

Accountability and Flexibility in Public Schools: New Evidence from Boston's Charters and Pilots

Atila Abdulkadiroglu, Duke
Josh Angrist, MIT
Susan Dynarski, University of Michigan
Thomas Kane, Harvard GSE
Parag A. Pathak, MIT

November 2009

Background

- An enduring question: How to improve the public education production function and close racial achievement gaps?
 - ✓ Inputs (class size, etc)
 - ✓ Incentives (for students and teachers)
 - ✓ Choice with the public system (magnet schools)
 - ✓ Autonomy and decentralization (charters, vouchers)
- Can *schools alone* close large achievement gaps ?
- We look at two autonomy / decentralization models in Boston

The Charter Model

- Charter schools are publicly funded, but operate with minimal supervision
 - ✓ Nonprofits, universities, teachers, or parents can open charters; no for-profit in this state
 - ✓ Charters are granted by the state DOE
 - ✓ Each Charter runs as its own district
 - ✓ Charters often adhere to a formula; most of ours are "No Excuses", similar to KIPP, a national franchise
- State Charters are funded through tuition paid by sending districts
 - ✓ Tuition \approx senders' average per-pupil expenditure
 - ✓ Since 1999, senders' tuition is partially reimbursed by state (determined by growth in costs)

Key Charter Features

- State Charters are outside local collective bargaining agreements
 - ✓ State Charters hire, re, and have loose work rules much like private schools
 - ✓ Charter teachers need not be certified, but must pass the state ed test in first year of work
- Charter schools are meant to be accountable
 - ✓ A charter is subject to periodic review; may be suspended, revoked, or non-renewed
 - ✓ Accountability criteria: success of academic program; organizational viability; faithfulness to a charter
 - ✓ Of 75 charters granted in Mass., 9 have been lost

The Pilot Alternative

- Pilots were introduced in the wake of charters
 - ✓ Free to: allocate staff, set budget priorities, curriculum, and scheduling
 - ✓ Boston pilots remain in BPS; typically use BPS student assignment mechanism

- Pilots are approved by the Boston Teachers Union and school staff (as start-up or conversion)
 - ✓ Free from: most collectively bargained work rules and district curriculum requirements
 - ✓ Covered by: union pay scales, seniority provisions, and employment protection
 - ✓ Some accountability

Practical Differences

1. Pilot schools use union sta
 - ◇ Charter schools hire almost as freely as private schools
2. Accountability is weaker for Pilots than for charters
 - ◇ Pilot schools do not appear to be at risk of closure
3. Pilot schools retain some union work rules
 - ◇ Pilots limit unpaid overtime
 - ◇ Charters use overtime extensively, often unpaid
4. Charters rely heavily on tutoring during and after school

Teacher characteristics compared: **Table 1**

Charter and Pilot Assignment

- Charter admissions
 - ✓ Charters cannot use admissions tests, and must take Special Ed and ESL students
 - ✓ No walk-zone priority
 - ✓ Charters use school-specific lotteries when oversubscribed
- Elementary and middle Pilots use the BPS assignment mechanism
 - ✓ The BPS assignment mechanism uses a lottery to break ties at in-demand schools
 - ✓ Two Pilot high schools use BPS assignment as well; Four have applications or auditions, no lottery
- Some Pilots and Charters are under-subscribed or filled with guaranteed applicants and/or siblings

Related work

- Lottery-based charter evaluations
 - ✓ Dobbie and Fryer (2009) Harlem Children's Zone
 - ✓ Hoxby-Muraka (2009) NYC; Hoxby-Rocko (2004) Chicago
- Design-based studies of related questions
 - ✓ IV Estimates of charter effects on graduation/college in Florida and Chicago (Booker, Sass, Gill, and Zimmer 2008)
 - ✓ RD: Grant-maintained schools in the UK (Clark 2009)
 - ✓ Lottery evaluation of Chicago magnet schools (Cullen, Jacob, and Levitt 2005)
- Qualitative charter studies
 - ✓ Merseth (2009) and Wilson (2008) describe Boston charters in our lottery study

Our Agenda

- To estimate causal effects of years (grades) spent in a Pilot or Charter school on MCAS test scores
- To this end, we use two study designs:
 1. Quasi-experimental ("lottery")
 - ✓ This solves the selection problem
 - ✓ Covers only schools with effective lotteries and reasonably good records
 2. Observational ("regression")
 - ✓ Relies on statistical controls
 - ✓ Covers all public schools in Metro Boston
 - ✓ We compare observational results for the lottery subsample to lottery results; this gives us confidence in the full-sample observational findings

Data

1. Quasi-experimental samples:

- ✓ Pilot applicants to lottery-using over-subscribed schools
 - ◇ exclude guaranteed applicants and siblings
 - ◇ with baseline data and MCAS in 2004-8
- ✓ Charter applicants to over-subscribed Boston charters with usable lottery records
 - ◇ exclude guaranteed applicants and siblings
 - ◇ with baseline data and MCAS in 2004-8

2. Observational sample:

- ✓ BPS residents attending BPS schools or a Boston Charter at baseline
- ✓ In state (SIMS) data files; with baseline demographics
- ✓ Have MCAS scores and attending BPS or Boston Charter in outcome years

Coverage Notes

- Charter lottery sample includes over-subscribed charters with usable records (middle, high only)
 - ✓ 5/11 middle schools; 2 of 6 omitted schools closed. Coverage among open is 5/9
 - ✓ 4/8 high schools; 2 of 4 omitted closed, 2 are 5-12 w/no 9th grade admits. Coverage among open 9-12 is 4/4
- 4 covered charters described in Merseth (2009): "high performing schools in high-poverty areas"
- Pilot lottery sample includes all over-subscribed pilots with lotteries
 - ✓ 5/7 elementary schools (2 under-subscribed)
 - ✓ 6/7 middle schools (1 under-subscribed)
 - ✓ 2/7 high schools (4 selective admits, 1 under-subscribed); among 9-12, coverage is 2/6

Descriptive Statistics

Table 2 shows demographics and baseline scores by school type for BPS and lottery samples

- ✓ BPS is majority nonwhite
- ✓ Charters have higher Black enrollment, lower Hispanic enrollment than BPS
- ✓ Pilots similar minority enrollment pattern but closer to BPS than charters
- ✓ Charters and Pilots have fewer SPED and ESL kids, with Charters less than Pilots
- ✓ Baseline scores show positive selection into Charters and Pilots in high school

Quasi-experimental study

Quasi-experimental Design: Charters

- We study charter applicants for spots in 6th (middle school) and 9th grade (high school)
 - ✓ Our charter applicant file includes non-sibling first-round applicants who apply to schools in our sample
 - ✓ Charters run and document their own lotteries
 - ✓ Charters are city-wide with no walk zones
- The *Charter lottery instrument* indicates students offered a seat at any Charter to which they applied
- The *Charter risk set* is defined by the set of schools to which an applicant applied (e.g., 3 schools generates 7 risk sets)

Quasi-experimental Design: Pilots

- We study non-sibling pilot applicants for spots in K2, 6th and 9th grade
 - ✓ The Pilot applicant sample includes those with a Pilot first choice on the BPS assignment form
 - ✓ Applicants are randomized within priority groups: Sibling-Walk; Sibling; Walk Zone; Others
 - ✓ Within priority groups at over-subscribed schools, offers are made by lottery number
- The *Pilot lottery instrument* indicates students with a BPS lottery number below the highest number offered at students' first-choice school
- The *Pilot risk set* is defined by: first-choice school * app year * walk zone

Covariate Balance

- Are lottery offers independent of observable characteristics?
- **Table 3** addresses this question for charters and pilots
 - The results show a few significant differences, but the overall picture is encouraging
 - Most differences are small (we should expect some sig. gaps given the many contrasts)
 - The differences do not all run the same way
 - With the exception of FRPL in pilot high schools, differences are borderline significant at most

2SLS Strategy

- The second stage controls for lottery risk sets:

$$y_{igt} = \alpha_t + \beta_g + \sum_j \delta_j d_{ij} + \gamma' X_i + \rho s_{igt} + \epsilon_{igt}, \quad (1)$$

where d_{ij} indicates i in risk set j , with effect δ_j ; s_{igt} is years in charter or pilot

- The corresponding first stage is:

$$s_{igt} = \lambda_t + \kappa_g + \sum_j \mu_j d_{ij} + \gamma' X_i + \gamma' Z_i + \eta_{igt} \quad (2)$$

- The instruments, Z_i , indicate lottery offers in student i 's risk set

Quasi-experimental Results

- Reduced form, first stage, and 2SLS results
 - ✓ Using ever-observer as IV: **Table 4**
- Large sig. charter effects in middle and high school, for ELA and esp. Math
- Pilots: modest sig. effects on elementary outcomes and a marg. sig. HS writing effect
 - ✓ **Visual IV** for middle school math
- Variations: **Table 5**
 - ✓ Charter results robust to controls for baseline scores
 - ✓ Pilot results negative with baseline scores - this is due to the absence of K-8 pilots
 - ✓ Extra instrument for charters; swapping HCA

Attrition

- Are we equally likely to find winners' and losers' MCAS scores?
- The model for attrition parallels the reduced form that goes with equations (1) and (2)
- Results: **Table 6**
 - ✓ In MS and HS, we find about .80 of charter controls; .70-.75 of pilot controls
 - ✓ Rates are .04-.05 higher among charter treated in MS, .05-.07 among pilot treated in HS
 - ✓ Other attrition gaps are insignificant
- As a check, we discarded imbalanced applicant cohorts (Table A3)
 - ✓ Results are similar in the balanced sample (Table A4)

Lottery Estimates in Depth

Compliers' School Characteristics

- Charter and Pilot lottery compliers school environment may differ
- Let X_0 denote non charter/pilot characteristics; X_1 denotes charter/pilot characteristics
- Following Abadie (2003), we estimate
 - $E[X_0|D_1 > D_0] = \frac{E[X(1-D)|Z=1] - E[X(1-D)|Z=0]}{E[(1-D)|Z=1] - E[(1-D)|Z=0]}$
 - $E[X_1|D_1 > D_0] = \frac{E[XD|Z=1] - E[XD|Z=0]}{E[D|Z=1] - E[D|Z=0]}$
- Results: **Table 7**
 - ✓ X_0 's are similar; both fall back to BPS
 - ✓ Charter treated have fewer LEP, SPED, higher baseline, less FRPL in MS
 - ✓ More girls, more black, similar FRPL students in HS
 - ✓ Pilot treated also have higher baseline in MS

Ability Interactions and Peer Effects

- Charter applicants are positively selected (Table 2); Charter compliers move to schools with better peers (Table 7)
 - ✓ This motivates us to interact years in charter with own and peer-mean baseline scores in the risk set
- **Table 8** reports the resulting main effects and interaction terms
 - ✓ Middle school charter treatment effects are larger for *weaker* students
 - ✓ No charter ability interactions in high school; one sig. neg. ability interaction for HS pilots
 - ✓ A high peer mean is associated with *smaller* treatment effects in charter MS; one pos. effect in high school
 - ✓ For pilots: one pos. effect in MS; HS interactions are imprecise

Observational study

Observational Study Methods

- Full-sample regression estimates offer a handle on external validity
- Regression model for scores of kid i in grade g , tested in year t :

$$y_{igt} = \alpha_t + \beta_g + \gamma'X_i + \rho'S_{igt} + \epsilon_{igt} \quad (3)$$

- ✓ Includes year and grade effects, demographics, and sometimes a baseline score
- ✓ S_{igt} is a *vector* of years in Pilot/Charter/Alt/Exam school from baseline to year t
- ✓ s.e.s clustered on student when grades are stacked, and always on school-by-year (2-way)
- ✓ MS models with baseline scores omit students in K-8s

Observational Study Results

- **Table 9** reports estimates by school level and score type
- Summary
 - ✓ Consistently positive Charter effects of $0.1\sigma - 0.2\sigma$ in models with baseline scores
 - ✓ Mixed Pilot effects: zero in elementary school, negative in middle school, positive in high school
 - ✓ The positive Pilot effects in high school are less than the corresponding charter effects (especially in Math)
- This is qualitatively similar to the lottery results, but magnitudes differ
- Can we generate a better match by looking at the lottery subsample?

Observational vs Lottery Estimates

- **Table 10** compares results by design and sample
- Charters
 - ✓ Observational results (with baseline scores) in the lottery sample are remarkably close to lottery estimates
 - ✓ This validates observational design, though obs results also suggest our lottery-sample charters are better
- Pilots
 - ✓ A match on modest effects for elementary pilots
 - ✓ Observational results for middle school pilots are, like lotteries, also negative, in and out of lottery sample
 - ✓ Observational results for pilot high schools ELA + Math are positive, while lottery results are insignificant
 - ✓ Observational pilot study agrees with lottery in that it shows weaker, mixed effects

(Tentative) Conclusions

- We can only study the experiments we've got: we hope to bring in more schools soon
 - ✓ Still, we have unusually complete follow-up and clean research designs, that line up well
- The evidence on Charters so far is encouraging
 - ✓ Our results show the *potential* for No Excuses Charters to generate large score gains for all types of students, including minorities and SPED/LEP
 - ✓ This does not appear to be a peer effect, though we can't yet say what features of the charter model are decisive
 - ✓ Gains may come partly from a focus on MCAS scores, but policy-makers and parents value this
- Pilot results are less conclusive, but clearly less encouraging

Tables and Figures

Table 1: Teacher Characteristics by School Type

	Traditional BPS	Pilot, Charter, Exam or Alternative School				Lottery Sample	
	Schools (1)	Charter (2)	Pilot (3)	Exam (4)	Alternative (5)	Charter (7)	Pilot (8)
<i>I. Elementary School (3rd and 4th grades)</i>							
Teachers licensed to teach assignment	86.0%	60.0%	73.2%	-	70.6%	-	71.9%
Core academic teachers identified as highly qualified	90.6%	61.3%	78.2%	-	56.6%	-	77.8%
Student/Teacher ratio	15.7	11.4	15.9	-	6.9	-	15.8
Proportion of teachers 32 and younger	26.6%	64.5%	51.8%	-	27.3%	-	50.4%
Proportion of teachers 49 and older	39.9%	8.0%	11.9%	-	31.6%	-	11.1%
Number of teachers	28.0	87.3	25.5	-	50.8	-	27.1
Number of schools	72	3	7	-	2	-	5
<i>II. Middle School (6th, 7th, and 8th grades)</i>							
Teachers licensed to teach assignment	77.8%	53.9%	65.8%	90.8%	48.6%	54.4%	65.5%
Core academic teachers identified as highly qualified	84.8%	70.4%	70.2%	94.5%	45.4%	73.1%	69.8%
Student/Teacher ratio	16.1	11.9	19.5	21.1	5.2	11.9	19.6
Proportion of teachers 32 and younger	27.1%	74.5%	55.0%	30.0%	28.6%	81.1%	54.4%
Proportion of teachers 49 and older	36.0%	4.8%	13.6%	43.3%	27.8%	1.3%	13.9%
Number of teachers	39.5	35.4	26.4	89.1	36.1	18.7	26.9
Number of schools	29	11	7	3	4	5	7
<i>III. High School (10th grade)</i>							
Teachers licensed to teach assignment	80.9%	57.6%	64.1%	90.7%	75.8%	57.7%	73.5%
Core academic teachers identified as highly qualified	85.7%	78.6%	72.7%	94.3%	80.6%	82.1%	83.6%
Student/Teacher ratio	17.6	10.9	16.0	21.1	8.9	10.6	17.5
Proportion of teachers 32 and younger	31.9%	66.9%	44.7%	30.0%	29.7%	64.3%	41.3%
Proportion of teachers 49 and older	40.3%	6.9%	15.0%	43.9%	25.3%	8.2%	7.7%
Number of teachers	62.5	20.7	20.8	89.4	35.9	17.9	9.0
Number of schools	22	8	7	3	4	4	2

Notes: This table reports student weighted average characteristics of teachers and school using data posted 2004-2007 posted on the Mass DOE website at http://profiles.doe.mass.edu/state_report/teacherdata.aspx. Teachers licensed in teaching assignment is the percent of teachers who are licensed with Provisional, Initial, or Professional licensure to teach in the area(s) in which they are teaching. Core classes taught by highly qualified teachers is the percent of core academic classes (defined as English, reading or language arts, mathematics, science, foreign languages, civics and government, economics, arts, history, and geography) taught by highly qualified teachers (defined as teachers not only holding a Massachusetts teaching license, but also demonstrating subject matter competency in the areas they teach). For more information on the definition and requirements of highly qualified teachers, see http://www.doe.mass.edu/nclb/hq/hq_memo.html.

Table 2. Descriptive Statistics

	Traditional BPS Schools (1)	Enrolled in Pilot or Charter		Applicants in Lottery Sample		Applicants in Lottery Sample with Baseline Scores	
		Charter (2)	Pilot (3)	Charter (4)	Pilot (5)	Charter (6)	Pilot (7)
		<i>i. Elementary School (2nd and 4th grades)</i>					
Female	48.3%	52.4%	48.5%	-	50.6%	-	-
Black	43.4%	71.9%	43.3%	-	54.3%	-	-
Hispanic	34.5%	15.8%	31.9%	-	22.0%	-	-
Special education	10.4%	6.4%	10.8%	-	9.9%	-	-
Free or reduced-price lunch	83.1%	68.0%	69.0%	-	66.5%	-	-
Limited English proficiency	28.8%	3.8%	19.3%	-	7.0%	-	-
Years in charter	0.016	4.542	0.011	-	0.222	-	-
Years in pilot	0.031	0.023	3.787	-	1.803	-	-
Number of students	10568	659	827	-	573	-	-
Number of schools	75	3	7	-	5	-	-
<i>ii. Middle School (6th, 7th, and 8th grades)</i>							
Female	47.0%	48.9%	49.9%	48.3%	52.6%	48.2%	54.9%
Black	46.9%	69.4%	50.5%	59.2%	49.8%	59.1%	50.6%
Hispanic	37.3%	19.0%	28.3%	19.4%	31.2%	19.6%	35.0%
Special education	24.5%	18.5%	21.4%	19.3%	17.5%	19.1%	18.2%
Free or reduced-price lunch	89.3%	73.1%	85.6%	69.1%	79.3%	69.1%	87.8%
Limited English proficiency	21.8%	7.1%	21.0%	7.7%	15.0%	7.8%	18.0%
4th Grade Math Score	-0.119	-0.069	-0.198	0.167	-0.077	0.167	-0.077
4th Grade ELA Score	-0.113	0.080	-0.127	0.235	-0.018	0.235	-0.018
Years in charter	0.018	2.458	0.012	0.120	0.954	0.119	1.054
Years in pilot	0.023	0.033	2.149	1.480	0.220	1.469	0.221
Number of students	12257	2382	2696	1355	1917	1331	1298
Number of schools	33	11	7	5	7	5	6
<i>iii. High School (10th grade)</i>							
Female	50.1%	59.9%	52.2%	59.1%	44.7%	59.0%	44.8%
Black	50.9%	65.8%	53.8%	67.6%	58.1%	67.6%	57.9%
Hispanic	36.1%	15.6%	26.7%	23.0%	24.9%	22.9%	25.0%
Special education	22.8%	14.8%	17.5%	15.5%	12.7%	15.3%	12.6%
Free or reduced-price lunch	84.7%	66.7%	77.1%	75.7%	78.5%	76.1%	79.0%
Limited English proficiency	18.9%	3.9%	7.2%	4.2%	5.5%	4.1%	5.6%
8th Grade Math Score	-0.288	0.131	0.059	0.092	0.163	0.092	0.163
8th Grade ELA Score	-0.187	0.231	0.148	0.193	0.209	0.193	0.209
Years in charter	0.006	0.009	1.951	0.483	0.971	0.484	0.970
Years in pilot	0.013	2.012	0.023	0.719	0.269	0.718	0.271
Number of students	9135	1149	1949	1957	1010	1934	1003
Number of schools	23	8	7	4	2	4	2

Notes: The table reports sample means in baseline years by school type in each column with the footnotes describing the sample. Demographic characteristics are taken from grade K for elementary school students, grade 4 for middle school students, and grade 8 for high school students. All students reside in Boston and must be enrolled in BPS or a charter school in the baseline year. Students must have at least one MCAS score to be included in the table.

1. BPS students excluding exam, alternative, charter and pilot students from 2004-2008.
2. Students enrolled in charter schools from 2004-2008.
3. Students enrolled in pilot schools from 2004-2008.
4. Charter applicant cohorts in randomized lotteries: middle school students in 2002-2007, and high school students in 2002-2006.
5. Pilot applicant cohorts: elementary school students in 2002-2004, middle school students in 2002-2007, and high school students in 2003-2006.

Table 3: Covariate Balance with Lottery Winners minus Lottery Loser at Charter and Pilot Schools

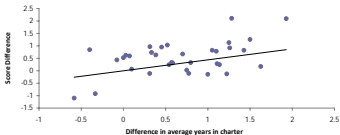
	Charter Schools				Elementary School		Pilot Schools		High School	
	Middle School		High School		Elementary School		Middle School		High School	
	All Lotteries	Lotteries with Baseline Scores	All Lotteries	Lotteries with Baseline Scores	All Lotteries	Lotteries with Baseline Scores	All Lotteries	Lotteries with Baseline Scores	All Lotteries	Lotteries with Baseline Scores
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Hispanic	-0.004 (0.024)	-0.005 (0.024)	-0.029 (0.023)	-0.028 (0.023)	-0.032 (0.038)	-	-0.016 (0.025)	-0.034 (0.038)	0.021 (0.028)	0.016 (0.028)
Black	-0.014 (0.029)	-0.013 (0.030)	0.026 (0.026)	0.027 (0.026)	0.016 (0.042)	-	0.007 (0.027)	0.008 (0.040)	-0.002 (0.031)	0.006 (0.031)
White	0.018 (0.023)	0.018 (0.024)	-0.010 (0.012)	-0.011 (0.012)	0.028 (0.036)	-	0.001 (0.019)	0.026 (0.022)	-0.017 (0.017)	-0.020 (0.017)
Asian	0.003 (0.008)	0.003 (0.008)	0.021** (0.011)	0.019* (0.011)	-0.031* (0.018)	-	0.001 (0.014)	-0.001 (0.021)	0.000 (0.015)	0.001 (0.016)
Female	0.025 (0.031)	0.030 (0.032)	-0.004 (0.026)	-0.004 (0.026)	0.013 (0.049)	-	0.017 (0.030)	0.030 (0.043)	0.015 (0.031)	0.009 (0.031)
Free or Reduced Price Lunch	-0.010 (0.029)	-0.008 (0.029)	0.007 (0.023)	0.008 (0.023)	-0.080* (0.043)	-	-0.013 (0.023)	-0.019 (0.029)	0.059** (0.026)	0.065** (0.026)
Special Education	-0.017 (0.025)	-0.017 (0.025)	-0.011 (0.020)	-0.013 (0.020)	-0.026 (0.026)	-	0.000 (0.020)	0.022 (0.034)	-0.025 (0.023)	-0.021 (0.023)
Limited English Proficiency	0.021 (0.015)	0.019 (0.015)	0.021* (0.011)	0.022* (0.011)	-0.018 (0.026)	-	-0.033** (0.016)	-0.051* (0.030)	0.015 (0.015)	0.007 (0.015)
Baseline ELA Test Score	-	0.029 (0.053)	-	0.022 (0.043)	-	-	-	0.031 (0.077)	-	0.013 (0.054)
Baseline Math Test Score	-	0.095* (0.055)	-	0.076 (0.048)	-	-	-	0.076 (0.078)	-	-0.092 (0.057)
Baseline Writing Composition Test Score	-	-	-	0.006 (0.044)	-	-	-	-	-	0.046 (0.053)
Baseline Writing Topic Test Score	-	-	-	-0.079 (0.048)	-	-	-	-	-	0.028 (0.055)
p-value: from F-test	0.829	0.713	0.113	0.061*	0.046**	-	0.714	0.775	0.470	0.611

Notes: This table reports coefficients on regressions of the variable indicated in each row on an indicator variable equal to one if the student won the lottery. Regressions also include (school choice)** (year of application) fixed effects. Samples in columns (1), (3), (5), (7), and (9) are restricted to students from cohorts where we should observe at least one test score. Samples in columns (2), (4), (6), (8), and (10) are restricted to students who also have baseline test scores. F tests are for the null hypothesis that the coefficients on winning the lottery in all regressions are all equal to zero. These tests statistics are calculated for the subsample that has non-missing values for all variables tested.

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

Level	Subject	First Stage (1)	Reduced Form (2)	2SLS (3)	2SLS w/demos (4)	First Stage (5)	Reduced Form (6)	2SLS (7)	2SLS w/demos (8)
Elementary School	ELA	-	-	-	-	2.852*** (0.193)	0.196** (0.078)	0.069** (0.027)	0.064*** (0.024) 876
		N							
	Math	-	-	-	-	2.858*** (0.194)	0.177** (0.078)	0.062** (0.027)	0.060** (0.026) 874
		N							
Middle School	ELA	0.9655							

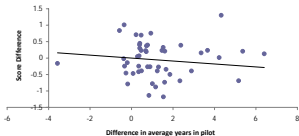
The Charter Middle School Math Effect



This figure plots treatment-control differences in test score means against treatment-control differences in years in charter. The unit of observation is a charter application risk set (N=34). The slope (weighted by risk set size) is 0.44, as is the corresponding 2SLS estimate.

A. Charter Schools

The Pilot Middle School Math Effect



This figure plots treatment-control differences in test score means against treatment-control differences in years in pilot. The unit of observation is a pilot application risk set (N=52). The slope (weighted by risk set size) is -0.045. The corresponding 2SLS estimate is -0.007.

B. Pilot Schools

Figure 1. VIV Estimates of Middle School Math Effects

Table 5: Lottery Results, Robustness Checks

Level	Subject	Charter Lotteries				Pilot Lotteries			
		Demo controls (1)	Demo & baseline score controls (2)	Overidentified model, demo controls (3)	High school w/HCA as pilot, demo controls (4)	Demo controls (5)	Demo & baseline score controls (6)	No K-8 pilot applicants, demo controls (7)	High school w/HCA as pilot, demo controls (8)
Middle School	ELA	0.149*** (0.052)	0.144*** (0.044)	0.134*** (0.051)	-	0.006 (0.043)	-0.035 (0.112)	-0.079 (0.110)	-
		N 2416	2365	2416		3390	2414	2645	
	Math	0.405*** (0.066)	0.386*** (0.054)	0.370*** (0.061)	-	-0.057 (0.048)	-0.251** (0.106)	-0.233** (0.119)	-
		N 2582	2528	2582		3851	2733	3075	
High School	ELA	0.187*** (0.055)	0.186*** (0.049)	0.162*** (0.053)	0.112 (0.076)	0.007 (0.073)	-0.053 (0.059)	-	0.111* (0.065)
		N 1947	1629	1947	1683	1007	949		1367
	Math	0.274*** (0.071)	0.226** (0.060)	0.251*** (0.065)	0.303** (0.084)	-0.011 (0.101)	0.007 (0.070)	-	0.086 (0.077)
		N 1929	1892	1929	1664	996	983		1355
	Writing Topic	0.267*** (0.078)	0.281** (0.083)	0.248*** (0.070)	0.225** (0.112)	0.173* (0.093)	0.151* (0.089)	-	0.214** (0.075)
		N 1931	1616	1931	1670	997	934		1354
	Writing Composition	0.168*** (0.062)	0.132** (0.059)	0.146*** (0.055)	0.156* (0.089)	0.111 (0.086)	0.097 (0.080)	-	0.131** (0.065)
		N 1931	1616	1931	1670	997	934		1354

Notes: This table reports the coefficients on regressions using years spent in charter or pilot schools. Sample restricted to students with baseline demographic characteristics. Demographics include female, black, hispanic, asian, other race, special education, limited english proficiency, free/reduced price lunch, and a female*minority dummy. Column 3 presents results using both initial offer and eventual offer dummies as instruments for charter school attendance, so the model is overidentified. All regressions also include year of test and year of birth dummies. Middle school and elementary school regressions pool grade outcomes and include dummies for grade level. Charter regressions include dummies for (combination of schools applied to)*(year of application) and exclude students with sibling priority. Pilot regressions include dummies for (first choice)*(year of application)*(walk zone) and exclude students with sibling priority or guaranteed admission. Regressions use robust standard errors and are clustered on year by 10th grade school for high school and student identifier as well as school by year for pooled regressions.

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

Table 6: Attrition

		Charter			Pilot		
		Prop of non-offered with MCAS	Differential Demographic Controls	Differential Demographics + Baseline Scores	Prop of non-offered with MCAS	Differential Demographic Controls	Differential Demographics + Baseline Scores
Level	Subject	(1)	(2)	(3)	(4)	(5)	(6)
Elementary School	ELA	-	-	-	0.796	0.033 (0.037)	-
	N				686	1085	-
	Math	-	-	-	0.796	0.032 (0.037)	-
	N				686	1085	
Middle School	ELA	0.805	0.042* (0.021)	0.040* (0.022)	0.699	0.029 (0.024)	0.008 (0.026)
	N	923	2869	2801	2625	4596	2778
	Math	0.811	0.046** (0.021)	0.046** (0.021)	0.702	0.030 (0.023)	0.009 (0.026)
	N	968	3034	2958	2874	5130	3124
High School	ELA	0.776	0.027 (0.022)	0.020 (0.024)	0.749	0.053** (0.026)	0.074*** (0.026)
	N	825	2433	2026	786	1300	1210
	Math	0.767	0.029 (0.023)	0.028 (0.023)	0.740	0.048* (0.026)	0.064** (0.026)
	N	825	2433	2375	786	1300	1271
	Writing Topic and Writing Composition	0.768	0.028 (0.023)	0.026 (0.024)	0.743	0.048* (0.026)	0.073*** (0.026)
	N	825	2433	2019	786	1300	1200

Notes: This table reports coefficients on regressions of an indicator variable equal to one if the outcome test score is non-missing on an indicator variable equal to one if the student won the lottery. Regressions in column (2) and (5) include dummies for (combination of schools applied to)*(year of application) as well as demographic variables, year of birth dummies, and year of baseline dummies. Column (5) controls for (first choice)*(year of application)*(walk zone) dummies, demographics, year of birth dummies and year of baseline dummies. Regressions in columns (3) and (5) add baseline test scores. Middle school and elementary school regressions pool grades and include grade dummies. Standard errors are clustered at the student level. Sample is restricted to students who participated in an effective lottery from cohorts where we should observe follow-up scores. High school students who take Writing Topic must also take Writing Composition.

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

Table 7: Characteristics of Treated and Non-treated Schools for Compilers

School Characteristic	Middle Schools				High Schools			
	Charter		Pilot		Charter		Pilot	
	Non-Treated (1)	Treated (2)	Non-Treated (3)	Treated (4)	Non-Treated (5)	Treated (6)	Non-Treated (7)	Treated (8)
Fraction female	0.464	0.545	0.465	0.477	0.494	0.652	0.473	0.406
Fraction black	0.469	0.361	0.455	0.361	0.547	0.652	0.544	0.507
Fraction hispanic	0.273	0.192	0.371	0.220	0.322	0.242	0.256	0.254
Fraction with limited English proficiency	0.123	-0.002	0.109	0.103	0.147	0.001	0.110	0.021
Fraction special ed	0.227	0.103	0.267	0.186	0.188	0.089	0.194	0.143
Fraction free or reduced price lunch	0.767	0.501	0.786	0.762	0.668	0.683	0.631	0.502
Fraction with first language not English	0.310	0.143	0.390	0.382	0.368	0.229	0.346	0.315
Mean baseline ELA MCAS score	0.110	0.353	-0.043	0.262	-0.211	0.202	-0.168	0.039
Mean baseline Math MCAS score	0.098	0.380	-0.019	0.293	-0.385	0.050	-0.276	-0.078
Fraction of teachers licensed to teach assignment	0.904	0.496	0.889	0.857	0.842	0.776	0.864	0.898
Student/teacher ratio	12.680	10.605	12.639	13.084	14.644	13.372	14.221	14.786

Notes: This table reports the results of IV regressions designed to estimate mean treated and non-treated characteristics for compliers in the charter and pilot lotteries. The non-treated means are produced by estimating models of the form: $X(1-D) = a + b(1-D) + R'g + e$, where X is the school characteristic of interest observed at the school actually attended by each student in the year immediately after the lottery, D is a dummy for whether the student attended charter/pilot in this year, R is a vector of risk set dummies, and $(1-D)$ is instrumented using the lottery win/loss dummy. The IV estimate of "b" gives an estimate of the mean of X for the compliers in the non-treated state. The treated means are produced by estimating models of the form $X \cdot D = a + b \cdot D + R'g + e$, where D is instrumented by the lottery win/loss dummy. Here, the IV estimate of "b" gives an estimate of the mean of X for the compliers in the treated state.

Table 8: Interaction Models

Level	Subject	Own baseline score				Mean baseline score in risk set				
		Charters		Pilots		Charters		Pilots		
		main effect	interaction	main effect	interaction	main effect	interaction	main effect	interaction	
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	
Middle School										
	ELA		0.145*** (0.044)	-0.094* (0.051)	-0.030 (0.114)	-0.044 (0.053)	0.185*** (0.050)	-0.716** (0.346)	-0.009 (0.138)	-0.269 (0.453)
		N	2,365		2,414		2,365		2,414	
	Math		0.386*** (0.052)	-0.137** (0.060)	-0.250** (0.107)	-0.002 (0.041)	0.441*** (0.059)	-1.015*** (0.279)	-0.341*** (0.130)	0.535* (0.291)
		N	2,528		2,733		2,528		2,733	
High School										
	ELA		0.189*** (0.050)	0.092 (0.083)	-0.053 (0.058)	-0.026 (0.087)	0.185*** (0.050)	0.052 (0.419)	-0.040 (0.059)	0.792 (0.672)
		N	1,629		949		1,629		949	
	Math		0.236*** (0.061)	0.086 (0.066)	0.010 (0.065)	-0.102* (0.052)	0.218*** (0.055)	0.609** (0.297)	0.023 (0.070)	0.606 (0.565)
		N	1,892		983		1,892		983	
	Writing Topic		0.282*** (0.084)	0.037 (0.082)	0.153* (0.090)	-0.081 (0.087)	0.272*** (0.086)	0.385 (0.942)	0.164* (0.090)	0.143 (0.629)
		N	1,616		934		1,616		934	
	Writing Composition		0.137** (0.059)	0.078 (0.073)	0.117 (0.082)	-0.079 (0.091)	0.140** (0.068)	-0.238 (0.614)	0.129 (0.087)	0.428 (0.557)
		N	1,616		934		1,616		934	

Notes: This table shows results analogous to those reported in the 2SLS lottery results in Table 4, but specifications now include interaction terms. The models estimated are of the form: $Y = \beta_1 S + \beta_2 (S \cdot T)$, where Y is the outcome of interest, S is years spent in charter (or Pilot), and T is own baseline test score or mean baseline test score in the risk set. The main effects are at the mean. Regressions also include risk set dummies, year of birth dummies, and year of test dummies, as well as demographic controls and an own baseline score main effect. Middle school regressions include grade dummies. Regressions use robust standard errors and are clustered on year by 10th grade school for high school and student identifier as well as school by year for middle school.

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

Table 9. Observational Analysis for Charter and Pilot

Level	Subject	Demographics		Demographics & Baseline Scores	
		Charter (1)	Pilot (2)	Charter (3)	Pilot (4)
Elementary School					
	ELA ¹	0.055*** (0.017)	0.015 (0.020)	-	-
	N		20058		
	R ²		0.134		
	Math ²	0.038 (0.023)	0.024 (0.023)	-	-
	N		17356		
	R ²		0.131		
Middle School					
	ELA ³	0.116*** (0.014)	-0.072*** (0.014)	0.104*** (0.012)	-0.078*** (0.011)
	N		34301		31620
	R ²		0.339		0.538
	Math ⁴	0.176*** (0.020)	-0.096*** (0.017)	0.180*** (0.018)	-0.100*** (0.013)
	N		38583		35764
	R ²		0.350		0.576
High School					
	ELA ⁵	0.228*** (0.020)	0.155*** (0.018)	0.166*** (0.018)	0.094*** (0.016)
	N		16609		12347
	R ²		0.487		0.623
	Math ⁶	0.247*** (0.040)	0.126*** (0.026)	0.151*** (0.031)	0.052** (0.023)
	N		16350		15868
	R ²		0.509		0.700
	Writing Topic ⁷	0.228*** (0.028)	0.154*** (0.023)	0.206*** (0.031)	0.141*** (0.024)
	N		16289		12181
	R ²		0.308		0.354
	Writing Composition ⁸	0.204*** (0.021)	0.148*** (0.019)	0.178*** (0.022)	0.129*** (0.018)
	N		16289		12181
	R ²		0.348		0.394

Notes: This table reports the coefficients on regressions using years spent in different types of schools. The excluded category is traditional BPS schools. Coefficients are estimated for years spent in pilot schools, charter schools, exam schools, and alternative schools. Sample restricted to students with baseline demographic characteristics. Demographics include female, black, hispanic, asian, other race, special education, limited english proficiency, free/reduced price lunch, and a female*minority dummy. Regressions also include year of test and year of birth dummies. Middle school and elementary school regressions pool grade outcomes and include dummies for grade level. Regressions use robust standard errors and are clustered on year by 10th grade school for high school and student identifier and school by year for the pooled middle school and elementary school regressions.

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

1. Elementary school ELA is for Grade 3 (2005-08) and Grade 4 (2005-08).
2. Elementary school Math is for Grade 3 (2005-08) and Grade 4 (2005-08).
3. Middle school ELA is for Grade 6 (2005-08), Grade 7 (2005-08), and Grade 8 (2005-08).
4. Middle school Math is for Grade 6 (2004-08), Grade 7 (2005-08), and Grade 8 (2006-08).
5. High school ELA is for Grade 10 (2004-08).
6. High school Math is for Grade 10 (2004-08).
7. High school Writing Topic is for Grade 10 (2004-08).
8. High school Writing Composition is for Grade 10 (2004-08).

Table 10: Estimates in and Out of the Lottery Sample

		Charters				Pilots			
		Lottery		Observational		Lottery		Observational	
Level	Subject	With Demographics	With Baseline Scores	In Lottery Sample	Not in Lottery Sample	With Demographics	With Baseline Scores	In Lottery Sample	Not in Lottery Sample
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Elementary School	ELA	-	-	-	0.055*** (0.018)	0.064*** (0.024)	-	0.051* (0.026)	-0.033 (0.025)
	N				20058	876		20058	
	Math	-	-	-	0.037 (0.023)	0.060** (0.026)	-	0.079*** (0.028)	-0.059* (0.032)
	N				17356	874		17356	
Middle School	ELA	0.149*** (0.052)	0.144*** (0.044)	0.158*** (0.017)	0.082*** (0.014)	0.006 (0.043)	-0.035 (0.112)	-0.076*** (0.015)	-0.079*** (0.016)
	N	2416	2365	31620		3390	2414	31620	
	Math	0.405*** (0.066)	0.386*** (0.054)	0.312*** (0.028)	0.129*** (0.020)	-0.059 (0.048)	-0.251** (0.106)	-0.116*** (0.015)	-0.078*** (0.019)
	N	2582	2528	35764		3851	2733	35764	
High School	ELA	0.187*** (0.055)	0.186*** (0.049)	0.188*** (0.023)	0.134*** (0.022)	0.007 (0.073)	-0.053 (0.059)	0.141*** (0.018)	0.077*** (0.017)
	N	1947	1629	12347		1007	949	12347	
	Math	0.274*** (0.071)	0.226** (0.060)	0.158*** (0.045)	0.140*** (0.032)	-0.011 (0.101)	0.007 (0.070)	0.139*** (0.036)	0.024 (0.023)
	N	1929	1892	15868		996	983	15868	
	Writing Topic	0.267*** (0.078)	0.281** (0.083)	0.253*** (0.041)	0.136*** (0.032)	0.173* (0.093)	0.151* (0.089)	0.242*** (0.019)	0.103*** (0.025)
	N	1931	1616	12181		997	934	12181	
	Writing Composition	0.168*** (0.062)	0.132** (0.059)	0.207*** (0.029)	0.134*** (0.024)	0.111 (0.086)	0.097 (0.080)	0.195*** (0.021)	0.104*** (0.018)
	N	1931	1616	12181		997	934	12181	

Notes: Columns (1) and (5) report 2SLS coefficients from Table 4. Columns (2) and (6) report 2SLS coefficients from Table 5. These models include demographic and baseline test score controls. Observational models include separate variables for years in lottery sample pilot schools, lottery sample charter schools, non-lottery sample pilot schools, and non-lottery sample charter schools. They also include the same covariates as in Table 10 as well as dummies for membership in the relevant lottery samples. For a given school level and test, columns (3), (4), (7), and (8) report coefficient estimates from the same regression. As in Table 10, observational models restrict the sample to students who were in Boston in the year of the relevant test.

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