

# Charter School Demand and Effectiveness

A Boston Update

Prepared for  
**The Boston Foundation**  
and  
**NewSchools Venture Fund**

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## Preface

Boston charter schools have had many reasons to tout their performance in 2013. Research reports and MCAS scores have shown exceptional progress by charter students. But while we were buoyed by these findings, the Boston Foundation and NewSchools Venture Fund sought to better understand in more detail not only how well charters are working, but for whom.

The answer—or at least the beginnings of it—is described in this report by a team of researchers from MIT’s School Effectiveness and Inequality Initiative (SEII). This is the third in a series of studies examining charter and Boston Public Schools (BPS) student performance. The first, released in 2009, was groundbreaking in its use of individual student data, its research design—which incorporated an observational study—and a lottery analysis. The second report, released in May 2013, examined Boston’s charter high schools and found gains in their students’ MCAS, Advanced Placement and SAT scores compared to their peers in the Boston Public Schools.

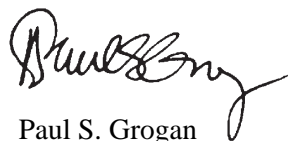
This report updates the 2009 study and uses a similar methodology. It examines the performance of all students enrolled in Boston’s charter schools as well as that of important subgroups of high-needs students, including those whose first language isn’t English or who have special needs. Importantly, this report also examines demand and enrollment patterns and finds a changing student population that includes more of these subgroups.

Like earlier studies, this report finds that attending a charter school in Boston dramatically improves students’ MCAS performance and proficiency rates. The largest gains appear to be for students of color and particularly large gains were found for English Language Learners.

At the same time, it is important to note that the analysis showed that charter school students are less likely to have special needs or to be designated as English Language Learners. While that gap has narrowed since the passage of education reform in 2010, the charters’ success with high-needs students should provide an even greater impetus to connect those student populations with charter schools.

In addition, the research team found that charter schools continue to be a popular option for Boston families. As the number of available seats grows, so too does the number of applicants. Nonetheless, the report finds that the odds of receiving a charter offer are roughly comparable to a student receiving his or her first choice through the BPS school-assignment process.

Readers of this report will draw many different conclusions, but the takeaway for us is clear: charters work for their students. It’s not only evident that we need more of these schools, but we must also redouble our efforts to ensure that students who have the most to gain are afforded greater access to them.



Paul S. Grogan  
President and CEO  
The Boston Foundation

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## CHAPTER ONE

### Introduction

#### A Changing Charter School Landscape

In January 2010, Governor Patrick signed *An Act Relative to the Achievement Gap* into law in Massachusetts. An ambitious piece of education legislation, several of its provisions focused on charter schools. Specifically, the Act increased the cap for charter schools in the 10 percent of lowest performing districts in the state from 9 percent to 18 percent of a district's annual budget, by allowing "proven providers" to start new schools or expand enrollment. The law also required all charter operators to create recruitment and retention plans for high-need students and to fill vacancies caused by student attrition in each school's lower grade levels. The law further allowed school districts to create up to 14 "in-district" (Horace Mann) charters, without prior approval from the local teachers' union.

The 2010 Act is the most substantive update to date of the Massachusetts Education Reform Act of 1993, which established the Massachusetts Comprehensive Assessment System (MCAS) and permitted the opening of charter schools in Massachusetts. In Massachusetts, charter schools are public schools authorized by the state and free of local district control and local collective-bargaining agreements. Charter schools are exempt from certain state laws and regulations, especially those governing teacher certification and tenure, and in exchange for this flexibility, are subject to additional accountability requirements. Charter schools must meet the terms of their charter and are subject to periodic review by the state to ensure that they do so. Charter schools that fail to meet state standards are subject to closure by the Board of Elementary and Secondary Education. If more students apply to charter than there are seats available, charters must hold a lottery to determine admission. Other than factors like sibling status and town of residence, there is no preferential treatment of student groups in the lottery.

Many factors spurred along the 2010 Act, including the national Race to the Top competition, but also a January 2009 report, *Informing the Debate*, sponsored by the Boston Foundation and the Massachusetts Department of Elementary and Secondary Education and authored by some of the members of this research team. That report showed large test score gains for students in Boston charter schools. Nearly three years since the passage of the law, this report revisits some of the original questions asked about charter schools in 2009 and goes beyond that work to investigate questions around charter school demand and attendance.

This new report was produced under the auspices of MIT's School Effectiveness and Inequality Initiative (SEII), using the same data sources and empirical methods as used for the 2009 report, but adding additional schools and more research questions. We have collected lottery records from a majority of charter schools in Boston, and the lottery sample of charter schools now covers 87 percent of charter school enrollment. This study also follows a May 2013 report from The Boston Foundation, NewSchools Venture Fund and SEII, *Charter Schools and the Road to College Readiness*, which found charter school gains on SAT, AP, and four-year college enrollment. All three reports rely on charter school admissions lotteries to make "apples to apples" comparisons that capture the causal effect of charter attendance. As in the 2009 report, we also include "non-lottery" estimates of charter school test score effects which are less rigorous than the lottery-based comparisons but include all of the charter schools in Boston. However, we have greatly improved coverage of charter schools in the lottery sample, making the non-lottery results less pertinent. We also add an examination of demand for charter schools.

How is this report different from past research?

To begin, we focus on applications to charter schools. While much attention has been focused

on charter school waitlists,<sup>i</sup> waitlist data can be misleading. It includes duplicates, but also includes waitlists that have been rolled over from year to year and might be an unrealistic measure of demand. Instead, we investigate three factors related to demand: the yearly percentage of each middle school and high school class that applies to a charter in our lottery sample; the percentage of applicants that receive an offer from a charter school; and where students ultimately attend. We also examine the demographic makeup of charter school enrollees and compare it to BPS.

We follow the path of charter school students and report their performance in charters using the evidence from the lotteries. The lottery sample now covers many more charter schools. The 2009 report included findings from eight schools. We now have MCAS results through 2012 from 12 schools and many more cohorts from the original schools, with additional newly opened schools contributing to the demand analysis. In addition to updating the test score results from the 2009 report, this report breaks down the test score effects by student subgroups. We investigate trends over time in charter performance and by school groups.

Finally, we report results using statistical controls, which allow us to estimate effects for attending charter schools that do not have sufficient lottery records for the more rigorous lottery based analysis. The lottery sample now contains almost all Boston charter schools with entry grades at middle or high school.

## Summary of Findings

*Demand:* Charter schools are a popular option in Boston. We track the percentage of 6<sup>th</sup> and 9<sup>th</sup> graders who applied to at least one charter school from school year 2009-2010 to school year 2012-2013 (the years for which we have consistent lottery records from Boston charters). Demand increased from about 15 percent of the 6<sup>th</sup> grade cohort applying for a charter school in 2009-10 to about 33 percent of the cohort applying to at least one charter school in 2012-13. The increase in application for 9<sup>th</sup> graders

was less dramatic. It increased from about 11 percent of the cohort applying to 15 percent in the same time period. The city of Boston added many more charter school seats in this period, but most additional seats are at the middle school level.

Over this same time period, applications per student increased, with more students applying to multiple schools. This increase in charter applications outstripped the increase in the number of seats, so that applicants per seat available increased from about 2 applicants per seat to 3 applicants per seat in middle school and from about 3 to 4 applicants per seat in high school.

While many students apply to Boston charters, a majority of applicants are offered a seat at one of the charter schools. Importantly, many of these offers do not occur on the night of the charter school lottery, but as late as the summer, as charter schools fill empty spots. About half of middle school students who apply are offered a seat. In high school, almost 70 percent of applicants are offered a seat. About two-thirds of charter middle school applicants and 40 percent of high school students who are offered a school seat accept it.

A comparison to Boston Public Schools helps to place these data in context. Through BPS, all Boston students and their families rank order their preferences for schools and a computer algorithm matches these preferences to the available seats to create a student assignment plan. In this plan, 68 percent of middle school students who submit preferences are offered their first choice school and 55 percent of high school students are offered their first choice school. These offer rates are similar to those for the charter schools, though a higher percentage of students take up the BPS offer at the high school level.

To summarize, we observe that while the number of charter seats has increased in Boston, so has the application rate, with more students applying to charters in recent years. A majority of students who apply to a charter are offered a seat, but that offer sometimes comes long after

the charter school lottery. Late offers may contribute to low acceptance rates, as many families have already accepted another option. The offer rate is generally similar to the BPS offer rate through the school assignment process.

*MCAS Performance:* The results reported here show that the causal impact of attending a year at a Boston charter school is large and positive in both subjects and both school levels. A year of attendance at a middle school increases test scores by about 0.25 standard deviations (henceforth referred to by the Greek letter sigma,  $\sigma$ ) in math and  $0.14\sigma$  in English/language arts (ELA). In high school, the impacts are  $0.25\sigma$  in math and  $0.27\sigma$  in ELA per year of attendance. These impacts translate into large one-year gains in student proficiency, as measured by the state exam. The positive per-year charter effect on middle school proficiency rates was 12 percentage points in math and 6 percentage points in English. At high school the per-year charter effect was approximately 10 percentage points in both subjects. In high school, the charter effect on reaching the advanced level on the MCAS was especially high, with increases of 18 percentage points in math and 12 percentage points in English, per year of attendance. The results for cohorts applying since 2009 are similar to results covering all years. This is important because the Boston lottery sample now covers almost all operating charters in the city.

We examined the score results by student subgroups and find that gains are largest for minority students but smaller for white students. In middle school, gains are larger for students who score worse on their baseline exams. At both school levels, gains are particularly large for English language learners, though the sample in high school is too small for precise estimates.

We also report results for all charters using statistical controls. This non-lottery method controls for the background characteristics we can observe, like demographics and program participation, but cannot account for unobserved factors like motivation and interest in school choice, which are accounted for in the lottery method. Non-lottery results are consistent with the large MCAS gains for charters with lottery records. Charters without lottery records have either zero or small positive impacts. These schools include closed schools and a few schools with incomplete records from the relevant years. In particular, this analysis suggests that the closed charters, which make up most of the non-lottery sample, were poor academic performers.

Combining the results from the demand and MCAS analysis leads to an interesting conclusion: those who are most likely to succeed in Boston charter schools are the least likely to enroll in them, especially in middle school.



## CHAPTER TWO

### Data and Sample

#### School Selection

We selected the sample for our study with the goal of including as many middle and high school Boston charters as possible. Schools are classified as middle schools if they serve grades six through eight; high schools serve grades nine through twelve. We excluded schools that admit students in kindergarten, since pre-application student characteristics (an integral part of our analysis) are not available for these schools. The key factors determining whether we can study a school are the availability and quality of its admission lottery records. Charter schools run lotteries to admit students and create waitlists whenever there are more applicants than available seats. These lottery records allow us to accurately measure application rates and estimate charter attendance effects.

We attempted to collect lottery records for Boston charter schools operating between 2002-2003 and 2011-2012. As shown in **Appendix Table A1**, a large majority of Boston charters held admission lotteries during this period and were able to provide records. During the early part of our sample (2003 to 2009), the study covers 7 of 10 charter middle schools and 6 of 9 charter high schools. Three of the 6 excluded schools have closed, which prevented us from obtaining their records. Our sample coverage is even more complete from 2010-2012: we include 9 of 11 middle schools and 7 of 8 high schools during this period. Moreover, records from one of the two missing middle schools have been collected, and will be used in a future analysis. Among currently operating charter schools eligible for the study, only one middle school and one high school failed to provide adequate records.

**Appendix Table A2** summarizes lottery records for the schools covered by the study. Most schools do not contribute lottery records to the

study every year; some schools were not open for part of the sample period, while others occasionally provided insufficient records. This table also differentiates between offers received on the day of a charter lottery (which we term *initial* offers) and offers received off the waitlist; we refer to offers received either initially or off the waitlist as *eventual* offers. Our demand analysis describes the frequency of both initial and eventual offers, while our analysis of MCAS effects uses eventual offers. Appendix Table A2 shows that some charters occasionally exhaust their waitlists, in which case every applicant receives an eventual offer.

#### Student Data

Our analysis uses state administrative data provided by the Massachusetts Department of Elementary and Secondary Education (DESE). The DESE database contains information on schools attended, student demographics, and MCAS test scores for all students in Massachusetts public schools. Demographic and attendance information is available for the 2001-2002 school year through the 2012-2013 school year, while MCAS scores are available from 2001-2002 through 2011-2012.

We matched lists of charter applicants to state administrative data provided by the Massachusetts Department of Elementary and Secondary Education (DESE). Charter applicants were matched to the DESE database based on name, year, and application grade. Ninety-five percent of applicants eligible for the study were matched to the state data. Our demand analysis uses information for all Boston charter applicants who attended a Boston public school or Boston-located charter at baseline (4<sup>th</sup> grade for middle school, 8<sup>th</sup> grade for high school). The sample for the MCAS analysis excludes siblings of current charter students, late applicants, some out-of-area applicants, and

other applicants disqualified from the lottery (usually students who applied to the wrong grade), since lottery offers for these groups are usually not randomly assigned. For more details on the sample construction and data sources, please see the **Data Appendix**.

Descriptive statistics for charter applicants, charter attenders, and the Boston Public Schools (BPS) district population are shown in **Table 1**. BPS statistics include all students who attended a Boston traditional public school, pilot, or exam school, excluding students outside Boston at baseline and those without follow-up test scores. Middle school statistics use data for 6<sup>th</sup> graders

between 2003 and 2012, while high school statistics are for 9<sup>th</sup> graders between 2003 and 2011.

Table 1 reveals that charter applicants and charter attenders are more likely to be African-American than BPS students. Charter students also have higher baseline test scores than students at BPS schools, and are less likely to have English language learner status. Middle school charter applicants are less likely than BPS students to have special education status or to be eligible for a subsidized lunch.

Table 1: Descriptive Statistics

	Middle school			High school		
	BPS Students (1)	Charter students (2)	Lottery applicants (3)	BPS Students (4)	Charter students (5)	Lottery applicants (6)
Female	48.2%	50.6%	49.3%	49.6%	56.2%	52.6%
African-American	41.4%	58.5%	51.0%	41.0%	63.3%	56.7%
Latino/a	34.9%	23.4%	27.6%	32.4%	18.6%	28.6%
Asian	8.5%	1.8%	2.8%	9.6%	1.8%	3.0%
White	12.2%	13.1%	14.1%	14.4%	12.8%	8.4%
Subsidized lunch	81.8%	67.9%	72.1%	70.1%	64.0%	72.1%
Special education	22.8%	15.4%	19.1%	17.6%	14.1%	17.7%
English language learner	20.2%	3.6%	11.4%	17.1%	2.0%	6.6%
% Proficient baseline math	17.9%	20.3%	24.4%	19.5%	27.5%	38.6%
% Proficient baseline ELA	24.5%	29.4%	31.8%	30.3%	43.9%	22.1%
N	44807	9254	6689	45436	4083	6716

Notes: This table shows descriptive statistics for Boston Public School (BPS), charter school, and lottery applicant students. BPS students includes students at traditional public schools, pilot schools, and exam schools and excludes students in charter schools and alternative schools. The sample is restricted to 5th or 6th grade middle school students from 2003 through 2012 and 9th grade high school students from 2003 to 2011 in BPS or a Boston charter. The sample further restricts to students in Boston at baseline and who have at least one outcome score. Charter students are those enrolled in a charter school. Lottery applicants are students for whom we have charter school application data.

## CHAPTER THREE

### Demand

#### Application, Enrollment, and Offer Rates

Our analysis of the demand for charter schools describes charter school application, enrollment, and offer rates in Boston. **Table 2** presents yearly snapshots of charter demand for the 2009-2010 school year through the 2012-2013 school year. During this time period, our charter lottery coverage is nearly complete: the charters in our study account for 87 percent of Boston's 6<sup>th</sup> and 9<sup>th</sup> grade charter enrollment between 2009 and 2013.<sup>ii</sup> This allows us to paint an accurate picture of the demand for charter schools and its evolution over time.

Measuring charter application rates is complicated by the fact that charter schools have different entry grades, so students have multiple chances to apply. At the middle school level, some schools accept students primarily in 5<sup>th</sup> grade, while others admit students in 6<sup>th</sup> grade. We study demand for middle schools by focusing on students attending 6<sup>th</sup> grade in a particular year, and define charter application rates retrospectively: if a 6<sup>th</sup> grader applied to either a 5<sup>th</sup> grade entry charter or a 6<sup>th</sup> grade entry charter before entering 6<sup>th</sup> grade, she is counted as a charter applicant. In high school, we focus on 9<sup>th</sup> graders and look at applications for entry into 9<sup>th</sup> grade. Importantly, this means that charters with 5<sup>th</sup> or 6<sup>th</sup> grade entry points that also serve 9<sup>th</sup> graders are included in the middle school demand analysis, but not the high school analysis.

Table 2 shows that charter schools are a popular option for Boston middle and high school students. In the 2009-2010 school year, 15 percent of Boston 6<sup>th</sup> graders applied to a charter middle school, and 7 percent enrolled in a charter. There were therefore 2.1 applicants for each available charter seat. Most charter applicants submitted a single application; 29 percent submitted more than one, and the

average applicant applied to 1.4 schools. In the same year, 11 percent of 9<sup>th</sup> graders applied to a charter, and 4 percent enrolled in one, yielding a rate of 3.1 applicants per charter seat. Multiple high school applications are more common: around half of high school applicants submitted more than one application, and the average applicant applied to 1.6 schools.

Over the time period we study, the number of available middle school charter seats expanded. Specifically, the share of Boston 6<sup>th</sup> graders enrolled in charters increased from 7 percent in the 2009-2010 school year to 11 percent in 2011-2012 and 2012-2013. This increase in charter capacity is due to the opening of UP Academy Charter School, the Roxbury Preparatory Lucy Stone Campus (formerly Grove Hall Preparatory), and Edward Brooke Mattapan, which opened for the 2011-2012 year; the latter two schools initially admitted 5<sup>th</sup> graders, serving their first classes of 6<sup>th</sup> graders in 2012-2013. In high school, Boston Green Academy opened for 2011-2012, but Match Charter High School stopped accepting applicants in 9<sup>th</sup> grade (as graduates from Match's new middle school began enrolling in the Match high school). The share of 9<sup>th</sup> graders applying to 9<sup>th</sup> grade entry charters therefore stayed at around 4 percent throughout our study period.

As charter capacity expanded, the application rate also increased. Table 2 shows that the share of 6<sup>th</sup> graders applying to charters more than doubled over our study period, reaching 33 percent in 2012-2013. This increase outstripped the expansion of charter seats, so that the number of applicants per seat increased from 2.1 to 3. The 9<sup>th</sup> grade charter application rate also increased from 11 percent to 15 percent despite no increase in available high school seats. This boosted the number of high school applications per seat to 3.9 in 2012-2013.

Table 2: Charter School Application, Offer and Attendance Rates

	2009-2010	2010-2011	2011-2012	2012-2013	All (2010-13)
	(1)	(2)	(3)	(4)	(5)
<i>Panel A: Middle school (Applying for 5th or 6th grade)</i>					
Percentage of Boston 6th graders applying to a charter	14.8%	14.3%	31.1%	32.9%	23.5%
Percentage of Boston 6th graders attending a charter	7.0%	6.1%	11.1%	11.0%	8.8%
Percentage of applicants applying to more than one	28.7%	25.3%	45.5%	43.8%	39.1%
Average number of applications for applicants	1.40	1.35	1.75	1.76	1.64
Applicants per charter seat	2.10	2.35	2.80	2.99	2.65
Percentage of applicants eventually offered a seat	66.4%	55.5%	50.7%	40.6%	50.1%
Percentage of admitted applicants attending a charter	65.8%	68.6%	62.6%	63.0%	64.4%
	N 4474	4456	4502	4785	18217
<i>Panel B: High school (Applying for 9th grade)</i>					
Percentage of Boston 9th graders applying to a charter	11.1%	11.1%	14.8%	15.3%	13.0%
Percentage of Boston 9th graders attending a charter	3.6%	3.6%	4.4%	3.9%	3.9%
Percentage of applicants applying to more than one	49.3%	52.3%	54.8%	56.4%	53.5%
Average number of applications for applicants	1.58	1.75	1.73	1.83	1.73
Applicants per charter seat	3.10	3.04	3.37	3.92	3.37
Percentage of applicants eventually offered a seat	69.4%	57.1%	60.9%	84.0%	68.9%
Percentage of admitted applicants attending a charter	44.5%	53.4%	40.3%	29.7%	39.6%
	N 4849	4592	4460	4784	18685

Notes: This table shows charter school application, offer, and attendance rates by cohort. Cohorts are defined using 6th grade year for middle school and 9th grade year for high school. The sample includes 6th graders from 2010 through 2013 in Panel A and 9th graders from 2010 through 2013 in Panel B. All statistics refer to charter schools for which we have lottery data. This definition covers 87% of charter enrollment in both middle and high school from 2010 to 2013.

Despite large and rising ratios of charter applicants to seats, however, a majority of applicants to Boston charter schools received offers during our study period. The definition of offers used here includes both initial offers and waitlist offers. Between 2009-2010 and 2012-2013, slightly over 50 percent of middle school charter applicants were eventually offered seats, while 69 percent of high school applicants received eventual offers. The middle school offer rate fell over time, from 66 percent in 2009-2010 to 41 percent in 2012-2013, while the high school rate stayed roughly constant over this period.

In part, these high offer rates reflect relatively low charter offer take-up rates, especially in high school. About two-thirds of admitted middle school applicants choose to attend a charter school. In high school, only 40 percent of admitted applicants choose to attend a charter. These low take-up rates may be due to the fact that many applicants receive waitlist offers well after the charter lottery, when they have already made plans to attend other schools. Other admitted applicants may prefer to attend one of the many additional school options available in Boston, including exam schools and private

schools. We next explore charter offers and alternative school choices in more detail.

### Offer and Take-up Rates in Charter Schools and BPS Schools

To benchmark charter offer and take-up rates, we compare these rates to corresponding rates for the Boston Public Schools (BPS) school assignment mechanism. Boston students in transitional grades (6<sup>th</sup> and 9<sup>th</sup>) submit school preference lists to BPS, and the district uses these lists to generate a school assignment for each student. **Table 3** describes the likelihood that a student receives her first choice in this process. We use data on school assignments for students who submitted preferences indicating a desire to switch schools between 2008 and 2012, excluding students who indicated preferences for some pilot schools not assigned through the mechanism. As in the charter analysis, we differentiate between initial offers received in the first assignment round, and waitlist offers received in subsequent rounds.

Table 3 shows that the odds of receiving a charter offer are roughly comparable to the chances of receiving a first-choice assignment in

the BPS process. The BPS first-choice offer rate is somewhat higher than the charter offer rate in middle school (68 vs. 55 percent), and lower in high school (55 vs. 70 percent). (Numbers here are slightly different than those in Table 2 since we use 6<sup>th</sup> grade entry charters and a different set of years to match to the BPS process.) A smaller fraction of BPS offers come from the waitlist. Roughly half of charter middle school offers are waitlist offers, while 72 percent (50/70) of charter high school offers come from the waitlist. In the BPS mechanism, 9 percent (6/67) and 17 percent (9/55) of offers are distributed to waitlisted students in middle and high school.

Offer take-up rates are lower in charter schools than in the BPS mechanism. Three-fourths of BPS students accept offers to attend their first-choice schools, compared to 60 percent in charter middle schools and 30 percent in charter high schools. These differences are partly explained by the higher frequency of waitlist offers in charter schools, since charter applicants are less likely to accept waitlist offers than initial offers. However, the waitlist offer take-up rate is also higher in the BPS mechanism than in charter lotteries.

**Table 3: Offer and Takeup Rates in Charter and Traditional and Pilot Public Schools**

	Middle school (6th grade entry)		High school (9th grade entry)	
	Charter (1)	Traditional and pilot public schools (2)	Charter (3)	Traditional and pilot public schools (4)
Eventual offer rate	55.2%	67.6%	70.3%	54.6%
Eventual offer takeup	60.0%	74.9%	30.1%	77.4%
Initial offer rate	32.2%	61.8%	30.7%	45.3%
Initial offer takeup	73.2%	74.7%	38.9%	75.7%
Waitlist offer rate	26.7%	5.8%	50.3%	9.3%
Waitlist offer takeup	35.6%	76.2%	20.1%	85.6%
N	1856	5838	2601	6165

Notes: This table compares offer and offer take up rates for Boston charter schools and traditional and pilot public schools, omitting pilots that do not admit students through the student assignment mechanism. BPS statistics are based on first choices submitted to the BPS school assignment mechanism between 2008 and 2012. The sample is restricted to students intending to switch schools in 6th or 9th grade, and who are not guaranteed seats at their first choice schools. Initial offers are coded using the first assignment round, while eventual offers are coded based on all four assignment rounds. The charter sample consists of applicants to charters with 6th or 9th grade entry in the same time window as BPS mechanism data. Charter initial offers are offers received on the lottery date, while eventual offers are offers received on the lottery date or later. A student receives a waitlist offer if she receives an eventual offer but not an initial offer. Takeup rates are based on school attendance in the first year after public school assignment or charter lotteries. The sample N indicates the total number of students eventually admitted.

## School Choices Among Charter Applicants

In **Table 4**, we unpack the charter take-up rate by describing the school choices of charter applicants. In middle school, the relevant alternative for most charter applicants is a Boston traditional public school. Sixty percent of middle school applicants not offered seats attend traditional public schools, while 12 percent attend pilot schools and 19 percent attend other charters outside our study sample. The 30 percent of offered middle school applicants who decline their offers also typically attend traditional public schools; a few attend pilot schools or leave Boston.

In high school, the set of school choices is more diverse, and this is reflected in the lower offer take-up rate. More than 60 percent of offered high school applicants choose not to attend charters, with many choosing to instead attend traditional public schools (20 percent), pilot schools (18 percent), or exam schools (8 percent). A plurality of not-offered high school applicants attend traditional public schools (35 percent), while 23 percent attend a pilot school, and 8 percent attend an exam school. The fact that exam attendance rates are similar for offered and not-offered students suggests that few students are induced to leave exam schools by charter offers.

Table 4: School Choices Among Charter School Applicants

School attended	Middle school (4th, 5th, or 6th grade entry)			High school (9th grade entry)			
	Offered (1)	Not offered (2)	All (3)	Offered (4)	Not offered (5)	All (6)	
Charter	70.7%	18.6%	48.5%	38.4%	11.4%	29.3%	
Traditional public	18.1%	59.9%	35.9%	20.0%	34.5%	24.9%	
Exam	0.1%	0.1%	0.1%	8.0%	8.4%	8.1%	
Pilot	4.2%	11.6%	7.3%	17.7%	23.1%	19.5%	
Alternative	0.1%	0.2%	0.1%	0.4%	0.5%	0.4%	
Public school outside Boston	2.1%	3.4%	2.6%	5.4%	8.6%	6.5%	
Private/Out of state	4.7%	6.2%	5.4%	10.1%	13.5%	11.3%	
	N	4977	3692	8669	4458	2290	6748

Notes: This table shows schools attended by charter lottery applicants. The sample includes charter applicants from 2002 through 2012 who attended Boston Public Schools at baseline (prior to the lottery). Middle schools are charters with entry grades in 4th, 5th, or 6th grade, and high schools are charters with 9th grade entry.

## Demographics in Charter Schools and Boston Public Schools

The last piece of our demand analysis investigates how the demographic mix at charter schools has changed over time relative to BPS schools. This can be seen in **Figure 1**, which plots fractions of charter and BPS students in various demographic categories. Middle and high schools are pooled to create the figure, and demographics are measured at baseline (prior to charter entry). It is important to note that the differences documented here are due to the

composition of students who choose to apply to charters, rather than selective admission of applicants.

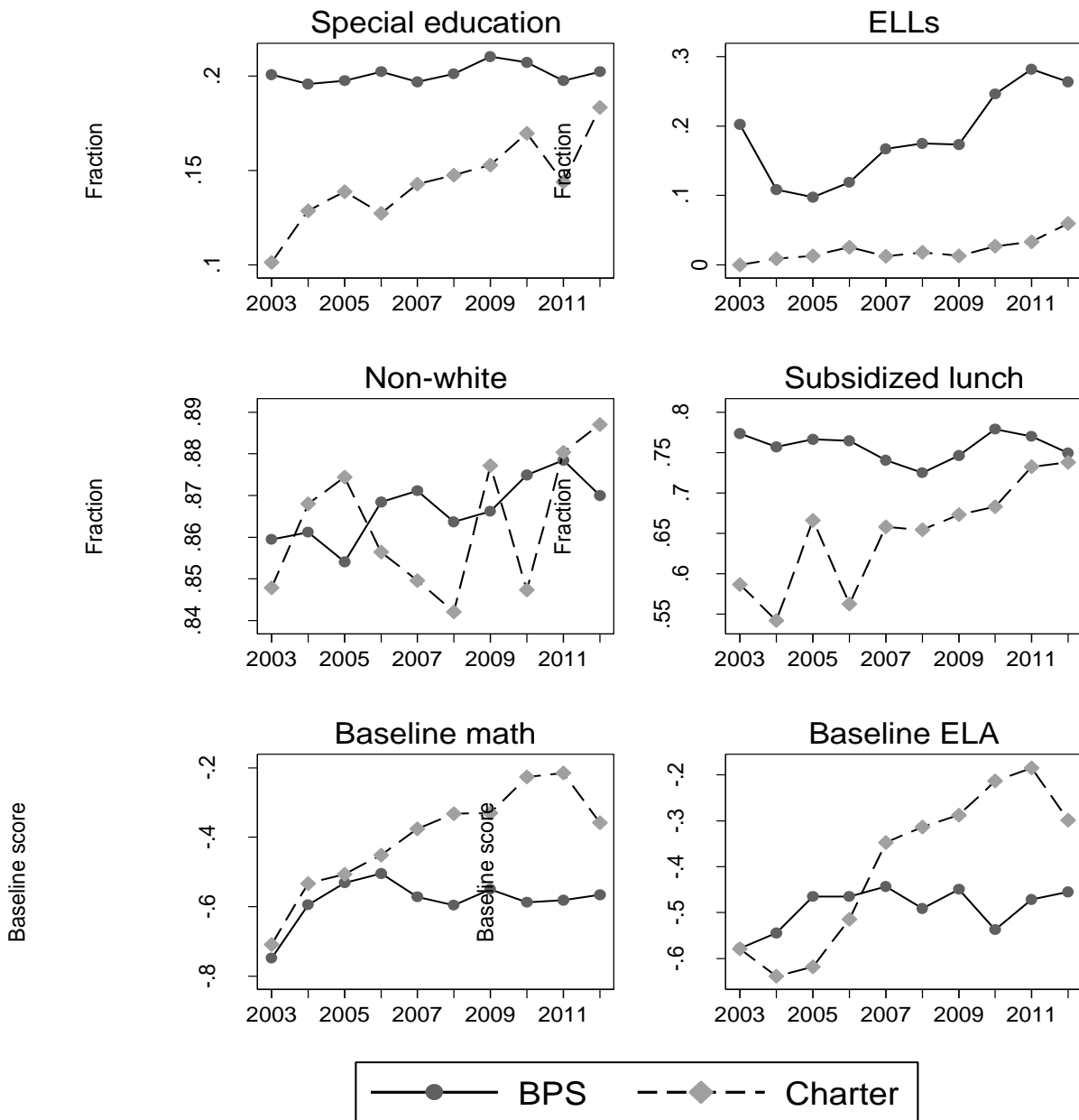
Mirroring the descriptive statistics in Table 1, Figure 1 shows that charter students are less likely to have special education or ELL status, though the gap for special education is rapidly decreasing. Charter schools enrolled more English language learners in recent years, but the gap with BPS is still large. Charters and Boston public schools served similar shares of non-white students throughout our study period.

Students at charter schools were much less likely to have subsidized lunch status in the earlier years of our sample, but the difference in this measure fell steadily over time, so that charter students were nearly as likely as BPS students to qualify for subsidized lunch in the most recent year. In contrast, baseline math and ELA scores for charter students increased relative to BPS between 2003 and 2011, though these

differences fell somewhat in 2012. As a whole, these demographic characteristics point to a charter school population that is somewhat more advantaged than the BPS population, however, many demographic differences are decreasing in recent years.



Figure 1: Demographics of Charter and BPS Students



Notes: This figure plots average demographic characteristics and baseline test scores for BPS and charter students over time. The sample restrictions are the same as those in Table 1.



## CHAPTER FOUR

### Empirical Framework

We use lotteries to estimate the effects of charter school attendance on MCAS scores and other outcomes. This empirical strategy is motivated by the fact that attending a charter school is a choice: the decision to apply to a charter may be correlated with family background, ability, or motivation. Comparisons between charter and non-charter students may be biased due to these differences. Our lottery-based strategy eliminates selection bias by comparing applicants who are offered admission in charter lotteries to applicants not offered admission. Since charter lotteries are random, offered and not-offered students are similar with respect to background characteristics, including unobserved characteristics, and differences in their subsequent outcomes reflect the causal effect of charter admission.

More specifically, we use random offers of charter school seats to construct instrumental variables (IV) estimates. The idea behind IV is to compare outcomes between offered and not-offered students (termed the *reduced form*), and then to adjust this comparison for the difference in charter enrollment rates between these groups (the *first stage*). To see how IV works, consider a stylized example with one charter school, say Match middle school. Suppose (hypothetically) that 200 students submit applications to Match, and there are 100 available seats. As a consequence of oversubscription, 100 of the applicants are randomly offered seats in Match's lottery. The reduced form is the difference in MCAS scores between the 100 applicants offered a seat and the 100 applicants not offered a seat. In 8<sup>th</sup> grade math, this might be a number like  $0.5\sigma$ ; in other words, offered students score half of a standard deviation higher than not-offered students. Because offers are randomly assigned, the reduced form is likely to be an accurate measure of the causal effect of a charter offer.

We could stop at this point if everyone offered a charter seat takes it, no seats are obtained otherwise, and students never switch schools. In practice, however, many students decline charter offers and choose to go elsewhere, while some not-offered students eventually attend, perhaps because they are admitted off the waiting list or apply again the next year; and some students who attend Match also leave before 8<sup>th</sup> grade. To determine the causal effect of charter *attendance*, we need to adjust the reduced form to take this into account. Suppose that admitted students spend an average of 2.5 years at Match by 8<sup>th</sup> grade, while not-offered students spend an average of 0.5 years there. The first-stage enrollment impact of a Match offer is then  $2.5 - 0.5 = 2.0$ .

Our IV estimate of the impact of Match attendance is the ratio of the reduced form effect of  $0.3\sigma$  to the first stage enrollment differential of 2.0. This calculation produces

$$\begin{aligned} \text{Effect of charter attendance} &= \frac{\text{Reduced Form}}{\text{First Stage}} \\ &= \frac{0.5\sigma}{2.0} \\ &= 0.25\sigma \end{aligned}$$

Thus, this calculation leads us to conclude that Match boosts math scores by a quarter of a standard deviation per year of attendance.

Our empirical strategy is somewhat more involved than this example suggests, because our data include many schools, many lottery cohorts, and test scores in multiple grades. We used a method known as two-stage least squares (2SLS for short) that generalizes IV to this setting. The **Technical Appendix** gives a more detailed explanation of the mechanics of 2SLS. It's also worth noting that our 2SLS estimates use an instrument based on the *eventual offer* concept defined in Chapter 3. Estimates using

initial offers received on lottery day were very similar.

### **Lottery Balance**

Our lottery-based empirical strategy depends critically on the assumption that charter lottery offers are randomly assigned. This random assignment balances both observed and unobserved characteristics between offered and not-offered students. While we cannot check balance for unobserved characteristics, it's

worth checking that lottery winners and losers are similar on observed dimensions like race, special education status, and baseline (pre-application) test scores. **Appendix Table A3** confirms that the pre-lottery characteristics of offered and not-offered students are similar. Differences between offered and not-offered students are small for all characteristics tested, and the  $p$ -value from a joint test is high. This suggests that we successfully reconstructed the random assignment in charter lotteries.<sup>iii</sup>

## CHAPTER FIVE

### MCAS Performance

As described above, our empirical framework eliminates selection bias in estimates of charter school effectiveness. We now present those findings, in **Table 5A**.

Before moving to impacts on test scores, we first confirm that the charter school eventual offer indeed predicts the likelihood that an applicant will attend a charter school. In the language of the framework described above, this is the first stage (Table 5A, column 2). Middle school students offered a seat in the lottery attend one more year of school at a charter than those not offered a seat. The difference is about half a year in high school. This satisfies the condition that charter offers predict charter attendance.

But why is the difference in years of charter attendance only one year in middle school and half a year in high school? If all students who were offered a seat at a charter enrolled in that school and stayed for all years prior to the MCAS, we would expect the first stage in high school to be two years, for 9<sup>th</sup> and 10<sup>th</sup> grade. (Middle school is a little more complicated, as we combine multiple grades so that the expected years of attendance will vary based on grade level.)

There are several reasons for the difference. Many students who are offered seats at a school choose not to attend, as discussed in Chapter 3. Some students leave a charter before we observe their MCAS score.<sup>iv</sup> And a few students who were not offered a seat in the lottery end up attending a charter, usually through sibling preference or application after the entry grade. Happily, our empirical method adjusts for actual attendance at a charter and scales the effect by the years of attendance. This is another benefit of using instrumental variables, in addition to controlling for selection bias.

Before we explain the test score results, we describe how we measure them. We “normalize” raw MCAS test scores across the whole state by subject and grade level. This means that we set the mean score to zero and the standard deviation (a measure of the distribution) to one. Since Boston performs below the state average, the mean level of achievement is negative. The normalized test scores provide a convenient unit to compare across grade levels and subjects, and can be interpreted as an “effect size” – a typical unit in educational program evaluation.

We now turn to the difference in test scores between those offered a seat in the lottery and those not offered a seat. These are the reduced form estimates presented in column 3 of Table 5A. Making no adjustments for charter attendance, we see that those who receive a lottery offer outperform students not offered. Middle school lottery winners outscore lottery losers by  $0.28\sigma$  in math and  $0.15\sigma$  in ELA. The corresponding estimates for high school are  $0.20\sigma$  in math and  $0.15\sigma$  in ELA. For reference, we present the non-charter means in column 1 – these scores represent the counterfactual for not attending a charter.

Finally, in column 4 of Table 5A we present the test score impacts for attending a charter. These effects are test score difference between offered and not offered students adjusted by the difference in years of charter attendance for the same groups. They can be interpreted as effects *per year* of charter attendance.

The effect of attending a middle school charter is  $0.26\sigma$  in math and  $0.14\sigma$  in ELA per year of charter school attendance. The high school charter effect is  $0.35\sigma$  in math and  $0.27\sigma$  in ELA per year of charter school attendance. All of these impacts are large and statistically significant.

Table 5A: Charter Effects on MCAS

Subject	Non-charter	First stage	Reduced form	Charter effect
	mean (1)	(2)	(3)	(4)
<i>Panel A. Middle school</i>				
Math	-0.302	1.097*** (0.047)	0.280*** (0.033)	0.256*** (0.027)
N		11260		
ELA	-0.341	1.098*** (0.047)	0.152*** (0.030)	0.138*** (0.026)
N		11003		
<i>Panel B. High school</i>				
Math	-0.231	0.564*** (0.081)	0.200*** (0.047)	0.354*** (0.061)
N		4051		
ELA	-0.296	0.564*** (0.081)	0.153*** (0.037)	0.271*** (0.053)
N		4110		

Notes: This table reports 2SLS estimates of the effects of time spent in charter schools on test scores. The endogenous variable is years spent in charter schools, and the instrument is a lottery offer dummy. Means are for non-charter students who applied to the lotteries. Columns (2)-(4) report estimates for MCAS scores normalized to the state by grade and year. Sample restricted to students with baseline demographic controls who attended BPS or a Boston charter school at baseline. All models control for race, sex, special education, limited English proficiency, subsidized lunch status, and a female by minority dummy. Year of birth, year of test, and risk set dummies are also included. Middle school regressions pool post-lottery outcomes in 2003-2012 from 4th through 8th grade and cluster by student identifier as well as school-grade-year. High school regressions include only scores for 10th grade from 2004-2012 and cluster by school-grade-year.

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

Normalized MCAS scores show average effects. To describe changes in the distribution of scores and to provide an aid in understanding the estimates, we also report charter school effects on MCAS proficiency levels in **Table 5B** and represented visually in **Figure 2**. We estimate the effect of attending a charter school on passing MCAS proficiency levels. To pass the Needs Improvement threshold a student must score at least a 220; to pass the Proficient threshold the score is 240; and to pass the Advanced threshold the score must be 260 or above.

In column 1, we show that most students pass the needs improvement threshold, with 74 percent of non-charter students scoring above in math and 90 percent scoring above in reading. Even more high school students are above the threshold in high school. Since so many students are above this threshold, there is not a lot of room for large effects. Still, there is some movement of students in charter schools. In middle school, charter attendance improves the chance of exceeding the needs improvement threshold by 7 percentage points in math and 1 percentage point in ELA for middle school. Attending a charter high school increases the

rate of meeting the threshold by 4 percentage points in math, with no difference in ELA.

Effects are larger around the proficient threshold. About half of non-charter students meet the proficient threshold in middle school, about two-thirds in high school. The middle school charter gain is 12 percentage points in math and 6 percentage points in ELA. For high school, the gain is around 10 percentage points for both subjects. Thus, the charter school effect pushes many students over the threshold to proficiency.

Figure 2 suggests that these per-year effects may accumulate over time and across grade levels, though it is not possible to separately estimate effects for each incremental year of attendance. We only show this accumulation at middle school, since there are not multiple test years in high school.

There is also an effect on scoring at the advanced level. Few non-charter middle school students meet the advanced threshold: 12 percent in math and 7 percent in reading. Attending a charter improves those rates by 7 percentage points in math and 3 percentage points in ELA. Effects are very large in high school. About a third of non-charter students meet the advanced level in math and 10 percent do so in ELA. The charter effect adds 18 and 12 percentage points to each of those subjects, respectively.

To sum up, we observe middle school charters moving many students to above the proficient threshold, with smaller but still substantive and significant movement around the needs improvement and advanced thresholds. Charter high schools also move a substantial number of students above the proficiency threshold, but have the largest effects on the advanced threshold.

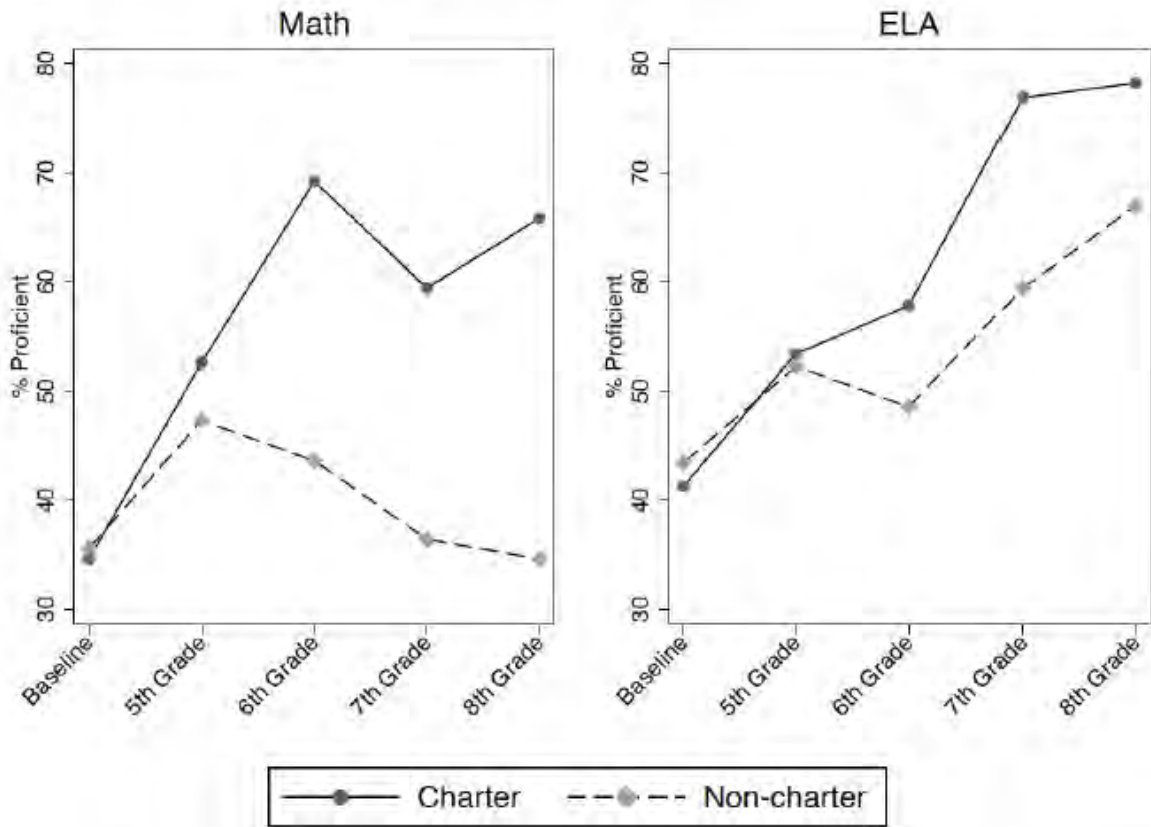
Table 5B: Charter Effects on MCAS Proficiency Levels

Subject	Needs improvement+		Proficient+		Advanced+	
	Non-charter mean (1)	Charter effect (2)	Non-charter mean (3)	Charter effect (4)	Non-charter mean (5)	Charter effect (6)
<i>Panel A. Middle school</i>						
Math	0.741	0.074*** (0.011)	0.398	0.123*** (0.013)	0.119	0.071*** (0.009)
N				11260		
ELA	0.898	0.014** (0.007)	0.563	0.057*** (0.012)	0.066	0.028*** (0.007)
N				11003		
<i>Panel B. Middle school</i>						
Math	0.919	0.038** (0.017)	0.654	0.101*** (0.034)	0.329	0.178*** (0.031)
N				4051		
ELA	0.963	0.000 (0.012)	0.681	0.108*** (0.030)	0.103	0.119*** (0.021)
N				4110		

Notes: Needs improvement+ is defined as a scaled score of 220+; proficient+ is defined as a scaled score of 240+; and advanced+ is defined as a scaled score of 260+. For all other notes, see Table 5A.

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

Figure 2: Charter Effects on MCAS Proficiency



Notes: This figure plots estimated achievement in charter schools and traditional public schools for each year relative to the charter lottery. The estimates are constructed using methods described by Abadie (2002, 2003), and can be interpreted as average achievement for applicants who would be induced to attend charter schools if they won the lottery. For a detailed description of these methods, see the technical appendix to Angrist, Cohodes, Dynarski, Pathak, and Walters (2013).

### Results over time

The estimates we present above include MCAS outcomes from 2003 to 2012. However, estimates from more recent years are important for two reasons. First, they are likely the most relevant, as they are closest to the current policy and demographic context in Boston. Second, in more recent years we have collected almost the complete set of lottery records, covering over 85 percent of charter enrollment in Boston.

In **Table 6**, we compare the overall MCAS estimates (column 1) with estimates for the most recent years (column 2). Charter effects in the most recent years are quite similar to effects for

the whole span of available years, indicating that our estimates with the greatest lottery coverage are similar to estimates in other years. Since 2009, the middle school charter yearly gains for math are  $0.23\sigma$  compared to  $0.26\sigma$  overall and the gains for ELA are  $0.15\sigma$  compared to  $0.14\sigma$  overall. The comparison for charter high schools is similar. In recent years, the high school charter gains for math are  $0.38\sigma$  compared to  $0.35\sigma$  overall and the gains for ELA are  $0.33\sigma$  compared to  $0.27\sigma$  overall.

We also separate the gains in recent years into two groups of schools: the schools included in the 2009 “Informing the Debate” report (column 3) and additional schools added since that

original data collection (column 4).<sup>v</sup> Middle school charter effects across these two groups of schools are largely similar. In high school, significant positive impacts are concentrated in the “Informing the Debate” sample. Results for additional schools are positive though not significant. This is not surprising given the small

sample size for additional charter high schools. These schools are the upper grades of schools that admit at middle school and few of these students are old enough to contribute 10<sup>th</sup> grade scores to the analysis.

Table 6: Lottery Effects by School Groups

Subject	All years (2003-2012)		Recent years (2009-2012)	
	All charters (1)	All charters (2)	"Informing the Debate" Schools (3)	Additional Schools (4)
<i>Panel A. Middle school</i>				
Math	0.256*** (0.027)	0.235*** (0.039)	0.215*** (0.042)	0.275*** (0.081)
N	11260	6136	4386	1750
ELA	0.138*** (0.026)	0.152*** (0.037)	0.157*** (0.040)	0.139* (0.079)
N	11003	6135	4381	1754
<i>Panel B. High school</i>				
Math	0.354*** (0.061)	0.375*** (0.093)	0.384*** (0.092)	0.138 (0.338)
N	4051	1792	1634	158
ELA	0.271*** (0.053)	0.333*** (0.085)	0.307*** (0.089)	0.506 (0.335)
N	4110	1826	1665	161

Notes: This table reports 2SLS estimates of the effects of time spent in charter schools for recent years of application, which covers a consistent sample of charter schools. For middle school, this includes applications from 2008 forward and outcomes from 2009 forward. For high school, this includes applications from 2007 forward and outcomes from 2009 forward. Column (2) reports estimates for all schools. Column (3) reports estimates for schools that were in the lottery sample in the 2009 report "Informing the Debate;" these middle schools are Academy of the Pacific Rim, Boston Collegiate, Boston Prep, and Roxbury Prep; these high schools are City on a Hill, Codman Academy, and Match High School. Column (4) reports estimates for schools that have been added to the sample since the previous report; these middle schools are Edward Brooke - Roslindale, Edward Brooke - Mattapan, Excel - East Boston, Roxbury Prep Lucy Stone/Grove Hall, and Match Middle School; these high schools the later grades of Academy of the Pacific Rim, Boston Collegiate, Boston Prep, and Match Middle School. There is not a large enough sample to report estimates separately for replication campuses opened during or after the 2011-2012 school year. Notes on the regression model are the same as notes in Table 5A.

### Results by student subgroups

We also estimate results for subgroups of students, to determine if the charter effect differs by type of student. **Appendix Table A6** includes results by student demographics and **Appendix Table A7** includes results by student program participation. Note that program participation is measured at baseline, before a student attends a charter.

For middle school math, charter effects are smaller for males and larger for females.

African-American and Latino students also have larger gains, while the gain for white students is smaller than the average effect. Students who receive subsidized lunch at baseline have slightly larger than average effect sizes, and students without subsidized lunch have smaller gains. Effects are slightly larger for non-special education students and smaller for special education students. The gains for English language learners are larger than the average effect. Since most students are not ELLs, the effect for these students is essentially the same as on average. Finally, we observe that low



scorers at baseline have larger impacts than high scorers at baseline.

There is no variation by gender in middle school ELA, but minority students have larger gains than white students. Again students with subsidized lunch, ELL status, or lower baseline scores have larger gains. Unlike in math, ELA gains are slightly larger for special education students.

In high school math, there are larger gains for African-American students but smaller ones for Latino students. Effects for white students are smaller and not significant. Gains are larger for students without subsidized lunch and those who are special education at baseline and smaller for the opposite groups. Gains are quite large for ELLs, though the sample size here is small. Finally, the charter impact is slightly larger for high scorers as compared to low scorers.

For high school ELA, males have larger gains than females (though females have much higher scores in the counterfactual). Latino students have larger gains, while white students have smaller, not significant ones. Unlike in high school math, gains are larger for those with subsidized lunch. There is a similar pattern for special education students. Again there are very large effects for ELLs, but due to small sample, these are not significant. The effect pattern by baseline score is similar to that for math.

While the differential effects are interesting in and of themselves, connecting them to our findings on charter school demand is even more

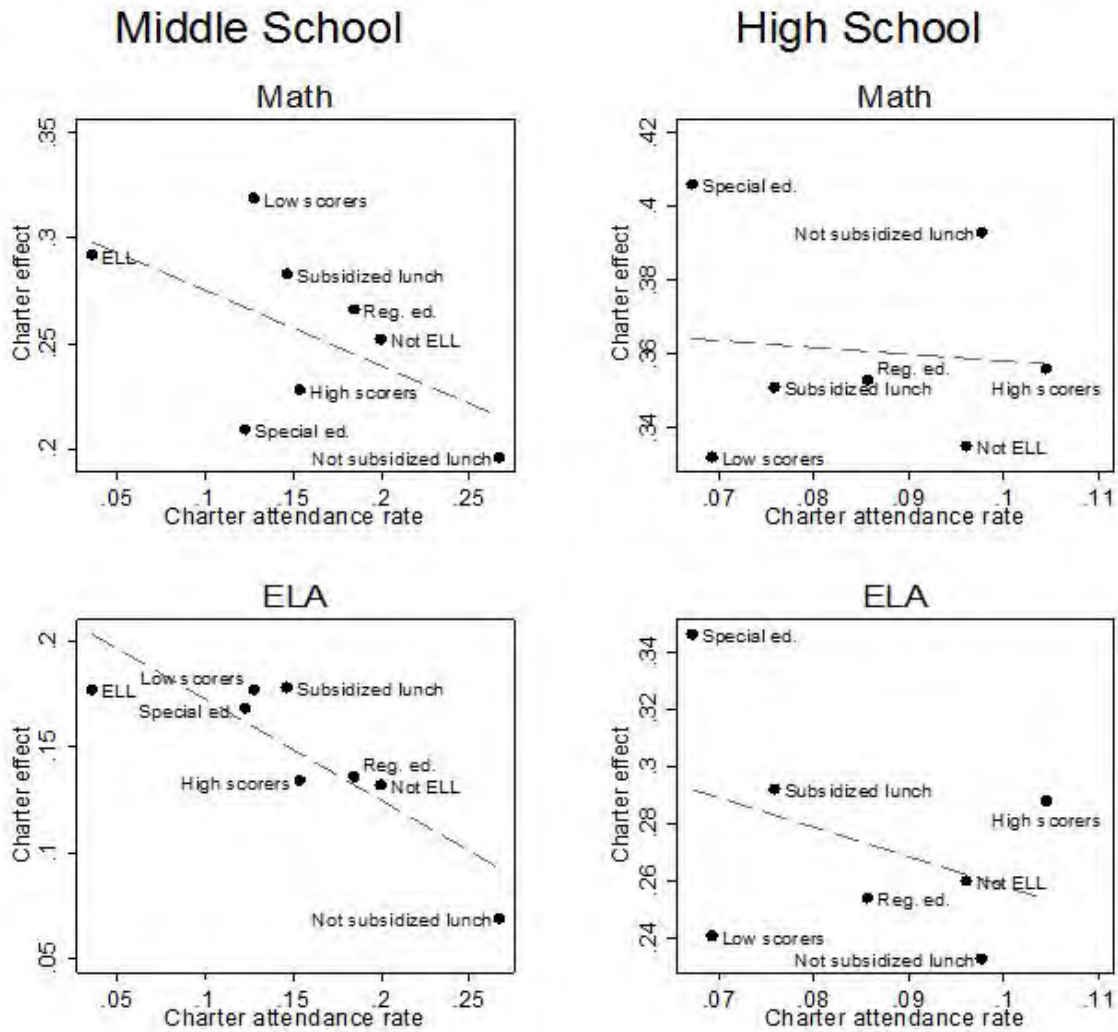
illuminating. Although most student sub-groups benefit from charter attendance, those that appear to benefit the most tend to enroll at lower rates than their peers. We saw particularly large effects on test scores ELLs at all levels and low scoring students in middle school, but these are some of the groups that are *least* likely to apply to and attend a charter school.

We refine this conclusion with an additional analysis, presented in **Figure 3**. This figure plots lottery-based estimates of charter effects by subgroup against charter enrollment rates, measured over our full study period. The enrollment rate is the proportion of students in that particular subgroup that attend a charter school. Recall that subgroup status is measured at baseline, so that this analysis is not about how schools categorize their students.

The middle school results show a sharp downward sloping relationship between the charter enrollment rate and the achievement gain from attending a charter in both math and ELA. Charter enrollment rates are lower in subgroups for which charters are more effective. High school results are show the same general pattern but have a weaker relationship between effect size and attendance rate. Similar findings are reported in Walters (2013), a study that investigates the relationships between charter application rates, enrollment rates, and gains from charter attendance using an economic model. As suggested by our graphs, this study finds that groups with the most to gain from charter attendance are less likely to apply to or attend charters.



Figure 3: Charter Attendance and Effects on MCAS by Subgroups



Notes: This figure plots the effects of attending charters on MCAS scores against charter attendance rates by subgroups. The charter attendance rate calculation is based on the sample in Table 1. The estimates of MCAS effects are reproduced from Table A7. We drop subgroups in which the number of applicants is below 200, which excludes ELLs from the high school results. Including ELLs would make the slope steeper, but the treatment effect for this group is not significant. All subgroup characteristics are measured at baseline grades. High scorers refer to students whose averaged baseline ELA and math score is above the median among Boston public and charter students; low scorers refer to those below the Boston median.

## Additional Results

### Non-Lottery Methods

The lottery-based analysis eliminates selection bias from our results. That is, since the lottery-based analysis only includes students who took the initiative to apply to charters, we are confident that all of our comparisons are between students with similar backgrounds and family motivation. But those results are necessarily limited to oversubscribed charter schools with sufficient lottery records. We have high participation of middle and high schools in Boston in the lottery results, especially in more recent years where the lottery study charters enroll 87 percent of charter school students.<sup>vi</sup>

But a few schools remain outside the lottery sample. For middle schools, these include two schools closed by the Massachusetts Department of Elementary and Secondary Education and two schools that were unable to supply complete records. For high schools, these include two closed schools and one school with incomplete records. Details on these schools and sample coverage are in Appendix Table A1. In order to include test score results for these schools, we also estimate our results using statistical controls.

These non-lottery results use information about students supplied in the state databases – demographic characteristics, program participation, sending school, and prior test scores – to control for differences between charter and non-charter students. Selection bias may still be a problem with this method. Unlike in the lottery method, we cannot control for family motivation or other unobserved factors.

The sample for the non-lottery results begins with all public school students who reside in Boston and have MCAS scores in their baseline year, 4th grade for middle schools and 8th grade for high schools. We compare students in charter schools with students in other public schools, controlling for baseline math and ELA scores

and baseline program participation. To further control for selection bias, we also match students into cells based on their demographics and sending school.

The matching procedure proceeds as follows. Charter school students are matched to non-charter students in the baseline year with the same baseline school, baseline year, sex, and race. Students only participate in the regression if they fall into a matching cell, i.e. a charter student must have at least one non-charter match to enter the regression, and a non-charter student must have at least one charter match to enter the regression. More than 95 percent of charter school students match to at least one comparison student. For more details on the non-lottery methods, please see the Technical Appendix.

Results from the non-lottery analysis are in **Table 7**. For reference, column 1 of this table repeats the lottery effects from Table 5. In column 2 we estimate non-lottery charter impacts for the schools for which we collected lottery records that contribute to the lottery-based analysis, representing over 80 percent of enrolled charter students. These results are remarkably similar to the lottery-based results.

Adjusting for student characteristics, students attending oversubscribed middle school charters outscore their peers by  $0.30\sigma$  in math and  $0.19\sigma$  in ELA. The corresponding causal gains from the lottery study are  $0.25\sigma$  in math and  $0.14\sigma$  in ELA. The results line up again in high school. Non-lottery high school gains are  $.33\sigma$  in math and  $0.25\sigma$  in ELA compared to the lottery study finding of  $0.35\sigma$  in math and  $0.37\sigma$  in ELA.

We also estimate results with statistical controls for the non-lottery schools. For shorthand, we call these “undersubscribed” charters and report results in column (3). Since we are unable to collect records from closed schools or those with incomplete records, we cannot confirm in all

Table 7: Non-Lottery Estimates of Charter Effects

Subject	Oversubscribed charters		Undersubscribed charters	All charters
	Lottery (1)	Non-Lottery (2)	Non-Lottery (3)	Non-Lottery (4)
<i>Panel A: Middle school</i>				
Math	0.256*** (0.027)	0.295*** (0.011)	0.021 (0.023)	0.251*** (0.011)
N	11260		59124	
ELA	0.138*** (0.026)	0.185*** (0.010)	0.020 (0.018)	0.156*** (0.010)
N	11003		56678	
<i>Panel B: High school</i>				
Math	0.354*** (0.061)	0.332*** (0.036)	-0.018 (0.019)	0.222*** (0.037)
N	4051		11655	
ELA	0.271*** (0.053)	0.251*** (0.021)	0.072*** (0.025)	0.195*** (0.022)
N	4110		11883	

Notes: This table reports observational estimates of the effects of charter attendance on test scores. The lottery estimates in column (1) are reproduced from Table 5A. The observational sample includes charter students and matched control students with outcome scores from 2004 through 2012, with matching cells defined by sending school, baseline year, sex and race at baseline. Baseline grades are 4th for the majority of middle schools and 3rd for Dorchester Collegiate, and 8th for high schools. Estimates in columns (2)-(4) come from regressions of test scores on years spent in charter schools, controlling for matching cell fixed effects, year effects, grade effects, subsidized lunch status, ELL status, special education status, and baseline test scores. Middle school regressions pool outcomes from 5th through 8th grade and double-cluster standard errors by student and school\*year. High school regressions use 10th grade outcomes and cluster by school\*year.

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

cases that these schools were undersubscribed. These schools enroll about 20 percent of the charter school students in the sample and generally have zero or small impacts on scores. We find small positive gains in high school ELA of  $0.07\sigma$ , but all other estimates are zero. This points to two conclusions. First, highly demanded charters are more successful in terms of MCAS gains than other charters. And second, schools closed by the state were making little difference for their students, suggesting that the school closure process identifies underperforming schools or that poor performance is correlated with other factors that lead to school closure.

However, these schools enroll a relatively small proportion of charter school students in Boston. The majority of charter schools produce positive MCAS gains. This can be seen in column 4, where we present non-lottery estimates for all charters, combining lottery study charters with closed schools and those with incomplete records. Overall, the charter sector still has large

positive gains. In middle school, these impacts are essentially the same size as the lottery gains, and in high school they are somewhat smaller than the lottery gains.

### School Switching

Some critics of charter schools claim that charter school MCAS effects are due to “selective out-migration” of students. We examine this two ways. First, we document how many charter and how many BPS students remain in the same school they attended in 6<sup>th</sup> or 9<sup>th</sup> grade, taking into account exam schools in middle school. This is a descriptive analysis, created by summarizing the state data. It is subject to potential selection bias issues, but is an accurate report of the facts on ground. Next we use remaining in the same school as an outcome for a lottery analysis, following the same procedure as above for MCAS outcomes. This approach is limited to the lottery sample, but controls for selection bias.

**Table 8**, columns 1 and 2 describe charter and BPS students switching behaviors. Both charter and BPS students are highly mobile. But as a whole, charter students are more likely to remain in the same school than BPS students.

While this is an interesting fact about students in Boston, we have described elsewhere in this report the risks of drawing conclusions from descriptive data. The descriptive analysis does not account for the fact that students in charter schools are likely different than students in BPS in unobserved ways – perhaps the higher retention rate is due to charter applicants being positively selected.

To account for this, in columns 3 and 4 we focus on the subsample of lottery applicants, the same sample we used for the MCAS impact analysis in Chapter 5. We use the same lottery methodology estimate the causal effect of attending a charter on the likelihood of remaining in the same school in Table 8. Here, the outcome is remaining in the same school in grades after 6<sup>th</sup> for middle school and 9<sup>th</sup> for high school.

Accounting for selection bias, middle charter schools are *more* likely to retain 6<sup>th</sup> graders in 7<sup>th</sup> and 8<sup>th</sup> grade. By the 8<sup>th</sup> grade, charter schools' retention rate is almost 24 percentage points higher. Less than half of this difference, 11 percentage points, is due to exam school attendance, since non-charter students more likely to switch schools in 7<sup>th</sup> grade to attend an exam school. Excluding exam school switching, middle charter students stay in the same school

at a rate 13 (24 minus 11) percentage points higher than their peers in non-charter schools.

In high school, charter students are *less* likely to remain in the same school they attend as 9<sup>th</sup> graders than their counterparts elsewhere. By 12<sup>th</sup> grade they are 16 percentage points less likely to be in the same school they were in 9<sup>th</sup> grade.

We also estimated the causal effects for school switching before and after 2010 in **Appendix Table A8**. Since the 2010 *Achievement Gap* law required charters to “backfill” their seats,<sup>vii</sup> after 2010 schools have different incentives around school retention. In middle school, charter schools are more likely to retain students than their counterparts in both time periods.

In high school, the story is different across time. Overall, we found that charter high schools are less likely to retain students throughout high school. However, this phenomenon is concentrated in the pre-2010 period. After 2010, high school charters retain students at the same rate as their BPS counterparts. This may be an indication that high school charters responded to the law change by retaining more students.

Might this difference in retention in high school account for the test score gains in high school?<sup>viii</sup> This is unlikely. In Table 6 we saw that estimates from more recent years were just as large as those for the full sample. These are the years that correspond to post-2010 period, where we observe no effect on switching.<sup>ix</sup>

Table 8: School Switching in Charter Schools and Boston Public Schools

	Descriptive		Causal Analysis	
	Charters (1)	BPS (2)	Non-charter mean (3)	Charter effect (4)
<i>Panel A: Middle school (6th grade entry)</i>				
Remained in the same school in 7th grade	0.751	0.654	0.552	0.212*** (0.038)
N	4571	34720		4203
In 8th grade	0.634	0.542	0.437	0.244*** (0.040)
N	4039	31589		3247
Attended exam school in 7th grade	0.064	0.140	0.158	-0.111*** (0.021)
N	4571	34720		4203
<i>Panel B: High school (9th grade entry)</i>				
Remained in the same school in 10th grade	0.779	0.743	0.855	-0.099* (0.058)
N	3364	37967		4954
In 11th grade	0.633	0.595	0.691	-0.111 (0.072)
N	2942	34877		4336
In 12th grade	0.526	0.518	0.613	-0.160* (0.085)
N	2568	31494		3656

Notes: This table compares school switching between charter attendees and Boston public school attendees. Charters with kindergarten entry are excluded. Samples for columns (1) and (2) include all charter and traditional public school, exam, and pilot school students in either 6th grade (middle school) or 9th grade (high school). The outcomes are indicator variables equal to one if a student remained in the same school through the relevant grade. The sample for these outcomes is restricted to students whose relevant grades can be observed before Spring 2013. The sample for columns (3) and (4) includes lottery applicants to study charters. Column (4) reports 2SLS estimates of the effect of charter attendance on the probability of remaining in the same school. The endogenous variable is an indicator for charter attendance in 6th or 7th grade for middle school, and 9th or 10th grade for high school. The instrument is an ever offer dummy. All models control for risk sets, cohort 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 for high school and 7th grade for middle school. Control means in columns (3) and (7) are for non-charter students. Other notes on the regression model are the same as notes in Table 5.

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

## CHAPTER SEVEN

### Summary and Conclusions

As in the 2009 report, we find that attending a charter school in Boston significantly boosts MCAS scores and proficiency levels. Positive test score effects from the most recent years where our lottery sample coverage is nearly complete are of similar magnitudes. Non-lottery results confirm the lottery results for charters from which we were able to collect lottery records, and point to lower performance for closed charters and those without complete records. However, test scores are only one part of the story. This report also provides evidence on the demand for charter schools.

Many students in Boston apply to a charter, with application rates rising in the past few years, especially for middle schools. A majority of students who apply get an offer to at least one school, but not all students accept these offers. A third of middle school students and 60 percent of high school students choose other options. Many of these offers arrive after the lottery, a contributing factor to low take up rates, along with the many school options available in Boston, especially for high school. Offer rates at

Boston charters are broadly similar to the offer rates for first choice schools in the BPS assignment mechanism.

Charter school students tend to have somewhat higher early test scores than the general BPS population. This most reflects that higher scoring students are more likely to apply in the first place. The proportion of students with special needs and English language learners is also lower in the applicant group than in the general population. Importantly, however, gaps between charter applicants and non-applicants are shrinking. In the most recent year, we see almost as many special education students applying as exist in the BPS population. At the same time, some gaps remain. This is important because our analysis of charter effectiveness (here, as in earlier work) uncovers substantial differences in impact. Students from groups least likely to apply, including English language learners and students with low achievement scores, are those for which achievement gains are likely to be the largest.

## 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). 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 19 Massachusetts charter schools between 2002 and 2012. The participating schools and lottery years are listed in Table A2. The demand analysis includes records from all schools and cohorts. The MCAS analysis includes records from application years prior to 2011 for middle school and prior to 2010 for high school to allow for MCAS records to become available and excludes “in-district” charters. A total of 91 school-specific entry cohorts are included in the demand analysis and 70 school-specific cohorts are included in the MCAS analysis.

The middle school lottery analysis sample includes (entry grade in parenthesis): Academy of the Pacific Rim (5/6), Boston Collegiate (5), Boston Prep (6), Edward Brooke-Roslindale (5), Edward Brooke-Mattapan (5), Excel – East Boston (5), Lucy Stone/Grove Hall (Uncommon Schools, 5), Match Middle School (6), and Roxbury Prep (Uncommon Schools, 5/6). In the demand analysis, we add UP Academy (6). We have collected lottery records from Dorchester Collegiate Academy (4), Dorchester Prep (Uncommon Schools, 5), Excel – Orient Heights (5), KIPP Boston (5) but current students are not yet old enough to appear in the data at the necessary years and grade levels. We will include these students in future analyses.

The high school lottery analysis sample includes schools with entry during the middle school years that also serve high school grades and for whom we observe 10<sup>th</sup> grade scores. The schools are (entry grade in parenthesis): Academy of the Pacific Rim (5/6), Boston Collegiate (5), Boston Prep (6), City on a Hill (9), Codman Academy (9), Match High School (9), and Match Middle School (6). The high school demand analysis includes 9<sup>th</sup> grade entry schools only, as demand for the middle school entry charters is accounted for in the middle school analysis. Schools in the high school demand analysis are: Boston Green Academy (9), City on a Hill, Codman Academy, and Match High School.

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 each panel of 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 12,535 to 11,047 for middle school and from 12,659 to 11,948 for high school.

#### 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 in our demand analysis. The *initial offer* instrument captures offers made on the day of the charter school

lottery. The *eventual 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 Table A2.

The lottery analysis uses only the eventual offer instrument. In some years, all applicants eventually received offers, in which case they do not add variation to the lottery analysis; these cases are listed as “No waitlist” for the eventual offer instrument. In 2010-2013, Fifty percent of middle school applicants are eventually offered a seat at a middle school charter, and 69 percent of high school applicants are eventually offered a seat.

## **SIMS Data**

### **Data description**

Our study uses SIMS data from the 2001-2002 school year through the 2012-2013 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 years of charter school attendance in grades prior to and MCAS outcome. A student is coded as attending a charter in each 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. The endogenous variable we use for lottery estimates sums each of these year records for all years prior to the test from the entrance year of the charter. For example, an 8<sup>th</sup> grade charter years variable would count potential years in charter from 5<sup>th</sup>-8<sup>th</sup> grade for 5<sup>th</sup> grade entry schools and 6<sup>th</sup>-8<sup>th</sup> grade for 6<sup>th</sup> grade entry schools.

## **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 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 for high school and grades 5-8 (depending on entry year) for middle school. We also use baseline tests taken prior to charter application, which are from 4<sup>th</sup>, 5<sup>th</sup>, or 8<sup>th</sup> 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 competency thresholds. We only use the first test taken in a particular subject and grade.

### **Matching Data Sets**

The MCAS data file is merged to the master SIMS data file using the unique SASID identifier. The lottery records do not include SASIDs; these records are matched using a computer algorithm and 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 each panel in Table A1 reports the number of applicant records matched to the SIMS in each applicant cohort. The overall match rate across all cohorts was 96 percent for middle school and 95 percent for high school.

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 23 percent of middle school charter applicants and 26 percent of high school applicants. Of the remaining 5,6539 middle school charter applicants, 5,262 (93 percent) contribute at least one score to our MCAS analysis. Students in the middle school MCAS analysis may contribute multiple scores at different grade levels. For the 6,115 remaining high school applicants 4,125 (67 percent) contribute at least one score to the MCAS analysis.

Table A.1: Charter School Study Coverage

Operating before:	2003-2009			2011-2012		
	Study charters (1)	Other charters (2)	All charters (3)	Study charters (4)	Other charters (5)	All charters (6)
	<i>Panel A: Middle school (serving 6th-8th grades)</i>					
Number of charters	7	3	10	9	2	11
Percentage of charters	70%	30%	100%	82%	18%	100%
6th-grade enrollment	2806	928	3734	2374	356	2730
Percentage of 6th-grade enrollment	75%	25%	100%	87%	13%	100%
	<i>Panel B: High school (serving 9th-12th grades)</i>					
Number of charters	6	3	9	7	1	8
Percentage of charters	67%	33%	100%	88%	13%	100%
9th-grade enrollment	2035	629	2664	1704	252	1956
Percentage of 9th-grade enrollment	76%	24%	100%	87%	13%	100%

Notes: The sample describes enrollment in study charters and charters not in our study by pre-2009 and post-2010 periods. The sample for pre-2009 period includes 6th or 9th charter attendees from 2003 through 2009 and the sample for post-2010 period includes 6th or 9th charter attendees from 2010 through 2013. Schools with kindergarten entry are excluded. Middle schools excluded from the study are Smith Leadership Academy, Frederick Douglas Charter, Uphams Corner Charter for 2003-2009, and Smith Leadership Academy and Dorchester Collegiate Academy for 2010-2013. Lottery records from Dorchester Collegiate Academy have recently been collected, but students in these cohorts will not reach 6th grade until 2015. High schools excluded from the study are Roxbury Charter High, Frederick Douglas Charter, Health Careers Academy from 2003-2009, and Health Careers Academy from 2010-2013.

Table A.2: Lottery Participation by Schools and Cohorts

Panel A: Middle School								
Application Year/School	Dorchester Collegiate Academy	Edward Brooke - Roslindale	Edward Brooke - Mattapan	Excel - East Boston	Lucy Stone/Grove Hall (Uncommon Schools)	Roxbury Prep (Uncommon Schools since '11)	UP Academy	
Entry Grade	4	5	5	5	5	5/6	6	
2002	Eventual					Yes		
	Initial			Not open		No		
2003	Eventual	No records				Yes		
	Initial					No		
2004	Eventual					Yes		
	Initial					No		
2005	Eventual	Not open	Incomplete records		Incomplete records	Yes		
	Initial					No		
2006	Eventual		No waitlist	Not open		Yes		Not open
	Initial		Yes		Not open	Yes		
2007	Eventual		Yes			Yes		
	Initial		Yes			Yes		
2008	Eventual		Yes		Yes	Yes		
	Initial		Yes		Yes	Yes		
2009	Eventual		Yes		Yes	Yes		
	Initial		Yes		Yes	Yes*		
2010	Eventual	No records			Yes	Yes		
	Initial				Yes	Yes		
2011	Eventual		Yes	Yes	Yes	Yes	Yes	Yes
	Initial		Yes	Yes	Yes	Yes	Yes	Yes
2012	Eventual	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Initial	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N		51	309	290	404	898	2312	913

Panel B: Combined Middle and High Schools (5th-6th - 12th grade)					Panel C: High School				
Application Year/School	Academy of the Pacific Rim	Boston Collegiate	Boston Prep	Match MS	Boston Green Academy	City on a Hill	Codman Academy	Match HS	
Entry Grade	5/6	5	6	6	9	9	9	9	
2002	Eventual	Yes				No waitlist		Yes	
	Initial	Yes	Not open			Yes	Incomplete records	Yes	
2003	Eventual	No records	Yes			No records		Yes	
	Initial		Yes					Yes	
2004	Eventual		Yes	Incomplete records		No waitlist	No waitlist	Yes	
	Initial		Yes			Yes	Yes	Yes	
2005	Eventual	Yes	Yes	No waitlist		Yes		Yes	
	Initial	Yes	Yes	Yes		Yes	Incomplete records	Yes	
2006	Eventual	Yes	Yes	Yes	Not open	Yes		Yes	
	Initial	Yes	Yes	Yes		Yes		Yes	
2007	Eventual	Yes	Yes	Yes		Yes	No records	Yes	
	Initial	Yes	Yes	Yes		Yes		Yes	
2008	Eventual	Yes	Yes	Yes	Yes	No waitlist	Yes	Yes	
	Initial	Yes	Yes	Yes	Yes	Yes	Yes	Yes*	
2009	Eventual	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
	Initial	Yes	Yes	Yes	Yes*	Yes*	Yes	Yes	
2010	Eventual	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
	Initial	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
2011	Eventual	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
	Initial	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
2012	Eventual	Yes	Yes*	Yes	Yes	No waitlist	Yes	Not entry grade	
	Initial	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
N		1560	2987	1787	1934	799	4942	1577	4281

Notes: This table shows study charters and their application cohorts. Some of the middle schools plan to serve older grades but do not do so yet. In 2012, Uncommon Schools (Roxbury Prep, Dorchester Prep, and Grove Hall) had a common lottery, so students are counted as having applied to all three schools. APR had 6th grade lotteries from 2005-2007 and 5th grade lotteries from 2007-2012. Roxbury Prep began using 5th grade lotteries in Spring 2012. Offer entries marked with a star were imputed using the previous year's initial or eventual offer cutoff. Four additional charter schools with 5th-grade entry points opened in 2012-2013: Dorchester Preparatory, Edward Brooke East Boston, Excel Orient Heights, and KIPP Boston. These schools are not included in the study since their first cohorts of sixth-graders will attend in 2013-2014. However, we collected entrance lottery records from these schools and will be able to study them in a future analysis.

Table A.3: Lottery Records

Year of application	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	All
<i>Panel A: Middle School</i>											
Total number of records	313	330	341	739	913	1143	1422	1406	1645	4283	12535
Excluding disqualified applications	313	330	341	738	911	1135	1404	1405	1623	4273	12473
Excluding late applications	313	330	340	738	909	1135	1363	1377	1576	4163	12244
Excluding out of area applications	313	329	340	733	900	1123	1353	1359	1557	4094	12101
Excluding siblings	295	302	300	677	836	1021	1223	1233	1406	3758	11051
Excluding repeat applications	295	302	300	677	836	1021	1222	1233	1406	3755	11047
Excluding records not matched to SIMS	268	260	266	634	801	1001	1182	1205	1333	3629	10579
Keep only first year of charter application	268	257	265	617	770	963	1094	1111	1234	3402	9981
Reshaping to one record per student	268	257	264	523	586	761	869	881	847	2113	7369
In Boston at baseline	184	172	177	378	425	565	657	651	630	1800	5639
Excluding applicants without a Math or ELA score	170	156	165	355	405	525	620	603	582	1681	5262
<i>Panel B: High School</i>											
Total number of records	775	653	1159	1473	1614	1970	1563	1642	1810		12659
Excluding disqualified applications	775	653	1159	1471	1612	1962	1559	1631	1806		12628
Excluding late applications	765	649	1148	1468	1612	1962	1540	1629	1806		12579
Excluding out of area applications	765	648	1148	1463	1603	1959	1540	1608	1771		12505
Excluding siblings	732	621	1094	1404	1561	1869	1492	1524	1654		11951
Excluding repeat applications	732	621	1094	1404	1561	1869	1490	1524	1653		11948
Excluding records not matched to SIMS	647	563	1013	1316	1507	1832	1434	1486	1606		11404
Keep only first year of charter application	647	561	1008	1294	1462	1785	1314	1308	1371		10750
Reshaping to one record per student	575	561	783	1018	1132	1340	967	972	921		8269
In Boston at baseline	372	403	607	734	822	1063	707	732	675		6115
Excluding applicants without a Math or ELA score	297	311	489	565	636	731	359	398	339		4125

Notes: This table summarizes the sample restrictions imposed for the lottery analysis. Disqualified applications are duplicate records and applications to the wrong grade.

Table A.4: Covariate Balance

	Middle School			High School		
	Eventually offered seat (1)	Never offered seat (2)	Difference (3)	Eventually offered seat (4)	Never offered seat (5)	Difference (6)
Female	0.486	0.494	-0.002 (.016)	0.531	0.548	-0.005 (.019)
African-American	0.555	0.493	-0.026* (.015)	0.628	0.588	-0.006 (.019)
Latino/a	0.277	0.273	0.030** (.014)	0.269	0.288	0.007 (.018)
Asian	0.017	0.023	0.002 (.004)	0.029	0.039	0.000 (.007)
White	0.127	0.175	-0.002 (.01)	0.055	0.059	0.001 (.009)
Subsidized lunch	0.714	0.722	-0.010 (.014)	0.748	0.749	0.009 (.017)
Special education	0.134	0.167	0.013 (.011)	0.049	0.051	0.014 (.009)
English language learner	0.182	0.182	0.000 (.012)	0.187	0.184	0.002 (.015)
Baseline MCAS ELA	-0.445	-0.397	-0.049 (.034)	-0.368	-0.350	-0.001 (.035)
Baseline MCAS math	-0.405	-0.369	-0.034 (.032)	-0.363	-0.323	-0.004 (.035)
N	2914	2490	5100	2613	1572	3727
P-value			0.402			0.402

Notes: This table reports coefficients from regressions of the variable in each row on an indicator variable equal to one if the student won the lottery. Regressions include risk set dummies and baseline grade dummies and exclude students with sibling priority and late applicants. The sample is restricted to students from cohorts where we should observe at least one test score. F-tests are for the null hypothesis that the coefficients on winning the lottery in all regressions are all equal to zero. Middle school results include cohorts in baseline years 2002-2011, high school results include cohorts in baseline years 2002-2010. These test statistics are calculated for the subsample that has non-missing values for all variables tested.

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

Table A.5: Attrition

Subject	Middle Schools		High Schools	
	Proportion of non-offered with MCAS (1)	Difference between offered and non-offered (2)	Proportion of non-offered with MCAS (3)	Difference between offered and non-offered (4)
Math	0.925	0.025*** (0.008)	0.770	0.007 (0.016)
ELA	0.921	0.019** (0.008)	0.784	0.007 (0.017)
N	2490	5404	1572	4185

Notes: This table reports coefficients from regressions of an indicator variable equal to one if a student has a followup test score on an indicator variable equal to one if the student won the lottery. Columns (1) and (3) show the fraction of non-offered students with followup scores, while columns (2) and (4) show the differential by offer status. Regressions include risk set dummies as well as demographic variables, year of birth dummies, year of baseline dummies, and baseline grade dummies. The sample is restricted to students who participated in an effective lottery from cohorts where we should observe follow-up scores, which includes outcome scores from 2003 to 2012 for middle school students and 2004-2012 for high school students.

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

Table A.6: Lottery Estimates of Effects on Demographic Subgroups

Group	Middle School				High School			
	Math		ELA		Math		ELA	
	Non-charter mean (1)	Charter effect (2)	Non-charter mean (3)	Charter effect (4)	Non-charter mean (5)	Charter effect (6)	Non-charter mean (7)	Charter effect (8)
All students	-0.302	0.256*** (0.027)	-0.341	0.138*** (0.026)	-0.231	0.354*** (0.061)	-0.296	0.271*** (0.053)
N		11260		11003		4051		4110
Male	-0.314	0.210*** (0.038)	-0.478	0.140*** (0.037)	-0.268	0.363*** (0.093)	-0.449	0.314*** (0.083)
N		5682		5556		1853		1878
Female	-0.288	0.306*** (0.037)	-0.193	0.136*** (0.034)	-0.199	0.343*** (0.078)	-0.167	0.229*** (0.066)
N		5578		5447		2198		2232
African-American	-0.536	0.311*** (0.039)	-0.517	0.159*** (0.039)	-0.392	0.393*** (0.079)	-0.392	0.264*** (0.068)
N		6053		5893		2450		2487
Latino/a	-0.299	0.338*** (0.052)	-0.417	0.230*** (0.051)	-0.176	0.232* (0.124)	-0.270	0.327*** (0.112)
N		2827		2771		1020		1036
Asian	0.701	0.182 (0.143)	0.260	0.135 (0.193)	0.677	0.374 (0.345)	0.118	0.432 (0.491)
N		213		208		141		142
White	0.213	0.099** (0.044)	0.161	0.046 (0.040)	0.157	0.249 (0.152)	0.018	0.117 (0.148)
N		1907		1871		368		370
Minority males	-0.444	0.256*** (0.044)	-0.609	0.171*** (0.043)	-0.333	0.378*** (0.099)	-0.509	0.349*** (0.090)
N		4726		4617		1651		1677

Notes: This table reports 2SLS estimates of the effects of time spent in charter schools for subgroups of students. Notes on the regression model are the same as notes in Table 5A.

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

Table A.7: Lottery Estimates of Effects on Program Participation Subgroups

Group at baseline	Middle School				High School			
	Math		ELA		Math		ELA	
	Non-charter mean (1)	Charter effect (2)	Non-charter mean (3)	Charter effect (4)	Non-charter mean (5)	Charter effect (6)	Non-charter mean (7)	Charter effect (8)
All students	-0.302	0.256*** (0.027)	-0.341	0.138*** (0.026)	-0.231	0.354*** (0.061)	-0.296	0.271*** (0.053)
N		11260		11003		4051		4110
Non-subsidized lunch	0.003	0.196*** (0.045)	0.014	0.069 (0.043)	-0.141	0.393*** (0.122)	-0.180	0.233** (0.107)
N		3386		3297		1094		1106
Subsidized lunch	-0.433	0.283*** (0.032)	-0.494	0.178*** (0.031)	-0.263	0.351*** (0.069)	-0.338	0.292*** (0.060)
N		7874		7706		2957		3004
Non-special education	-0.156	0.266*** (0.030)	-0.165	0.136*** (0.028)	-0.095	0.353*** (0.063)	-0.136	0.254*** (0.053)
N		9258		9031		3320		3361
Special education	-0.949	0.209*** (0.063)	-1.117	0.168** (0.068)	-0.878	0.406*** (0.146)	-1.042	0.346** (0.147)
N		2002		1972		731		749
Non-English language learner	-0.256	0.252*** (0.028)	-0.262	0.132*** (0.027)	-0.228	0.335*** (0.061)	-0.275	0.260*** (0.053)
N		9981		9733		3876		3929
English language learner	-0.629	0.292*** (0.078)	-0.900	0.177** (0.082)	-0.287	0.572* (0.300)	-0.738	0.631 (0.392)
N		1279		1270		175		181
Above Boston median, baseline math & ELA	0.203	0.228*** (0.027)	0.120	0.134*** (0.026)	0.253	0.356*** (0.067)	0.115	0.288*** (0.060)
N		6369		6276		2123		2147
Below Boston median, baseline math & ELA	-1.036	0.319*** (0.041)	-1.021	0.177*** (0.042)	-0.839	0.332*** (0.077)	-0.808	0.241*** (0.077)
N		4488		4426		1858		1889

Notes: This table reports 2SLS estimates of the effects of time spent in charter schools for subgroups of students. Notes on the regression model are the same as notes in Table 5A.

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



Table A.8: School Switching by Time

Outcomes	Application year pre-2009		Application year post-2010		All students	
	Non-charter	Charter effect	Non-charter	Charter effect	Non-charter	Charter effect
	mean (1)	(2)	mean (3)	(4)	mean (5)	(6)
<i>Panel A: Middle school (6th grade entry)</i>						
Remained in the same school in 7th grade	0.529	0.262*** (0.043)	0.591	0.102 (0.078)	0.552	0.212*** (0.038)
N		2929		1274		4203
In 8th grade	0.433	0.255*** (0.043)	0.463	0.155* (0.086)	0.437	0.244*** (0.040)
N		2927		320		3247
Attended exam school in 7th	0.171	-0.105*** (0.024)	0.138	-0.117*** (0.038)	0.158	-0.111*** (0.021)
N		2929		1274		4203
<i>Panel B: High school (9th grade entry)</i>						
Remained in the same school in 10th grade	0.855	-0.125* (0.066)	0.855	0.006 (0.128)	0.855	-0.099* (0.058)
N		4167		787		4954
In 11th grade	0.698	-0.126 (0.080)	0.628	-0.009 (0.161)	0.691	-0.111 (0.072)
N		3926		410		4336

Notes: This table reports estimates of the effect of charter attendance on the probability of remaining in the same school, separately for applicants prior to 2009 (column (2)) and post 2010 (column (4)). See notes to table 8 for additional details.

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

## Technical Appendix

### Two-Stage Least Squares

Our empirical strategy uses randomly assigned charter lottery offers to estimate causal effects of attending charter schools. The *offer* instrument,  $Z_i$  is a dummy variable indicating offers made initially or later, as a consequence of movement down a randomly sequenced waiting list. The first stage comes from estimating a linear model linking lottery offers and charter attendance. Specifically, we estimate:

$$S_{it} = \lambda_t + \sum_j \mu_j d_{ij} + \beta' X_i + \pi Z_i + \eta_{it}$$

where  $S_{it}$  indicates years of charter attendance by student  $i$  in applicant cohort  $t$ . In practice we supplement this model with grade fixed effects in the middle school results where there are multiple grades of outcomes. The parameter,  $\pi$ , captures the effect of the offer of a charter seat on the number of years of attendance.

This first stage model controls for differences in application patterns across students through a of application “risk set” dummies,  $d_{ij}$ . These indicate each unique combination of charter school applications in a particular year. We include risk set effects because the application mix determines the probability of receiving an offer even when offers at each school are randomly assigned.<sup>x</sup> 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. The lottery analysis omits siblings of current applicants as well as applicants who apply after a school's initial admissions lottery (such applicants are often offered seats non-randomly). We also control for a vector of baseline demographic variables,  $X_i$ .

Because our instrumental variables (IV) estimation strategy involves more than one instrument and takes account of risk sets and other covariates, we use an IV procedure known as Two-Stage Least Squares (2SLS). This procedure is an econometric generalization of the simple "ratio of differences" calculation in our stylized example. 2SLS begins with the first stage equation above. The fitted values from this model then replace observed charter attendance ( $S_{it}$ ) in a "second stage equation" that links charter school attendance with outcomes as follows:

$$y_{it} = \alpha_t + \sum_j \delta_j d_{ij} + \gamma' X_i + \rho S_{it} + \varepsilon_{it}$$

Here,  $y_{it}$  is the outcome of interest; the parameter  $\alpha_t$  captures a cohort effect;  $\varepsilon_{it}$  is an error term; and  $\rho$  is the causal effect of interest. The second stage controls for the same risk set dummies and demographic variables as the first stage. With two instruments used to estimate a single causal effect, we can interpret 2SLS estimates as a statistically efficient weighted average of what we'd get from a simpler calculation using the instruments one at a time, as in the stylized example in the text.

### Non-Lottery Method

In addition to the lottery estimates described above, we estimate the charter school effect using regressions with matching and statistical controls to control for differences between charter and non-charter students. We match charter students to non-charter students based on demographics and sending school at baseline. 97 percent of charter high school students are matched to at least one non-charter student; over 95 percent of charter middle school students are successfully matched. The matching procedure is described in detail the text above. Here, we detail the estimating equation for the non-lottery estimates:

$$y_{itc} = \alpha_t + \kappa_c + \theta' X_i + \rho S_{it} + \varepsilon_{itc}.$$

Again,  $S_{it}$  is a dummy variable indicating attendance at a charter school in the year after baseline. The vector  $X_i$  is a vector of student demographic and program participation controls, including baseline math and ELA test scores. We also include year fixed effects,  $\alpha_t$ , and matching cell fixed effects,  $\kappa_c$ . Middle school regressions also include grade fixed effects. The parameter of interest is  $\rho$ , which measures the difference in outcomes between charter and non-charter students, controlling for matching cell and student characteristics.

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## ENDNOTES

<sup>i</sup> See, for example, the Boston Globe article on April 7, 2013 (Vaznis, 2013) and the state's report on charter school waitlists ("Report on Charter School Waitlists").

<sup>ii</sup> Four additional charter schools with 5th-grade entry points opened in 2012-2013: Dorchester Preparatory, Edward Brooke East Boston, Excel Orient Heights, and KIPP Boston. These schools are not included in the study since their first cohorts of sixth-graders will attend in 2013-2014. However, we collected entrance lottery records from these schools and will be able to study them in a future analysis.

<sup>iii</sup> Even with random assignment, the validity of comparisons between offered and not-offered students is threatened if the likelihood of generating follow-up data differs for these groups. Appendix Table A5 shows that we observe 92 percent of possible follow-up scores in middle school and 77 percent in high school. Moreover, follow-up rates are similar by offer status: offered students are two percentage points less likely than not-offered students to exit the sample in middle school, and there is no difference in high school. The very small difference in middle school follow-up rates is unlikely to affect our causal estimates.

<sup>iv</sup> We assign a student to a charter school for the full year of attendance if they even attend the charter school for a day. We explore school switching in more detail later in this report.

<sup>v</sup> Column (3) reports estimates for schools that were in the lottery sample in the 2009 report "Informing the Debate;" these middle schools are Academy of the Pacific Rim, Boston Collegiate, Boston Prep, and Roxbury Prep; these high schools are City on a Hill, Codman Academy, and Match High School. Column (4) reports estimates for schools that have been added to the sample since the previous report; these middle schools are Edward Brooke - Roslindale, Edward Brooke - Mattapan, Excel - East Boston, Lucy Stone/Grove Hall, and Match Middle School; these high schools the later grades of Academy of the Pacific Rim, Boston Collegiate, Boston Prep, and Match Middle School.

<sup>vi</sup> Across all years, lottery study charters enroll 80% of middle school charter students and 81% of high school student charter effects. See Appendix Table A1 for details.

<sup>vii</sup> "Backfilling" is the practice of offering a seat to a student on the waitlist if seat opens up at a charter school, no matter the time in the school year. Some charters used this practice before the law change.

<sup>viii</sup> Since middle school charters are *more* likely to retain their students in the causal analysis, out-migration of students is not a good explanation for charter school impacts.

<sup>ix</sup> In our May 2013 report on charter school SAT, AP, and college outcomes we also discussed the potential for switching to influence effects. See that report for a discussion of peer effects and how they are unlikely to contribute to the charter school impacts.

<sup>x</sup>For example, in a world with three charter schools, there are 7 risk sets: all schools, each school, and any two.

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