Does a Common Application Increase Access? Theory and Evidence from Boston's Charters*

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Abstract

Several U.S. cities have recently adopted a common application to assign pupils to schools. In a common application, students can apply to multiple schools on a single form, and each school admits students without taking offers from other schools into account. A common application increases access by reducing application costs, but since each school receives more applications it can also decrease access. We develop a model of a common application system and compare it to a (1) decentralized system, where each application is costly, and a (2) ranked system, where applicants rank choices on a common application and offers are generated by a matching algorithm. Compared to the decentralized system, the common application yields more applications to each school. However, the screening benefits of costly applications in the decentralized system can outweigh increases in school access from lower application costs in the common application because of greater competition. We show that under independently drawn preferences, the distribution of ordinal applicant rankings from the decentralized system stochastically dominates the distribution from the common application. The ranked system improves upon the common application by minimizing issues caused by multiple offers, while still benefitting from lower application costs.

We then empirically examine the effects of switching from decentralized applications to a common application in Boston's charter sector. Demand estimation and counterfactual simulations suggest that the common application performs worse than either a decentralized application system or a ranked system on several dimensions. We estimate that fewer students receive their first choice under the common application than either decentralized or ranked systems. The common application appears not to have differentially increased school access for disadvantaged student groups. We use our empirical model to examine how levels of competition and the extent of changing preferences between application and enrollment decisions affect the comparison across systems.

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1 Introduction

Several U.S. cities have recently adopted common application systems to assign pupils to K-12 choice schools. In a **common application** system, students apply to multiple schools on a single application, but do not report a ranking over their choices. Schools make offers to students without taking into account offers from other schools. Table 1 lists 12 large cities where a common application has been adopted since 2017. In most cases, only the charter schools are part of the common application. Discussion from these locations focuses on three main rationales for adopting a common application: (1) lowering costs and logistical barriers for applicants, (2) increasing information about schools, and (3) equalizing opportunities to exercise choice for all families.[1]

Common application systems often replace decentralized systems. In a **decentralized** system, applicants must apply to each school by submitting an application to the school and schools make offers to students without taking into account offers from other schools. Often, applications must be physically submitted at the school building and an applicant must be present when the school makes offers of admission. This is commonplace when a charter school runs a public admissions lottery. Relative to a decentralized system, a common application reduces application costs for students interested in multiple schools because a student interested in more than one school can simply fill out a single application form rather than separate applications for each school.

Several of the cities listed in Table 1 also considered a ranked system. In a **ranked** system, applicants use a common application form and submit a ranking over schools and offers of placement are given to students using a matching algorithm and each student is given at most one offer. Boston, for example, adopted a common application for charter schools in 2017, following more than a decade with a decentralized application system. During the debate over Boston's common charter application, several stakeholders argued that the city should adopt a ranked system unifying applications across all school sectors, following the model of Denver and New Orleans (Fox, 2016). The Mayor convened a working group to consider a ranked system and the plan received strong support from several groups, but was not ultimately adopted (Globe, 2015).

In this paper, we develop a model to study the effects of a common application on student access to schools. The model captures the trade-off between reducing application barriers and increasing

[1]These rationales were highlighted when new systems were announced. Oakland Enrolls, for example, described that "Oakland families no longer have to drive all over town from one charter school to another, fill out various papers applications, and keep track of different deadlines." Buffalo officials explained: "It's our hope that this platform increases access to and knowledge of the area's charter schools and simplifies the application process for families." Los Angeles staff highlighted that "A common enrollment system tends to level the playing field and get more equal opportunity to all families." Appendix A provides more details about these reforms.

competition for schools. In the model, under the common application, a student's first application has cost c, but subsequent applications are costless. Under the decentralized application, each application to a school costs c. Under the ranked application, an application costs c and students express a ranking over choices. In all three cases, schools use independent admissions lotteries and offers are made to equilibrate supply and demand. Our main interest is using the model to compare the common application to these two alternatives.

The model generates several intuitive predictions: (1) each school receives (weakly) more applications in equilibrium with the common application than the decentralized application, (2) the equilibrium admissions rate under the common application is (weakly) lower than the equilibrium admissions rate under the decentralized application, and (3) the common application implements an assignment that is not pairwise stable with positive probability, but the ranked system's assignments are always pairwise stable. Our main theoretical result is that with independent symmetric preferences, the distribution of ordinal rankings for enrolled students under the decentralized system stochastically dominates the distribution of ordinal ranks under the common application.

Our model represents a frictionless comparison between assignment systems under specialized assumptions. These assumptions are made to isolate fundamental trade-offs between the systems analytically. However, even with this frictionless environment, we do not have definitive comparisons about student welfare or increased school access across systems. Several examples from our model show why sharp comparisons are likely not possible without strong assumptions on costs or the distribution of student preferences. Moreover, the model does not incorporate changing preferences after applications and assumptions about how the market clears dynamically, which are important in real-life settings. We therefore develop an empirical model with several real-life frictions, taking advantage of unique data from Boston's charter sector, which moved from a decentralized system to a common application in 2017. We estimate student preferences for charter and traditional public schools together with school admissions rules to examine the decentralized, common, and ranked application systems. The model allows us to quantify magnitudes of forces highlighted by the theoretical model and also to incorporate some aspects that are not part of the theoretical model. The demand estimates also allow us to examine a hypothetical ranked system, which was nearly adopted by Boston's charter sector.

Using our empirical model, we find that fewer students receive their first choice under the common application than either a decentralized or ranked system. Boston's charter common application appears not to have differentially increased school access for disadvantaged student groups. To consider situations outside of Boston, we then use the empirical model to examine how levels of competition and the extent of changing preferences affect our comparison of one system over the other. The best-

case scenario for the common application is in situations where students apply to a few schools and are admitted to almost all of them and when preferences change substantially between the application decision and the enrollment decision.

This paper is related to several literatures. First, several studies examine the *Common App* used for U.S colleges and universities. Knight and Schiff (2022) document that the *Common App* increased the number of applications received by schools and reduces the yield on accepted students. We find the same pattern with the adoption of Boston's common charter application. Other studies of the *Common App* include Liu, Ehrenberg, and Mrdjenovic (2007), Smith (2013), and Klasik (2012). Fu (2014) develops a structural model of the college market, where tuition, applications, admissions and enrollment are determined as the outcome of a game. Second, our work also connects to the literature on "preference signaling" in matching markets, which is also focused on colleges and universities. Avery and Levin (2010) study how early admissions affects student applications and sorting. Chade, Lewis, and Smith (2014) examine frictional matching, motivated by college admissions. Che and Koh (2016) develop a model of college admissions when a college strategically admits students that are likely to be overlooked by competitors and consider an alternative institution based on a centralized matching algorithm. Third, our work connects to a literature that focused on market clearing in student assignment. A non-exhaustive list of related papers includes Abdulkadiroğlu and Sönmez (2003), Abdulkadiroğlu, Agarwal, and Pathak (2017), and Chen and He (2021). Finally, since a common application is seen as a way to reduce application frictions, our work is related to literature which documents and examines ways to alleviate application barriers in the context of college admissions (see, e.g., Hoxby and Avery (2013), Hoxby and Turner (2015), and Pallais (2015)) and in accessing social programs (see, e.g., Deshpande and Li (2019)).

This paper is structured as follows. Section 2 compares decentralized application to the common application and Section 3 compares common application to the ranked application. Section 4 provides details on the Boston charter common application. Section 5 describes the structural model. Section 6 reports estimates and the counterfactual simulations. The last section concludes.

2 Decentralized vs. Common Application

2.1 Model and Basic Properties

Suppose there are S schools and N students. Each school has capacity K. Student i has utility values $(u_{i1}, u_{i2}, \ldots, u_{iS})$ where $u_{ij} > 0$ represents student i's utility for attending school j, Each student's

utility values $(u_{i1}, \ldots, u_{iS})$ are independent and identically distributed draws from a symmetric joint distribution F, so that all rank orders of preferences are equally likely for students.

We start by considering two application systems:

- **Decentralized Application**: Each application to a single school has known cost $C > 0$. Each student chooses to apply to any number of schools from 0 to S.
- **Common Application**: A student's first application has cost $C > 0$, but all subsequent applications are costless, so each student applies either to no schools or to all S schools.

We consider the Nash equilibrium of the game where applicants simultaneously decide which schools to apply after observing their utility values, but not the utility values of other students. Our first result is about equilibrium existence:

Proposition 1 *There exists a unique pure-strategy equilibrium for the Common Application system and it yields the same admission probability at each school. There exists a symmetric equilibrium for the Decentralized Application system, but it is not necessarily unique.*

An increase in admissions probability at any school necessarily promotes applications. Thus, enrollment is broadly increasing in the admissions probability, which in turn results in a unique equilibrium with the Common Application.

By contrast, while an increase in admissions probability for one school promotes applications from students for whom that school is a first choice, it may discourage further applications to other schools from those same students. As a result, the total number of applications submitted need not be monotonic in the admission rates for the schools, which in turn can produce multiple equilibria. We illustrate the phenomenon of multiple equilibria in the following example.

Example 1 *Suppose that there are* $2N$ *students and two schools, each with capacity* $0.75N$*. Half of the students have utility values (8, 4) and the other half have utility values (4, 8).*

Under the Decentralized Application system, if each student submits a single application to her most preferred school, then the schools choose admission probability $p = 3/4$ to fill their classes. This is an equilibrium if (1) all students gain by submitting the first application, i.e. $(3/4) * 8 > C$, or $C < 6$ and (2) all students prefer to submit only one application, i.e. $(3/4)(1/4)4 < C$ or $C > 3/4$. By contrast, if each student applies to both schools, then the schools reduce their admission probabilities

to $p' = 1/2$ in order to fill their classes. This is an equilibrium if each student's second application yields positive expected utility, i.e. $(1/2)(1/2)4 > C$, or $C < 1$. (Note that this condition is also sufficient for each student's first application to yield positive expected utility.)

In a pure-strategy equilibrium under the Common Application system, once again, each student submits two applications and the schools choose admission probability $p' = 1/2$ to fill their classes. But now the equilibrium condition is that students prefer two applications at cost C to no applications, i.e. $(1/2)8 + (1/4)4 > C$ or $C < 5$.

Cost C	Decentralized Application	Common Application
$C < 3/4$	2 apps per student	2 apps per student
$3/4 \leq C \leq 1$	Multiple Equilibria	2 apps per student
$1 \leq C \leq 5$	1 app per student	2 apps per student

Comparison of Equilibria in Example 1

The table summarizes the equilibrium analysis above. One immediate observation is that there can be multiple pure-strategy equilibria of the Decentralized Application system with $3/4 < C < 1$. For the lowest values of C, students submit two applications under either admissions rule. In this case, the Common Application rule yields higher expected utility to students than does the Decentralized Application rule by students, for the two rules achieve the same school assignments (in probability) but with lower application costs for the Common Application.

For higher values of C between 1 and 5, students submit one application given a Decentralized Application rule and two applications given the Common Application rule. In this case, application costs are the same in both systems, but students receive higher expected utility under the Decentralized Application rule because the Decentralized Application rule only assigns admitted students to first-choice schools whereas the Common Application rule assigns some admitted students to second-choice schools.

Propositions 2 and 3 below verify that the intuitions suggested by Example 1 hold for general symmetric distributions of utility values for students and for more than two schools.

Proposition 2 *Comparing the Common Application and (any) symmetric equilibrium of Decentralized Application, the Common Application equilibrium yields more applications to each school and each school admits a lower percentage of applicants.*

Proof. (Admissions Rate) If the admissions rate is the higher under Common Application than in the Decentralized system, then the same students who apply under Decentralized Application will all apply under the Common Application. In addition, some students who do not apply under the Decentralized Application will apply under Common Application. Then, more students will be admitted under the Common Application and more will enroll at each school. (The single exceptional case occurs if exactly the same students apply in both cases and all apply to all schools, in which case, both systems would yield the same outcome, but this does not occur with a continuous distribution of values.)

(Number of Applications) Suppose in equilibrium under Decentralized Application, there are n_k students who apply to k schools, so that we can summarize the number of applications by $(n_1, n_2, \ldots, n_S)$. In a symmetric equilibrium, these applications are distributed equally across the S schools. The number of students admitted to at least one school is then given by the sum:

$pn_1+[p+p(1-p)]n_2\ldots+[p+(1-p)p+(1-p)^2p+\ldots+(1-p)^{S-1}p]n_S = \sum_{s=1}^{S}(\sum_{j=1}^{s} p(1-p)^{j-1})n_s$.

Thus, a student's k^{th} application adds probability $(1-p)^{k-1}p$ of admission to at least one school, which is decreasing in k. For any given admission probability p, the minimum total applications to clear the market occurs if each student applies to only one school, while the maximum total applications to clear the market occurs if each student applies to all S schools. Further, both the minimum total number of applications and maximum total number of applications to clear the market are clearly decreasing in p.

The Common Application equilibrium has all students applying to S schools, so corresponds to the maximum number of applications for admission probability p_C, which in turn is greater than the maximum number of applications for the (larger) admission probability for the decentralized equilibrium. This proves the theorem. ■

2.2 Drawbacks of Common Application

Our next proposition shows that assignments of students to schools that result from an Decentralized Application equilibrium stochastically dominate (in student utility) the assignments of students to schools that result from a Common Application equilibrium. Intuitively, there are two distinct forces that achieve this result. First, the Common Application induces students to apply to a longer list of schools, thereby increasing the proportion of admissions to less preferred schools. Second, since the Common Application equilibrium has a lower probability of admission than an Decentralized Application equilibrium, a student who is admitted to a less preferred school is relatively unlikely to also be admitted to a more preferred school in a Common Application system. These two forces

together yield a systematically less desirable assignment of students to schools with the Common Application.

To facilitate welfare comparisons, assume that when there multiple equilibria for Decentralized Application, then the symmetric equilibrium with fewest applications is played. This is a Pareto improvement over any other symmetric equilibrium for the Decentralized Application rule. This refinement allows us to state the next result.

Proposition 3 *With independent symmetric preferences, the distribution of ordinal ranks for enrolled students under the Decentralized Application system stochastically dominates the distribution of ordinal ranks for enrolled students under the Common Application system.*

2.3 Heterogeneous Application Costs

One motivation for the Common Application is to enhance opportunities for low-income students and others who have limited access to skilled guidance. To allow for this possibility, we expand the model to allow for differential application costs for two types of students, where applicants of Type 1 ("Advantaged") have cost per application c_1 and applicants of Type 2 ("Disadvantaged") have cost per application $c_2 > c_1$. Under the Common Application system, we assume that Type 1 students can apply to all schools at cost c_1 and that Type 2 students can apply to all schools at cost c_2. We continue to assume that both types of students have identical and symmetric distributions of utility values for the schools.

Proposition 4 *With differential costs, if $c_1 = 0, c_2 > 0$ and Type 2 students do not all apply to both schools in the Decentralized Application equilibrium, then the Common Application unambiguously increases the number of Type 2 students who are assigned to a school.*

Proof. If $c_1 = 0$, then all Group 1 students apply to all schools under any admissions system. As in Proposition 2, the admission probability at each school in the Common Application must be lower than the admission probability at each school for the Decentralized Application. Otherwise, more students will apply and more students will be admitted to at least one school using the Common Application rule, thereby causing over-enrollment. But since all Type 1 students apply exhaustively in each system, they have lower probability of admission to at least one school in the Common Application equilibrium. Thus, to make up the deficit in enrollment and maintain the market clearing condition,

a larger number of Type 2 students must enroll in the Common Application equilibrium than in the Decentralized Application equilibrium. ■

Proposition 4 is still limited in two important ways. First, it does not consider application costs. Even if the assignments to Type 2's improve with the Common Application, there might be an even larger increase in costs for this group. Second, Proposition 4 pertains specifically to the number of seats assigned to Type 2 students and not the expected utility to Type 2 students of school assignments, either net of or excluding application costs. The assignments for Type 2 students might be worse with Common Application than with Decentralized Application. As a result, it is possible that Type 2 students could gain seats but lose expected utility from school assignments with the Common Application. (This is true for Type 1 in Example 2.)

Despite the natural intuition that the Common Application should level the playing field and thus be beneficial to Type 2 students, it could have the opposite effect, as shown by Example 2.

Example 2 *Adjust Example 1 as follows. Suppose that there are* $2.5N$ *students and two schools, each with capacity* $0.75N$*. There are* $2N$ *students of Type 1 with application cost* c_1*. Of these students, half (N students) have utility values (8, 2) and the other half (N students) have utility values (2, 8). There are* $0.5N$ *students of Type 2 with application cost* $c_2 > c_1$*. Of these students, half (0.25N students) have utility values (8, 2) and the other half (0.25N students) have utility values (2, 8).*

Note that the conditions for Proposition 4 do not hold in this example. Under the Decentralized Application system, if all students submit a single application to the most preferred school, then each school receives $1.25N$ applications and each school can fill its class by choosing an admission probability of 0.6.

Under the Common Application system, if only students of Type 1 apply, $2N$ students apply to each school and, after accounting for the students who are admitted to both schools, each school would fill its class by choosing an admission probability of $1/2$.

Given these admission probabilities, students achieve expected utility from school assignments of $0.6 * 8 = 4.8$ in the Decentralized Application system and expected utility from school assignments of $0.5 * 8 + 0.25 * 2 = 4.5$ with a Common Application rule. So for any pair of values c_1 and c_2 satisfying $0.5 < c_1 < 4.5 < c_2 < 4.8$, these are the unique equilibrium outcomes for the two application rules.

In this example, the introduction of the Common Application induces students of Type 1 to apply to both schools rather than to a single school, and that choice in turn reduces the equilibrium admission probability and discourages Type 2 students from participating. Therefore, we have to add a caveat to

the earlier intuition – the Common Application will be beneficial to disadvantaged types if advantaged types are already applying very extensively.

3 Common Application vs. Ranked Application

3.1 Ranked Application

Next, we consider a ranked application system. Under this system, students submit a rank ordering of schools. Schools use a single lottery to order students, and then the student-proposing deferred acceptance (DA) is run.[2] We no longer assume that all schools have the same capacity. Suppose now that school capacities may differ and denote school s's capacity as k_s.

Definition 1 *A Common Application equilibrium consists of admission probabilities* $(p_1, \ldots, p_S)$ *such that expected enrollment at school* j *is* k_j *given independent admissions decisions.*

This is the rule that would be chosen by a school that seeks to hit their enrollment target with symmetric loss function for over and under-enrollment.

Proposition 5 *There is a unique combination* $(p_{1C}, p_{2C}, \ldots, p_{SC})$ *of admission probabilities such that each school enrolls* K *students in expectation. In the limit as* N *and* K *become large, the school-proposing or student-proposing version of the DA algorithm match students to schools with the same probabilities as the Common Application if schools submit independent and randomly generated rankings of students.*

The mechanical intuition for the asymptotic equivalence of these rules is straightforward. In the school-proposing version of the DA algorithm, each school progresses down its rank order preference list, making offers to some number of most preferred candidates in each round in rote fashion. This process is analogous to a Common Application rule, as the students have implicitly submitted applications to all of the schools and the schools respond by making offers to students in stages as the algorithm progresses. The algorithm concludes with each school having enrolled its desired number of students, at which point, each school j will have admitted some proportion q_j of applicants. Since each school's rank order list in this context is generated at random, the admission probabilities $(q_1, q_2, \ldots, q_S)$ observed in a single implementation of the DA algorithm produce the same statistical

[2] When all schools share a common ranking over students, both student-proposing and school-proposing DA produce the same outcome.

distribution of assignments of students to schools as a Common Application rule with these same admission probabilities.

The proof of the equivalence of the student-proposing and school-proposing versions of the DA algorithms follows similar lines. In both the student-proposing and school-proposing versions of the algorithm, the schools set cutoffs in their ranking lists and then each school admits only those students who are above its cutoff. Unmatched students in the student-proposing version of the algorithm make proposals and are rejected by all schools. Each matched student makes proposals to schools on her preference lists until she reaches the school where she is accepted and assigned by the algorithm. Yet, though these students do not make proposals to all schools, they would receive the same assignments if they did make proposals to all schools, as these additional proposals would be to schools that they would not choose if admitted. So we can view the student-proposing version of the algorithm as another way of arriving at the assignment probabilities from the unique Common Application outcome.

Intuitively, the Ranked Application relies on the principle of revealed preference to determine assignments of students to schools, with the well-known result that it achieves an ex-post efficient matching. In particular, the first school to reach capacity in a Ranked Application only enrolls students who prefer it to all other schools. By contrast, under the Common Application, every school enrolls some students who were admitted only to that school and had no other options. With two schools, in fact, the ordinal distribution of matches from the Ranked Application stochastically dominates that from the Common Application. With more than two schools, the relative advantage of the Ranked Application is most easily expressed in terms of the stability of the assignment outcome.

3.2 Comparison in Large Markets

Our next two results assume large n and that admissions probabilities converge to expected values.

Proposition 6 *Each school offers admission to a smaller proportion of students with the Common Application than it does with Ranked Application.*

Proof. Order the schools so that in expectation, if $j < j'$ then School j reaches capacity before School j' with Ranked Admissions. With Ranked Application, every student who is admitted to School 1 is also admitted to all other schools. But with the Common Application, some students who are admitted to School 1 are not admitted to all other schools. Therefore the probability of enrolling at School 1 conditional on receiving an offer from School 1 is higher with the Common Application than with Ranked Application, which means in turn that School 1 fills its class with fewer offers using the Common Application than with Ranked Admissions..

Furthermore, with Ranked Application, every student admitted to School 2 is also admitted to Schools 3, 4, 5, ..., S, and some proportion are also admitted to School 1. School 1 admits a lower proportion of students with the Common Application than with Ranked Admissions, so for School 2 the probability of competing with School 1 is lower with the Common Application than with Ranked Application. Thus, the probability of enrolling at School 2 conditional on receiving an offer is higher with the Common Application than with Ranked Admissions, so once again, School 2 fills its class with fewer offers with the Common Application than with Ranked Application. A similar argument demonstrates in order that Schools 3, 4, ..., S, each make fewer offers in expectation with the Common Application than with Ranked Application. ■

Corollary 7 *A higher proportion of students are assigned to first-choice schools with Ranked Application than with the Common Application.*

This is immediate because the probability of admission to any particular (first-choice) school is higher with Ranked Application than with the Common Application. However, as shown in Example 3 in the Appendix, the ordinal distribution of assignment probabilities with Ranked Application does not necessarily stochastically dominate the ordinal distribution of assignment probabilities with the Common Application.

Proposition 8 *Given a set of applicants who do not all have the same set of preference orderings over schools, Ranked Application guarantees a pairwise stable assignment of students to schools, while there is positive probability that the Common Application implements an assignment of students to schools that is not pairwise stable.*

Proof. Comparing any two applicants with distinct set of preference orderings, suppose that Student A is assigned to school s_A and student B is assigned to school s_B with Ranked Application. If Student A prefers s_B to s_A, then by revealed preference, school s_B was not available when it was her turn to choose a school. So student B must had priority over A and had the option of choosing either s_A or s_B were available. By revealed preference, then both student A and student B prefer s_B to s_A and so cannot gain from pairwise trade.

By contrast, if students A and B have different preference orderings in the context of the Common Application rule, then there is some pair of schools s_A and s_B such that student A prefers s_A to s_B while student B prefers s_B to s_A. But there is positive probability that student A is admitted only to school B and that student B is admitted only to school A and thus positive probability that

there would be a gain from pairwise trade for the students given their assignments in the Common Application. ■

4 Boston's Charter Common Application

The model developed in the previous section makes simplifying assumptions that allow for an analytical comparison between assignment systems. Our analysis shows that the Decentralized Application exhibits a force towards positive selection in the choice of applications, which results in placing more applicants at preferred schools. However, students who submit multiple applications pay larger costs for doing so in Decentralized Application than with the Common Application system. This tradeoff between the better matches enacted with Decentralized Application and lower costs of applications with a Common Application system may either benefit or hurt students, and we do not believe that it is possible to produce a universal ranking of the systems in terms of student welfare without very strong assumptions. Furthermore, admissions probabilities in the model are the consequence of static equilibration of demand and supply. In practice, applicant preferences may change after application as students experience taste shocks due to changing information or circumstances. When a student turns down an admissions offers, schools often make a set of offers from their wait lists.

In this section, we develop an empirical model to quantify the differences between systems, taking advantage of unique data from Boston's charter sector, which moved form a decentralized admissions system to a common application system. Our empirical model is based on data from two different decision points for an applicant: the application and the enrollment decision. To accommodate dynamic aspects of admissions, the model allows for student preferences to change between the admissions and enrollment stage.

4.1 Background

In 2016, Boston charter schools announced an online common application for Fall 2017 enrollment known as the *Boston Public Charter School Application* (BPCSA). The BPCSA system replaced a decentralized application in which applicants would fill out a separate form for each school. This change was implemented partially in response to the failure of an effort to integrate the enrollment of Boston's charter and district schools (Vaznis, 2016). At the time of the application's launch, the BPCSA included all Commonwealth charters – those "overseen by the state education department and operate independently of Boston Public Schools" – with the exception of Bridge Boston (Kennedy,

2016).[3]

The main entry points for Boston charter schools are grades 5, 6, and 9. We focus throughout on grade 5 to focus on the charter sector and a fallback outside option of traditional public schools.[4] Our focus on grade 5 allows us to avoid choice within traditional public schools, where grade 6 is the main transition grade, and choice for exam schools, which admit students in grade 7.[5] For admissions starting at grade 5, our sample includes five schools for which we observe application data: Academy of the Pacific Rim, Boston Collegiate, Match, Neighborhood House, and Uncommon Schools/Roxbury Prep. We exclude additional schools (e.g. Excel and KIPP) due to incomplete application data. The BPSCSA website launched in October 2016 and the deadline to submit an application is February 2017. Each school obtained a list of applicants and separately conducted lotteries to generate offers of admission in March 2017.

Figure 1 shows the geographic distribution of the school choice environment for Grade 5 students in Boston in 2017, with charter schools shown as triangles and the charter schools that are in our sample shown as shaded triangles. First, this shows that there is a lot of school choice for Boston students. Second, this shows that there is some geographic concentration in the location of the charters, with many of the charters located in the East Zone, which includes Dorchester, Mattapan, and Hyde Park.

4.2 Sample and Data

4.2.1 Sample Restrictions

The main data sources used are records from the Student Information Management System (SIMS) provided to us by the Massachusetts Department of Elementary and Secondary Education and individual charter school records. The SIMS data contains information on student demographics like race and subsidized lunch eligibility. Charter admissions records contain information on applicants and lottery offers. We match charter applicants to the SIMS file using name and date of birth, following the procedure described in Abdulkadiroğlu, Angrist, Dynarski, Kane, and Pathak (2011). We also use data from Boston Public Schools (BPS) to measure a student's location.

To build the sample, we start with all students who attended a Massachusetts school in fourth grade according to SIMS (or the grade prior to an entry point for some of the time series analyses. For

[3] Massachusetts Horace Mann charter schools, a hybrid model approved and part of the local district, were also not included in the BPCSA.

[4] For more background and related studies on Boston's charters, see Abdulkadiroğlu, Angrist, Dynarski, Kane, and Pathak (2011), Angrist, Cohodes, Dynarski, Pathak, and Walters (2016), Cohodes, Setren, and Walters (2021), and Walters (2018)

[5] Abdulkadiroğlu, Angrist, and Pathak (2014) provide additional detail and context on Boston exam school admissions.

the time series analysis, we consider these students during the school years beginning in 2014-2016. For the structural analysis we use students who were in fourth grade in the school year beginning in 2016. We then drop (1) students who are missing an ID number; (2) students who applied late to a charter school or applied but were deemed ineligible (due, for example, to being too young, being too young, or withdrawing an application); and (3) students who applied to charter schools for multiple grades in a year.

For the structural analyses, we impose additional restrictions. First, we limit the sample to students who attended a school within Boston in fourth grade in the 2016-2017 school year other than one of the schools on the BPCSA for fifth grade. We impose this restriction since a large share of students remain at the school that they were already attending and are not actively applying to school. Second, we limit the sample to students for whom we observe or can estimate a valid residential location, as described below. Notably, our sample includes both applicants and non-applicants to schools listed on the BPCSA.

The final sample consists of 2,034 applicants across all three years in the time series analysis, and 5,138 individuals in the one year of the structural analysis (701 applicants and 4,437 non-applicants). The data appendix provides details on how we compute a student's residential location and distance to school.

4.3 Summary Statistics

Table 2 below shows summary statistics for the sample used in the structural estimation. Student neighborhoods are determined based on the neighborhoods listed in the charter application files; charter applicants are disproportionately located in the East Zone, consistent with the large concentration of charter schools in this zone. Boston is like many large urban school districts with a large fraction of Black and Hispanic students, and students who qualify for a subsidized school lunch. Compared to the overall pool of applicants, charter applicants are less likely to be Hispanic and more likely to be Black. This patterns contrasts with the patterns documented in Abdulkadiroğlu, Angrist, Dynarski, Kane, and Pathak (2011) where charter applicants were more likely to be Black and may reflect growing Hispanic enrollment in Boston. Applicants in the BPCSA tend to have similar baseline MCAS scores as non-applicants. Studies using application data from Boston's decentralized period tend to find that charter applicants have higher baseline MCAS scores than non-applicants (see, e.g., Walters (2018).). However, charter applicants tend to be more representative in cities that where all applicants must rank schools Abdulkadiroğlu, Angrist, Narita, and Pathak (2017).

4.4 Motivating Descriptive Results

To motivate the structural estimation that follows, we use the time series patterns to check whether the theoretical predictions on applications and enrollment hold in the data. Specifically, the theory predicts that the number of applications per applicant will increase and admissions rates will decrease as a result of moving from Decentralized Application to Common Application.

Figure 2 shows these results for grade 5 using the time series from the school years starting in 2015 through 2017; Appendix A shows additional results for grades 5, 6, and 9 combined, as well as for grade 9 separately. We use a balanced panel of schools for which we have data in all of these years (APR, Match, and Uncommon for Grade 5; Boston Prep for grade 6; and City on a Hill, Codman, Boston Prep, and Uncommon for grade 9). To account for the fact that our data on waitlist offers may be incomplete, we use initial offers rather than final offers as the measure of acceptances.

Figure 2(a) (and the table in Appendix B for grade 5) shows that applications per applicant increase and admissions rates decrease. Both patterns are consistent with our theoretical model. Results in Appendix B are less clear for grade 9, since application results have clear pre-trends and acceptance rates increase in 2017 (which may be due to a smaller number of applicants). Figure 2(b) shows time series of the applications and unique applicants received by the grade 5 schools. The theory is ambiguous about how the number of applications may change. Empirically, there is no clear break from the previous pattern.

The patterns demonstrated in Figure 2 are only suggestive and cannot be solely attributed to the BPCSA because of other contemporaneous changes occurring during the roll out of BPCSA. For example, in November 2016, there was a statewide referendum on charter school expansion and this may have influenced parental preferences for charter schools. We next turn to the structural model to evaluate counterfactual admissions systems holding fix the demand patterns for a given year.

5 Structural Model and Estimation

5.1 Model Motivation and Setup

We develop a structural model of the BPCSA and use it to simulate decentralized and ranked systems for several reasons. First, to obtain analytical results, we had to abstract away from several important frictions in the theoretical model. The key assumptions are that (1) preferences likely evolve over time; (2) waitlists and the after-market for each system are not perfectly efficient; and (3) only some of the schools moved to a BPCSA in practice, so we do not observe the move from a decentralized to

a ranked system directly in the data. The structural model will allow us to examine whether some of the sharp theoretical predictions seem to hold in practice with these frictions. Second, some of our theoretical results are ambiguous and depend on the distribution of preferences and application costs. Estimates from the structural model will inform these parameters and will allow us to measure the welfare effects of different admissions systems. Finally, the structural model is also necessary for extrapolation. While Boston's charters switched from a decentralized system to the BPCSA, it is necessary to extrapolate behavior to understand the consequences of a ranked admissions system.

Timing

The environment consists of two periods. In stage 1, potential applicants have an initial utility over each school. Between stages 1 and 2, schools make admissions decisions. In stage 2, students have an updated utility from each school, and use this utility to determine their enrollment based on their set of admitted schools. We follow Walters (2018) and include a second-stage shock to rationalize the fact that many students enroll in their outside option despite being admitted to a BPCSA school (see also Kapor, Neilson, and Zimmerman (2020)).

Application Decision: Common and Ranked Application

At the time of the application (Stage 1), utility for each common application model school $j \in \{1, ..., S\}$ for student i is given by:

$$u_{ij} = \beta_D D_{ij} + \delta_j + \epsilon_{ij}$$

where D_{ij} is the estimated driving distance in minutes, δ_j is a school fixed effect, and ϵ_{ij} is a Type 1 extreme value error term variance normalized to $\frac{\pi^2}{6}$. The outside option has a utility given by another Type 1 extreme value error term: $u_{i0} = \epsilon_{i0}$.. There is no fixed effect here since we cannot separately identify all of the fixed effects; therefore each school fixed effect δ_j is relative to the outside option.

We assume that students do not take into account acceptance probabilities when applying to schools. This is a point of departure from the expected utility maximization model underlying the theoretical section and is made to justify the fact that students do not apply to every charter school. We also motivate the assumption based on evidence from other settings that families have mistaken beliefs about admissions probabilities (e.g., Kapor, Neilson, and Zimmerman (2020). We expect this phenomenon to be particularly relevant in during the first year of the BPCSA, where applicants will have to anticipate odds of admission in a completely new system. Moreover, the descriptive evidence from BPCSA suggests that the Boston's common charter app did not result in a large change in the

set of applicants. We therefore instead impose the following assumption:

- Submitting any application has a fixed cost C which does not vary across individuals; there is no additional marginal cost for each application. Students will apply using the common application if the utility from at least one school is greater than the outside cost plus the outside option, so

$$\max\{u_{i1}, ..., u_{iS}\} \geq C + u_{i0}$$

- If a student applies using the common application, she applies to all schools for which $u_{ij} \geq u_{i0}$ due to the assumption of zero marginal cost for applications beyond the first application.

We assume that the set of schools that students will list under ranked application is the exact same as the set of schools that they would apply to under the common application model. This implies that the fixed cost C is the same in each system, each system has zero marginal cost beyond the first school, and students use the same behavioral assumption under each system. However, under the common application model, students simply indicate the schools for which they are applying. Under the ranked application model, students rank these schools based on their u_{ij}, reporting truthful preferences.

Application Decision: Decentralized Applications

The key feature of the decentralized model is that it becomes more costly to submit the applications beyond the initial application. We model this by assuming that in the first stage, identical to the common application model, individuals submit an application if and only if

$$\max\{u_{i1}, ..., u_{iN}\} \geq C + u_{i0}.$$

For each subsequent application, there is a marginal cost $\tilde{c}$, where we hypothesize (but do not impose) that $\tilde{c} < C$. Students then apply to all schools for which $u_{ij} \geq \tilde{c} + u_{i0}$.

In the decentralized application model, the set of students that will submit an application in this model is identical to the set that will submit an application in the common application model because the decision to apply only depends on the maximum school utility in the first stage and the fixed cost of an application, which remains the same. This feature is consistent with descriptive patterns above. Conditional on submitting an application, the number of applications per applicant will be lower in the decentralized application model than in the common application model. Finally, just like the common application model, none of the costs C or $\tilde{c}$ are relevant for the preference ranking of schools or the enrollment decision after the first stage of deciding whether to submit an application.

Enrollment Decision

After application, a students may be accepted to a subset of the schools where they applied. In Stage 2, the utility for each school (including the outside option) is given by:

$$U_{ij} = u_{ij} + \xi_{ij}$$

where ξ_{ij} follows a Type 1 extreme value distribution, but with an estimated variance that differs from the Stage 1 error term. Specifically, ϵ_{ij} has standard deviation $\frac{\pi}{\sqrt{6}}$ while ξ_{ij} has standard deviation $\frac{\kappa\pi}{\sqrt{6}}$.The variable κ regulates the extent to which we allow preferences to change across stages. A students then attends the school (which may be the outside option) for which she's received an acceptance that has the highest U_{ij} value. By definition, all students are accepted at their outside option. The application cost C is no longer relevant in Stage 2, since it is a sunk cost.

For the common application and decentralization application models, students receive a fixed set of acceptances and then choose their best offer among these schools.

5.2 Likelihood and Estimation of Model Parameters

Among the set of applicants and non-applicants who are considered potential applicants, we estimate the parameters of the model above (school fixed effects, distance coefficients, the fixed cost C, and the variance of the second stage error) using simulated maximum likelihood in Python, using data from the BPCSA in 2017. The current implementation uses a grid of several initial conditions, and then keeps the solution that has the highest value of the likelihood function across all initial conditions. Optimization is carried out using the built-in Powell's Method solver from the `scipy.optimize` package.

Define the following notation:

- A_i is the observed set of schools where student i applies. $A_i = \phi$ is the event where student i does not apply to any schools on the Common App (i.e. $\max\{u_{i1}, ..., u_{iN}\} < u_{i0} + C$).
- Z_i is the observed set of schools for which student i receives acceptances. This is determined in equilibrium based on school capacity constraints.
- S_i is the observed school chosen by student i (which may be a common application school or the outside option).

- Denote the set of parameters as $\theta = (\delta, \beta)$ and the set of observed individual characteristics (e.g., location) as X_i.

There are three types of students potentially observed in the data, so we consider the likelihood for each separately.

Case I: Non-Applicants – These are potential applicants who are not observed applying, so $A_i = \phi$. The likelihood of somebody not applying is the probability that the outside option utility plus the application cost is greater than the utility from *all* of the common application model schools. The likelihood is then given by:

$$\mathcal{L}_i = \frac{1}{1 + \sum_j \exp(u_{ij} - C)}.$$

Case II: Applicants with No Acceptances – These are applicants who are not accepted to any school, so their contribution to the likelihood function is only given by the set of schools where they apply. Their contribution to the likelihood is:

$$\begin{aligned}\mathcal{L}_i &= Pr(A_i|\theta, X_i) \\ &= Pr(A_i|\theta, X_i, A_i \neq \phi) Pr(A_i \neq \phi|\theta, X_i).\end{aligned}$$

By the same logic as in Case I, we have $Pr(A_i \neq \phi) = 1 - \frac{1}{1+\sum_j \exp(u_{ij}-C)}$.

The term $Pr(A_i|\theta, X_i, A_i \neq \phi)$ can be estimated via simulation for each individual, by drawing a large number of error terms, keeping the simulations for which the individual would choose to apply, and then recording the empirical probability of the observed application set A_i among these simulations.

Case III: Applicants with Acceptances – These are applicants who apply to at least one Common App school, and receive at least one acceptance, so that we observe a Stage 2 choice for these applicants.

Their (unconditional) likelihood is given by:

$$\begin{aligned}\mathcal{L}_i &= Pr(A_i, S_i|\theta, X_i) \\ &= Pr(A_i|\theta, X_i) * Pr(Z_i|A_i, \theta, X_i) * Pr(S_i|Z_i, A_i, \theta, X_i) \\ &= Pr(A_i|\theta, X_i) * Pr(Z_i|A_i) * Pr(S_i|Z_i, A_i, \theta, X_i).\end{aligned}$$

Conditional on the observed applications, the charter school acceptances do not depend on θ.

Therefore, the $Pr(Z_i|A_i)$ term should drop out, and the θ that maximizes the log of this likelihood is equivalent to the θ that maximizes the following for each individual:

$$\ell_i = \log(Pr(A_i|\theta, X_i)) + \log(Pr(S_i|Z_i, A_i, \theta, X_i)).$$

The expression within the log in the second term is equal to:

$$\int Pr(S_i|Z_i, \theta, X_i, \epsilon_i) f(\epsilon_i|A_i, X_i, \theta) d\epsilon_i = \int \frac{Z_{ij}\exp(\frac{v_{ij}+\epsilon_{ij}}{\kappa})}{\exp(\frac{\epsilon_{i0}}{\kappa}) + \sum_{j'=1}^{J} Z_{ij'}\exp(\frac{v_{ij'}+\epsilon_{ij'}}{\kappa})} f(\epsilon_i|A_i, X_i, \theta) d\epsilon_i$$

where $f(\epsilon_i|A_i, X_i, \theta)$ is the pdf of the ϵ_{ij} terms conditional on a given application decision, parameter estimates, and student characteristics. Note that we can simplify this conditional pdf as:

$$f(\epsilon_i|A_i, X_i, \theta) = \frac{Pr(A_i|\epsilon_i, X_i, \theta) f(\epsilon_i)}{Pr(A_i|X_i, \theta)}.$$

Since each error term is independent, $f(\epsilon_i)$ is simply the product of the unconditional pdfs of each extreme value error term. In addition, since the application decision is deterministically given by ϵ_i, X_i, θ, the quantity $Pr(A_i|\epsilon_i, X_i, \theta)$ is simply an indicator variable of whether an individual would have the observed application set. Finally, since $Pr(A_i|X_i, \theta)$ does not depend on ϵ_i, it can be taken out of the integral, and will cancel with the first term of ℓ_i. Putting this all together, the likelihood for these students is:

$$\ell_i = \log\Big(\int \frac{Z_{iS_i}\exp(\frac{v_{iS_i}+\epsilon_{iS_i}}{\kappa})}{\exp(\frac{\epsilon_{i0}}{\kappa}) + \sum_{j'=1}^{J} Z_{ij'}\exp(\frac{v_{ij'}+\epsilon_{ij'}}{\kappa})} \mathbb{1}_{(A_i|\epsilon_i, X_i, \theta)} f(\epsilon_i) d\epsilon_i \Big)$$

There are two computational tricks to computing this likelihood; these are each described in more detail in Appendix D. First, the integral within the log likelihood cannot be computed explicitly so is estimated via simulation. Second, the indicator variable within the integral is not computationally feasible for uncommon combinations of applications, so a logit smoother following Train (2009) combined with the analytical formula for common application combinations given the logit error term following Ophem, Stam, and Praag (1999) is used to avoid values of 0 and 1. The only way the indicator takes on a value of 0 now is if the ϵ_i and θ values imply that the individual will not submit an application to the common application at all.

5.3 Estimation of Decentralized Application Marginal Costs

We use the following procedure to estimate the marginal costs $\tilde{c}$:

1. From the estimated parameters of the model with a fixed cost, generate simulated error terms which rationalize the observed application and enrollment decisions of each student in 2017.

2. Determine the empirical number of applications per applicant in 2016 – the year before the BPCSA was introduced, when a decentralized application was still in effect. Table 4 shows that an average of 1.6 applications per applicant was submitted; as expected, this is lower than the 2.65 applications per applicant observed under the BPCSA in 2017.

3. From the simulations in 2017, assume that if a decentralized application system were still in effect, the number of applications per applicant would have been the same as in 2016. Then find the value of $\tilde{c}$ such that, based on the simulated error terms and our model of a decentralized application, the average number of applications per applicant (across all simulations) matches the 2016 value.

5.4 Simulating the Three Application Systems

To evaluate each of the application systems, we first need to simulate the set of error terms that rationalize the given application and enrollment decisions for each student, similar to Abdulkadiroğlu, Agarwal, and Pathak (2017). We generate 100 unique simulations in the data.

For the common application model, we use the observed acceptances and enrollment, and can determine the rank and utility associated with the school that each student accepted within each simulation.

For the ranked application model, we simulate a student-proposing deferred acceptance (DA) algorithm. Waitlists and an aftermarket are accounted for by using two rounds of the algorithm. School capacities are set to be exactly equal to the eventual enrollments under the common application model with the given set of students. School priorities for students are randomly generated by lotteries and are set to be identical across schools so that DA is efficient. To complete the first round of DA, run DA given the setup described above. At this point, some students are assigned to a school and some students remain unassigned. We say that students are on the waitlist for a school if there are schools for which they originally applied and were not assigned under DA, but prefer to the school that they were assigned. DA is then run for a second round among individuals who did not receive

their eventual first choice (either through DA assignment or if the outside option became their first choice) given the new waitlist rankings.

For the decentralized application model, we assume that the capacity for each common application school among the estimation sample is identical to the observed final enrollment in 2017 among this group (as in the ranked simulation). Then we determine equilibrium acceptance rates in the decentralized application model using the following greedy algorithm:

- First, for each school, randomly generate a priority order among all potential applicants. This priority order may differ across schools.
- Each school then starts with accepting 0 students and incrementally accepts another student if they still have capacity.
- Then given the full set of acceptances, students attend the school where they have the highest utility in the second round.
- Schools stop increasing their acceptance rate when they either or at capacity or have an acceptance rate of 100%.

As with the two other assignment systems, the simulated utilities can be used to determine the rank and utility associated with the school that each student receives.

6 Structural Estimates

Table 3 shows results for a model in which costs can differ across student groups, but all other parameter estimates remain identical. Appendix C contains additional details on the characteristics of these groups, including the joint distribution between minority status and free lunch status.

Full Sample: For the results within the full sample, the coefficient on distance is negative. The negative fixed effect for each school reflect the fact that a very small share of the sample ends up applying to any of the common application model schools. In addition, estimated application costs and changes in preferences between the two stages are both large.

To estimate hypothetical marginal costs, we use the procedure described above and estimate $\tilde{c} \approx 1.07$. This is lower than C. This value of $\tilde{c}$ is then used in all simulations, so the average number of applications per applicant can vary slightly across simulations.[6]

[6]To benchmark these estimates, Fu (2014) estimates application costs for college applications, and finds that marginal application costs decrease rapidly in the number of applications, with the cost of the first application being quite large (1900 dollars for the first application and 900 dollars for the second application).

Heterogeneity: The other columns in each table show heterogeneous results by demographic groups, defined during Grade 4. Free/reduced lunch students seem to have larger costs, which is consistent with their larger increase in applications per applicant in 2017. Black/Hispanic students seem to have, if anything, smaller marginal costs than other applicants; one potential source of this is that the model with identical school fixed effects may be misspecified based on the stark differences based on minority status in the share applying to each school in Panel C. Therefore, when we perform counterfactuals with these estimates, we only focus on free/reduced lunch heterogeneity.

To further understand the results of this estimation, Table 4 shows the transition matrix across simulations of how school rankings change. The large variance of the error term in the second stage means that rankings shift drastically between stages. However, the fixed cost makes the first choice slightly more stable relative to the other choices.

The results of simulating the decentralized system are shown below in Column (3) of Table 5. We find that acceptance rates for all schools increase relative to the observed rates in the common application. On average, all enrollments in Column (3) match enrollments in Column (2) except for one school. This is because increasing this school's acceptance rate to 100% still does not reach the school's capacity due to the decrease in applications. Some observed acceptance rates in 2017 are much lower than expected. This could partially reflect the incomplete waitlist information or the substantial variation in acceptance rates by year.

6.1 Ranking and Welfare Comparisons

With the simulations for each application system in hand, we can compare the distribution of rankings of the schools that students enroll in under each. These results are shown below in Table 6 and Figure 3. In general, the decentralized system performs the best based on this metric, and is roughly similar to the ranked system. Figure 4 shows the results of a "vote" between each pair of systems. The magnitudes of differences between the systems are relatively small, but in proportional terms they are still substantial. For example, over 10% more students get their top choice under the decentralized system than the common application. Results for the votes are also pushed toward 50% given the large number of students who receive the same assignment under each system.

Note that these simulations require the assumption that preferences change to the same extent between stages regardless of the application system used. However, each application system may change the incentives to acquire information (Chen and He, 2021). As a result, we also report results for the "Ranked Full Information" case. Ranked Full Information corresponds to the limit case in

which ranked induces students to learn their full preferences prior to applying (and therefore report their second-stage preferences).

To evaluate welfare and compare magnitudes of differences between the systems for individual students, one strategy is to convert the implied utility differences for the school into distance units, based on the estimated distance coefficient in Table 3. Figure 5 shows the result of estimating, within each simulation, the average of the difference in utility in distance units for each student between each pair of systems and then plotting this distribution of averages. These results suggest that across all simulations, expected utility from the decentralized system is greater than under the common application.

We can additionally evaluate the magnitudes by benchmarking the total utility in each system relative to a first-best allocation and a lower-bound allocation. For the first-best, we consider the allocation that maximizes total utility, subject to school capacity constraints ("First-Best'), as well as the allocation that maximizes total utility, subject to both school capacity constraints and restricting students to be assigned to one of the schools that they list on the Common Application ("First-Best, Applied"). For the lower-bound allocations on utility, we consider a "Random" allocation, in which students are randomly assigned to schools subject to capacity, and a "Outside Option" allocation in which every student receives their outside option. Figure 6 shows that relative to these benchmarks, differences between total utility in the application systems that we consider are fairly small. Nevertheless, if we assume that the marginal costs for applying in the decentralized system are primarily behavioral costs, the decentralized system and the full-information DA both perform better than the Common App. The Common App performs better than the baseline DA and the decentralized application if we assume that all of the marginal costs are "real costs."

6.2 Decentralized Applications with Heterogeneous Marginal Costs

It is possible ex ante that the previous results obscure heterogeneity on the basis of marginal costs that occurs due to the common application eliminating the marginal costs for disadvantaged groups.

The parameter estimates from Table 3 suggest that applicants on free/reduced lunch have a higher marginal (and fixed) cost for applications than those not on free/reduced lunch. Therefore, we can consider free/reduced lunch students as the "disadvantaged" group that would be more likely to benefit from the introduction of the common application.

Figure 8 shows the share of students in each free/reduced lunch category that receive their 1st choice, 2nd choice or better, or 3rd choice category under the following models:

- Decentralized (Same MC) uses the model in which all costs are imposed to be the same across the two groups (Column (1) of Table 3).

- Decentralized (Heterogeneous MC) uses the model in which costs are allowed to differ across the two groups (Columns (2) and (3) of Table 3).[7] This model predicts that free/reduced lunch applicants would have applied to 1.61 schools on average in 2017 and those not on free/reduced lunch would have applied to 1.59 schools on average.

- Decentralized (Lower MC) sets the marginal costs for all students equal to the estimated (lower) marginal costs for the students not on free or reduced lunch. This model predicts that now free/reduced lunch applicants would have applied to 1.80 schools on average in 2017 (those not on free/reduced lunch would have remained at 1.59 schools on average).

- The common application model results are identical to the original analyses, since this does not depend on marginal costs, but results are now shown separately for each group.

In addition, Figure 8 carries out the thought experiment of comparing the common application and the decentralized application under different marginal costs for the subsidized lunch applicants (holding the marginal costs for the other applicants fixed). Panel (a) shows that at the observed marginal cost, approximately 38% of subsidized lunch applicants are expected to receive their first choice under a common app (relative to approximately 34% under the decentralized application). In fact, the marginal costs would have to be approximately four times higher than what we estimate in order for the common app to be beneficial for this group. Panels (b) and (c) show the same exercise for "second choice or better" and "third choice or better." In both of these cases as well, true marginal costs for subsidized lunch applicants would need to be larger than what we estimate in order for the common application to be beneficial.

The results in these figures suggest that the difference in marginal costs for disadvantaged groups makes only a minor difference in their average ability to obtain their preferred schools. This is particularly small relative to the difference between the decentralized system and the common application. Therefore, in this setting, it does not appear that the common application makes a large difference in helping disadvantaged groups. One potential explanation for these small differences is that the large share of applicants on free/reduced lunch may mitigate the effects of having applicants with lower marginal costs, or the difference in marginal costs may be small enough to not matter substantially.

[7] For intuition in this model, note that the disadvantaged group will apply to fewer schools on average relative to the previous case, so would be expected to receive an acceptance to fewer common application model schools.

6.3 Testing Common Application vs. Decentralized Application Predictions

With the simulation results in hand, we can evaluate each of the results from the theory section. We highlight some of the results that hold mechanically due to the structure of the model.

- Result 1: With the Common Application, the equilibrium admissions rate must be (weakly) less than the equilibrium admissions rate under the Decentralized application rule
- Result 2: Each school receives (weakly) more application in equilibrium with the Common Application rule than it does in equilibrium with the Decentralized Application rule
  - These results mechanically hold due to the structure of the application rule given our model.
- Result 5: With independent symmetric preferences, the distribution of ordinal ranks for enrolled students under the Decentralized System stochastically dominates the distribution of ordinal ranks under the Common Application rule.
  - Empirically, this result holds in the data (see Table 5); at each rank, more students cumulatively receive that choice or better under the decentralized system than the Common App.
- Result 3 (extensive margin): It could be that more or fewer students apply to at least one school with the Common Application vs. the Decentralized Application rule.
  - Due to the structure of the model, we impose that exactly the same number of students apply to at least one school under both systems, so we cannot evaluate this with the structural model. Descriptive results in Table 5 suggest that the number of applicants decreased, but it is difficult to draw conclusions from this.
- Result 4: Expected utility (neglecting application costs) could be either higher or lower with Common Application system than with the Decentralized Application rule.
  - Empirically, the previous results suggest that expected utility in this setting is higher under the decentralized application system (see panel (a) of Figure 5). This holds across all simulations.

6.4 Testing Common Application vs. Ranked Application Predictions

We can similarly use the previous estimates to evaluate the theoretical claims comparing the common application and ranked application:

- Result 9: Each school offers admission to a smaller proportion of students with the Common Application than it does with Ranked Application. Corollary: A higher proportion of students are assigned to first-choice schools with Ranked than with the Common Application.
  - While it's not clear how the admissions rate should be defined in our given simulation, Table 6 can be used to check the corollary. We indeed find that this holds in our setting.
- Result 10 (Mismatch): Given a set of applicants who do not all have the same set of preference orderings over schools, Ranked guarantees a pairwise stable assignment of students to schools, while there is positive probability that the Common Application implements an assignment of students to schools that is not pairwise stable.
  - Due to the second stage error terms, it is mechanically no longer the case that Ranked will guarantee a pairwise stable assignment of students.[8] Nevertheless, we can check for the share of students that are eligible to trade. This is shown below in Table 7, which confirms that fewer students are eligible to trade under ranked application model than under the common application model.

7 Conclusion

[TBD]

[8] Clearly, a school could end up being a student's first choice despite the fact that they never ranked it, and the student would never be able to enroll in this school.

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Table 1. Examples of Metropolitan Areas with Common Application Systems

Metropolitan Area	For School Year	Name of Portal
Atlanta	2020-2021	Apply APS Charter
Baton Rouge	2018-2019	EnrollBR
Boston	2017-2018	Boston Charter Public School Application
Buffalo	2021-2022	Enroll Buffalo Charters
Kansas City	2019-2020	Show Me KC Schools
Houston	2018-2019	Apply Houston
Los Angeles	2019-2020	ApplyLA Charter Common Application
New York City	2010-2011	Common Online Charter School Applicatio
Oakland	2017-2018	Oakland Enrolls
Philadelphia	2019-2020	Apply Philly Charters
Rhode Island	2020-2021	EnrollRI
Rochester	2017-2018	GoodschoolsRoc

Notes: List of cities using a single common application for charter schools from author's calculations.

Table 2: Boston Applicants vs. Non-Applicants Sample, Grade 5 (2017)

	(1)	(2)
	Applicants Sample	Non-Applicants Sample
Number of Students	701	3591
Panel A: Demographics		
Special Ed	.203	.243
Free/Reduced Lunch	.765	.791
Black, Non-Hispanic	.405	.284
Hispanic	.407	.484
Panel B: Geography		
Minutes to Closest Charter	7.59	10.4
East Zone	.489	.363
North Zone	.197	.383
West Zone	.314	.254
Panel C: Grade 4 School		
Charter	.0799	.039
Traditional Boston Public	.92	.961
Panel D: Previous MCAS Scores		
Non-Missing MCAS Score	664	3355
4th Grade MCAS Average Z-Score	-.00296	.0131

Notes: This table shows descriptive statistics for the applicants sample and non-applicants sample for Boston Grade 5 Common App charter schools in 2017. The non-applicant sample consists of students who attended a non-Common App school within Boston in 2016-2017, and for whom we can infer distances to charter schools. All characteristics are based on 4th grade. MCAS scores from 4th grade are normalized to have a mean of 0 and a standard deviation of 1 among all students in Boston during the given year; the score shown is the average of the standardized math and reading scores.

Table 3: Demand Estimation, with Cost Heterogeneity by Group (Grade 5, 2017)

	(1)	(2)	(3)	(4)	(5)
		Free/Reduced Lunch		**Black/Hispanic**	
Parameter	Full Sample	Free/Reduced Lunch	No Free/Reduced Lunch	Black or Hispanic	Not Black or Hisp.
Panel A: Applicants					
Applicants	701	536	165	569	132
Non-Applicants	3591	2841	750	2758	833
Apps/Applicant (2016)	1.60	1.61	1.60	1.69	1.23
Apps/Applicant (2017)	2.65	2.74	2.34	2.80	1.97
Panel B: Parameter Estimates					
100*Distance Coeff.	–3.40	–3.24	–3.24	–2.86	–2.86
Fixed Cost	1.96	2.05	1.86	2.20	2.17
(Dist. Units)	(57.75)	(63.26)	(57.35)	(77.01)	(75.92)
Marginal Cost	1.05	1.13	0.87	1.06	1.41
(Dist. Units)	(30.92)	(34.85)	(26.87)	(36.98)	(49.18)
Kappa	3.93	3.61	3.61	3.70	3.70
(Dist. Units)	(115.38)	(111.30)	(111.30)	(129.42)	(129.42)
School 1 FE	–0.34	–0.29	–0.29	–0.50	–0.50
(Dist. Units)	(–10.01)	(–9.03)	(–9.03)	(–17.57)	(–17.57)
School 2 FE	–0.57	–0.48	–0.48	–0.40	–0.40
(Dist. Units	(–16.79)	(–14.77)	(–14.77)	(–14.06)	(–14.06)
School 3 FE	–0.57	–0.52	–0.52	–0.44	–0.44
(Dist. Units)	(–16.86)	(–16.16)	(–16.16)	(–15.55)	(–15.55)
School 4 FE	–0.87	–0.76	–0.76	–0.96	–0.96
(Dist. Units)	(–25.54)	(–23.39)	(–23.39)	(–33.72)	(–33.72)
School 5 FE	–1.02	–0.87	–0.87	–0.82	–0.82
(Dist. Units)	(–29.84)	(–26.95)	(–26.95)	(–28.80)	(–28.80)
Panel C: Share Applying					
School 1	0.51	0.52	0.48	0.55	0.33
School 2	0.62	0.58	0.74	0.55	0.89
School 3	0.56	0.61	0.39	0.64	0.23
School 4	0.46	0.47	0.41	0.48	0.36
School 5	0.50	0.56	0.32	0.58	0.17

Notes: This table shows the estimated parameters of the structural model with a fixed cost, and marginal costs in the case of decentralized applications. The model is estimated separately three times: the full model, the model with free lunch heterogeneity in costs, and the model with minority status heterogeneity in costs. Results are shown in the full sample (Column (1)) as well as separately by demographics, with demographics defined during 4th grade. Distance units are in minutes of drive time. Panel C shows the share of applicants applying to each school.

Table 4: Boston Charter Rankings Transition Matrix 2017, Grade 5 with Application Cost

	(1)	(2)	(3)	(4)	(5)	(6)
Stage 1 Ranking	Stage 2 Ranking 1	Stage 2 Ranking 2	Stage 2 Ranking 3	Stage 2 Ranking 4	Stage 2 Ranking 5	Stage 2 Ranking 6
1	0.32	0.25	0.18	0.13	0.08	0.04
2	0.18	0.19	0.19	0.18	0.15	0.10
3	0.16	0.17	0.18	0.18	0.18	0.14
4	0.13	0.14	0.16	0.18	0.19	0.19
5	0.11	0.13	0.15	0.17	0.20	0.23
6	0.10	0.12	0.13	0.16	0.20	0.29

Notes: This table shows the transition matrix of estimated school rankings, among Common App applicants using the model with a fixed application cost. The six schools are the five Common App charter schools and the outside option. The sample is all students across the 100 simulations.

Table 5: Boston Common App vs. Decentralized Application Comparison (Grade 5)

	(1)	(2)	(3)
	2016	**2017**	
	Decentralized Observed	Common App Observed	Decentralized Simulated
Panel A: Applicants			
Avg. Apps/Applicant	1.60	2.65	1.61
Applicants in Sample	920	701	701
Panel B: School Acceptance Rates			
APR	52%	36%	60%
BosCol	27%	16%	47%
Match	31%	9%	20%
NH	100%	12%	25%
Uncommon	100%	81%	100%
Panel C: School Enrollments			
APR	72	67	67
BosCol	74	74	74
Match	43	25	25
NH	23	22	22
Uncommon	206	164	116

Notes: Columns (1) and (2) show observed outcomes within the estimation sample for 2016 and 2017, with the decentralized Common App systems, respectively. Columns (3) show results for simulated outcomes in 2017 using a decentralized system, with 100 simulations. Simulations set marginal costs for each application between the first application so that the average number of applications per applicant matches the value in Column (1), and school acceptance rates are set to match those in Column (2), unless the acceptance rate is already at 100. Averages in Panels B and C are based on the averages across all 100 simulations.

Table 6: Application System Comparisons, Grade 5

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Common Application		**Ranked Application**		**Decentralized Application**		**Ranked Full Info**	
Final Ranking	Avg. Share	[90% CI]	Avg. Share	[90% CI]	Avg. Share	[90% CI]	Avg. Share	[90% CI]
1st Choice	0.335	[0.308, 0.361]	0.368	[0.343, 0.392]	0.369	[0.342, 0.397]	0.400	[0.371, 0.429]
1st-2nd Choice	0.575	[0.548, 0.603]	0.590	[0.563, 0.618]	0.612	[0.584, 0.640]	0.601	[0.574, 0.627]
1st-3rd Choice	0.747	[0.725, 0.769]	0.747	[0.723, 0.771]	0.772	[0.748, 0.796]	0.746	[0.722, 0.770]
1st-4th Choice	0.868	[0.850, 0.887]	0.863	[0.844, 0.882]	0.879	[0.859, 0.898]	0.856	[0.835, 0.877]
1st-5th Choice	0.951	[0.939, 0.964]	0.946	[0.934, 0.958]	0.952	[0.939, 0.964]	0.941	[0.927, 0.955]
1st-6th Choice	1.000	[1.000, 1.000]	1.000	[1.000, 1.000]	1.000	[1.000, 1.000]	1.000	[1.000, 1.000]

Notes: This table shows the share of students predicted to receive a school that is in the given position of their rankings by the end of the second stage, using the estimated parameter values from the two-stage model with a fixed cost. Confidence intervals are based on the 5th and 95th percentiles of 100 simulations, using variation due to the simulations but ignoring errors on the original parameter estimates; comparisons of the systems use the same sets of simulated error terms. The Ranked Application columns assume that students can be on the wait list for any school that they originally listed.

Table 7: Potential Trades, by Application System

	(1)	(2)
Outcome	Value	90% CI
Panel A: Students Eligible to Trade		
Common Application	20.7%	[18.5%, 23.1%]
Ranked Application	16.1%	[12.4%, 19.1%]
Decentralized Application	21.6%	[19.5%, 23.8%]
Panel B: Simulations with More Eligible to Trade		
Common Application vs. Ranked Application	99%	
Decentralized vs. Ranked Application	100%	
Decentralized vs. Common Application	68%	

Notes: Panel A shows, for each application system, the estimated share of students who would be eligible to trade placements with another student such that both students are better off. Panel B shows the share of the 100 simulations under which more students would be eligible to trade under the first listed application system compared to the second listed application system.

Figure 1: Boston Schools Map

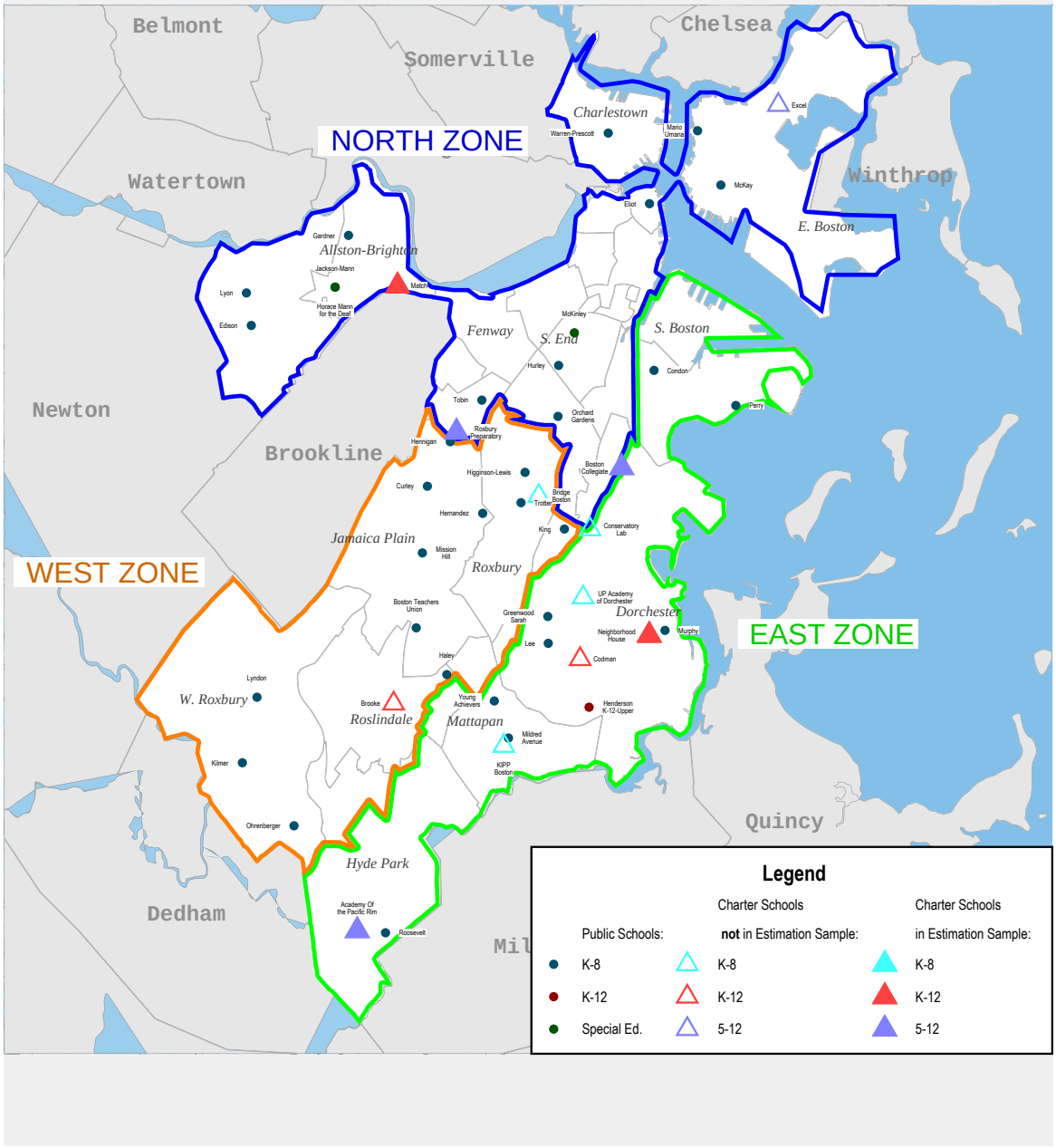
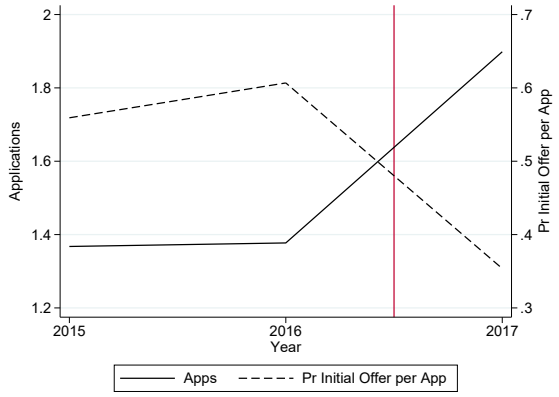
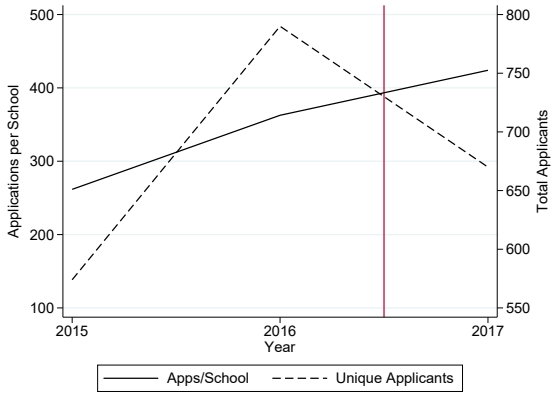


Figure 2: Time Series of Grade 5 Applicants and Applications (2015 Balanced Panel)



(a) Student Side Demand: Grade 5



(b) School Side Demand: Grade 5

Figure 3: Comparison of Application Systems

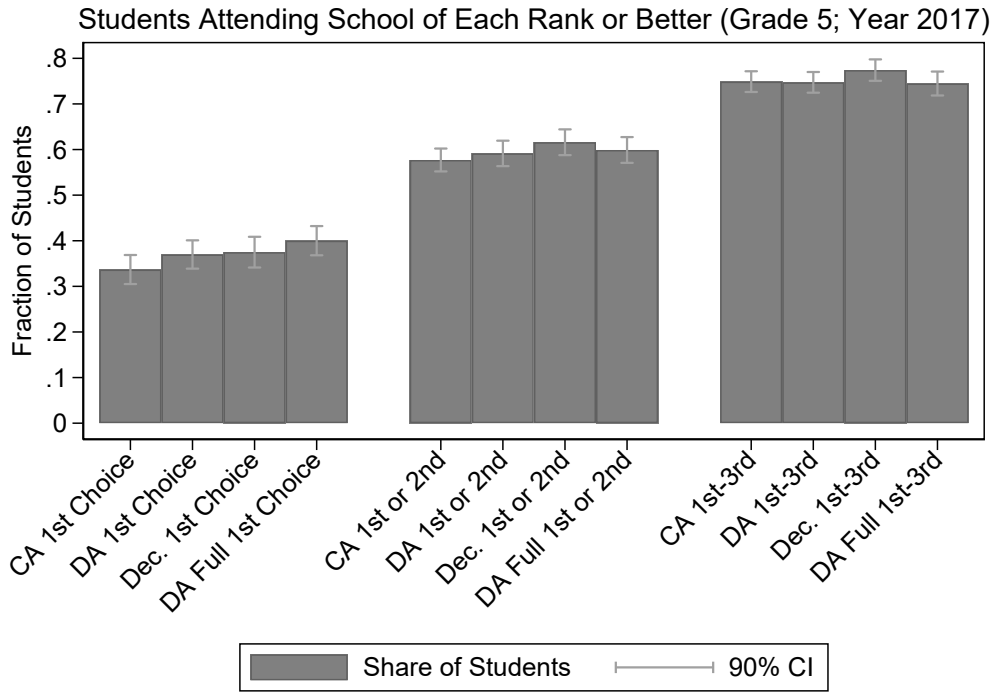
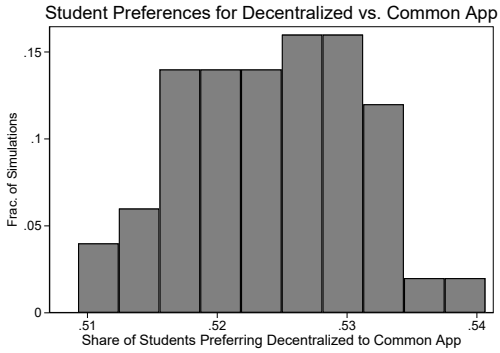
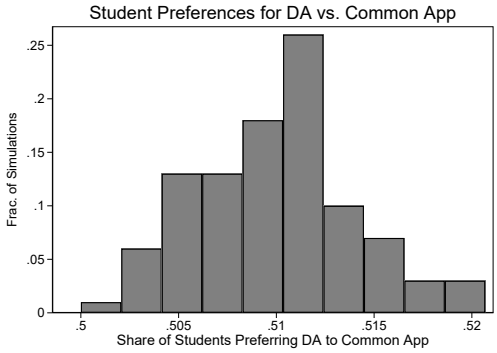


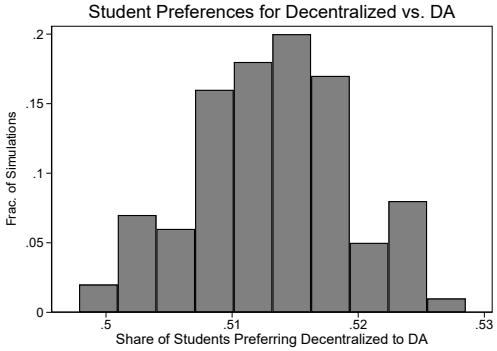
Figure 4: Pairwise Votes between Application Systems



(a) Decentralized vs. Common Application

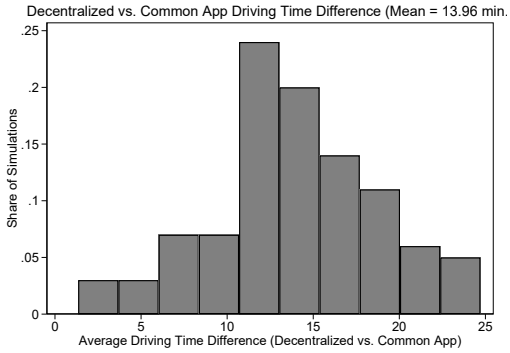


(b) Ranked vs. Common Application

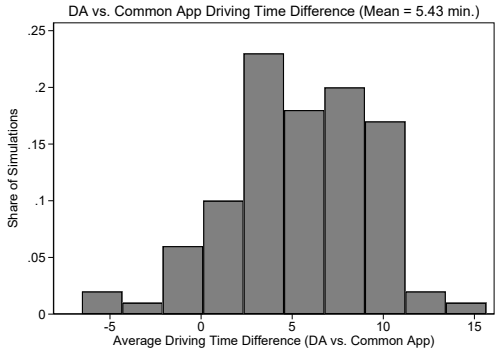


(c) Decentralized Application vs. Ranked Application

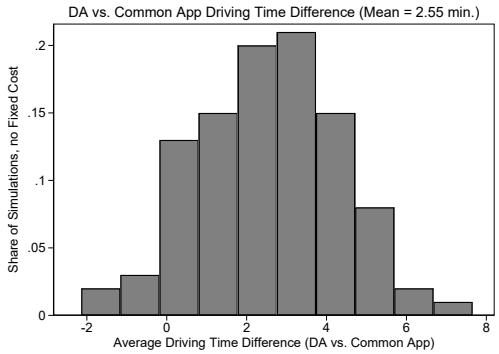
Figure 5: Magnitudes of Comparison between Application Systems



(a) Decentralized vs. Common Application (Fixed Cost Model)



(b) Ranked vs. Common App (Fixed Cost Model)



(c) Ranked vs. Common Application (Model without Fixed Cost)

Figure 6: Comparison of Total Utility Across Application Systems

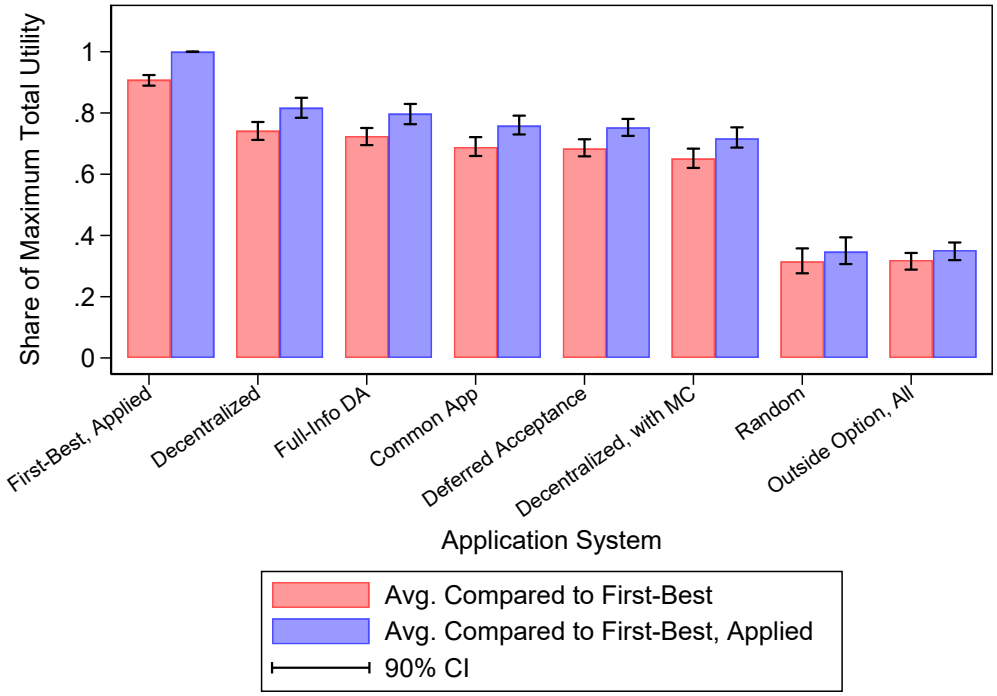
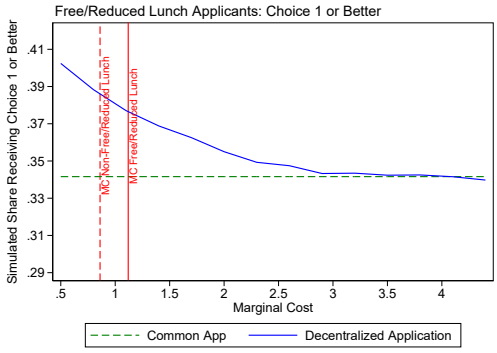
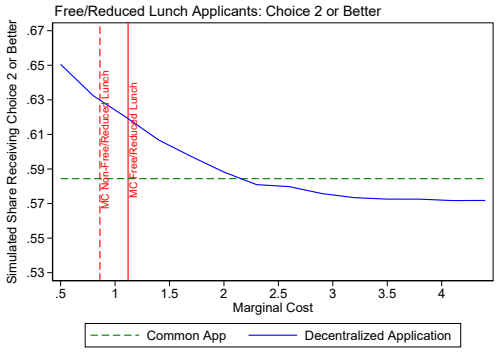


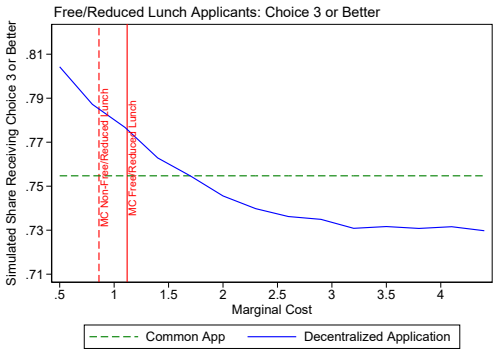
Figure 7: Common Application vs. Decentralized among Free/Reduced Lunch Applicants



(a) 1st Choice

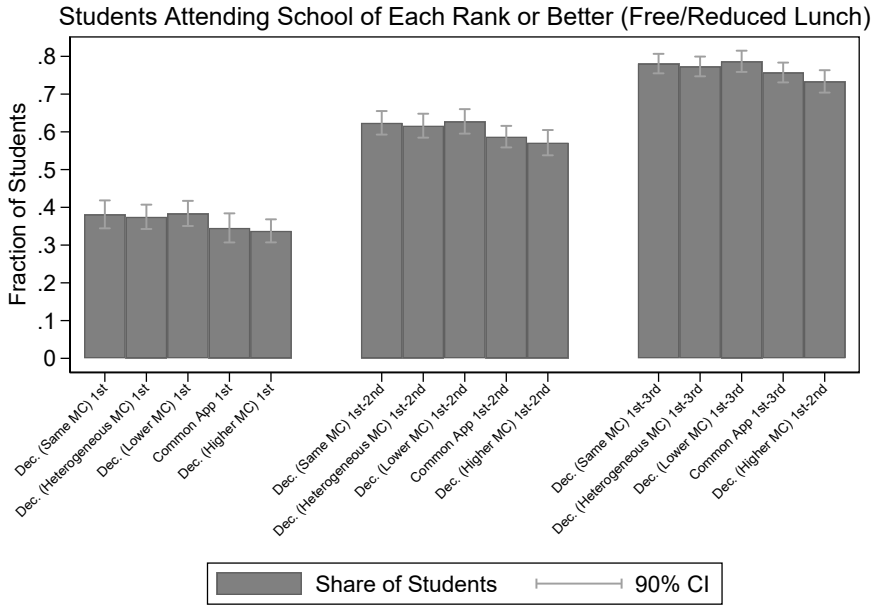


(b) 1st or 2nd Choice

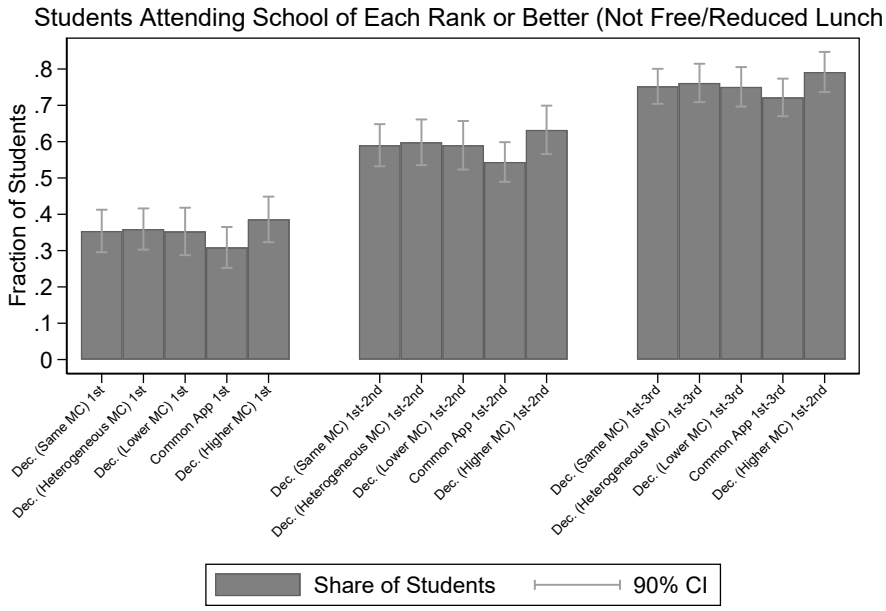


(c) 1st-3rd Choice

Figure 8: Comparison of Common App and Decentralized by Free Lunch Status



(a) Free/Reduced Lunch (Higher MC)



(b) Non-Free/Reduced Lunch (Lower MC)

Appendix A Theoretical Appendix

A.1 Existence and Uniqueness of Common Application Equilibrium

Suppose that there are S schools with capacities $K_1, K_2, \ldots, K_S$, where total capacity $K = K_1 + K_2 + ...K_S < 1$. Define the enrollment function $e_j(p_1, \ldots, p_S)$ as the proportion of students who enroll in school j given these admission probabilities when all students apply to all schools.

Lemma 1 *Consider any two distinct vectors of probabilities* $(p_1, \ldots, p_S)$ *and* $(q_1, \ldots, q_S)$ *where* $(1 - p_1)(1-p_2)\ldots\ (1-p_S) = (1-q_1)(1-q_2)\ldots\ (1-q_S) = 1 - K$. *Then for some school* j, $e_j(p_1, \ldots, p_S) > e_j(q_1, \ldots, q_S)$ *and also for some school* $j\prime$, $e_{j'}(q_1, \ldots, q_S) > e_{j'}(p_1, \ldots, p_S)$.

Proof. Divide the schools into three sets – S^1, where $p_j > q_j$ for each j, S^2 where $p_j < q_j$ for each j and S^3 where $p_j = q_j$ for each j. Sets S^1 and S^2 must each contain at least one school as otherwise $(1 - p_1)(1 - p_2)\ldots\ (1 - p_S) < (1 - q_1)(1 - q_2)\ldots\ (1 - q_S)$ (if S^1 is empty) or $(1 - p_1)(1 - p_2)\ldots\ (1 - p_S) > (1 - q_1)(1 - q_2)\ldots\ (1 - q_S)$ (if S^2 is empty) given that the two vectors are not identical. Now suppose that we start at $(p_1, \ldots, p_S)$ and adjust the admission probabilities from p_j to q_j one at a time starting with school 1 and continuing school by school through school S. (This procedure does not maintain the total capacity of enrollment at K at each step.). If $q_j > p_j$, then switching from $(q_1, \ldots, q_{j-1}, p_j, p_{j+1}, \ldots, p_S)$ to $(q_1, \ldots, q_{j-1}, q_j, p_{j+1}, \ldots, p_S)$ simply adds admissions offers to some students who were previously not admitted to school j. Students who are affected by this change either choose the same school under both systems or choose school j when they would not have done so in the original outcome. Since all admission probabilities are less than 1, a positive measure of students are admitted to none of the schools under original probabilities and are admitted only to school j given the adjusted probabilities. Thus, total enrollment in S^2 strictly increases and total enrollment in S^1 weakly decreases when we switch from $(q_1, \ldots, q_{j-1}, p_j, p_{j+1}, \ldots, p_S)$ to $(q_1, \ldots, q_{j-1}, q_j, p_{j+1}, \ldots, p_S)$. By a similar argument, total enrollment in S^2 weakly increases and total enrollment in S^1 strictly decreases given a switch from $(q_1, \ldots, q_{j-1}, p_j, p_{j+1}, \ldots, p_S)$ to $(q_1, \ldots, q_{j-1}, q_j, p_{j+1}, \ldots, p_S)$ when $q_j < p_j$. Combining these results, total enrollment is S^1 is strictly lower with $(q_1, q_2, \ldots, q_S)$ than with $(p_1, p_2, \ldots, p_S)$ and thus enrollment for at least one school in S^1 must be strictly lower with $(q_1, q_2, \ldots, q_S)$ while the reverse holds for S^2. ■

We now proceed to the proof, using the following induction on the number of unknown admission probabilities.

Part 1. Suppose that 2 (or 1) admission probabilities remain unknown.

Claim: If $S-2$ admission probabilities are fixed (and fewer than K students are admitted to those schools) then there is a unique choice of the last two probabilities such that

(1) K students enroll, i.e. $(1-p_1)(1-p_2)\ldots\ (1-p_S) = 1-K$

(2) $e_{S-1}/e_S = k_{S-1}/k_S$.

If fewer than K students are admitted to schools 1 to $S-2$, then $(1-p_1)\ (1-p_2)\ \ldots\ (1-p_{S-2}) > 1-K$. Define $\gamma = (1-p_1)(1-p_2)\ldots\ (1-p_{S-2})$. Since $\gamma(1-p_{S-1}) < K$ and $\gamma(1-p_S) < K$, p_{S-1} and p_S are each bounded above by $1-(1-K)/\gamma$.

Solving (1) for p_S gives

$(1-p_{S-1})(1-p_S) = (1-K)/\gamma$

OR $p_S = [\gamma(1-p_S-1)-(1-K)]/\gamma(1-p_{S-1})]$. (3)

Thus, p_S is positive, continuous and strictly decreasing in p_{S-1} for $p_{S-1} < 1-(1-K)/\gamma$ and $p_S = 0$ at $p_{S-1} = 1-(1-K)/\gamma$. Given $p_1, p_2, \ldots, p_{S-2}$ and $p_S = [\gamma(1-p_{S-1})-(1-K)]/\gamma(1-p_{S-1})]$, the enrollment values e_{S-1} and e_S are continuous functions of p_{S-1} where e_{S-1} is strictly increasing and e_S is strictly decreasing in p_{S-1}. At the extreme values $p_{S-1} = 0$ and $p_{S-1} = (1-K)/\gamma$, one of the last two schools does not enroll any students: $e_{S-1}(p_{S-1}=0) = 0$ and $e_S(p_{S-1} = (1-K)/\gamma) = 0$. Thus the ratio e_{S-1}/e_S is strictly decreasing in p_{S-1} and takes on all positive values as p_{S-1} ranges from 0 to $(1-K)/\gamma$. Therefore, there must be a unique choice p_{S-1} such that condition (2) holds.

More generally, this shows that for each $(p_1, \ldots, p_{S-2})$ with $(1-p_1)(1-p_2)\ldots\ (1-p_{S-2}) > 1-K$, there is a unique pair (p_{S-1}, p_S) such that (1) and (2) hold. Further, (p_{S-1}, p_S) varies continuously with $(p_1, \ldots, p_{S-2})$ as a jump in (say) p_{S-1} would require a corresponding reduction in p_S with the result that at least one of the two schools would miss its enrollment target.

Part 2 (Induction Step). Suppose that these properties hold when J admission probabilities are fixed and $S-J$ admission probabilities are unknown. Show that the properties also hold when $J+1$ admission probabilities are fixed and $S-J-1$ admission probabilities are unknown.

Formally, suppose $J < S-2$ and that for each $(p_1, p_2, \ldots, p_J)$ satisfying $(1-p_1)(1-p_2)\ldots\ (1-p_J) > 1-K$, there exists a unique combination $(p_{J+1}, \ldots, p_S)$ where $p_{J+1}, \ldots, p_S$ are continuous in $(p_1, p_2, \ldots, p_J)$ and

(1J) $(1-p_1)(1-p_2)\ldots\ (1-p_S) = 1-K$;

(2J) For each pair (i,j) with $i,j > J$, the enrollment ratio $e_i/e_j = k_i/k_j$

We want to show that result holds when $J-1$ probabilities are known and $S-J+1$ are to be determined.

Fix $(p_1, p_2, \ldots, p_{J-1})$ with $(1-p_1)(1-p_2)\ldots\ (1-p_{J-1}) > 1-K$. Set $\lambda = (1-K)/[(1-p_1)(1-p_2)\ldots(1-p_{J-1})]$.

If $p_J = \lambda$ then $(1-p_1)(1-p_2)\dots\ (1-p_J) = 1-K$, so $(1-p_1)(1-p_2)\dots\ (1-p_J) < 1-K$ if $p_J < \lambda$. By inductive hypothesis, for each p_J such that $0 < p_J < \lambda$, there exists a unique choice of probabilities $(p_{J+1}(p_J)\dots, p_S(p_J))$ such that $(1J)$ and $(2J)$ hold.

At p_J =0, enrollment $e_J = 0$ and enrollments $e_{J+1}, \dots, e_S > 0$, so $e_J/e_{J+1} = 0$. At $p_J = \lambda$, enrollment $e_J > 0$ and enrollments $e_{J+1}, \dots, e_S = 0$, so e_J/e_{J+1} becomes arbitrarily large in the limit at p_J approaches λ from below. Since $(p_{J+1}, \dots, p_S)$ vary continuously in p_J (holding $p_1, \dots, p_{J-1}$ fixed), the ratio e_J/e_{J+1} is continuous in p_J for $0 < pJ < \lambda$ and so there must exist some value p_J^* such that $e_J/e_{J+1} = k_J/k_{J+1}$ at p_J^*. By (2), then $e_J/e_{J+2} = k_J/k_{J+2}\ \dots\ e_J/e_S = k_J/k_S$ as desired.

Suppose that there are two different combinations of probabilities $(p_1, \dots, p_{J-1}, p_J, p_{J+1}, \dots, p_S)$ and $(p_1, \dots, p_{J-1}, q_J, q_{J+1}, \dots, q_S)$ satisfying (1). Then by the lemma, one school must have increased enrollment and antoher must have decreased enrollment as a result of the change in probaibliites, so it is not possible for both probabilities to sastify (2). By the lemma, there must be schools $j, j' > J$ such that

$e_j(p_1, \dots, p_{J-1}, p_J, p_{J+1}, \dots, p_S) > e_j(p_1, \dots, p_{J-1}, q_J, q_{J+1}, \dots, q_S)$ and

$e_{j'}(p_1, \dots, p_{J-1}, p_J, p_{J+1}, \dots, p_S) < e_{j'}(p_1, \dots, p_{J-1}, q_J, q_{J+1}, \dots, q_S)$ and

So the ratio of enrollments between schools j and $j\prime$ are different given the two different sets of admissions probabilities. This shows that there is (at most) a unique choice of probabilities for schools J to S that satisfy (1) and (2), where these probabilities must be continuous in $(p_1, p_2, ..., p_J)$ as a discontinuous jump up in any of $(p_{J+1}, ..., pS)$ would make it impossible to maintain (2J) for every pair (i, j) with $i, j > J$.

A.2 Proof of Proposition 6

Proof. Under the Decentralized Application system, with symmetric preferences and identical admission probabilities at each school, students apply in order to their most preferred schools, with sequentially increasing thresholds in utility values for each application. So, if m_k students apply to a k^{th} choice school in equilibrium, then $m_1 \geq m_2 \geq m_3 \dots \geq m_S$.

Step 1: Given the market clearing condition that K students enroll at each school and probability p of admission to each school, the number of students attending k^{th} choice schools or better is minimized by the Common Application pattern: $m_1 = m_2 = \dots\ = m_S$.

The minimum number of students attending k^{th} choice schools corresponds to the maximum number of students (given the market constraint) attending schools of $k + 1^{st}$ choice or worse. For any combination of applications $(m_1, m_2, \dots, m_k; p)$ satisfying the market clearing constraint:

(1) If $m_l > m_{l+1}$ for any $l < k$, then we could maintain the market clearing constraint by increasing all of $(m_{l+1}, \ldots\ m_S)$ while reducing each of $(m_1, m_2, \ldots\ m_l)$. This change increases each of m_{k+1}, m_{k+2}, ..., m_S, thus increasing the number of students attending $k+1^{st}$ choice schools or worse and thereby reducing the number of students attending k^{th} choice schools or better. So the application pattern yielding the minimum number of students attending k^{th} choice schools or better sets $m_1 = m_2 = \ldots\ = m_k$.

(2) Consider any application pattern $(m_1 = m, m_2 = m, \ldots, m_k = m, m_{k+1}, \ldots, m_S)$. If $m_l > m_{l+1}$ for any $l > k+1$, then we could maintain the market clearing conditions by increasing each of $(m_{l+1}, m_{l+2}, \ldots\ , m_S)$ and reducing each of $(m_1, m_2, \ldots, m_{l+1})$. Since this change reduces each of $(m_1, m_2, \ldots, m_k)$, it reduces the number of students attending k^{th} choice schools or better.

Combining points (1) and (2), the application pattern that yields the minimum number of students attending k^{th} choice schools or better is $m_1 = m_2 = \ldots\ = m_S$, i.e. the Common Application pattern where every student applies to all S schools.

Step 2: Given the market clearing condition that K students enroll at each school, the Common Application pattern $m_1 = m_2 = \ldots\ = m_S$ and probability p of admission to each school, the number of students attending k^{th} choice schools or better is increasing in p.

By symmetry, an equal number of students will be admitted to first choice schools, to second choice schools, ... to S^{th} choice schools in a Common Application equilibrium. Denote this number as $A(p)$ as a function of the equilibrium admission probability p per application.

A student who is admitted to a k^{th} choice school will attend that school if not admitted to a preferred school – i.e. with probability $(1-p)^{k-1}$. So the market clearing condition is

$$A(p) + A(p)(1-p) + A(p)(1-p)^2 + \ldots\ + A(p)(1-p)^{S-1} = K * S. \qquad (*)$$

Since each of the $(1-p)$ terms is declining in p, $A(p)$ must be strictly increasing in p to maintain this market clearing condition. So a higher equilibrium probability of admission, means that a larger number of applicants must be admitted to each school (since this higher probability of admission increases the likelihood that an applicant will be admitted to multiple schools).

Compare the admission outcomes for two distinct values $p_1 > p_2$. Since $A(p)$ is increasing in p, a greater number of students will attend 1st choice schools when $p = p_1$ than when $p = p_2$. To maintain the market clearing condition, some terms in the sum must decline when p increases from p_1 to p_2. Since $p_1 > p_2$, we know that $(1-p_2) > (1-p_1)$, so $A(p_2)(1-p_2)k - 1 > A(p_1)(1-p_1)^{k-1}$ implies $A(p_2)(1-p_2)^{n-1} > A(p_1)(1-p_1)^{n-1}$ for all subsequent terms $n > k$. That is, the initial terms in the sequence $\{A(p_1), (1-p_1)A(p1) \ldots, (1-p_1)^{S-1}A(p_1)\}$, representing the number of students assigned to $1^{st}, 2^{nd}, \ldots\ S^{th}$ choice schools given p_1, are greater than the initial terms in the corresponding

sequence $\{A(p_2), (1-p_2)A(p_2) \ldots, (1-p_2)^{S-1}A(p_2)\}$, but the inequality is reversed for the final terms in those sequences.

Thus, the number of students attending 1st choice schools is greater for $p = p_1$ than for $p = p_2$. Beyond that point, the difference between the number of students attending kth choice schools for $p = p_1$ than for $p = p_2$ increases up to some point then gradually decreases until exactly the same number of students $(S * K)$ attend S^{th} choice schools or better with either p_1 or p_2. This proves that the number of students attending k^{th} choice schools or better with a Common Application equilibrium is increasing in the admission probability p.

Step 3: Combine Steps 1 and 2: In sum, Step 1 shows that the Common Application pattern achieves the lowest probability of attending a k^{th} choice school or better for a given probability of admission, while Step 2 shows that given the Common Application pattern, the probability of attending a k^{th} choice school or better increases with the probability of admission. Proposition 2 shows that in equilibrium the Common Application probability of admission is lower than the decentralized admission probability of admission. So, the Common Application pattern achieves the lowest probability of attending a k^{th} choice school or better given admission probability p_C and this is lower than the probability of attending a k^{th} choice school for any market clearing pattern of applications given admission probability $p > p_C$. This proves the result. ■

A.3 Example 3

Example 3 *Suppose that there are three schools S_1, S_2, and S_3, each wishing to enroll 1/3 of all students, that 80% of the students have strict preference ordering (S_1, S_2, S_3) and that 20% of the students have strict preference ordering (S_2, S_3, S_1) over the three schools. Denote the probabilities of receiving an offer to each school as p_{1R}, p_{2R}, p_{3R} for the Ranked Admission rule and as p_{1C}, p_{2C}, p_{3C} for the Common Application.*

Then with the Ranked Application rule, when there are a large number of students, the first students in line choose either School 1 or School 2, with School 1 reaching capacity after making offers to $(1/3)/(0.8) = 5/12$ of the students. The next students in the line are offered the choice between Schools 2 and 3, and since all prefer School 2, it reaches capacity when it has made offers to 2/3 of the students. Then School 3 makes offers to the remaining students, who all enroll. The resulting offer probabilities are $p_{1R} = 5/12, p_{2R} = 2/3$ and $p_{3R} = 1$.

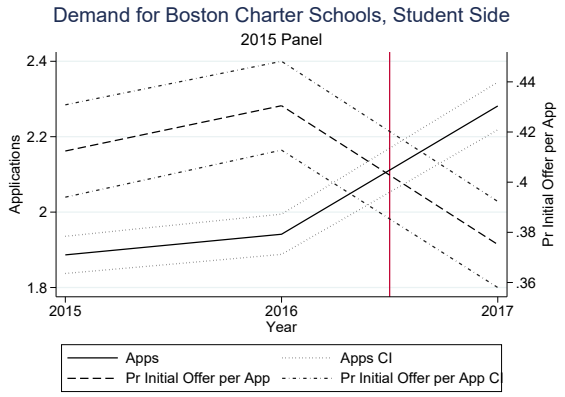
Similarly, with the Common Application, School 3 must make offers to all students to meet its enrollment target, so $p_{3C} = 1$. Then students with preference ordering (S_2, S_3, S_1) enroll at school S_2

with probability p_{2C} and at School S_3 with probability $1 - p_{2C}$. Students with preference ordering (S_1, S_2, S_3) enroll at school S_1 with probability p_{1C}, at School S_2 with probability $p_{2C}(1 - p_{1C})$ and otherwise enroll at school S_3. Solving in order for p_{1C} and p_{2C}, we have $0.8p_{1C} = 1/3$, or $p_{1C} = 5/12$ and $0.8\ p_{2C}\ (1 - p_{1C}) + 0.2p_{2C} = 1/3$, with solution $p_{2C} = 1/2$.

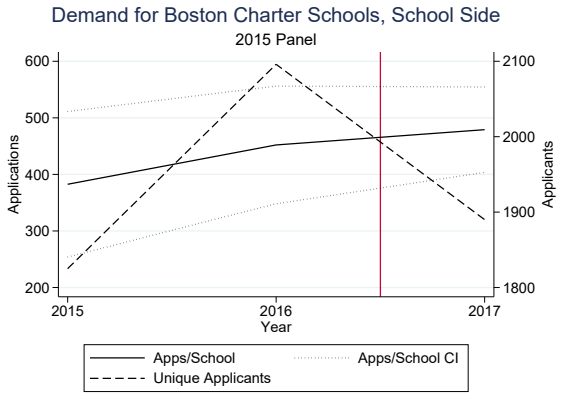
Under Ranked Application, all students with preferences (S_2, S_3, S_1) enroll at a first-choice or second-choice school while 2/3 of the students with preferences (S_1, S_2, S_3) do so. Thus, $0.8 * 2/3 + 0.2 * 1 = 11/15$ of students enroll at either a first-choice or second-choice school. Under the Common Application Rule, all students with preferences (S_2, S_3, S_1) enroll at a first-choice or second-choice school while $(5/12 + 1/2 - 5/12 * 1/2) = 17/24$ of the students with preferences (S_1, S_2, S_3) do so. Thus, $0.8 * 17/24 + 0.2 * 1 = 23/30$ of students enroll at either a first-choice or second-choice school. Here, the probability of enrolling at a first-choice or second-choice school is higher with the Common Application than with the Ranked Application, so the ordinal distribution of outcomes with the Ranked Application does not stochastically dominate the ordinal distribution of outcomes with the Common Application.

Appendix B Additional Empirical Results

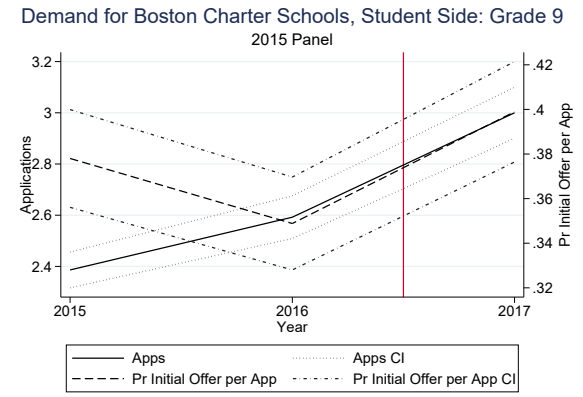
Figure B.1: Time Series of Applicant and Application Numbers: 2015 Balanced Panel



(a) Student Side Demand: All Grades



(b) School Side Demand: All Grades



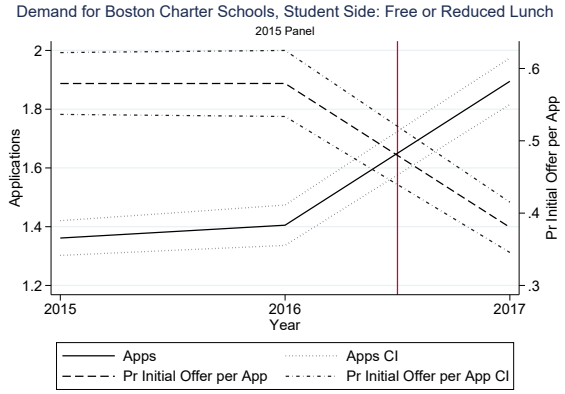
(c) Student Side Demand: Grade 9

Table B.1: Applications and Initial Offers per Applicant, 2015 Balanced Panel

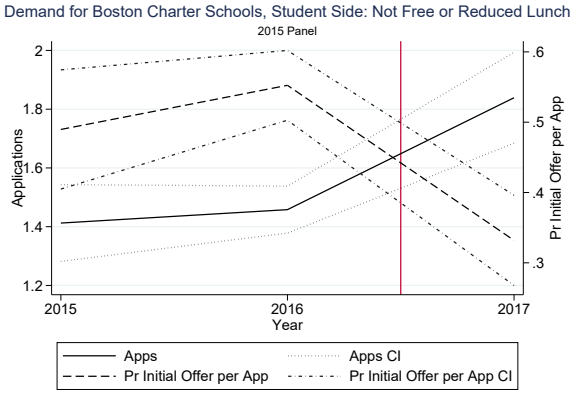
	(1)	(2)	(3)	(4)	(5)	(6)
	Applications per Applicant			**Prob of Initial Offer per App**		
Year	All	Grade 5	Grade 9	All	Grade 5	Grade 9
2016	0.0547	0.0096	0.2060***	0.0181	0.0475**	–0.0292*
(SE)	(0.0370)	(0.0340)	(0.0555)	(0.0130)	(0.0234)	(0.0154)
2017	0.3949***	0.5309***	0.6138***	–0.0373***	–0.2055***	0.0209
(SE)	(0.0409)	(0.0416)	(0.0621)	(0.0128)	(0.0228)	(0.0160)
Constant (2015)	1.8866***	1.3676***	2.3862***	0.4124***	0.5592***	0.3780***
(SE)	(0.0251)	(0.0250)	(0.0356)	(0.0094)	(0.0177)	(0.0112)
N	5811	2034	2977	5811	2034	2977

Notes: This table shows the coefficients from regressing applicants and the probability of an initial offer per application on year dummies, omitting 2015. The sample is the balanced panel of Common App schools that were available for all years 2015-2017. The column for All includes applicants to grades 5, 6, and 9. Heteroskedasticity-robust standard errors are shown in parentheses. *: p-value less than 0.1, **: p-value less than 0.05, ***: p-value less than 0.01.

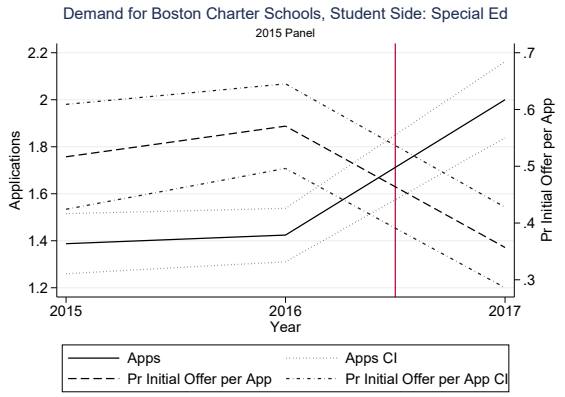
Figure B.2: Grade 5 Student-Side Demand by Demographics: 2015 Balanced Panel



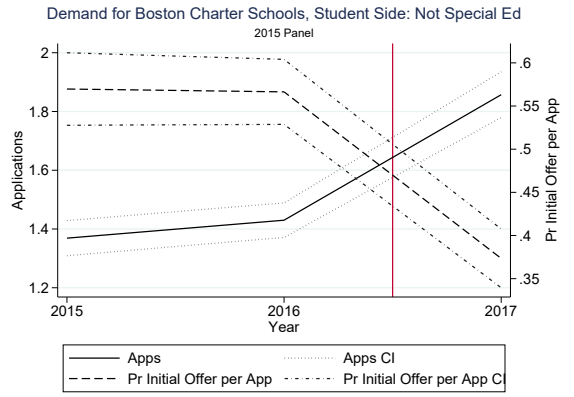
(a) Free/Reduced Lunch



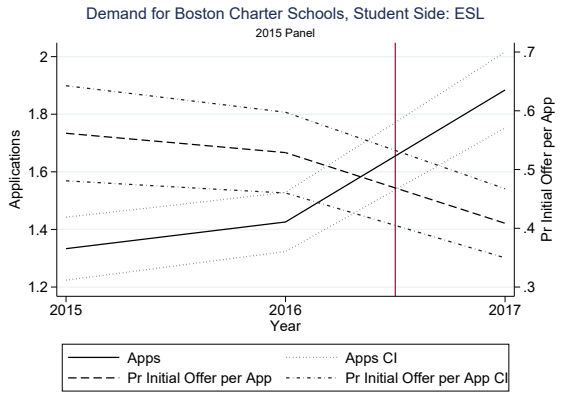
(b) Not Free/Reduced Lunch



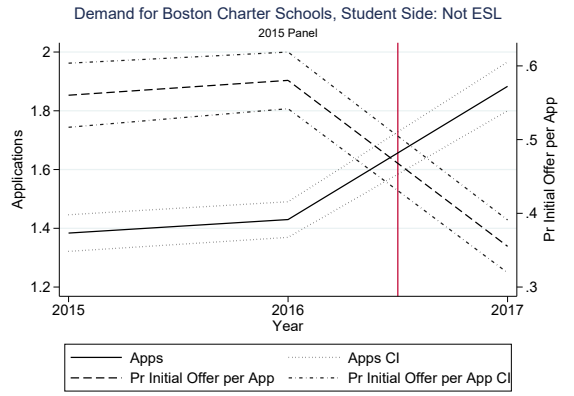
(c) Special Ed.



(d) Not Special Ed.

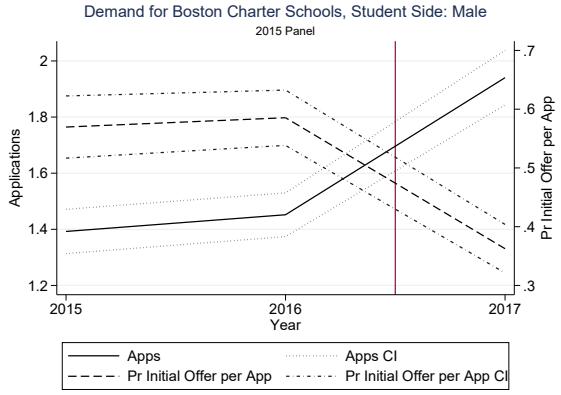


(e) ESL

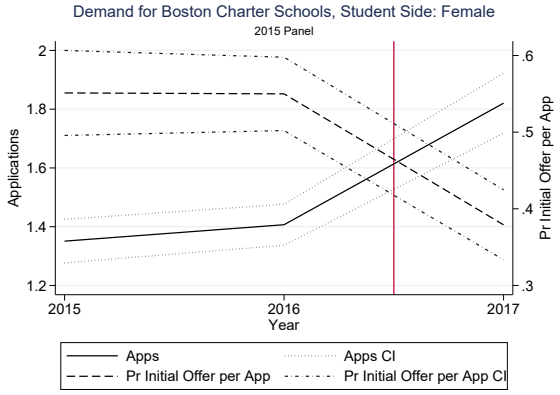


(f) Non-ESL

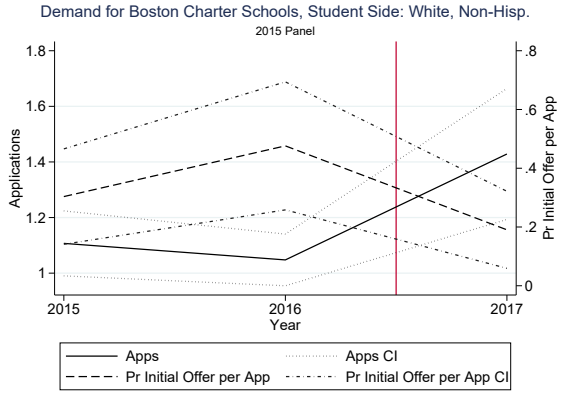
Figure B.2: Grade 5 Student-Side Demand by Demographics: 2015 Balanced Panel (con.)



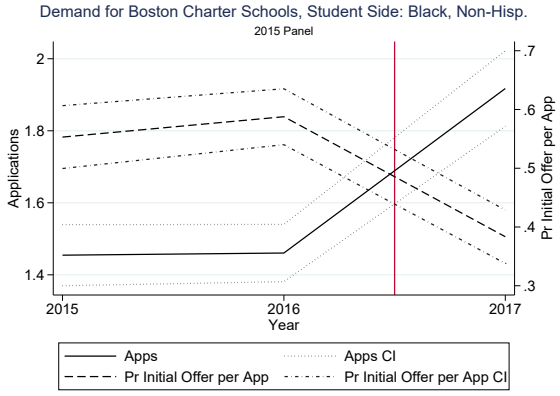
(g) Male



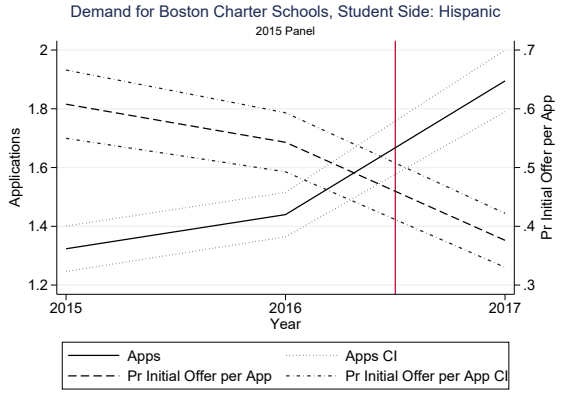
(h) Female



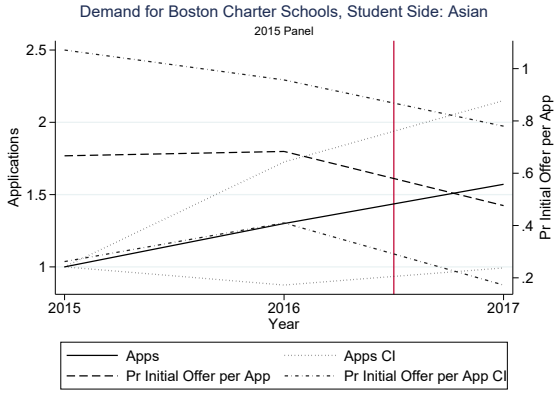
(i) White, non-Hispanic



(j) Black, non-Hispanic



(k) Hispanic



(l) Asian

Table B.2: Change in Grade 5 Applications by Demographics: 2015

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		Applicants			**Avg. Applications/Applicant**			**Change in Avg. Apps**	
	2015-2017	2015	2016	2017	2015	2016	2017	2016 to 2017	2015/2016 Avg. to 2017
Panel A: Free/Reduced Lunch									
Free/Reduced Lunch	1178	368	353	457	1.36	1.41	1.89	0.49	0.51
Not Free/Reduced Lunch	501	97	286	118	1.41	1.46	1.84	0.38	0.40
Panel B: Special Ed.									
Special Ed.	318	80	132	106	1.39	1.42	2.00	0.58	0.59
Not Special Ed.	1361	385	507	469	1.37	1.43	1.86	0.43	0.46
Panel C: ESL									
ESL	434	108	162	164	1.33	1.43	1.88	0.46	0.50
Not ESL	1245	357	477	411	1.38	1.43	1.88	0.45	0.48
Panel D: Gender									
Male	851	237	312	302	1.39	1.45	1.94	0.49	0.52
Female	828	228	327	273	1.35	1.41	1.82	0.41	0.44
Panel E: Race									
White, Non-Hisp.	77	28	21	28	1.11	1.05	1.43	0.38	0.35
Hispanic	752	204	291	257	1.32	1.44	1.89	0.46	0.51
Black, Non-Hisp.	790	220	304	266	1.45	1.46	1.92	0.46	0.46
Asian	23	6	10	7	1.00	1.30	1.57	0.27	0.42

Notes: This table shows the change in applications for grade 5 charter schools by demographic group, where demographics are defined based on grade 4 characteristics among students enrolled in Boston schools. The sample includes students who applied to at least one of the three charter schools included in the 2015 balanced panel: APR, Match, and Uncommon. Sample sizes correspond to the number of unique applicants.

Appendix C Additional Heterogeneity Results

Table C.1 below shows information on the joint distribution between racial minority status and free/reduced lunch status. Some takeaways from this table are the following:

- A majority of both applicants and non-applicants are *both* racial minorities and on free or reduced lunch.
- Racial minorities are more likely to be on free/reduced lunch than non-minorities, although the free/reduced lunch share is non-trivial even among those who are not Black or Hispanic (.402 for applicants and .567 for non-applicants).
- Being on free/reduced lunch is correlated with being a minority, but the overlap between these two groups is far from perfect.
- Among Black and Hispanic individuals, free/reduced lunch status shares are almost identical between applicants and non-applicants. Among non-Black/Hispanic individuals, non-applicants are less likely than applicants to be on free/reduced lunch.

Table C.1: Heterogeneity Joint Distribution for Applicants vs. Non-Applicants, Grade 5 (2017)

	(1)	(2)
	Applicants Sample	Non-Applicants Sample
Number of Students	701	4437
Panel A: Shares		
Fr/Reduced Lunch and Black/Hispanic	.689	.659
Fr/Reduced Lunch and Not Black/Hispanic	.0756	.125
Not Fr/Reduced Lunch, but Black/Hispanic	.123	.12
Not Fr/Reduced Lunch and Not Black/Hispanic	.113	.0956
Panel B: Conditional Probabilities		
Pr(Fr/Reduced Lunch if Black/Hispanic)	.849	.846
Pr(Fr/Reduced Lunch if Not Black/Hispanic)	.402	.567
Pr(Black/Hispanic if Fr/Reduced Lunch)	.901	.84
Pr(Black/Hispanic if Not Fr/Reduced Lunch)	.521	.557

Notes: This table shows the joint distribution of free/reduced lunch status and minority status for the applicants sample and non-applicants sample, for Boston Grade 5 Common App charter schools in 2017. The non-applicant sample consists of students who attended a non-Common App school within Boston in 2016-2017. All characteristics are based on 4th grade.

Appendix D Estimation Computational Details

Logit Smoother

This very closely follows the exposition in Train (2009) Section 5.6.2. In a "standard" discrete choice setting, in which we observe one choice from a set of options, the algorithm is described as follows:

1. For each of $s = 1, 2, ..., S$ simulations, draw a set of error terms $\epsilon_{ij}^{(s)}$ from a desired distribution for each student and school.

2. Using the drawn error terms and the deterministic utility estimates v_{ij}, construct for each simulation, student, and school: $u_{ij}^{(s)} = v_{ij} + \epsilon_{ij}^{(s)}$.

3. Suppose that each student was required to select exactly one school. Then given the error terms in each simulation, we should know deterministically the school chosen by each student. We can use a smooth approximation, however, by introducing an additional error term with a small variance. For small λ, the approximated probability that student i chooses school j is then $P_{ij} = \frac{1}{S}\sum_{s=1}^{S} \frac{\exp(u_{ij}^{(s)}/\lambda)}{\sum_{j=1}^{J}\exp(u_{ij}^{(s)}/\lambda)}$.

   As λ approaches 0, the expression $\frac{\exp(u_{ij}^{(s)}/\lambda)}{\sum_{j=1}^{J}\exp(u_{ij}^{(s)}/\lambda)}$ approaches the indicator function.

Train (2009) also notes that this approximation is conceptually similar to adding a further extreme value error term with a low variance to the decision problem.[9]

Our model differs from the standard discrete choice problem in that individuals may apply to multiple schools and do not rank these choices in the first stage. Nevertheless, the logic above extends directly to our setting. Consider a basic example in which there are three schools (A, B, C) and a student applies to A and B, but not C. Given a simulation with error terms ϵ_j for each school, the deterministic indicator function for this observed application would be $\mathbb{1}_{\{u_A, u_B > u_O > u_C\}}$, where u_j is the sum of the deterministic utility and its error term.

In contrast, the approximation with the logit smoother would be given by (for small λ, and following the formula from Ophem, Stam, and Praag (1999)):

$$\Big(1-\frac{\exp(\frac{u_O}{\lambda})+\exp(\frac{u_C}{\lambda})}{\exp(\frac{u_A}{\lambda})+\exp(\frac{u_O}{\lambda})+\exp(\frac{u_C}{\lambda})}-\frac{\exp(\frac{u_O}{\lambda})+\exp(\frac{u_C}{\lambda})}{\exp(\frac{u_B}{\lambda})+\exp(\frac{u_O}{\lambda})+\exp(\frac{u_C}{\lambda})}+\frac{\exp(\frac{u_O}{\lambda})+\exp(\frac{u_C}{\lambda})}{\exp(\frac{u_A}{\lambda})+\exp(\frac{u_B}{\lambda})+\exp(\frac{u_O}{\lambda})+\exp(\frac{u_C}{\lambda})}\Big)\Big(\frac{\exp(\frac{u_O}{\lambda})}{\exp(\frac{u_O}{\lambda})+\exp(\frac{u_C}{\lambda})}$$

[9] He writes that: "instead of seeing the logit smoother as providing an approximation that has no behavioral relation to the model (simply serving a numerical purpose), we can see it as arising from a particular type of error structure in the behavioral model itself. Under this interpretation, the logit formula applied to simulated utilities is not an approximation but actually represents the true model."

While this formula admittedly looks complicated, note that the first factor is analogous to the formula from Ophem, Stam, and Praag (1999) for $Pr(A, B \succ O, C)$ and the second factor is analogous to the standard discrete choice formula for $Pr(O \succ C)$.

Simulation Procedure

The integral within the likelihood function (for Case III) can be computed as follows:

1. For each of $s = 1, 2, ..., S$ simulations, draw a set of i.i.d. error terms $\epsilon_{ij}^{(s)}$ from the Gumbel distribution for each student and school. (Use this same set of simulated error terms in each iteration of the optimization procedure.)

2. Within each simulation, use the logit smoother to determine the probability that the resulting set of applications $A_i^{(s)}$ is consistent with the observed application decisions A_i. Denote this as P_i^s. This is a continuous approximation of the indicator variable function. This requires setting a value of $\lambda \in [0, 1]$, where lower values of λ are a better approximation of the indicator function.

3. Then approximate the integral within the likelihood function as:

$$\frac{1}{S}\sum_{i=1}^{s}\Big(\frac{Z_{iS_i}\exp(v_{iS_i}+\epsilon_{iS_i}^{(s)})}{\exp(\epsilon_{i0}^{(s)})+\sum_{j'=1}^{J}Z_{ij'}\exp(v_{ij'}+\epsilon_{ij'}^{(s)})}P_i^{(s)}\Big)$$

Appendix E Data Appendix

E.1 Estimation of Location and Distance

Boston is split into 867 geocodes for the purposes of school assignment and transportation. A geocode is unit that is typically smaller than a census block group. For reference, in the 2020 Census Boston has 581 census block groups and 207 census tracts. We use data on a student's geocode to compute addresses as follows:

1. Check if the student also participated in a traditional BPS match during the same year. If so use this location. For grade 5 in 2017, 69% of students are assigned a location from this method.

2. Check if the student participated in a traditional BPS match during any of the previous 5 years. If so, use the location of the most recent year. For grade 5 in 2017, about 11% of students are assigned a location from this method.

3. If neither of the two methods above apply, infer student location based on the current school attended, using the closest geocode to the school address.For grade 5 in 2017, about 10% of students are assigned a location from this method.

Using this procedure, we assign 90% of students a location.

Once we determine student location, driving time (in minutes) between the center of the student geocode and the school address is used as the measure of distance, using the Google Maps API. For the Uncommon charter network, there are multiple school locations, so we computed the distance between each student and the closest location.