Predicting the Effect of Affirmative Action Plans in New York City Elite Public High Schools*

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November 15, 2019

Job Market Paper

[Link to the latest draft]

Abstract

In recent years, there have been concerns about the lack of diversity in schools, especially elite schools that select students based on exams. This paper studies the impact of two possible affirmative action plans in New York City by estimating students' underlying preferences and then simulating their actions under the two proposed plans. There is a trade-off between promoting diversity and maintaining student quality in elite schools. A tier-based plan similar to that in Chicago does little to increase the overall racial diversity of this sector, but it preserves the quality of incoming students. In contrast, a plan to guarantee elite school seats to students who placed in the top seven percent (by academic performance) of each public middle school causes substantial exchanges of students between the elite and regular sectors, thereby giving more access to Black and Hispanic students at the cost of lower student quality. The two plans also change the distribution of diversity across schools in different ways. The Chicago plan reduces the differences among schools within the elite sector, while the Top 7% plan bridges the gap in diversity between the two sectors even as it increases within-sector dispersion. Both plans result in considerable changes in school assignments in the regular school sector.

1 Introduction

In recent years, the lack of diversity in schools has been a concern for policymakers. This problem is particularly intense for selective "elite" public schools. For example, this academic year, Stuyvesant,

*I am very grateful to my advisors, Yeon-Koo Che, Miguel Urquiola, and Bernard Salanié for their invaluable guidance and support. I also thank Claudia Allende, John Asker, Pierre-André Chiappori, Evan Friedman, Guillaume Haeringer, Dong-Woo Hahm, Kate Ho, Han Huynh, Adam Kapor, Janet Martin, Yusuke Narita, Suanna Oh, Andrea Prat, Silvio Ravaioli, Mike Riordan, Tobias Salz, Cailin Slattery, Yue Yu, and participants at the Industrial Organization Colloquium, Applied Microeconomics Theory Colloquium, and Industrial Organization and Strategy Workshop at Columbia University for helpful discussions and comments.

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arguably the most prestigious high school in New York City, initially made 895 offers of admission, only 7 of which went to Black students (Shapiro, 2019). This situation has prompted urgent calls for affirmative action policies that might allow more minority and low socioeconomic status students to enroll.

The effects of such policies could be quite complex as they would likely propagate throughout the entire public high school system. Specifically, some seats in regular public high schools might be freed up when policy beneficiaries leave them in favor of elite schools, and they might be taken up by students displaced from elite schools. Previous studies have abstracted from this issue due to the technical challenge of accounting for students' choices in two connected school systems. In short, they have overlooked the impacts of affirmative action on those who would neither gain nor lose offers to elite high schools.

This paper addresses this challenge and quantifies the effects of affirmative action on both elite and regular schools. I consider two widely-discussed affirmative action plans in New York City. The first has been put in place by the Chicago Public School District and takes into account the socioeconomic status of students' neighborhoods. The second was proposed by New York City Mayor Bill de Blasio and would accept into the elite sector students in the top 7% by academic performance of each public middle school. The latter plan is reminiscent of others in the country, such as those implemented at the college level in Texas and California.

I find that the two plans have quite different effects. First, there is a trade-off between improving diversity and maintaining student quality in elite schools as measured by state test scores in middle school. The Chicago plan mostly gives rise to reshuffling within elite schools, which does little to increase the racial diversity of this sector as a whole but, at the same time, preserves the quality of incoming students. In contrast, the Top 7% plan causes considerable flows of students between the elite and regular sectors. The elite sector experiences a substantial increase in the proportions of Black and Hispanic students, along with a decrease in average student quality. Analyzing the difference between the outcomes of these two policies provides some insight into how the two objectives—diversity and student quality in elite schools—might be better balanced in general. The second difference between the plans arises because they transform the distribution of diversity across schools in different ways. The Chicago plan reduces the differences among schools within the elite sector. In contrast, while the Top 7% plan reduces the gap in diversity between the two sectors, it increases the dispersion within each sector.

One effect that both plans have in common is that they change the average student quality in regular high school programs: more than half of these schools have higher student quality than under the status quo, whereas the rest undergo decreases in quality. This is due to the movements of students between the elite and regular sectors, as well as reshuffling within the regular sector. This result confirms that not considering regular schools is an important omission in evaluating affirmative action policies.

In New York City, the elite sector includes eight specialized high schools, which are public high schools that select their students based on the Specialized High School Admission Test (SHSAT). In the 2011-2012 school year, White and Asian students made up about 85% of specialized high schools, whereas Blacks and Hispanics made up only about 15% of these schools. These percentages are out of proportion to those in the broader population.[1]

The key feature that facilitates spillover effects from specialized high schools to regular schools is that the Department of Education (DoE) determines most school assignments in two rounds: a "Specialized Round" and then a "Main Round." This assignment procedure begins after all students have already submitted their rank-ordered lists over both types of schools (when applicable), and both rounds use these lists as inputs. The Specialized Round selects students who get offers to specialized high schools and also provides each of them with a regular school offer. These students are then allowed to choose between these two offers. Based on their decisions, the availability of seats at regular schools is adjusted before the Main Round is run to determine the rest of the regular school assignments.

I exploit properties of Gale and Shapley (1962)'s student-proposing Deferred Acceptance (DA) mechanism—defined broadly to include cases both with and without restrictions on the length of the rank-ordered lists—to inform my treatment of the link between the school rankings that students submit and their true preferences. Following Abdulkadiroglu, Agarwal and Pathak (2017), my empirical strategy relies on weak truth-telling.[2] Unlike strict truth-telling, this assumption does not presume any particular preference relation between unranked schools and the outside option of not attending any New York City public high school (i.e., attending a private school or a school outside of the city). Specifically, weak truth-telling includes two parts. First, the order of schools in the submitted rank-ordered list is according to true preferences, which is likely to hold for both specialized high schools and regular schools as this is a dominant strategy in the student-proposing DA mechanism. Second, ranked schools are preferred to all unranked schools. This latter part may be violated for regular schools, where students can only rank twelve out of nearly 700 programs. When students are constrained to ranking only a strict subset of the schools available, it may be optimal for them to drop some schools to which they are unlikely to be admitted to make space for less-preferred schools where they have a better chance (Haeringer and Klijn, 2009). However, the assumption may still be reasonable in this particular setting, given that only 14.6% of students ranked all twelve programs.

I devise a two-step estimation procedure to infer preferences between the two connected school systems: specialized and regular. Within one system, given truth-telling, students' rankings over schools give rise to a generalization of the standard discrete choice model in which instead of

[1] For instance, public middle schools comprised of 28% White and Asian and 71% Black and Hispanic students.

[2] There is an alternative approach where this weak-truthtelling assumption is relaxed to allow for payoff-insignificant "mistakes" (Artemov, Che and He, 2017; Fack, Grenet and He, 2019). However, this method is not applicable in my setting due to the higher level of uncertainty students face, which I will discuss in more details in Section 5.

choosing one single alternative, agents express preferences over multiple alternatives. Such a model, especially one with logit errors, is well-studied.[3] With two systems, the lack of a universal ranking poses a problem in ensuring that the cardinalizations of preferences for the two sets of schools are comparable. To address this, I make use of the choices between elite and regular schools, which are observed for students with elite school offers. In each step of the procedure, I estimate a rank-ordered logit model for preferences over one set of schools via maximum likelihood. Estimation for regular schools is done first so that the results can be used to normalize utilities for specialized high schools both in terms of location and scale. Said normalization involves a modification of the standard likelihood function to account for the regular vs. elite choice mentioned above.

The Chicago affirmative action plan assigns 40% of total specialized high school capacity purely on merit. The rest are divided equally among each of four neighborhood tiers. In my implementation of this policy in New York City, each student's tier is the tier of his or her zip code (assigned based on its median family income). I assume that those who wish to gain admission to specialized high schools would still have to take the SHSAT, which would be used as the criterion for merit seats as well as a tie-breaker among students of the same tier. Meanwhile, the Top 7% plan involves abolishing the current admission test and guaranteeing specialized high school seats for students in the top 7% of each public middle school in the city, determined by their combined English Language Arts (ELA) and mathematics scores on the Grade 7 state tests. I assume that these students would be asked for their rank-ordered lists over specialized high schools, and schools would rank students based on the aforementioned scores.

For the analysis of both counterfactual policies, estimates of the students' underlying preferences are used to simulate rankings that were not submitted in reality. First, students who did not apply to specialized high schools did not submit rankings for them, but in the Top 7% plan, some of these students would be eligible for seats there, and thus, such rankings are required to determine their school assignments. Second, we can only compare students' preferences between specialized high schools and regular schools for those who received specialized high school offers, and for each of these students, only between a specific pair of specialized high school and regular school. In both counterfactuals, new comparisons arise either when students receive specialized high school offers while they previously would not have or when they obtain a different specialized high school offer than the one they would have received in the current system. These "missing" rankings are constructed using the systematic part of the utility function that I estimated from the aforementioned random utility model; that is, a student is said to prefer one school over another in the constructed rankings if they are expected do so on average across all possible realizations of the idiosyncratic preference shocks.

Using the estimated parameters, I simulate both policies in the short run when preferences remain unchanged and find considerable differences in their effects. The Chicago plan causes very

[3] See, for instance, Beggs, Cardell and Hausman (1981) and Hausman and Ruud (1987).

little exchange of students between the two school sectors (approximately 9% of total specialized high school capacity) but instead mostly gives rise to reshuffling within specialized high schools. As a result, both the racial composition and student quality[4] of specialized high schools as a whole remain relatively stable while different specialized high schools become more similar to one another. Concretely, for Stuyvesant and Brooklyn Latin (the two schools with the lowest and highest percentages of Blacks and Hispanics, respectively), these percentages go from approximately 3% and 38% to 8% and 34%. The Top 7% plan results in considerable inflows from regular public high schools and vice versa (amounting to approximately 49% of the total specialized high school capacity), radically increasing the percentages of Black and Hispanic students in specialized high schools while lowering the overall quality. Under this plan, the elite and regular sectors become more similar in terms of racial composition, but within the elite sector, schools become more different from one another (Black and Hispanic students making up about 19% of Stuyvesant compared to 80% of Brooklyn Latin).

Despite differences in volumes of the flows between specialized high schools and regular schools, under both the Chicago and Top 7% plans, many students who are not directly affected—that is, they neither gain nor lose specialized high school offers—still experience a change in their school assignments. Within regular schools, there is slightly more reshuffling for Black and Hispanic students than for White and Asian students. Both plans induce increases in average student quality in more than half of the regular high school programs and decreases or no change in the rest. However, only some of these changes are statistically significant. The Top 7% plan additionally changes the distribution of racial compositions in such a way that there is a notable increase in the number of programs with very low percentages (0-10%) of Black or Hispanic students, a sign of more segregation within the regular school sector.

On the student level, changes in peer quality are heterogeneous across the students' own scores. Under both plans, those belonging to the lowest two score deciles in the population of all public middle school students lose out in terms of peer quality, whereas those belonging to higher deciles (fifth to ninth) gain better peers. The sizes of the increases for the latter are either similar across plans or higher for the Top 7% plan. The two plans differ in the direction of the changes when it comes to students in the highest-scoring decile, who experience an increase in peer quality in the Chicago plan but a decrease in the Top 7% plan. The same type of assignment changes (e.g., from specialized to regular high schools) under the two plans can result in different experiences in terms of peer quality.[5] For instance, under the same label "always specialized high schools," students who stay in specialized high schools under both the status quo and the Chicago plan can be either better off or worse of in terms of peer quality depending on their own scores, while those who stay in

[4]Quality is measured by combined scores on Grade 8 state tests, which are taken after the admission process but before students enter high school. This measure is therefore distinct from the selection criterion of the Top 7% plan.

[5]The full list of types that I consider includes: always specialized high schools, specialized to regular, regular to specialized (offer gained), regular to specialized (better offer), different regular schools, same regular schools (main round), and same regular schools (specialized round).

specialized high schools under both the status quo and the Top 7% plan are always worse off.

Three main factors drive the differences in the outcomes of the two policies. First, the pool from which students are selected into specialized high schools is much more restrictive in the Chicago plan, where the students must have taken the SHSAT to be considered. On the contrary, the Top 7% plan considers all aspiring high school students, and in fact, nearly half of the students who are reassigned from regular schools to specialized high schools under this plan (1280 out of 2666) did not take the SHSAT. Second, the two plans currently use two different criteria to define "merit," with the Chicago plan using the SHSAT and the Top 7% plan using Grade 7 state test scores. When I restrict the selection pool to specialized high school applicants (for whom both types of scores are available) and compare a policy that selects the top 7% of each public middle school based on state test scores versus one that selects the top 7% based on SHSAT scores, the overlap in offers comprises of only 29% of the total specialized high school capacity. Third, the policy outcomes depend on how students are assigned into subgroups, either neighborhood tiers in the Chicago plan or public middle schools in the Top 7% plan. An affirmative action plan is more likely to promote diversity if the subgroups being used have sufficiently different racial compositions, which is the case for public middle schools. Meanwhile, a plan is more likely to maintain student quality in the elite sector if student quality is sufficiently similar across subgroups, such as neighborhood tiers.

The rest of the paper is organized as follows. Section 2 reviews the related literature and highlights my contributions. Section 3 provides relevant background on the New York City high school admission process. Section 4 introduces the data sources and my descriptive analysis. Section 5 describes the structural model, estimation procedure, and estimated parameters. Section 6 presents the effects of the two affirmative action plans and the policy implications. Section 7 concludes by discussing the paper's key findings and avenues for future research.

2 Related Literature

This paper makes several contributions to the literature on affirmative action in centralized school choice, particularly that in selective public high schools. In doing so, it also contributes in terms of empirical methodology to the emerging literature on divided enrollment systems.

Among papers that evaluate affirmative action in selective public high schools, this is the first that considers the indirect impact on regular public high schools in addition to the direct impact on selective ones. In the same setting of New York City specialized high schools, Treschan (2015) and Corcoran and Baker-Smith (2018) both simulate alternative admission rules keeping the total number of offers in specialized high schools fixed. Due to data limitations, neither study takes into account the students' preference rankings over specialized high schools, whether with or without the alternative policy. They treat all specialized high schools as a single entity and only provide results in terms of offers, not actual enrollment. In contrast, my paper accounts for students' preferences over specialized high schools as well as regular schools and finds two types of effects on specialized high schools that these studies miss. First, a non-trivial share of students with specialized high school offers decline them in favor of regular high school programs in all scenarios (status quo and alternative plans). The affirmative action plans that I consider both reduce the fraction of such students compared to the status quo by giving them offers to a specialized high school that they prefer over the specialized high school they would have been assigned before. Thus, even for specialized high schools as a whole, looking at offers instead of enrollment presents a consequential oversight. Second, by not considering assignments to specific specialized high schools, previous studies also overlook the possible reshuffling within specialized high schools, an important effect of the Chicago plan in my paper. In addition to neglecting some direct impacts on the elite sector, these studies do not consider the impact on the regular sector, which I find to be substantial in my analysis.

In terms of outcomes that are considered by both these authors and myself, Corcoran and Baker-Smith (2018) offer a similar result for their Top 10% rule (based on grade 7 state test scores and course grades) as my result for the Top 7% plan (based on grade 7 state test scores). Specifically, both show substantial changes in specialized high school offers that bring the racial composition of specialized high schools closer towards that of the population of public middle school students but at the same time reduces average student quality. It must be noted that Corcoran and Baker-Smith (2018) most likely understate the magnitude of the aforementioned decrease because, as the authors themselves admit, they measure quality by achievement in grade 7 state tests, which is part of the selection criteria. To assess student quality, my paper uses grade 8 state tests, taken after the admission process but before students enter high schools. This is a better measure because it is both independent of the admission process and more recent. In contrast to the aforementioned results, Treschan (2015) finds that his proposed policy slightly improves both diversity and student quality in specialized high schools. The opposite result regarding student quality should be taken with a grain of salt because the policy assigns all except for about 9% of specialized high school offers based on city-wide rank in grade 7 state test scores, and student quality is then measured by the same tests.[6] The increase in "quality" thus follows by construction.[7]

Another paper on affirmative action in elite high schools is Ellison and Pathak (2016), which considers the Chicago exam schools. However, their focus is on the efficiency of policies based on proxies for membership of the underrepresented group compared to policies based directly on membership status, for instance, race-blind affirmative action policies compared to race-based ones. To define efficiency, the authors assume that social welfare is the sum of students' expected educational outcomes, which, for each student, depends on the student's own type (ability and/or preparation), how well the school curriculum matches the student's type, and how well the composition of stu-

[6] The paper is unclear about which state tests are used for student quality, but given the lack of expressed distinction between them and those used for selection, it is likely that they are the same.

[7] This problem is of greater concern here than in Corcoran and Baker-Smith (2018), where top students from each middle school are selected instead of city-wide.

dents in the school reflects the composition in the population. Using data from Chicago for the year 2013-2014, the authors evaluate the efficiency of the current Chicago tier-based policy as well as some alternative policies (including a Top 10% rule). The authors focus only on the two most selective schools. In all policies, only students who did apply to elite schools are considered, which means submitted school rankings are enough for counterfactual simulations, precluding the need for preference estimation as in my paper.

My second contribution is to provide further empirical evidence to illustrate previous theoretical results regarding the importance of precedence order, that is, the order in which the school seats are filled in the Deferred Acceptance (DA) mechanism in the presence of reserved seats such as the tier seats in the Chicago plan. In fact, this plan directly inspires Dur, Pathak and Sonmez (2016)'s theoretical model, which is simplified to a single school setting. The authors show that even with a tier-blind precedence order—where tiers are treated as anonymous, and thus, none is explicitly favored—one can still exploit the statistical properties of the scores to generate (dis)advantageous allocations to certain tier(s). Specifically, assuming that the school is oversubscribed, the precedence order where all merit seats are filled before all tier seats is the best tier-blind precedence for the tier with the worst distribution of scores, and the worst tier-blind precedence for the tier with the best distribution of scores.[8] The opposite is true for the precedence order where all tier seats are filled before all merit seats. My empirical analysis in the multiple-school setting of New York City specialized high schools gives similar results to that by Dur, Pathak and Sonmez (2016) of the Chicago exam schools and supports their theoretical results. Dur et al. (2017) instead focus on the effect of the change in the size of the reserve compared to the change in the precedence order. Theoretically, increasing the size of the reserve and moving non-reserve seats up in the precedence order both weakly increase the number of reserve-eligible students admitted. In their empirical analysis of the Boston Public School system, the effects of these two different adjustments are quantitatively similar. In this paper, I also find that moving (non-reserve) merit seats up in the precedence order can be as effective as increasing the number of tier seats (the reserve).

My third contribution is to show empirical evidence of the effect of affirmative action in a real-life setting. This complements the theoretical literature on affirmative action under different centralized school choice mechanisms, which is mostly agnostic when it comes to the effect of affirmative action under specific conditions. Both Kojima (2012)'s and Dogan (2016)'s theoretical results show that there exist students' preference profiles under which more affirmative action can hurt the minority that it aims to help. Dogan (2016) points out that this problem is because for some minority students, being treated as a minority does not affect their own outcomes, but it can negatively affect the outcomes for other minority students. Thus, the author proposes an alternative mechanism where this problem is alleviated. Although the type of affirmative action he considers is different, a similar insight applies to the Chicago plan. Specifically, having merit seats filled last is

[8]"Worst" ("best") in the sense that at every possible score, they have the lowest (highest) representation among all tiers.

bad for the disadvantaged tier as mentioned above because high-achieving students in this tier, who would have been admitted purely on merit, end up filling tier seats, leaving their lower-achieving peers to compete for merit seats. It must be noted, however, that both Kojima (2012) and Dogan (2016) are silent on what would happen under specific students' preference profiles (such as those occurring in practice). My empirical results demonstrate that in New York City, affirmative action policies do help more students in disadvantaged groups gain access to specialized high schools.

In terms of methodology, I devise an estimation procedure to handle the two connected school systems in New York City, thus contributing to the literature on divided enrollment systems that has been mostly theoretical until now.[9] Divided enrollment systems refer to school systems in which students may apply to and receive offers of admission from multiple groups of schools, which conduct their admission processes separately. Manjunatha and Turhan (2016) show that this can lead to wastefulness in the sense that many students may not receive offers despite seats still being available in some schools. They propose an iterative mechanism in which these different groups can each independently match and re-match students to its schools to alleviate this problem while accounting for schools' priorities. This process is demonstrated to Pareto-improve the outcome in every iteration and arrive at a non-wasteful outcome in a finite number of iterations. Turhan (2019) studies the effects of the partition structure—in other words, how schools are divided into groups—on the properties of the aforementioned mechanism. He finds that students' welfare increases and the mechanism becomes less manipulable as the partition becomes coarser. Dogan and Yenmez (2018) prove that given substitutable school priorities, a unified system, where each student submits one ranking over all schools and receives at most one school offer, achieves an outcome that (weakly) Pareto dominates that from a divided system. They also characterize three different sources of inefficiency in the divided system. My setting involves the coarsest possible partition short of unification, and while it does not use Manjunatha and Turhan (2016)'s mechanism, some waste is reduced when the DA mechanism is re-run for regular schools. The first source of inefficiency identified by Dogan and Yenmez (2018) is evidenced in the fact that declined specialized high school offers are not re-distributed. I show that under affirmative action plans, this waste is lessened when more students choose specialized high schools over regular schools.

Finally, this research is also related to the literature on affirmative action in the decentralized higher education markets, particularly Kapor (2016)'s paper on Texas Top Ten, which guarantees admission to Texas public universities for students in the top ten percent of their high school class. The paper finds that Texas Top Ten has a substantial effect on admission for all students due to displacement effects, like in my setting. The author considers a counterfactual where there is no affirmative action. In such a scenario, attendance at flagship universities decreased by 10% for Black

[9] Hahm (2019) also estimates students' preferences for these two connected school systems, but in order to answer a different research question. As such, the author focuses his analysis only on specialized high school applicants. In terms of estimation strategy, he uses the choice between specialized high schools and regular school programs to create a global ranking for each student, and thus, preferences for both types of schools are estimated jointly.

and Hispanics students compared to under Texas Top Ten, but increases by 17% for students from affluent high schools. Entering students under Texas Top Ten or in its absence perform similarly in their first- and second- year GPA in college. In summary, Texas Top Ten improves diversity without compromising the educational outcomes of admitted students.[10]

3 New York City Public High School Admission

Middle-school students in NYC have two public high school options: specialized high schools and regular schools. A key feature that facilitates spillover effects from specialized high schools to regular school admissions is that admission results for the former are finalized first and thus affect admission to the latter. Private schools and schools outside of the New York City school districts are also among possible options.

3.1 Application Process

Grade 8 students can be divided into two groups: specialized high school applicants and specialized high schools non-applicants, that is, those who plan to apply for specialized high schools and those who do not. The sets of actions that needed to be taken differ for these two groups.

Specialized high school applicants need to go through a multi-step process. First, in October, they take the specialized high school Admission Test (SHSAT). The test includes two sections (verbal and mathematics) and can only be taken once.[11] Testing locations are assigned based on the geographic district of each student's middle school. In 2010-2011, Queens borough had two test locations, and the other boroughs each had one. During the test, students must express their preferences over the specialized high schools by filling out a rank-ordered list (ROL) on the answer booklets. Each student must select one specialized high school as the first choice, and then can additionally specify the second choice, third choice, and so on, up to the eighth choice (i.e., ranking all eight specialized high schools) if he/she so chooses. These lists will be used as an input to determine specialized high school offers. Second, in December, they must submit their applications for regular schools, in which they can rank up to 12 programs out of approximately 700. At this point, students know about the admission methods of the regular school programs—which I will elaborate on in the next subsection—but not their actual chance of getting into these programs. They also have not yet received their scores for the SHSAT. Even if a student is not interested in any regular schools, this step is necessary for receiving results from specialized high schools. Finally, in February, those who qualify for offers from specialized high schools receive the aforementioned

[10] For details on other papers in this strand of literature, Arcidiacono, Lovenheim and Zhu (2015) and Arcidiacono and Lovenheim (2016) provide excellent literature surveys.

[11] Strictly specking, students who fail to gain admission into specialized high schools can take the test again the following year when they are in grade 9. However, the test result will be used for admission into grade 10 in specialized high schools, which is separate from the admission into grade 9 that I focus on.

offer as well as an offer from a regular school program. They will then need to choose among these two options and the outside option of exiting the NYC public school system.

Specialized high school non-applicants go through a more straightforward process. They only need to submit one application for regular schools in December, the same as in the second step for specialized high school applicants. The ROLs from both specialized high school applicants and non-applicants will be used as an input to determine regular school assignments. Specialized high school non-applicants and specialized high school applicants without specialized high school offers will receive one regular school offer after the admissions for specialized high school applicants with specialized high school offers have been set.

3.2 School Assignment Procedures

The NYC Department of Education determines most school assignments centrally in two rounds: a "Specialized Round" and then a "Main Round."[12] In both rounds, Gale and Shapley (1962)'s student-proposing Deferred Acceptance (DA) mechanism, as defined below, is used.

In addition to students' submitted ROLs described in the previous subsection, the DA mechanism also takes schools' capacities and schools' strict priorities over students as inputs. All specialized high schools have a common priority rule: students are ranked according to their total scores on the SHSAT. For regular schools, different programs have different admission methods ranging from generating priority based on a random lottery in unscreened programs to evaluating each individual student based on criteria such as grades from the prior school year, standardized test scores, attendance and punctuality, and interviews or essays in screened programs. Programs that evaluate students individually are given a list of students who include them on their ROLs and asked to return a priority ranking over these students to the central enrollment office. Crucially, schools do not observe where they are ranked on the students' ROLs, so students do not have any incentive to influence schools' priorities by strategically changing their rankings.

Given the aforementioned inputs, students are matched to school seats using the following algorithm:

Step 1:

- Each student proposes to her first choice school according to her submitted ROL.
- Each school tentatively accepts the applicants who have applied to it, one at a time, using the school's priority list and starting with the applicant with the highest priority. It does so until it has admitted as many students as its capacity or runs out of applicants. The remaining applicants (if any) are rejected.

Step $k > 1$:

[12] There are also supplementary rounds afterwards for those unassigned or unhappy with their assignment by the end of the Main Round. However, these student only make up 14% of the total in application year 2010-2011.

- Students who are rejected in the previous step apply to the next school on their submitted ROLs. If a student has already applied to all the schools in her ROL, then that student remains unassigned (and the algorithm ends for that student).

- Each school considers the set of students it accepted at the previous step together with the set of new applicants. From this larger set, the school tentatively accepts students, one at a time, using the school's priority list and starting with the applicant with the highest priority. It does so until it has admitted as many students as its capacity or runs out of applicants. The remaining applicants (if any) are rejected.

End: The algorithm ends when there are no new proposals; that is, either no one was rejected in the previous step or all rejected students have exhausted their ROLs.

When students are allowed to rank all available schools, student-proposing DA is strategy-proof for students; that is, it is a weakly dominant strategy for students to report their true preferences (Dubins and Freeman, 1981; Roth, 1982).[13] When they are only allowed to rank a subset of schools, it is still a weakly dominant strategy to submit a truthful order of the schools one does rank, but it may be optimal to drop schools (for instance, at the top of the true preference ranking) to make space for worse schools where the student have a higher chance of getting in. A more detailed discussion on how this affects my empirical strategy can be found in Section 5.

In the Specialized Round, the DA mechanism is run separately for specialized high schools and regular schools. Due to the common priority among specialized high schools, the mechanism is essentially reduced to a serial dictatorship where the serial order is from the highest- to the lowest-scoring student. Specifically, the student with the highest score chooses her first-choice school, then the student with the second-highest score chooses her highest-ranked school among those with available seats, and so on. For regular school programs, priorities vary depending on the admission methods described above.

The resulting assignments are sent out to those who received specialized high school offers. Once these students have made their choices between their specialized high school offer and regular school offer, their assignments are finalized, they are removed from the system, and the numbers of remaining seats in regular school programs are adjusted accordingly. Then, the DOE proceeds to the Main Round, where DA is run again for the remaining students and regular school seats.

[13]Strictly speaking, these papers state the result for the marriage market, where one agent on each side is matched to each other. In the school choice context where each school can be matched with multiple students, this result holds if schools' preferences over students are responsive—informally, schools' preferences over sets of students can be completely described by their preferences over individual students—which is the case in New York City high school admission.

Table 4.1: Students' Characteristics for Application Year 2010-2011

	All High School Applicants	specialized high schools Applicants Only
Grade 7 State Math	672.7	695.03
	(32.7)	(28.7)
Grade 7 State ELA	661.5	677.7
	(28.9)	(33.0)
Zip code income ($)	54940	60211
	(25705)	(29001)
Subsidized lunch eligibility (%)	66.49	56.03
White	13.41	17.73
Asian	14.78	29.74
Black	31.34	26.70
Hispanic	39.88	25.11
N	66068	23255

Notes: Statistics is based on the analysis sample, consisting of 66068 students. Zip code income is median family income for each zip code from the American Community Survey 2007-2011.

4 Data and Descriptive Analysis

4.1 Students

I link together three data sets from the New York City Department of Education containing the universe of students who applied to any public high schools during the 2010-2011 application year. The New York City High School Admission Process data contains all high school applicants with information on their zip codes, middle schools, scores on the Grade 7 English Language Arts (ELA) and mathematics state tests, submitted rank-ordered lists, priority ranks, and admission decisions. The SHSAT data set contains a subset of the above who applied to specialized high schools with additional information on the specialized high school admission process. Finally, the June biographic data supplements the aforementioned data sets with demographic information such as ethnicity, home language, eligibility for subsidized lunch, etc.

I make two restrictions for the main analysis sample, which is described in this section and used for the first step of structural estimation in Section 5. First, only students in New York City's public middle schools during the application year are included because demographic information is not available for students in private middle schools. Second, I only consider only those who appear in the Specialized or Main Round of the admission process. The sample used for the second step of estimation, henceforth referred to as the specialized high school sample, is a subset of the main analysis sample, restricted to only specialized high school applicants.

Table 4.1 summarizes the characteristics of students in the main analysis sample as well as the

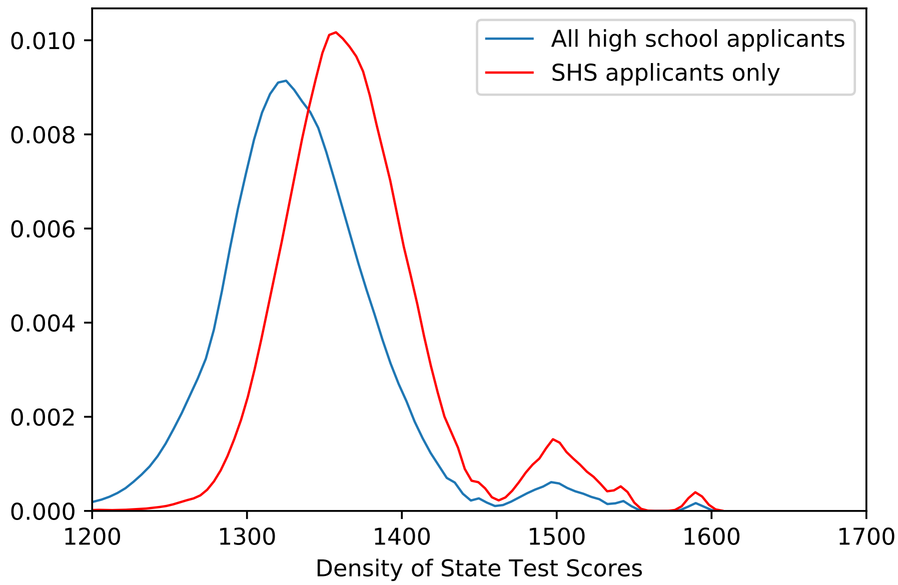


Figure 1: Distribution of State Test Scores - All High School Applicants vs. specialized high schools Applicants Only

specialized high school sample. There is selection into applying to specialized high schools in terms of all observable characteristics. On average, specialized high school applicants score higher on the grade 7 state tests, come from more affluent neighborhoods, and are less likely to be eligible for subsidized lunch. In terms of scores, specialized high school applicants are doing better not only on average: Figure 1 shows that for the specialized high school sample, there is a higher density of students at every score above 1330. The three spikes on the right tail of each distribution are likely attributable to a property of the scoring scale of the test.[14] The percentages of White and Asian students among specialized high school applicants are higher than those in the full sample, and the percentage of Black and Hispanic students are lower. The differentials in compositions are especially pronounced for Asians and Hispanics.

In terms of students' choice, the amount of information I observe differs by student type as defined by their actions during the application process. For specialized high schools non-applicants (i.e., those who appear in the main analysis sample but not the specialized high school sample), only their rank-ordered lists over regular school programs and regular school offers are available. For specialized high school applicants, I also observe rank-ordered lists over specialized high schools.

[14]For both tests, the score increments are much smaller for the lower range of scores compared to that between the top two scores (698 and 790 for ELA; 752 and 800 for mathematics), and there are bunchings at these top scores. Therefore, from left to right, the three spikes in the distribution of combined scores correspond to those who obtain the second-highest score in both tests, those who obtain the second-highest score on one test and highest score on the other, and those who obtain the highest score in both tests. This is unlikely due to the specific student population as test score data for other school years exhibit the same pattern.

Among these students, those who receive specialized high school offers additionally have their specialized high school offers, and their choice between specialized high school and regular school offers available.

Table 4.2 describes the rank-ordered lists over regular school programs for all students in the analysis sample. Regular school programs that are ranked higher tend to be closer to the students' home, have a bigger grade 9 cohort, higher percentages of White students, lower percentages of students eligible for subsidized lunch, and higher percentages of admitted students who performed well in the Regent exams. Schools that are ranked by students differ by their own race, their baseline mathematics achievement as measured by their score on the grade 7 state test, and the median family income of their neighborhoods. Details for this heterogeneity can be seen in Table A.1 of the appendix, where average school characteristics by the rank of student choice are shown for different subgroups.

From the observed responses between specialized high school and regular school offers summarized in table 4.3, we can see that it is not an obvious choice. A considerable fraction (19.08%) of students with specialized high school offers opted for a regular public school instead. Out of these students, 70% got their first-choice regular school programs, suggesting that the reason they applied to specialized high schools but did not accept their offers may be due to uncertainty in their admission chance at their preferred regular schools.

4.2 Schools

School characteristics for 2009-2010, the school year before the application year, come from the New York State Report Card Database publicly accessible on the New York State Education Department website. Program descriptions are taken from the official New York City High School Directory. Both types of information would have also been available for parents and students at the time of application.[15] A few schools and, therefore, their associated programs have their characteristics censored due to the Department's restriction on publishing data for groups with fewer than five students. Table 4.4 summarizes the characteristics of all high school programs for the 2009-2010 school year. On average, specialized high schools have a higher percentage of White students, lower percentage of students eligible for subsidized lunch, and markedly outperform regular high school programs in terms of their current students' achievement in the Regent mathematics exam.

5 Estimating Student Preferences

To quantify students' preferences in both the elite and regular high school sectors, I devise a two-step estimation procedure, exploiting the choice between one elite and one regular school that is

[15] For school characteristics from the Report Card Database, there may be some slight difference between the later version that I use compared to the initial version available at the time.

Table 4.2: Regular School Application - (Average) School Characteristics by Rank of Student Choice (All Students)

	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th
Students ranking choice (%)	100.00	91.01	86.39	79.01	69.65	59.08	48.21	39.10	30.83	24.69	19.51	14.61
Distance in miles: Mean	4.76	5.06	5.19	5.31	5.49	5.60	5.71	5.79	5.89	5.87	5.91	5.67
Distance in miles: Median	3.69	3.92	4.11	4.25	4.42	4.54	4.63	4.72	4.79	4.77	4.85	4.53
Size of grade 9	465.53	488.26	469.82	447.98	426.87	404.53	384.38	368.35	348.39	340.86	329.43	331.33
Percent white	17.96	16.64	15.67	14.47	13.38	12.53	11.43	10.98	10.15	9.72	9.08	8.43
Percent subsidized lunch	62.77	63.84	65.45	66.88	68.03	68.95	70.01	70.56	71.45	72.17	72.84	73.44
High math achievement (%)	11.78	9.98	9.65	9.25	8.84	8.64	8.08	7.78	7.40	6.96	6.48	5.82

Notes: Statistics is based on the analysis sample, consisting of 66068 students. The high math achievement measure for each high school is the percentage of admitted students in said school who score higher than 85% in the Regents mathematical exams in the 2009-2010 school year.

Table 4.3: Responses to Specialized High School Offers

	Number	Percent
Accept	3319	76.11
Regular Public Schools	832	19.08
Other Options	210	4.81
Total	4361	100

Notes: This table only accounts for offers to public middle school students, whom the estimation and counterfactual simulations focus on. There are additionally about 1000 other offers to private middle school students.

Table 4.4: Program Characteristics for School Year 2009-2010

	Regular HS Programs	specialized high schools
Size of grade 9	430	464
Percent white	10.82	28.63
Percent subsidized lunch	71.21	42.00
High math achievement (%)	4.98	62.04
N	697	8

Notes: The high math achievement measure for each high school is the percentage of admitted students in said school who score higher than 85% in the Regents mathematical exams in the 2009-2010 school year.

observed for a subset of students.

5.1 Model and Estimation

Preferences over specialized high schools and regular schools both take the form of a random utility model in which students with different backgrounds have heterogeneous tastes over multiple dimensions of school characteristics. Although student preferences over the two types of schools have the same functional form, I allow the parameters to be different to reflect the fact that students may evaluate the characteristics of specialized high schools and regular schools differently.

Estimation step 1

The first step of the estimation procedure recovers the utility function for attending regular school programs from the rank-ordered lists over these programs submitted by all students in the analysis sample. Suppose $s = 1, ..., S$ is a regular public high school program. Student i's utility of attending program s is:

$$u_{is} = \underbrace{\delta_s + \sum_m \sum_n \alpha_{mn} x_{sm} z_{in} - d_{is}}_{V_{is}} + \lambda \epsilon_{is} \tag{1}$$

where x_s denotes program characteristics, z_i denotes students characteristics, and d_{is} denotes the distance between the student's home and the school. Following the convention in the school choice literature, I normalize the parameter for distance to -1 so that the unit can be interpreted in terms of the disutility of traveling. The program fixed effect δ_s represents how much an "average" student in the analysis sample[16] values program s (disregarding traveling distance). Parameters α_{mn} capture how students of different backgrounds evaluate program characteristics differently from the average. Peer preferences are captured by including racial and socioeconomic compositions as program characteristics. I assume that these compositions are uncorrelated to ϵ_{is} because each student is small enough that the changes in his or her preferences and, hence, behaviors should not make a difference in the aggregate compositions.

Each student always has the outside option to exit the NYC public school system (e.g., attend a private high school) with utility:

$$u_{i0} = \lambda\epsilon_{i0}.$$

In the above notation, V_{is} is the systematic part of the utility function. The idiosyncratic preference shocks ϵ_{is} and ϵ_{i0} are independently and identically distributed according to type I extreme value distribution.

Similar to Abdulkadiroglu, Agarwal and Pathak (2017), the identification assumption I use is weak truth-telling, which consists of two parts. First, the order of schools in the submitted rank-ordered list is according to true preference. Second, ranked schools are preferred to all unranked schools. Unlike strict truth-telling, this assumption does not presume any relationship between unranked schools and the outside option of not attending any New York City public high school (i.e., attending a private school or a school outside of the city).

Given this assumption, the validity of which will be discussed later in this section, one can derive the likelihood of the observed data as follows. For student i who submits a rank-ordered list $r_i = (r_{i1}, .., r_{ik})$, the individual likelihood is the probability of observing said ranking:

$$\begin{aligned}
L_i(\boldsymbol{\theta_{reg}}) &= Pr(r_i) \\
&= Pr(u_{i1} > u_{i2} > ... > u_{ik} > u_{ij} \forall j \notin \{1, 2, ...k\}) \\
&= Pr(u_{i1} > u_{ij} \forall j \neq 1) \times Pr(u_{i2} > u_{ij} \forall j \notin \{1, 2\}) \times ... \\
&\quad ... \times Pr(u_{i1} > u_{i2} > ... > u_{ik} > u_{ij} \forall j \notin \{1, 2, ...k\}) \\
&= \prod_{s=1}^{k} \frac{exp\left(\frac{V_{is}}{\lambda}\right)}{\sum_{t=s}^{S+1} exp\left(\frac{V_{it}}{\lambda}\right)}
\end{aligned}$$

where $\boldsymbol{\theta_{reg}} = (\boldsymbol{\delta_{reg}}, \boldsymbol{\alpha}, \lambda)$ is the vector of preference parameters. From the first part of the weak

[16] This student belongs to the omitted category for all dummies (White and not eligible for subsidized lunch) and has characteristics that are equal to the average of the analysis sample for all continuous variables, which means all z_i are 0 in the standardized data. For a full description of such a student, see table 4.1.

truth-telling assumption, observing r_i implies that the true utility ranking is $u_{i1} > u_{i2} > ... > u_{ik}$. From the second part of the assumption, the lowest-ranked regular high school program k has utility $u_{ik} > u_{ij}$, where j represents indices of unranked schools and the outside option. The third line follows from the independence of irrelevant alternatives (IIA) property of the logit model, and the last line utilizes the analytical form of the logit probability.

Thus, the log-likelihood for a sample of I students, each faced with $S+1$ alternatives (S programs and one outside option), is:

$$\mathcal{L}(\boldsymbol{\theta_{reg}}) = \sum_{i=1}^{I}\sum_{s=1}^{k}\frac{V_{is}}{\lambda} - \sum_{i=1}^{I}\sum_{s=1}^{k}\log\left[\sum_{t=s}^{S+1} exp\left(\frac{V_{it}}{\lambda}\right)\right]$$

I estimate the parameters $\boldsymbol{\theta_{reg}}$via maximum likelihood and use the standard asymptotic theory for the estimation of the variance-covariance matrix of the estimates.

Estimation Step 2

The second step of the estimation procedure recovers the utility function for attending specialized high schools from the rank-ordered lists over them submitted by specialized high school applicants in the specialized high school sample. Suppose $j = 1, ..., J$ is a specialized high school. Student i's utility of attending specialized high schools j is:

$$u_{ij} = \delta_j + \sum_m \sum_n \beta_{mn} x_{jm} z_{in} - \gamma d_{ij} + \hat{\lambda}\epsilon_{ij}, \quad (2)$$

with notations being similar to equation (1).

For utilities for the two types of schools to be comparable, they need to be similar in both scale and location.[17] To ensure that utilities are of the same scale, the coefficient of the idiosyncratic preference shock in equation (2) is fixed at $\hat{\lambda}$, the estimated value of λ in the utility function for attending regular school (equation (1)). Given this normalization, the coefficient of distance to specialized high schools $-\gamma$ potentially differs from -1 (that for regular schools). To ensure that utilities are comparable in terms of location, I link the two sets of utilities by the comparison of utilities between one specialized high school and one regular school. For students who are allowed to choose between a specialized high school offer and a regular school match, these two schools are used, and the ranking is based on the student's enrollment decision. For students who do not have the opportunity to choose, I assume that they prefer their highest-ranked specialized high schools to their lowest-ranked regular school. Otherwise, for this student, all ranked regular schools must have been better than all specialized high schools, which means they would not have applied to specialized high schools in the first place given any non-negative cost of application.

[17] This is because given an ordinal ranking, cardinal utilities are only identified up to an affine transformation.

For student i who submits a rank-ordered list $r_i = (r_{i1}, .., r_{ik})$ over specialized high schools and chooses specialized high schools m over regular program s, the individual likelihood is now the probability of simultaneously observing said rank-order list and choice:

$$\begin{aligned} L_i(\boldsymbol{\theta_{SHS}}, \boldsymbol{\hat{\theta}_{reg}}) &= Pr(r_i \text{ and } u_{im} > u_{is}) \\ &= Pr(r_i) \times Pr(u_{im} > u_{is}) \\ &= \prod_{j=1}^{k} \frac{exp\left(\frac{V_{ij}}{\hat{\lambda}}\right)}{\sum_{t=j}^{J} exp\left(\frac{V_{it}}{\hat{\lambda}}\right)} \times \frac{exp\left(\frac{V_{im}}{\hat{\lambda}}\right)}{exp\left(\frac{\hat{V}_{is}}{\hat{\lambda}}\right) + exp\left(\frac{V_{im}}{\hat{\lambda}}\right)}, \end{aligned}$$

where $\hat{V_{is}}$ is the systematic part of the utility of attending regular program s, evaluated at the estimated $\boldsymbol{\hat{\theta}_{reg}}$. We can take the product of unconditional probabilities as in the second line due to the IIA property of the logit model. The first part of the product is derived, under the assumption of weak truth-telling, in a similar fashion to that in the regular school case, and the second part is the logit probability of choosing m over s.

Symmetrically, if student i chooses regular program s over specialized high schools m, her individual likelihood would be:

$$L_i(\boldsymbol{\theta_{SHS}}, \boldsymbol{\hat{\theta}_{reg}}) = \prod_{j=1}^{k} \frac{exp\left(\frac{V_{ij}}{\hat{\lambda}}\right)}{\sum_{t=j}^{J} exp\left(\frac{V_{it}}{\hat{\lambda}}\right)} \times \frac{exp\left(\frac{\hat{V}_{is}}{\hat{\lambda}}\right)}{exp\left(\frac{\hat{V}_{is}}{\hat{\lambda}}\right) + exp\left(\frac{V_{im}}{\hat{\lambda}}\right)}.$$

The log-likelihood for a sample of I students, where i chooses specialized high schools m_i for $i = 1, .., n$ and h choose regular program s_h for $h = n+1, ..., I$, is:

$$\begin{aligned} \mathcal{L}(\boldsymbol{\theta_{SHS}}, \boldsymbol{\hat{\theta}_{reg}}) = & \sum_{i=1}^{I}\sum_{j=1}^{k} \frac{V_{ij}}{\hat{\lambda}} - \sum_{i=1}^{I}\sum_{j=1}^{k} \log\left[\sum_{t=j}^{J} exp\left(\frac{V_{it}}{\hat{\lambda}}\right)\right] \\ & + \sum_{i=1}^{n} \frac{V_{im_i}}{\hat{\lambda}} + \sum_{i=n+1}^{I} \frac{\hat{V}_{is_i}}{\hat{\lambda}} - \sum_{i=1}^{I} \log\left[exp\left(\frac{\hat{V}_{is_i}}{\hat{\lambda}}\right) + exp\left(\frac{V_{im_i}}{\hat{\lambda}}\right)\right] \end{aligned}$$

I also estimate the parameters $\boldsymbol{\theta_{SHS}}$ via maximum likelihood. In computing the standard errors for the estimated parameters $\boldsymbol{\hat{\theta}_{SHS}}$, I need to account for the fact that the estimates from the first step are used as an input. Thus, I take independent and identically distributed draws from the distribution of $\boldsymbol{\hat{\theta}_{reg}}$ and re-estimate the second step for each draw. The resulting distribution of $\boldsymbol{\hat{\theta}_{SHS}}$ is used to calculate its standard errors.

The Validity of Weak Truth-telling Assumption

As previously stated in the description of the student-proposing Deferred Acceptance (DA) mechanism, when students are allowed to rank all available schools as is the case for specialized high schools, it is a weakly dominant strategy for students to report their true preferences (strict truth-telling). Consequently, both parts of the weak truth-telling assumption are likely to hold for specialized high schools. Reporting the correct order among those that are ranked (part 1 of weak truth-telling) is still a dominant strategy when the length of the rank-ordered list is restricted as in the case for regular school programs. However, because students can only rank twelve out of nearly 700 programs, the second part may be violated because it may be optimal for students to drop some schools that they are unlikely to get in to make space for less-preferred schools where they have a better chance (Haeringer and Klijn, 2009). Only 14.61 % of students ranked all twelve choices, which somewhat alleviates concerns over students dropping true top choice(s) due to restricted rank-ordered lists.

The possibility of payoff-insignificant mistake as introduced by Artemov, Che and He (2017), that is, students dropping schools they are unlikely to get in even when they still have space for them in the rank-ordered list, is still present for both types of schools. It must be noted, however, that there is more uncertainty in admission chances in my setting compared to the empirical setting of their paper, where priority is based on a score and students already know their own score before submitting rank-ordered lists. Although specialized high schools also use one single score to determine priority, specialized high school applicants have to submit their rank-ordered lists before learning their own scores. Yet more uncertainty is present for regular school programs, some of which based priority on a lottery. Even for those which have deterministic criteria for assigning priority like screened programs, how these different criteria are weighed is somewhat opaque from the students' perspective.

5.2 Preference Estimates

The distribution of estimated program fixed effects shown in figure 2 looks approximately normal. As expected, the mean fixed effect for specialized high schools falls within the right tail of this distribution, demonstrating the fact that these elite schools are highly valued. There is some small mass of programs around as well as above this point in accordance with the observation in Section 4 that there exist regular high school programs that are preferred to some specialized high schools.

The estimates for the coefficients of the utility functions for both regular high school programs and specialized high schools are reported in Table A.2. In both estimations, schools' characteristics are centered around the average characteristics of the population of regular high school programs as seen in the first column of Table 4.4. Students' continuous characteristics are standardized based on the mean and standard deviation in the main analysis sample. There are some notable patterns of differences between the coefficients for regular school programs and specialized high schools. First, while students of all races tend to prefer regular programs with higher percentages of White students, the opposite is true for specialized high schools, although it is only significant for Hispanics and students in the other race category.[18] Second, the effects of the size of grade 9

[18]This category includes multiracial and Native American students.

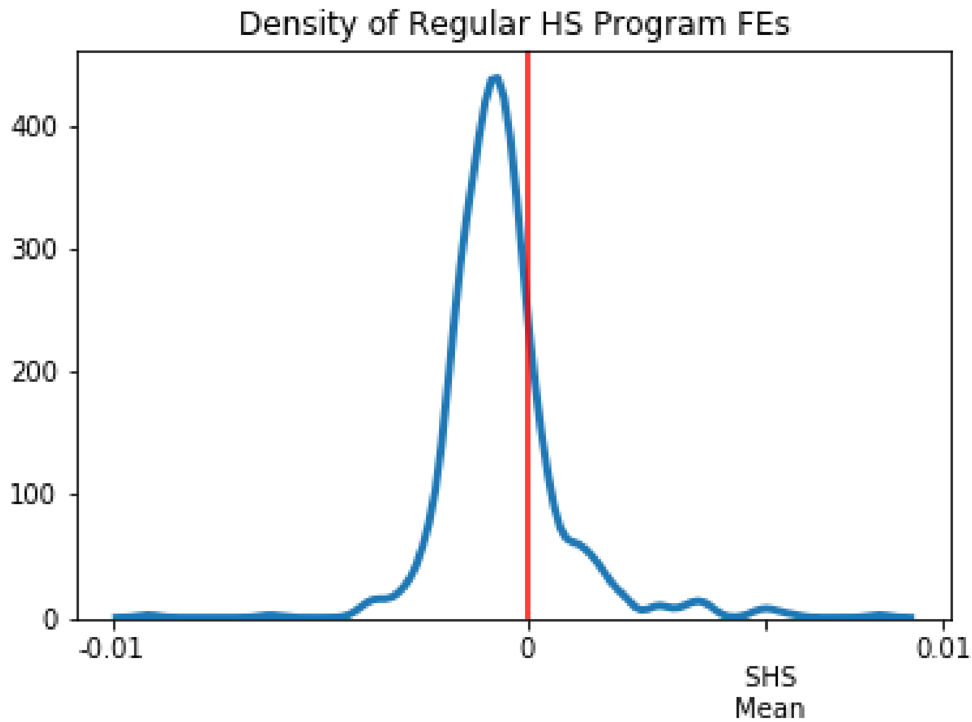


Figure 2: Distribution of Estimated Fixed Effects for Regular High School Programs

are reversed for students of all races except Black. Third, although regular school programs tend to be more attractive to students with higher baseline achievement in both ELA and mathematics, the corresponding effect is only significant for students with higher baseline mathematics when it comes to specialized high schools.

6 The Effects of Affirmative Action Plans

There are three main findings from my simulation of the affirmative action plans currently considered. First, there is a trade-off between improving diversity and maintaining student quality in specialized high schools. The Chicago plan does poorly in terms of increasing overall racial diversity but preserves the quality of incoming students. In contrast, the Top 7% plan increases diversity substantially at the cost of student quality. Second, the Chicago plan reduces the differences among schools within the elite sector, whereas the Top 7% plan increases these differences. Third, both plans also change regular school assignments and thereby the student quality in regular high school programs.

6.1 Implementing Counterfactual Policies

I simulate the effects of each affirmative action plan in the first year that it is implemented, using the estimated parameters presented in the previous section. The analysis is based on two main assumptions. First, in this short-run scenario, I assumed that parents and students are myopic with respect to the possible changes in the school characteristics, including the composition of incoming students; that is, their preferences over schools do not change. Subsequent versions of the paper will address the effects in medium- and long-run when parents and students also adjust their preferences in response to the policy. Second, to recover preferences over specialized high schools of students who did not apply, I assume that these can be extrapolated from students who did apply with the same observables. Rankings are constructed using the systematic part of the utility function; that is, a student is said to prefer one school over another in the constructed rankings if they are expected do so on average across all possible realizations of the error terms.

In both counterfactuals, I run two rounds: Specialized and Main, as in the status quo. In the Specialized Round, the selection rules are different for specialized high schools, leading for different offers. For regular school programs, the Specialized Round proceeds in the same way as in the status quo. Given the new specialized high school offers, students who receive them are allowed to choose between one specialized high school and one regular school program. If a student would have chosen between these exact same schools in the status quo, his or her actual choice is used in the counterfactuals. If not, then I predict this choice by comparing the systematic parts of the utilities of going to these two schools. Given the difference in the outcomes of the Specialized Round between the counterfactuals and the status quo, the inputs for the Main Round are different. However, the procedure remains the same.

I assume that the capacities of specialized high schools used in the Deferred Acceptance mechanism Specialized Round under the status quo are maintained in both counterfactuals, but the total numbers of incoming students, given their responses to specialized high school offers, can change. In particular, although specialized high school offers fill up their capacities, some students decline these offers in favor of other options. In the current system, there are no waiting lists dependent on the number of accepted offers.[19] I maintain this feature under the affirmative action policies, which means if more or fewer students decide to accept their specialized high school offers, the total numbers of admitted students under the counterfactual policies may indeed differ from those in reality.

When considering the effects on regular schools, I assume that the specialized high school offers and choices between specialized high schools and regular schools (if applicable) do not change for private middle school students. This is because there are no unique identifications that allow

[19] The current analysis does not consider the Discovery Program, which allows students belonging to disadvantaged who barely miss the cutoff to apply for conditional offers at specialized high schools. However, the numbers of seats for this program are committed to before the entire application process and thus do not depend on how many students accept their specialized high school offers.

matching private school students between the specialized high school and regular school admission data sets. In both counterfactuals, since these students do experience changes in specialized high school offers (or lack thereof), thereby influencing the school assignments in regular schools, we can consider the current results with respect to the changes in regular school admission as a lower bound for the actual changes. Because the number of private school students being affected under the Chicago plan is much lower than that in the Top 7% Plan, the extent to which this assumption influences the results is different for the two plans. As such, we should view within-regular-school outcomes for the two plans as two examples of the types of spillover effects that are possible instead of comparing them head-to-head.

Chicago Plan

In the Chicago plan, some seats are assigned purely on merit, and some are reserved for each of four tiers of socioeconomic status determined by students' neighborhood. An implementation in NYC would still require those who wish to gain admission to specialized high schools to take the SHSAT, which would be used as the criterion for merit seats as well as a tie-breaker among students of the same tier.

I assume that 40% of total capacity at each specialized high school is set aside as merit seats, and the remaining seats are divided equally among four tiers. Tier 1 student has the highest priority for tier 1 seats, and so on. Similar to the current policy in Chicago, when running the Deferred Acceptance mechanism to determine specialized high school offers, I fill all merit seats first, then tier seats.[20] In theory, if the applicants in one tier run out before the seats in that tier are filled, students from other tiers would be admitted, which means the precedence order in which different tiers are filled is also important. In practice, all tier seats are oversubscribed, so any precedence order among the four tiers gives the same result.

Tiers are determined based on students' zip codes. For public middle school students, actual zip codes are used. For private middle school students, individual zip codes do not appear in the specialized high school admission data, so the tier for each is proxied by assigning his or her middle school the average tier of all specialized high school applicants from that school. Each zip code is given a tier depending on its median family income. Tier 1 has income in the lowest quantile compared to the rest of New York City; tier 4 has income in the highest quantile. To avoid dependency on the population of students who submitted public high school applications, income quantiles are calculated based on the population of families in New York City in the American Community Survey 2007-2011.

[20] In Appendix B, I explore different precedence orders as well as different proportions of total capacity set aside as merit seats. I find that filling merit seats first, as in the main specification, does in fact favor the more disadvantaged tier(s).

Top 7 % Plan

In the Top 7% plan, I assume that academic performance is measured by the combined English Language Arts (ELA) and mathematics scores on the Grade 7 state test. The top 7% of students in each public middle school based on this measure obtain automatic eligibility for one of the specialized high schools. The specific school assignments among these students are determined by running the Deferred Acceptance mechanism, using Grade 7 state test scores as the criterion of the common priority of all specialized high schools. For the 3474 students who applied before, I use their submitted rank-ordered lists over specialized high schools. For the 1280 students who never applied, I simulate their rank-ordered lists from the estimated preferences (of those who applied). After the top 7% public middle school student have taken their seats, there are 652 seats (approximately 12% of the total capacity) left for private school students. I do not consider the allocation of these seats due to two reasons. First, the demographic information of this group is unavailable, thereby prevent me from any conclusion regarding their compositions. Second, even if I establish their assignments in specialized high school admission, they cannot be linked to regular school admission.

6.2 Students' Movements

The Chicago plan causes reshuffling within specialized high schools but little flow of students between specialized high schools and regular schools, whereas the Top 7% plan causes considerable flows of students between specialized high schools and regular schools. In both cases, the exchange of students between the two sectors also results in extensive changes in regular school assignments for those who neither gain nor lose specialized high school offers.

As shown in table 6.1, there are considerably more exchanges of students between the elite and regular sectors under the Top 7% plan. The second row for each plan corresponds to the proportions of students out of all those from public middle schools who move from specialized high schools to regular schools. Under both policies, only small fractions of Black and Hispanic students lose access to specialized high schools (0.08% and 0.05% for Chicago, and 0.56% and 0.49% for Top 7%) contrasted with considerably more movement of White and Asian students. However, the plans differ starkly in terms of the magnitude of the flows of these students from specialized high schools to regular schools: approximately 11 times more White students and 22 times more Asian students are displaced from specialized high schools under the Top 7% plan compared to Chicago plan. As a result, the total inflow of students from regular schools to specialized high schools is also much larger under Top 7%. There are two types of inflow: 1) those who gain specialized high school offers under the affirmative action plan when they would not have had any offers under the status quo and 2) those who would get a better offer under the affirmative action plan and thus choose specialized high schools even though they would have chosen regular schools before. Most of the disparity between the two plans comes from the first type. First, there are substantial differences in magnitude between the two plans across all the races considered (0.48-1.59% and 4.68-5.28% for

Table 6.1: Comparison of School Assignments between the status quo and Affirmative Action Plans

	White	Asian	Black	Hispanic
School Assignments - status quo vs. Chicago Plan (% of total)				
Always specialized high schools	8.43	20.23	0.90	0.84
Specialized to regular	0.57	0.64	0.08	0.05
Regular to specialized (offer gained)	0.65	1.59	0.46	0.48
Regular to specialized (better offer)	0.60	0.92	0.10	0.10
Different regular schools	28.89	30.32	49.89	49.04
Same regular schools (Main Round)	55.64	43.24	48.12	48.98
Same regular schools (Specialized Round)	2.06	2.02	0.16	0.17
School Assignments - status quo vs. Top 7% Plan (% of total)				
Always specialized high schools	2.62	6.67	0.42	0.39
Specialized to regular	6.38	14.20	0.56	0.49
Regular to specialized (offer gained)	4.68	4.83	5.28	4.77
Regular to specialized (better offer)	0.72	0.87	0.07	0.10
Different regular schools	28.34	29.90	47.74	46.72
Same regular schools (Main Round)	53.86	42.10	45.61	47.14
Same regular schools (Specialized Round)	0.70	0.50	0.06	0.06
Total Number of Students	9011	9813	21306	26893

Notes: The last row shows the total numbers of public middle school students in four racial categories. For each column, the corresponding number represents 100%.
In terms of school assignments, there is one category omitted from the table for students who would always go to La Guardia (a performing art school) or exit the public school system.
Theoretically, those who move from specialized high schools to regular schools can be divided into those who lose offers and those who choose regular school because they receive worse specialized high school offers. I do not make the distinction in this table because the second category is very small (0 and 7 students, across all races, for Chicago and Top 7%, respectively).
Students who move from regular schools to specialized high schools are divided into 1) those who gain specialized high school offers under the affirmative action plan when they would not have had any offers under the status quo and 2) those who would get a better offer under the affirmative action plan and thus choose specialized high schools even though they would have chosen regular schools before. Students who attend the same regular school are divided into 1) those who are assigned in the Specialized Round (i.e. they choose regular schools over specialized high school offers) under both status quo and affirmative action plan and 2) those who are assigned in the Main Round under both scenarios.

Chicago and Top 7%, respectively). Second, a markedly higher percentage of Asians gain access compared to other races under the Chicago plan, while the percentages for all four races are similar under the Top 7% plan. Note that in absolute numbers, there are still many more Black and Hispanic than White and Asian students who gain access in the Top 7% plan.

Substantial portions of students are also reshuffled among regular school programs under both plans. Specifically, Black and Hispanic students are more affected both in percentage and absolute terms. Surprisingly, even a small exchange between the two sectors in the Chicago plan causes substantial spillover effects in regular schools. Although it is not appropriate to compare the outcomes of the two plans here as a way of evaluating their merits against one another,[21] the results here show that exchanges of different sizes can cause similar disturbances in regular school admission, and the identities of the individuals being exchanged (i.e., both their submitted preferences and priorities at various schools) most likely play an important role.

6.3 Effects on specialized high schools

The overall diversity and student quality in specialized high schools remain relatively unchanged under the Chicago plan, whereas there is a substantial increase in the proportions of Black and Hispanic students and a decrease in overall student quality under the Top 7% plan.

In terms of racial composition, both plans increase the percentages of Black and Hispanic students in specialized high schools but with remarkably different orders of magnitude. Figure 3 shows that the changes in the Chicago plan are small enough (all less than 5 percentage points) that the resulting composition still look very similar to that under the status quo. Meanwhile, the changes in the Top 7% plan are all very drastic: the percentage of Black students increases from 6.27% to 25.70% and that of Hispanic students from 7.18% to 30.21%. While the proportions of White and Asian both decrease, Asian students, who are most over-represented in specialized high schools under the status quo, experience the most substantial change that more than halves their percentage. The resulting racial composition in specialized high schools under the Top 7% plan thus becomes much closer to that of the public middle school population, the main source of high school applicants, although Blacks and Hispanics are still under-represented.

The effects on compositions are heterogeneous across individual specialized high schools, as seen in Table A.3. Under the Chicago plan, this is mostly due to shuffling within specialized high schools in the direction of reducing the dispersion in racial compositions across specialized high schools. First, although all specialized high schools experience decreases in percentages of Whites, the greatest changes in terms of percentage points are at the two most predominantly White schools originally. Second, all but the three schools with the lowest fractions of Asian originally experience decreases in percentages of Asians. Finally, percentages of Black students increase in all schools except for one where Blacks would have been most well-represented among specialized high schools

[21] This is due to an assumption on private middle school students. For more details, please refer to Subsection 6.1.

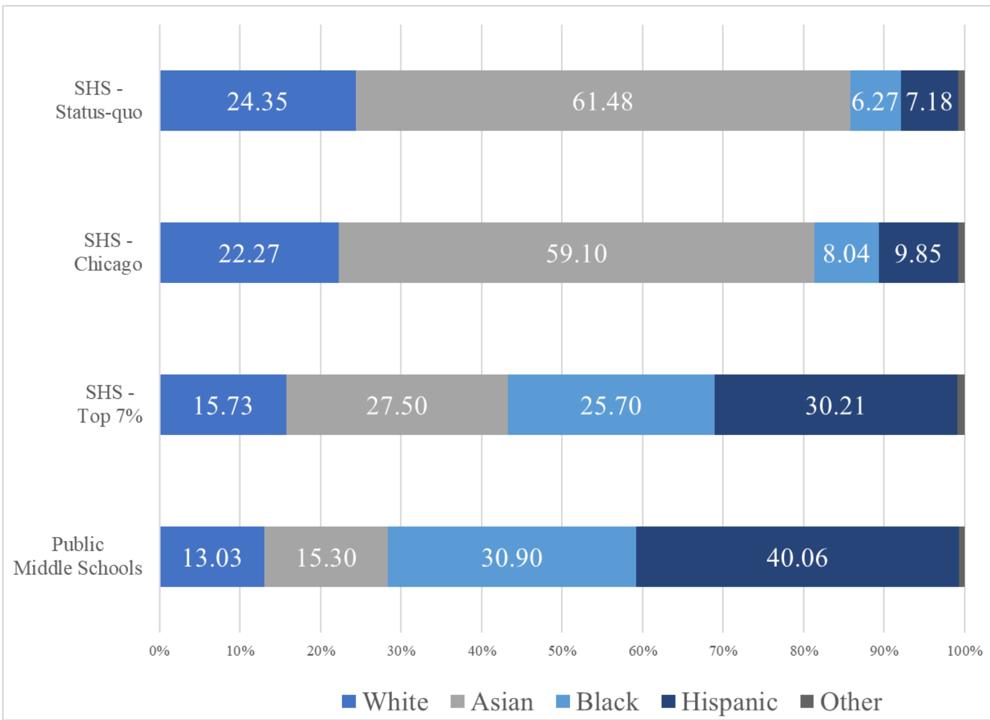
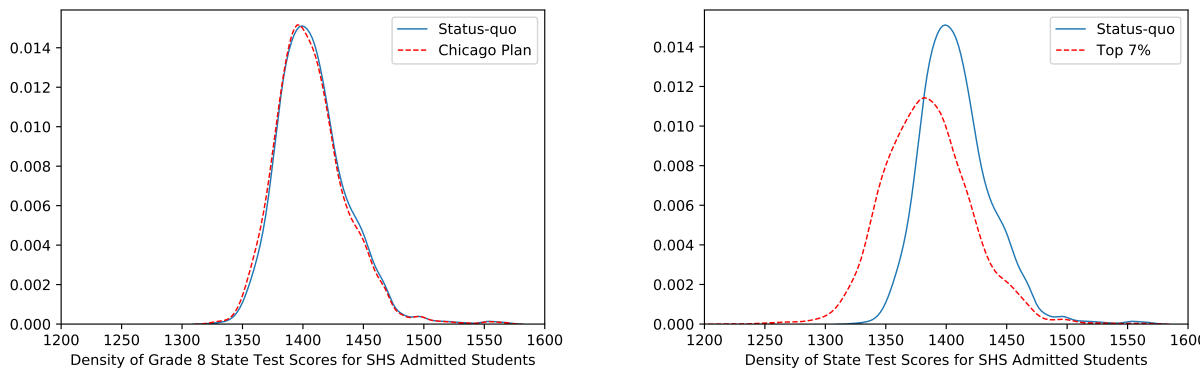


Figure 3: Racial Composition of specialized high schools under Different Policies

Notes: This figure only takes into account public middle school students for whom racial identities are known, so 100% for each bar corresponds to the total number of such students who would enroll in specialized high schools in each scenario. For comparison purpose, I include the last bar that represents the population of all public middle school students, the main source of high school applicants.



(a) Chicago Plan (b) Top 7% Plan

Figure 4: Distribution of Grade 8 State Test Scores of Admitted Students to specialized high schools

Table 6.2: Grade 8 State Test Scores of Admitted Students to Specialized High Schools

	status quo	Chicago Plan		Top 7% Plan	
	Mean	Mean	Difference	Mean	Difference
Stuyvesant	1427.5	1419.1	-8.4***	1412.2	-15.3***
Bronx Science	1410.8	1407.7	-3.2**	1386.1	-24.8***
Queens Sciences	1405.4	1404.3	-1.1	1392.4	-13.0***
HS of American Studies	1400.5	1404.8	4.3	1377.6	-22.9***
Staten Island Tech	1398.1	1398.9	0.8	1373.0	-25.1***
HS of Maths, Science & Engineering	1404.1	1400.3	-3.8*	1395.0	-9.2***
Brooklyn Tech	1400.7	1403.7	2.9***	1368.9	-31.8***
Brooklyn Latin	1384.8	1394.3	9.4***	1362.7	-22.1***
All	1408.3	1406.4	-1.8***	1384.1	-24.2***
Standard Deviation (specialized high schools Admitted Students under status quo): 29.1					

under the status quo. Under the Top 7% plan, even though percentages of Black and Hispanic students increase across the board, the high variance in the magnitude of the increases cause more dissimilarities among specialized high schools. On one end of the spectrum, Stuyvesant still has a severe under-representation of Blacks and Hispanics, which only account for 9.98% and 9.70% of its population, respectively. In contrast, more than 50% of Bronx Science's and Brooklyn Latin's students under the Top 7% plan are Black, which would be an over-representation if the population of public middle school students is used as a benchmark.

Student quality, as measured by Grade 8 state test scores, remains almost the same under the Chicago plan but decreases considerably under the Top 7% plan. Figure 4 shows that the distribution of test scores of admitted students under the Chicago plan tracks that under the status quo quite closely, which is expected given that the overall specialized high school student population

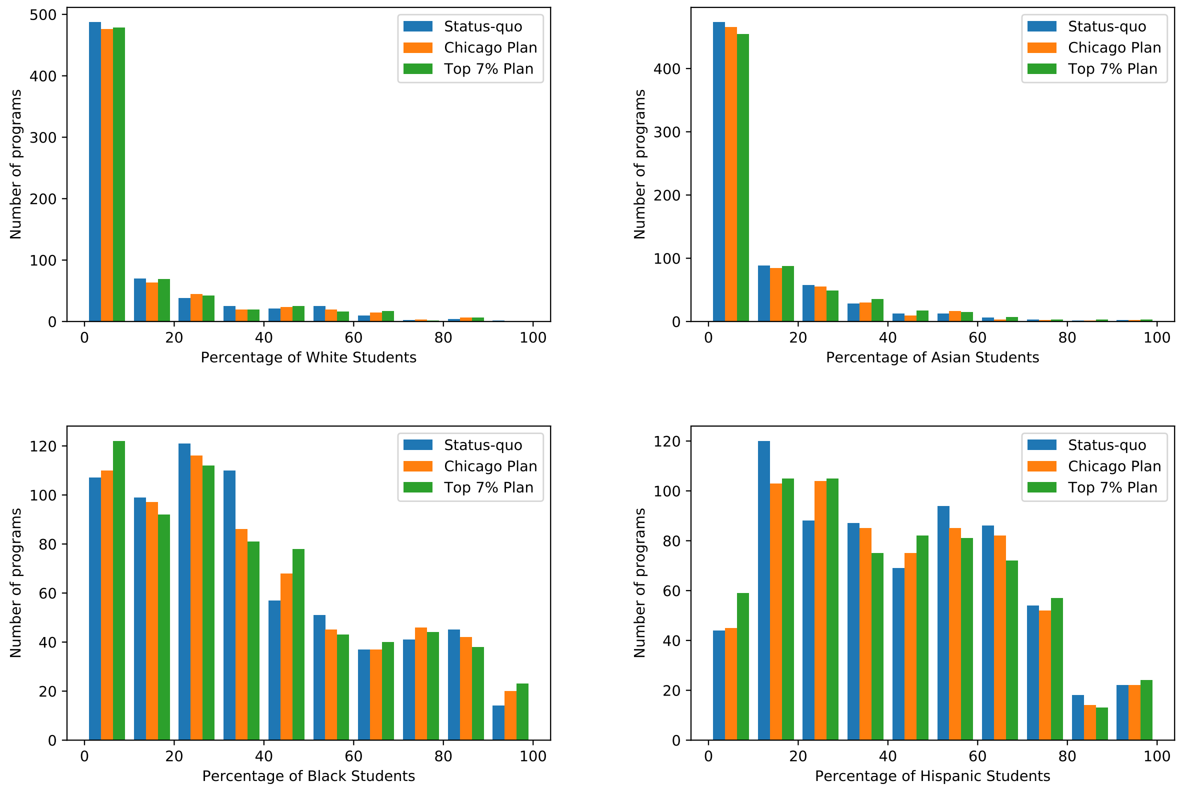


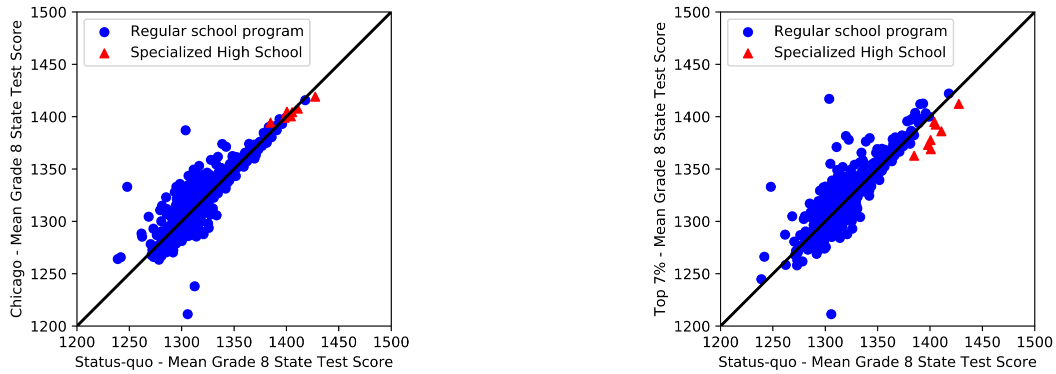
Figure 5: Distribution of Racial Compositions across Regular High School Programs

changes very little. In contrast, the distribution clearly shifts left under the Top 7% plan compared to the status quo. As seen in Table 6.2, the decreases in mean score of specialized high schools are significant at the 1% level for both plans, but the magnitude for Chicago plan is negligible whereas the decrease for the Top 7% plan is nearly one standard deviation of scores for the status quo specialized high school student population. In terms of school-specific average student quality, some increase and some decrease under the Chicago plan, leaving the specialized high schools more similar to each other than before, while average qualities decrease for all specialized high schools under the Top 7% plan.

6.4 Effects on Regular High School Programs

Due to considerable reshuffling within regular school programs, both the distributions of racial compositions and student qualities across these programs change.

The top two histograms in Figure 5 show that concerning the percentages of White and Asian students across programs, the three policies (status quo and two affirmative action plans) look quite similar. However, concerning the percentages of Black and Hispanic students, as shown in the bottom histograms, there are noticeable changes compared to the status quo, especially for the Top



(a) Chicago Plan

(b) Top 7% Plan

Figure 6: Mean Grade 8 State Test Scores of Admitted Students - status quo v.s. Affirmative Action Plans

7% plan in which there are more schools with very low percentages (0-10%) of these two races.

In terms of student quality as measured by mean scores on Grade 8 state test of admitted students, the effects of the two plans are similar: about 52% of regular high school programs experience increases while the rest experience decreases or no change. Figure 6 visualizes this result. When one considers only changes that are statistically significant at the 5% level, the mean scores increase for about 9% and 10% of the programs under Chicago and Top 7% plans, respectively, and decrease for about 3% and 4% of the programs.

6.5 Heterogeneous Changes in Peer Quality

In the previous two subsections, I have looked at changes in student quality at the school level. In this subsection, I will consider peer quality at the student level. For each student, the peer quality is measured by the mean student quality at his or her assigned school, excluding the student him-or-herself.

Figure 7 shows the average Grade 8 state test scores of peers for students in the ten different deciles of scores in the entire population of public middle school students. The changes in peer quality under both affirmative action plans (compared to the status quo) are in the same direction for all deciles except for the highest one. In particular, students in the two lowest deciles experience lower peer quality under the counterfactuals (although their peers still outperform them on average). Peer quality for students in the third and fourth deciles remains relatively stable. Meanwhile, peer quality increases for students in the fifth to ninth deciles. The magnitudes of the increases are similar across plans for the fifth and ninth deciles, whereas they are higher for the Top 7% plan for the sixth to eighth deciles. Students in the highest decile, in other words, the best-performing students in the population, experience an increase in peer quality under the Chicago plan but a

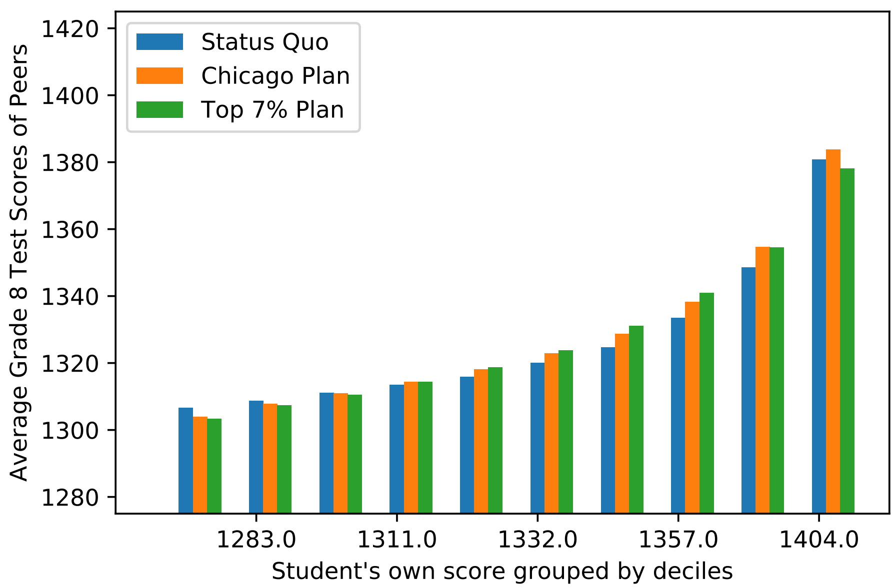


Figure 7: Changes in Peer Quality in High Schools - All students

Notes: Peer quality is measured by average Grade 8 state test scores of peers. Deciles are based on the entire population of public middle school students. Deciles are based on the entire population of public middle school students.

decrease under the Top 7% plan.

To further investigate the heterogeneity of the effects, I divide students into groups based on the changes (or lack thereof) in their high school assignments. Figures A.4 and A.5 show the changes in peer quality of these different groups, compared to in the status quo, for the Chicago and Top 7% plans, respectively. Deciles are still based on the entire population of public middle school students, so if certain deciles are missing for a particular group, it means there are no students from said group who belong to those deciles. Although there may be overlaps, groups with the same label are generally different across affirmative action plans. For instance, "Always Specialized High Schools" for each plan refers to students who are assigned to specialized high schools in both the status quo and said plan (regardless of their assignments in the other plan). Despite this disparity, it is helpful to look at them side-by-side to highlight the fact that the same type of assignment changes under the two plans can mean different experiences in terms of peer quality.

As seen in Panel (a) of each figure, students who stay in specialized high schools under both the status quo and the Chicago plan all belong to one of the top six score deciles in the broader population. Changes in peer quality are heterogeneous across the students' own score deciles: students in the lowest decile (out of the six) experience a sizable increase in peer quality, those in the next four deciles experience moderate increases, and those in the highest decile experience a small decrease. This is consistent with the within-specialized-high-school reshuffling documented in Subsection 6.2. Meanwhile, students who stay in specialized high schools under both the status quo and the Top 7% plan, who are part of the top four score deciles in the population, all experience considerable decreases in peer quality due to the drop in overall student quality in specialized high schools under this plan.

Panel (b) shows, for each plan, that across all relevant deciles, students who move from specialized high schools (under the status quo) to regular schools (under the plan) experience considerable decreases in peer quality, which is expected given the marked difference in student quality between specialized high schools and most regular schools. The effects are worse for lower-scoring students in the groups. Notably, under Top 7%, those scoring between 1326 and 1327 points (i.e., in the fifth decile of the large population and lowest relevant decile for the "Specialized to Regular" group under this plan) go from peers who perform much better than them on average (at 1385 points) to having peers who perform worse than them on average (at 1299 points).

Panels (c) and (d) demonstrate that students who move from regular schools to specialized high schools, whether due to gaining offers or receiving better offers, enjoy higher peer quality under both plans compared to under the status quo, regardless of their own scores. The sizes of the gains are generally greater for lower-scoring deciles. In two cases, the increases in peer quality for the lowest relevant deciles in the groups are so large that the students in these deciles end up with better-performing peers than those in the next deciles. First, those gaining offers to specialized high schools under the Chicago plan who are in the fifth score decile[22] would have had worse peers compared to the other deciles under the status quo but have the best-performing peers under the plan. Second, those gaining better offers under the Top 7% plan who are in the seventh decile would have had only slightly better peers than those in the eighth decile under the status quo but now have much better peers that are more similar to the peers of the two highest deciles.

From Panels (e) and (f), we can see a similar trend under both plans for students who end up in a different regular schools as well as those who are assigned the same regular school during the the Main Round. Specifically, those in the lowest deciles are exposed to lower peer quality under affirmative action compared to the status quo, whereas higher deciles either experience little changes or increases. This pattern agrees with that stated above for the broader population of all public middle school students under both plans for the first nine deciles. For the highest decile, it agrees with the overall effect under the Chicago plan. We have the opposite overall effect for this decile under the Top 7% plan due to the effect for these groups being canceled out by that for those moving from specialized to regular schools, who are much more numerous here than under the Chicago plan.

6.6 Factors Driving the Results and Policy Implications

Three main factors drive the differences in the outcomes of the two policies: the pools of students to select from, the "merit" criteria, and the division of students into subgroups.

First, the pool from which students are selected into specialized high schools is much more restrictive in the Chicago plan, where the students must have taken the SHSAT to be considered. On the contrary, the Top 7% plan considers all aspiring high school students. In fact, the 1280 students who are eligible for specialized high schools under this plan but never took the SHSAT account for 26.9% of the total offers and 48.0% of the policy beneficiaries. Given that it is not feasible to incentivize disadvantaged students into taking the SHSAT by explicitly favoring them with bonus scores or similar measures, this result demonstrates that it is hard to get far in improving specialized high school diversity without abolishing the SHSAT barrier.[23]

Second, the two plans currently use two different criteria to define "merit," with the Chicago plan using the SHSAT and Top 7% plan using grade 7 state test scores. To investigate this, I restrict attention to only specialized high school applicants, for whom both types of scores are available. Given this population as the selection pool, a policy that selects the top 7% of each public middle school based on state test scores versus one that selects the top 7% based on SHSAT scores result in an overlap in specialized high school eligibility that comprises only 29% of the total number of specialized high schools seats. This is because the quantile rank to which a student belongs within this population can be quite different depending on the score being used. Figure A.1 plots the

[22] The graph shows a lower score decile for this group, but there is only one student in that decile.

[23] At the same time, it must be noted that if state tests are used, the current specialized high school applicants will most likely increase their effort in preparing for the state tests, which may still give them some advantage.

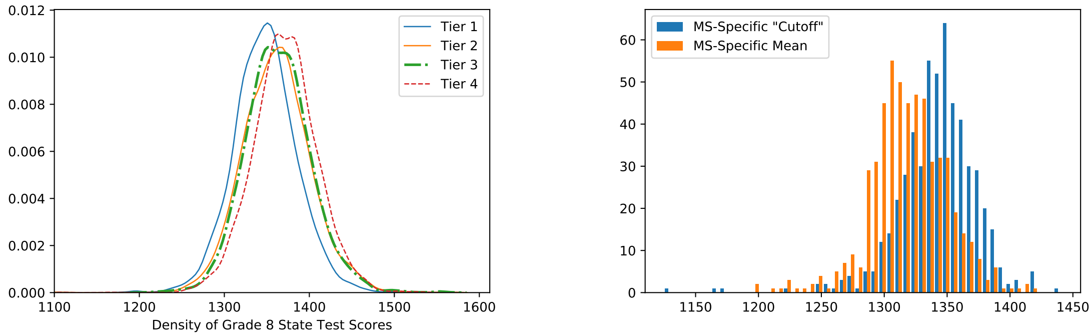
quantile rank of all specialized high school applicants based on SHSAT scores against that based on grade 7 state test scores. Although there is some concentration of students along the 45-degree line, especially for lowest and highest quantiles, there is also significant dispersion. There exist students who may rank very high on one test but very low on the other.

Third, the policy outcomes depend on the dispersion of race as well as student quality across subgroups into which students are assigned. On one hand, a policy is more likely to increase diversity if the racial compositions are very different across subgroups. On the other, too much dispersion in student quality across subgroups means that even the best students selected from lower-performing subgroups are likely to be low-performing compared to the overall population, thereby reducing the average quality of those admitted to the elite schools.

The first of the two aforementioned points explains why the Top 7% plan is so much more effective than the Chicago plan at improving overall specialized high school diversity. Figure A.2 illustrates severe racial segregation within New York City public middle schools, which are the relevant subgroups for Top 7%. In the first two panels, we can see that there is a large number of schools where there are no White or Asian students. Thus, these schools contribute greatly to the number of Black and Hispanic students selected for specialized high school eligibility. In contrast, the differences in racial compositions across neighborhood tiers, the relevant subgroups for the Chicago plan, are more subdued, as seen in Figure A.3. The more similar the compositions within subgroups are to one another, and thus to the overall composition, the more the selection of top students from each subgroup resembles the selection of top students from the entire population. As a result, the set of specialized high school offers in Chicago plan is close to that in the status quo.

Likewise, the more similar the student qualities are across subgroups, the more likely that the top students within each subgroup are also top students in the population, and their selection into elite schools would lead to higher student quality in this sector. This is true for the Chicago plan, where the distributions of student qualities across tiers as measured by Grade 8 state test scores are quite alike, as shown in Panel (a) of Figure 8. By comparison, a lot of dispersion is evidenced in the histograms of two middle-school-specific quality measures in Panel (b) of Figure 8. The first measure, labeled as the middle-school-specific "cutoff," is the lowest Grade 8 state test score among students eligible for specialized high schools at each middle school;[24] and the second measure is the mean Grade 8 state test score of all students in the school. By plotting them together, one can see that for most schools, except very high-performing ones, the "cutoff" is lower than the mean at some other schools. This means some students from the middle school currently being considered receive specialized high school offers even though they are not as qualified (solely on academic performance) as an average student at another school, who would not have received offers.

[24] This is not the actual cutoff used during the selection process, which is based on Grade 7 state test scores.



(a) Chicago Plan

(b) Top 7% Plan

Figure 8: Dispersion of Student Qualities (Grade 8 State Test Scores) across Subgroups

Notes: The two panels are not exact counterparts of each other, due to the difference in the numbers of subgroups: 4 tiers (Chicago) v.s. 569 public middle schools (Top 7%). Panel (a) shows the full distribution of student qualities for each tier. Panel (b) shows the histograms of two middle-school-specific statistics: the "cutoff" for being eligible for specialized high schools and the mean student quality. Here, the "cutoff" at each school refers the lowest Grade 8 state test score among students eligible for specialized high schools under Top 7% plan; it is not the actual cutoff used during the selection process, which is based on Grade 7 state test scores.

7 Conclusions

In this paper, I estimate a model of students' preferences during the New York City high school admission process and simulate the effect of two counterfactual affirmative action plans on both elite and regular high schools in the city.

There are three key findings from this analysis. First, there is a trade-off between improving diversity and maintaining student quality in elite schools. A tier-based plan similar to the one implemented by the Chicago public schools (Chicago plan) barely increases overall racial diversity but preserves the quality of incoming students. In contrast, a plan that admits top students in each public middle school based on their academic performance (Top 7% plan) increases diversity substantially while lowering student quality. Second, the Chicago plan reduces the differences among schools within the elite sector, whereas the Top 7% plan increases these differences despite making the elite and regular sectors more similar. Third, both plans also change regular school assignments and thereby the student quality in regular high school programs.

The factors driving the results give further insights into how to design affirmative action plans in general. Most noticeably, the division of the overall population into subgroups that are treated separated during the assignment process plays an important role. To increase racial diversity among those selected, there must be sufficient dispersion in racial compositions across groups, but to maintain student quality, there should not be too much dispersion in student quality across groups. I am currently working on fine-tuning a hybrid policy that aims to achieve the same overall diversity in specialized high schools as the Top 7% plan but do better than that plan in terms of specialized high school student quality.

Another direction for further research is to consider the medium- and long-term effects of these affirmative action plans. Unlike the short-run where I assume that preferences over schools remain unchanged, in the long-run, parents and students will have learned what to expect of the policy, how it changes school characteristics, and thus their “new” preferences over schools. It is reasonable to assume that they have rational expectations over these characteristics, and the new equilibrium is found in the simulation by iterating until a fixed point in the distribution of school characteristics is reached.

Both topics of the hybrid policy and longer-term effects of affirmative action will hopefully be available in subsequent versions of this paper in the near future.

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A Additional Tables and Figures

Table A.1: Regular School Application - School Characteristics by Rank of Student Choice (by Subgroups)

	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th
Panel A. Split by high math achievement												
Students with low baseline math												
Percent white	10.27	9.71	9.13	8.63	7.87	7.42	7.06	7.11	6.49	6.58	6.54	6.28
Percent subsidized lunch	72.24	72.67	73.25	74.05	74.53	75.28	75.68	75.45	76.17	76.52	76.28	76.70
High math achievement (%)	5.31	5.24	4.98	4.90	4.74	4.67	4.58	4.51	4.41	4.31	4.24	3.97
Students with high baseline math												
Percent white	28.90	26.42	25.18	23.32	21.86	20.45	18.20	17.16	16.30	15.03	13.80	12.52
Percent subsidized lunch	48.62	51.00	53.96	56.18	58.28	59.62	62.01	62.58	64.15	65.29	66.83	67.73
High math achievement (%)	23.32	16.95	16.26	15.69	15.14	14.79	13.49	13.21	12.50	11.66	10.76	9.31
Panel B. Split by zip code income												
Students from bottom zip code income quantile												
Percent white	9.16	9.25	8.87	8.55	8.21	7.78	7.55	7.52	7.18	7.07	6.61	6.17
Percent subsidized lunch	73.10	73.03	73.74	74.32	74.84	75.38	75.52	75.72	75.89	76.49	76.61	77.34
High math achievement (%)	6.85	6.74	6.44	6.34	5.98	5.86	5.63	5.48	5.37	5.31	5.02	4.45
Students from top zip code income quantile												
Percent white	36.26	32.10	29.35	26.00	23.59	21.74	19.22	18.00	16.88	15.96	14.41	14.63
Percent subsidized lunch	45.03	48.56	51.29	53.89	55.55	56.90	59.12	59.86	61.47	62.46	63.91	63.80
High math achievement (%)	17.76	14.30	14.49	13.93	13.64	13.41	12.66	12.17	11.84	10.45	9.58	9.76
Panel C. Split by race												
White students												
Percent white	41.66	36.66	34.47	31.76	29.77	27.67	25.63	24.00	23.17	21.23	19.43	19.56
High math achievement (%)	16.19	14.30	14.62	14.58	14.23	14.31	13.56	12.62	12.89	11.84	11.28	9.69
Asian students												
Percent white	24.08	23.61	23.34	22.33	21.01	20.25	18.38	17.35	15.95	15.88	14.97	13.35
High math achievement (%)	25.44	17.62	16.63	16.04	15.47	15.39	14.44	13.94	13.25	12.93	11.95	10.55
Black students												
Percent white	11.61	11.34	10.73	10.11	9.74	9.42	8.91	9.02	8.41	8.25	8.03	7.85
High math achievement (%)	7.93	7.71	7.42	6.99	6.88	6.71	6.41	6.49	6.24	5.76	5.41	5.31
Hispanic students												
Percent white	13.46	12.76	12.07	11.48	10.68	10.25	9.57	9.26	8.92	8.63	7.83	7.10
High math achievement (%)	8.64	8.00	7.79	7.69	7.32	7.28	6.90	6.67	6.46	6.37	5.80	5.02

Notes: Statistics is based on the analysis sample, consisting of 66068 students. High baseline math students score above the seventy-fifth percentile for Grade 7 math state test; low baseline math students score below the twenty-fifth percentile. Zip code income is median family income for each zip code from the American Community Survey 2007-2011; bottom and top income quantiles correspond to Tiers 1 and 4, respectively, in the Chicago counterfactual. The high math achievement measure for each high school is the percentage of admitted students in said school who score higher than 85% in the Regents mathematical exams in the 2009-2010 school year.

Table A.2: Estimated Coefficients

	Regular high schools programs		specialized high schools	
	Estimate	Std. Error	Estimate	Std. Error
Percent subsidized lunch				
× ELA State test score	-0.0033***	9.73E-06	-0.0031	0.0034
× Mathematics State test score	-0.0020***	9.65E-06	-0.0060	0.0052
× Zipcode income	0.0118***	1.11E-05	0.0046	0.0038
× Eligible for subsidized lunch	-0.0070***	1.78E-05	-0.0008	0.0217
× Asian	-0.0169***	3.95E-05	-0.0101	0.0279
× Black	0.0041***	3.77E-05	0.0000	0.0287
× Hispanic	-0.0100***	3.90E-05	-0.0546***	0.0200
× Other	-0.0183***	9.98E-05	0.0040	0.0026
Percent white				
× ELA State test score	0.0052***	1.76E-05	-0.0044	0.0035
× Mathematics State test score	0.0033***	1.92E-05	-0.0088*	0.0048
× Zipcode income	-0.0010***	2.35E-05	0.0034	0.0033
× Eligible for subsidized lunch	-0.0130***	3.05E-05	0.0048	0.0202
× Asian	0.0117***	6.84E-05	-0.0294	0.0257
× Black	0.0600***	7.80E-05	-0.0227	0.0269
× Hispanic	0.0438***	8.21E-05	-0.0626***	0.0177
× Other	0.0274***	2.68E-04	-0.0039**	0.0512
Size of grade 9				
× ELA State test score	-3.95E-05***	4.15E-07	0.0001***	0.0000
× Mathematics State test score	-0.0002***	4.37E-07	0.0004***	0.0001
× Zipcode income	-0.0006***	5.93E-07	0.0001	0.0000
× Eligible for subsidized lunch	-3.75E-05***	7.16E-07	0.0004*	0.0002
× Asian	-0.0007***	1.35E-06	0.0013***	0.0003
× Black	0.0001***	1.59E-06	0.0010***	0.0003
× Hispanic	-0.0001***	1.38E-06	0.0009***	0.0002
× Other	-0.0002***	5.35E-06	0.0013	0.0006
Percent high math achievement				
× ELA State test score	0.0042***	1.50E-05	0.0021	0.0018
× Mathematics State test score	0.0130***	1.96E-05	0.0095***	0.0030
× Zipcode income	0.0098***	1.30E-05	0.0032*	0.0017
× Eligible for subsidized lunch	0.0018***	2.77E-05	0.0005	0.0091
× Asian	0.0340***	6.37E-05	0.0271***	0.0101
× Black	0.0275***	6.64E-05	0.0142	0.0097
× Hispanic	0.0192***	6.54E-05	0.0020	0.0075
× Other	0.0121***	1.74E-04	-0.0059	0.0701
Distance ($-\gamma$)	-1	–	-0.0024	0.0072
Scale (λ)	1.5700***	1.20E-03	–	–

Notes: *** $p<0.01$; ** $p<0.05$; * $p<0.1$.

Table A.3: Racial Composition of Individual specialized high schools (%)

	status quo				Chicago Plan				Top 7% Plan			
	White	Asian	Black	Hispanic	White	Asian	Black	Hispanic	White	Asian	Black	Hispanic
Stuyvesant	22.05	74.38	1.51	1.51	21.59	69.64	2.97	5.13	28.19	52.20	9.98	8.70
					-0.46	-4.75	1.46	3.62	6.14	-22.18	8.47	7.19
Bronx Science	21.63	67.63	3.34	6.68	19.90	62.40	4.78	12.02	9.62	26.46	52.51	10.88
					-1.73	-5.23	1.44	5.34	-12.00	-41.17	49.17	4.20
Queens Sciences	5.68	78.41	11.36	4.55	3.16	75.79	12.63	8.42	8.06	39.52	20.97	30.65
					-2.52	-2.62	1.27	3.88	2.38	-38.89	9.60	26.10
HS of American Studies	60.53	17.11	7.89	14.47	47.92	21.88	15.63	14.58	20.75	4.40	42.14	2.38
					-12.61	4.77	7.73	0.11	-39.77	-12.70	34.24	18.23
Staten Island Tech	19.61	47.06	9.80	22.55	20.33	42.28	11.38	24.39	3.92	6.37	57.84	31.86
					0.72	-4.78	1.58	1.84	-15.69	-40.69	48.04	9.31
HS of Maths, Science & Engineering	52.67	42.39	0.41	3.70	43.30	46.74	4.60	4.98	55.29	27.40	11.54	5.29
					-9.38	4.36	4.19	1.28	2.61	-14.98	11.13	1.58
Brooklyn Tech	21.46	59.70	8.90	9.14	20.84	59.26	9.91	9.19	9.42	19.93	25.63	43.76
					-0.62	-0.44	1.01	0.05	-12.04	-39.77	16.73	34.62
Brooklyn Latin	22.07	37.93	24.83	13.79	16.89	47.97	18.24	16.22	14.81	5.56	53.70	25.93
					-5.18	10.04	-6.58	2.42	-7.25	-32.38	28.88	12.13

Notes: The second row for each school represents the changes in composition in percentage points.

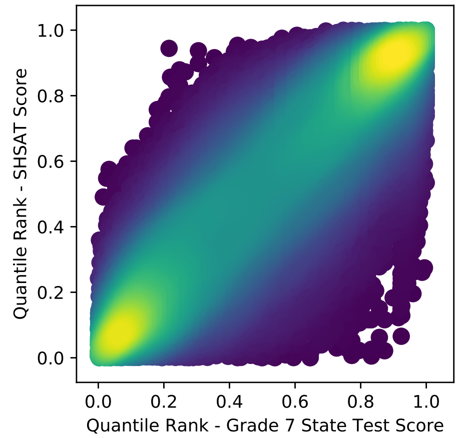
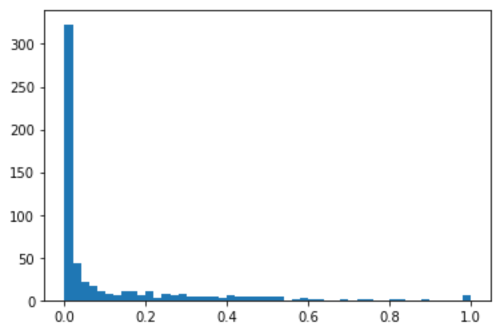
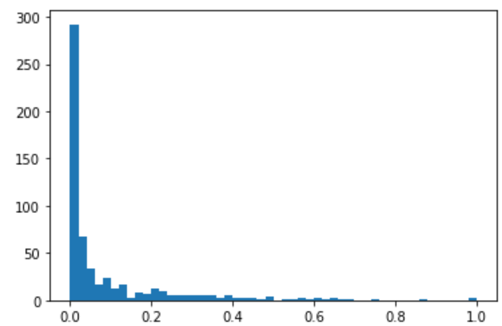


Figure A.1: Quantile Rank of Students within specialized high schools Applicants Based on Grade 7 State Test v.s. SHSAT

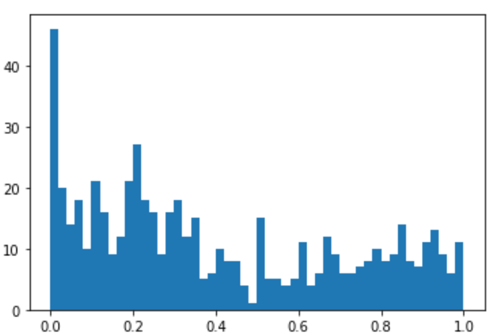
Notes: From dark blue to solid yellow, the density of students increases.



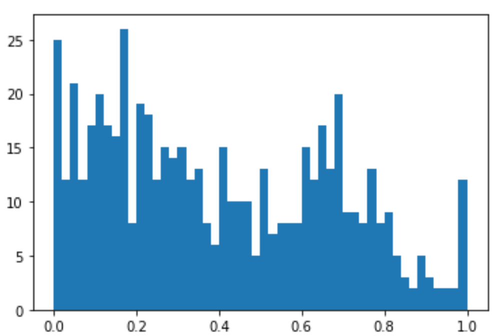
(a) White



(b) Asian



(c) Black



(d) Hispanic

Figure A.2: Distribution of Racial Compositions across Public Middle Schools

Notes: Each panel is a histogram of the school-specific percentages of one race. The population includes all public middle schools.

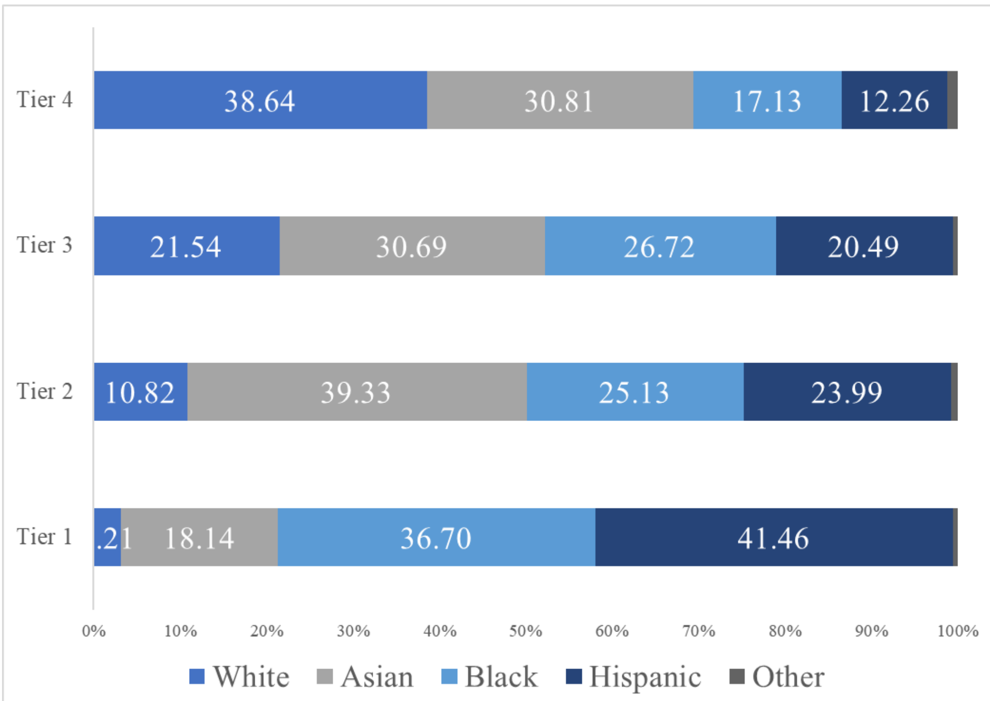
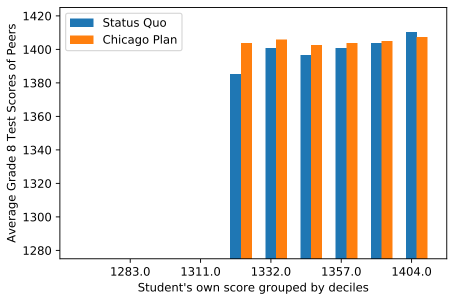
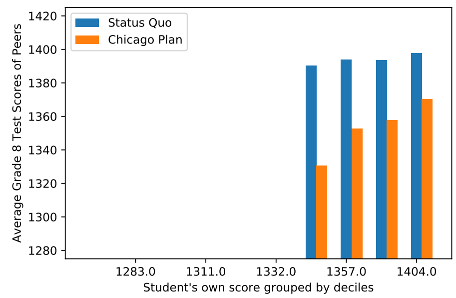


Figure A.3: Racial Compositions by Neighborhood Tiers

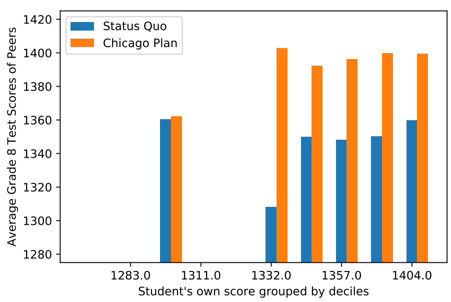
Notes: Tiers are assigned based on median family income of each zip code according to the American Community Survey 2007-2011. Tier 1 has income in lowest quantile compared to the rest of New York City; tier 4 has income in the highest quantile.



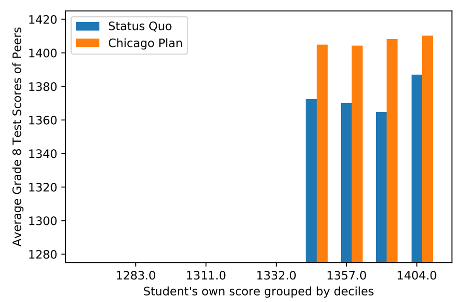
(a) Always Specialized High Schools



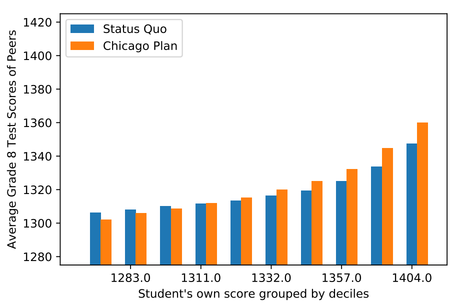
(b) Specialized to Regular



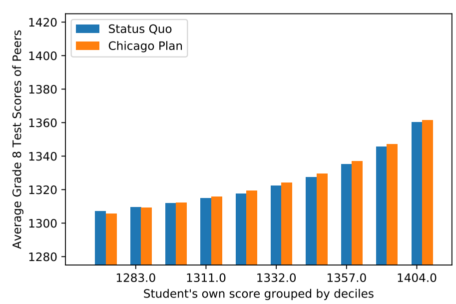
(c) Regular to Specialized (offer gained)



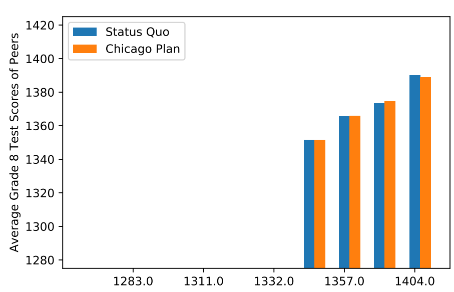
(d) Regular to Specialized (better offer)



(e) Different Regular Schools



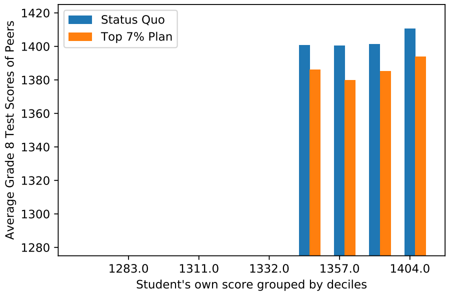
(f) Same Regular Schools (Main Round)



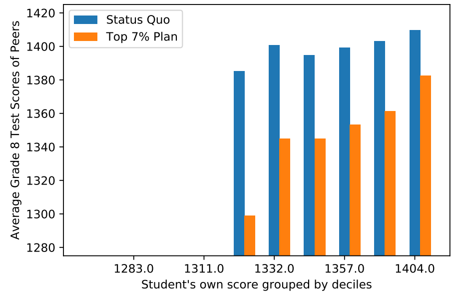
(g) Same Regular Schools (Specialized Round)

Figure A.4: Changes in Peer Quality in High Schools - Status Quo v.s. Chicago Plan

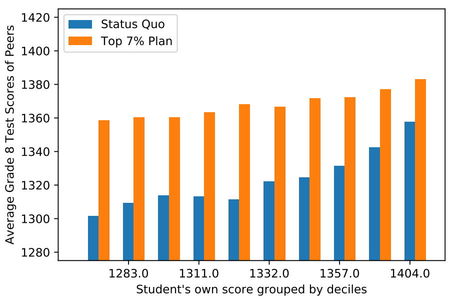
Notes: Peer quality is measured by average Grade 8 state test scores of peers. Deciles are based on the entire population of public middle school students.



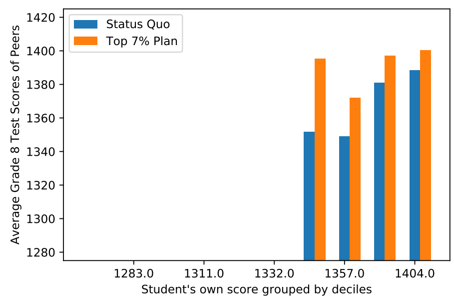
(a) Always Specialized High Schools



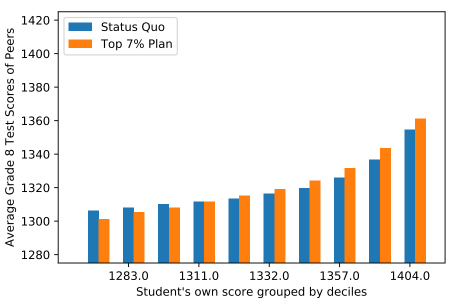
(b) Specialized to Regular



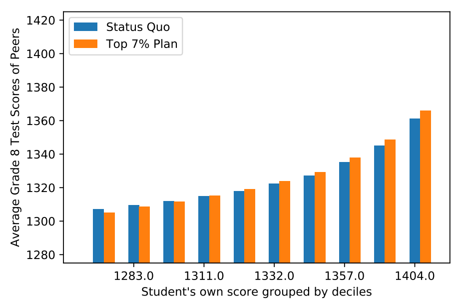
(c) Regular to Specialized (offer gained)



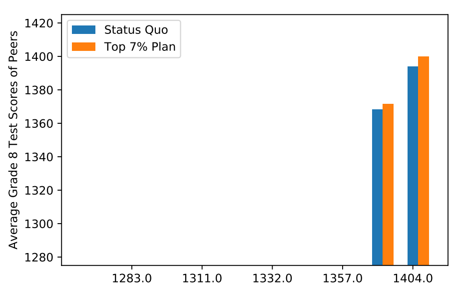
(d) Regular to Specialized (better offer)



(e) Different Regular Schools



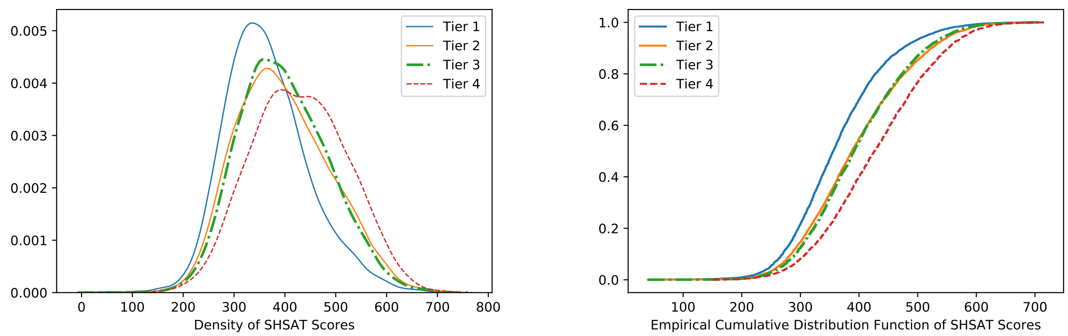
(f) Same Regular Schools (Main Round)



(g) Same Regular Schools (Specialized Round)

Figure A.5: Changes in Peer Quality in High Schools - Status Quo v.s. Top 7% Plan

Notes: Peer quality is measured by average Grade 8 state test scores of peers. Deciles are based on the entire population of public middle school students.



(a) Empirical Probability Density Function (b) Empirical Cumulative Distribution Function

Figure B.1: Distributions of SHSAT Scores by Tiers

B Different Precedence Orders and Merit Reserves for the Chicago Plan

I examine four variations of the Chicago plan which combine two different tier-blind precedence orders (merit first and merit last) with two different percentages of merit seats (40% merit/60% tier and 30% merit/70% tier). My empirical result in the multiple-school setting of New York City specialized high schools supports the theoretical result in Dur, Pathak and Sonmez (2016). Since their result is only in terms of offers, not enrollment, I also restrict my attention to offers in this appendix.

For there to be the best and worst tier-blind precedence orders for different tiers, the score distributions need to satisfy certain assumptions, which is approximately the case in my current setting. Specifically, their Assumption 2 formally requires the "worst-scoring" tier to have the lowest density among all tiers at every possible score, but the authors also state that this property of the density function needs only hold for sufficiently high scores to obtain the result. In my setting, Tier 1 does have the lowest density among all tiers for all SHSAT scores above 420 as seen in Panel (a) of Figure B.1. Similarly, their Assumption 3 regarding the "best-scoring" tier is not satisfied for every possible score, but the required property does hold for the range of scores where students may receive offers. The lowest score that allows admission into at least one of the specialized high schools is 472 under the status quo, where all offers are based on merit, and Tier 4 does have the highest density for all scores above this point as seen in Panel (a) of Figure B.1. Although the theoretical result is not based on first-order stochastic dominance, it is interesting to also note that the empirical score distribution of Tier 4 first-order stochastically dominates those of Tiers 2 and 3, which are very similar and both dominate the score distribution of Tier 1 as shown in Panel (b) of Figure B.1. This order agrees with the order from the most to the least disadvantaged tiers in terms of neighborhood income.

Table B.1: Percentages of Offers by Tiers for Different Variations of the Chicago Plan

	Tier 1	Tier 2	Tier 3	Tier 4
Merit First - 40% Merit/60% Tier	18.78	25.95	25.18	26.38
Merit First - 30% Merit/70% Tier	20.33	25.62	25.21	25.23
Merit Last - 40% Merit/60% Tier	15.04	25.58	25.82	29.43
Merit Last - 30% Merit/70% Tier	17.54	24.81	24.68	28.95

Table B.1 shows the percentages of students receiving offers from specialized high schools by their tiers. Given the same proportions of merit v.s. tier seats, having merit seats filled first is the best tier-blind precedence for Tier 1 and the worst for Tier 4, and having merit seats filled last is the worst tier-blind precedence for Tier 1 and the best for Tier 4, as per the theoretical prediction. To see this, we need to compare the first and third rows, which both have 40% merit seats but different precedence, and compare the second and last rows. In both cases, higher percentages of admitted students belong to Tier 1 and lower percentages belong to Tier 4 when merit seats are filled first. Note that when merit seats are filled last, for both variations considered here, the percentages of admitted students that belong to Tier 1 are almost exactly the same as the percentages set aside for Tier 1 seats (15% and 17.5% respectively), that is, almost no Tier 1 students get in through merit seats.

Given the same precedence order, when the proportion of merit seats is reduced, Tier 1 students, who have systematically lower scores and hence less likely to get in through merit seats, gain more access whereas some Tier 4 students lose access. Note that by decreasing the percentage of merit seats from 40% to 30% (concurrently increasing the percentage of Tier 1 seats from 15% to 17.5%), the percentages of Tier 1 students among those admitted only increase by around 1.5 to 2.5 percentage points depending on the precedence. Meanwhile, changing the precedence order form merit last to merit first has larger effects, resulting in increases of 2.7 to 3.7 percentage points depending on the proportion of merit seats. A similar comparison of the effects of change in the proportion of merit seats v.s. change in precedence order can be made for Tier 4 students.