The Impact of Attending a School with High-Achieving Peers: Evidence from the New York City Exam Schools[†]

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This paper uses data from three prominent exam high schools in New York City to estimate the impact of attending a school with high-achieving peers on college enrollment and graduation. Our identification strategy exploits sharp discontinuities in the admissions process. Applicants just eligible for an exam school have peers that score 0.17 to 0.36 standard deviations higher on eighth grade state tests and that are 6.4 to 9.5 percentage points less likely to be black or Hispanic. However, exposure to these higher-achieving and more homogeneous peers has little impact on college enrollment, college graduation, or college quality. (JEL H75, I21, J15)

Public exam schools are prominent around the world—offering students the opportunity to attend schools with exceptionally high-achieving peers. This provides a rich laboratory to investigate peer effects among the elite. Stuyvesant, the most selective exam school in New York City, has the highest average Scholastic Aptitude Test (SAT) scores of any high school in New York state. Bronx Science, another New York City exam school, is attended by students with average SAT scores at around the 99.9th percentile of the New York state distribution, and has produced more Intel Science Talent Search finalists than any other high school in the nation. Even the least selective of New York City's traditional exam schools, Brooklyn Tech, has average SAT scores at around the 99th percentile of the New York state distribution (Abdulkadiroglu, Angrist, and Pathak 2011).

To the extent that students benefit from social interactions with high-achieving peers, exam schools are likely to increase achievement for the typical applicant. Indeed, many argue that the success of exam school alumni is prima facie evidence of the importance of attending a school with high-achieving peers. Conversely, exam school alumni may be successful simply because they were highly gifted and motivated teenagers who would have prospered in any school, independent of their set of peers. In fact, social interactions in exam schools could be negative, especially for students who are lower in

the ability distribution with a comparative advantage in nonacademic activities (Cicala, Fryer, and Spenkuch 2011). Lower relative ability may also make students less competitive in college admissions, even if their absolute level of achievement is unchanged (Attewell 2001). In these cases, exam school students might be better served by a less competitive environment or greater heterogeneity among their peers.

This paper estimates the impact of attending a school with high-achieving peers on longer term academic outcomes using data from three of the most prominent exam high schools in the United States: Brooklyn Technical High School, the Bronx High School of Science, and Stuyvesant High School. Our identification strategy exploits the fact that admission into New York City's exam high schools is a discontinuous function of an individual's admissions test score. As a result, there exist cutoff points around which very similar applicants attend different high schools with markedly different peers. Exam school applicants just eligible for one of the three exam schools in our sample attend schools with peers that score 0.17 to 0.36 standard deviations higher on eighth grade math and reading tests. Successful applicants are also 3.5 to 4.8 percentage points less likely to have peers that are black, and 2.9 to 4.7 percentage points less likely to have peers that are Hispanic. Our identification strategy attributes any discontinuous relationship (or lack thereof) between average outcomes and admissions test scores at these cutoffs to the causal impact of attending a school with different peer characteristics.

In our empirical analysis, we find that the stark changes in peer characteristics associated with exam schools have little causal effect on longer term outcomes. The impact of exam school eligibility on college enrollment or graduation is, if anything, *negative*. Students just eligible for Brooklyn Tech are 2.3 percentage points (approximately 3.0 percent) less likely to graduate from a four-year college. Students eligible for Bronx Science and Stuyvesant are neither more or less likely to graduate—the 95 percent confidence interval rules out impacts larger than 2.8 percentage points (approximately 3.4 percent) for Bronx Science and 2.5 percentage points (approximately 3.0 percent) for Stuyvesant. The results are nearly identical when examining college enrollment, enrollment in more selective institutions, or enrollment in a post-baccalaureate program.

Our work is one of two regression discontinuity analyses of highly selective US exam schools. In independent, contemporaneous work, Abdulkadiroglu, Angrist, and Pathak (2011) estimate the impact of attending an elite exam school in Boston and New York City on high school academic outcomes, finding little effect of exam school eligibility for most students. The key difference between our work and Abdulkadiroglu, Angrist, and Pathak (2011) is that we focus on college outcomes, which are available for all students, not just the selected sample who choose to attend a public school if not admitted into an exam school. In the subsample of applicants enrolling in New York City public high schools, we find that exam school eligibility increases the likelihood that a student takes more advanced high school coursework and the probability that a student graduates with a more advanced high school diploma, but there is little impact of attending an exam school on SAT reading and writing scores, and, at best, a modest positive impact on SAT math scores (Dobbie and Fryer 2011).[1]

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[1] Outside of the United States, Pop-Eleches, and Urquiloa (2011) use almost 2,000 regression discontinuity quasi-experiments observed in the context of Romania's high school educational system to show that students with

There are two important caveats to our analysis. First, as previously mentioned, peer composition may not be the only component of the educational production function that changes with exam school attendance. While observable school inputs such as teacher experience, teacher absences, and teacher salary do not differ systematically across exam schools and traditional public schools in New York City, it is possible that the exam schools differ in unobservable ways, such as through a different curriculum or level of parent involvement. Second, we estimate the benefit of attending an exam school for the *marginal* student admitted to each exam school. It is plausible that the impact of attending an exam school is different for other parts of the distribution. To partially address this issue, we estimate the effect of exam school eligibility separately for students with high and low state test scores in eighth grade, finding no statistically significant differences. This finding suggests that exam schools affect high- and low-ability students in a similar way. Moreover, many commonly proposed exam school policies, from creating new exam schools to giving preference to disadvantaged students in exam school admissions, are likely to affect students near current admissions margins.

The next section provides a brief overview of our institutional setting and contribution to the literature on peer effects. Section III reviews some theoretical explanations for why students may or may not benefit from exam schools. Section IV describes our data and presents summary statistics. Section V details our research design. Section VI presents results estimating the impact of exam school eligibility on a host of academic outcomes. The final section concludes. An online Appendix presents additional results and describes our sample construction.

I. New York City Exam Schools

New York City's three original academic exam schools are Stuyvesant High School, Bronx High School of Science, and Brooklyn Technical High School. Each school enrolls students in grades 9–12, and is run by the NYC Department of Education (NYCDOE).[2] Stuyvesant, the most selective exam school in New York

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access to higher-achieving schools and tracks within schools score higher on an end-of-high-school exam. Dustan (2010) exploits the allocation mechanism to elite high schools in Mexico City to show that attending an elite school is associated with higher end-of-school test scores. Clark (2007) employs a regression discontinuity design using entrance exam assignment rules to grammar schools in the United Kingdom, finding little effect of admission on exit scores four years later. There is also an impressive literature examining peer effects in other educational settings (Hoxby 2000; Hanushek et al. 2003; Angrist and Lang 2004; Hoxby and Weingarth 2006; Lavy, Silva, and Weinhardt 2009; Ammermueller and Pischke 2009; Imberman, Kugler, and Sacerdote 2012; and Carrell, Sacerdote, and West 2012). See Sacerdote (2011) for a review of this literature.

[2] In 2002, the High School for Math, Science, and Engineering at City College, the High School of American Studies at Lehman College, and Queens High School for the Sciences at York College were created to educate students who did not get into one of the three original specialized schools. Staten Island Technical High School was declared a specialized school in 2005, and Brooklyn Latin School was founded in 2006 to further expand the set of specialized schools. Staten Island Technical High School and Brooklyn Latin School are too new to have alumni data, and LaGuardia High School does not admit students using the Specialized High Schools admissions test. The High School of American Studies at Lehman College, the High School for Math, Science, and Engineering at City College, and the Queens High School for the Sciences at York College have alumni data for only the 2007 through 2009 high school cohorts, none of which have graduated from college. We therefore focus our analysis on the three original exam schools where we have richer data on outcomes. Results including all academic exam schools for the 2007–2013 cohorts are available in online Appendix Tables 3 through 7. In all results we omit LaGuardia High School, an exam school that focuses on the arts and does not select students using the SHSAT exam. There is also a fourth original New York City exam school—Hunter College High School—that is publicly funded but

City, was founded in 1904. The school was ranked thirty-first on the 2010 *US News and World Report* Best High Schools rankings, and has produced 103 Intel Science Talent Search semi-finalists, 13 of which were finalists, in the past eight years, the second best in the nation. Bronx Science, the second most selective exam school in our sample, has produced another 59 Intel Science Talent Search semi-finalists and six finalists over the same eight year stretch, the fifth and eighth best totals in the nation, respectively. Bronx Science was ranked fifty-eighth in the *US News and World Repor*t Rankings. Brooklyn Tech, the largest and least selective of the three original exam high schools, was ranked the sixty-third best high school by *US News and World Report*, and, along with Stuyvesant and Bronx Science, has been designated a "public elite" high school by *Newsweek*. Stuyvesant typically enrolls just over 3,000 students, Bronx Science enrolls between 2,600 and 2,800 students, and Brooklyn Tech enrolls about 4,500 students.

Admissions to each of the academic exam schools are determined by the Specialized High Schools admissions test (SHSAT). On the day of the exam, students rank the schools in order of preference. The typical exam school applicant ranks multiple schools, with 94.1 percent of applicants ranking at least 2 schools and 85.7 percent ranking at least 3 schools. Over 70 percent of applicants rank every exam school. Test results are then ranked from the highest score to the lowest, and administrators place students in high schools starting with the students with the highest score. Each student is placed into their most preferred school that still has seats until no seats remain at any school. Each exam school makes their offers simultaneously and there is no waitlist for exam school placement. Eighth grade applicants can retake the SHSAT in ninth grade and reapply. See Dobbie and Fryer (2011) for additional details on the SHSAT.

As previously discussed, New York City's exam schools are characterized by very high-achieving students. Students at all three traditional exam schools have average SAT scores at the ninety-ninth percentile of the New York state distribution (Abdulkadiroglu, Angrist, and Pathak 2011). Eighty-four percent of Stuyvesant graduates in our sample later enroll in a 4-year college, with 28.4 percent enrolling in a school with a median SAT score of more than 1,400. At Bronx Science, 83.4 percent of students enroll in a 4-year college, with 13.8 percent enrolling in a school with a median incoming SAT score of more than 1,400, and at Brooklyn Tech, 77.7 percent of students enroll in a 4-year college, with 4.8 percent enrolling in a school with a median incoming SAT score of more than 1,400. In sharp contrast, only 32.2 percent of NYC students enroll in a 4-year college, with 0.9 percent enrolling in a school with a median SAT score of more than 1,400. Over half of New York City students attending a college with a median SAT score of more than 1,400 attended one of the 3 exam schools in our study, with 64 percent of NYC students attending Harvard, Princeton, or Yale having attended one of the three NYC exam schools in our sample.

Differences in educational inputs between NYC exam schools and traditional public schools are far less dramatic. The typical teacher at Stuyvesant earned $78,152 in

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administered by Hunter College, with admissions determined by a test taken in sixth grade. Admissions data from Hunter were not available for this analysis.

2008–2009, with teachers at Bronx Science and Brooklyn Tech earning $72,088 and $76,213, respectively. The typical teacher in NYC earned $72,557. Teachers in the exam schools have somewhat more experience than other teachers, but are absent approximately the same number of school days each year.[3] These sharp differences in peer characteristics, and more muted differences in school characteristics, offer a rich laboratory to investigate the effects of high-achieving peers.

II. Conceptual Framework

There are at least two theories for why the marginal student might benefit from attending a school with high-achieving peers. First, a well-developed literature emphasizes the importance of peer groups (Coleman et al. 1966), social interactions (Case and Katz 1991; Cutler and Glaeser 1997), and network externalities (Borjas 1995; Lazear 2001) in the formation of skill and values, and the development of human and social capital (see Sacerdote 2011 for a recent review). In particular, there are likely to be fewer "bad apples" in exam schools that exert negative externalities on high-achieving students (Lazear 2001; Hoxby and Weingarth 2006; Carrell and Hoekstra 2011). Second, if teachers teach to the median student in their classrooms, exam schools are likely to have higher academic rigor as a result of the higher-achieving student population (Duflo, Dupas, and Kremer 2011).

There are also several theories that argue a school with highly achieving peers may be bad for the marginal student, particularly for boys. Peer interactions may be negative for the marginal student if she is lower in the ability distribution, leading her to have a comparative advantage in nonacademic activities (Cicala, Fryer, and Spenkuch 2011). The marginal student is also likely to have a lower class rank than she otherwise would have, making her less competitive in college admissions even if her absolute level of achievement is unchanged (Attewell 2001). The marginal student may also suffer from an "invidious comparison" with her now higher-achieving peers, leading to decreased academic achievement (Hoxby and Weingarth 2006). Very high-achieving peers may also have no impact if other endogenous variables in the production of achievement (e.g., parental inputs or time on homework) are substitutes for better peers. For instance, parents whose children score above the admission threshold may invest less in their child's education, provide less monitoring of their teachers, or simply be more trusting of the school with the education of their child (Cullen, Jacob, and Levitt 2006; Pop-Eleches and Urquiola 2011). Finally, it is also possible that exam school courses are taught too far above the level of the marginal student.

It is impossible to identify the separate impact of each of these potential channels with the data available here. Instead, this paper's goal is to produce credible estimates of the net impact of attending a high school with higher-achieving peers on college enrollment and graduation. The resulting reduced-form estimates will likely reflect a number of the channels specified in this section.

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[3]One dimension on which exam schools and traditional public schools differ is in their students per teacher ratio, with exam schools having approximately three to six fewer students per teacher, although their overall total enrollments are much higher.

III. Data and Descriptive Statistics

To test the impact of exam school attendance on later outcomes, we merge information from the Specialized High Schools Admissions Test (SHSAT) records, data on college enrollment and completion from the National Student Clearinghouse (NSC), and data on student demographics and outcomes from the New York City Department of Education (NYCDOE).

SHSAT records are available from 1989 to 2008, encompassing the high school graduating cohorts of 1994 to 2013. The admissions data include name, date of birth, gender, math and English scale scores, school preferences, and whether each student was eligible at each of the exam schools.

To explore the impact of exam school attendance on college outcomes, we match the admissions records to information on college attendance from the NSC, a non-profit organization that maintains enrollment information for 92 percent of colleges nationwide. The NSC data contain information on enrollment spells for all covered colleges that a student attended, though not grades or course work. The admissions data were matched to the NSC database by NSC employees using each student's full name, date of birth, and high school graduation date. Students who are not matched to the NSC database are assumed to have never attended college. Additionally, 4 percent of records in our sample were blocked by the student or student's school. Students eligible for an exam school are no more or less likely to have a record blocked than other students. Other than the blocked records, the NSC data is available for all cohorts and students in the admissions data, regardless of eventual high school enrollment.

To provide a measure of college quality, we match the NSC records to data on college characteristics from the 2010 *US News and World Report Best Colleges Rankings*. The *US News and World Report* collects data on college characteristics and statistics for four-year colleges in the United States, including average class size, size of the faculty, graduation rates, tuition, room and board, average debt, loan size, percent of students receiving aid, acceptance rate, standardized test scores, high school GPA where available, demographic information on gender and the diversity index, freshman retention, and annual alumni donations. We use the midpoint SAT score in 2010 as our primary measure of college quality. When only ACT scores are available, we convert them to SAT scores using the ACT's official score concordance. We code all college outcomes through 2009, regardless of high school cohort. Results are identical if we only use the first four, five, or six years after a student graduates high school.

To explore the impact of exam school attendance on peer characteristics, we also match SHSAT scores to administrative data from NYCDOE. The NYCDOE data contain detailed information on students' enrollment histories, test scores, course-taking, and other outcomes of interest for students that stay in the public school system. The NYCDOE is available for only the 2002 through 2013 graduating cohorts, with some data available over fewer years. See Dobbie and Fryer (2011) for additional details.

Summary statistics for each exam school are displayed in Table 1. We include all of the available cohorts for each outcome as detailed in online Appendix Table 2. School characteristics are for the 2008–2009 school year, which are the most recent

TABLE 1—SUMMARY STATISTICS

	NYC (1)	Exam takers (2)	Stuyvesant (3)	Bronx Science (4)	Brooklyn Tech (5)
Student characteristics					
Male	0.510	0.494	0.575	0.561	0.576
White	0.124	0.169	0.280	0.269	0.214
Asian	0.137	0.284	0.670	0.599	0.570
Black	0.337	0.296	0.018	0.038	0.128
Hispanic	0.388	0.238	0.030	0.075	0.084
Free lunch	0.619	0.532	0.390	0.312	0.621
Eighth math	0.005	0.778	2.081	1.750	1.601
Eighth ELA	0.003	0.690	1.975	1.612	1.344
Regents taking outcomes					
Math 1	0.537	0.879	0.744	0.736	0.757
Math 2	0.171	0.404	0.748	0.741	0.717
English language arts	0.631	0.605	0.957	0.952	0.924
US history	0.518	0.555	0.762	0.770	0.909
Global history	0.641	0.698	0.965	0.963	0.943
Number of science regents	1.220	1.925	3.217	2.544	2.181
Living environment	0.615	0.838	0.959	0.968	0.910
Earth system science	0.296	0.396	0.358	0.252	0.356
Chemistry	0.214	0.456	0.960	0.377	0.391
Physics	0.095	0.235	0.940	0.947	0.525
Graduation outcomes					
HS graduate	0.468	0.748	0.930	0.911	0.871
Local diploma	0.227	0.140	0.001	0.007	0.042
Regents diploma	0.171	0.326	0.122	0.228	0.192
Adv. regents diploma	0.091	0.390	0.814	0.686	0.653
SAT outcomes					
Took SAT	0.355	0.323	0.933	0.909	0.863
SAT score (if taken)	1,340.487	1,516.619	2,058.556	1,935.007	1,795.396
College outcomes					
Start four-year college	0.319	0.549	0.840	0.834	0.777
College SAT > 1,200	0.048	0.125	0.663	0.508	0.249
College SAT > 1,300	0.024	0.067	0.519	0.321	0.129
College SAT > 1,400	0.009	0.025	0.284	0.138	0.048
School characteristics					
Teacher salary	72,557	71,866	78,152	72,088	76,213
Teacher experience	11.018	10.647	13.955	11.180	12.447
Teacher absences	0.404	0.377	0.535	0.254	0.387
Students per teacher	15.413	10.816	11.295	12.497	9.479
Students per staff	14.440	10.090	10.675	10.165	9.281

Notes: This table reports summary statistics for New York City's exam high schools. The sample is restricted to NYC public school students in the 2002 through 2013 high school cohorts. Ethnicity is further restricted to the 2008 through 2013 high school cohorts. Regents outcomes are restricted to the 2005–2009 high school cohorts. SAT outcomes are restricted to the 2007–2010 high school cohorts. Regents Math 1 includes Math A and Integrated Algebra. Math 2 includes Math B and Trigonometry. School characteristics are from the 2008–2009 school year.

available. Students at exam schools are more likely to be white or Asian than the typical student in NYC or the typical student who took the SHSAT, less likely to be black or Hispanic, and less likely to be eligible for free or reduced price lunch. As previously discussed, New York City's exam schools are also characterized by exceptionally high-achieving students. Students at Stuyvesant score about 2.0 standard deviations higher than the typical NYC student on the state math and English

exam in eighth grade, while students at Bronx Science and Brooklyn Tech score about 1.7 and 1.5 standard deviations higher, respectively.

Students at Stuyvesant, Bronx Science, and Brooklyn Tech are far more likely to take Regents exams compared to the typical NYC student or SHSAT taker, particularly in optional and more advanced subjects such as a second math class covering Trigonometry, Chemistry, and Physics.[4]

Students at exam schools are more likely to graduate high school than their peers in other NYC schools. Ninety-three percent of Stuyvesant students graduate from high school, compared to 53.7 percent of students in NYC as a whole. And 91.1 and 87.1 percent of Bronx Science and Brooklyn Tech students graduate from high school. Exam school students are also far more likely to receive a Regents or Advanced Regents diploma, earned by taking more advanced math and science courses. While 81.4 percent of Stuyvesant students, 68.7 percent of Bronx Science students, and 65.6 percent of Brooklyn Tech students receive an Advanced Regents diploma, only 9.2 percent of students in NYC do.

Students at exam schools are also much more likely to enroll in a four-year college than the typical NYC student or SHSAT taker, and tend to attend more selective colleges than other students. 84 percent of Stuyvesant students enrolled in a four-year college during our sample period, with 28.4 percent of them enrolling in a school with a median SAT score of more than 1,400. At Bronx Science, 83.4 percent of students enrolled in a four-year college, with 13.8 percent enrolling in a school with a median incoming SAT score of more than 1,400. At Brooklyn Tech, 77.7 percent of students enrolled in a four-year college, with 4.8 percent enrolling in a school with a median incoming SAT score of more than 1,400. To put this in context, only 32.2 percent of NYC students enroll in a four-year college, and only 0.9 percent enroll in a school with a median SAT score of more than 1,400. Of that 0.9 percent, 51.3 percent attended 1 of the 3 exam schools in our sample. Sixty-four percent of NYC students attending Harvard, Princeton, or Yale graduated from Stuyvesant, Bronx Science, or Brooklyn Tech.

IV. Research Design

Our research design exploits the fact that entry into each exam school is a discontinuous function of a student's SHSAT score. Consider the following model of the relationship between future outcomes (y) and enrollment in a school (S_i):

$$(1) \qquad\qquad y_i = \alpha_0 + \alpha_1 S_i + \varepsilon_i.$$

The parameter of interest is α_1, which measures the causal effect of exam school attendance on future outcomes y_i. The problem for inference is that if individuals select into high schools because of important, unobserved determinants of later outcomes, such estimates may be biased. In particular, it is plausible that people who

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[4]The structure of the New York math Regents changed over the sample period. Following the advice of the NYCDOE, we combine Math A and Integrated Algebra into a single score, and Math B and Trigonometry into a second score. Results are identical if we use Math A and B only, which make up the majority of the scores in our sample.

select into specialized high schools had different academic skills and motivation before they enrolled. Since exam school enrollment may be a function of ability, this can lead to a bias in the direct estimation of (1) using OLS. The key intuition of our approach is that this bias can be overcome if the distribution of unobserved characteristics of individuals who are just barely eligible for a school is the same as the distribution among those who were just barely ineligible:

$$(2) \qquad E[\varepsilon_i | score_i = c_s^* + \Delta]_{\Delta \to 0^+} = E[\varepsilon_i | score_i = c_s^* - \Delta]_{\Delta \to 0^+},$$

where $score_i$ is an individual's SHSAT score and c_s^* is the cutoff score below which applicants are not admitted to school s. Equation (2) implies that the distribution of individuals to either side of the cutoff is as good as random with respect to unobserved determinants of future outcomes (ε_i). Since enrolling in an exam school is a discontinuous function of SHSAT scores, whereas the distribution of unobservable determinants of future outcomes ε_i is by assumption continuous at each cutoff, the coefficient α_1 is identified. Intuitively, any discontinuous relation between future outcomes and the SHSAT score at the cutoff can be attributed to the causal impact of school enrollment under the identification assumption in equation (2).

We estimate the reduced-form impact of scoring just above the eligibility cutoff for each school separately using standard methods for regression discontinuity analysis (e.g., Lee and Lemiuex 2010). First, we restrict the data to scores within 0.25 standard deviations of each school's cutoffs. This range is the largest bandwidth that never includes another school's eligibility cutoff. Rule of thumb and cross-validation selection procedures suggest somewhat larger bandwidths of 0.35 to 0.75 standard deviations. Our somewhat smaller bandwidth of 0.25 standard deviations includes only the observations in the immediate neighborhood of the cutoffs, but at the cost of including less information, which can lessen precision. Results for our main outcomes using different bandwidths and a second-order polynomial are available in online Appendix Table 9.

Second, within our bandwidth we estimate the following reduced-form model of outcomes for each school:

$$(3) \qquad y_i = \pi_0 + \pi_1(score_i \geq c_s^*) + \pi_2(score_i \geq c_s^*) \times (score_i - c_s)$$

$$+ \pi_3(score_i - c_s) + \pi_4 \mathbf{X}_i + \pi_t + \varepsilon_i,$$

where y_i is a future outcome, such as college enrollment or graduation, and $(score_i \geq c_s^*)$ is an indicator that the student scored at or above the eligibility cutoff. We include separate score trend terms above and below the eligibility cutoff. We also control for gender, whether a student attended a private or public middle school, and the year of high school entry t. To address potential concerns about discreteness in the SHSAT score, we cluster our standard errors at the SHSAT score level (Lee and Card 2008).

The identified parameter π_1 measures the average reduced-form treatment effect of scoring just above the cutoff for each school. This parameter is the causal impact

of being eligible for an exam school with high-achieving peers. One key threat to a causal interpretation of our reduced-form estimates is that exam school applicants are not distributed randomly around the school cutoffs. Such nonrandom sorting could invalidate our empirical design by creating discontinuous differences in respondent characteristics around the score cutoff. Dobbie and Fryer (2011) evaluate this possibility by testing whether the frequency and characteristics of applicants trend smoothly through each cutoff, finding no evidence that our identifying assumption is violated.

A more general threat to our interpretation of π_1 is that peer composition may not be the only component of the educational production function that changes with exam school attendance. While observable school inputs such as teacher experience, teacher absences, and teacher salary do not differ systematically across exam schools and traditional public schools in New York City, it is possible that the exam schools differ in unobservable ways. In particular, it is plausible that the exam schools offer a more difficult curriculum or have more resources than other schools. In this scenario, our estimates represent the impact of both these unobserved differences and the exposure to higher-achieving peers. Abdulkadiroglu, Angrist, and Pathak (2011) provide an econometric model that formalizes this result.

V. Results

A. *Exam School Eligibility and High School Peer Composition*

The effect of exam school eligibility on the peer characteristics of a student's graduating high school is presented graphically in Figure 1. Figure 1 plots baseline peer characteristics against SHSAT scores. We also plot a predicted line from a local linear regression of baseline peer characteristics on SHSAT score, an indicator for school eligibility, and SHSAT score interacted with eligibility. In all results, the first cutoff is Brooklyn Tech, the second Bronx Science, and the third Stuyvesant. Point estimates and standard errors for the eligibility variable for each school are presented next to each cutoff. Regression estimates add controls for cohort, gender, and middle school type. We present these results for the 2002 to 2009 high school cohorts. See Dobbie and Fryer (2011) for additional first stage results.

Exam school eligible students attend high school with much higher-achieving peers compared to ineligible students. From an already high starting point, students eligible for Brooklyn Tech attend schools with baseline math test scores that are 0.324 standard deviations higher than ineligible students, and baseline English Language Arts (ELA) scores that are 0.311 standard deviations higher. Students eligible for Bronx Science attend schools with baseline math scores that are 0.171 standard deviations higher and baseline ELA scores that are 0.173 standard deviations higher. Students eligible for Stuyvesant attend schools with baseline math and ELA scores that are 0.335 and 0.357 standard deviations higher, respectively.

Students eligible for an exam school are also less likely to attend a high school with black or Hispanic students. Students eligible for Brooklyn Tech attend schools with 3.5 percentage point fewer blacks and 4.7 percentage point fewer Hispanics. Students eligible for Bronx Science and Stuyvesant attend schools with 4.8 and 4.6 percentage point fewer blacks, respectively, and 2.9 and 3.3 percentage point fewer Hispanics.
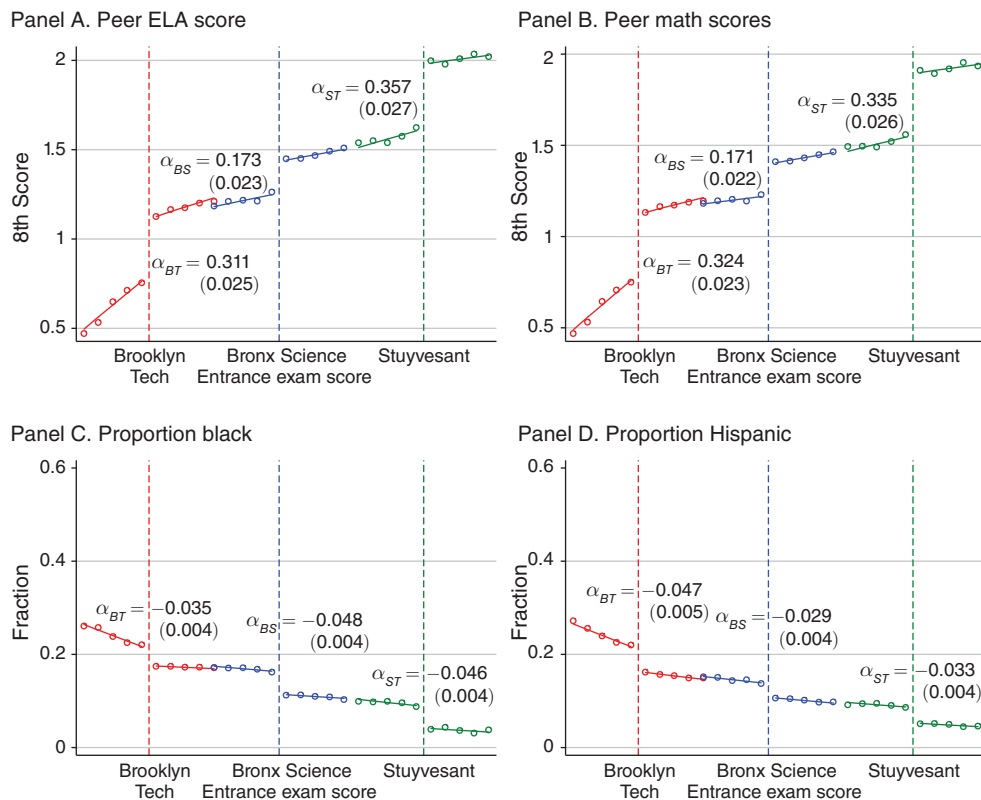
Panel A. Peer ELA score

Panel B. Peer math scores

Panel C. Proportion black

Panel D. Proportion Hispanic

FIGURE 1. EXAM SCHOOL ELIGIBILITY AND BASELINE PEER CHARACTERISTICS

Notes: This figure plots exam school eligibility and average peer characteristics for the graduating high school. The sample includes exam school applicants in the 2002–2009 high school cohorts. The smoothed line in each figure comes from a single local linear regression of each outcome on entrance exam score, school eligibility, and school eligibility interacted with the entrance exam score. Point estimates and standard errors clustered at the exam score level from an analogous regression that also controls for cohort fixed effects are presented next to each eligibility cutoff. The dependent variable for each regression is the average peer characteristic at the student's graduating high school. See text for additional details.

One threat to our interpretation of Figure 1 is the attenuating impact of within-school tracking on peer exposure. In this scenario, the marginal exam school eligible student is tracked into courses with lower-achieving peers than Figure 1 would suggest. We explore this issue using course data from the NYCDOE. The data includes each course taken by a student in the relevant school year, and are available for the 2003 to 2007 school years. We calculate the average peer characteristics in each course using the NYCDOE enrollment and test scores. Online Appendix Figure 6 presents these results for the 2006 through 2012 high school cohorts. We present results for freshmen year courses, though the results are identical using additional years and fewer cohorts. Exam school eligible students take courses with much higher-achieving peers than ineligible students. Students eligible for Brooklyn Tech take courses with baseline math test scores that are 0.308 standard deviations higher than ineligible students, and baseline English Language Arts (ELA) scores that are 0.375 standard deviations higher. Students eligible for Bronx Science attend schools

with baseline math scores that are 0.156 standard deviations higher and baseline ELA scores that are 0.171 standard deviations higher. Students eligible for Stuyvesant attend schools with baseline math and ELA scores that are 0.387 and 0.344 standard deviations higher, respectively. None of the results suggest that within-school tracking attenuates the impact of exam school eligibility on peer exposure.

Enrollment in private schools may also attenuate the impact of exam school eligibility on peer exposure. In Dobbie and Fryer (2011), we examine whether individuals who score above an exam school cutoff are more likely to enroll in ninth grade in the NYC public school system and characterize the students leaving the NYC system. We find that students who score just below an exam school cutoff are more likely to attend a private school or transfer to another district, but that there is no clear pattern of nonrandom attrition out of the NYC public school system. We also find that the impact of exam school attendance on college outcomes for our restricted high school sample is the same as in the full sample of all exam school applicants. We interpret these results as suggesting that, at least among public middle school students for whom we observe baseline characteristics, our peer exposure results are not biased by nonrandom attrition. However, our first stage results from Figure 1 should be interpreted with this possibility in mind.

These large and systematic changes in peer composition at each cutoff motivate our focus on peers as the primary mediator of the exam school treatment effect. To put the magnitudes of these changes in context, consider the average change in peer characteristics resulting from the inflow of Hurricane Katrina and Hurricane Rita evacuees, one of the largest quasi-experimental changes in peer quality documented in the peer effects literature (Imberman, Kugler, and Sacerdote 2012). The typical incumbent student in Houston had peers that scored about 0.028 standard deviations lower in both math and reading/English than he otherwise would have after the influx of evacuees, with the largest observed change in peer characteristics totaling about 0.26 standard deviations. In Louisiana, the typical incumbent student had peers that scored about 0.008 standard deviations lower after the influx of evacuees, with the largest observed change totaling about 0.134 standard deviations.[5] Thus, the change in peer characteristics associated with exam school eligibility are among the largest ever observed, particularly given the already high baseline peer characteristics of the typical exam school applicant.

B. *Exam School Eligibility and College and Graduation*

Reduced-form results of the impact of attending an exam school on college enrollment and graduation are presented in Figure 2. We plot the average outcome for each bin and predicted outcomes from a local linear regression.[6] Enrollment outcomes are presented for the 1994 to 2009 high school cohorts, while graduation outcomes are presented for the 1994 to 2004 cohorts only. Point estimates and standard errors from separate regressions that include controls for exam score, exam

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[5] Author's calculations from table 1 of Imberman, Kugler, and Sacerdote (2012).

[6] Including a linear spline by year or renorming the data so that the eligibility cutoffs are constant over time both give nearly identical results. These additional results are available from the authors by request.
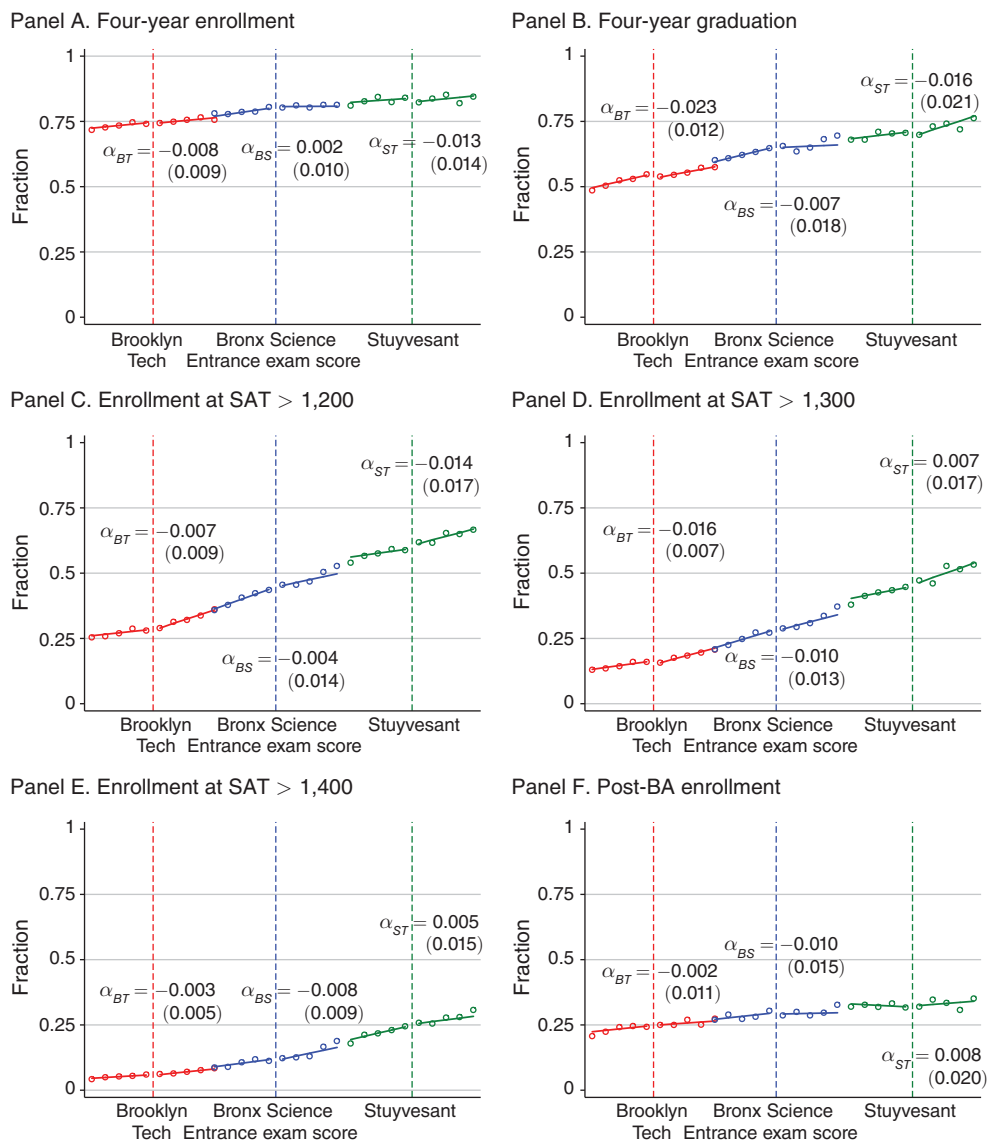
Panel A. Four-year enrollment

Panel B. Four-year graduation

Panel C. Enrollment at SAT > 1,200

Panel D. Enrollment at SAT > 1,300

Panel E. Enrollment at SAT > 1,400

Panel F. Post-BA enrollment

FIGURE 2. EXAM SCHOOL ELIGIBILITY AND COLLEGE OUTCOMES

Notes: This figure plots exam school eligibility and college outcomes. The sample for enrollment outcomes includes exam school applicants in the 1994–2009 high school cohorts. The sample for graduation and post-BA outcomes includes exam school applicants in the 1994–2002 high school cohorts. The smoothed line in each figure comes from a single local linear regression of each outcome on entrance exam score, school eligibility, and school eligibility interacted with the entrance exam score. Point estimates and standard errors clustered at the exam score level from an analogous regression that also controls for cohort fixed effects are presented next to each eligibility cutoff. The dependent variable for each regression is an indicator for enrollment in indicated program. See text for additional details.

score interacted with school eligibility, cohort, gender, and middle school type are presented next to each cutoff. These estimates include all students who applied to an exam school, even if they later left the NYC school system.

Surprisingly, there appears to be little impact of exam schools on four-year college enrollment and graduation. If anything, students eligible for exam schools are

less likely to have attended or graduated from college by 2009. Students just eligible for Brooklyn Tech are 2.3 percentage points less likely to graduate from a 4-year college. Students just eligible for Bronx Science are 0.7 percentage points less likely to graduate, and students just eligible for Stuyvesant are 1.6 percentage points less likely to graduate, though neither estimate is statistically significant. With that said, the 95 percent confidence interval rules out impacts larger than 2.8 percentage points for Bronx Science and 2.5 percentage points for Stuyvesant.

The results are similar when examining college enrollment in more selective institutions. We regress an indicator variable equal to 1 if a student was ever enrolled in a 4-year college with a median SAT score above 1,200, 1,300, and 1,400 on each school's eligibility indicator, exam score, and exam score interacted with eligibility. Colleges with median SAT scores above 1,200 include Binghamton University, Boston University, and Fordham University. Colleges with median SAT scores above 1,300 include Boston College, Carnegie Mellon, Lehigh University, Geneso University, New York University, and the University of Rochester. Colleges with SAT scores above 1,400 include the Ivies and schools such as the University of Chicago and Washington University. Students eligible for Brooklyn Tech are 1.6 percentage points less likely to enroll in a school with a median SAT of above 1,300. There is no impact of Stuyvesant or Bronx Science eligibility on enrollment in a school with a median SAT score of above 1,300, and none of the schools have an impact on enrollment in schools with SAT scores above 1,200 or above 1400. Students eligible for an exam school also appear no more likely to enroll in a postbaccalaureate program. The relatively small standard errors rule out large positive effects for all college outcomes.

The regression discontinuity estimates presented in Figure 2 capture the causal effect of admission for students near the cutoff. We can explore the impact of exam schools on students of different ability by exploiting the fact that any single test is a noisy measure of true skill. As a result, there exists a distribution of ability at each cutoff. Some high-ability students may score lower on the entrance exam by chance, putting them nearer a cutoff than their ability would suggest, while some low-ability students may, by chance, score higher on the entrance exam, gaining admission to a school with far more able students on average. We test for the heterogeneous impact of exam school admission by ability by splitting the same by state test scores in eighth grade. This approach assumes that baseline state test scores capture some element of true ability that the admissions test does not. We first drop students more than 0.25 standard deviations below the Brooklyn Tech eligibility cutoff to eliminate students with no chance of admissions. We then split the remaining sample at the median and seventy-fifth percentile of combined math and English eighth grade state test score. We allow the linear trend in exam score to differ by both the group being tested and the cutoff variable.

Table 2 presents these results separately by eighth grade state test score for students who were enrolled in a NYC middle school, the only group we have baseline state scores for. Perhaps surprisingly, there are no clear patterns by baseline state test score. Of the 18 results considered, only one difference is statistically significant at the 10 percent level. These results suggests that high- and low-ability students are affected by exam school eligibility similarly.

TABLE 2—COLLEGE RESULTS BY SUBSAMPLE

	Public middle (1)	Private middle (2)	Male (3)	Female (4)	Upper half (5)	Lower half (6)	Upper quartile (7)	Lower 3 quartiles (8)
Panel A. Start a four year degree								
Stuyvesant	−0.023	0.019	−0.014	−0.012	0.003	−0.087	0.011	−0.046
	(0.017)	(0.022)	(0.018)	(0.022)	(0.028)	(0.076)	(0.027)	(0.044)
	10,732	3,424	7,646	6,510	3,797	453	2,653	1,597
Bronx Science	−0.003	0.020	0.004	−0.001	−0.024	0.043	−0.014	−0.004
	(0.012)	(0.019)	(0.014)	(0.014)	(0.021)	(0.041)	(0.031)	(0.027)
	20,907	6,213	13,969	13,151	5,809	1,958	3,149	4,618
Brooklyn Tech	−0.001	−0.030*	−0.022	0.007	0.013	−0.005	0.005	0.008
	(0.012)	(0.017)	(0.015)	(0.011)	(0.022)	(0.040)	(0.040)	(0.024)
	30,094	8,913	19,422	19,585	6,053	4,233	2,475	7,811
Panel B. Graduate four year college								
Stuyvesant	−0.043	0.056	0.026	−0.068**	0.069	−0.005	0.031	0.004
	(0.026)	(0.039)	(0.030)	(0.027)	(0.085)	(0.244)	(0.095)	(0.148)
	7,013	2,545	5,162	4,396	627	69	421	275
Bronx Science	−0.016	0.031	0.003	−0.018	−0.054	0.173*	−0.036	−0.005
	(0.022)	(0.028)	(0.021)	(0.022)	(0.077)	(0.095)	(0.108)	(0.085)
	14,094	4,615	9,597	9,112	1,044	300	488	856
Brooklyn Tech	−0.016	−0.039	−0.045***	−0.001	0.010	0.025	0.003	0.020
	(0.045)	(0.026)	(0.017)	(0.017)	(0.045)	(0.063)	(0.098)	(0.045)
	21,063	6,787	13,662	14,188	1,060	770	349	1,481
Panel C. Start at college with median SAT > 1,200								
Stuyvesant	0.019	0.003	0.013	0.015	0.055*	−0.099	0.062*	−0.027
	(0.020)	(0.028)	(0.025)	(0.026)	(0.032)	(0.103)	(0.036)	(0.048)
	10,732	3,424	7,646	6,510	3,797	453	2,653	1,597
Bronx Science	−0.007	0.011	−0.013	0.006	−0.013	0.048	0.000	−0.007
	(0.015)	(0.026)	(0.017)	(0.019)	(0.023)	(0.042)	(0.032)	(0.030)
	20,907	6,213	13,969	13,151	5,809	1,958	3,149	4,618
Brooklyn Tech	−0.012	0.017	−0.012	0.000	−0.004	0.000	−0.009	0.001
	(0.010)	(0.024)	(0.012)	(0.013)	(0.022)	(0.025)	(0.042)	(0.016)
	30,094	8,913	19,422	19,585	6,053	4,233	2,475	7,811
Panel D. Start at college with median SAT > 1,300								
Stuyvesant	0.007	0.009	0.005	0.007	0.056*	−0.011	0.059	−0.005
	(0.021)	(0.036)	(0.024)	(0.025)	(0.032)	(0.090)	(0.037)	(0.038)
	10,732	3,424	7,646	6,510	3,797	453	2,653	1,597
Bronx Science	−0.018	0.021	−0.030*	0.012	−0.002	−0.003	0.002	−0.014
	(0.014)	(0.026)	(0.016)	(0.018)	(0.021)	(0.038)	(0.028)	(0.030)
	20,907	6,213	13,969	13,151	5,809	1,958	3,149	4,618
Brooklyn Tech	−0.014*	−0.022	−0.014	−0.017	−0.020	−0.006	0.009	−0.020
	(0.008)	(0.020)	(0.009)	(0.012)	(0.017)	(0.016)	(0.034)	(0.013)
	30,094	8,913	19,422	19,585	6,053	4,233	2,475	7,811
Panel E. Start at college with median SAT > 1,400								
Stuyvesant	0.018	−0.032	0.023	−0.018	0.051**	0.008	0.060*	−0.001
	(0.018)	(0.037)	(0.019)	(0.025)	(0.025)	(0.053)	(0.032)	(0.027)
	10,732	3,424	7,646	6,510	3,797	453	2,653	1,597
Bronx Science	−0.017**	0.022	−0.020*	0.004	−0.016	−0.024	−0.027	−0.017
	(0.009)	(0.028)	(0.011)	(0.013)	(0.016)	(0.016)	(0.023)	(0.014)
	20,907	6,213	13,969	13,151	5,809	1,958	3,149	4,618
Brooklyn Tech	−0.004	0.001	−0.005	−0.001	−0.014	−0.005	0.010	−0.016**
	(0.005)	(0.014)	(0.006)	(0.009)	(0.011)	(0.009)	(0.023)	(0.008)
	30,094	8,913	19,422	19,585	6,053	4,233	2,475	7,811

(*Continued*)

Table 2 also presents results by middle school type and gender, the only two control variables available across all years and students.[7] We interact the linear trend

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[7] Subsample results for other outcomes are available in the online Appendix. Results follow the same pattern.

TABLE 2—COLLEGE RESULTS BY SUBSAMPLE (*Continued*)

	Public middle (1)	Private middle (2)	Male (3)	Female (4)	Upper half (5)	Lower half (6)	Upper quartile (7)	Lower 3 quartiles (8)
Panel F. Start post-grad program								
Stuyvesant	−0.002	0.031	0.038	−0.029	0.025	−0.120	−0.034	0.062
	(0.022)	(0.040)	(0.028)	(0.026)	(0.064)	(0.200)	(0.078)	(0.075)
	7,013	2,545	5,162	4,396	627	69	421	275
Bronx Science	−0.017	0.021	−0.010	−0.010	− 0.101*	0.105	−0.142	−0.034
	(0.018)	(0.028)	(0.018)	(0.024)	(0.053)	(0.080)	(0.112)	(0.042)
	14,094	4,615	9,597	9,112	1,044	300	488	856
Brooklyn Tech	0.001	−0.007	−0.024*	0.019	−0.058*	0.026	−0.067	−0.013
	(0.012)	(0.023)	(0.012)	(0.018)	(0.033)	(0.056)	(0.085)	(0.030)
	21,063	6,787	13,662	14,188	1,060	770	349	1,481

Notes: This table reports reduced-form estimates of the impact of exam school eligibility on college outcomes separately by baseline characteristic. The sample for enrollment outcomes includes exam school applicants in the 1994–2009 high school cohorts. The sample for graduation and Post-BA outcomes includes exam school applicants in the 1994–2002 high school cohorts. We report the coefficient on exam school eligibility estimated separately by baseline characteristic. We also control for entrance exam score, entrance exam score interacted with school eligibility, and cohort fixed effects. Standard errors are clustered at the exam score level. See text for additional details.

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

in exam score with both the group being tested and the cutoff variable. There are also no clear patterns by ethnicity or free lunch status among the subset of students for which we have that data. In particular, Asians, who make up the majority of the population in all three exam schools, show no differential results. Males and students who attended private middle schools benefit somewhat more from being eligible for Stuyvesant, and women seem to benefit somewhat more from being eligible for Brooklyn Tech. Given the general lack of clear patterns and statistical significance, however, our estimates suggest that all groups are affected by exam school eligibility similarly.

The null result stands in contrast to estimates reported in the peer effects literature and the popular view of exam schools. Recall that the impact of exam school eligibility on combined baseline peer math and English ability is 0.318 standard deviations for Brooklyn Tech, 0.172 standard deviations for Bronx Science, and 0.346 standard deviations for Stuyvesant. Taking these first-stage estimates at face value, this suggests that a 1 standard deviation in peer math and English ability is associated with a 0.14 standard deviation decrease in the probability of graduating from a 4-year college at Brooklyn Tech, a 0.08 standard deviation decrease at Bronx Science, and a 0.10 standard deviation decrease at Stuyvesant, with the 95 percent confidence interval ruling out impacts larger than 0.06 and 0.05 standard deviations at Bronx Science and Stuyvesant. These small peer effects are significantly different from the achievement results reported in the existing literature. For example, Hoxby (2000) reports that a 1 standard deviation increase in peer ability increases own test scores by 0.3 to 0.5 standard deviations, while Hanushek et al. (2003) find that a 1 standard deviation increase in peer ability increases own test scores by 0.15 to 0.24 standard deviations.

However, a null result on the impact of exam schools on college enrollment and outcomes, while surprising, is broadly consistent with the literature on the effect of

school choice on college outcomes (e.g., Cullen, Jacob, and Levitt 2006; Deming et al. 2011). In Chicago, Cullen, Jacob, and Levitt (2006) find no impact of winning a school choice lottery on test scores, but some benefits on behavioral outcomes, such as self-reported criminal activity. On the other hand, Deming et al. (2011) find that high school choice winners in Charlotte-Mecklenburg score no better on high school exams, but are more likely to graduate from high school and attend college. In a setting more closely related to our own, Berkowitz and Hoekstra (2011) find that students who attend an elite private high school also attend more selective colleges than students who were admitted but did not attend.

VI. Concluding Remarks

Public exam high schools have educated some of the world's most successful scientists and professionals. We provide evidence that applicants just eligible for an exam school have peers that score 0.17 to 0.36 standard deviations higher on eighth grade state tests and that are 6.4 to 9.5 percentage points less likely to be black or Hispanic. Surprisingly, however, the impact of exam school eligibility on college enrollment and graduation is, if anything, negative. The results are similar across gender, middle school type, and baseline state test scores.

Our results suggest that the typical applicant does not significantly benefit from attending a school with dramatically higher-achieving and more homogeneous peers. With that said, without longer-term measures such as income, health, or life satisfaction, it is difficult to fully interpret our results. To the extent that attending an exam school with higher-achieving peers increases social capital in ways that are important for later outcomes that are independent of college enrollment, graduation, or human capital, then there is reason to believe that our conclusions are premature and the true impact of an elite exam school will only be understood with the passage of time. If, on the other hand, college enrollment and graduation are "sufficient statistics" for later life outcomes, then our results show the impact of attending a school with elite peers for the marginal student is likely to be small.

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