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Stand and Deliver: Effects of Boston's Charter High Schools on College Preparation, Entry, and Choice

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Abstract

We use admissions lotteries to estimate the effects of attendance at Boston's charter high schools on college preparation, college attendance, and college choice. Charter attendance increases pass rates on the high-stakes exam required for high school graduation in Massachusetts, with especially large effects on the likelihood of qualifying for a state-sponsored college scholarship. Charter attendance has little effect on the likelihood of taking the SAT, but shifts the distribution of scores rightward, moving students into higher quartiles of the state SAT score distribution. Boston's charter high schools also increase the likelihood of taking an Advanced Placement (AP) exam, the number of AP exams taken, and scores on AP Calculus tests. Finally, charter attendance induces a substantial shift from two-to four-year institutions, though the effect on overall college enrollment is modest. The increase in four-year enrollment is concentrated among four-year public institutions in Massachusetts. The large gains generated by Boston's charter high schools are unlikely to be generated by changes in peer composition or other peer effects.

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1 Introduction

One of the most important questions in education research is whether the gains from interventions for which we see short-term success can be sustained. For example, test score gains generated by pre-school interventions, highly effective teachers, and elementary-school class size reductions often appear to fade as students progress through school, though some of these gains may re-emerge later in non-cognitive outcomes.[1] The possibility of short-lived impacts is especially relevant for research on charter schools, where charter operators who face high-stakes assessments have an incentive to "teach to the test." The fact that charters are subject to intense scrutiny and evaluation may even create incentives for cheating (Jacob and Levitt, 2003), strategic instruction (Jacob, 2007), and a focus on small groups of students that are pivotal for official accountability measures (Neal and Schanzenbach, 2010).

The purpose of this paper is to assess the impact of attendance at Boston's charter high schools on outcomes where the link with human capital and future earnings seems likely to be sustained and strong. Specifically, we focus on outcomes that are either essential to or facilitate post-secondary schooling: high school graduation, the attainment of state competency thresholds, scholarship qualification, Advanced Placement (AP) and SAT scores, college enrollment, and college persistence. Importantly, most of these outcomes are less subject to strategic manipulation than are the state's test-based assessments. As in earlier work, the research design implemented here exploits randomized enrollment lotteries at over-subscribed charter schools. The resulting estimates are likely to provide reliable measures of average causal effects for charter applicants.

Our analysis focuses on Boston's charter high schools. For our purposes, an analysis of high schools is both a necessity and a virtue. It's necessary to study high schools because most students applying to charters in earlier grades are not yet old enough to generate data on post-secondary

[1] Currie and Thomas (2000) show that the effect of Head Start on test scores fades, while Garces et al. (2002) and Deming (2009) document long-term effects on educational attainment and non-schooling outcomes. While the effect of smaller classes on test scores diminishes after children return to larger classes (Krueger and Whitmore, 2001), positive effects re-emerge for post-secondary attainment (Dynarski et al., 2011) and financial well-being (Chetty et al., 2011a). Three randomized, preschool interventions show fading effects on cognitive tests but large impacts on labor market attachment and crime reduction (Anderson, 2008). Teacher assignment and international educational interventions also appear to generate impacts that fade (see Kane and Staiger (2008); Jacob et al. (2010) for evidence on the first and Andrabi et al. (2011); Banerjee et al. (2007) for evidence on the second), though there is some evidence that teachers can influence later life outcomes (Chetty et al., 2011b).

outcomes. Charter high schools are also of substantial policy interest: a growing literature suggests that high school may be too late for cost-effective human capital interventions (see, for example, Cunha et al. (2010)). Consistent with this view, impact analyses of interventions for urban youth have mostly generated disappointing results.[2] We're interested in ascertaining whether charter schools, which are largely budget-neutral, can have a substantial impact on the life course of affected students. The set of schools studied here comes from an earlier investigation of the effects of charter attendance in Boston on test scores (Abdulkadiroğlu et al., 2011). The high schools in our earlier study, which enroll the bulk of charter high school students in Boston, generate statistically and socially significant gains on state assessments in 10th grade. We turn here to the question of whether these gains are sustained.

Our findings suggests that the gains from Boston's high-performing charter high schools are remarkably persistent. Charter school attendance increases the pass rate on the exam required for high school graduation in Massachusetts, with especially large effects on the likelihood of qualifying for a state-sponsored college scholarship. Lottery estimates also show gains on the SAT and on Advanced Placement tests. Charter attendance boosts SAT scores sharply, especially in math, while doubling the likelihood that a student sits for an AP exam and increasing the fraction of students who pass AP Calculus. Our evidence suggests that charter attendance increases college enrollment, but the number of charter applicants old enough to be in college is still too small for this result to be conclusive. At the same time, charter attendance induces a clear shift from two-year to four-year colleges, with gains most pronounced at four-year public institutions in Massachusetts.

An analysis of results by subgroup shows broadly distributed gains, with evidence of larger effects for students who appear weaker at baseline. Finally, because Boston's charter applicants are positively selected relative to the traditional Boston Public School (BPS) population, we explore the possibility that peer composition mediates charter effects. The results of this exploration are inconsistent with the notion that changes in peer composition account for the main findings.

The next section provides background on Massachusetts charter schools and describes the data.

[2]For example, Dynarski et al. (1998) and Dynarski and Gleason (2002) document an array of discouraging findings for interventions meant to reduce dropout rates. See also Dynarski and Wood (1997) and Kemple and Snipes (2000) for results on alternative schools and career academies, where the findings are mixed at best.

Section 3 outlines our empirical strategy, and reports first-stage estimates and benchmark effects on standardized test scores. Section 4 reviews findings for college preparation, while Section 5 discusses effects on college enrollment, choice, and persistence. Section 6 reports effects in subgroups and discusses our evidence on peer effects. The last section concludes.

2 Background and Data

2.1 Boston's Charter Sector

Boston's over-subscribed charter schools generate impressive score gains. Lottery estimates show that each year spent at a charter middle school boosts scores by about a fifth of a standard deviation in English Language Arts (ELA) and over a third of a standard deviation in math. High school gains are just as large (Abdulkadiroğlu et al., 2011). These effects are in line with those generated by urban charters elsewhere in Massachusetts, as we've shown in studies of a Knowledge is Power Program (KIPP) school in Lynn, Massachusetts (Angrist et al., 2010, 2012), and in an analysis of charter lottery results from around the state (Angrist et al., 2011a,b).

A defining feature of Massachusetts' successful urban charter schools appears to be adherence to *No Excuses* pedagogy, an approach to urban education described in a book of the same name (Thernstrom and Thernstrom, 2003). *No Excuses* schools emphasize discipline and comportment, traditional reading and math skills, extended instruction time, and selective teacher hiring. Massachusetts' *No Excuses* charters also make heavy use of Teach for America (TFA) participants and alumni and provide extensive and ongoing feedback to teachers. Like most Boston charter schools, the high schools studied here largely identify with the *No Excuses* approach, a fact documented in Table 1.[3] Another feature of the Massachusetts charter landscape is the state's rigorous charter authorization and monitoring process. To date the state has closed 12 charter schools after they began operations and an additional 4 schools before they opened (Massachusetts Department of Elementary and Secondary Education, 2013).[4]

[3] Other lottery-based evidence on *No Excuses* effectiveness includes the Dobbie and Fryer (2011a) study of a charter school in the Harlem Children's Zone, the Dobbie and Fryer (2011b) study of a larger sample of New York charters, and results for a sample of KIPP schools from around the country (Tuttle et al., 2013).

[4] Two schools marked as closed in the state's charter school factsheet have been consolidated under the charter of

Charter schools are a recent innovation; Massachusetts' first charter schools opened in 1995. Not surprisingly, therefore, most evidence on charter effectiveness comes from outcomes measured while children are still enrolled in elementary and secondary school. An exception is Dobbie and Fryer's (2012) recent lottery-based study, which follows applicants to a single charter middle school in the Harlem Children's Zone, estimating effects on college enrollment while also looking at non-educational outcomes related to crime and teen pregnancy. Dobbie and Fryer (2012) find that Promise Academy students are more likely to go to college, while girls are less likely to get pregnant and boys are less likely to be incarcerated. Earlier work by Booker et al. (2008) uses statistical controls and distance instruments to identify the effects of charter school attendance on high school graduation and college enrollment. Both empirical strategies suggest gains for charter students. We complement this earlier work with new results on post-secondary preparation, enrollment, and choice for a large cohort of charter high school lottery applicants.

2.2 Data and Sample

School Selection

We set out to study the effects of attendance at six charter high schools in Boston. These schools generated the lottery-based estimates of charter high school achievement effects reported in our earlier study (Abdulkadiroğlu et al., 2011), and account for the bulk of charter high school enrollment in Boston today.[5] Two additional charter high schools serving Boston students in the same period are now closed. One school that is still open has poor records and appears unsuitable for a lottery-based analysis.

Table 1 describes features of the charter schools included in this study, as well as those of the full set of charter high schools in Boston and Boston's traditional public schools, including exam schools. This table classifies charters according to whether they cover grades 9-12 or are limited to grades 9-12. Boston's charters run a longer school year and day than traditional public schools, and make frequent use of Saturday school. As a result, charter school students receive about 1500

a third school; they remain in operation and are thus not counted in the school closure totals.

[5]The six schools are Academy of the Pacific Rim Charter Public School, Boston Collegiate Charter School, Boston Preparatory Charter Public School, City on a Hill Charter Public School, Codman Academy Charter Public School, and Match High School.

hours per year of instruction, compared to 1150 in the traditional public schools. Most of Boston's charters adhere to the *No Excuses* instructional approach. Panel B of Table 1 compares teacher characteristics, per-pupil expenditure, and Title I eligibility. Charter teachers are younger than their traditional public school counterparts: 76 percent of teachers in our analysis sample are 32 or younger, compared to 28 percent of public school teachers. Similarly, only 5 percent of (study sample) charter teachers are 49 or older, while 35 percent of public school teachers are at least 49. Charters appear to be close to budget-neutral, and their class sizes are smaller.[6] All public schools in Boston, including charters, qualify for Title I aid.

Student Data

Massachusetts charter schools admit students by lottery when they have more applicants than seats. We collected lists of charter school applicants and information on the results of admissions lotteries from individual charter schools. These lists were then matched to administrative records covering all Massachusetts public school students. Our analysis sample is limited to charter applicants who applied for a charter school seat from Fall 2002 through Fall 2009. Additional information on applicant lotteries appears in Appendix Table A1 and in the Data Appendix.

We matched applicant records to administrative data using applicants' names, cohorts, and grades of application. Where available, information on date of birth, town of residence, race or ethnicity, and gender was used to break ties. Among applicants eligible for our study, 94 percent were matched to state data.[7] Applicants were excluded from the analysis if they were disqualified from the lottery (these are mostly applicants to the wrong grade). We also omit siblings of current charter students, late applicants, and some out-of-area applicants. Students submitting charter applications in multiple years appear only once in the sample, with data recorded for the first application only. Information on baseline demographics and test scores comes from the most recent

[6]Per pupil expenditures are slightly larger at charter schools than BPS schools. However state generated PPE numbers are only available at the district level, so it is not possible to report the high school only BPS PPE. Generally, PPE is higher at high schools than elementary schools (Heuer and Stullich, 2011). Charter and BPS per pupil spending is likely similar when grade level adjustments are made.

[7]Match rates differ little by win/loss status, a fact documented in Web Appendix Table B1. Web Appendix Table B2 shows that results for applicant cohorts where match rate differentials are largest (mostly recent cohorts with projected graduation dates after 2009) are typically similar to those for the larger sample, though effects on reading scores are somewhat smaller for the balanced cohorts.

pre-lottery data available in the state database. In addition to providing demographic information and scores on state assessments, state administrative records include AP and SAT scores for all public school students tested in Massachusetts.

Information on college enrollment and choice comes from the National Student Clearinghouse (NSC). The Massachusetts Department of Elementary and Secondary Education routinely requests an NSC match for Massachusetts high school graduates; as described in the Data Appendix, we combined the graduate files with supplemental information on non-graduates. NSC data record enrollment spells at participating post-secondary institutions, which account for 94% of Massachusetts undergraduates. Missing schools mostly run small vocational and technical programs.

Different outcomes generate different follow-up horizons, depending on when in a student's schooling career they are collected. We define follow-up horizons based on each applicant cohort's projected senior year of high school.[8] The earliest information available on baseline (pre-application) characteristics is from the school year ending in Spring 2002. The earliest outcome data are therefore contributed by students projected to graduate in Spring 2006. Outcome-specific samples range over projected senior years as follows:

- *MCAS scores:* These results are for students with projected senior years ending in Spring 2006 to Spring 2013; the outcome here is a 10th-grade score on the Massachusetts Comprehensive Assessment System (MCAS) assessment. Some students retake 10th-grade MCAS tests in a later grade, an outcome we also see. MCAS scores are standardized to the state score distribution by grade, year, and subject. MCAS results include an analysis of effects on state-determined competency standards and scholarship awards.

- *AP and SAT scores:* These results are for applicants with projected senior years 2007-2012, including tests taken earlier than senior year. AP and SAT scores are in their original units (AP scores run from 1-5; SAT subject scores run from 200-800).

- *High school graduation:* High school graduation data are for cohorts projected to finish

[8]The projected senior year equals eighth-grade-year plus 4 for applicants to City on a Hill, Codman Academy, and Match (schools where applicants apply for 9th grade entry), 4th-grade-year plus 8 for applicants to Boston Collegiate (where applicants apply for 5th grade entry), and 5th-grade-year grade plus 7 for applicants to Academy of the Pacific Rim and Boston Preparatory (schools where applicants apply for 6th grade entry.)

between 2006 and 2012 (the most recent graduation year covered by state data is 2012). We also see General Educational Development (GED) test-taking and results for GED exams taken between 2006 and 2010.

- *College outcomes:* These are for students with projected senior years 2006-2011 (the most recent cohort for which we have NSC data is the high school class of 2011).

Table 2 compares charter applicants with the full sample of traditional BPS 9th graders in each outcome sample. Applicants tend to have higher baseline test scores than the traditional BPS population, and are more likely to be black. Limited English proficient students are under-represented among charter applicants, but the proportion of applicants identified as qualifying for special education services is almost as high among applicants as in the traditional BPS population.[9]

3 Empirical Framework

We estimate the effects of charter school attendance on high school graduation rates, measures of AP and SAT test-taking and scores, college enrollment and type, and college persistence. As a benchmark, we also report results for 10th-grade MCAS scores, including effects on competency thresholds in Massachusetts and eligibility for the state's Adams Scholarship, which grants public university tuition waivers to public high school students based on a combination of MCAS math and ELA cutoffs.

Our lottery-based empirical strategy is motivated by the observation that charter attendance is a choice variable that may be correlated with motivation, ability, or family background. Conventional regression estimates of the effects of charter attendance may therefore fail to capture causal effects. To eliminate selection bias, our empirical strategy uses randomly assigned charter lottery offers to estimate the effects of attending charter schools. The second-stage equation for our lottery-based

[9]The percentage of BPS categorized as Limited English proficient in the 2011-12 school year across all grades is 30.7%. This number is larger than the 12.0% we see in this sample because of a large-scale reassessment of students required by a 2010 settlement between BPS and the US Department of Justice. See http://www.justice.gov/crt/about/edu/documents/bostonsettle.pdf for details, accessed July 2013.

two-stage least squares (2SLS) analysis links charter school attendance with outcomes as follows:

$$y_i = \sum_j \delta_j d_{ij} + \gamma' X_i + \rho C_i + \epsilon_i, \tag{1}$$

where y_i is the outcome of interest for student i, X_i is a vector including 10th-grade-year dummies and a set of pre-lottery demographic characteristics (race, special education, limited English proficiency, subsidized lunch status, and a female-minority interaction) and ϵ_i is an error term. The d_{ij} are dummy variables for all combinations of charter school lotteries (indexed by j) seen in the lottery sample. In what follows, we refer to these combinations as "risk sets." These are included because the application mix determines the probability of receiving an offer, even when offers at each school are randomly assigned.[10] The variable of interest, C_i, indicates attendance at any of the six charter schools in our lottery sample in 9th or 10th grade. The parameter ρ captures the causal effect of charter school attendance.

We use charter offer variables as instruments. The *initial offer* instrument, Z_{i1}, is a dummy variable indicating offers made on the day of the charter school lottery. Because some applicants who don't receive offers on lottery day do so at a later date when their names are reached on a randomly ordered wait list, we also code a second instrument, denoted *ever offer*, or Z_{i2}. The ever offer instrument indicates applicants who receive an offer at any time, whether on lottery day or later. Applicants who receive an initial offer thus have both instruments switched on, while those who receive later offers without an initial offer have only the ever offer instrument switched on. Missing values for either instrument are coded as no offer. Because the model controls for the pattern of schools and cohorts with lottery data of each type through application risk sets, this convention is innocuous. Appendix Table A1 describes the schools and application cohorts for which we observe ever and initial offers.

The first stage for our 2SLS procedure is:

$$C_i = \sum_j \mu_j d_{ij} + \beta' X_i + \pi_1 Z_{i1} + \pi_2 Z_{i2} + \eta_i, \tag{2}$$

[10] For example, in a world with three charter schools and one entry cohort, there are 7 risk sets: all schools, each school, and any two.

where two separate parameters, π_1 and π_2, capture the effects of initial and eventual offers. As in the second stage equation, the first stage includes risk set controls, 10th-grade-year dummies, and baseline demographic characteristics. With two instruments used to estimate a single causal effect, we can interpret 2SLS estimates as a statistically efficient weighted average of what we would get from an estimation strategy that uses the instruments one at a time. Standard errors are clustered at the 10th-grade-school-by-year level.

Randomly-assigned lottery offers are likely to be independent of student ability or family background (within risk sets). Consistent with presumed random assignment, Columns (3) and (4) of Table 2 show that pre-lottery demographics and test scores are similar for offered and non-offered students. Differences in baseline characteristics by offer status are small and statistically insignificant for all variables tested, and p-values from joint tests are high.

Although random assignment ensures apples-to-apples comparisons among all those who apply, this statistical comparability is threatened by differential attrition between offered and non-offered students. Appendix Table A2 documents an MCAS follow-up rate close to 80 percent. Moreover, Panel B, which reports the effect of lottery offers on the likelihood students contribute an MCAS score to our analysis sample, shows no significant effects of lottery offers on follow-up. Follow-up rates for further downstream outcomes are largely determined by whether a student is seen in a Massachusetts school in 12th grade. Here too, the estimates in Panel B are encouraging, with no systematic difference between offered and non-offered students.

First Stage Estimates and an MCAS Benchmark

An admissions offer in a charter lottery boosts the probability of charter enrollment by 23 percentage points. This can be seen in column (1) of Table 3, which reports ever-offer first stage estimates. Column (2) shows that an initial offer boosts charter enrollment by an *additional* 13 points. The overall first stage is therefore close to 40 percentage points for those who receive an offer on or immediately following lottery day.[11]

The relationship between lottery offers and charter enrollment - the size of the first stage - is

[11] First stage estimates differ slightly across outcomes due to small changes in sample composition.

determined by the likelihood an applicant chooses to accept an offer (some accepted applicants opt for a traditional public school, one of Boston's pilot schools, or an exam school). Similarly, some students who receive no offer in the lotteries for which we have data receive one at a later date. The 2SLS estimates adjust for differences between offers and enrollment on both sides, with the resulting estimates capturing causal effects for those who *comply* with (that is, enroll in a charter school in response to) the offers recorded in our data (Imbens and Angrist, 1994).

As a starting point, Panel A of Table 3 also reports 2SLS estimates similar to those reported in our earlier Boston study for 10th-grade MCAS scores (Abdulkadiroğlu et al., 2011). Column (4), which reports second-stage estimates of the parameter ρ from equation (1), shows that attendance at the charter high schools in our sample boosts 10th-grade ELA scores by 0.4σ, that is, four-tenths of a standard deviation, while raising math scores by more than half of a standard deviation.[12]

The analysis of longer-term outcomes necessarily covers fewer applicant cohorts than are available for an analysis of MCAS scores. As a check on the representativeness of the subsamples used to produce the estimates of effects on later outcomes, we constructed 2SLS estimates of MCAS effects for the subsamples of applicants contributing to our AP/SAT and college-going analyses below. Estimates of effects on 10th-grade MCAS scores in the AP/SAT and college-going samples in Panel B and C of Table 3 are similar to estimates for the full MCAS sample, suggesting that the short-run effects of charter attendance are similar for older and more recent cohorts.

4 College Preparation

4.1 MCAS Thresholds

Charter school attendance has large effects on the likelihood applicants score in the upper two MCAS score categories. Specifically, Table 4 documents large and statistically significant increases in the likelihood charter applicants earn scores at a level deemed Proficient or Advanced. The gains

[12]The estimates reported in our earlier study, Abdulkadiroğlu et al. (2011), are smaller than this because the former are scaled to measure the effect of years of charter attendance, while those reported here show a charter enrollment effect, without adjusting for years attended. We opted for a dummy-endogenous-variable approach because this produces consistent specifications across outcomes, while sidestepping issues related to timing and reverse causality. High school graduation, for example, causes years of charter enrollment as well as vice versa.

here remain substantial whether measured by first attempts or final scores.

Since 2003, high school graduation in Massachusetts has been determined in part by 10th-grade MCAS scores. The initial state competency standard required students to pass the "Needs Improvement" threshold with scaled scores of 220 in both math and ELA; for the graduating class of 2010 and onward, standards were increased to require "Proficient" scores of at least 240 in math, ELA, and science.[13] Consistent with the score gains documented in Table 3, charter attendance appears to boost the likelihood of meeting competency standards, with a gain ranging from 10-18 points in each subject and overall.

Beginning with the high school class of 2005, the state has used the MCAS to determine qualification for public-university tuition waivers, an award known as the Adams Scholarship. Qualification for an Adams Scholarship requires an MCAS score in the "Advanced" category in either ELA or math, a score that is at least "Proficient" in the subject where the Advanced standard isn't met, and a total MCAS score in the upper quartile of the distribution of scores in a scholarship candidate's home school district.[14] Awardees qualify for a tuition waiver at a Massachusetts public college or university.[15] Charter attendance boosts the likelihood of qualifying for an Adams Scholarship by 24 percentage points.

The nature of the charter-induced shift in the distribution of MCAS scores emerges clearly in Figure 1. This figure plots estimated score distributions for lottery compliers, that is, for applicants who take a charter seat when offered one in a lottery, but enroll in a traditional public school otherwise. We plot densities for compliers because, as with our 2SLS estimates, such comparisons are purged of the selection bias that contaminates an unadjusted contrast between those who do and don't enroll in a charter school. Comparisons for compliers therefore have a causal interpretation.

Complier distributions are estimated here by adapting methods introduced by Abadie (2002; 2003). Specifically, for a grid of values, v, in the support of an outcome variable, y_i, we estimate

[13]See http://www.doe.mass.edu/mcas/graduation.html for details. The new rules include an exception for students who pass the needs improvement threshold only and also meet personal goals. We ignore this exception here.

[14]Charter school students can earn a scholarship in either the district of attendance (the charter school) or the district of residence (Boston). The two standards differ due to the requirement for a score in the upper quartile of the district score distribution. The Adams Scholarship cutoff is defined here using BPS thresholds.

[15]Cohodes and Goodman (2013) estimate effects of Adams Scholarships on college enrollment and choice, showing these appear to increase enrollment in public universities in spite of the fact that they cover only a small portion of college costs.

equations of the form:

$$K_h(v - y_i)(1 - C_i) = \sum_j \kappa_{0j}(v)d_{ij} + \gamma_0(v)(1 - C_i) + u_{0iv} \quad (3)$$

$$K_h(v - y_i)C_i = \sum_j \kappa_{1j}(v)d_{ij} + \gamma_1(v)C_i + u_{1iv}, \quad (4)$$

where charter attendance C_i is treated as an endogenous regressor and instrumented with lottery offers. Here $K_h(v) = \frac{1}{h}K(v/h)$ is a kernel function with bandwidth h. The resulting estimates of $\gamma_1(v)$ and $\gamma_0(v)$ describe densities for treated (charter) and untreated (non-charter) compliers.[16]

The x-axis in Figure 1 marks MCAS score category cutoffs; these occur at 20 point intervals. Charter school attendance clearly pushes the first-attempt score distribution into the upper three score groups. The effect of charter attendance on ELA scores is striking: very few non-charter students achieve at an Advanced level, while many charter students are in the Advanced group. Kolmogorov-Smirnov tests of distributional equality suggest that the distributional shifts documented in this figure are very unlikely to be a chance finding.

4.2 SAT Taking and Scores

The SAT is a major milestone for college-bound high school students and, for many, a major hurdle on the path to college. Designed to be challenging for all takers, SAT scores are a special concern for low-income and minority applicants. Gaps in SAT scores by race and socioeconomic status that might be attributable to family background and school quality are further accentuated by the willingness of higher income families to invest heavily in SAT preparation classes (see, e.g., Bowen and Bok (2000)).

Many high schoolers in Boston's traditional public schools take the SAT, and charter attendance does little to change this rate. As can be seen in the first two columns of Table 5, nearly two-thirds of non-charter students in our applicant sample take the SAT, while the estimated effect of charter attendance on SAT taking is a modest 3 points, a gap far from statistical or quantitative

[16] The grid for v covers each percentile of the observed MCAS distribution; the kernel is Epanechnikov, with bandwidth twice the Silverman (1986) rule-of-thumb

significance.[17]

SAT scores are much lower in Boston than in the rest of the state, with fewer than 10% of non-charter applicants scoring above the state median on the composite test, which is the sum of math, verbal, and writing scores (column (5)). Three-quarters of non-charter applicants score in the lowest quartile of the state distribution. Charter attendance increases the share of students scoring above the bottom quartile by 12 percentage points (from 25% to 37%, column (6)).[18] Gains in math contribute most to this boost in composite scores (column (2)); effects on verbal and writing scores are smaller, though the estimated shift of verbal scores out of the bottom quartile is statistically significant (column (4)). Charter attendance also raises by 11 percentage points (from 9% to 20%) the probability that applicants earn an SAT reasoning score (the sum of math and verbal) above the state median, with math again the largest contributor to this gain.

Table 5 also reports SAT effects estimated in samples limited to those who take the test. Because charter attendance has little effect on the decision to take the SAT, such conditional comparisons are unlikely to be biased by compositional shifts. These conditional results show that Boston's charters have large and statistically significant effects on SAT scores, especially in math. Specifically, charter attendance boosts average math scores by 52 points, a gain that amounts to over four-tenths of a standard deviation in the US score distribution.[19] This is almost as large (in standard deviation units) as the MCAS math effect reported in Table 3, suggesting that the gains in math skills demonstrated on the MCAS carry over to the SAT. Although charter attendance has smaller effects on verbal and writing scores, the composite SAT score gain is estimated to be about 100 points, a statistically significant result. The gain here amounts to almost one-third of a standard deviation in the US composite score distribution. The corresponding effect on SAT reasoning is 75 points, also a large gain.

The effect of charter attendance on the SAT score distribution is summarized in Figure 2, which plots the distribution of SAT scores for treated and untreated lottery compliers (estimated as in

[17]Charter applicants are positively selected, as shown by their somewhat higher baseline test scores than the general BPS population. Similarly, the SAT-taking rate among applicants of 0.63 exceeds the SAT-taking rate of 0.49 in the non-charter BPS population (see columns (5) and (6) of Table 2).

[18]In this calculation we assign an SAT score of zero to those who do not take the test.

[19]Means (and standard deviations) of the US SAT distribution in 2012 were 512 (117) in math, 496 (114) in verbal, 488 (114) in writing, 1010 (214) for reasoning and 1498 (316) for the composite.

Figure 1). Charter school attendance causes a pronounced rightward distributional shift in all three SAT subjects, as well as for the composite score. Formal statistical tests of distributional equality suggest these shifts are very unlikely to be a chance finding. On balance, Boston's charter high schools produce substantial gains on the SAT as well as the MCAS.

4.3 AP Taking and Scores

Advanced Placement coursework allows high schoolers to experience the rigor of college-level courses and potentially earn college credit. Five of the six charter schools in our sample offer AP classes, and one school requires that students pass AP exams in order to graduate. As shown in Table 6, charter school attendance increases the probability that a student takes at least one AP exam by 29 percentage points. Consequently, over half of charter students take at least one AP test, compared with about a quarter of the students in traditional public schools.

Charter attendance increases the average number of AP tests that students take by nearly a full exam, a result that can be seen in the second row of the table. At the same time, gains in AP *scores* are more modest. Charter school attendance increases the likelihood of taking a test and earning a score of at least 2 by 15 percentage points, a statistically and quantitatively significant gain. But a score of 3 or better is required to earn college credit, and many colleges and universities require at least a 4. Charter attendance increases the probability of earning a score of 3 by a marginally significant 9.6 percentage points, a large effect relative to the non-charter mean of 7 percent. At the same time, charter attendance generates no significant increase in the likelihood of earning a 4 or 5.[20] Note that by including zeros for non-takers in this analysis of score impact, we avoid bias from possible composition effects due to the large effect of charter attendance on the likelihood applicants take a test.

AP results by subject, reported in columns (3)-(10) of Table 6, show a large increase in the likelihood charter applicants take tests in science, calculus, and history, three of the most common categories of AP exams. Paralleling charters' large effect on MCAS math scores, the clearest

[20]Some colleges, including the University of California, accept a 3 for college credit; however, both UMass-Amherst and UMass-Boston require at least a 4 on the AP Calculus exam for college credit, a threshold that most Boston students do not meet.

AP score gains emerge for calculus. Charter attendance boosts the probability of taking the AP calculus test by 21 percentage points, and increases the likelihood of earning a score of at least 2 by nearly 9 points. The corresponding impact on the likelihood of earning a 3 on AP calculus is 7 percentage points; relative to the non-charter mean of 1.5 percent, this implies that charter attendance more than quintuples the chances a student earns a 3 in calculus, though both the two-plus and three-plus calculus effects are only marginally statistically significant. Charter attendance increases test-taking in science and US history, with no corresponding score effect in these subjects. Charter schools have little effect on AP English test-taking or scores.

4.4 High School Graduation

Does charter attendance also increase high school graduation rates? Perhaps surprisingly given the gains in test score graduation requirements reported in Table 4, the estimates in Table 7 suggest not. In fact, charter attendance reduces the likelihood a student graduates on time by 12.5 percentage points, a statistically significant effect.[21] This negative estimate falls to zero when the outcome is graduation within five years of 9th-grade entry. Interestingly, charter schools appear no more likely to cause students to repeat 9th, 10th, or 11th grade than are traditional public schools. This is apparent from an analysis of effects on the likelihood of starting 10th, 11th, or 12th grade on time. Instead, as can be seen in the repeat 12th grade estimate, it appears that charter students take an additional 12th-grade year to graduate, perhaps due to more rigorous graduation requirements. The subset of students taking an additional year in high school may be substituting the high school year for remediation in community college, which is less expensive for the student.[22]

Some Massachusetts high school graduates earn a GED instead of a traditional diploma. GED completion data are available for tests taken between 2006 and 2010, so our analysis here is limited to students projected to graduate in this time period. Panel B of Table 7 shows the decline in four-year graduation shrinks when GED diplomas are included, though this is mostly due to a smaller estimate of the non-GED graduation effect in the sample with available GED data. At the

[21] On-time graduation dates are determined by counting from the entry grade to grade 12.

[22] High school is less expensive for the student, but Masschusetts community college per-pupil expenditures are around $10,000 per student, compared to about $14,000 in high school.

same time, consistent with the results in Panel A, five-year graduation rates including GEDs are largely unaffected by charter attendance.

5 College Enrollment and Choice

The charter schools in this study focus on college readiness. Nearly half of the applicants in our sample enroll in college immediately, while 60 percent start college within a year of expected graduation. While the estimated effect of charter attendance on college attendance is positive, it is not large enough to generate a statistically significant finding. This can be seen in the first row of Table 8, which reports enrollment rates and charter effects for two subsamples. The first sample includes cohorts for whom we have college attendance data for the fall immediately following their expected high school graduation (the "immediate enrollment" sample). The second, smaller sample includes cohorts we can follow for an additional year (the "immediate or one year later" sample). Columns (2) and (4) report enrollment effects on applicants who can be followed in these two windows. Although substantial, the resulting estimates of 0.063 and 0.115 are not measured precisely enough to rule out a chance finding.

While the estimates of overall enrollment effects are inconclusive, the results in Table 8 show a clear shift from two-year colleges to four-year colleges. Specifically, in the immediate enrollment window, charter attendance decreases two-year attendance by 11 points, while increasing four-year attendance by 17 points. The decline in two-year attendance is just 6 points in the longer window, while the estimated gain in four-year attendance is unchanged. Gains in four-year attendance are large enough to generate highly significant estimates, with confidence intervals well away from zero.

The gains in four-year enrollment documented in Table 8 are driven entirely by increases in attendance at public four-year schools, with no effect on private attendance. The last row of Panel A in Table 8 shows that most of this gain is through enrollment at Massachusetts public colleges. In fact, the Boston campus of the University of Massachusetts is the modal institution for former charter students in our sample. The Adams Scholarship likely contributes to this pattern, though college counseling may also play a role.

In a recent study, Cohodes and Goodman (2013) suggest Adams Scholarship awards tend to reduce the selectivity of colleges chosen by scholarship winners. Panel B of Table 8 reports charter effects on college enrollment by selectivity tier, as defined by the Barron's ranking system. These results show that charter attendance has little effect on the selectivity of schools charter applicants choose to attend. College downgrading does not appear to be an unintended consequence of charter attendance, perhaps because most of Boston's Adams scholarship recipients come from lower-income backgrounds. The Cohodes-Goodman findings are driven by higher-income students who might otherwise have attended private schools.

In addition to college enrollment, we look briefly at college persistence, as measured by the likelihood of enrolling for three or more semesters. The samples available for such an analysis are necessarily smaller than those available to study college enrollment. The persistence results, reported in Table 9, suggest charter attendance increases the fraction of students who attempt at least three academic semesters by about 13 points, a marginally significant effect. The corresponding estimate for the one year later sample is a little smaller, at 11 points, but less precisely estimated. Estimates of effects on 4-plus semester enrollment are too imprecise to be useful.

Taken together, the estimates reported here show that charter high school attendance boosts outcomes both in the short run (standardized test scores) and in the long run (college preparation and choice). We summarize the relationship between short-run and long-run impacts in Figure 3. Specifically, this figure plots MCAS estimates against estimates for longer-run outcomes for each of the within-risk-set experiments in our charter lottery data. Each risk set is represented by a bubble, with bubble sizes inversely proportional to the standard error of the MCAS estimate for that risk set. SAT score gains track MCAS gains closely (Panel A). Likewise, risk sets where score gains are larger also appear to generate larger enrollment effects, though here the relationship between impacts is looser than for the two test scores (Panel B). These findings suggest that the short-run effects of Boston's charter high schools on MCAS scores are a reliable guide to their longer-run effects.

6 Additional Results

6.1 Effects in Subgroups

We next turn to an investigation of effects by subgroup. Results for most outcomes are similar for boys and girls, as can be seen in the estimates reported in columns (1) and (2) of Table 10. Charters reduce the four-year high school graduation rate more for boys than for girls, but the affected boys seem to catch up, as there is no effect on five-year graduation for either gender. Our point estimates of effects on SAT scores and four-year college enrollment are large and positive for both boys and girls, though these gender-specific effects are not precisely estimated. In view of evidence that many educational interventions do not work well for males, this finding seems noteworthy (Anderson, 2008; Legewie and DiPrete, 2012; Angrist et al., 2009; Deming et al., 2013).

MCAS, SAT, and four-year enrollment effects are larger for special-needs students than for other applicants. In fact, SAT gains are roughly twice as large for special education students as they are for other students, a pattern documented in Panel D of Table 10. Moreover, as in the analysis for boys, charter attendance reduces the four-year high school graduation rate considerably in the special education group, but has little effect on the five-year rate.[23] This pattern of results suggests that charters are likely to hold back the most at-risk students for an additional year of instruction.

As in the special-education analysis, columns (5) and (6) suggest that students with baseline scores below the sample median are more likely to gain from charter attendance than are high-scorers.[24] Effects on MCAS scores are somewhat larger for below-median students, while the effect on composite SAT scores is much larger for the lower-scoring group (138 points vs. 77 points). The effect of charter attendance on four-year college enrollment is driven entirely by students whose scores are below median at baseline, and much of the 4-year effect on this group (0.21 out of 0.29 percentage points) comes from an increase in the overall rate of college enrollment rather than a shift from two-year to four-year institutions.

Columns (7) and (8) show a less-consistent pattern by poverty status (as proxied by qualification

[23]There is some overlap between male students and special education students: about 63% of special education students in our sample are boys.

[24]Here we split the sample by whether the sum of baseline math and ELA scores is below the median of this measure in the full MCAS ELA sample.

for a subsidized lunch), with the disadvantaged group gaining more in terms of college enrollment and AP-taking but less on the SAT. At the same time, the estimate for four-year college attendance among subsidized lunch students is striking: charter attendance raises the probability of four-year attendance by 22 percentage points in this group. This finding is notable given recent evidence that qualified poor students often choose not to attend four-year institutions (Bowen et al., 2009; Hoxby and Avery, 2012). Overall, Table 10 suggests that Boston's charter high schools boost key outcomes for most subgroups, with large effects on at-risk groups, including boys, special-education students, and those who enter high school with low achievement.[25]

6.2 The Peer Channel

Charter schools are sometimes said to generate gains by the selective retention of higher performing students (see, for example, Skinner (2009)). In this view, charter effectiveness is at least partly attributed to a tendency to eject trouble-makers and stragglers, leaving a student population that is easier to teach. Importantly, the causal interpretation of our lottery-based estimation strategy is unaffected by selective retention because we follow all winners and losers, regardless of whether they stay in charter. Moreover, the charter enrollment variable is "switched on" even for students who spend only a single day enrolled in a charter school. Thus, outcomes for poor-performing charter students who leave the school still count on the charter side of our IV estimation strategy.

At the same time, selective retention, if substantial, may lead to a favorable population mix that generates positive peer effects on students who remain enrolled in charters. In other words, charter schools may do well for most of their students in part because a few bad apples who would otherwise be disruptive to all, or slow down the class, are encouraged to leave. While not invalidating the evidence of gains reported here, this peer channel has different policy implications than other explanations for charter effectiveness, such as differences in teacher quality or training.

We explore the peer channel by looking directly at school switching and how this affects peer composition. School switching is defined as being observed in two or more schools after a lottery

[25] In addition to looking at heterogeneity in effects across subgroups of students, we also examined heterogeneity across charter schools. Specifically, we asked whether our results are driven by any one charter school. Appendix Table A3 reports estimates for our key outcomes in samples that drop data for our six sample schools one-at-a-time. The results are similar across samples, suggesting that our findings are not due to the performance of any one charter.

application. As shown in column (1) of Table 11, Boston's charter lottery applicants are highly mobile: more than one-third of the sample changes schools by this measure. Column (2), which reports 2SLS estimates of effects on school switching, shows that charter enrollment raises the likelihood of a switch by about 12 percentage points, though this change is not significantly different from zero. The switching effect increases to 15 percentage points, a marginally significant finding, when switching is defined to omit natural transitional grades such as from fifth to sixth (some charters have unusual grade structures, a fact that might alter transition rates).

Might this evidence of differential switching account for the charter school gains reported here? Panel B assesses the explanatory power of the peer channel by showing the effects of charter enrollment on peer quality throughout high school. Here, peer quality is defined as the average baseline test score of the students with whom a lottery applicant attends school. Not surprisingly, given the positive selection of charter applicants, charter enrollment is associated with increases in peer achievement in the first post-lottery year: the (marginally significant) effect here is roughly 0.13σ in each subject. This composition effect would be even larger if not for the fact, documented in the last row of Panel A, that charter enrollment reduces exam school enrollment. In other words, the counterfactual for some charter students is an exam school, which also enrolls positively selected peers.

Panel B also shows, however, that the positive effect of charter attendance on peer quality *falls* through high school: the coefficients shrink as students progress through school and are not significantly different from zero after the first year. The pattern of peer composition effects is driven, in part, by increasing peer quality in the schools attended by those who lose charter lotteries. This is documented in Figure 4, which plots the profile of mean peer quality for charter lottery compliers, separately by treatment status. Mean peer quality for compliers is estimated using methods similar to those used to construct the densities in figures 1 and 2.[26] Figure 4 documents a large initial gap in favor of lottery winners. This gaps closes with time, as peer quality rises more sharply for compliers who lose the lottery. This pattern is likely driven by high dropout rates at traditional public schools among students with the lowest baseline scores. These results suggest that the

[26]Specifically, we estimate versions of equations (3) and (4) that put the level of peer composition on the left hand side, without kernel weighting.

paper's results cannot be attributed to low-quality peers leaving charter schools. If anything, such a dynamic is more pronounced at Boston's traditional public schools. [27]

7 Conclusion

Studies of many educational interventions show promising short-run gains followed by discouragingly fast fadeout. This paper uses randomized admission lotteries to ask whether the substantial short-run test score effects of Boston's charter high schools translate into gains on longer-run outcomes like SAT scores, Advanced Placement test-taking and scores, college attendance, and college choice. Our estimates suggest that the effects of Boston's charters are remarkably persistent. Specifically, charter attendance raises the probability that students pass the score thresholds for high-stakes exams required for high-school graduation, boosts the likelihood that students qualify for an exam-based college scholarship, increases SAT scores, increases the frequency of AP test-taking with modest gains in scores, and shifts students away from attending two-year institutions and towards four-year attendance. The effect of charter attendance on the probability of attending a four-year public institution in Massachusetts is particularly large. Moreover, these schools seems to be highly effective for subgroups that are often difficult to serve, including boys, special education students, and students with low achievement at high school entry.

In view of often-voiced concerns about the effect of charter schools on student attrition, we explore a possible explanation for these gains in the form of school switching and peer effects. Charter attendance increases school switching outside of transitional grades, but this does not accentuate the effect of charter enrollment on peer composition. If anything, charter peers become more like peers at traditional public schools as students progress through high school. As a result, it seems unlikely that changes in peer composition are the primary driver of our findings.

These results suggest that the short-run test score impacts reported in our previous work on

[27] We also explored the importance of the peer channel by estimating 2SLS models where the endogenous variable is peer quality. The results of this analysis are reported in Web Appendix Table B3. These models imply that, in order for peers to account for the estimated effect of charters, a 1σ increase in initial peer quality must improve a student's test score by between 2.5 and 2.8σ. This peer multiplier is implausibly large relative to peer effects estimated elsewhere, including Hoxby (2000) ($0.3\text{-}0.5\sigma$), Hanushek et al. (2003) ($0.15\text{-}0.24\sigma$), and other studies summarized in Sacerdote (2011)'s recent survey.

Boston's charter schools are not driven by gaming or teaching to the test; rather, they seem to represent increases in underlying human capital, with effects that generalize to a number of other contexts. The cohorts of lottery applicants in our sample are too young to generate reliable estimates of effects on college persistence or graduation. In future work, we plan to investigate the effects of Boston's charter schools on these outcomes, as well as longer-run labor market outcomes like employment and earnings.

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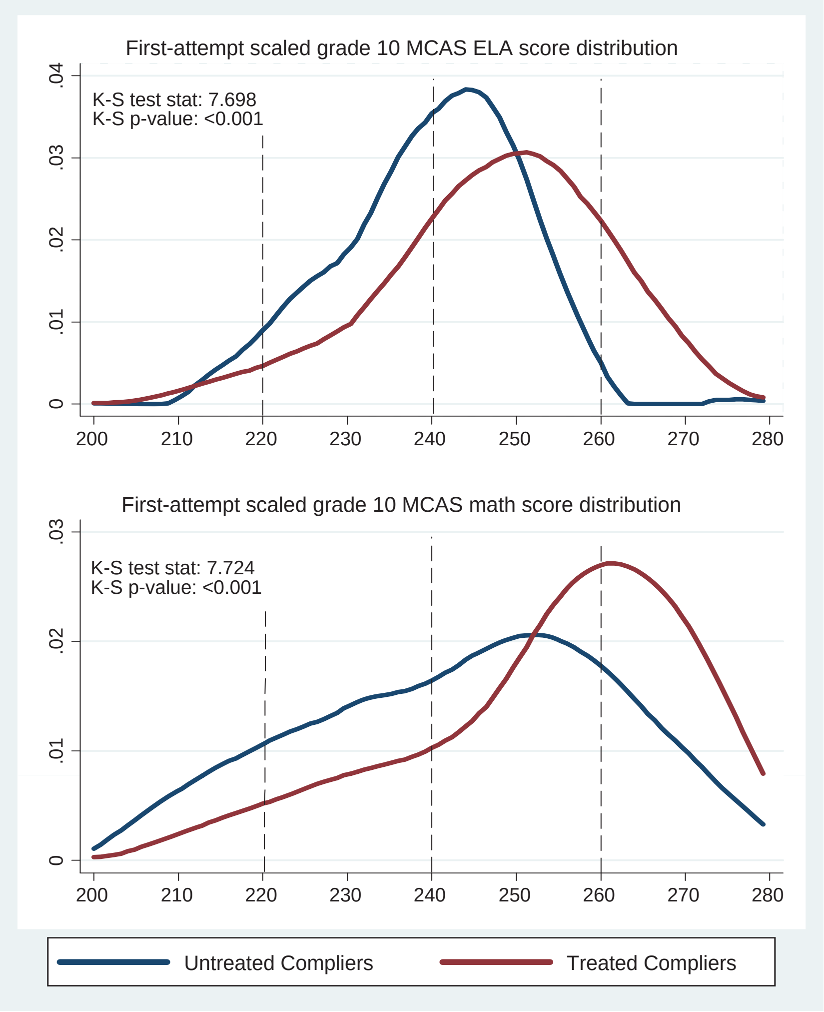
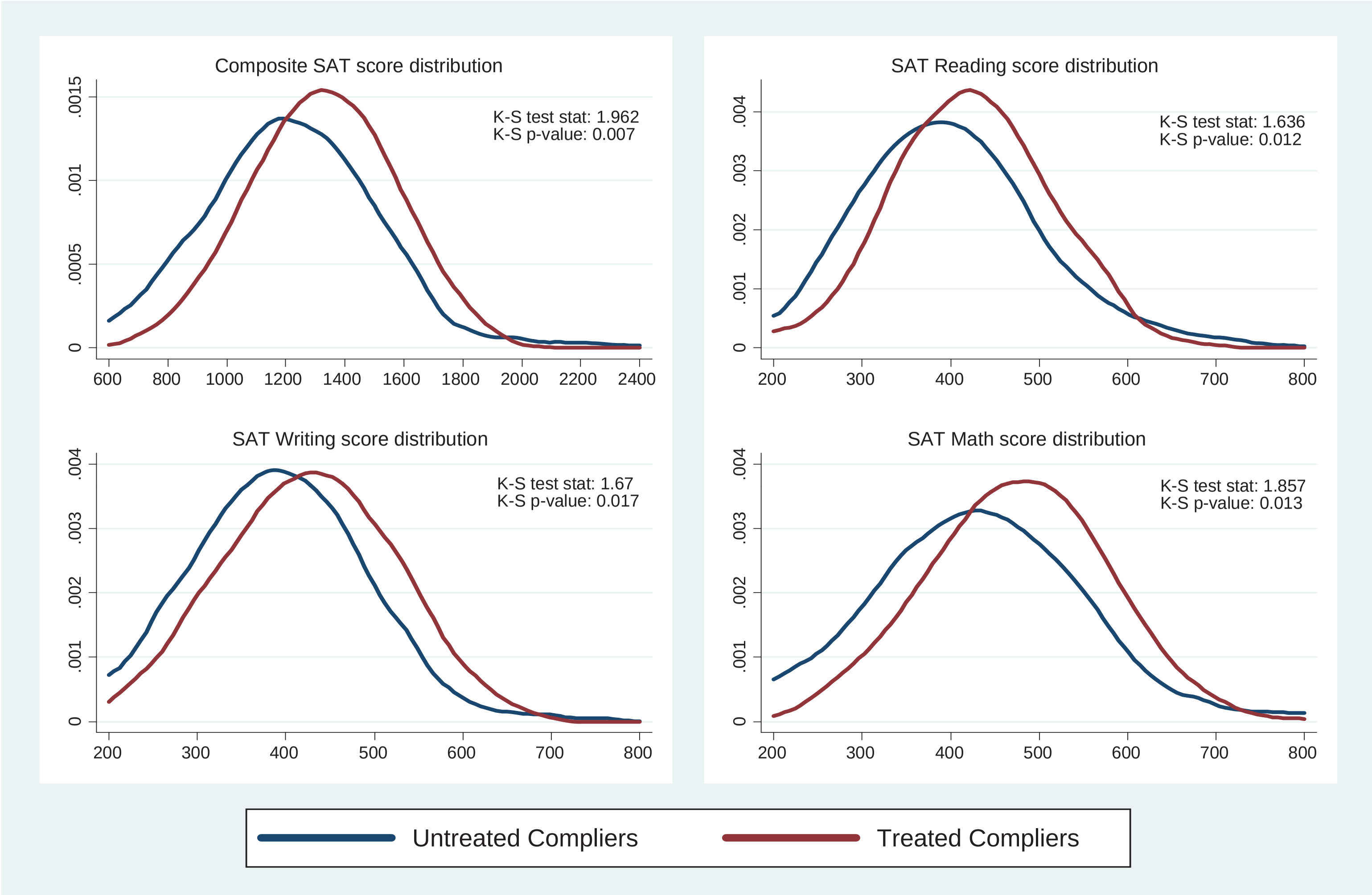
Figure 1: Complier Distributions for MCAS Scaled Scores



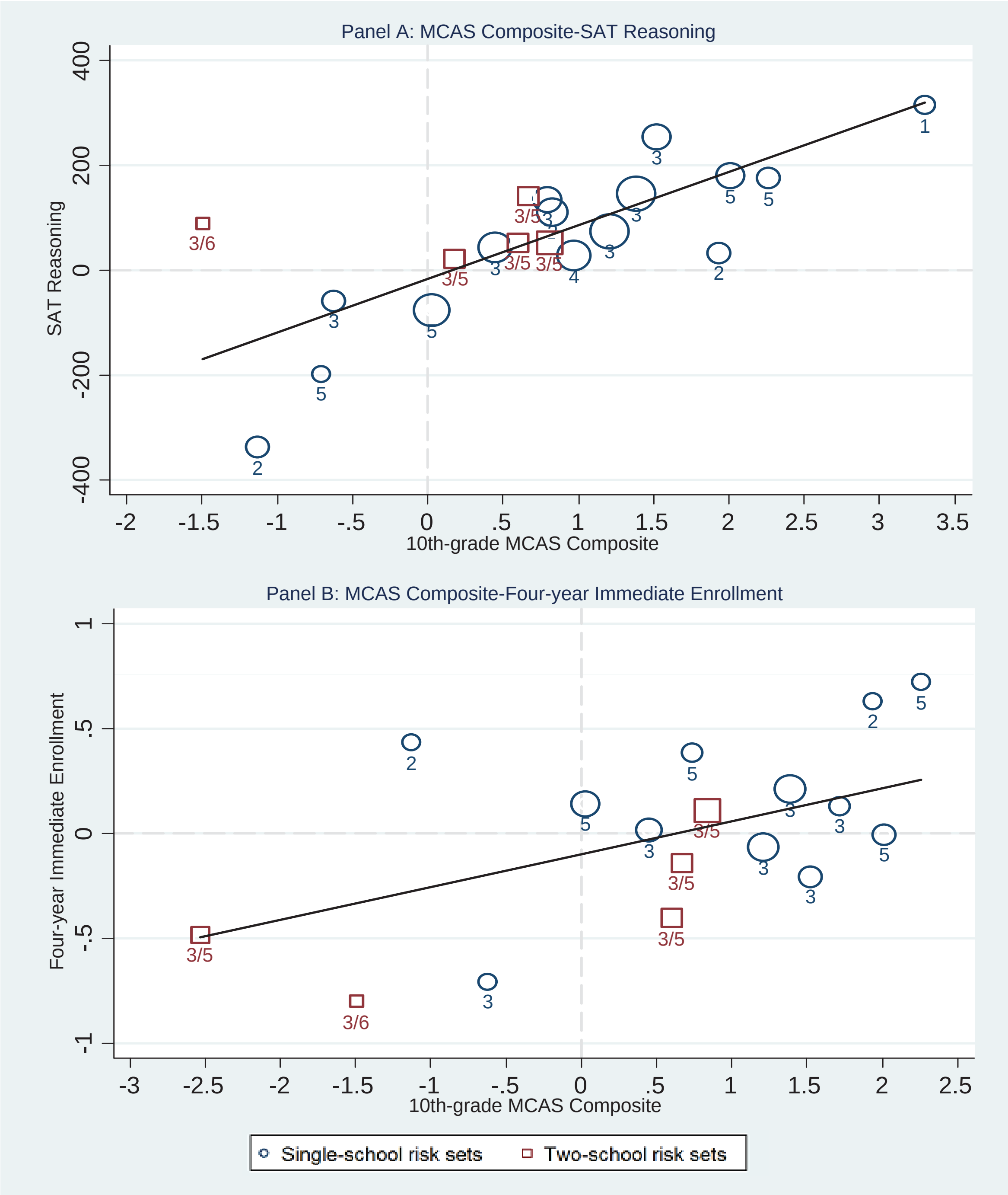
Notes: This figure plots smoothed MCAS scaled score distributions for treated and untreated charter lottery compliers. The sample is restricted to lottery applicants who are projected to graduate between 2006 and 2013, assuming normal academic progress from baseline. Dotted vertical lines indicate MCAS performance category thresholds (220 for Needs Improvement, 240 for Proficient, and 260 for Advanced). Densities are estimated using an Epanechnikov kernel function with a bandwidth equal to twice the Silverman (1986) rule-of-thumb. Kolmogorov-Smirnov statistics and p-values are from bootstrap tests of distributional equality for treated and untreated compliers.

Figure 2: Complier Distributions for SAT Scores



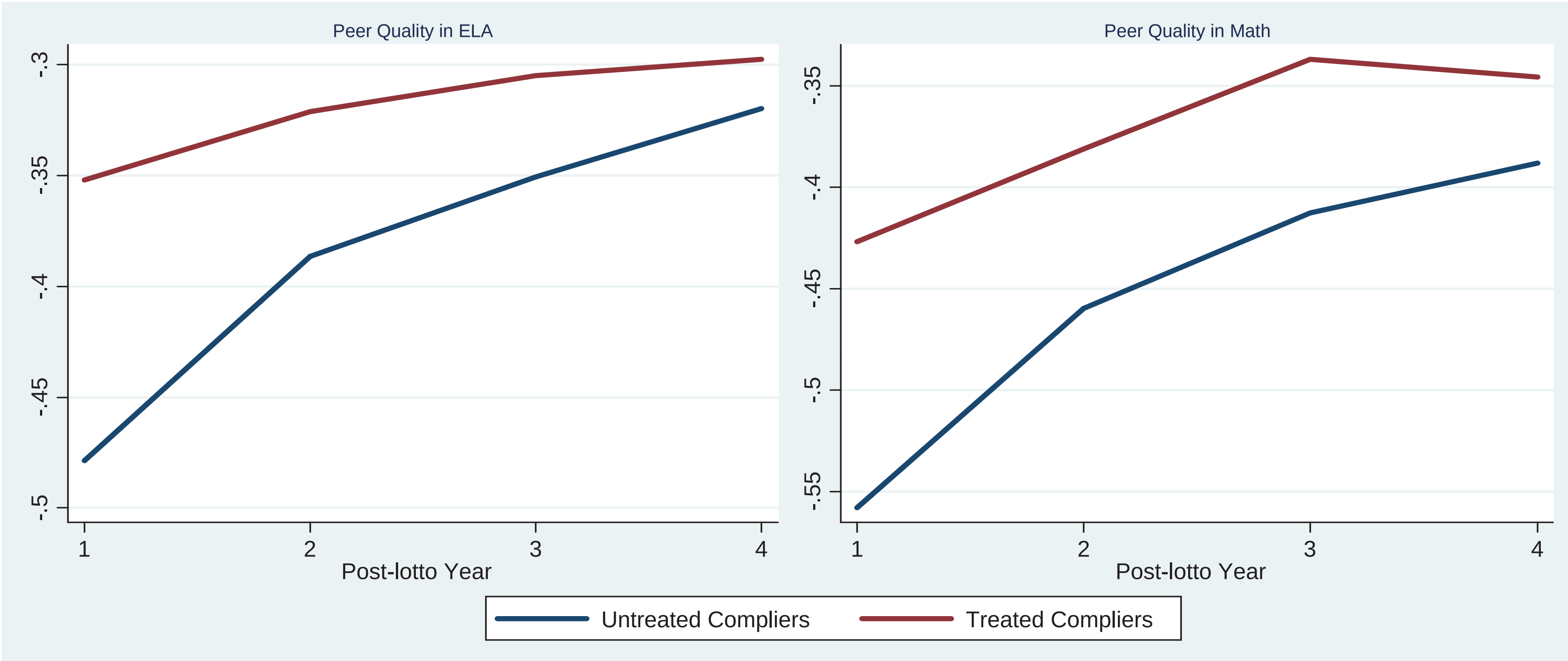
Notes: This figure plots smoothed SAT score distributions for treated and untreated charter lottery compliers. The sample is restricted to lottery applicants who are projected to graduate between 2007 and 2012, assuming normal academic progress from baseline. Densities are estimated using an Epanechnikov kernel function with a bandwidth equal to twice the Silverman (1986) rule-of-thumb. Kolmogorov-Smirnov statistics and p-values are from bootstrap tests of distributional equality for treated and untreated compliers.

Figure 3: Lottery Estimates of Effects within Risk Sets



Notes: This figure plots within-risk-set lottery estimates of the effects of charter school attendance. Panel A plots effects on SAT Reasoning (Verbal + Math) against effects on MCAS Composite scores. Panel B plots effects on the probability of immediate enrollment in a four-year college against effects on MCAS Composite scores. The sample in Panel A includes students projected to graduate between 2007 through 2012 while the sample in Panel B includes students projected to graduate between 2006 through 2011. Data points are labeled by school number, with schools numbered in decreasing order of their MCAS math effects. Blue circles indicate risk sets in which students applied to one school, while red squares indicate risk sets in which students applied to two. Marker sizes are proportional to the inverse of the standard errors of the estimates on the x-axis. Estimates for a given risk set use the instrument (ever or initial offer) with the larger first-stage t-statistic. The sample excludes risk sets with first-stage t-statistics less than one; this restriction would remove all data for one school, so the largest risk set for that school is retained.

Figure 4: Peer Quality For Charter Lottery Compliers



Notes: This figure plots mean peer quality in the first, second, third and fourth years after the lottery for treated and untreated charter lottery compliers. The sample is restricted to lottery applicants who are projected to graduate between 2006 and 2012. Peer quality is measured as the average baseline score for other students in the same school and year.

Table 1: Boston School Characteristics

	Public High Schools	Charters Serving Grade 9-12	Charters Serving Grade 9-12 Only	Charters in the Study
	Mean	Mean	Mean	Mean
	(1)	(2)	(3)	(4)
Panel A: Charter School Characteristics				
Number of years open	-	14	15	14
Days per year	180	190	189	191
Average minutes per day	389	478	477	489
Have Saturday school	-	0.71	0.75	0.83
Avg. math instructions (min)	-	92.0	83.5	97.3
Avg. reading instruction (min)	-	92.0	89.8	97.3
No Excuses	-	0.71	0.75	0.83
Panel B: Comparison with Traditional Boston Public Schools				
Number of teachers	45	27	19	28
Student/teacher ratio	14.6	13.0	13.6	13.3
Proportion of teachers licensed in teaching assignment	0.97	0.63	0.71	0.58
Proportion of teachers 32 and younger	0.28	0.71	0.71	0.76
Proportion of teachers 49 and older	0.35	0.09	0.10	0.05
Proportion of core classes taught by highly qualified teachers	0.93	0.97	0.98	0.97
Avg. per-pupil expenditure	$12,573	$13,694	$15,581*	$13,499
Title I eligible	1	1	1	1
N (schools)	21	7	4	6

Notes: This table reports characteristics of Boston charter schools and Boston public schools operating in academic calendar year 2012-13. Charter school characteristics are obtained from a survey of school administrators. Panel B compares Boston charter high schools to Boston public high schools. Data on public schools are from http:\\www.doe.mass.edu. Boston public high schools (column 1) include Another Course to College, Boston Arts Academy, Boston Community Leadership Academy, Boston Latin Academy, Boston Latin School, Brighton High, Boston International High, Burke High, Charlestown High, Community Academy of Science and Health, Dorchester Academy, East Boston High, The English High, Excel High, Fenway High, Greater Egleston High, New Mission High, O'Bryant School of Math and Science, Quincy Upper, Snowden International High, and Urban Science Academy. Data for West Roxbury Academy and TechBoston Aacdemy are missing. Boston charters serving grade 9-12 (column 2) include Academy of the Pacific Rim, Boston Preparatory, City on a Hill, Codman Academy, Boston Collegiate High, Health Careers Academy, and Match. Boston charter high schools serving grade 9-12 only (column 3) are City on a Hill, Codman Academy, Match, Health Careers Academy. Charters in this study (column 4) include Academy of the Pacific Rim, Boston Preparatory, City on a Hill, Codman Academy, Boston Collegiate High, and Match. Statistics are based on data from the 2010-2011 school year. Average per pupil expenditures data is weighted by school enrollment and includes administration, instructional leadership, classroom and specialist teachers, other teaching services, professional development, instructional materials, equipment, and technology, guidance counseling and testing, pupil services, operations and management, and insurance and retirement programs. This statistic for the Boston Public Schools includes spending for all grade levels. The Boston Public Schools Expenditure statistic comes from MA DOE District Profiles Finance Table “Total Expenditure Per Pupil, All Funds, By Function.” The charter school finance data comes from MA DOE “FY2011 Charter School End of Year Financial Report Summary.” *This calculation excludes one of the 9-12 schools because we only have expenditure data for this school's middle and high school combined.

Table 2: Descriptive Statistics

	Projected Senior Year							
	2006-13 (MCAS outcome sample)				2007-12 (AP/SAT outcome sample)		2006-11 (NSC outcome sample)	
	BPS 9th Graders	Lottery Applicants			BPS 9th Graders	Lottery Applicants	BPS 9th Graders	Lottery Applicants
	Mean	Mean	Ever Offer	Initial Offer	Mean	Mean	Mean	Mean
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Female	0.496	0.542	0.007	0.025	0.497	0.536	0.499	0.542
			(0.021)	(0.019)				
Black	0.421	0.614	-0.007	0.004	0.419	0.606	0.436	0.624
			(0.021)	(0.018)				
Hispanic	0.308	0.248	0.000	0.000	0.310	0.263	0.300	0.252
			(0.018)	(0.016)				
Asian	0.101	0.034	0.000	-0.004	0.100	0.033	0.099	0.035
			(0.008)	(0.006)				
Subsidized Lunch	0.743	0.728	0.020	0.015	0.749	0.738	0.744	0.738
			(0.019)	(0.017)				
Special Education	0.205	0.180	-0.005	0.009	0.199	0.180	0.201	0.175
			(0.017)	(0.015)				
Limited English Proficiency	0.120	0.035	0.003	0.002	0.112	0.037	0.118	0.033
			(0.008)	(0.007)				
Baseline MCAS ELA	-0.489	-0.292	-0.008	-0.036	-0.473	-0.339	-0.450	-0.295
			(0.037)	(0.034)				
Baseline MCAS Math	-0.427	-0.306	0.011	-0.021	-0.411	-0.329	-0.406	-0.334
			(0.038)	(0.034)				
P-Value	-		0.947	0.902	-		-	
Took any AP	-		-		0.267	0.312	-	
Took SAT	-		-		0.493	0.642	-	
On-time College Enrollment	-		-		-		0.367	0.479
Charter Attendance		0.297				0.280		0.275
Ever Offer		0.654				0.639		0.618
Initial Offer		0.314				0.310		0.296
N	29857		3671		22467	2957	19674	2599

Notes: This table shows descriptive statistics for charter lottery applicants and Boston Public School (BPS) students. Column (1) shows means for BPS attendees projected to graduate between 2006 and 2013, assuming normal academic progress from 8th grade. Column (2) shows means for charter applicants in the same projected graduation year range. Columns (5) and (6) show means for the AP/SAT sample (projected graduation dates 2007-2012). Columns (7) and (8) show means for the NSC (National Student Clearinghouse) sample (projected graduation dates 2006-2011). Columns (3) and (4) report coefficients from regressions of observed characteristics on ever and initial lottery offers, controlling for risk set indicators. The sample for these regressions is restricted to charter lottery applicants with follow-up MCAS ELA scores. P-values are from tests of the hypothesis that all coefficients are zero. Baseline grade is defined as 4th grade for Boston Collegiate applicants, 5th grade for Boston Preparatory and Academy of the Pacific Rim, and 8th grade for Match, Codman Academy and City on a Hill. Baseline grade for BPS 9th graders is 8th grade. On-time college enrollment is indicates enrollment by the semester after projected high school graduation, assuming normal academic progress from baseline.

*significant at 10%; **significant at 5%; ***significant at 1%

Table 3: Lottery Estimates of Effects on 10th-Grade MCAS Scores by Projected Senior Year

	First Stage		Outcome Mean	
	Ever Offer	Initial Offer	[s.d.]	Effect
Subject	(1)	(2)	(3)	(4)
Panel A: 2006-2013 (MCAS outcome sample)				
Standardized ELA	0.228***	0.134***	-0.285	0.411***
	(0.041)	(0.026)	[0.833]	(0.104)
N	3671			
Standardized Math	0.229***	0.134***	-0.231	0.569***
	(0.041)	(0.026)	[0.911]	(0.120)
N	3615			
Panel B: 2007-2012 (AP/SAT outcome sample)				
Standardized ELA	0.230***	0.123***	-0.298	0.345***
	(0.050)	(0.031)	[0.841]	(0.130)
N	2776			
Standardized Math	0.232***	0.122***	-0.234	0.477***
	(0.050)	(0.031)	[0.893]	(0.156)
N	2732			
Panel C: 2006-2011 (NSC outcome sample)				
Standardized ELA	0.239***	0.118***	-0.289	0.303**
	(0.054)	(0.036)	[0.833]	(0.139)
N	2438			
Standardized Math	0.242***	0.118***	-0.238	0.543***
	(0.054)	(0.036)	[0.894]	(0.154)
N	2399			

Notes: This table reports 2SLS estimates of the effects of Boston charter attendance on 10th-grade MCAS test scores. The sample for each panel includes students projected to graduate in the year range specified in the panel title. The endogenous variable is an indicator for charter attendance in 9th or 10th grade. The instruments are ever offer and initial offer dummies. Initial offer is equal to one when a student is offered a seat in any charter school immediately following the lottery, while ever offer is equal to one for students offered seats at any time. All models control for risk sets, 10th grade calendar year dummies, race, sex, special education, limited English proficiency, subsidized lunch status, and a female by minority dummy. Standard errors are clustered at the school-year level in 10th grade. Means and standard deviations in column (3) are for non-charter students.
*significant at 10%; **significant at 5%; ***significant at 1%

Table 4: Lottery Estimates of Effects on MCAS Performance Categories

	First Attempt		Ever	
	Mean	Effect	Mean	Effect
	(1)	(2)	(3)	(4)
Panel A: MCAS ELA				
Needs Improvement or Higher	0.964	-0.016	0.990	-0.014
		(0.023)		(0.011)
Proficient or Higher	0.659	0.170***	0.661	0.167***
		(0.061)		(0.061)
Advanced or Higher	0.091	0.187***	0.091	0.190***
		(0.036)		(0.036)
Meets Competency Determination	0.810	0.165***	0.828	0.151***
		(0.053)		(0.052)
N				3671
Panel B: MCAS Math				
Needs Improvement or Higher	0.914	0.082**	0.977	0.031**
		(0.033)		(0.015)
Proficient or Higher	0.642	0.172***	0.645	0.148**
		(0.065)		(0.065)
Advanced or Higher	0.319	0.267***	0.319	0.267***
		(0.061)		(0.061)
Meets Competency Determination	0.757	0.133**	0.799	0.101*
		(0.058)		(0.056)
N				3615
Panel C: ELA and Math Combined				
Needs Improvement or Higher	0.903	0.080**	0.975	0.019
		(0.035)		(0.016)
Proficient or Higher	0.542	0.173**	0.544	0.166**
		(0.071)		(0.073)
Advanced or Higher	0.075	0.161***	0.075	0.165***
		(0.035)		(0.035)
Meets Competency Determination	0.694	0.177***	0.741	0.144**
		(0.066)		(0.066)
Eligible for Adams Scholarship	0.199	0.242***		
Using BPS Cutoffs		(0.059)		
N				3594

Notes: This table reports 2SLS estimates of the effects of Boston charter attendance on 10th-grade MCAS performance categories and eligibility for the Adams Scholarship. The Competency Determination requires scaled scores of 220 in both ELA and math for the classes of 2006-2009, and scores of 240 in both subjects for the classes of 2010-2013. A student is eligible for the Adams Scholarship if he or she is proficient in both subjects, advanced in at least one subject, and scores among the top 25% of the Boston district on his or her first attempt. BPS cutoffs for projected graduation cohorts 2012 and 2013 are imputed with the 2011 cutoff. A student "needs improvement" if he or she scores at or above 220 on both tests; "is proficient" if he or she scores at or above 240 on both tests; and "is advanced" if he or she scores at or above 260 on both tests. See Table 3 notes for detailed regression specifications. Means are for non-charter attendees.

*significant at 10%; **significant at 5%; ***significant at 1%

Table 5: Lottery Estimates of Effects on SAT Test-taking and Scores

	Taking		Reasoning (1600)		Composite (2400)	
	Mean [s.d.]	Effect	Mean [s.d.]	Effect	Mean [s.d.]	Effect
	(1)	(2)	(3)	(4)	(5)	(6)
Took SAT	0.634	0.033				
	[0.482]	(0.078)				
Score Above MA Bottom Quartile	-		0.253	0.135**	0.253	0.116*
			[0.435]	(0.066)	[0.435]	(0.067)
Score Above MA Median	-		0.092	0.113**	0.082	0.100**
			[0.289]	(0.049)	[0.275]	(0.040)
Score In MA Top Quartile	-		0.026	0.000	0.019	-0.009
			[0.160]	(0.016)	[0.137]	(0.017)
N						2957
Average Score (For takers)	-		846.4	75.2***	1254.3	102.8**
			[166.6]	(29.1)	[240.1]	(42.9)
N						1897

	Math (800)		Verbal (800)		Writing (800)	
	Mean [s.d.]	Effect	Mean [s.d.]	Effect	Mean [s.d.]	Effect
	(1)	(2)	(3)	(4)	(5)	(6)
Score Above MA Bottom Quartile	0.299	0.165**	0.263	0.121**	0.278	0.107
	[0.458]	(0.080)	[0.440]	(0.061)	[0.448]	(0.067)
Score Above MA Median	0.116	0.144**	0.102	0.064	0.096	0.054
	[0.320]	(0.057)	[0.303]	(0.046)	[0.294]	(0.041)
Score In MA Top Quartile	0.032	0.047*	0.025	-0.019	0.022	0.010
	[0.177]	(0.028)	[0.157]	(0.021)	[0.147]	(0.021)
N						2957
Average Score (For takers)	434.1	51.7***	412.3	23.5	407.9	27.5*
	[95.5]	(16.9)	[87.4]	(15.7)	[86.7]	(16.2)
N						1897

Notes: This table reports 2SLS estimates of the effects of Boston charter attendance on SAT test-taking and scores. The sample includes students projected to graduate between 2007 and 2012. SAT outcomes are coded using the last test taken by each student. The average score outcomes restrict the sample to SAT takers. All other outcomes are equal to zero for non-SAT takers. Maximum possible scores are shown in parenthesis next to outcome labels. See Table 3 notes for detailed regression specifications. Means are for non-charter attendees.

*significant at 10%; **significant at 5%; ***significant at 1%

Table 6: Lottery Estimates of Effects on Advanced Placement Test-taking and Scores

	All AP Exams		Science		Calculus		US History		English	
	Mean	Effect	Mean	Effect	Mean	Effect	Mean	Effect	Mean	Effect
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Took Exam	0.266	0.287***	0.099	0.324***	0.062	0.212***	0.034	0.178*	0.147	0.076
		(0.073)		(0.061)		(0.070)		(0.093)		(0.078)
Number of Exams	0.512	0.963***	0.112	0.314***						
		(0.274)		(0.070)						
Score 2 or Higher	0.136	0.154**	0.028	0.044	0.018	0.087*	0.023	0.056	0.087	0.070
		(0.068)		(0.032)		(0.045)		(0.048)		(0.054)
Score 3 or Higher	0.070	0.096*	0.016	0.020	0.015	0.073*	0.014	0.028	0.023	0.034
		(0.052)		(0.015)		(0.040)		(0.019)		(0.027)
Score 4 or 5	0.039	0.008	0.009	-0.001	0.008	0.021	0.007	-0.010	0.009	0.003
		(0.033)		(0.012)		(0.019)		(0.011)		(0.012)
N										2957

Notes: This table reports 2SLS estimates of the effects of Boston charter attendance on AP test-taking and scores. The sample includes students projected to graduate between 2007 and 2012. Outcomes are equal to zero for students who never took AP exams. Science subjects include Biology, Chemistry, Physics B, Physics Mechanics, Physics Electricity/Magnetism, Computer Science A, Computer Science AB, and Environmental Science. Outcomes for Calculus combine Calculus AB and Calculus BC. Outcomes for English combine English Literature and English Language. See Table 3 notes for detailed regression specifications. Means are for non-charter attendees.

*significant at 10%; **significant at 5%; ***significant at 1%

Table 7: Lottery Estimates of Effects on High School Graduation and Grade Repetition

				Excl. Transferred and Deceased	
		Mean	Effect	Mean	Effect
		(1)	(2)	(3)	(4)
		Panel A: Grade Progression			
Start 10th Grade On-time		0.896	-0.020	0.901	-0.004
			(0.027)		(0.027)
Start 11th On-time		0.813	-0.033	0.837	-0.005
			(0.049)		(0.047)
Start 12th On-time		0.780	0.002	0.820	0.010
			(0.057)		(0.055)
	N		3205		3030
Repeat 12th		0.076	0.144***	0.075	0.153***
			(0.048)		(0.052)
	N		2599		2424
Four-year Graduation		0.688	-0.125**	0.728	-0.119*
			(0.063)		(0.063)
	N		3205		3030
Five-year Graduation		0.785	0.000	0.839	0.042
			(0.065)		(0.060)
	N		2599		2424
		Panel B: Graduation and GED			
Four-year Graduation		0.693	-0.059	0.734	0.013
			(0.083)		(0.113)
	N		1887		1305
Four-year Graduation or GED		0.709	-0.039	0.748	-0.014
			(0.081)		(0.112)
	N		1884		1302
Five-year Graduation		0.789	0.072	0.847	0.149
			(0.099)		(0.097)
	N		1382		1282
Five-year Graduation or GED		0.825	0.019	0.875	0.069
			(0.094)		(0.086)
	N		1379		1279

Notes: This table reports 2SLS estimates of the effects of Boston charter attendance on high school graduation and on-time grade progression. On-time grade progression (graduation) outcomes are equal to one if a student is observed in the relevant grade (graduates) by her projected year, assuming normal academic progress from baseline. The on-time outcome sample includes students projected to graduate between 2006 and 2012. Five-year graduation is equal to one if a student graduates by the year following her projected graduation year. Repeat 12th is one if a student repeats 12th grade for at least one academic year. The sample for repeat 12th and five-year graduation includes students projected to graduate by Spring 2011. Panel B shows effects on high school graduation and GED in the sample where GED outcomes are available (projected graduation dates 2006-2010). Four-year graduation or obtaining GED credential is equal to one if a student graduates or obtains GED credential before or in the spring of her projected graduation year. The sample includes students projected to graduate between 2006 and 2010. Columns (3) and (4) remove transferred or deceased applicants to match Massachusetts' official graduation rate definitions. See Table 3 notes for detailed regression specifications. Means are for non-charter attendees.

*significant at 10%; **significant at 5%; ***significant at 1%

Table 8: Lottery Estimates of Effects on College Enrollment

	Immediate Enrollment		Immediate or One-year-later Enrollment	
	Mean	Effect	Mean	Effect
	(1)	(2)	(3)	(4)
Panel A: Any NSC-Covered School				
Any	0.484	0.063	0.601	0.115
		(0.072)		(0.084)
Two-year	0.121	-0.106**	0.183	-0.058
		(0.051)		(0.064)
Four-year	0.363	0.170**	0.418	0.173**
		(0.070)		(0.079)
Four-year Public	0.135	0.154***	0.145	0.195***
		(0.059)		(0.070)
Four-year Private	0.228	0.016	0.273	-0.022
		(0.076)		(0.094)
Four-year Public In MA	0.116	0.116**	0.121	0.146**
		(0.054)		(0.063)
Panel B: Barron's-Ranked Schools				
Lowest Selectivity Tier Only	0.195	-0.025	0.284	0.032
		(0.056)		(0.071)
Second Lowest Selectivity Tier Only	0.197	0.076	0.206	0.067
		(0.062)		(0.068)
Top Three Selectivity Tiers	0.092	0.012	0.111	0.016
		(0.056)		(0.055)
N		2599		1887

Notes: This table reports 2SLS estimates of the effects of Boston charter school attendance on college enrollment. Immediate enrollment (columns 1 and 2) is defined as enrollment by the semester following a student's projected high school graduation, while immediate or one-year-later enrollment (columns 3 and 4) is defined as enrollment within two fall semesters after projected graduation. The immediate enrollment sample includes students projected to graduate in 2011 or earlier. The one-year-later sample is restricted to students projected to graduate in 2010 or earlier. See Table 3 notes for detailed regression specifications. Means are for non-charter attendees.

*significant at 10%; **significant at 5%; ***significant at 1%

Table 9: Lottery Estimates of Effects on College Persistence

	Any		Two-year		Four-year	
	Mean	Effect	Mean	Effect	Mean	Effect
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Immediate Enrollment						
One academic semester	0.484	0.063	0.121	-0.106**	0.363	0.170**
		(0.072)		(0.051)		(0.070)
N						2599
Three academic semesters	0.358	0.118	0.064	-0.015	0.294	0.133*
		(0.080)		(0.035)		(0.072)
N						1887
Panel B: Immediate or One-year-later Enrollment						
One academic semester	0.601	0.115	0.183	-0.058	0.418	0.173**
		(0.084)		(0.064)		(0.079)
N						1887
Three academic semesters	0.462	0.018	0.128	-0.095	0.334	0.113
		(0.117)		(0.073)		(0.119)
N						1382

Notes: This table reports 2SLS estimates of effects of Boston charter attendance on college persistence. Panel A shows estimates of effects on the probability of attempting one or three academic semesters on-time, that is, in the minimum possible time given a student's projected high school graduation date. Panel B shows corresponding estimates that allow one additional year to elapse before measurement of the outcome. See Table 3 notes for detailed regression specifications. Means are for non-charter attendees.
*significant at 10%; **significant at 5%; ***significant at 1%

Table 10: Lottery Estimates of Effects by Subgroup

		Gender		Special Education		Baseline Scores		Subsidized Lunch	
		Boy	Girl	Yes	No	Below Median	Above Median	Yes	No
Outcomes		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: 10th- Grade MCAS									
Standardized ELA		0.446***	0.372***	0.529*	0.379***	0.423***	0.358***	0.394***	0.558***
		(0.164)	(0.118)	(0.272)	(0.107)	(0.144)	(0.116)	(0.116)	(0.188)
		1682	1989	662	3009	1765	1762	2673	998
Standardized Math		0.498***	0.615***	0.676***	0.551***	0.570***	0.497***	0.526***	0.748***
		(0.186)	(0.145)	(0.256)	(0.128)	(0.148)	(0.132)	(0.136)	(0.223)
	N	1653	1962	645	2970	1723	1734	2630	985
Panel B: SAT Outcomes									
Took SAT		-0.079	0.119	-0.137	0.067	-0.021	0.144	0.032	0.036
		(0.127)	(0.090)	(0.176)	(0.080)	(0.115)	(0.091)	(0.089)	(0.135)
	N	1371	1586	531	2426	1343	1314	2181	776
SAT Composite (2400)		90.0	96.8*	166.4**	91.8**	138.2***	77.2	85.4**	216.7**
		(64.9)	(52.2)	(82.6)	(45.2)	(50.7)	(50.4)	(41.5)	(94.9)
	N	772	1125	249	1648	777	1034	1372	525
Panel C: AP Outcomes									
Took any AP		0.227**	0.320***	0.293***	0.278***	0.269***	0.333***	0.320***	0.135
		(0.106)	(0.096)	(0.108)	(0.083)	(0.086)	(0.111)	(0.075)	(0.130)
Score 3 or Higher, any AP		0.148**	0.051	0.014	0.108*	0.034	0.180*	0.089	0.135
		(0.068)	(0.072)	(0.059)	(0.065)	(0.030)	(0.103)	(0.061)	(0.088)
	N	1371	1586	531	2426	1343	1314	2181	776
Panel D: High School Graduation Outcomes									
Four-year Graduation		-0.225**	-0.042	-0.433***	-0.076	-0.309***	0.072	-0.109	-0.140
		(0.101)	(0.082)	(0.159)	(0.069)	(0.090)	(0.086)	(0.070)	(0.136)
	N	1474	1731	573	2632	1447	1429	2354	851
Five-year Graduation		-0.022	-0.013	-0.089	0.018	-0.104	0.100	-0.018	0.084
		(0.097)	(0.077)	(0.167)	(0.070)	(0.091)	(0.087)	(0.074)	(0.136)
	N	1190	1409	454	2145	1168	1158	1918	681
Panel E: Immediate or One-year-later Enrollment in College									
Any		0.162	0.054	-0.038	0.125	0.213*	-0.027	0.093	0.190
		(0.126)	(0.103)	(0.252)	(0.088)	(0.118)	(0.131)	(0.089)	(0.190)
Four-year		0.165	0.173	0.253	0.152*	0.291***	-0.046	0.217**	0.028
		(0.119)	(0.116)	(0.238)	(0.086)	(0.111)	(0.141)	(0.085)	(0.167)
	N	866	1021	319	1568	842	832	1393	494

Notes: This table reports 2SLS estimates of the effects of Boston charter attendance by subgroup. The above- and below-median samples are constructed by splitting the sample by the median of the sum of baseline ELA and math scores, computed in the MCAS ELA outcome sample. See Table 3 notes for detailed regression specifications. Means are for non-charter attendees.
*significant at 10%; **significant at 5%; ***significant at 1%

Table 11: Lottery Estimates of Effects on School Switching and Peer Quality

	Mean (1)	Effect (2)	Mean (3)	Effect (4)	Mean (5)	Effect (6)	Mean (7)	Effect (8)
Panel A: School Switching								
Any switch	0.362	0.116						
		(0.086)						
N		3072						
Switch excluding transitional grades	0.330	0.151*						
		(0.082)						
N		3063						
Ever attend an exam school	0.145	-0.096**						
		(0.042)						
N		3205						
Panel B: Peer Quality								
	First Post-lotto Year		Second Post-lotto Year		Third Post-lotto Year		Fourth Post-lotto Year	
Peer Baseline ELA	-0.403	0.127*	-0.357	0.065	-0.301	0.046	-0.277	0.022
		(0.068)		(0.073)		(0.075)		(0.070)
Peer Baseline Math	-0.407	0.131*	-0.361	0.078	-0.298	0.076	-0.273	0.042
		(0.075)		(0.079)		(0.073)		(0.075)
Peer Baseline Sum of ELA and Math	-0.794	0.245*	-0.703	0.151	-0.585	0.124	-0.537	0.066
		(0.140)		(0.148)		(0.143)		(0.140)
N		3147		3188		2898		2744

Notes: This table reports 2SLS estimates of the effects of Boston charter attendance on school switching and peer quality. The sample includes applicants projected to graduate between 2006 and 2012. The any switch outcome is one for students observed in two or more schools at any time after the lottery. The switch excluding transitional grades outcome is one for students who transition from one observed school to another at a grade other than the exit grade of the first school. Peer quality is measured as the average baseline score of other students in the same school and year. See Table 3 notes for detailed regression specifications. Means are for non-charter attendees.
*significant at 10%; **significant at 5%; ***significant at 1%

A Data Appendix

The data used for this study come from several sources. Lists of charter applicants and lottery winners are constructed from records provided by individual charter schools. Information on schools attended and student demographics come from the Student Information Management System (SIMS), a centralized database that covers all public school students in Massachusetts. Test scores are from the Massachusetts Comprehensive Assessment System (MCAS). Advanced Placement (AP) and Scholastic Aptitude Test (SAT) scores are provided by the College Board. College attendance information comes from the National Student Clearinghouse (NSC). This Appendix describes each data source and details the procedures used to clean and match them.

Lottery Data

Data description and sample restrictions

Our sample of applicants is obtained from records of lotteries held at six Massachusetts charter schools between 2002 and 2009. The participating schools and lottery years are listed in Table A1. A total of 26 school-specific entry cohorts are included in the analysis. Lotteries for three participating schools, Match, Codman Academy and City on a Hill, were conducted for entry to 9th grade; two schools, Boston Preparatory and Academy of the Pacific Rim, held lotteries for 6th grade entry. Records for Boston Collegiate are from 5th grade lotteries.

The raw lottery records typically include applicants names, dates of birth, contact information and other information used to define lottery groups, such as sibling status. The first five rows in Table A1 show the sample restrictions we impose on the raw lottery records. We exclude duplicate applicants and applicants listed as applying to the wrong entry grade. We also drop late applicants, out-of-area applicants, and sibling applicants, as these groups are typically not included in the standard lottery process. Imposing these restrictions reduces the number of lottery records from 9,256 to 8,851.

Lottery offers

In addition to the data described above, the lottery records also include information regarding offered seats. We used this information to reconstruct indicator variables for whether lottery participants received randomized offers. We make use of two sources of variation in charter offers, which differ in timing. The *initial offer* instrument captures offers made on the day of the charter school lottery. The *ever offer* instrument captures offers made initially or later, as a consequence of movement down a randomly sequenced waiting list. The pattern of instrument availability across schools and applicant cohorts is documented in Panel B of Appendix Table A1. In some years, all applicants eventually received offers, in which case only the initial offer instrument contributes to the analysis; these cases are listed as No Variation for the ever offer instrument. As documented in Table 2, initial and ever offer rates were 31 and 65 percent in our MCAS analysis sample, and these rates were similar in the samples for other outcomes.

SIMS Data

Data description

Our study uses SIMS data from the 2001-2002 school year through the 2011-2012 school year. Each year of data includes an October file and an end-of-year file. The SIMS records information on demographics and schools attended for all students in Massachusetts public schools. An observation in the SIMS refers to a student in a school in a year, though there are some student-school-year duplicates for students that switch grades or programs within a school and year. The SIMS includes a unique student identifier known as the SASID, which is used to match students from other data sources as described below.

Coding of demographics and attendance

The SIMS variables used in our analysis include grade, year, name, town of residence, date of birth, sex, race, special education and limited English proficiency status, free or reduced price lunch and school attended. We constructed a wide-format data set that captures demographic and attendance information for every student in each year in which he or she is present in Massachusetts public schools. This file uses information from the longest-attended school in the first calendar year spent in each grade. Attendance ties were broken at random; this affects only 0.007 percent of records. Students classified as special education, limited English proficiency, or eligible for a free or reduced price lunch in any record within a school-year-grade retain that designation for the entire school-year-grade. The SIMS also includes exit codes for the final time a student is observed in the database. These codes are used to determine high school graduates and transfers.

We measure charter school attendance in 9th or 10th grade. A student is coded as attending a charter in his or her 9th or 10th-grade year when there is any SIMS record reporting charter attendance in that year. Students who attend more than one charter school within a year are assigned to the charter they attended longest.

MCAS Data

We use MCAS data from the 2001-2002 school year through the 2011-2012 school year. Each observation in the MCAS database corresponds to a students test results in a particular grade and year. The MCAS outcomes of interest are math and English Language Arts (ELA) tests in grade 10. We also use baseline tests taken prior to charter application, which are from 4th grade or 8th grade depending on a students application grade. The raw test score variables are standardized to have mean zero and standard deviation one within a subject-grade-year in Massachusetts. We also make use of scaled scores, which are used to determine whether students meet MCAS thresholds, which are Needs Improvement, Proficient, and Advanced. Unless otherwise noted, we only use the first test taken in a particular subject and grade.

AP and SAT Data

We use AP and SAT data files provided to the Massachusetts Department of Elementary and Secondary Education by College Board. The AP and SAT files include scores on all AP exams and SAT tests for graduation cohorts 2007 and 2012; for student who took the SAT more than once, the file includes only the score for the most recent exam. The AP and SAT files also include SASID identifiers, which are used to merge these outcomes with the SIMS database.

GED Data

Information on GED test-taking is provided by the Massachusetts Department of Elementary and Secondary Education's GED Office. This data includes testing dates and outcomes (pass or fail) for students taking tests from 2002 to 2010. The GED information is merged to the SIMS administrative database by first, middle, and last name, and birth date. This procedure matched 70 percent of GED tests to records in the SIMS database.

NSC Data

Data on college outcomes comes from the National Student Clearinghouse (NSC) database, which captures enrollment for 94% of undergraduates in Massachusetts. We combine information from three separate searches of the NSC database:

- A 2010 search for all students in the SIMS database between 2002 and 2009 with projected graduation years earlier than 2014, assuming normal academic progress from the last observed grade and year (not restricted to students who graduated high school);
- A 2011 search of students who graduated from Massachusetts public high schools in the class of 2010;
- A 2012 search of all students who graduated from Massachusetts public high schools in the classes of 2003 through 2010;
- A 2013 search of students who graduated from Massachusetts public high schools in the classes of 2003 through 2012.

All students in our charter applicant sample were included in the 2010 NSC search, and Massachusetts high school graduates were included in multiple searches. College types are coded using the first attended college after the last date a student is observed in the SIMS. NSC searches were conducted using criteria like name and date of birth; the NSC files also include SASIDs, which are used to merge the college outcomes with the SIMS database.

Matching Data Sets

The MCAS, AP, SAT and NSC data files are merged to the master SIMS data file using the unique SASID identifier. The lottery records do not include SASIDs; these records are matched manually to the SIMS by name, application year and application grade. In some cases, this procedure did not produce a unique match. We accepted some matches based on fewer criteria where the information on grade, year and town of residence seemed to make sense.

Our matching procedure successfully located most applicants in the SIMS database. The sixth row of Panel A of Table A1 reports the number of applicant records matched to the SIMS in each applicant cohort. The overall match rate across all cohorts was 94 percent (8,342/8,851).

Once matched to the SIMS, each student is associated with a unique SASID; at this point, we can therefore determine which students applied to multiple schools in our lottery sample. Following the match, we reshape the lottery data set to contain a single record for each student. If students applied in more than one year, we keep only records associated with the earliest year of application. Our lottery analysis also excludes students who did not attend a Boston Public Schools (BPS) school at baseline, as students applying from private schools have lower follow-up rates. This restriction eliminates 22 percent of charter applicants. Of the remaining 4,700 charter applicants, 3,671 (78 percent) contribute a score to our MCAS analysis.

Table A1: Lottery Records

Panel A: Lottery Records

Projected Senior Year	2006	2007	2008	2009	2010	2011	2012	2013	All
Total number of records	600	450	940	883	1117	1533	1753	1980	9256
Excluding disqualified applicants	600	450	940	883	1117	1530	1753	1968	9241
Excluding late applicants	590	446	930	880	1117	1530	1733	1968	9194
Excluding applicants from outside of area	590	446	930	880	1114	1529	1733	1950	9172
Excluding siblings	570	437	905	864	1101	1482	1642	1850	8851
Excluding records not matched to the SIMS	509	419	858	816	1055	1395	1547	1743	8342
Reshaping to one record per student-year	437	419	632	594	799	1025	1100	1273	6279
Excluding repeat applications	437	419	629	589	778	1004	1028	1164	6048
In Boston schools at baseline	289	337	511	481	606	849	761	866	4700
Excluding applicants without 10th-grade ELA	232	267	415	378	482	664	570	663	3671

Panel B: Comparison of Ever Offer and Initial Offer Records by Schools and Cohorts

Application Year/School		Boston Preparatory	Academy of Pacific Rim	Boston Collegiate	City on a Hill	Codman Academy	Match
Entry grade		6	6	5	9	9	9
2002	Ever	Not Open	No Records	Yes	Not Oversubscribed	No Records	Yes
	Initial			Yes	Yes		Yes
2003	Ever	Not Open	No Records	Yes	No Records	No Records	Yes
	Initial			Yes			Yes
2004	Ever	Incomplete Records	No Records	Yes	Not Oversubscribed	Not Oversubscribed	Yes
	Initial			Yes	Yes	Yes	Yes
2005	Ever	Not Oversubscribed	Yes	Yes	Yes	Incomplete Records	Yes
	Initial	Yes	Yes	Yes	Yes		Yes
2006	Ever	Yes	Yes		Yes	Incomplete Records	Yes
	Initial	Yes	Yes		Yes		Yes
2007	Ever	Too Young for Follow-up			Yes	No Records	Yes
	Initial				Yes		Yes
2008	Ever				Not Oversubscribed	Yes	Yes
	Initial				Yes	Yes	Yes
2009	Ever				Yes	Yes	Yes
	Initial				Yes	Yes	Yes
N		208	178	265	1889	148	2330

Notes: Panel A summarizes the sample restrictions imposed for the lottery analysis. Disqualified applications are duplicate records and applications to the wrong grade. In Panel B, "Not Oversubscribed" indicates that every applicant received an offer in the relevant cohort. "Yes" means that lottery records with non-missing information on ever offer and initial offer were available, and that some applicants did not get offers. "Incomplete Records" indicates schools and years for which lottery records are inadequate to allow reliable coding of initial or ever offers. The last row shows the number of applicants to each school in the lottery sample excluding applicants without 10th-grade ELA (N = 3,671). Cohorts are too young for follow-up if they don't generate AP, SAT, high school graduation, or college-going outcomes in time for our study. For City on a Hill 2009 and Match 2008 applicants, we impute initial offer using 2008 City on a Hill and 2007 Match initial offer cutoffs. Starting in 2006, Academy of Pacific Rim has operating grades from 5 to 12.

Table A2: Grade 10 and Grade 12 Attrition

	Panel A: Observed 10th-Grade MCAS Scores and Grade 12 In MA Status				*Panel B: Attrition Differentials by Ever Offer and Initial Offer*					
	Either Math or ELA	ELA	Math	Grade 12 MA	ELA		Math		Grade 12 MA	
Projected Senior Year	Mean	Mean	Mean	Mean	Ever Offer	Initial Offer	Ever Offer	Initial Offer	Ever Offer	Initial Offer
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
2006	0.803	0.803	0.803	0.747	0.108	0.031	0.108	0.031	0.015	0.068
					(0.083)	(0.053)	(0.083)	(0.053)	(0.079)	(0.062)
2007	0.795	0.792	0.789	0.774	-0.038	-0.063	-0.034	-0.036	0.011	0.017
					(0.058)	(0.066)	(0.058)	(0.065)	(0.057)	(0.062)
2008	0.820	0.812	0.800	0.765	0.100	-0.034	0.072	-0.035	0.028	-0.011
					(0.064)	(0.043)	(0.066)	(0.045)	(0.070)	(0.050)
2009	0.794	0.786	0.771	0.763	-0.033	-0.061	-0.020	-0.048	-0.037	-0.050
					(0.042)	(0.042)	(0.044)	(0.043)	(0.044)	(0.043)
2010	0.799	0.795	0.785	0.766	0.036	-0.010	0.028	-0.015	-0.033	-0.040
					(0.044)	(0.040)	(0.045)	(0.041)	(0.046)	(0.042)
2011	0.786	0.782	0.760	0.729	-0.005	0.037	-0.005	0.046	0.012	0.029
					(0.031)	(0.032)	(0.032)	(0.033)	(0.033)	(0.035)
2012	0.756	0.749	0.742	0.607	0.037	-0.018	0.057	-0.009	-0.046	-0.059
					(0.052)	(0.036)	(0.052)	(0.037)	(0.057)	(0.041)
2013	0.768	0.766	0.752	-	-0.025	-0.013	-0.020	0.002	-	
					(0.035)	(0.032)	(0.036)	(0.033)		
All Cohorts	0.786	0.781	0.769	0.725	0.005	-0.009	0.007	-0.001	-0.011	-0.011
					(0.016)	(0.014)	(0.016)	(0.014)	(0.019)	(0.017)
N (All Cohorts)						4700		4700		3834

Notes: This table summarizes attrition for 10th-grade MCAS scores and 12th-grade enrollment status for charter school lottery applicants. Columns (1)-(3) show fractions of applicants with observed MCAS scores in each subject among those expected to take the test, assuming normal academic progress after the lottery. Column (4) shows the fraction of applicants with 12th-grade records in the SIMS administrative database. Columns (5)-(10) report coefficients from regressions of indicators for follow-up data on ever offer and initial offer dummies. Regressions also control for risk set dummies.
*significant at 10%; **significant at 5%; ***significant at 1%

Table A3: Lottery Estimates of Effects Excluding Each School

	Excl. School 1	Excl. School 2	Excl. School 3	Excl. School 4	Excl. School 5	Excl. School 6	All Schools
	Effect	Effect	Effect	Effect	Effect	Effect	Effect
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: 10th- Grade MCAS							
Standardized ELA	0.398***	0.357***	0.401***	0.416***	0.392***	0.409***	0.411***
	(0.114)	(0.136)	(0.107)	(0.105)	(0.109)	(0.157)	(0.104)
Standardized Math	0.565***	0.701***	0.532***	0.556***	0.607***	0.479**	0.569***
	(0.131)	(0.159)	(0.122)	(0.121)	(0.121)	(0.189)	(0.120)
Panel B: SAT Outcomes							
Took SAT	0.018	0.077	0.024	0.022	0.042	0.009	0.033
	(0.083)	(0.095)	(0.077)	(0.079)	(0.080)	(0.127)	(0.078)
SAT Composite (2400)	95.6**	183.2***	96.9**	99.6**	95.7**	66.6	102.8**
	(45.9)	(56.0)	(42.8)	(43.6)	(44.6)	(64.1)	(42.9)
Panel C: AP Outcomes							
Took any AP	0.316***	0.412***	0.279***	0.291***	0.295***	0.085	0.287***
	(0.074)	(0.103)	(0.074)	(0.073)	(0.075)	(0.137)	(0.073)
Score 3 or Higher, any AP	0.089*	0.184***	0.091*	0.093*	0.085	0.021	0.096*
	(0.052)	(0.059)	(0.052)	(0.052)	(0.054)	(0.066)	(0.052)
Panel D: High School Graduation Outcomes							
Four-year Graduation	-0.128**	-0.034	-0.129**	-0.133**	-0.117*	-0.190*	-0.125**
	(0.065)	(0.089)	(0.063)	(0.063)	(0.065)	(0.100)	(0.063)
Five-year Graduation	-0.010	-0.045	0.001	0.004	0.000	0.088	0.000
	(0.068)	(0.087)	(0.065)	(0.065)	(0.065)	(0.105)	(0.065)
Panel E: Immediate or One-year-later Enrollment in College							
Any	0.102	0.045	0.115	0.115	0.115	0.305*	0.115
	(0.087)	(0.108)	(0.084)	(0.087)	(0.084)	(0.169)	(0.084)
Four-year	0.167**	0.098	0.173**	0.169**	0.173**	0.235	0.173**
	(0.081)	(0.106)	(0.079)	(0.081)	(0.079)	(0.150)	(0.079)

Notes: This table reports 2SLS estimates of the effects of charter attendance, excluding data from each of the six schools in the sample at a time. See Table 1 notes for outcome sample descriptions and Table 3 notes for detailed regression specifications. Sample size is excluded to avoid identifying individual schools.
*significant at 10%; **significant at 5%; ***significant at 1%