and New Zealand, has expanded income contingent loans that base a student's repayment amount on her current ability to pay. Chapman and Ryan (2004) argue that such reforms did increase enrollment rates, but only of students from the middle of the wealth distribution. The United States and Canada have increasingly favored merit-based financial aid, in which grants to students are contingent on demonstrated academic skill. This last form of student support is the focus of this paper.

In the U.S., the increased popularity of merit-based aid can be partly explained by rapidly rising college costs. From 2000 to

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* Tel.: +1 917 439 7907; fax: +1 212 851 2206.
E-mail address: jg2394@columbia.edu.

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2005, the price (tuition and fees) of public and private colleges rose annually by an average of 9.1% and 5.6% respectively, far exceeding the inflation rate of 2.5%. State governments have reacted particularly strongly to political pressures to reduce these costs. Since 1980 the amount of financial aid offered by the states has more than doubled relative to that offered by the federal government. By 2005, state and local governments were spending $59 billion (7.4% of revenue) on students enrolled in public postsecondary institutions, in the form of both financial aid for students and direct support for those institutions.[1]

As the states have increased their funding for financial aid programs, they have also shifted the mix of funding away from need-based programs and toward programs based partially or solely on academic merit. By 2005, 31 states were providing undergraduate financial aid at least partly on the basis of merit. This merit-based aid totalled $2.1 billion (29% of all state-based financial aid), of which $1.2 billion was based solely on merit and $0.9 billion was based on a combination of merit and need.[2] Advocates argue that these programs raise college attendance rates, incentivize student achievement, prevent state-level brain drain, and reduce the financial burden of college. Opponents argue that targeting aid based on merit rather than need diverts funds toward high-income students and away from those low-income students whom the funds would most benefit.[3]

Evaluating merit-based programs depends in large part upon understanding how students, particularly at the upper end of the skill distribution, respond to changes in the costs of various college options. I explore this question in the context of Massachusetts' Adams Scholarship, which is assigned on the basis of a standardized test score and reduces the price of in-state public colleges by about 17% in order to attract more talented students to those colleges. Using data provided by the state's Board of Education, I exploit two quasi-experimental aspects of the scholarship in order to identify its effects. First, the scholarship's unexpected introduction allows construction of a difference-in-difference estimator that compares the college intentions of winners and losers in the year before and after the scholarship began.[4] Second, the assignment of the scholarship on the basis of test scores allows a regression discontinuity design that compares college intentions of students just above and below the eligibility threshold.

This paper makes four contributions to the literature on financial aid generally and merit-based scholarships specifically. First, the Adams Scholarship grants students much less money than do the most widely studied merit scholarships, allowing measurement of students' reactions to financial incentives that are arguably quite small. Second, the analysis uses a clean quasi-experiment and student-level data for every Massachusetts high school graduate from 2003–2005, making the estimated effects very precise and robust to alternative specifications. Third, the scholarship's design allows comparison of the performance of difference-in-difference and regression discontinuity estimators. Fourth, the differing results from these estimators can be explained by heterogeneity in price sensitivity among students of varying academic skill. This is the first paper to demonstrate such heterogeneity, which may help explain the variety of results from previous quasi-experimental studies of the effect of financial aid.

The primary result is that, despite its small monetary value, the Adams Scholarship induced 6% of winners to choose four-year public colleges instead of four-year private colleges, suggesting an elasticity of demand for public college enrollment above unity. Nonetheless, most funds flowed to students who would have enrolled in public colleges absent the scholarship and the aid had no effect on winners' overall college enrollment rate, which already exceeded 90%. Regression discontinuity estimates are larger than those from difference-in-difference specifications because winners with relatively low academic skill, and thus nearest the treatment threshold, reacted much more strongly to the price change than did highly skilled winners. Conditional on academic skill, low-income winners reacted similarly to their higher income peers, suggesting that previous research may have mistaken income heterogeneity for skill heterogeneity.

The paper proceeds as follows. Section 1 reviews previous literature on the effects of financial aid and merit scholarships. Section 2 explains the details of the Adams Scholarship. Section 3 reviews the data and describes the population of students in question. Sections 4 and 5 respectively use difference-in-difference and regression discontinuity methodologies to estimate the scholarship's impact on students' college intentions, while Section 6 explores heterogeneity in these impacts by academic skill. Section 7 concludes with a discussion of these findings' implications.

This paper builds on three strands in the economics literature, the first of which focuses on students' elasticity of demand for college education. A large and growing quasi-experimental literature has exploited plausibly exogenous changes in college costs to accurately identify this elasticity. Such quasi-experiments include discontinuities in a college's financial aid formula, as in van der Klaauw (2001); changes in Pell grant rules, as in Seftor and Turner (2002); the effect of GI bills, as in Bound and Turner (2002); and elimination of Social Security student benefits, as in Dynarski (2003). According to Dynarski (2002), these studies consistently suggest that eligibility for $1000 in annual aid raises college attendance rates by about 4 percentage points but are split as to whether college subsidies have a greater impact on low- or high-income students. The central result of this literature is that financial aid has a substantial impact on the college decisions of American high school graduates.

The second strand evaluates merit scholarship programs specifically. Previous evaluations of small state-run merit scholarship programs have suffered from data limitations, as in Binder and Ganderton's (2004) analysis of New Mexico's merit aid program, or selection bias, as in St. John's (2004) analysis of programs in Washington and Indiana that award scholarships only to students who

[1] See Tables 280 and 282 of the U.S. Census Bureau's *Statistical Abstract of the United States: 2007* (*126th Edition*).

[2] U.S. merit aid data come from Table 8 of National Association of State Student Grant and Aid Programs (2006). Gucciardi (2004) finds that Canada now spends $200 million annually on merit scholarships, of which $80 million or so comes from the national or provincial governments.

[3] Heller and Rasmussen (2002) show that the association between income and test scores causes Florida and Michigan, two of the largest funders of merit-based aid, to have disproportionately low representation of low-income students in their pool of merit scholarship winners. The authors argue that this diminishes the ability of the scholarships to raise college attendance rates, which are lowest among low-income students.

[4] As I explain in Section 4, the status of "winner" or "loser" in years prior to the scholarship's existence is imputed by determining whether, based on her test scores, a given student would have won the scholarship had it then existed.

pledge to uphold certain academic standards. The best evaluations have focused on the largest state programs, in Georgia and California. Dynarski (2000) analyzes Georgia's HOPE Scholarship Program, which aimed to raise low college attendance rates by eliminating tuition (roughly $3500 in 2005$) at Georgia's public colleges for state residents with at least a B average in high school, regardless of income. With other southeastern states as controls, Dynarski's difference-in-difference estimates using the Current Population Survey suggest that introduction of the program increased Georgia's college attendance rate by over 7 percentage points, though the effect was due almost entirely to the strong reactions of white students. Cornwell et al. (2006) update this analysis using the National Center for Education Statistics' Integrated Postsecondary Education Data System (IPEDS), which reports institutional enrollments by students' original states of residence. They roughly agree with Dynarski's estimate of the increased attendance rate, but conclude that both black and white students exhibited such an increase. They also estimate that much of the increase stemmed from students choosing Georgia institutions over out-of-state ones, and that ultimately only 15% of scholarship winners changed their college decision based on the increased aid.

Kane (2003) evaluates California's CalGrant program, which primarily aimed to ease capacity constraints in the state's public postsecondary system by giving grants worth most if used at private colleges (up to $11,000 in 2005$) to federal financial aid applicants who had achieved a minimum high school GPA and fell below certain income and asset limits. Kane uses detailed student information from federal financial aid applications and exploits the multiple discontinuities inherent in the program design (minimum GPA, maximum income and maximum assets). That the GPA threshold was determined late in the process by state funding availability eliminates the possibility that students more desirous of aid tried “to claw their way above the threshold,” which would invalidate the smoothness assumption underlying regression discontinuity designs. Kane concludes that the grants caused a 3–4 percentage point rise in college enrollment among financial aid applicants and caused the lowest income applicants to more than double their rate of private college attendance (from 15% to over 30%).

The above papers make clear that merit-based financial aid can significantly impact a student's decision whether to attend college and, if so, whether in the public or private sector. Dynarski's and Kane's estimates are, however, hard to compare because the former measures a treatment effect averaged over all scholarship winners while the latter measures a treatment effect only for those near the eligibility threshold. The third strand that this paper therefore relates to is the tradition begun by LaLonde (1986) and more recently reviewed by Ham and LaLonde (2005) comparing experimental evaluations to non-experimental evaluations of public policies. The design of the Adams Scholarship allows comparison of difference-in-difference and regression discontinuity methods, as well as offering clear evidence on the heterogeneous treatment effects that lead to differences in estimates derived from these two methods. No previous paper on merit aid has done this.

2. The Adams Scholarship Program

All Massachusetts public high school sophomores take the Massachusetts Comprehensive Assessment System (MCAS), which includes an English portion and a mathematics portion. Scores on each portion range in multiples of two from 200 to 280, with 260–280 categorized as “advanced” and 240–258 as “proficient”. Students in the class of 2005 took their MCAS exams in April 2003. Nine months later, in January 2004, Massachusetts Governor Mitt Romney proposed the John and Abigail Adams Scholarship Program,[5] which would waive tuition at in-state public colleges for any student whose total MCAS score placed her in the top 25% statewide. At a meeting of the state Board of Higher Education, Governor Romney explained that “the Abigail and John Adams Scholarship will attract Massachusetts students to stay in Massachusetts by providing a special incentive to our brightest students…. It is a priority to attract the very best students to our public colleges.”[6]

Concerned that Governor Romney's statewide standard would assign scholarships largely to students in wealthy, high-performing school districts, the state Board of Higher Education ultimately approved a modified version of the program in October 2004, nine months after the original proposal and thus a year and half after the scholarships' first recipients, the class of 2005, had taken their MCAS exams. Under the modified version, a student receives a tuition waiver if her total MCAS score falls in the top 25% of scores in her school district and scores in the “advanced” (=260) category on one portion and the “proficient” (=240) or “advanced” category on the other.

Fig. 1 provides a graphical interpretation of scholarship eligibility in a typical medium-performing school district. About half of the graduates attend such districts (those with cutoff scores between 502 and 518), where the cutoff score interacts with the proficient/advanced threshold in a complex way. Students must pass the proficient/advanced threshold represented by the thick solid line and must also achieve their own district's cutoff score, represented by the thick dashed line. Scholarship winners are those students whose test scores fall in the shaded region. In low-performing districts (with cutoff scores of 500 or lower), the cutoff is so low that passing the proficient/advanced threshold is sufficient to win a scholarship, whereas in high-performing districts (with cutoff scores of 520 or higher), the cutoff is so high that passing it alone is sufficient to win. These complexities will inform construction of the eligibility variable to be used in Section 5's regression discontinuity estimates.

[5] The eponymous couple placed great value on education. John Adams wrote, in 1780, that “I must study politics and war that my sons may have liberty to study mathematics and philosophy. My sons ought to study mathematics and philosophy, geography, natural history, naval architecture, navigation, commerce, and agriculture, in order to give their children a right to study painting, poetry, music, architecture, statuary, tapestry, and porcelain.” His wife, Abigail Adams, may have agreed with her husband's sentiment but not with his single-sex phrasing of the issue. She once wrote, “It is really mortifying, sir, when a woman possessed of a common share of understanding considers the difference of education between the male and female sex, even in those families where education is attended to.” Mrs. Adams would likely have been pleased that women constituted the majority of the first class of scholarship winners.

[6] Minutes of the June 15, 2004 meeting can be found at http://www.mass.edu/p_p/home.asp?id=5.

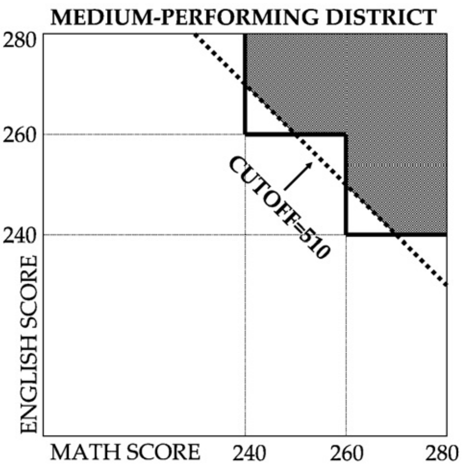

Fig. 1. Scholarship eligibility.

Scholarship winners are automatically notified in the fall of their senior year, which eliminates the selection bias potentially confounding evaluations of aid programs that require applications. The scholarship waives tuition at any of fifteen (two-year) community colleges, seven (four-year) state colleges, or four University of Massachusetts (U. Mass.) campuses.[7] Receipt of the scholarship does not, however, eliminate the cost of college attendance, as Table 1 shows. In fall 2005, tuition at individual public colleges in Massachusetts ranged from only 16–24% of the direct cost of attendance, with mandatory fees not covered by the scholarship comprising the remaining 76–84%. The average annual (total) value of the Adams Scholarship was therefore $740 ($1480) for community college students, $961 ($3846) for state college students, and $1575 ($6299) for U. Mass. students.

The Adams Scholarship thus differs from other studied merit-based aid programs both in award value and in its definition of merit. The maximum Adams Scholarship is roughly half the value of a HOPE award and one-sixth the value of a CalGrant award. Dynarski (2004) lists over a dozen states' merit-based aid programs in which the definition of merit includes over 30% of the student population, including some where the proportion is much greater. The Adams Scholarship, in contrast, is awarded to less than 25% of graduating Massachusetts seniors.

Of critical importance in the estimation strategies that follow is the fact that the class of 2005, the first class of scholarship recipients, took the exams that determined their treatment status long before knowing those scores could have monetary value. There is thus no reason to believe that students more desiring of scholarships tried, as Kane (2003) puts it, to "claw" their way above the thresholds.[8] This means that the imputed "winners" from years prior to 2005 should have similar observable and unobservable characteristics to actual winners from 2005, and that students who barely achieve the thresholds necessary to win the scholarship should look similar to those who barely miss those thresholds.

Two approaches to estimating the scholarship's effect are thus possible. The first explores the difference in college intentions between winners and losers, using classes prior to 2005 as a control for pre-treatment differences between these two groups. As emphasized in Athey and Imbens (2006), this traditional difference-in-difference approach results in an estimator of the form

$$\beta^{\mathrm{DID}} = (E[Y_i|\mathrm{WIN}_i = 1, 2005_i = 1] - E[Y_i|\mathrm{WIN}_i = 0, 2005_i = i]) - (E[Y_i|\mathrm{WIN}_i = 1, 2005_i = 0] - E[Y_i|\mathrm{WIN}_i = 0, 2005_i = 0])$$

where Y_i is the college intention of student i, WIN_i is an indicator for scholarship receipt, and 2005_i is an indicator for the class of 2005. Most important is the fact that β^{DID} represents an average treatment effect on the treated, where all of the treated students are weighted equally.

The second approach is to define a variable GAP_i that measures the number of points by which a student succeeded or failed to win a scholarship (i.e. $\mathrm{GAP}_i=0$ is the threshold between winning and losing). In this case, a regression discontinuity estimator has the form

$$\delta^{\mathrm{RD}} = E[Y_i|\mathrm{WIN}_i = 1, \mathrm{GAP}_i = 0] - E[Y_i|\mathrm{WIN}_i = 0, \mathrm{GAP}_i = 0],$$

which Lee (2007) shows is a weighted average treatment effect where the weights are determined by an individual's likelihood of being near the threshold value of $\mathrm{GAP}_i=0$. The size of the discontinuity is thus driven by those students likely to fall near the threshold, the lowest skilled winners, than those far away from it, the highest skilled winners. Differences between the

[7] After receiving that letter, a student must then file a FAFSA and must enroll in college the semester immediately following her high school graduation. She must also maintain a 3.0 grade point average in college in order to continue receiving the tuition waiver.

[8] There is some evidence that manipulation of the system began for later scholarship classes. One education official told me of an assistant principal who had transferred her 10th grade daughter to a lower-performing school district in order to guarantee she win a scholarship.

Table 1
Average costs of Massachusetts' public colleges, fall 2005

	N	1 year		Total (2 or 4 years)		Tuition as % of total cost
		Tuition	Fees	Tuition	Fees	
University of Mass.	4	$1575	$7612	$6299	$30,448	17.1%
State colleges	7	961	4389	3846	17,557	18.0%
Community colleges	15	740	2782	1480	5563	21.1%

Averages are weighted by enrollment, but vary little within category.
Source: Massachusetts Board of Higher Education: Fiscal Policy (Tuition and Fee Survey).

estimates from these two approaches will be suggestive of heterogeneous treatment effects, which I will be able to explore in further detail in Section 6.

3. The data

The data come from the Massachusetts Department of Education's Student Information Management System (SIMS) and include all graduates from the classes of 2003 to 2004, who graduated prior to the scholarship's existence, and 2005, the first class eligible for the scholarship. The most important variables are each student's MCAS scores,[9] post-graduation intentions as reported by her high school's guidance department, and a randomized school district identifier that allows me to identify students from the same district but not the district itself. The data also contain variables that will serve as controls and allow for subgroup analysis, including: gender; race; poverty status (based on participation in a reduced price lunch program); vocational education status; special education status; limited English proficiency status; and English-as-second-language status. I label students as coming from "medium poverty" districts if their graduating class had a poverty rate between 20% and 40% and "high poverty" if the poverty rate exceeded 40%.

Each student's post-graduation plan, the outcome variable of interest, falls into one of 5 categories: four-year public college; four-year private college; two-year public college; two-year private college; or other, which includes trade school, work, military, unknown plans, etc. I assign students to a graduating class based on when their guidance departments reported their post-graduation plans. I remove the 6% of students missing MCAS scores, school district identifiers, or post-graduation plans. The final sample consists of over 160,000 graduates.

Table 2 shows the mean characteristics of each graduating class. In the class of 2004, 78% of students intend to enroll in some form of college, with 26% choosing four-year public colleges and 33% choosing four-year private colleges. The two-year category is dominated by public colleges, as very few students attend two-year private colleges. Also important for the subsequent analysis is that MCAS scores appear to increase slightly with time, so that an increasing proportion of students pass the proficient/advanced thresholds. About 14% of graduates are poor, and 13% are black or Hispanic.

To check that students' reported postsecondary intentions reflect actual college attendance, I used IPEDS' Residence and Migration data, which reports for each U.S. postsecondary institution the number of "first-time degree/certificate-seeking undergraduate students who graduated from high school in the past 12 months" broken down by students' states of residence at the time of admission to the institution. According to IPEDS, 46,846 students originally residing in Massachusetts started college somewhere in the U.S. in 2004, a slightly higher number than the 41,912 (78% of 53,715) reported in the SIMS data. This is likely due to students I discarded, as well as IPEDS' inclusion of GED recipients, private school graduates, and students who enroll one year after graduating high school. The proportions of students attending various categories of college are, however, nearly identical in the IPEDS and SIMS data. According to IPEDS (SIMS), the proportions of these students attending four-year public college is 32.0% (32.9%), two-year public college is 22.6% (21.5%), four-year private college is 43.2% (42.3%), and two-year private college is 2.2% (3.2%). This suggests, at least on average, that reported intentions reflect actual enrollment decisions.

4. Difference-in-difference methodology and results

Estimation of the scholarship's effects through comparison of the postsecondary plans of scholarship winners and losers would be heavily biased by the omission of academic skill as an explanatory variable. I eliminate this bias by constructing a difference-in-difference estimator comparing scholarship winners to losers in the year before and after the scholarship's introduction. To do this, I create a dummy variable WIN_{ij}, equal to 1 for any 2005 graduate *i* in district *j* who won the Adams Scholarship as well as for 2003 and 2004 graduates who would have won, according to their test scores, had the scholarship then existed. To impute this value to the 2003 and 2004 graduates, I determine whether each student passed the proficient/advanced threshold and scored in the top 25% of her school district in her graduation year. The identifying assumption of the difference-in-difference approach is that, according to the construction of WIN_{ij}, between 2004 and 2005 nothing other than the Adams Scholarship affected the difference in college enrollment patterns between winners and losers.

[9] Students may retake the exam multiple times, so I use only scores from the first exam taken.

Table 2
Mean characteristics by class

	Class of 2003	Class of 2004	Class of 2005
College intentions			
Any college	0.771	0.780	0.802
Four-year public college	0.257	0.257	0.278
Four-year private college	0.319	0.330	0.327
Two-year public college	0.172	0.168	0.176
Two-year private college	0.023	0.025	0.021
Scholarship variables			
MCAS score — English	241.7	244.7	246.6
MCAS score — Math	240.5	240.6	244.0
Proficient/advanced	0.262	0.300	0.340
Scholarship winner	0.196	0.211	0.239
Demographics			
Female	0.518	0.508	0.514
Black	0.065	0.067	0.068
Hispanic	0.059	0.060	0.067
Poor	0.132	0.143	0.162
Medium poverty district	0.086	0.107	0.110
High poverty district	0.114	0.124	0.149
Special education	0.100	0.120	0.115
Vocational education	0.190	0.184	0.167
Limited English proficiency	0.023	0.019	0.037
English-as-second-language	0.098	0.100	0.110
N	52,750	53,715	54,499

One possible identification problem is that lower MCAS scores in 2003 and 2004 reduced the number of students passing the proficient/advanced threshold, so that fewer of those students are scholarship winners based on my construction of WIN_{ij}. Table 2 confirms this, showing the proportion of students labeled winners rising from 19.6% to 23.9% over the three years. This could bias the difference-in-difference estimator if WIN_{ij} identifies slightly different parts of the skill distribution in different years. In Sections 5 and 6, I address this potential bias with a regression discontinuity design that uses only a single year of data and with regressions that include a students' rank in the skill distribution.

Here I address this possible bias by computing two difference-in-difference estimators simultaneously, one comparing 2005 to 2004, and another comparing 2004 to 2003. I therefore treat the class of 2004 as the omitted category and run regressions of the form

$$Y_{ij} = \beta_0 + \beta_1 (2005_{ij}{*}\mathrm{WIN}_{ij}) - \beta_2 (2003_{ij}{*}\mathrm{WIN}_{ij}) + \beta_3 2005_{ij} + \beta_4 2003_{ij} + \beta_5 \mathrm{WIN}_{ij} + \varepsilon_{ij} \tag{1}$$

where Y_{ij} is an indicator for student i in district j planning to attend a particular type of college, 2005_{ij} and 2003_{ij} are indicators for each class, and WIN_{ij} is the variable described above. β_1 thus compares 2005 to 2004 and would be an unbiased estimator of the scholarship's average effect on the winners if not for rising MCAS scores. Subtracting β_2, which by construction compares 2004 to 2003, will help control for the tendency over time for WIN_{ij} to identify more of the distribution. The estimate of most interest is therefore $\beta_1-\beta_2$, a difference-in-difference-in-difference.

Table 3 shows the results of these regressions from Eq. (1), with each column in each panel representing a separate regression for each college category. Reported standard errors are heteroscedasticity robust and clustered by school district to allow for intra-district correlation in ε_{ij}. In panel (A), which includes no demographic controls, β_1 suggests that the scholarship induced roughly 6% of winners to choose four-year public colleges over four-year private colleges, while having no significant impact on the two-year college categories. Subtracting β_2 has relatively little effect, reducing the estimated proportion of switchers to 5%. Panel (B) adds demographic controls interacted with class to further account for potential changes in the population of winners over time. These controls change the estimates of $\beta_1-\beta_2$ relatively little, continuing to suggest that the scholarship induced roughly 6% of winners to switch from four-year private colleges to four-year public colleges and thus left the overall college attendance rate unchanged.[10]

Given that, as listed below panel (B), the 2004 winners' mean attendance rate at four-year public colleges was 30.7%, the scholarship seems to have induced a nearly 20% increase in the number of winners attending such colleges. That this stemmed from a 17% price decrease suggests winners' elasticity of demand for four-year public college has magnitude above unity. These may be underestimates given that some students may switch from out-of-state public colleges to in-state public colleges. These

[10] The negative, though statistically insignificant, coefficient on the "Any College" category is due largely to the impact of the "Two-Year Public College" category, for which the linear probability model performs poorly given the extremely low mean value of the dependent variable. Probit specifications eliminate this discrepancy but are omitted for brevity.

Table 3
Difference-in-difference (-in-difference) results

	Any college	Four-year public college	Four-year private college	Two-year public college	Two-year private college
(A) All students, no controls					
β_1 (2005 vs. 2004)	−0.014* (0.006)	0.058** (0.009)	−0.062** (0.009)	−0.009 (0.007)	−0.001 (0.002)
β_2 (2004 vs. 2003)	0.006 (0.009)	0.008 (0.008)	−0.014 (0.009)	0.011 (0.006)	0.000 (0.002)
R^2	0.045	0.007	0.084	0.039	0.004
$\beta_1-\beta_2$	−0.019	0.050**	−0.048**	−0.019	−0.002
$P(\beta_1=\beta_2)$	0.120	0.001	0.002	0.109	0.671
(B) All students, with controls					
β_1 (2005 vs. 2004)	−0.011* (0.005)	0.065** (0.009)	−0.072** (0.009)	−0.002 (0.006)	−0.002 (0.002)
β_2 (2004 vs. 2003)	0.009 (0.007)	0.007 (0.008)	−0.010 (0.009)	0.013* (0.005)	−0.000 (0.002)
R^2	0.148	0.037	0.127	0.053	0.009
$\beta_1-\beta_2$	−0.020	0.059**	−0.062**	−0.015	−0.001
$P(\beta_1=\beta_2)$	0.070	0.000	0.004	0.089	0.714
Mean for all 2004 winners	0.951	0.307	0.604	0.031	0.009
(C) Poor students, with controls					
β_1 (2005 vs. 2004)	0.004 (0.018)	0.127** (0.024)	−0.103** (0.023)	−0.014 (0.021)	−0.007 (0.011)
β_2 (2004 vs. 2003)	0.062* (0.026)	0.015 (0.029)	0.018 (0.027)	0.025 (0.019)	0.005 (0.007)
R^2	0.095	0.048	0.094	0.036	0.013
$\beta_1-\beta_2$	−0.059	0.112*	−0.121**	−0.038	−0.012
$P(\beta_1=\beta_2)$	0.106	0.015	0.005	0.251	0.483
Mean for poor 2004 winners	0.889	0.278	0.528	0.068	0.015

Robust standard errors are clustered by school district (*$p<0.05$, **$p<0.01$). $P(\beta_1=\beta_2)$ represents the p-value from a Wald test of the hypothesis $\beta_1=\beta_2$. Panels (B) and (C) include Table 2's demographic controls fully interacted with class. In panels (A) and (B), $N=160{,}949$. In panel (C), $N=23{,}479$.

estimates therefore imply that at least 780 students (6% of the 2005 winners) were induced to switch from private to public colleges. The state reported that roughly one fourth, or 3360, of the 2005 winners ultimately used the scholarship, suggesting that 23% (=780/3360) of scholarship users changed their behavior due to the scholarship, while the remaining 77% had their previous behavior subsidized by the state. The marginal effects of this scholarship were thus small in comparison to the inframarginal effects, though somewhat larger than those found in Georgia by Cornwell et al. (2006).

To test whether price sensitivity varies by income, panel (C) of Table 3 limits the sample to poor students. The estimates of $\beta_1-\beta_2$ for poor students are roughly 12%, implying that scholarship's effects are twice as large for poor students as for the general population. The same regressions limited to black students show even higher coefficients, on the order of 20%. Taken as a whole, these results suggest that disadvantaged students are much more likely to take advantage of the scholarship than their more advantaged peers. In Section 6 I will argue that this heterogeneity by income may be due to heterogeneity by academic skill.

5. Regression discontinuity methodology and results

The primary disadvantage of the difference-in-difference approach is that WIN_{ij} may include different parts of the skill distribution in different years. A regression discontinuity design eliminates this concern by focusing on only a single class. I exploit the fact that scholarship receipt is a discontinuous function of a student's test scores due to the proficient/advanced and district cutoff thresholds. Students whose scores place them just inside the dark region in Fig. 1 are similar to students whose scores place them just outside those regions, yet the former receive the scholarship and the latter do not.

The major hurdle here is the complexity of the various thresholds that students must achieve in order to win the Adams Scholarship. Previous papers, such as Kane (2003) and van der Klaauw (2001), consider financial aid that is granted once students pass a single threshold that is applied uniformly to all students. Here, the location of the discontinuity varies by district. To construct a single measure that exploits the discontinuity, I first define BEST_{ij} and WORST_{ij} as the highest and lowest of each student's two MCAS scores. I then define

$$\text{GAP}^*_{ij}=\min\left(\text{TOTAL}_{ij}-\text{CUTOFF}_j,\text{BEST}_{ij}-260,\text{WORST}_{ij}-240\right) \quad (2)$$

where TOTAL_{ij} represents the total MCAS score of student i in district j and CUTOFF_j represents the cutoff score of district j. These three terms respectively represent the distance the student fell from the district cutoff threshold, the advanced threshold, and the proficient threshold (recall that a score of 260 is advanced and 240 is proficient). GAP* thus assigns to each student the number of points by which she failed most or succeeded least to meet one of the thresholds. By this definition, any student with $\text{GAP}^*_{ij}<0$ fails to win a scholarship and any student with $\text{GAP}^*_{ij}\geq 0$ has passed all the thresholds and is thus guaranteed a scholarship. Values of GAP^*_{ij} range from −132 to 20.

Fig. 2 graphs graduates' mean college intentions against GAP^*_{ij} and for visual purposes show only the portion for which $\text{GAP}_{ij}\geq -20$. For the 2004 graduates, two features are worth noting in panels (A), (C) and (E). First, students with higher

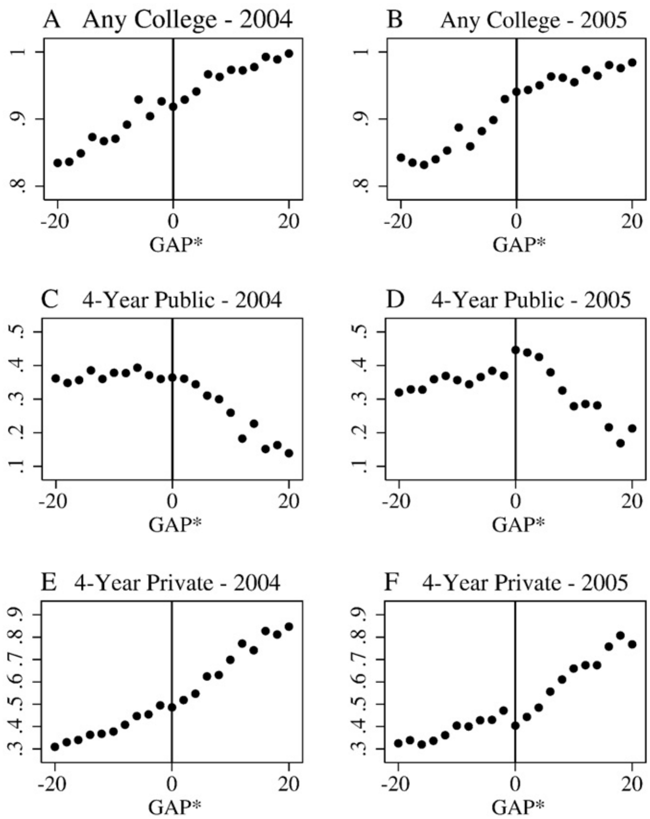

Fig. 2. College intentions vs. GAP*.

values of GAP_{ij}^* are more likely to attend four-year private colleges and less likely to attend four-year public colleges, confirming that private colleges attract more academically talented students than do public colleges. Second, as expected, none of the panels show a discontinuity at the threshold value of $GAP_{ij}^*=0$.

In the right column, the graphs of 2005 graduates' college intentions have roughly the same shape as their 2004 counterparts, but panels (D) and (F) exhibit clear discontinuities at $GAP_{ij}^*=0$. Compared to students who just missed winning the scholarship, students who just succeeded in winning are noticeably more likely to attend four-year public colleges and less likely to attend four-year private colleges. The apparently similar magnitude of these two discontinuities explains why the scholarship had no apparent impact on the overall college attendance rate, as shown by the lack of a discontinuity in panel (B).

To quantify the discontinuity more precisely, I run regressions of the form

$$Y_{ij} = \delta_0 + \delta_1 I + \delta_2 \mathrm{GAP}_{ij}^* + \delta_3 \mathrm{GAP}_{ij}^* \times I + \varepsilon_{ij} \tag{3}$$

where I is an indicator for $GAP_{ij}^* \geq 0$. This specification fits separate lines to each side of the threshold, so that the coefficient of interest is the size of the discontinuity δ_1. As discussed in Section 2, this measures a weighted average treatment effect where the weights are determined by the probability of being near $GAP_{ij}^*=0$.

Panel (A) of Table 4 show the values of δ_1 estimated from running regressions of the form given by equation (3), with the sample limited to students within 20 points of the threshold to make the assumption of linearity plausible. For the class of 2004, estimates of the discontinuity are all small and statistically insignificant, as expected. For the class of 2005, a large and highly significant discontinuity appears in the four-year college categories, and the estimates change little when demographic controls are added to the regressions, as should be the case with regression discontinuity designs. The estimates from this specification suggest that the scholarship induced 7.6% of winners to enroll in four-year public colleges and 5.6% of winners to leave four-year private colleges. Unlike the difference-in-difference approach, the regression discontinuity thus suggests that the scholarship did raise the proportion of students intending to attend college, by 2–3 percentage points.

Panel (B) relaxes the linearity assumption, including all values of GAP* and fitting to each side of the threshold a quartic polynomial, the lowest degree polynomial not rejected at a 5% significance level by the goodness-of-fit statistic suggested by Lee and Card (2007). Using the quartic specification, the class of 2004 again shows no discontinuities, while the class of 2005 shows 7.8% of winners switching between the four-year private and public college categories. Addition of demographic controls has

Table 4
Regression discontinuity results

	Any college	Four-year public college	Four-year private college	Two-year public college	Two-year private college
(A) Linear fit, $\|GAP^*\| \le 20$					
Class of 2004, no controls					
δ_1	−0.010 (0.007)	0.001 (0.010)	−0.011 (0.013)	−0.001 (0.006)	0.000 (0.002)
R^2	0.025	0.013	0.072	0.028	0.002
Class of 2005, no controls					
δ_1	0.023** (0.008)	0.075** (0.011)	−0.061** (0.012)	0.008 (0.006)	−0.000 (0.002)
R^2	0.029	0.013	0.054	0.032	0.004
Class of 2005, with controls					
δ_1	0.027** (0.006)	0.076** (0.011)	−0.056** (0.011)	0.007 (0.006)	−0.000 (0.002)
R^2	0.100	0.019	0.085	0.054	0.007
(B) Quartic fit, GAP unrestricted*					
Class of 2004, no controls					
δ_1	−0.007 (0.009)	0.004 (0.014)	−0.008 (0.015)	−0.006 (0.008)	0.003 (0.004)
R^2	0.127	0.060	0.146	0.074	0.007
Class of 2005, no controls					
δ_1	0.016 (0.010)	0.078** (0.013)	−0.078** (0.015)	0.014 (0.009)	0.002 (0.003)
R^2	0.110	0.062	0.125	0.089	0.009
Class of 2005, with controls					
δ_1	0.020* (0.009)	0.079** (0.013)	−0.078** (0.014)	0.017 (0.009)	0.003 (0.003)
R^2	0.177	0.071	0.155	0.098	0.015

Robust standard errors are clustered by school district (*$p<0.05$, **$p<0.01$).
In panel (A), $N=24{,}611$ for 2004 and $N=27{,}885$ for 2005. In panel (B), $N=53{,}715$ for 2004 and $N=54{,}484$ for 2005.

nearly no effect on these estimates. These discontinuity estimates thus tell a similar story as the difference-in-difference estimates but imply a stronger effect of the scholarship. The simplest explanation for the discrepancy is that the discontinuity measures a local average treatment effect with heavier weights assigned to students likely to fall near the threshold. These are the least skilled of the winners, so it may be that lower skilled students react more strongly than higher skilled students.

6. Heterogeneity by academic skill

To test this hypothesis directly, I return to the difference-in-difference methodology but add one more layer of interactions with a measure of academic skill. To do this, I assign each student to one of 10 deciles within her class based on her total MCAS score. I then fully interact these decile indicators with all the terms in Eq. (1), so that β_1 is now a difference-in-difference-in-difference estimate of the effect of being a scholarship winner (compared to loser) in 2005 (compared to 2004) and in a given skill decile (compared to the other deciles). Because scholarship winners come from above the 60th percentile, Table 5 replicates Table 3 where each value of β_1 is derived from a separate regression treating each of the top four deciles as the omitted category.

A clear pattern emerges. About 12–13% of scholarship winners in the 60–79th skill percentiles switched from four-year private colleges to four-year public colleges, an effect that diminishes to 5–6% in the 80–89th percentiles and then disappears entirely in the 90–99th percentiles. These estimates are robust to inclusion of demographic controls in panel (B) and the overall conclusions change little if β_2 (comparing 2004 to 2003, but not shown here) is subtracted from β_1. Table 5 thus reveals that the original difference-in-difference estimate that 6% of winners switched college categories is an average of high responsiveness among the lowest skilled winners and little or no responsiveness among the most highly skilled winners.[11] This confirms that the regression discontinuity design captures an effect weighted more heavily for the lowest skilled scholarship winners.

The heterogeneity analysis also provides insight into the decision-making processes of high school graduates. The simplest explanation for the observed pattern of heterogeneity by academic skill is that students trade off quality and price when deciding which college to attend. Many of the highly skilled students have gained admission to selective private colleges of higher quality than the public colleges, so that the small price reduction the Adams Scholarship offers is insufficient to induce such a drop in quality. Conversely, for the lowest skilled winners, the perceived quality drop is smaller (or non-existent) so that a switch to the public sector given the price reduction is worthwhile. The pattern in Table 5 is suggestive, though not conclusive, that students are considering such price and quality tradeoffs when making college decisions.

The heterogeneity by academic skill may also explain why poor students seem more price sensitive than other students, given that test scores and income are positively correlated. Panel (C) repeats panel (B)'s regressions, restricting the sample to poor students. Though the estimates are quite noisy because so few poor students win scholarships, the most precise estimates in the 60–69th and 70–79th percentiles are surprisingly similar to their counterparts in panel (B). Conditional on academic

[11] Highly skilled students may not be totally unresponsive. With finer skill divisions, the coefficient on students in the 95–99th percentiles is significant but small, which may be evidence that those students are attracted to honors colleges that some U. Mass. campuses reserve for their most elite students.

Table 5
Heterogeneity by academic skill

	Any college	Four-year public college	Four-year private college	Two-year public college	Two-year private college
(A) All students, no controls					
β_1 (60–69th)	0.035 (0.023)	0.130** (0.029)	−0.117** (0.032)	0.017 (0.020)	0.005 (0.009)
β_1 (70–79th)	0.004 (0.013)	0.126** (0.024)	−0.132** (0.026)	0.009 (0.009)	0.002 (0.008)
β_1 (80–89th)	0.018* (0.008)	0.064** (0.024)	−0.049 (0.027)	0.003 (0.006)	−0.000 (0.002)
β_1 (90–99th)	−0.016* (0.008)	−0.001 (0.040)	−0.008 (0.045)	−0.003 (0.002)	−0.005 (0.004)
(B) All students, with controls					
β_1 (60–69th)	0.026 (0.020)	0.126** (0.028)	−0.109** (0.030)	0.006 (0.020)	0.004 (0.008)
β_1 (70–79th)	0.004 (0.011)	0.126** (0.024)	−0.124** (0.024)	0.001 (0.010)	0.002 (0.007)
β_1 (80–89th)	0.024** (0.008)	0.066** (0.025)	−0.040 (0.026)	−0.002 (0.007)	0.001 (0.002)
β_1 (90–99th)	−0.025* (0.011)	−0.004 (0.040)	−0.005 (0.046)	−0.010** (0.003)	−0.006 (0.005)
(C) Poor students, with controls					
β_1 (60–69th)	0.002 (0.053)	0.123 (0.070)	−0.081 (0.061)	−0.034 (0.044)	−0.006 (0.019)
β_1 (70–79th)	−0.080* (0.039)	0.072 (0.072)	−0.126 (0.067)	−0.036 (0.054)	0.010 (0.019)
β_1 (80–89th)	0.062 (0.116)	−0.109 (0.176)	0.264 (0.172)	−0.090 (0.071)	−0.003 (0.011)
β_1 (90–99th)	−0.080* (0.039)	0.072 (0.072)	−0.126 (0.067)	−0.036 (0.054)	0.010 (0.019)

Each coefficient is from a separate regression with the given decile as the omitted category. Robust standard errors are clustered by school district (*$p<0.05$, **$p<0.01$). Panels (B) and (C) include Table 2's demographic controls fully interacted with class. In panels (A) and (B), $N=160{,}949$. In panel (C), $N=23{,}479$.

skill, there is little evidence that poor students reacted more strongly to the scholarships than did non-poor students, suggesting that poor students' higher price sensitivity may be picking up correlations between poverty and relatively low test scores.

7. Conclusions

In its first year, the Adams Scholarship spent $4 million on tuition waivers for over 3000 students attending in-state public colleges. Nearly half of those attended U. Mass. Amherst, the most prestigious of the state's public postsecondary institutions. Most of the remaining students attended other U. Mass. campuses, so that nearly half of the entering freshmen classes were scholarship winners. This paper suggests that about 800 of those students, largely from the 60–79th percentiles of academic skill, would have attended four-year private colleges had the scholarship not existed. This translates into roughly $5000 per student induced to switch into the public sector.

One critical question is whether these 800 students would have attended private colleges in Massachusetts or elsewhere. Though the SIMS data can not resolve this, the IPEDS Residence and Migration mentioned in Section 3 can be used to examine trends over time in the college choices of recent Massachusetts high school graduates as a whole. Though the IPEDS data is unfortunately noisy, there is no evidence after the scholarship's introduction of an increase in the fraction of those recent graduates attending in-state colleges. Though not conclusive, this suggests that the scholarship's primary effect is to move students from in-state private colleges to in-state public colleges.

Does Massachusetts benefit from the Adams Scholarship? First, the IPEDS data suggests that the original motivation for the scholarship may have been misplaced, in that the state does not suffer from brain drain. According to IPEDS, each year Massachusetts attracts roughly 5000 more out-of-state students to its colleges than it loses of its own high school graduates to other states. Second, even if all 800 switching students would have otherwise attended out-of-state colleges, any benefit to the

Table 6
College intentions, academic skill and poverty, class of 2004

	Percentile of academic skill				
	0–19	20–39	40–59	60–79	80–99
Any college					
Poor students	0.52	0.66	0.76	0.84	0.93
Non-poor students	0.53	0.72	0.82	0.92	0.97
Scholarship winners					
Poor students	0	0	0	386	336
Non-poor students	0	0	0	2415	8201
Students					
Poor students	3577	1752	1134	855	351
Non-poor students	7833	9064	9166	10,427	9556

state would accrue only if in the long run students tend to settle where they attend college. Recent work by Groen (2004) shows, however, that only 10% of students induced to stay in-state by such financial incentives will remain in that state's labor market 10–15 years later. This means that the Adams Scholarship would annually add 80 college-educated workers to the state's workforce, at an annual cost of $50,000 per added worker. It seems implausible that the benefits to the state in additional tax revenue would exceed this amount, or that the proportion of college-educated workers would rise enough to induce the positive externalities documented by Moretti (2004).

Possible improvements for Massachusetts are prompted by Table 6, which decomposes college intentions by poverty status and quintile of academic skill for the class of 2004. Two facts are worth noting. First, poor students in the middle part of the skill distribution are 8 percentage points less likely to attend college than their non-poor peers, though that gap within quintiles is only half the size of the overall enrollment gap. Second, very few poor students win Adams Scholarships because they are bunched very heavily at the low end of the skill distribution. These facts suggest two possible avenues for state policies to encourage more efficient production of human capital. First, Massachusetts could assign scholarships based on both merit and income, which might help target those students whose enrollment decisions are most price sensitive. Second, the state could direct more of its budget toward remedying the skill gaps that explain so much of the college enrollment gaps. Either of these plans could potentially be more efficient that the Adams Scholarship in its current form. They would also be more redistributive and thus would likely face more political opposition than a non-means tested merit aid program does, which may explain why such programs have proliferated in recent years.

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