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

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We use admissions lotteries to estimate effects of attendance at Boston's charter high schools on college preparation and enrollment. Charter schools increase pass rates on Massachusetts' high-stakes exit exam, with large effects on the likelihood of qualifying for a state-sponsored scholarship. Charter attendance also boosts SAT scores sharply and increases the likelihood of taking an Advanced Placement (AP) exam, the number of AP exams taken, and AP scores. Charters induce a substantial shift from 2- to 4-year institutions, though

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the effect on overall college enrollment is modest. Charter effects on college-related outcomes are strongly correlated with charter effects on earlier tests.

I. Introduction

A growing body of evidence indicates that many urban charter schools have large, positive effects on the test scores of disadvantaged students. Oversubscribed charter schools in Boston increase the test scores of low-income students by a third of a standard deviation a year—enough to eliminate the black-white test score gap in a few years of attendance (Abdulkadiroğlu et al. 2011). Similar effects have been found in New York City (Dobbie and Fryer 2011) and in a nationwide study of oversubscribed urban charter schools (Clark et al. 2011).

Although encouraging, gains on state-mandated standardized tests provide an inconclusive gauge of the benefits of charter attendance. Like other American public schools, charters are evaluated in part by the performance of their students on these tests. A growing literature suggests that educators respond strategically to the incentive to boost test scores (Neal and Schanzenbach 2010). In some cases, teachers have been found to cheat in order to avoid sanctions or to garner the rewards associated with high scores on tests used for accountability (Jacob and Levitt 2003).

The potentially distortionary effect of test-based accountability may be especially large in the charter sector, where schools whose students do poorly on state assessments can be closed. In our Massachusetts setting, for example, 14 out of 96 charters granted through 2013 have been lost. Charter schools would appear to have a particularly strong incentive to teach to the test, at the expense, perhaps, of a focus on the development of skills with a longer-term payoff.

This paper assesses the consequences of Boston charter high school attendance for outcomes beyond the test scores used for accountability purposes. We look here at outcomes where the link with human capital and

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future earnings seems likely to be sustained and strong, focusing on variables that are essential to or facilitate postsecondary schooling. These outcomes include high school graduation, the attainment of state competency thresholds, scholarship qualification, Advanced Placement (AP) and SAT performance, college enrollment, type of institution, and college persistence. Few of these measures are targeted for accountability purposes. Postsecondary schooling is also strongly linked with earnings, although we cannot, as yet, look at earnings directly.

Our analysis covers Boston's charter high schools for cohorts who applied when there were more applicants than seats. Oversubscribed Massachusetts charters allocate seats by lottery, thereby generating our research design. For our purposes, an analysis of high schools is both a necessity and a virtue. It is necessary to study high schools because most students applying to charters in earlier grades are not yet old enough to generate data on postsecondary 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, e.g., Cunha, Heckman, and Schennach 2010). Consistent with this view, impact analyses of interventions for urban youth have mostly generated disappointing results.[1] We assess whether charter high schools produce meaningful long-term gains for disadvantaged urban youth.

Our findings suggest that the gains from Boston's high-performing charter high schools extend well beyond high-stakes tests. Charter attendance doubles the likelihood that a student sits for an Advanced Placement (AP) exam, with especially large gains in the share of students taking science exams. Attending a charter school quadruples the likelihood of taking an AP Calculus exam and increases the fraction of students earning an AP Calculus score high enough to qualify for college credit from 2%, for noncharter attendees, to 13%, for charter attendees. Charters also boost SAT scores sharply, especially in math. Importantly, our estimated SAT gains are about as large as the estimated gains on the state's high-stakes high school exit exam, in spite of the fact that SAT scores are unrelated to state-mandated accountability standards. Although overall college enrollment effects are not statistically significant, charter attendance induces a clear shift from 2-year to 4-year colleges, with gains most pronounced at 4-year public institutions in Massachusetts.

Our analysis also links gains on accountability assessments to gains in later outcomes, finding that effects on the two sets of outcomes are highly

[1] 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.

positively correlated. In other words, whether or not state assessments are of intrinsic interest, gains on state tests predict gains elsewhere. 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 our main findings.

The next section provides background on Massachusetts charter schools and describes the data used here. Section III outlines our empirical strategy and reports first-stage estimates and benchmark effects on standardized test scores. Section IV reviews findings for college preparation, while Section V discusses effects on college enrollment, choice, and persistence. Section VI reports effects in subgroups and discusses our evidence on peer effects. Section VII concludes.

II. Background and Data

A. Boston's Charter Sector

Boston's oversubscribed charter schools generate impressive test 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 have 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. 2011; Angrist, Pathak, and Walters 2013).

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) corps members 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.[2]

Charter schools are a recent innovation; Massachusetts' first charter schools opened in 1995. Not surprisingly, therefore, most evidence on

[2] Other lottery-based evidence on *No Excuses*'s effectiveness includes the Dobbie and Fryer (2011) study of a charter school in the Harlem Children's Zone, the Dobbie and Fryer (2013) 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).

Table 1
Boston High School Characteristics

	Public High Schools (1)	Charters Serving Grades 9–12 Only (2)	Charters Serving Grades 9–12 (3)	Charters in the Study (4)
A. School characteristics:				
No. of years open		15	14	14
Have Saturday school		3 schools	5 schools	5 schools
Average math instructions (minutes)		83.5	92.0	97.3
Average reading instruction (minutes)		89.8	92.0	97.3
No Excuses		3 schools	5 schools	5 schools
Days per year	180	189	190	191
Average minutes per day	392	477	478	489
Average per pupil expenditure ($)	16,902[a]	15,842[b]	13,694	13,499
Title I eligible	22 schools	4 schools	7 schools	6 schools
No. of schools in sample	22	4	7	6
B. Teacher characteristics (grades 9–12 only):				
No. of teachers per school	45	17	16	16
Student/teacher ratio	13.8	13.1	12.4	12.6
Proportion of highly qualified teachers	.70	.88	.90	.91
Proportion of teachers licensed in teaching assignment	.89	.80	.69	.64
Proportion of core classes taught by highly qualified teachers	.93	.97	.97	.96
Average teacher age	41	32	33	32
Proportion of teachers age 32 and younger	.23	.64	.63	.69
Proportion of teachers age 49 and older	.30	.09	.08	.04
Proportion of teachers assigned to SPED or ELL classes	.17	.08	.06	.06
Proportion of teachers assigned to AP classes	.04	.07	.07	.07
No. of teachers in sample	993[c]	71	121	101

NOTE.—This table reports characteristics of Boston charter schools and Boston public schools operating in academic year 2012–13. Information on charter schools in panel A is from a 2010–11 survey of school administrators, except for per pupil expenditures, which are fiscal year 2011 figures obtained from http://www.doe.mass.edu/charter/finance/revexp/. Data for public schools were obtained from www.nctq.org, www.bostonpublicschools.org and http://profiles.doe.mass.edu and refer to academic year 2010–11, except for average minutes per day, which were extracted from the Boston Public Schools website in March 2013. Average per pupil expenditures include spending for all grade levels for both public and charter schools and are weighted by student enrollment. Teacher characteristics in panel B are derived from Massachusetts EPIMS teacher data and SIMS administrative data. Panel B reports averages for teachers employed in the 2010–11 and 2011–12 school years. See the the data appendix (app. A) for details. Except where otherwise noted, entries in panel A are averages across schools.

[a] This figure corresponds to the total reported expenditures in the Massachusetts DESE District Profiles Finance Table "Total Expenditure per Pupil, All Funds, by Function" for fiscal year 2011 and is an enrollment-weighted average of in-district and out-of-district expenditures.

[b] Data for Match Charter High School include spending at the Match middle school as well.

[c] 2010–11 EPIMS teacher data for West Roxbury Academy are missing, as this school opened in academic year 2011–12.

charter effectiveness comes from outcomes measured while children are still enrolled in elementary and secondary school. An exception is Dobbie and Fryer's recent (2015) lottery-based study, which follows applicants to a charter middle school in the Harlem Children's Zone, estimating effects on college enrollment while also looking at noneducational outcomes related to crime and teen pregnancy. Dobbie and Fryer find that Promise Academy boosts college enrollment while reducing pregnancy for girls and incarceration for boys. 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. Results from both of these empirical strategies suggest gains for charter students. We complement this earlier work with new results on postsecondary preparation, enrollment, and college choice for a large sample of charter high school lottery applicants.

B. Data and Sample

1. 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 they account for the bulk of charter high school enrollment in Boston today.[3] 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 day and year than traditional public schools, and they make frequent use of Saturday school. As a result, charter school students receive about 1,500 hours per year of instruction, compared to 1,150 in the traditional public schools. Most of Boston's charters adhere to the *No Excuses* instructional approach. As shown in panel B of table 1, charter teachers are younger than their traditional public school counterparts: 69% of teachers in our analysis sample are age 32 or younger, compared to 23% of traditional public school teachers. Similarly, only 4% of (study sample) charter teachers are age 49 or older, while 30% of public school teachers are at least age 49. Charter

[3] 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.

class sizes are smaller than those at traditional public schools. Per pupil expenditures are broadly similar across sectors, with traditional public high schools spending about $1,000 more per student. All public schools in Boston, including charters, qualify for Title I aid.

2. *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 the data appendix (app. A) and table A1.

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% were matched to state data.[4] 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 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 nongraduates. NSC data record enrollment spells at participating postsecondary

[4] Match rates differ little by win/loss status, a fact documented in app. table A2. Online app. table B3 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 full sample, though effects on reading scores are somewhat smaller for the balanced cohorts. Appendix B, table B4, reports Lee (2009) bounds accounting for differential attrition. The bounds imply substantial and significant test score impacts in both subjects.

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.[5] 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 tenth-grade score on the Massachusetts Comprehensive Assessment System (MCAS) assessment. Some students retake tenth-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 2007–13, including tests taken earlier than the senior year. AP and SAT scores are in their original units (AP scores run from 1 to 5; SAT subject scores run from 200 to 800).
- *High school graduation:* High school graduation data are for cohorts projected to finish between 2006 and 2013.
- *College outcomes:* These are for students with projected senior years 2006–12 (the most recent cohort for which we have NSC data is the high school class of 2012).

Table 2 compares charter applicants with the full sample of traditional BPS ninth-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 underrepresented among charter applicants, but the proportion of applicants identified as qualifying for special education services is almost as high among charter applicants as in the traditional BPS population.

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

Table 2
Descriptive Statistics

	All BPS Ninth-Graders	Charter Lottery Applicants		
	Mean (1)	Mean (2)	Immediate Offer Gap (3)	Waitlist Offer Gap (4)
A. Projected senior year 2006–13 (MCAS outcome sample):				
Female	.496	.540	.025	−.014
			(.019)	(.011)
Black	.421	.613	−.004	−.001
			(.018)	(.010)
Hispanic	.308	.250	.006	−.002
			(.016)	(.009)
Asian	.101	.033	−.003	.002
			(.006)	(.003)
Subsidized lunch	.743	.729	.020	−.006
			(.017)	(.010)
Special education	.204	.182	.012	−.009
			(.015)	(.008)
Limited English proficiency	.120	.035	−.001	.002
			(.007)	(.004)
Baseline MCAS ELA	−.489	−.298	−.046	.026
			(.035)	(.019)
Baseline MCAS Math	−.427	−.312	−.027	.018
			(.035)	(.020)
p-value			.805	.748
Charter attendance		.297		
Immediate offer		.308		
Waitlist offer		.347		
N	29,846		3,685	
B. Other outcome samples:				
Projected senior year 2007–13:				
Took any AP	.268	.286		
Took SAT	.496	.642		
N	22,467	3,672		
Projected senior year 2006–12:				
On-time college enrollment	.368	.488		
N	26,584	3,205		

NOTE.—This table shows descriptive statistics for Boston Public School (BPS) students and charter lottery applicants as well as differences by lottery offer status. Column 1 shows means for BPS ninth-graders projected to graduate between 2006 and 2013, assuming normal academic progress from eighth grade. Column 2 shows means for charter applicants in the same projected graduation year range. Columns 3 and 4 report coefficients from regressions of characteristics on immediate and waitlist lottery offers, controlling for risk set indicators. The sample for these regressions is restricted to charter lottery applicants with tenth-grade MCAS ELA (Massachusetts Comprehensive Assessment System English language arts) scores. The *p*-values are from tests of the hypothesis that all coefficients are zero. Baseline grade is defined as fourth grade for Boston Collegiate applicants, fifth grade for Boston Preparatory and Academy of the Pacific Rim applicants, and eighth grade for Match High, Codman Academy, and City on a Hill applicants. The baseline grade for BPS ninth-graders is eighth grade. Panel B shows outcome means for the AP/SAT and NSC analysis samples. On-time college enrollment indicates enrollment by the semester after projected high school graduation. Standard errors are shown in parentheses.

III. Empirical Framework

A. Models and Instruments

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

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

where y_i is the outcome of interest for student i, X_i is a vector including tenth-grade-year dummies and a set of pre-lottery demographic characteristics (gender, 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) to which lottery sample applicants applied. 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.[6] The variable of interest, C_i, indicates attendance at any of the six charter schools in our lottery sample in ninth or tenth grade. The parameter ρ captures the causal effect of charter school attendance.

We use charter offer dummies as instruments. The *immediate offer* instrument, Z_{i1}, indicates offers made on the day of the charter school lottery. Because some applicants who do not receive offers on lottery day do so at a later date when their names are reached on a randomly ordered waitlist, we also use a second instrument, called *waitlist offer*, or Z_{i2}. Some risk sets have only one instrument, in which case the other is set to zero and absorbed by controls for risk sets. Appendix table A1 details the schools and application cohorts for which we observe immediate and waitlist offers.

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

The first stage for our 2SLS procedure is

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

where two separate parameters, π_1 and π_2, capture the effects of immediate and waitlist offers on charter attendance. As in the second-stage equation, the first stage includes risk set controls, tenth-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 tenth-grade-school-by-year level.

Randomly assigned lottery offers are independent of student ability or family background. Consistent with presumed random assignment, columns 3 and 4 of table 2 show that pre-lottery demographic variables and test scores are similar for offered and nonoffered students. Specifically, 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 nonoffered students. Appendix table A3 documents an MCAS follow-up rate close to 80%. 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 twelfth grade. Here too the estimates in panel B are encouraging, with no systematic difference between offered and nonoffered students.

B. First-Stage Estimates and an MCAS Benchmark

A waitlist admissions offer in a charter lottery boosts the probability of charter enrollment by 24 percentage points. This can be seen in column 3 of table 3, which reports waitlist offer first-stage estimates. Column 2 shows that an immediate offer boosts charter enrollment by an additional 13 points. The first-stage effect of an offer immediately following lottery day is therefore 37 percentage points.[7]

The relationship between lottery offers and charter enrollment—the size of the first stage—is determined by the likelihood that an applicant chooses to accept an offer. Our first-stage estimates are far from one because many lottery winners choose not to enroll in charter schools. This is driven in

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

Table 3
Lottery Estimates of Effects on Tenth-Grade MCAS Scores by Projected Senior Year

	Charter Enrollment (First Stage)			MCAS Scores (Reduced Form and 2SLS)			
Subject	Nonoffered Mean (1)	Immediate Offer (2)	Waitlist Offer (3)	Noncharter Mean (4)	Immediate Offer (5)	Waitlist Offer (6)	Charter Effect (7)
A. Seniors in 2006–13 (MCAS outcome sample):							
Standardized ELA	.104	.373***	.239***	−.285	.148***	.136***	.408***
	[.306]	(.047)	(.042)	[.833]	(.046)	(.044)	(.102)
N							3,685
Standardized math	.106	.374***	.241***	−.233	.221***	.152***	.592***
	[.307]	(.048)	(.041)	[.911]	(.058)	(.054)	(.117)
N							3,629
B. Seniors in 2006–12 (NSC outcome sample):							
Standardized ELA	.097	.363***	.228***	−.296	.110**	.073	.304**
	[.296]	(.053)	(.048)	[.830]	(.055)	(.050)	(.127)
N							3,008
Standardized math	.097	.365***	.230***	−.241	.178***	.118*	.489***
	[.296]	(.053)	(.048)	[.893]	(.068)	(.065)	(.146)
N							2,965

Note.—This table reports first-stage, reduced form, and two-stage least squares estimates for the effects of Boston charter attendance on tenth-grade MCAS (Massachusetts Comprehensive Assessment System) test scores. The panel A sample includes students projected to graduate between 2006 and 2013; the panel B sample includes students projected to graduate between 2006 and 2012. The endogenous variable is an indicator for charter attendance in ninth or tenth grade. The instruments are immediate and waitlist offer dummies. Immediate offer is equal to one when a student is offered a seat in any charter school immediately following the lottery, while waitlist offer is equal to one for students offered seats later. All models control for risk sets, tenth-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 tenth grade. The means in col. 1 are for students who received no charter offer, while the means in col. 4 are for noncharter students. Standard errors are reported in parentheses, and standard deviations are reported in brackets.

* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.

part by the variety of options available to Boston high school students: online appendix table C1 shows that some accepted applicants opt for a traditional public school, one of Boston's pilot schools, or an exam school. In addition, some students who receive no offer in the lotteries for which we have data receive one at a later date, further reducing the first stage. The 2SLS estimates adjust for differences between offers and enrollment, with the resulting estimates capturing causal effects for those who comply with (i.e., enroll in a charter school in response to) the offers recorded in our data (Imbens and Angrist 1994).

As a starting point, table 3 also reports first-stage, reduced form, and 2SLS estimates similar to those reported in our earlier Boston study for tenth-grade MCAS scores (Abdulkadiroğlu et al. 2011). Column 7, which shows second-stage estimates of the parameter ρ from equation (1), indicates that attendance at the charter high schools in our sample boosts tenth-grade ELA scores by 0.4σ, that is, four-tenths of a standard deviation, while raising math scores by almost 0.6σ.[8]

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 subsample of applicants contributing to our college-going analysis below. Estimates of effects on tenth-grade MCAS scores in the college-going sample, reported in panel B of table 3, are similar to estimates for the full MCAS sample.

IV. College Preparation

A. MCAS Thresholds

Charter school attendance has large effects on the likelihood applicants score in the upper-two MCAS score categories. This can be seen in column 2 of table 4, which documents large and statistically significant increases in the likelihood charter applicants earn scores at a level deemed "Proficient" or "Advanced."

Since 2003, high school graduation in Massachusetts has been determined in part by tenth-grade MCAS scores. The initial state competency standard required students to pass the Needs Improvement threshold with scaled

[8] 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, e.g., causes years of charter enrollment as well as vice versa.

Table 4
Lottery Estimates of Effects on High School Milestones

MCAS Performance Categories (Math and ELA Combined)			Grade Progression and Graduation		
Category	Noncharter Mean (1)	Effect (2)	Category	Noncharter Mean (3)	Effect (4)
Needs Improvement or higher	.975	.014	Start twelfth grade on time (N = 3,920)	.781	−.024
		(.015)			(.049)
Proficient or higher	.543	.171**	Repeat twelfth grade (N = 2,415)	.070	.124**
		(.071)			(.050)
Advanced or higher	.076	.161***	4-year graduation (N = 3,920)	.687	−.145***
		(.034)			(.055)
Meets competency determination	.740	.147**	5-year graduation (N = 3,208)	.787	−.003
		(.065)			(.059)
Eligible for Adams Scholarship using BPS cutoffs	.198	.242***			
		(.058)			
N	3,608				

Note.—This table reports two-stage least squares estimates of the effects of Boston charter attendance on tenth-grade MCAS (Massachusetts Comprehensive Assessment System) performance categories, eligibility for the Adams Scholarship, and progression through high school. The competency determination requires scaled scores of 220 in both ELA and math for the classes of 2006–9 and scores of 240 in both subjects for the classes of 2010–13. 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. Non–Adams MCAS outcomes indicate whether a student reached the threshold on any attempt. Starting grade 12 on time is one if a student is observed in twelfth grade by his or her projected senior year, assuming normal academic progress from baseline. Repeat twelfth is one if a student repeats twelfth grade for at least 1 academic year. Five-year graduation is equal to one if a student graduates by the year following his or her projected graduation year. The sample for repeat twelfth and 5-year graduation includes students projected to graduate by spring 2012. All other outcome samples include students projected to graduate from 2006 through 2013. The sample for repeat twelfth is restricted to students who started twelfth grade on time. The note to table 3 details the 2SLS models used to construct these estimates. Standard errors are shown in parentheses.

** Significant at the 5% level.

*** Significant at the 1% level.

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.[9] Consistent with the score gains documented in table 3, charter attendance boosts the likelihood of meeting competency standards, with a gain of 15 points. This estimate also appears in column 2 of table 4.

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 is not met, and a total MCAS score in the upper quartile of the distribution of scores in a scholarship candidate's home school district.[10] Awardees qualify for a tuition waiver at a Massachusetts public college or university.[11] As can be seen at the bottom of column 2 of table 4, charter attendance increases the likelihood of qualifying for an Adams Scholarship by 24 percentage points. This finding is notable in view of concerns regarding racial imbalance in eligibility for some scholarship programs (Dynarski 2000). Attendance at Boston charter schools increases scholarship eligibility for a mostly poor minority population.

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 do not 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 equations of the following form:

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

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

[9] See http://www.doe.mass.edu/mcas/graduation.html for details. Updated rules include an exception for students who pass the Needs Improvement threshold only and also meet personal goals. We ignore this exception here.

[10] Charter school students can earn a scholarship in either the district of attendance (the charter school) or the district of residence (Boston). The Adams Scholarship cutoff is defined here using BPS thresholds.

[11] Cohodes and Goodman (2014) 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.

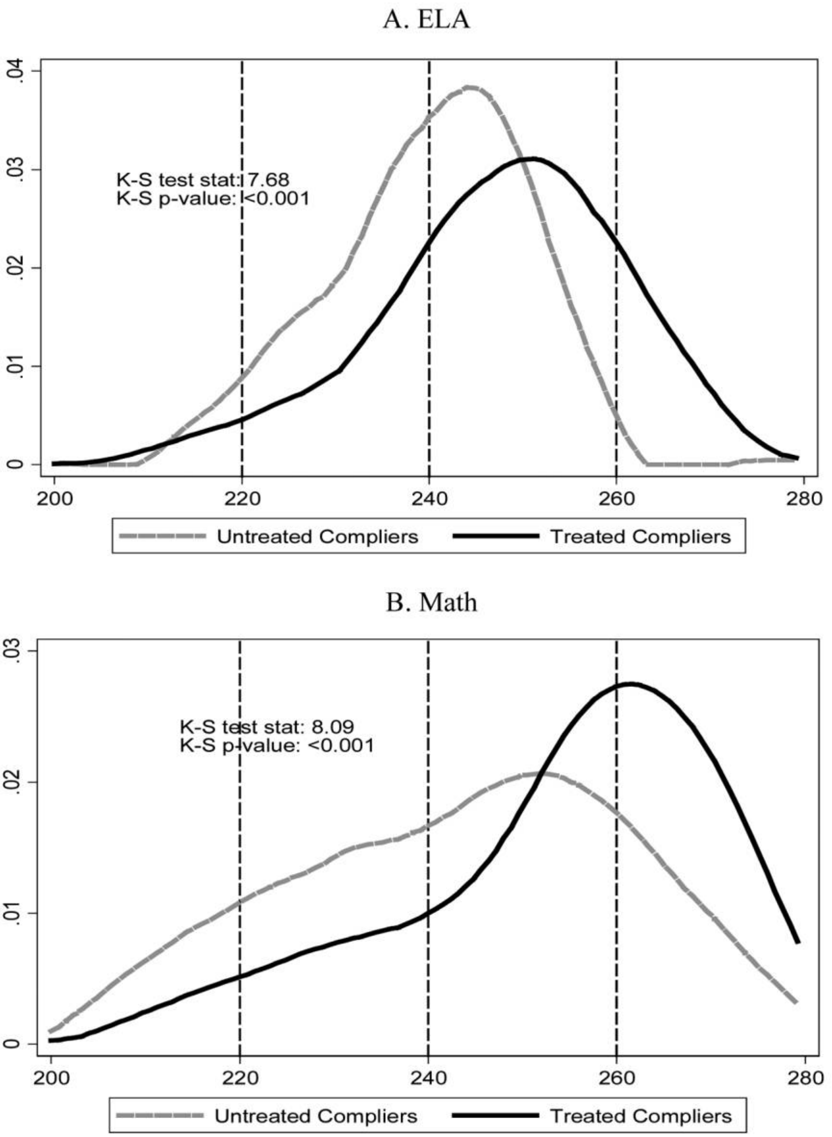

FIG. 1.—Complier distributions for MCAS scaled scores in ELA and math. This figure plots smoothed MCAS scaled score distributions for treated and untreated charter lottery compliers. The sample is restricted to lottery applicants projected to graduate between 2006 and 2013. Dotted vertical lines indicate MCAS performance category thresholds (220 for Needs Improvement, 240 for Proficient, and 260 for Advanced). Densities are estimated using an Epanechnikov kernel with 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.

where charter attendance C_i is treated as an endogenous regressor and instrumented with lottery offers. Here $K_h(v) = (1/2)K(v/h)$ 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 (noncharter) compliers.[12]

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 noncharter 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.

B. Grade Progression and High School Graduation

Does charter attendance also increase high school graduation rates? Perhaps surprisingly given the gains in test score graduation requirements reported in column 2 of table 4, the estimates in column 4 of this table suggest not. In fact, charter attendance reduces the likelihood a student graduates on time by 14.5 percentage points, a statistically significant effect.[13] This negative estimate falls to zero when the outcome is graduation within 5 years of ninth-grade entry. Interestingly, charter schools appear no more likely to cause students to repeat ninth, tenth, or eleventh grade than are traditional public schools. This is apparent from an analysis of effects on the likelihood of starting twelfth grade on time. Instead, it appears that many charter students take an additional twelfth-grade year to graduate, perhaps due to their 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.[14]

C. SAT-Taking and Scores

The SAT is a major milestone for college-bound high school students, and for many it is 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

[12] 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. Walters (2013) shows that this method produces consistent estimates of density functions for compliers.

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

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

status that might be attributable to family background and school quality are further accentuated by the willingness of higher-income families to invest 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 noncharter students in our applicant sample take the SAT, while the estimated effect of charter attendance on SAT-taking is about 8 points, a gap far from statistical significance.[15]

SAT scores are much lower in Boston than in the rest of the state, with fewer than 10% of noncharter students in our applicant sample scoring above the state median on the composite test (the sum of math, verbal, and writing scores). About three-quarters of noncharter students score in the lowest quartile of the state distribution or do not take the SAT. Charter attendance increases the share of students scoring above the bottom quartile by 15 percentage points (from 27% to 42%, as can be seen in col. 6).[16] Gains in math contribute most to this boost in composite scores; effects on verbal and writing scores are smaller, though still statistically significant. Charter attendance increases 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 score 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.[17] 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. The score gain in verbal and writing is about 26 points in each subject. Although charter attendance has smaller effects on verbal and writing scores, the composite SAT score gain is estimated to be about 104 points,

[15] 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 noncharter BPS population.

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

[17] 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.

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

	Took SAT		Reasoning (Top Score = 1600)		Composite (Top Score = 2400)	
	Noncharter Mean (1)	Effect (2)	Noncharter Mean (3)	Effect (4)	Noncharter Mean (5)	Effect (6)
Took SAT	.635	.084				
	[.481]	(.063)				
Score above bottom quartile			.267	.165***	.265	.147***
			[.443]	(.057)	[.441]	(.056)
Score above median			.103	.124***	.094	.108***
			[.304]	(.041)	[.292]	(.036)
Score in top quartile			.033	.017	.027	.008
			[.178]	(.016)	[.162]	(.016)
Average score (for takers)			855.5	78.1***	1,268.2	104.3***
			[173.9]	(23.9)	[250.3]	(34.3)
	Math (800)		Verbal (800)		Writing (800)	
	Noncharter Mean (1)	Effect (2)	Noncharter Mean (3)	Effect (4)	Noncharter Mean (5)	Effect (6)
Score above bottom quartile	.315	.174**	.271	.139***	.289	.101*
	[.465]	(.068)	[.445]	(.054)	[.453]	(.056)
Score above median	.126	.166***	.112	.086**	.104	.079**
	[.332]	(.049)	[.315]	(.042)	[.306]	(.037)
Score in top quartile	.042	.065**	.034	.011	.029	.037
	[.201]	(.027)	[.180]	(.019)	[.167]	(.024)
Average score (for takers)	439.1	52.1***	416.4	26.0**	412.7	26.2**
	[98.3]	(14.3)	[91.0]	(12.9)	[89.3]	(12.6)

NOTE.—This table reports two-stage least squares estimates of the effects of Boston charter attendance on SAT test-taking and scores. The sample includes students projected to graduate between 2007 and 2013. SAT outcomes are coded using the last test taken by each student. The average score outcome is for a sample of SAT takers. Other outcomes are equal to zero for non-SAT takers. Score quartile values are from the distribution of Massachusetts SAT takers. Maximum possible scores are shown in parentheses next to outcome labels. The note to table 3 details the 2SLS models used to construct the estimates. Standard deviations are shown in brackets, and standard errors are shown in parentheses. *N* of total sample = 3,672; *N* of sample taking the SAT = 2,378.
* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.

a large and 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 78 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 fig. 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.

D. 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 its students to 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 30 percentage points. Consequently, almost 60% of charter students take at least one AP test, compared with 28% of students in traditional public schools.[18]

Charter attendance increases the average number of AP tests that students take by over a full exam, a result that can be seen in the second row of table 6. 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 16 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 12 percentage points, a large effect relative to the noncharter mean of 8%. At the same time, charter attendance generates no significant increase in the likelihood of earning a 4 or 5.[19] Note that by including zeros for nontakers 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,

[18] The AP-taking effect does not reflect a lack of AP options in traditional public schools. BPS schools offer AP classes at the same or higher rates than charter schools. See online appendix tables C3 and C4 for details.

[19] The University of Massachussetts–Amherst and the University of Massachussetts–Boston require at least a 4 on the AP Calculus exam for college credit, a threshold that most Boston students do not meet.

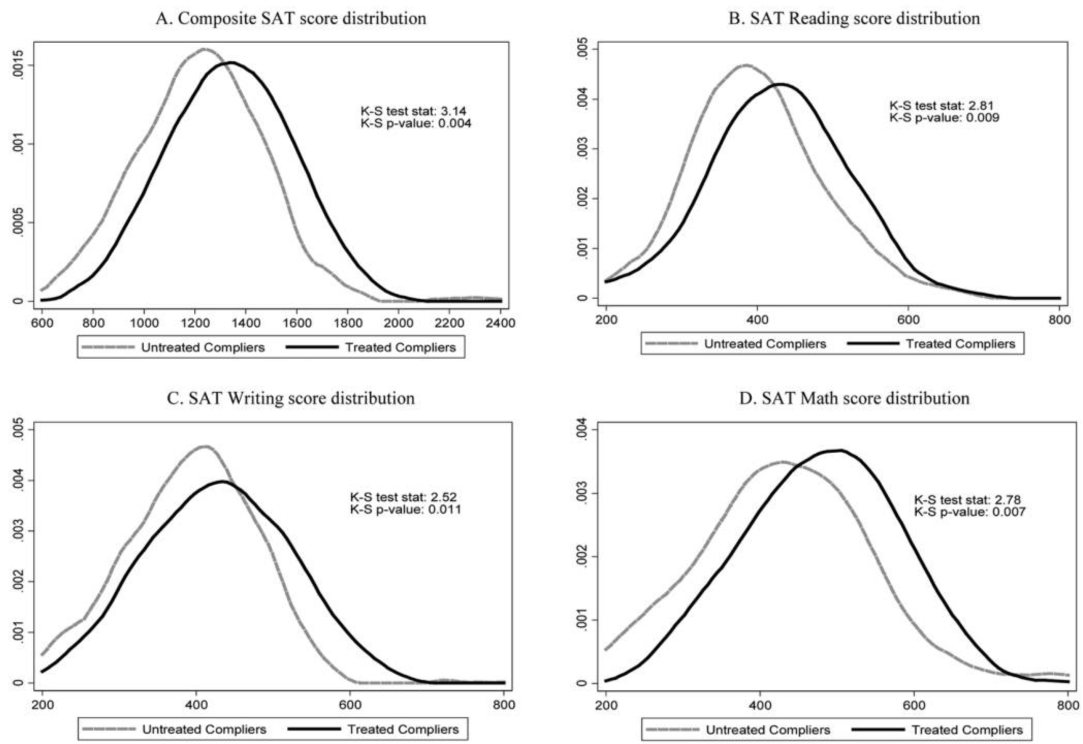

FIG. 2.—Complier distributions for SAT scores. This figure plots smoothed SAT score distributions for treated and untreated charter lottery compliers. The sample is restricted to lottery applicants who are projected to graduate between 2007 and 2013. Densities are estimated using an Epanechnikov kernel with 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.

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

	All AP Exams		Science		Calculus		US History		English	
	Noncharter Mean (1)	Effect (2)	Noncharter Mean (3)	Effect (4)	Noncharter Mean (5)	Effect (6)	Noncharter Mean (7)	Effect (8)	Noncharter Mean (9)	Effect (10)
Took exam	.279	.298***	.103	.308***	.070	.223***	.041	.181**	.162	.083
		(.062)		(.052)		(.061)		(.078)		(.069)
No. of exams	.586	1.037***	.119	.293***						
		(.245)		(.060)						
Score 2 or higher	.156	.162**	.035	.067**	.025	.128***	.029	.087**	.105	.067
		(.064)		(.030)		(.049)		(.041)		(.048)
Score 3 or higher	.083	.122**	.020	.045**	.019	.108***	.019	.058***	.035	.038
		(.051)		(.018)		(.039)		(.022)		(.026)
Score 4 or 5	.046	.050	.011	−.003	.011	.036*	.011	.021	.014	.008
		(.032)		(.010)		(.020)		(.017)		(.012)

NOTE.—This table reports two-stage least squares estimates of the effects of Boston charter attendance on AP test-taking and scores. The sample includes students projected to graduate between 2007 and 2013. Outcomes are equal to zero for nontakers. 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. The note to table 3 details the 2SLS models used to construct these estimates. Standard errors are shown in parentheses. N = 3,672.

* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.

and history, three of the most common categories of AP exams. Paralleling charters' large effect on MCAS math scores, the clearest AP score gains emerge for calculus. Charter attendance boosts the probability of taking the AP Calculus test by 22 percentage points and increases the likelihood of earning a score of at least 2 by nearly 13 points. The corresponding impact on the likelihood of earning a 3 on AP Calculus is 11 percentage points; relative to the noncharter mean of 1.9%, this implies that charter attendance more than quintuples the chances a student earns a 3 in calculus. There is also an effect on the 4 or higher threshold, with charter attendance increasing the likelihood of scoring in the highest categories by a marginally significant 3.6 percentage points. This is more than three times the probability of scoring 4 or higher for noncharter students. Charter attendance also increases AP scores in science and US history, with more students scoring above a 2 and above a 3 in both subjects. Charter schools have little effect on AP English test-taking or scores.

V. 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 in the fall after graduation, while 60% start college within 18 months of expected high school graduation. While the estimated effect of charter attendance on college attendance is positive, it is not large enough to generate a statistically significant gain. This can be seen in the first row of table 7, 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 "within 6 months" sample). The second, smaller, sample includes cohorts we can follow for an additional year (the "within 18 months" sample). Columns 2 and 4 report enrollment effects on applicants who can be followed in these two windows. The estimated enrollment effects of 0.028 and 0.075 are not precise enough to rule out chance findings.

While the estimates of overall enrollment effects are inconclusive, the results in table 7 show a clear shift from 2-year colleges to 4-year colleges. Specifically, in the 6-month enrollment window, charter attendance decreases 2-year attendance by 11 points, while increasing 4-year attendance by 13 points. The decline in 2-year attendance is again 11 points in the longer time window, while the estimated gain in 4-year attendance is an even larger 18 percentage points. Gains in 4-year attendance are large enough to generate highly significant estimates, with confidence intervals well away from zero.

The gains in 4-year enrollment documented in table 7 are driven entirely by increases in attendance at public 4-year schools, with no effect

Table 7
Lottery Estimates of Effects on College Enrollment

	Within 6 Months		Within 18 Months	
	Noncharter Mean (1)	Effect (2)	Noncharter Mean (3)	Effect (4)
Any postsecondary enrollment	.497	.028	.596	.075
		(.066)		(.081)
2-year	.123	−.107**	.186	−.108*
		(.046)		(.061)
4-year	.374	.134**	.410	.183**
		(.064)		(.073)
4-year public	.143	.141***	.148	.145**
		(.053)		(.060)
4-year private	.231	−.007	.262	.038
		(.069)		(.081)
4-year Massachusetts public	.123	.121**	.126	.115**
		(.049)		(.057)
N		3,205		2,599

NOTE.—This table reports two-stage least squares estimates of the effects of Boston charter school attendance on college enrollment. Enrollment within 6 months (cols. 1 and 2) is defined as enrollment by the semester following a student's projected high school graduation, while enrollment within 18 months (cols. 3 and 4) is defined as enrollment within two fall semesters after projected graduation. The within 6 months enrollment sample includes students projected to graduate in 2012 or earlier. The within 18 months sample includes students projected to graduate in 2011 or earlier. The note to table 3 details the 2SLS models used to construct these estimates. Standard errors are shown in parentheses.
* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.

on private attendance. The last row of table 7 shows that most of this gain is generated by 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 (2014) argue that Adams Scholarship awards tend to reduce the selectivity of colleges chosen by many scholarship winners. We therefore estimated the effects of charter attendance on college selectivity as measured by Barron's rankings (not shown). College selectivity downgrading does not appear to be a consequence of charter attendance, perhaps because most of Boston's Adams scholarship recipients come from lower-income backgrounds. The Cohodes and 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 3 or 5 semesters. The samples available for such an analysis are necessarily smaller than those available to study college enrollment. Persistence results within 18 months of high school graduation, reported in table 8, suggest that charter attendance increases the fraction of students who attempt at least 3 academic semesters at 4-year schools by about 12 points, a marginally significant effect. The corresponding estimate in panel B, computed in a sample window that allows an additional year to elapse before measurement of the outcome, is smaller (6 percentage points) but less precisely estimated. Estimated effects on 5-plus semesters of enrollment are similarly imprecise.

Taken together, the estimates reported here show that charter high school attendance generates gains through college preparation and institutional choice as well as in short-run achievement. Figure 3 summarizes the relationship between short-run and long-run impacts. 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. As can be seen in panel A, SAT score gains track MCAS gains closely. Likewise, risk sets where score gains are larger also appear to generate larger 4-year enrollment effects, though here the relationship between impacts is looser than for the two test scores (shown in 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.

VI. Additional Results

A. Effects in Subgroups

Estimates of effects within subgroups pinpoint the characteristics of students who benefit most from charter attendance. This section briefly summarizes a large set of subgroup results reported in online appendix B. Results for most outcomes are similar for boys and girls. For example, estimates of effects on SAT scores and 4-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 (see, e.g., Anderson 2008; Angrist, Lang, and Oreopoulos 2009; Legewie and DiPrete 2012; Deming et al. 2014).

MCAS, SAT, and 4-year enrollment effects are larger for special needs students than for other applicants. Similarly, students with baseline scores below the sample median are more likely to gain from charter attendance than are high-scorers.[20] Effects on MCAS scores are somewhat larger for

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

Table 8
Lottery Estimates of Effects on College Persistence

	Any Postsecondary Enrollment		2-Year College Enrollment		4-Year College Enrollment	
	Noncharter Mean (1)	Effect (2)	Noncharter Mean (3)	Effect (4)	Noncharter Mean (5)	Effect (6)
A. Within 6, 18, and 30 months of expected high school graduation:						
One academic semester (N = 3,205)	.497	.028	.123	−.107**	.374	.134**
		(.066)		(.046)		(.064)
Three academic semesters (N = 2,599)	.367	.105	.067	−.018	.300	.123*
		(.073)		(.040)		(.069)
Five academic semesters (N = 1,887)	.299	.005	.048	−.006	.251	.011
		(.078)		(.032)		(.071)
B. Within 18, 30, and 42 months of expected high school graduation:						
One academic semester (N = 2,599)	.596	.075	.186	−.108*	.410	.183**
		(.081)		(.061)		(.073)
Three academic semesters (N = 1,887)	.473	−.018	.125	−.080	.348	.062
		(.081)		(.049)		(.078)
Five academic semesters (N = 1,382)	.376	.068	.088	−.009	.287	.077
		(.103)		(.061)		(.106)

Note.—This table reports two-stage least squares estimates of the effects of Boston charter attendance on college persistence. Panel A shows estimates of effects on the probability of attempting one, three, or five academic semesters on time, that is, in the minimum possible time given a student's projected high school graduation date. Panel B shows a set of estimates computed in a sample that allows an additional year to elapse before measurement of the outcome. The note to table 3 details the 2SLS models used to compute these estimates. Standard errors are shown in parentheses.
* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.

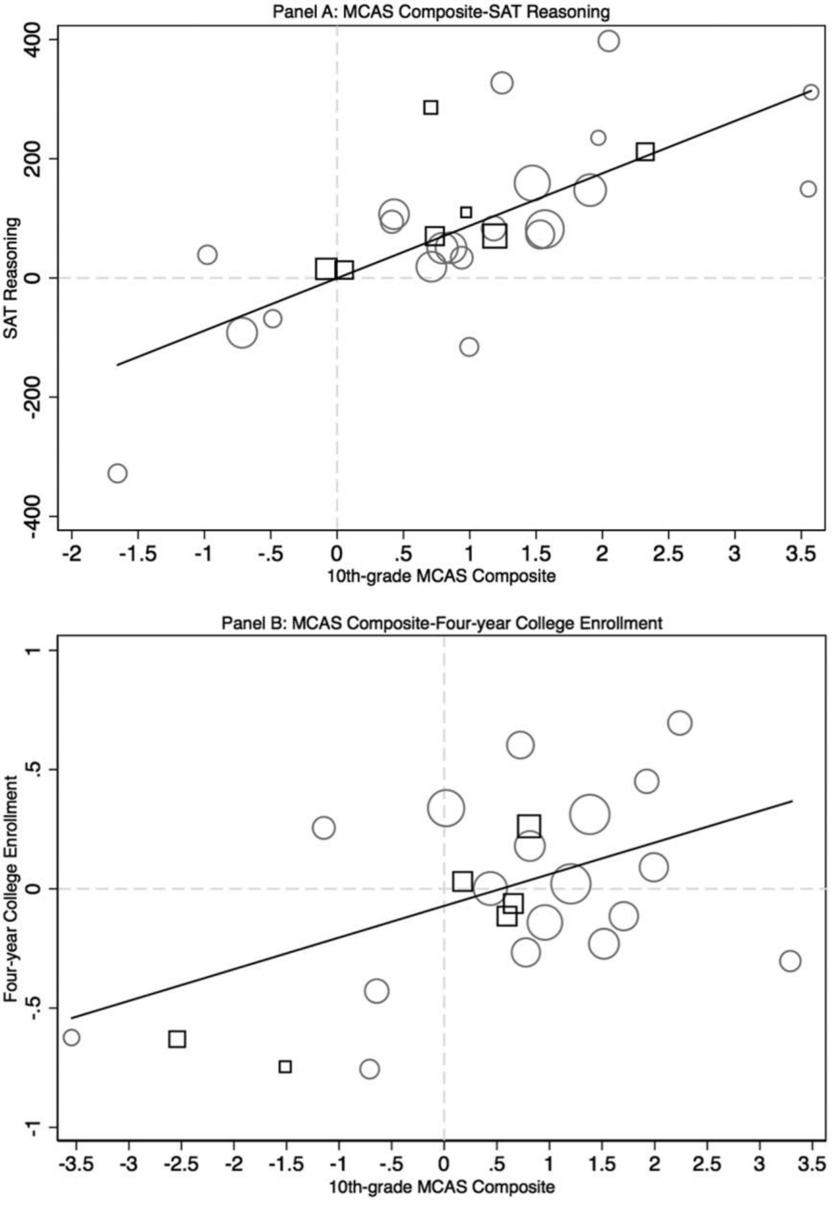

FIG. 3.—Comparisons of lottery estimates of effects on earlier and later outcomes. This figure plots within-risk-set lottery estimates of the effects of charter school attendance. Panel *A* plots effects on SAT Reasoning (verbal and math) against effects on MCAS composite scores. Panel *B* plots effects on the probability of enrollment in a 4-year college within 6 months of projected graduation against effects on MCAS composite scores. The sample in panel *A* includes students projected to graduate between 2007 and 2013, while the sample in panel *B* includes students projected to graduate between 2006 and 2012. Samples in both panels are further restricted to students with available data for both outcomes. Circles indicate risk sets in which students applied to one school, while squares indicate risk sets in which students applied to two. Marker sizes are proportional to the inverse of the standard errors of the MCAS estimates. Estimates for a given risk set use the instrument (immediate or ever offer) with the larger first-stage t-statistic. The sample excludes risk sets with first-stage t-statistics less than 1. Lines show weighted least squares regressions with weights inversely proportional to standard errors. The slopes are 87.9 (SE = 16.9) for the SAT plot and 0.133 (SE = 0.053) for the 4-year enrollment plot.

below-median students, and the effect on composite SAT scores is also larger for the lower-scoring group. The effect of charter attendance on 4-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 comes from an increase in the overall rate of college enrollment rather than a shift from 2-year to 4-year institutions.

The subgroup analysis shows a less consistent pattern by poverty status (as proxied by qualification for a subsidized lunch), with the disadvantaged group gaining more in college enrollment and AP-taking but less on the SAT. This finding is notable given recent evidence that apparently college-ready poor students often choose not to attend 4-year institutions (Bowen, Chingos, and McPherson 2009; Hoxby and Avery 2012). Overall, 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.[21]

B. The Peer Channel

Charter schools are sometimes said to generate gains by the selective retention of higher-performing students (see, e.g., 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 the charter school. 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 are encouraged to leave. While not invalidating the evidence of gains reported here, this peer channel has different policy implications than other explanations of charter effectiveness, such as differences in teacher quality or training.

[21] In addition to looking at heterogeneity in effects across subgroups of students, we also asked whether the results are driven by any one charter school. Online appendix table B3 reports estimates for key outcomes in samples that drop data for one school at a time. The results are similar across samples, suggesting that the overall results are not due to the performance of any one school.

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 application. As shown in panel B, column 1, of table 9, Boston's charter lottery applicants are highly mobile: more than 40% 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 2 percentage points, though this change is not significantly different from zero. The switching estimate increases to roughly 9 percentage points, again not significant, 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 A 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 effect here is roughly 0.19σ in each subject. This composition effect would be even larger if not for the fact, documented in the last row of panel B, 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 A also shows, however, that the positive effect of charter attendance on peer quality falls through high school: peer composition effects shrink as students progress through school and are not significantly different from zero after the second 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.[22] Figure 4 documents a large initial gap in favor of lottery winners. This gap 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 positive charter effects cannot be attributed to low-quality peers leaving charter schools. If anything, selective

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

Table 9
Lottery Estimates of Effects on School Switching and Peer Quality

	First Year after Lottery		Second Year after Lottery		Third Year after Lottery		Fourth Year after Lottery	
	Noncharter Mean (1)	Effect (2)	Noncharter Mean (3)	Effect (4)	Noncharter Mean (5)	Effect (6)	Noncharter Mean (7)	Effect (8)
A. Peer quality:								
Peer baseline ELA	−.417	.188***	−.353	.137**	−0.295	.081	−.276	.048
		(.061)		(.064)		(.064)		(.060)
Peer baseline math	−.414	.193***	−.349	.139**	−.284	.116*	−.264	.066
		(.067)		(.069)		(.062)		(.064)
Peer baseline sum of ELA and math	−.815	.368***	−.688	.277**	−.567	.197	−.528	.111
		(.125)		(.129)		(.123)		(.120)
N		3,841		3,881		3,557		3,467
B. School switching:								
Any switch	.403	.019						
		(.072)						
N		3,772						
Switch excluding transitional grades	.365	.086						
		(.071)						
N		3,758						
Ever attend an exam school	.162	−.084**						
		(.036)						
N		3,920						

NOTE.—This table reports two-stage least squares estimates of the effects of Boston charter attendance on school switching and peer quality. The sample includes applicants projected to graduate between 2006 and 2013. The any switch outcome indicates students observed in two or more schools at any time after the lottery. Transitional grades are excluding by omitting switches after the first school's exit grade. Peer quality is measured as the average baseline score of other students in the same school and year. The note to table 3 details the 2SLS models used to compute these estimates. Standard errors are shown in parentheses.
* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.

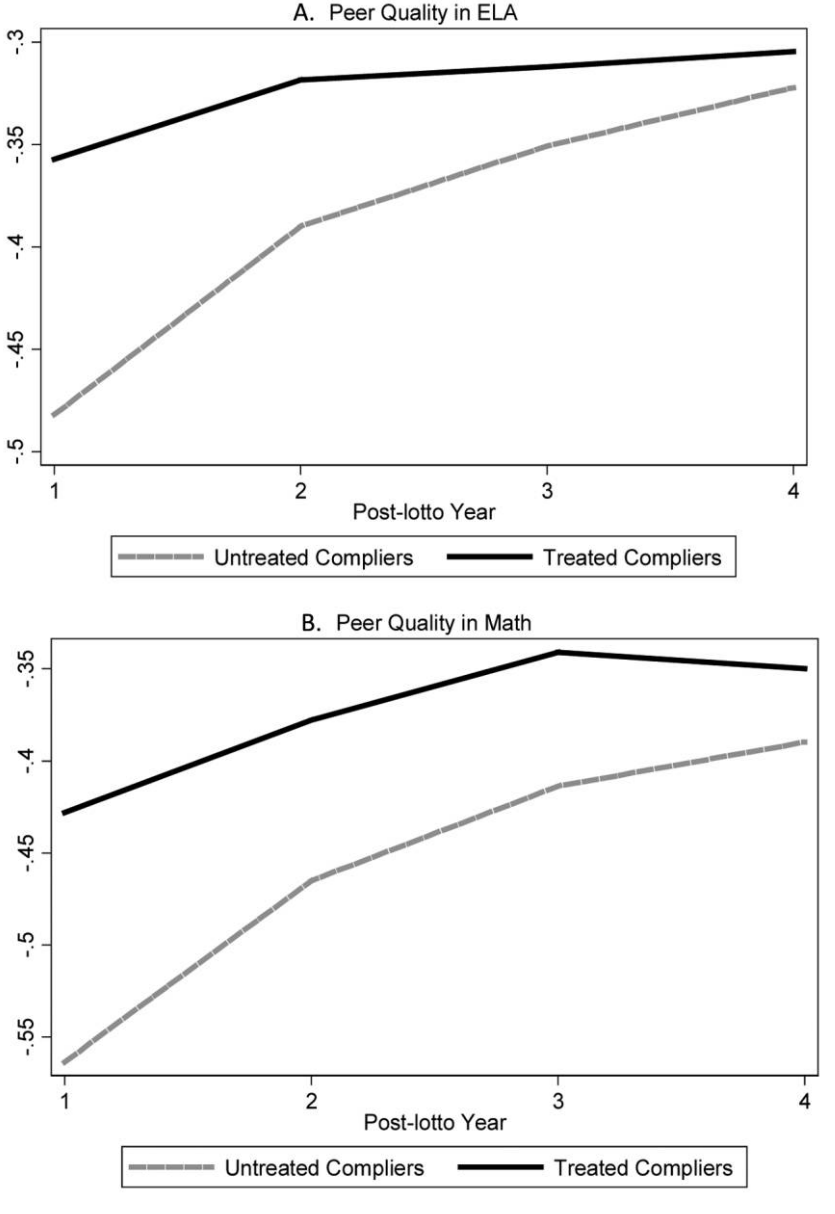

FIG. 4.—Peer quality for charter lottery compliers. This figure plots mean peer quality in the first, second, third, and fourth years after the lottery for treated and untreated charter lottery compliers. The sample includes lottery applicants who are projected to graduate between 2006 and 2013. Peer quality is measured as the average baseline score for other students in the same school and year.

exit of low achievers is more pronounced at Boston's traditional public schools.[23]

VI. Conclusion

This paper uses randomized admission lotteries to ask whether Boston's charter high schools affect outcomes beyond the standardized tests that are used for statutory accountability reviews and charter renewal. Charter schools may be particularly likely to "teach to the test," since they are at risk of closure if their students score poorly. We therefore estimate charter effects on high school graduation, college attendance, and college choice, outcomes that are more clearly linked to long-term economic well-being than state assessments. We also look at performance on SAT and Advanced Placement subject exams, assessments not directly involved with accountability that might also be connected with postsecondary gains. Our estimates suggest that Boston's charters improve educational outcomes in many domains.[24]

Charter attendance has no clear effect on high school graduation, though charter students take slightly longer to complete their degrees. Charter attendance also has no statistically significant effect on the overall likelihood of college enrollment, but it shifts students away from 2-year institutions and toward 4-year colleges. The shift toward 4-year colleges is consistent with the substantial gains in college readiness seen for charter students. In particular, charter attendance more than doubles the likelihood of sitting for an Advanced Placement exam, with especially large effects on the likelihood of taking and passing AP Calculus. This finding is noteworthy since very few poor nonwhite students in Boston (or other urban areas) take and pass AP Calculus.

Charters significantly increase SAT scores, with charter students scoring a third of a standard deviation higher than students in Boston's traditional public schools. Charter attendance also increases the probability that students pass the score thresholds for high-stakes exams required for high school graduation and boosts the likelihood that students qualify for an exam-based public college scholarship. Boston's charter high schools seem

[23] 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 online appendix table B5. 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 1.8 and 2σ. This peer multiplier is implausibly large relative to peer effects estimated elsewhere, including Hoxby (2000) (0.3–0.5σ), Hanushek et al. (2003) (0.15–0.24σ), and other studies summarized in Sacerdote (2011)'s recent survey.

[24] Also weighing against the "teaching to the test" hypothesis, Cohodes (2015) reports no difference in effects on frequently and infrequently tested MCAS item areas for a sample of Boston middle school charters.

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 looked briefly at charter attendance effects on school switching and peer composition. Charter students have somewhat higher baseline test scores than other Boston students. At the same time, we see that charter attendance does not produce increasingly favorable selection of peers. In fact, charter peers become more like peers at traditional public schools as students progress through high school because attrition for weak students is even more pronounced in the traditional public sector. It therefore seems unlikely that changes in peer composition are the primary driver of our findings.

A final important result is the correlation between gains on state-mandated assessments and gains elsewhere. While MCAS scores may not be of intrinsic interest, schools that tend to boost these also tend to increase SAT scores and 4-year college enrollment. In other words, causal effects on MCAS scores appear to predict effects that may be more closely tied to human capital and earnings.

As a caveat, it is worth noting that our results apply to charter lottery applicants, a group that may differ from nonapplicants. In addition, our estimates may not reflect the effects of expanding the number of seats in Boston's charter sector, which depend on the supply of teachers and other inputs, as well as potential effects of changes in peer mix for students who remain in traditional public schools. The estimates reported here show gains for recent cohorts of charter applicants. As these cohorts continue to progress through college and enter the labor market, we plan to use our lottery-based research design to determine whether the effects reported here extend to college completion, employment, and earnings.

Appendix A

Data Appendix

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 High, Codman Academy, and City on a Hill, were conducted for entry to ninth grade; two schools, Boston Preparatory and Academy of the Pacific Rim, held lotteries for sixth-grade entry. Records for Boston Collegiate are from fifth-grade entry lotteries.

The raw lottery records typically include applicant 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 *immediate offer* instrument captures offers made on the day of the charter school lottery. The *waitlist offer* instrument captures offers made 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 immediate offer instrument contributes to the analysis; these cases are listed as "Exhausted" for the waitlist offer instrument. As documented in table 2, immediate and waitlist offer rates were 31% and 35%, respectively, 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 2001–2 school year through the 2012–13 school year. 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, gender, race, special education and limited English proficiency status, free or reduced-price lunch receipt, 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 a Massachusetts public school. 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% 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 ninth or tenth grade. A student is coded as attending a charter in his or her ninth-grade or tenth-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 2001–2 school year through the 2012–13 school year. Each observation in the MCAS database corresponds to a student's 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 fourth grade or eighth grade depending on a student's 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 (DESE) by the College Board. The AP and SAT files include scores on all AP exams and SAT tests for graduation cohorts 2007 and 2013; for students 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.

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 five separate searches of the NSC database:

- A 2010 search for all students in the SIMS database between 2002–9 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 2003–10
- A 2013 search of students who graduated from Massachusetts public high schools in the classes of 2003–12
- A 2013 search of all students in the charter applicant sample with the projected graduation between 2006–13

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% (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 1 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% of charter applicants. Of the remaining 4,711 charter applicants, 3,685 (78%) contribute a score to our MCAS ELA analysis.

Table A1
Lottery Records

	A. Sample Restrictions by Projected Senior Year								
	2006	2007	2008	2009	2010	2011	2012	2013	All
Total number of records	600	450	940	883	1,117	1,533	1,753	1,980	9,256
Excluding disqualified applicants	600	450	940	883	1,117	1,530	1,753	1,968	9,241
Excluding late applicants	590	446	930	880	1,117	1,530	1,733	1,968	9,194
Excluding applicants from out of area	590	446	930	880	1,114	1,529	1,733	1,950	9,172
Excluding siblings	570	437	905	864	1,101	1,482	1,642	1,850	8,851
Excluding records not matched to the SIMS	509	419	858	816	1,055	13,95	15,47	1,743	8,342
Reshaping to one record per student-year	437	419	632	594	799	1,025	1,100	1,273	6,279
Excluding repeat applications	437	419	629	589	778	1,004	1,028	1,164	6,048
In Boston schools at baseline	289	337	511	481	607	850	761	875	4,711
Excluding applicants without tenth-grade ELA	232	267	415	378	482	664	571	676	3,685

Application Year	Acceptance Status	Boston Preparatory	Academy of Pacific Rim	Boston Collegiate	City on a Hill	Codman Academy	Match
B. Immediate and Waitlist Offer Records by School and Cohort							
Entry grade:		6	6	5	9	9	9
2002	Immediate	Not open	No records	Yes	Exhausted	No records	Yes
	Waitlist			Yes	Yes		Yes
2003	Immediate	Not open	No records	Yes	No records	No records	Yes
	Waitlist			Yes			Yes
2004	Immediate	Incomplete records	No records	Yes	Exhausted	Yes	Yes
	Waitlist			Yes	Yes	Exhausted	Yes
2005	Immediate	Yes	Yes	Yes	Yes	Incomplete records	Yes
	Waitlist	Exhausted	Yes	Yes	Yes		Yes
2006	Immediate	Yes	Yes		Yes	Incomplete records	Yes
	Waitlist	Yes	Yes		Yes		Yes
2007	Immediate	Too young for follow-up			Yes	No records	Yes
	Waitlist				Yes		Yes
2008	Immediate				Yes	Yes	Yes
	Waitlist				Exhausted	Yes	Yes
2009	Immediate				Yes	Yes	Yes
	Waitlist				Yes	Yes	Yes
N		211	180	267	1,867	144	2,326

NOTE.—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, "Exhausted" indicates that every applicant eventually received an offer. "Yes" means that lottery records with nonmissing information 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 offers. The last row shows the number of applicants to each school in the lottery sample excluding applicants without tenth-grade ELA scores. Cohorts are too young for follow-up if they do not 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 immediate offers using 2008 City on a Hill and 2007 Match immediate offer cutoffs. Starting in 2006, Academy of Pacific Rim has operated grades from 5 to 12.

Table A2
Matching School Lottery Data to SIMS

Projected Senior Year	Number of Applicants (1)	Sample Mean (2)	Immediate Offer (3)	Waitlist Offer (4)
2006	570	.912	−.016	.034
			(.023)	(.027)
2007	437	.959	−.006	−.007
			(.025)	(.028)
2008	905	.950	.000	−.002
			(.007)	(.019)
2009	864	.944	−.001	.005
			(.005)	(.018)
2010	1,101	.959	−.004	.024**
			(.003)	(.012)
2011	1,482	.941	−.007***	.043***
			(.003)	(.014)
2012	1,642	.942	−.008***	.056***
			(.002)	(.012)
2013	1,850	.942	−.003**	.026**
			(.001)	(.011)
All cohorts	8,851	.944	−.002	.028***
			(.006)	(.006)

NOTE.—This table summarizes the match from the lottery records to the Student Information Management System (SIMS) administrative data. The sample excludes disqualified applicants, late applicants, out-of-area applicants, and siblings. Columns 3 and 4 report coefficients from regressions of an indicator for a successful SIMS match on immediate and waitlist offer dummies. The immediate offer dummy is equal to one when a student is offered a seat in any charter school immediately following the lottery, while the waitlist offer dummy is equal to one for students offered seats later. All regressions include risk set dummies. Standard errors are shown in parentheses.

** Significant at the 5% level.

*** Significant at the 1% level.

Table A3
Attrition

Projected Senior Year	A. Follow-up Rates				B. Attrition Differentials by Offer Status					
					ELA		Math		Observed in Grade 12	
	Either Math or ELA (1)	ELA (2)	Math (3)	Observed in Grade 12 (4)	Immediate Offer (5)	Waitlist Offer (6)	Immediate Offer (7)	Waitlist Offer (8)	Immediate Offer (9)	Waitlist Offer (10)
2006	.803	.803	.803	.747	.021	.031	.021	.031	−.046	.069
					(.047)	(.053)	(.047)	(.053)	(.051)	(.062)
2007	.795	.792	.789	.774	.038	−.063	−.017	−.036	−.007	.017
					(.096)	(.066)	(.105)	(.065)	(.100)	(.062)
2008	.820	.812	.800	.765	.076*	−.037	.063	−.037	.027	−.017
					(.040)	(.043)	(.042)	(.045)	(.045)	(.049)
2009	.794	.786	.771	.765	.030	−.060	.029	−.046	.010	−.050
					(.042)	(.042)	(.043)	(.043)	(.043)	(.043)
2010	.797	.794	.784	.766	.042	−.008	.040	−.014	.007	−.031
					(.039)	(.040)	(.039)	(.041)	(.043)	(.042)
2011	.785	.781	.759	.751	−.049	.041	−.059	.050	.005	.047
					(.038)	(.032)	(.039)	(.033)	(.038)	(.034)
2012	.757	.750	.744	.745	.036	−.022	.037	−.013	.028	−.015
					(.036)	(.036)	(.036)	(.036)	(.036)	(.036)
2013	.775	.773	.759	.744	−.011	−.018	−.018	−.005	−.018	−.029
					(.032)	(.034)	(.033)	(.034)	(.033)	(.035)
All Cohorts	.787	.782	.770	.755	.014	−.010	.008	−.002	.000	−.004
					(.014)	(.014)	(.015)	(.015)	(.015)	(.015)

Note.—This table summarizes attrition for tenth-grade MCAS scores and twelfth-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 twelfth-grade records in the SIMS administrative database. Columns 5–10 report coefficients from regressions of indicators for follow-up data on immediate and waitlist offer dummies. Regressions also control for risk set dummies. Standard errors are shown in parentheses. $N = 4{,}711$.
* Significant at the 10% level.

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