Win or Lose: Residential Sorting After a School Choice Lottery

Andrew Bibler*

Stephen Billings†

March 6, 2018

Abstract

Typically, studies of school choice lotteries show large gains in school quality and better long-term outcomes for winners. In practice, losers may compensate by opting out of the public school system, obtaining after hours tutoring, attending a magnet school or relocating to another neighborhood with a higher quality home school. The research presented here examines residential relocation and opting out of the public school system in response to the results of a school choice lottery. We show that rising kindergarten and sixth grade students who lose a school choice lottery are about 6 percentage points more likely to exit the district or change neighborhood schools (30% increase) and make up 0.25-0.28 standard deviations in average school test scores between lottery assignment and attendance the following year. Using hedonic-based estimates of land prices, we estimate a 10% to 14% housing price premium for access to a school with one standard deviation higher test scores for families that have a high and immediate demand for better quality schools.

*University of Alaska Anchorage, ajbibler@alaska.edu

†University of Colorado - Boulder, stephen.billings@colorado.edu

Acknowledgements: We thank seminar participants at Tulane University, University of Alaska-Anchorage, University of Colorado as well as participants at 2017 Urban Economics Association Meetings, 2017 Association for Public Policy Analysis and Management Annual Meetings and the 2018 Association for Education Finance and Policy Annual Meetings .

1 Introduction

The popularity of school choice in public school systems across the U.S. has led to the development of new allocation mechanisms to assign children to oversubscribed choice schools. A number of large and diverse school districts (e.g. Boston, Charlotte, Chicago, New York, San Francisco, etc.) administer school choice lotteries with a goal of random assignment to oversubscribed schools. Over the last 2 decades, the use of random assignment has led to a proliferation of economics and education studies that examine the impact of higher quality and specialized schools on the academic and behavioral outcomes of children. These papers consistently find mixed impacts for winners on short-term outcomes[1] , but substantial benefits in longer-term outcomes.[2] The literature also finds heterogeneity in impacts due to student attributes such as gender as well as different dimensions upon which one can measure school quality such as school peers, teachers and other inputs.

In spite of this sizeable literature on the impacts of winning a school choice lottery, little is known about what happens to the losers of school choice lotteries. Scholars often recognize non-compliance with lottery assignment, and serious discussion is given to Intent-to-Treat (ITT) effects based on lottery assignment or Average Treatment Effects (ATE) for lottery compliers, but little attention is paid to the behavior of losers who need to compensate for the lower quality school assignment. This compensation likely takes the form of moving to a neighborhood with higher assigned school quality, exiting public schools for private schools or even moving to another public school district. Losers may compensate in smaller ways through extra tutoring or parental involvement in the classroom. The research presented here examines the behavior of school choice applicants and attempts to highlight compensating residential movements that may help minimize differences between the school attended of lottery winners and losers. The cost of this compensation is nontrivial with households having to pay for private school tuition, or higher home prices for homes assigned to higher quality schools as well as moving costs to change school assignment. Results provide two new insights. First, we can estimate how much of the gap in school quality is made up by lottery losers through residential relocation. Second, we provide a new estimate of the value of school quality by examining incurred home price differentials for losers to improve school quality after losing the school choice lottery. Thus, we provide an estimate of the value of school quality for a population that has strong preferences for school quality and an immediate need to purchase more school quality. This method for estimating school quality should be less sensitive to neighborhood quality

[1] e.g. end-of-grade test scores (Abdulkadiroglu et al. [2015] ; Cullen et al. [2006].; Hoxby and Murarka [2009]; Hastings et al. [2006]; Rouse [1998]); self-reported disciplinary issues (Cullen et al. [2006])

[2] e.g. adult crime (Deming [2011]), and high school graduation and college matriculation (Deming et al. [2014])

as families have a clear need to move explicitly for accessing a higher quality residentially assigned school. Relocation choices of winners even provides insight into housing consumption reallocation after gaining access to a higher quality school.

Specifically, we use a school choice lottery that has been incorporated into previous work (Deming [2011], Deming et al. [2014], Bibler [2017]), the Charlotte-Mecklenburg Schools (CMS) open enrollment program. This school lottery assigns children to oversubscribed schools and began in 2002 after the end of racial-based busing. CMS is a large urban school district and its school choice lottery provides a number of choice options at all levels of primary education. We limit our analysis to lottery applicants that applied to oversubscribed schools in CMS in order to compare lottery winners and losers across a number of outcomes. Traditionally, school lottery papers provide two types of estimates. First, one can estimate an intent-to-treat (ITT) effect of winning the lottery on various outcomes. Second, one could use a 2SLS estimator to provide a LATE for students who comply with lottery assignment on various academic and behavioral outcomes. The difference between these two estimators is the endogenous reaction of students to the lottery results. The fact that winners and losers likely react quite differently to lottery results in terms of residential location decisions is the focus of our analysis.

We find that rising kindergarten and sixth grade students who lose a school choice lottery are about 6 percentage points more likely to exit the district or change neighborhood schools, which represents an increase of about 30% over baseline moving probabilities. Rising Kindergartners and 6th graders who lost the lottery and change neighborhood schools make up between 0.23 and 0.46 standard deviations in average school test scores between lottery assignment and attendance the following year. Using a hedonic-based estimate of land prices that controls for neighborhood attributes , we estimate a willingness to pay of between 5.3% and 5.4% in housing prices for these respective gains in school quality. Consistent with post lottery sorting based on student composition, we find that kindergarten lottery losers move to schools with less economic disadvantage and more white students even after controlling for school quality, but this effect does not hold for rising 6th grade lottery losers. For the smaller sample of winners that move, we find limited evidence of sorting to higher or lower priced neighborhoods or moving to be closer to their first choice school.

Our results for school value complement a long literature on the non-market valuation of school quality (see Black [1999];Andreyeva and Patrick [2017];Figlio and Lucas [2004] Fack and Grenet [2010]; Dhar and Ross [2012], etc.). This literature finds between a 2% and 10% increase in home values for a 1 standard deviation increase in school quality. Given we observe residential movements, we can directly link incurred

changes in school quality to residential housing prices. We start comparing our results to the literature by first verifying that a standard boundary discontinuity estimate using our data and study area provides similar results as the literature - a 7% house price premium for a 1 SD increase in school quality. We then interact our change in school quality estimates for lottery losers with changes in neighborhood housing prices (conditional on neighborhood atrtibutes). Using lottery losers that move, we estimate a housing price premium of 14% for Kindergartners and 10% for 6th graders for a 1 standard deviation increase in test scores. The larger estimate for school quality using lottery losers is quite plausible for two reasons. First, lottery applicants are living in neighborhoods with above average school quality to begin with and thus increasing school quality by 1 standard deviation would represent moving from an above average school to one of the best schools in the district. Thus, there may be a substantial premium for this type of school quality. Second, these estimates of the value of school quality are only for families that have strong preferences for school quality whereas traditional estimates are diluted by the presence of households without school age children or households that only consume private schooling.

Our work also complements recent papers (Billings et al. [2017], Brunner et al. [2012];Cullen et al. [2013] ;Mertens Horn [2017]) that provide empirical evidence of households with strong preferences for school quality responding to changes in school choice through residential location decisions. For example, Billings et al. [2017] show that households gentrify neighborhoods assigned to failing schools when they are allowed to opt out of their neighborhood school under No Child Left Behind. Cullen et al. [2013] and Cortes and Friedson [2014] find that households strategically move to neighborhoods located in lower-performing school attendance zones in order to improve their odds of qualifying for the Texas "Top Ten Percent Plan." Together, this work provides empirical evidence of theoretical assumptions and models used in Ferreyra [2007] and Nechyba [2000] to explain residential sorting based on school quality. In our context, lottery losers have a strong incentive to relocate to improve school quality and based on the revealed strong preferences for school quality given by being a lottery applicant, this work predicts residential relocation. More generally, better understanding the losers of school choice lotteries will provide insight into the design of school choice systems and how school choice policies affect residential location decisions. The design of improved school choice is important as states and cities expand and refine school choice (Jordan and Gallagher [2015]).

Our results have important implications for education policy. Often, little attention is paid to lottery losers who may be incurring substantial costs to improve school quality and thus policymakers may want to try expand popular school choice options to minimize the number of families that are not given access

to a school because it is oversubscribed. Additionally, our large estimates of the value of school quality point to substantial heterogeneity in how families value school quality and that families with strong school preference and high performing schools likely have nonlinear or larger marginal benefits from improving school quality. Our results cannot speak to the optimal distribution of school quality within a school district, but results show that parents are willing to incur large costs so that their child can gain access to a high quality school. Given these costs, there are likely large returns to public investments that expand access to high quality or specialized magnet school programs. The paper proceeds as follows. Section 2 describes the school choice lottery in our study area of Charlotte-Mecklenburg Schools; Section 3 describes our data of students and school lottery applications; Section 4 provides an empirical model to examine the impact of lottery results on residential relocations and Section 5 provides results. Section 6 concludes.

2 Lottery

Every student enrolled in Charlotte-Mecklenburg Schools (CMS) is assigned to a neighborhood (home) school based on geographic boundaries. CMS students can opt out of their neighborhood school through a centralized lottery, for which they can submit up to three programs (school, grade and year) in order of preference.[3] Non-guaranteed seats are assigned in three rounds.[4] Only first choices are considered in the first round. If there are fewer applicants than seats available to a given program, then all of the applicants to that program will be assigned to their first choice.[5] We focus on oversubscribed programs, because identification comes from comparing winners and losers from the same lottery. When the number of applicants is greater than the number of available seats (the choice is oversubscribed), seats are assigned quasi-randomly. Seat assignment is not completely random, because the probability of winning for a particular student depends on their priority group. Priority groups refer to sets of students that meet (or do not meet) some pre-specified criteria. Over our sample period, priorities were based on geographic location and whether the student's neighborhood school is a Title I *choice school*.[6] We use lottery (program of application by year) fixed effects and condition on other lottery rules to exploit the fact that winners should be randomly

[3]We will use the terms neighborhood school and home school interchangeably to refer to the school that the student is assigned to based on geographic location, which is the school they would attend unless they opt out through the lottery, relocate, or exit the district.

[4]Students with an older sibling in a school are guaranteed a seat in that school by making it their first choice.

[5]We use the term program rather than school since students apply for specific grades at a school as well as special magnet programs that encompass only a portion of classrooms in a school.

[6]Title I schools are those with a high percentage of economically disadvantaged students. A Title I school becomes a Title I *choice* school if they fail to meet adequate yearly progress in the same subject for two consecutive years. No Child Left Behind (NCLB) requires that the district allow students assigned to Title I choice schools the opportunity to attend a non-Title I choice school, but it does not require the district to allow students to choose the school they are offered.

chosen within these groups.[7]

Our identification strategy relies on comparing students in the same priority groups who varying in winning the lottery. After going through all first choices, second and then third choices are considered in a similar fashion. If a student's second or third choice filled up in a previous round, then they remain unassigned in that round. All students are assigned to a neighborhood school based on pre-determined geographic zones, which is the school they will be assigned to if they are not otherwise assigned in the lottery. The lottery considers student choices in sequence, so students are most likely to win a choice by picking it first, and more seats are awarded in the first round than in the second or third. The treatment assignment variable is a dummy variable for winning their first choice, which should be random after conditioning on the lottery fixed effects and rules.

The data contain up to three choices for every student in order of preference, as well as sibling placement, Title I choice placement, economic disadvantage status, and transportation zone.[8] We start with the sample of all applicants without a guaranteed seat and proceed in the following way. We generate lottery fixed effects as the application number by year combinations.[9] We proxy for Title I choice school using whether or not any student from their neighborhood school was placed under the Title I choice option that year. In all specifications, we condition on lottery fixed effects, and Title I choice school status by year, and economic disadvantage status by year. The assignment, conditional on lottery fixed effects and rules, provides the exogenous variation used to estimate the treatment effects.

In addition to conditioning on lottery rules, we must also consider the stated requirements for specific lottery programs. This is mainly a concern for the sixth grade sample, for which some programs restrict access to students who meet certain requirements. These requirements are generally based on whether or not the student scored at grade level or more on end of grade exams in the prior year. For example, students who wish to enter one of the STEM programs in their sixth grade year must score at grade level in reading, math, and science on their fifth grade end of grade exams. In this case, we can check whether each student met the stated requirements for the program that they applied to with their first choice in the lottery. We restrict to students who met the requirements for their first choice program.[10] Appendix

[7] In addition to priority groups, all applicants are ordered based on randomly assigned numbers. When a choice is oversubscribed, the combination of priority groups and randomly assigned numbers determine who wins the lottery.

[8] CMS stopped reporting economic disadvantage after 2010. For years 2011-2012 we proxy for economic disadvantage at the time of application using economic disadvantage status from the NCERDC data. For kindergarten students, the economic disadvantage proxy comes from their third grade observation in NCERDC. For rising sixth grade students, we use their lagged (fifth grade) value for economic disadvantage.

[9] We also test moving, attrition, and balance using application-year-home school fixed effects as a robustness check. There are some lottery rules that these fixed effects might capture, whereas the more general fixed effects may not.

[10] In some cases, we can not view whether the student met the stated requirements. Specifically, arts schools require an audition or portfolio assessment, and and leadership schools require an interview. We drop these programs from the analysis, because

Table 1 provides the breakdown of the portion of applicants that win access to an oversubscribed school by lottery application year. There is a fair amount of heterogeniety across years with the share of applicants obtaining their first choice averaging about 42% for rising Kindergarterners and 48% for rising 6th graders over our study time period of 2009-2013 and the varying probabilites from year to year may limit the ability for applicants (especially 6th grade) to consistently predict probabilities from past year results.

3 Data

In order to examine residential movement for students that apply to a school choice lottery, we incorporate student level data for the Charlotte-Mecklenburg Schools school choice lottery linked to data on neighborhood location and student demographics that is provided by the North Carolina Education Research Data Center (NCERDC). This data is unique in that it allows us to to define residential location for students based on geographic attendance boundaries for school assignment (home school) during the lottery application time period (most often the year prior to kindergarten and 5th grade) as well as the following year (K and 6th grade). For 5th and 6th graders, we can also determine Census Block Group (CBG) 2000 of residence. Therefore, we can observe any changes in residential location across neighborhoods and/or school assignment zones. The home school is the school that a student will be assigned to in the following year, unless they opt out through the lottery or change residence and move into the boundary of a different school. NCERDC linked the lottery data from CMS with statewide data.[11] Linking the lottery data with statewide data provides additional information on end-of-grade exam scores, 3rd-8th grade CBG of residence, and student demographic data.[12] We focus on rising kindergarten and sixth grade students, because students are more likely to apply through the lottery in those years since they are at the beginning of elementary and middle school for most students in CMS.[13] The analysis sample includes students entering kindergarten and sixth grade from the 2008-2009 through 2011-2012 school years who submitted an application for a program in the CMS school choice lottery, and were linked from the CMS data to the NCERDC data. For the kindergarten lottery sample, we are limited to only CMS lottery data. For the sixth grade sample, we include a combination of the CMS lottery data and the NCERDC data which provides a richer set of covariates. We restrict our lottery sample to students who made at least one choice in the 2009 - 2012 lotteries, did

assignment is not random, conditional on observables.

[11]NCERDC was able to link between 93% and 97% of all observations from the CMS data in each year.

[12]Even though in previous work, Billings et al. [2017] incorporated exact student addresses, this data could not be incorporated into this study due to restrictions by CMS in providing the lottery data. Additionally, all end-of-grade exams are scaled to have mean zero and standard deviation of one based on statewide testing results for each grade and year.

[13]The number of high school students applying to oversubscribed schools is too small to include as a separate analysis.

not receive a sibling placement, and applied to a program-year for which at least one individual won and one lost the lottery. We then drop students who applied to a program at their neighborhood school, applied to a program with subjective entrance requirements. For the sixth grade sample, we restrict to those with a lagged observation from the NCERDC data.[14]

Since we later want to incorporate information on housing prices by CBG and also attendance zone boundaries, we also incorporate detailed data on home attributes (e.g. beds, baths, lot size, building area, etc.), CBG neighborhood attributes (e.g. median household income, population density, etc.) and information on the sale of a property (e.g. sales price, date of sale). This dataset represents an extract of all the tax assessor records from Mecklenburg County from 1995-2015. We focus on the year of application to determine the set of home sales that populate a given CBG neighborhood and year. We later use all this information to generate an estimated average neighborhood land price for a given year which, conditional on all of our controls for housing and neighborhood attributes, is representative of the value of school quality. We describe the details of constructing our value of school quality in the next section.

3.1 Summary Statistics and Random Assignment Check

Tables 1 and 2 summarize all rising kindergarten and sixth grade students in CMS with breakdowns for winners and losers in our lottery samples. In general, we see a fair amount of mobility amongst all rising kingergarten and sixth grade CMS students with 27% of students moving by the following year. These mobility rates are somewhat lower for lottery applicants given by won and lost column headings and consistent with a lottery applicant pool that is economically better off and likely has more housing stability than other CMS students. Overall, lottery applicants are less hispanic, have less economic disadvantaged (free and reduced lunch) and score better on end-of-grade exams.

These two tables summarize our lottery applicants by comparing the winners and losers. Columns 2 and 3 for each table summarize averages for lottery winners and losers. Columns 4 through 7 test for differences in outcomes and student attributes between the winners and losers. Column 4 provides unconditional differences between winners and losers, while column 5 adds lottery fixed effects (program of application by year) and control for other variables that alter the probability of winning the lottery.[15] Column 7 uses lottery fixed effects that are program by year by neighborhood school indicators. Because the lottery groups

[14]Later results are similar when we include NCERDC data without lagged observations.

[15]Other lottery controls include economically disadvantaged status, title I choice status of assigned neighborhood school, interaction between economic disadvantage and title I choice status, and English second language eligibility status. For the sixth grade sample, we also include dummies for grade level achievement, gifted status, and an indicator for being below grade level in reading and applying to a non-magnet school.

are more restricted in this case, and we only use lotteries with at least one winner and one loser, the number of observations falls in column 7, relative to columns 4 - 6. The reason for adding economic disadvantage, ESL (English as a second language) status, grade level achievement, and gifted status is that winning can depend on these criteria. In addition, we add home school fixed effects for comparison.[16]

The first outcome, *Mover (Change HS + Exit)*, is a dummy variable indicating whether a student has a different neighborhood school in the following year, which includes those missing a lead neighborhood school (i.e. they exited CMS). As such, the first row in each table shows the estimates for the effect of winning the lottery on the probability of changing home schools or exiting CMS. After conditioning on lottery fixed effects (application choice by year of application), adding other covariates has little impact. For example, from kindergarteners in Table 1, column 4 with lottery fixed effects and controls, suggests that lottery winners are 6.8 pp less likely to exit or change neighborhood schools. Column 6 uses application by year by home school groups as lottery fixed effects, in which case we estimate that lottery winners in the kindergarten sample are 5.7 pp less likely to exit CMS or change neighborhood schools. Either estimate is large relative to average lottery mover probabilities of 24%.

The second outcome, *Change HS (Stay)*, is a dummy that is equal to one for students who do show up in the CMS data the following year and have a different home school than indicated in the applicant year. This allows us to isolate how much of the difference in exits plus movers is due to students who remain in the public school system, but change home schools. From Table 1, kindergarten lottery winners are between 0 and 2 pp more likely to remain in the district with a different home school, indicating that almost the entire win-lose difference in movement between lotteries comes from an increased probability of exiting for those who lost the lottery. The findings of a large effect of losing the lottery on exiting CMS is consistent with opting out of the public school system and attending private school or more suburban school districts which in this study area contain higher quality schools in terms of test scores. However, the fact that winning the lottery has a much smaller impact on the probability of moving to a different home school within the school district does not limit residential sorting in reaction to lottery results. Even if the winners and losers move at the same rate, they could still choose new locations specifically based on school and neighborhood quality, and housing prices. This could show up as differences on the intensive margin,

[16]There are at least two reasons why adding home school fixed effects or using application-year-home school combinations as lottery fixed effects could help control for lottery rules. First, full magnet schools have an additional priority for students who live in close proximity to a full magnet school. Since we don't have information on exact location of residence, the home school fixed effects may help mitigate any error from mis-measuring this priority. Second, magnet lotteries could, in theory, limit the number winners from a specific home school. Based on the magnet process explanation, students from a home school lose some priority if there are already a disproportionately high number of students admitted to that program from their home school. Anecdotally, this constraint is not generally binding in practice. Lastly, since the final priority is based on whether or not the magnet school serves the transportation zone of the students, conditioning on home school effectively controls for this priority criteria.

i.e. even though winners are just as likely to move, they care less about the school quality in their new neighborhood because they have already lotteried out of that school in favor of their first choice program in the district.

Finally, the third variable in Table 1 , *Attend Lagged HS*, is in indicator equal to one for students who attend the school that was their assigned home school in the initial lottery. For kindergarten students, they are assigned a home school based on location of residence at the time of the lottery (the school year before they enter kindergarten). So attending their lagged home school simply means that at the time of the lottery in their kindergarten year, they are attending the school that was their assigned home school for their kindergarten year one year earlier. From Table 1 , about 40% of lottery losers in the sample attended their initial home school assignment. There are several ways in which students who lost the lottery end up attending a different school. They could be admitted to their first choice from the wait list up until the end of the first quarter of the school year. They could also win their second or third choice in the lottery, which would lead to an assignment that does not match their home school. Of the lottery losers in the kindergarten sample, 80% made a second choice in the lottery, and almost 64% made a third choice. Among students who lost their first choice, 30% won their second or third choice in the lottery. Relocating residence into a difference home school boundary, and exiting CMS are other ways in which a student can end up in a different school.[17] In comparison, only 6% of lottery winners attend their lagged home school assignment. After conditioning on lottery fixed effects and lottery rules, we find that lottery winners are about 30 - 32 pp less likely to attend their lagged home school.

The comparable estimates on moving, exiting, and lagged home school attendance for the sixth grade sample are shown in the first three rows of Table 2. Lottery winners in the sixth grade sample are 5 - 6 pp less likely to changes home school or exit the district, a similar number to that in the kindergarten sample. In contrast to the kindergarten sample, the estimated impact of winning the lottery on staying in the district with a different home school is almost identical to the impact on exiting plus moving, about 5 - 6 pp. That suggests that the entire difference in responses to the lottery outcomes between winners and losers is due to students remaining in the district, but changing home schools between school years. The main difference between the kindergarten and sixth grade samples is that lottery losers in the sixth grade sample are moving within the school district rather than exiting the school district. This result is consistent

[17] There is also a second lottery in the district that students can apply through. However, this lottery is typically designed for students who entered the district too late to participate in the first lottery. A student who participated in the first lottery could also apply through the second lottery, but they would forego any outcomes from the initial lottery process. It seems unlikely that many students will find it desirable to apply in the second lottery after losing the first, since most seats are assigned in the first lottery, and in particular, high demand programs are filled up in the first lottery.

with families initially applying to enter a high quality magnet public school and if they are unsuccessful they may opt out to suburban school districts or private schools. Sixth grade families are already invested in the public school system and may have other children that are in public school and thus are less likely to switch to private school or move to suburban school districts. In the sixth grade sample, the impact of lottery outcomes on the probability of attending their initial home school assignment or being assigned their second or third choice schools is similar to that in the kindergarten sample, about a 30 pp higher probability for lottery losers.

Tables 1 and 2 include balance tests for some baseline characteristics, and F-tests for the joint significance of student characteristics that should not alter the probability of winning the lottery. Table 1 includes an F-test for joint significance of female, black, white, hispanic, and whether the student made a second or third choice in the lottery on predicting if the student won the lottery. The p-value when using the program by year fixed effects is 0.47. When using the more restrictive program by year by neighborhood school lottery fixed effects in column 6, the p-value for joint significance of these variables is 0.8. In both cases, we accept the null hypothesis that these student characteristics do not explain winning the lottery. In Table 2 , we also include balance tests for lagged achievement and limited english proficiency (LEP) status, and the p-value for joint significance in the sixth grade sample is around 0.8 with both the basic and more restrictive lottery fixed effects. In both cases, student attributes do not explain lottery results.

Before we formally analyze how lottery winners and losers residentially sort, we should quantify how much initial location matters for where families apply to schools in the lottery. Travel distance to school is costly for families and in some cases, families may have to provide transportation to the school. The location of students and magnet schools of varying quality at the time of application may be important in interpreting the impacts of lottery results more broadly and in thinking about families on the margin of applying to the school choice lottery for magnet schools, but should have no bearing on our identification strategy since all of our results are conditional on applying to the lottery and home school fixed effects. Figure 1 provides an initial check that sixth grade winners and losers are similar in distance to their first choice school. We see minimal differences in the distribution of distances from a student's home CBG and their first choice school at the time of application. The fact that losers appear to be slightly further away from first choice schools simply speaks to the fact that students are willing to apply to schools that are further away if they are higher quality and higher quality schools are more oversubscribed in the school lottery (lower probability of being a winner). Figures 2 and 3 confirm this fact with Figure 2 showing no relationship between potential gains in school test scores and distance to first choice school at time of

application for schools with higher win probabilities ($\geqslant 0.5$) in the lottery. However, Figure 3 shows that students are willing to travel further to higher test score schools if the school is higher quality in multiple dimensions as shown by the school being in high demand in the lottery (win probability < 0.5). In general, these statistics show that distance likely matters, but lots of students are willing to incur travel costs for a high quality school.

4 Methodology

4.1 Lottery Outcomes, Moving, and School Quality

In order to directly test the role of lottery outcomes on school quality attended, moving and housing prices in new neighborhoods, we need to formalize our empirical model. We begin our analysis by estimating the impact of winning the lottery on assigned school quality using the following specification.

$$S_{it}^{as} = \alpha^{as} + \beta^{as} \cdot W_{it} + \Gamma^{as} \cdot X_{it} + \Omega_{i}^{as} + \varepsilon_{it}^{as} \tag{1}$$

Where S_{it}^{as} represents the average end of grade average math and reading exam score in the school that student i was assigned to in the lottery at time t.[18] The assigned school is the final assignment that the student received in the lottery. For a student who won their first choice in the lottery, S_{it}^{as} equals the average test score at their first choice school. Similarly, if a student won their second (third) choice, the quality measure will reflect the quality of the school the student specified with their second (third) choice. In equation 1, W_{it} is a dummy variable equal to one if student i won their first choice in the lottery, and Ω_{i}^{as} represents lottery fixed effects. The most basic lottery fixed effects are application choice by year group indicators. Let X_{it} represent a vector of student level characteristics, including other factors that influence the probability of winning the lottery. For example, economically disadvantaged status, assignment to a title one choice school, and grade level status in math, reading, and science for sixth grade students.[19] In addition to controlling for factors that influence the lottery outcomes, X_{it} also includes student level characteristics including sex, race indicators, and lagged test scores for sixth grade students. So $\hat{\beta}^{as}$ represents the within lottery difference in average test scores of assignment schools between winners and losers. If $\hat{\beta}^{as} > 0$ it means that students who won the lottery were assigned to schools with higher average test scores than the students who lost the same lotteries, and represents a measurement of the assignment test score advantage

[18] Assignment is made at time t to a school that the student will attend in time $t + 1$.
[19] Test scores may matter for choice schools with academic entrance requirements.

of winners.

In our second specification, we replace the left hand side variable in equation 1 with the average test score of the school that the student actually attended in the following year, S^{at}_{it+1}. Now the analogous estimator, $\hat{\beta}^{at}$, represents the difference in average test scores between the schools that the winners and losers actually attended, or the attendance test score advantage. Similar to $\hat{\beta}^{as}$, $\hat{\beta}^{at} > 0$ indicates that lottery winners attend schools with higher average test scores than those who lost the same lotteries. We then combine the two measure of school quality to form a third measure of interest, $\Delta S_i = S^{as}_{it} - S^{at}_{it+1}$, and provide estimates of the following specification.

$$\Delta S_i = \alpha^{\Delta} + \beta^{\Delta} \cdot W_{it} + \Gamma^{\Delta} \cdot X_{it} + \Omega^{\Delta}_i + \varepsilon^{\Delta}_{it} \tag{2}$$

Where ΔS_i represents the difference in the average score between the school that student i was assigned at time t (to attend in time $t+1$) and the school that student i actually attended in time $t+1$. This will equal zero for students who attend the school that they were initially assigned in the lottery, and will be non-zero when student i attends a different school than they were assigned in the lottery. Differences in average scores, i.e. non-zero values of ΔS_i, come from some form of non-compliance with lottery assignment. For example, a student could be admitted off of a waitlist to their first choice school or a family could alter the student's assigned neighborhood school by relocating. In such a case, if the student attends their new neighborhood school in the following year then the average assigned and attended scores will likely differ.[20] $\hat{\beta}^{\Delta}$ provides a measurement of the school quality that lottery losers make up between the end of the lottery assignment and school attended in the following year. If $\hat{\beta}^{\Delta} = 0$, then any changes in school quality between assignment and attendance for the lottery losers are offset by equivalent changes for the lottery winners. This would be true, for example, if every student complied with their initial assignment. In that case, the assignment and attendance advantage for winners are equivalent, and lottery losers took no action to makeup for losing the lottery by finding a way into a different school than they were initially assigned. On the other extreme, if $\hat{\beta}^{\Delta} = \hat{\beta}^{as}$, that suggests that the assignment advantage disappears in the time between lottery assignment and school attendance in the following year. One way that this could happen, would be if every lottery loser attended a school with equivalent test scores as their first choice school in the lottery. In that case, there would be no attendance advantage for lottery winners. When $0 < \hat{\beta}^{\Delta} < \hat{\beta}^{as}$, there is some reduction of the assignment gap between the time of assignment and

[20] Unless the student was also assigned to their future neighborhood school in the inital assignment process. Or in the unlikely event that the assigned and attended schools are different schools, but have identical average test scores.

attendance. One way that this would occur is from lottery losers attending schools with higher test scores than they were initially assigned, although it is also possible that lottery winners attend schools with lower test scores than they were initially assigned.

We also expand on equations (1) and (2) by incorporating the moving decisions of lottery winners and losers. We focus on whether or not the students had a change in their assigned home school between the time of the lottery and the following year. We construct a dummy variable to indicate whether or not a student changed home schools, $move_i = 1[HS_{it} \neq HS_{it+1}]$. Where HS_{it} represents the home (neighborhood) school that student i was assigned to in year t.[21] A change in neighborhood school between lotteries indicates changing residence because neighborhood schools are assigned based on geographic boundaries. We use the information on neighborhood school assignments to estimate versions of equation (2) where we compute average $\Delta\widetilde{S}_i$ for students that win the lottery and move, win the lottery and stay, lose the lottery and move, and lose the lottery and stay.[22] For winners, we are limited to looking at those that do not comply with assignment otherwise $\Delta\widetilde{S}_i = 0$. Therefore, winners that comply are the reference groups in our moving analysis.

4.2 Lottery Outcomes, Moving, and Housing Prices

After considering the changes in assigned and attended school quality between lottery winners and loser, and movers and stayers, we consider differences in housing prices by home school zones. We focus on making analogous comparisons to the school quality results. That is, how do housing prices change for lottery winners and losers that move after the lottery? The analysis and results are slightly different in the case of housing prices, because we care about capitalized school quality, which would only be reflected in the home price of neighborhoods that have guaranteed access to a school, namely the resident's home school. Therefore, we focus on neighborhood school boundaries for home schools that students are geographically assigned to even if the student attends another school. For the purpose of computing average housing price residuals, neighborhood school assignments are based on the year that a student applies for the kindergarten/sixth grade lottery and the following year after the student begins school. We begin by estimating hedonic housing price regressions for home sales in the county, as shown in equation (3).

[21] Home school assignments in the lottery data in year t refer to the home school that the student is assigned to for year $t+1$, based on current location. The assigned home school of a student is the school that they will be assigned to attend unless they opt out through the school choice lottery, move into a different home school zone, or exit the district through relocation or entering a charter/public school.

[22] Where $\Delta\widetilde{S}_i$ reverses the difference from equation 2, i.e. $\Delta\widetilde{S}_i = S^{at}_{it+1} - S^{as}_{it}$. Since the focus is on the lottery losers in this specification, using $\Delta\widetilde{S}_i$ helps to compare these estimates for lottery losers with the estimates of equation 2.

$$Ln(P_{hst}) = \beta \cdot X_{hst} + \alpha N_{hst} + \delta_t + \varepsilon_{hst} \tag{3}$$

Where P_{hst} represents the sale price of home h in home school boundary s at time t. X_{hst} represents characteristics of the home including lot size, home size, age of the home and other structural attributes; N_{hst} provides controls for neighborhood attributes including median household income, population density, percent unemployed, distance to central business district (CBD), distance to the interstate, indicators for being located on a busy road and in a floodplain, and distance to a park; and δ_t indicates fixed effects for the year and quarter of sale. We then average the residuals from the housing price regression within home school boundaries to get a measure of the average unexplained portion of the home sales, which reflects school quality.

$$\tilde{P}^h = \bar{\hat{\varepsilon}}_s = \frac{1}{n_s} \sum_{h=1}^{n_s} \hat{\varepsilon}_{hst} \tag{4}$$

Where $\tilde{P}^h$ then represents the average residualized price within home school boundary h. Let $\tilde{P}^h_{it}$ represent the average residualized price for the home school that student i is assigned to at time t. In models that include rising 6th graders, we also implement models that use school assignment variation within a home school boundary based on CBG fixed effects. We estimate housing price residual parameters for winners and losers that move based on Equation 5 below.

$$\Delta\tilde{P}^h_i = \alpha^p + \gamma^p_{lost} \cdot move_i \cdot (1 - W_{it}) + \gamma^p_{won} \cdot move_i \cdot W_{it} + \Gamma^p \cdot X_{it} + \Omega^p_i + \varepsilon^p_{it+1} \tag{5}$$

Where $\widetilde{\Delta P}^h_i = \tilde{P}^h_{it+1} - \tilde{P}^h_{it}$, and $\hat{\gamma}^p_{lost}$ and $\hat{\gamma}^p_{won}$ are now estimators of the change in the average residual sale price in the new neighborhood school boundary for those who moved after losing and winning the lottery, respectively. Since we are using changes in home school assignment to determine movers, the neighborhood school residual prices only vary for students who move. So these estimates are relative to non-movers, for whom the change between old and new neighborhood average residual prices is zero by construction.

5 Results

Our summary statistics highlighted that winners and losers are balanced on observables and that losers are more likely to leave the school district or move to another neighborhood school after losing the lottery relative to winners. We still need to test if losers are moving to improve school quality and how much are they paying for changes in school quality in terms of housing prices.

5.1 School Quality - Assignment to Attendance

Table 3 highlights the school quality (test scores) of school assignment based on the first round results of the school choice lottery relative to the school quality actually attended in the next school year after students may have moved to gain access to a different neighborhood school, received access to a different school based on a wait list/other school choice option, or simply chosen not to attend the school assigned in the lottery and instead attend their home (neighborhood) school. Table 3 provides two dimensions of insight. First, row values for Won and Lost and their differences provide unconditional means for average math and reading test scores for these groups and highlight a small difference between assigned and attended school test scores for lottery winners, but substantial improvements for losers. Second, this table highlights the differences in school quality (test scores) for winners and losers from assignment to actual school attended once we account for all the priority group rules in the lottery.

A couple elements of Table 3 are interesting. First, winners are clearly assigned to higher test score schools consistent with the nature of the school choice lottery. The assignment difference, $\hat{\beta}^{as}$ from equation 1, is given in the Conditional Difference row for the assigned column and indicates an assignment advantage of 0.45 standard deviations for Kindergarten and 0.61 standard deviations for 6th grade. This substantial difference between winners and losers is expected, but the key for our analysis is how this difference changes when we look at the actual school attended. Columns 2 and 5 provide differences between winners and losers based on test scores of actual school attended in the school year following the lottery. Differences between winners and losers are now only 0.30 and 0.26 standard deviations for kindergarten and 6th grade students, respectively. This large decrease is summarized in columns 3 and 6 as a difference-in-difference estimate, which shows estimates of β^{Δ} from equation 2, and indicates the amount of test score gap differences between winners and losers that is made up between initial assignment and attendance in the following year. Results show that 0.14 standard deviations were made up between assignment and attendance by Kindergarteners, and 0.35 standard deviations for 6th graders.

Changes in school quality between assignment and attendance in Table 3 appear to be entirely driven by the behavior of losers. Kindergarten and 6th grade winners end up attending schools of the same quality as they are assigned in the lottery, but losers improve school quality by about 0.14 standard deviations and 0.35 standard deviations respectively. Even though most winners comply with lottery assignment, about 10% of winners do not comply with lottery assignment and attend their neighborhood or another school.[23] Parents may forgo their winning lottery assignment for a number of reasons including attending schools with their friends, obtaining more information about lottery choice and deciding they prefer a neighborhood school, or transportation costs/issues in accessing a non-neighborhood magnet school chosen in the lottery. This dynamic highlights the importance of considering the actions of lottery winners in this analysis since they may, for a number of reasons, decide not to attend their assigned school in the lottery.

Table 4 breaks down the intuition from Table 3 into movers and stayers after lottery assignment. These results will provide some insight into the role of stayers and movers in generating the narrowing of school quality differences between winners and losers given in column 7 of Table 3 The results in Table 4 show the difference in test scores for assigned versus attended school for four groups: Losers that move neighborhoods (change home schools), Losers that stay (same home school), Winners that move neighborhoods (change home schools) and do not comply with lottery assignment, and winners that stay in their neighborhood and do not comply with lottery assignment. Outcomes for these groups are relative to the group that has no difference between assigned and attended school - winners that comply with assignment. If residential relocation to improve school quality is the main story in our results, then losers that change home schools should see the biggest gains in school quality from lottery assignment to actual school attended.

Results for Kindergarten in column 1 of Table 4 provide evidence that losers who move (change home schools) are able to generate large gains in average school test scores between lottery assignment and school attended the following year, with this group attending schools that score 0.22 standard deviations higher than the schools that they were assigned in the lottery. These results are larger for 6th graders and indicate gains of 0.43 standard deviations. We also estimate effects of about half to two-thirds the size for losers that do not move which is indicative of changing schools via followup lottery assignment or accessing a non-home school via waitlists or even opt-out provisions based on failing schools and No Child Left Behind education policy.[24] Effects are quite different for lottery winners that do not comply with assignment. Kindergarteners that win the lottery, move and attend a different school see decreases of

[23]The percentage of non-compliers is based on the the portion of winners that do not attend first choice school minus those students that left CMS.

[24]Billings et al. [2017]show that about 30% of children are assigned to failing schools during a similar time period in CMS and about 1/3 of students opt out to a non-neighborhood or magnet school as allowed under NCLB.

0.20 standard deviations in test scores while non-complying winners that stay also lose about 0.20 standard deviations in test scores between assignment and attendance. These magnitudes grow for 6th graders with difference of between 0.36 and 0.58 standard deviations. Larger negative effects for non-complying winners is mostly a result of oversubscribed lotteries assigning high quality schools to lottery winners and any other public school options will typically be lower quality. Differences between winning/non-complying movers and stayers are minimal for kindergartners, but more substantial for 6th graders. This larger effect for 6th graders is partially driven by winners that stay in the same neighborhood school zone, but forego lottery assignment and opt into their neighborhood school. This result is consistent with families that may simply apply to the lottery for the option value of attending another school. Applying for the lottery is costless and some families may apply to magnet schools or non-neighborhood schools with limited information, and upon becoming more informed about the school or transportation costs, decide to attend neighborhood schools. The fact that this result is stronger for 6th graders makes sense if families have stronger ties to neighborhood schools because a child already attended a public elementary school. Families of upcoming kindergartners likely have weaker ties to neighborhood schools. Since lottery assigned schools are high quality, attending any school but the lottery assigned school will likely decrease school quality. Non-complying winners that move for sixth grade have the largest decrease in school quality. These families may be moving for non-school reasons or families that only entered the lottery for the option of a magnet/non-neighborhood school.

Appendix Tables 2 and 3 provide summary statistics for movers and stayers by lottery winners and losers. Of note is that movers and stayers differ on some dimensions with lottery winners and losers that move being more likely to be black and economically disadvantaged than non-movers. These result suggest that mobility may be limited by housing tenure with families that are economically disadvantaged more able to move. The fact that movers that win are more likely to be black and economically disadvantaged than losers that move may represent housing reallocation for winners who have no benefits to moving for school quality, but may want to reallocate housing and neighborhood and housing consumption. We investigate this story further in the next section.

One other factor that may explain differences between movers and stayers is that movers may be relocating to be closer to the new school won in the lottery. For movers, Figure 4 provides some evidence that lottery applicants live closer to their future attended school in the year following the lottery. This figure likely indicates that either losers are moving closer to a school they want to gain access to, winners are moving closer to their first choice school in order to lower transportation costs, or both. Figure 5 breaks

down the distribution of distance to school attended separately for movers that won and lost. Only losers are consistently moving closer to the school they attend in the year following lottery application, consistent with moving to gain access to a new neighborhood school. These figures shows limited evidence that winners are moving to lower transportation costs of attending a non-neighborhood, and likely further away school.

We also investigate heterogeneous effects in the changes in school quality between assignment and attendance across a number of subsets of our data. Specifically, we bisect our four groups by gender, race, a dummy for economic disadvantage, home school test score terciles and neighborhood housing price terciles in Appendix Tables 4 and 5. For Kindergartners, we see larger school quality gains for moving lottery losers that are wealthier and white, live in low or medium school quality and medium housing price neighborhoods. For lottery losers that stay, results are fairly consistent across groups. For non-complier winners, we see a different pattern. Poorer, non-white households living in lower school quality and housing price neighborhoods are attending schools that are considerably worse than the average non-complying winner. These patterns are less pronounced for lottery losers in 6th grade, but consistent with Kindergartners for non-complying winners. Taken together these results lend support for larger potential gains for losers living in neighborhoods with worse school assignment to improve school quality through resdiential relocation. The results for non-complying winners highlights the greater loss of school quality for lower income households that do not comply. Addiionally, we show results are consistent for different type of magnet schools applied to as well as the probability of obtainig entry to a given school in Appendix Tables 6 and 7.

One may be concerned with our measure of school quality, so we provide results using alternative school quality measures in Appendix Tables 8 and 9. These results highlight consistent results for school quality gains for our four groups across a measure of school value-added, portion of students that are academically gifted, share economically disadvantaged or with limited english proficiency and percent of students that are white. One additional piece of analysis that is informative for current policy debates about school choice lotteries and the role of lotteries in promoting or discouraging economic and racial diversity is given in Tables 5 and 6. In these tables, we run our main analysis but look at how well our four groups explain changes in economic disadvantage and percent of the students that are white. The idea is that residential relocation in response to lottery outcomes may impact the larger composition of schools. We provide 2 sets of results for each outcome with the first and third columns replicating our analysis for these 2 outcomes. Of interest is the second and fourth columns which control for changes in test scores. The

results for kindergartners highlight that lottery losers move to schools with less economic disadvantage and more white students even after controlling for school quality. We see similar effects for non-compliers that win. These results suggest that some of the post lottery sorting may be due to changes in student composition in Kindergarten. These results weaken for movers in 6th grade and may indicate less race and income based residential sorting for kids with prior exposure to public schools.

5.2 Housing Prices and School Quality

Given the prevelance of moving to higher quality home school neighborhoods for lottery losers, we want to first test if housing prices reflect neighborhood school quality and then directly link changes in school quality after the lottery to property values. Given the range of estimates of the in the extant literature on valuation of school quality, we want to first provide a standard hedonic based value of school quality using a boundary disconitnuity design. Table 7 provides a housing price hedonic that estimates that impact of a one standard deviation increase in property values of housing prices. We present three models that include more detailed controls for structural and neighborhood attributes and finally our preferred model which uses CBG (census block group) 2000 fixed effects mimics a boundary discontinuity design by limiting identification to differences in housing prices for homes on opposites sides of a elementary attendance zones that bisects a CBG neighborhood. This analysis finds that a one standard deviation increase in test scores generates a 7% increase in housing prices, which is in the middle of the 2-10% range of estimates typically found in this literature.

Returning to our sample of lottery applicants, we implement our value of school quality estimates using the first step of estimating a housing price residual for our sample of housing transactions in Table 7 after controlling for structural and neighborhood attributes. We then average housing price residuals to the smallest geographical area of residence for our lottery data which is elementary attendance zone for our rising Kindergarten sample and attendance zone by CBG for our sample of rising 6th graders. Table 8 reports the results from a model that examines how neighborhood price residuals change from assignment to attendance for 3 groups: movers who lose; movers who win and comply with lottery assignment as well as winners who move but do not comply with lottery assignment. All groups exhibit some positive price premium relative to non-movers with effects shrinking when we implement CBG fixed effects for neighborhood quality in our initial hedonic regressions to create our measure of average price residuals. The lottery loser estimates are larger and more precise than lottery winners that move. These models highlight that movers are relocating to better school quality neighborhoods with losers paying premiums

of 5.3% for Kindergartners and 5.4% for sixth graders. From earlier results, winners did not appear to move closer to attended school and thus any incurred price premiums for winners may simply be housing consumption reallocation to nicer neighborhoods. Conclusions are somewhat limited by the small sample sizes of winners that move.

In order to interpet results in the context of changes in school quality, we multiply the dummy variable for each group by change in (attended - assigned) test scores. Table 9 provides results for these 2 groups with the omitted group being non-movers and compliers. Columns 1 and 3 in Table 7 highlight the price premium for lottery losers in Kindergarten and sixth grade and illustrates that in a model where we do not control for neighborhood quality, one gets large estimates for the value of school quality. Preferred estimates are based on columns 2 and 4 with CBG fixed effects used to generate average price residuals for a neighborhood. For our sixth grade sample, we can even implement destination CBG fixed effects so we can create average price residuals at the CBG by school attendance zone. In this last column, identification is limited to the subset of lottery mover destination CBGs that are bisected by school attendance zones. Using the estimates from columns 2 and 5, we estimate that lottery losers consistently buy homes in neighborhoods with a 14% price premium for elementary school and a 10% price premium for middle school for a one standard deviation increase in test scores. Winners that do not comply experience a noisy and limited relationship between incurred changes in school quality and changes in neighborhood housing prices. This result supports families moving for non-neighborhood school quality reasons.

The estimates for the value of school quality obtained from lottery losers are above the range of estimates from this literature as well as our boundary discontinuity estimate of 7% given in Table 7. As mentioned, this is not that surprising given the fact that losers have a strong and immediate preference for obtaining access to high quality schools relative to traditional value of school estimates that incorporate mean estimates for a full range of schools and households. Additionally, the finding of larger impacts for Kindergartners relative to 6th graders is consistent with a longer stream of potential benefits for households accessing a good school earlier in a child's academic career.

Appendix Table 10 extends kindergarten results to examine if estimates for the value of school quality for losers and winners that move vary by gender, race, economic disadvantage, school test score terciles, and neighborhood housing price terciles. We focus our discussion on losers since we only have a small sample of winners that do not comply with assignment as well as move and results are quite imprecise. In most subgroups, there is limited heterogeniety for losers with the only exception being a larger and more precise effect for students that are wealthier (not economically disadvantaged). Turning to rising 6th

graders in Appendix Table 11, we once again find limited heterogeniety in our price effects but we do some differences for school quality and average neighborhood housing prices. In these 2 set of terciles, we find no price effect for households moving out of the more expensive and higher quality neighborhoods based on residence at the time of lottery applications. This result is consistent with families that already have better home school options gaining less from paying for access to better home schools, especially in 6th grade with a shorter time period for which a student can realize potential benfits from an improved homes school. Appendix Tables 12 and 13 examine if the type of magnet school program and/or the expected probability of winning access to a student's applied school matters for our value of school quality estimates. Most effects are similar across different types of schools applied to , with the most notable results based on comparing applicants that apply to schools that are more oversubscribed ($p < 0.5$) versus less oversubscribed ($p > 0.5$). Applicants to less oversubscribed schools generate larger estimates of the value of school quality than applicants to more oversusbcribed schools. This result would be consistent with students that unexpectedly lose and thus may have a more immediate and high demand for quickly accessing a higher quality school which may result in a housing price premium at transaction. This premium is even larger for the Kindergarten sample which is consistent with the longer potential stream of benefits from accessing a higher quality school.

6 Conclusion

We examine the responses of school choice lottery losers, with a primary focus on residential relocation and opting out of the public school system in response to the results of a school choice lottery. Despite a large literature on the benefits to lottery winners, little is known about the behavior of losers who need to compensate for the lower quality school assignment, a population who may be incurring substantial costs to improve school quality. We show that rising kindergarten and sixth grade students who lose a school choice lottery are about 6 percentage points more likely to exit the district or change neighborhood schools, which represents an increase of about 30% over baseline moving probabilities. Lottery losers are assigned to schools with substantially lower average performance on end of grade exams, but those who lost the lottery and change neighborhood schools make up 0.23-0.46 standard deviations in average school test scores between lottery assignment and attendance the following year. Using hedonic-based estimates of land prices, we estimate a housing price premium of 10-14% for a one standard deviation increase in school test scores. Results provide two new insights. First, we estimate how much of the gap in school

quality is made up by lottery losers through residential relocation. Second, we provide a new estimate of the value of school quality by examining incurred home price differentials for losers to improve school quality after losing the school choice lottery. Together, these findings provide insight on the potential benefits to expanding popular school choice options to minimize the number of families that are not given access to a school because it is oversubscribed. Additionally, our large estimates of the value of school quality point to substantial heterogeneity in how families value school quality, suggesting that families with strong school preference and high performing neighborhood schools likely have nonlinear or larger marginal benefits from gaining access to a high quality school. Given the large costs incurred by lottery losers to improve school quality, there are likely large returns to public investments that expand access to high quality or specialized magnet school programs.

References

Atila Abdulkadiroglu, Parag A Pathak, and Christopher R Walters. Free to choose: Can school choice reduce student achievement? Technical report, National Bureau of Economic Research, 2015.

Elena Andreyeva and Carlianne Patrick. Paying for priority in school choice: Capitalization effects of charter school admission zones. *Journal of Urban Economics*, 100:19–32, 2017.

Andrew Bibler. Dual language education and student achievement. *Unpublished Draft*, 2017.

Stephen B Billings, Eric J Brunner, and Stephen L Ross. Gentrification and failing schools: The unintended consequences of school choice under nclb. *Review of Economics and Statistics*, (0), 2017.

Sandra E Black. Do better schools matter? parental valuation of elementary education. *The Quarterly Journal of Economics*, 114(2):577–599, 1999.

Eric J Brunner, Sung-Woo Cho, and Randall Reback. Mobility, housing markets, and schools: Estimating the effects of inter-district choice programs. *Journal of Public Economics*, 96(7):604–614, 2012.

Kalena E Cortes and Andrew I Friedson. Ranking up by moving out: the effect of the texas top 10% plan on property values. *National Tax Journal*, 67(1):51, 2014.

Julie Berry Cullen, Brian A Jacob, and Steven Levitt. The effect of school choice on participants: Evidence from randomized lotteries. *Econometrica*, 74(5):1191–1230, 2006.

Julie Berry Cullen, Mark C Long, and Randall Reback. Jockeying for position: Strategic high school choice under texas' top ten percent plan. *Journal of Public Economics*, 97:32–48, 2013.

By David J Deming, Justine S Hastings, Thomas J Kane, and Douglas O Staiger. School Choice, School Quality, and Postsecondary Attainment. *The American Economic Review*, 104(3):991–1013, 2014.

David J Deming. Better schools, less crime? *The Quarterly Journal of Economics*, 126(4):2063–2115, 2011.

Paramita Dhar and Stephen L Ross. School district quality and property values: Examining differences along school district boundaries. *Journal of Urban Economics*, 71(1):18–25, 2012.

Gabrielle Fack and Julien Grenet. When do better schools raise housing prices? evidence from paris public and private schools. *Journal of public Economics*, 94(1):59–77, 2010.

Maria Marta Ferreyra. Estimating the effects of private school vouchers in multidistrict economies. *The American Economic Review*, 97(3):789–817, 2007.

David N Figlio and Maurice E Lucas. What's in a grade? school report cards and the housing market. *American economic review*, 94(3):591–604, 2004.

Justine S Hastings, Thomas J Kane, and Douglas O Staiger. Preferences and heterogeneous treatment effects in a public school choice lottery. Technical report, National Bureau of Economic Research, 2006.

Caroline M Hoxby and Sonali Murarka. Charter schools in new york city: Who enrolls and how they affect their students' achievement. Technical report, National Bureau of Economic Research, 2009.

Reed Jordan and Megan Gallagher. Does school choice affect gentrification? *Posing the Question and Assessing the Evidence. Washington, DC: The Urban Institute*, 2015.

Keren Mertens Horn. School accountability and residential location patterns: Evaluating the unintended consequences of no child left behind. 2017.

Thomas J Nechyba. Mobility, targeting, and private-school vouchers. *American Economic Review*, pages 130–146, 2000.

Cecilia Elena Rouse. Private school vouchers and student achievement: An evaluation of the milwaukee parental choice program. *The Quarterly Journal of Economics*, 113(2):553–602, 1998.

Tables and Figures

Table 1: Kindergarten Summary

	CMS	Won	Lost	Won - Lost			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Outcomes							
Mover (Change HS + Exit)	0.27	0.20	0.27	-0.070***	-0.068***	-0.053**	-0.057**
	(0.44)	(0.40)	(0.44)	(0.019)	(0.020)	(0.020)	(0.022)
Change HS (Stay)	0.20	0.15	0.18	-0.023	-0.022	-0.007	-0.007
	(0.40)	(0.36)	(0.38)	(0.016)	(0.016)	(0.016)	(0.020)
Attend App Year HS	0.55	0.06	0.40	-0.336***	-0.316***	-0.321***	-0.308***
	(0.50)	(0.24)	(0.49)	(0.022)	(0.021)	(0.022)	(0.020)
Attend First Choice Schl	0.16	0.84	0.19	0.651***	0.636***	0.642***	0.656***
	(0.37)	(0.37)	(0.39)	(0.028)	(0.030)	(0.032)	(0.023)
Attend Assigned Schl	0.71	0.84	0.55	0.291***	0.301***	0.300***	0.317***
	(0.45)	(0.37)	(0.50)	(0.019)	(0.019)	(0.020)	(0.025)
Won Any Choice	0.20	1.00	0.31	0.693***	0.686***	0.676***	0.659***
	(0.40)	(0.00)	(0.46)	(0.020)	(0.021)	(0.020)	(0.019)
Student Attributes							
Made Second Choice	0.19	0.84	0.81	0.034	0.039*	0.029	0.003
	(0.39)	(0.37)	(0.39)	(0.024)	(0.021)	(0.020)	(0.021)
Made Third Choice	0.15	0.68	0.64	0.043*	0.032*	0.018	-0.016
	(0.36)	(0.47)	(0.48)	(0.023)	(0.017)	(0.018)	(0.026)
Female	0.48	0.49	0.50	-0.013	-0.006	-0.000	-0.005
	(0.50)	(0.50)	(0.50)	(0.019)	(0.018)	(0.018)	(0.026)
Black	0.42	0.46	0.38	0.080**	0.030	0.012	0.015
	(0.49)	(0.50)	(0.49)	(0.035)	(0.024)	(0.018)	(0.021)
White	0.21	0.25	0.33	-0.086**	-0.026	0.009	0.014
	(0.41)	(0.43)	(0.47)	(0.035)	(0.023)	(0.016)	(0.018)
Hispanic	0.27	0.18	0.14	0.035***	0.001	-0.004	-0.009
	(0.44)	(0.38)	(0.35)	(0.013)	(0.010)	(0.011)	(0.017)
Ec. Disadvantage	0.52	0.42	0.30	0.111***			
	(0.48)	(0.48)	(0.44)	(0.028)			
Joint Test (P-value)				.004	.470	.420	.813
Program-Year FE				-	✓	✓	-
Program-Year-Nbhd School FE				-	-	-	✓
Nbhd School FE				-	-	✓	-
Other Lottery Controls				-	✓	✓	✓
Observations	26,966	1,254	1,751	3,005	3,005	3,005	1,693

Notes: Lottery fixed effects are application by year indicators (columns 4 and 5) or application by year by neighborhood school indicators (column 6). HS = home school/neighborhood school. Ec. Disad. = economically disadvantaged. Columns 4 - 6 include controls for economic disadvantage, English second language status, a proxy for having a title I choice neighborhood school, and an interaction between economic disadvantage and title I choice neighborhood school. For 2010 - 2012, economic disadvantage status at the time of application is not available, so status in third grade is used, and an indicator for missing is included. Joint Test based only on student attributes at the time of lottery application (e.g. gender, race, econ. disadv). In the tests, standard error are clustered at the level of the lottery fixed effect, i.e. the application-year level for columns 4 - 6.

Table 2: Sixth Grade Summary

	CMS	Won	Lost	Won - Lost			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Outcomes							
Mover (Change HS + Exit)	0.26	0.13	0.20	-0.069***	-0.057***	-0.060***	-0.051***
	(0.44)	(0.34)	(0.40)	(0.020)	(0.018)	(0.016)	(0.017)
Change HS (Stay)	0.14	0.11	0.17	-0.062***	-0.054***	-0.057***	-0.051***
	(0.35)	(0.31)	(0.37)	(0.016)	(0.015)	(0.012)	(0.015)
Attend App Year HS	0.60	0.05	0.38	-0.339***	-0.300***	-0.294***	-0.305***
	(0.49)	(0.21)	(0.49)	(0.053)	(0.053)	(0.051)	(0.032)
Attend First Choice Schl	0.11	0.89	0.31	0.584***	0.536***	0.543***	0.544***
	(0.31)	(0.31)	(0.46)	(0.054)	(0.049)	(0.049)	(0.028)
Attend Assigned Schl	0.72	0.89	0.52	0.367***	0.403***	0.400***	0.408***
	(0.45)	(0.31)	(0.50)	(0.054)	(0.056)	(0.056)	(0.031)
Won Any Choice	0.13	1.00	0.29	0.710***	0.700***	0.695***	0.686***
	(0.34)	(0.00)	(0.45)	(0.016)	(0.016)	(0.017)	(0.017)
Student Attributes							
Made Second Choice	0.15	0.75	0.75	-0.001	0.005	-0.004	-0.020
	(0.35)	(0.43)	(0.43)	(0.036)	(0.023)	(0.020)	(0.017)
Made Third Choice	0.11	0.51	0.52	-0.001	0.009	-0.004	-0.032*
	(0.31)	(0.50)	(0.50)	(0.032)	(0.022)	(0.022)	(0.019)
Female	0.50	0.54	0.53	0.002	0.010	0.010	0.008
	(0.50)	(0.50)	(0.50)	(0.016)	(0.018)	(0.018)	(0.020)
Black	0.41	0.48	0.52	-0.040	-0.001	-0.006	-0.014
	(0.49)	(0.50)	(0.50)	(0.039)	(0.024)	(0.020)	(0.018)
White	0.34	0.28	0.27	0.006	0.002	0.004	0.009
	(0.47)	(0.45)	(0.45)	(0.031)	(0.017)	(0.016)	(0.013)
Hispanic	0.16	0.14	0.11	0.036**	0.010	0.008	0.016
	(0.36)	(0.35)	(0.31)	(0.016)	(0.011)	(0.010)	(0.012)
Ec. Disadvantage	0.52	0.46	0.43	0.033			
	(0.49)	(0.50)	(0.50)	(0.025)			
Math Lag 1	0.14	0.52	0.50	0.021	-0.015	-0.015	-0.004
	(1.02)	(0.90)	(0.90)	(0.084)	(0.028)	(0.028)	(0.028)
Read Lag 1	0.10	0.50	0.48	0.026	-0.012	-0.014	0.001
	(1.01)	(0.82)	(0.85)	(0.083)	(0.029)	(0.027)	(0.029)
LEP Lag 1	0.10	0.06	0.04	0.014	0.007	0.006	0.007
	(0.30)	(0.23)	(0.21)	(0.009)	(0.007)	(0.008)	(0.009)
Joint Test (P-value)				.666	.852	.909	.808
Progrm-Year FE				-	✓	✓	-
Program-Year-Nbhd School FE				-	-	-	✓
Nbhd School FE				-	-	✓	-
Other Lottery Controls				-	✓	✓	✓
Observations	36,342	1,637	1,798	3,435	3,435	3,435	2,540

Notes: Lottery fixed effects are application by year indicators (columns 4 and 5) or application by year by neighborhood school indicators (column 6). HS = home school/neighborhood school. Ec. Disad. = economically disadvantaged. Columns 4 - 6 include controls for achieving at grade level, academically gifted status, interaction between grade level in reading and applying to a non-magnet school, economic disadvantage, English second language status, a proxy for having a title I choice neighborhood school, and an interaction between economic disadvantage and title I choice neighborhood school. Joint Test based only on student attributes at the time of lottery application (e.g. gender, race, econ. disadv, lagged test scores, LEP). LEP = Limited English Proficiency. Standard errors are clustered at the level of the lottery fixed effect, i.e. the program-year level for columns 4 - 6.

Table 3: Lottery Outcomes, Moving, and School Quality (Avg Test Scores)

	Kindergarten Sample			*Sixth Grade Sample*		
	Assigned	Attended	Difference	Assigned	Attended	Difference
	(1)	(2)	(3)	(4)	(5)	(6)
Won	0.294	0.270	0.024	0.507	0.470	0.037
	(0.305)	(0.333)	(0.195)	(0.259)	(0.311)	(0.200)
Lost	-0.033	0.089	-0.122	-0.087	0.184	-0.271
	(0.364)	(0.393)	(0.323)	(0.443)	(0.473)	(0.465)
Unconditional Diff	0.327	0.181	0.146	0.594	0.286	0.308
	(0.052)	(0.047)	(0.014)	(0.048)	(0.041)	(0.050)
Conditional Difference	0.446***	0.301***	0.144***	0.616***	0.263***	0.354***
	(0.041)	(0.037)	(0.015)	(0.046)	(0.031)	(0.048)
Observations	2690	2690	2690	3244	3244	3244

Notes: This table reports unconditional means for assigned and attended school scores, unconditional differences in scores, and the conditional difference in scores between winners and losers. *Conditional Differences* are coefficients from regressions of (assigned - attended) school quality measures on winning the lottery. The dependent variable is either the average test score at the school the student was assigned in the lottery (columns 1 and 4), the average test score at the school the student was attending at the time of the lottery the following year (columns 2 and 5), or the difference in average test scores between the school the student was assigned and attended (columns 3 and 6). Rows labeled *Won* display unconditional means for winners. Rows labeled *Lost* are unconditional means for lottery losers. Rows labeled *Unconditional Difference* display unconditional means in the score difference, i.e. the difference between winning and losing. A student will have a difference of zero if they attend the school that they were assigned to in the lottery. All conditional regressions control for lottery fixed effects, and all other lottery controls (e.g. priority groups). Lottery fixed effects are application choice by year indicators. Standard errors clustered by lottery. There are 66 and 46 lotteries (program-year combinations) in the kindergarten and sixth grade samples, respectively.

Table 4: Lottery Outcomes and Moving

	Attended - Assigned Score (Avg Test Scores)	
	Kindergarten	Sixth Grade
Lottery Loser		
Change HS	0.224***	0.429***
	(0.024)	(0.031)
Same HS	0.099***	0.294***
	(0.014)	(0.053)
Lottery Winner		
Non-Complier X Change HS	-0.199***	-0.582***
	(0.064)	(0.102)
Non-Complier X Same HS	-0.199**	-0.360***
	(0.087)	(0.098)
Observations	2,690	3,244

Notes: The omitted category is winners who complied with their assignment, for whom the outcome is zero by definition. All regression are conditional on application choice by year fixed effects, and all other lottery controls. Standard errors clustered by lottery. There are 66 and 46 lotteries (program-year combinations) in the kindergarten and sixth grade samples, respectively.

Table 5: Sorting Based on Student Attributes (Kindergarten)

	School Characteristics (Attended - Assigned)			
	Change in Ec. Disad.		Change in Pct. White	
	No Qual.	Cond Scores	No Qual.	Cond Scores
Lottery Loser				
Change HS	-0.126***	-0.012*	0.128***	0.033**
	(0.014)	(0.007)	(0.016)	(0.013)
Same HS	-0.044***	0.007	0.028***	-0.013**
	(0.006)	(0.005)	(0.006)	(0.005)
Lottery Winner				
Non-Complier X Change HS	0.084**	-0.017	0.004	0.088**
	(0.032)	(0.023)	(0.037)	(0.041)
Non-Complier X Same HS	0.065*	-0.036**	0.066**	0.150***
	(0.035)	(0.017)	(0.028)	(0.030)
School Quality Measure				
Change in Test Scores		-0.508***		0.421***
		(0.017)		(0.033)
Observations	2,690	2,690	2,690	2,690

Notes: Estimates for differences in school characterstics (Attended - Assigned) for kindergarten sample. Alternative measures, comparable with Tables 8 and 9. Uses interaction terms between lottery outcomes and moving decisions. Dependent variable is change (Attended - Assigned) in percent economically disadvanted students for columns 1 and 2. Dependent variable is change (Attended - Assigned) in percent white students for columns 3 and 4. Columns 2 and 4 condition on the change (Attended - Assigned) in average school test scores. Standard errors clustered by lottery.

Table 6: Sorting Based on Student Attributes (Sixth Grade)

	School Characteristics (Attended - Assigned)			
	Change in Ec. Disad.		Change in Pct. White	
	No Qual.	Cond Scores	No Qual.	Cond Scores
Lottery Loser				
Change HS	-0.155***	0.002	0.127***	0.008
	(0.018)	(0.010)	(0.030)	(0.018)
Same HS	-0.086***	0.022***	0.031***	-0.050***
	(0.011)	(0.007)	(0.009)	(0.013)
Lottery Winner				
Non-Complier X Change HS	0.189***	-0.032	-0.122*	0.046
	(0.055)	(0.026)	(0.068)	(0.045)
Non-Complier X Same HS	0.077*	-0.056**	0.061	0.163***
	(0.040)	(0.024)	(0.042)	(0.031)
School Quality Measure				
Change in Test Scores		-0.369***		0.280***
		(0.015)		(0.032)
Observations	3,244	3,244	3,244	3,244

Notes: Estimates for differences in school characterstics (Attended - Assigned) for sixth grade sample. Alternative measures, comparable with Tables 8 and 9. Uses interaction terms between lottery outcomes and moving decisions. Dependent variable is change (Attended - Assigned) in percent economically disadvanted students for columns 1 and 2. Dependent variable is change (Attended - Assigned) in percent white students for columns 3 and 4. Columns 2 and 4 condition on the change (Attended - Assigned) in average school test scores. Standard errors clustered by lottery.

Table 7: Hedonic Pricing of School Quality

	Log(Price)	Log(Price)	Log(Price)
Avg. Elem. Test Scores (t-1)	0.7282***	0.2950***	0.0711***
	(0.0060)	(0.0070)	(0.0170)
R-squared	0.6080	0.6988	0.7602
Observations	66,001	62,471	62,471
Basic Controls	✓	✓	✓
Property/Neigh Controls	-	✓	✓
CBG FEs	-	-	✓

Notes: Regressions of log(price) on neighborhood school quality for Mecklenburg County home sales. Basic controls include structural attributes for age, building area, lot size, number of bathrooms, indicator for fireplace and indicators for building material/structure types. Neigh Controls include Census Block Group (CBG) 2000 median household income, population density, percent unemployed, indicator for floodplain, indicator for on busy road, distance to CBG, distance to Highway and distance to park. All models include year by quarter fixed effects and standard errors clustered at the CBG level. This model include only arm's length transactions of between $10,000 and 1,000,000 for properties sold between 2009-2013.

Table 8: Lottery Outcomes, Moving, and Housing Prices

	HS(t+1) - HS(t) Price Residuals				
	Kindergarten	Kindergarten	Sixth Grade	Sixth Grade	Sixth Grade
Lost X Change HS	0.091***	0.053***	0.083***	0.058***	0.054***
	(0.023)	(0.020)	(0.019)	(0.017)	(0.020)
Winners X Change HS					
Complier	0.059*	0.044	0.037	0.001	0.041
	(0.032)	(0.027)	(0.045)	(0.035)	(0.035)
Non-Complier	0.051	0.018	0.039	0.014	0.032
	(0.041)	(0.040)	(0.048)	(0.048)	(0.055)
Destination CBG FE					✓
1st Stage CBG Controls		✓		✓	✓
Observations	2690	2690	3244	3244	3084

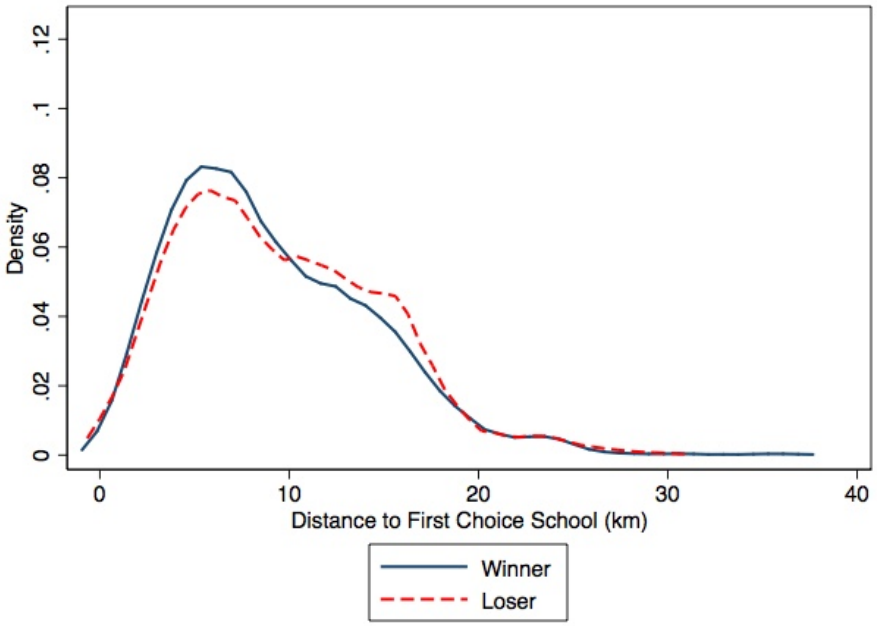
Notes: All regressions include application choice by year fixed effects, and other controls. The outcome variable is the difference in the average home price residual aggregated to either the home school level (for kindergarten sample) or home school by census block group level (for sixth grade sample) for students who changed home schools between lotteries. For students who did not change neighborhood schools, the outcome variable is zero. The omitted category is all applicants who had the same home school in applicant and following year. For the sixth grade sample, the school-CBG level residual difference is imputed using the neighborhood school level residuals when data are missing. The last column includes CBG fixed effects for the CBG that the student was in for the year following the lottery. The drop in observations in the final column is due to missing data on CBG and dropping singleton sets of the absorbed set of fixed effects, i.e. lottery and destination CBG. Standard errors clustered by lottery. There are 66 and 46 lotteries (program-year combinations) in the kindergarten and sixth grade samples, respectively.

Table 9: Lottery Outcomes, Moving, and Housing Prices II

	HS(t+1) - HS(t) Price Residuals				
	Kindergarten	Kindergarten	Sixth Grade	Sixth Grade	Sixth Grade
Lost X Change HS X Score Diff	0.259***	0.140***	0.159***	0.132***	0.103***
	(0.041)	(0.038)	(0.037)	(0.032)	(0.038)
Winners X Change HS X Score Diff					
Non-Complier	0.011	-0.014	-0.008	0.024	0.019
	(0.102)	(0.103)	(0.075)	(0.073)	(0.081)
Destination CBG FE					✓
1st Stage CBG Controls		✓		✓	✓
Observations	2690	2690	3244	3244	3084

Notes: Same as Table 8, but with the inclusion of All Lottery Outcome X Moving decision dummies which are interacted by the change in school average test scores (Attended - Assigned) to scale the estimates according to a one standard deviation change in school quality. The drop in observations in the final column is due to missing data on CBG and dropping singleton sets of the absorbed set of fixed effects, i.e. lottery and destination CBG. Standard errors clustered by lottery. There are 66 and 46 lotteries (program-year combinations) in the kindergarten and sixth grade samples, respectively.

Figure 1: Distance Between Census Block Group and First Choice School (km)



Notes: Distance in km between census block group and first choice school by lottery outcome for the sixth grade sample. Census block group is from the spring of the application year, i.e. their 5th grade year.

Figure 2: Potential Test Score Gains and Distance to Application School (Win Probability >= 0.5)

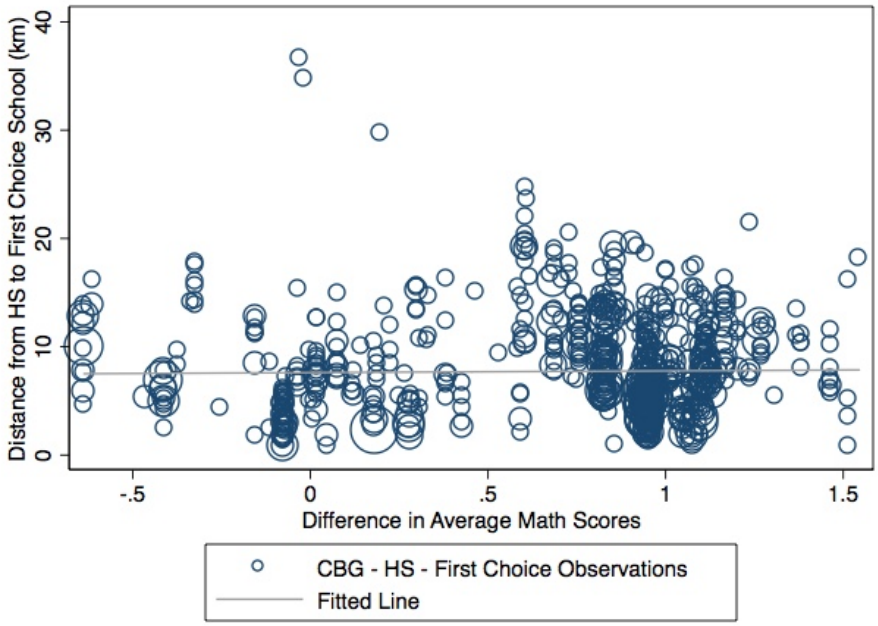
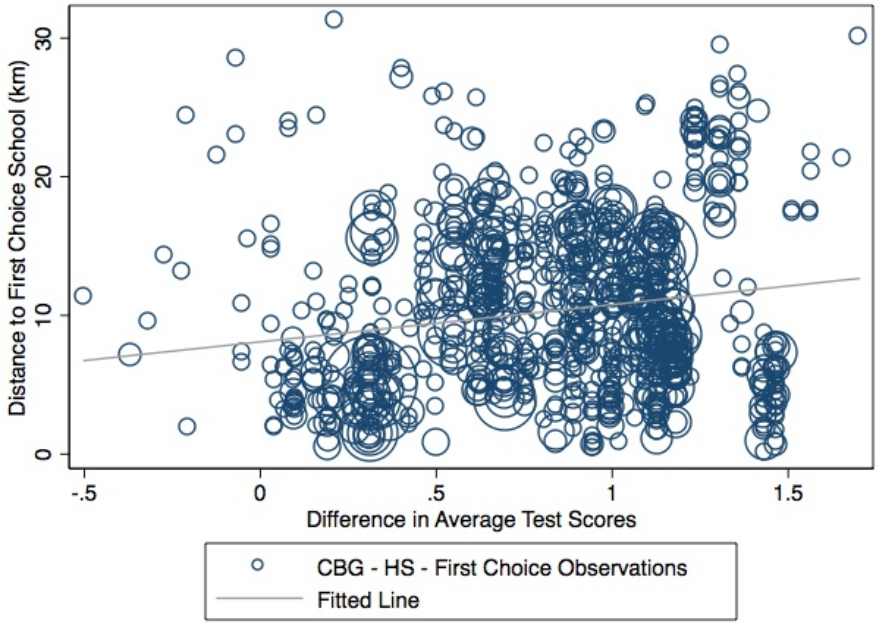
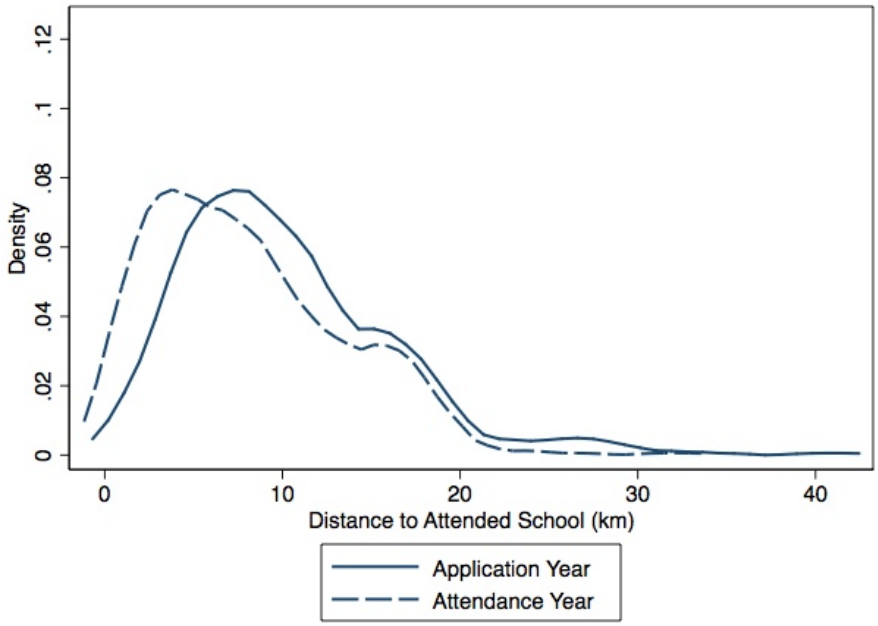


Figure 3: Potential Test Score Gains and Distance to Application School (Win Probability < 0.5)



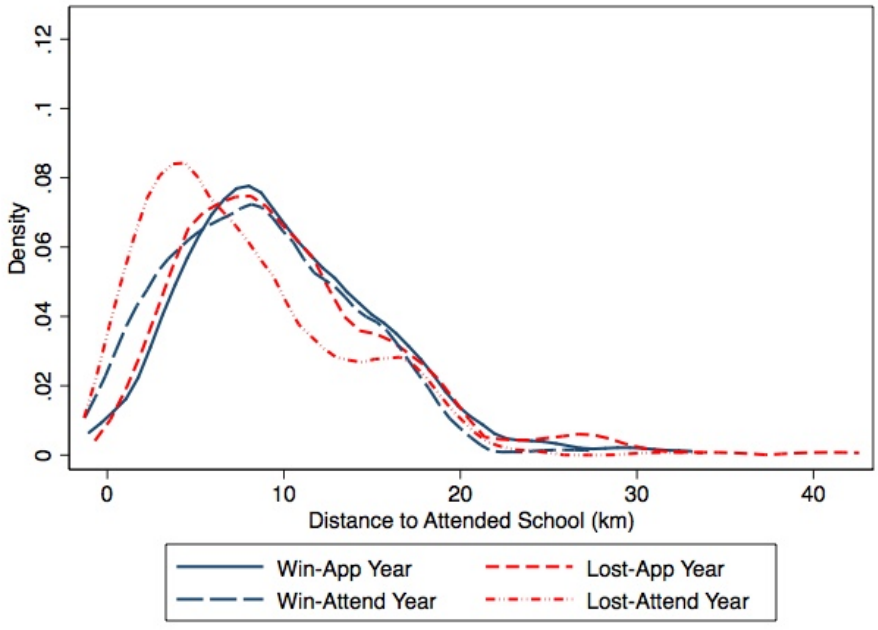
Notes: The figures above shows distance to first choice application school, and the difference in school math/reading scores between the application school and student's neighborhood school for the sixth grade sample. Each circle represents a CBG - Neighborhood School - First Choice School cell, weighted by the number of individuals, i.e. the size of a circle reflects the number of students it represents. Figure 2 is for those with average win probability of 0.5 or greater. Figure 3 if for those with win probability greater less than 0.5.

Figure 4: Distance Between Census Block Group and Attended School for Movers



Notes: Densities of the distance (km) between the census block group of the student's residence and the school they end up attending at two points in time: The year of the application and the year of attendance. Distances are measured in the spring of the corresponding year. These are based on the sixth grade sample of movers only.

Figure 5: Distance to Attended - Before and After Moving



Notes: Densities of the distance (km) between the census block group of the student's residence and the school they end up attending by lottery outcome at two points in time: The year of the application and the year of attendance. Distances are measured in the spring of the corresponding year. These are based on the sixth grade sample of movers only.

Appendix Tables and Figures

Table A1: Proportion of Lottery Winners by Year

	Kindergarten Sample			
	2009	2010	2011	2012
Proportion Won First Choice	0.37	0.33	0.46	0.49
	(0.48)	(0.47)	(0.50)	(0.50)
Win Probabilities				
25th Pctile	0.23	0.24	0.28	0.37
50th Pctile	0.33	0.28	0.40	0.45
75th Pctile	0.40	0.41	0.56	0.64
Observations	775	603	862	767

	Sixth Grade Sample			
	2009	2010	2011	2012
Proportion Won First Choice	0.33	0.61	0.41	0.62
	(0.47)	(0.49)	(0.49)	(0.49)
Win Probabilities				
25th Pctile	0.12	0.40	0.30	0.52
50th Pctile	0.31	0.40	0.43	0.55
75th Pctile	0.47	1.00	0.43	0.83
Observations	1,203	793	636	803

Notes: Proportion of analysis sample applicants who won their first choice in each year. The analysis sample includes applicants who did not have a guaranteed seat to their first choice option, and who applied to a program which had at least one winner and one loser in that lottery.

Table A2: Summary Stats by Lottery Outcome and Moving

	Kindergarten Sample					
	Lottery Winners			Lottery Losers		
	Full Sample	Same HS	Change HS	Full Sample	Same HS	Change HS
Outcomes						
Mover (Change HS + Exit)	0.15	0.00	1.00	0.17	0.00	1.00
	(0.36)	(0.00)	(0.00)	(0.37)	(0.00)	(0.00)
Change HS (Stay)	0.15	0.00	1.00	0.17	0.00	1.00
	(0.36)	(0.00)	(0.00)	(0.37)	(0.00)	(0.00)
Attend Lagged HS	0.07	0.08	0.02	0.45	0.52	0.09
	(0.25)	(0.26)	(0.13)	(0.50)	(0.50)	(0.28)
Attend First Choice School	0.88	0.91	0.73	0.20	0.21	0.15
	(0.33)	(0.29)	(0.45)	(0.40)	(0.41)	(0.36)
Attend Assigned School	0.88	0.91	0.73	0.60	0.68	0.24
	(0.33)	(0.29)	(0.45)	(0.49)	(0.47)	(0.43)
Won Any Choice	1.00	1.00	1.00	0.32	0.32	0.33
	(0.00)	(0.00)	(0.00)	(0.47)	(0.47)	(0.47)
Student Attributes						
Made Second Choice	0.84	0.84	0.86	0.81	0.80	0.85
	(0.36)	(0.37)	(0.34)	(0.39)	(0.40)	(0.35)
Made Third Choice	0.69	0.68	0.72	0.64	0.62	0.73
	(0.46)	(0.47)	(0.45)	(0.48)	(0.49)	(0.44)
Female	0.49	0.50	0.43	0.50	0.50	0.50
	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)
Black	0.47	0.45	0.60	0.39	0.38	0.47
	(0.50)	(0.50)	(0.49)	(0.49)	(0.49)	(0.50)
White	0.24	0.26	0.11	0.31	0.33	0.20
	(0.42)	(0.44)	(0.31)	(0.46)	(0.47)	(0.40)
Hispanic	0.18	0.18	0.18	0.16	0.15	0.20
	(0.39)	(0.39)	(0.39)	(0.37)	(0.36)	(0.40)
Ec. Disadvantage	0.42	0.41	0.50	0.32	0.30	0.42
	(0.48)	(0.48)	(0.49)	(0.45)	(0.44)	(0.48)
Observations	1168	992	176	1522	1267	255

Notes: Summary stats for estimation sample by lottery outcome and moving decision. HS = home school/neighborhood school. Ec. Disad. = economically disadvantaged. For 2010 to 2012, economic disadvantage status at the time of application is not available, so status in third grade is used.

Table A3: Summary Stats by Lottery Outcome and Moving

	Sixth Grade Sample					
	Lottery Winners			Lottery Losers		
	Full Sample	Same HS	Change HS	Full Sample	Same HS	Change HS
Outcomes						
Mover (Change HS + Exit)	0.09	0.00	1.00	0.16	0.00	1.00
	(0.29)	(0.00)	(0.00)	(0.36)	(0.00)	(0.00)
Change HS (Stay)	0.09	0.00	1.00	0.16	0.00	1.00
	(0.29)	(0.00)	(0.00)	(0.36)	(0.00)	(0.00)
Attend Lagged HS	0.05	0.05	0.01	0.40	0.46	0.10
	(0.21)	(0.22)	(0.08)	(0.49)	(0.50)	(0.31)
Attend First Choice School	0.91	0.93	0.73	0.32	0.31	0.34
	(0.28)	(0.26)	(0.44)	(0.47)	(0.46)	(0.47)
Attend Assigned School	0.91	0.93	0.73	0.54	0.61	0.20
	(0.28)	(0.26)	(0.44)	(0.50)	(0.49)	(0.40)
Won Any Choice	1.00	1.00	1.00	0.29	0.29	0.29
	(0.00)	(0.00)	(0.00)	(0.45)	(0.45)	(0.45)
Student Attributes						
Made Second Choice	0.74	0.74	0.83	0.75	0.73	0.83
	(0.44)	(0.44)	(0.37)	(0.43)	(0.44)	(0.38)
Made Third Choice	0.51	0.50	0.62	0.51	0.49	0.60
	(0.50)	(0.50)	(0.49)	(0.50)	(0.50)	(0.49)
Female	0.54	0.54	0.46	0.53	0.53	0.54
	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)
Black	0.47	0.45	0.65	0.52	0.51	0.58
	(0.50)	(0.50)	(0.48)	(0.50)	(0.50)	(0.49)
White	0.29	0.31	0.08	0.28	0.30	0.19
	(0.45)	(0.46)	(0.27)	(0.45)	(0.46)	(0.39)
Hispanic	0.14	0.14	0.12	0.10	0.10	0.09
	(0.35)	(0.35)	(0.32)	(0.30)	(0.30)	(0.28)
Ec. Disadvantage	0.45	0.43	0.71	0.42	0.41	0.49
	(0.50)	(0.49)	(0.46)	(0.49)	(0.49)	(0.50)
Math Lag 1	0.54	0.57	0.24	0.50	0.51	0.47
	(0.90)	(0.90)	(0.87)	(0.90)	(0.90)	(0.91)
Read Lag 1	0.52	0.54	0.29	0.49	0.49	0.47
	(0.83)	(0.82)	(0.82)	(0.85)	(0.85)	(0.86)
LEP Lag 1	0.06	0.06	0.07	0.04	0.05	0.03
	(0.23)	(0.23)	(0.26)	(0.20)	(0.21)	(0.16)
Observations	1541	1402	139	1703	1434	269

Notes: Summary stats for estimation sample by lottery outcome and moving decision. HS = home school/neighborhood school. Ec. Disad. = economically disadvantaged. LEP = Limited English Proficiency

Table A4: School Quality - Heterogeneity - Kindergarten

	Avg. Math & Reading Score Difference (Attended - Assigned)											
	Ec. Disad.		Sex		Race		HS (t) Quality			Avg HS Price (t)		
	Yes	No	Male	Female	White	Non-white	Low	Middle	High	Low	Middle	High
Lottery Loser												
Change HS	0.099***	0.286***	0.215***	0.229***	0.310***	0.198***	0.275***	0.274***	0.070	0.152***	0.366***	0.125**
	(0.035)	(0.039)	(0.040)	(0.038)	(0.067)	(0.030)	(0.040)	(0.040)	(0.054)	(0.037)	(0.040)	(0.055)
Same HS	0.074***	0.129***	0.099***	0.101***	0.118***	0.097***	0.128***	0.145***	0.049***	0.097***	0.151***	0.073***
	(0.027)	(0.014)	(0.014)	(0.016)	(0.022)	(0.020)	(0.025)	(0.025)	(0.014)	(0.021)	(0.027)	(0.015)
Lottery Winner												
Non-Complier X Change HS	-0.355***	-0.056	-0.200*	-0.196**	0.195	-0.274***	-0.291***	-0.265**	0.223*	-0.426***	-0.018	-0.005
	(0.120)	(0.096)	(0.115)	(0.095)	(0.188)	(0.077)	(0.096)	(0.130)	(0.123)	(0.106)	(0.092)	(0.122)
Non-Complier X Same HS	-0.412***	-0.029	-0.320***	-0.094	0.036	-0.279***	-0.626***	-0.426***	0.161**	-0.529***	-0.399***	0.148**
	(0.112)	(0.083)	(0.097)	(0.085)	(0.087)	(0.103)	(0.113)	(0.083)	(0.074)	(0.095)	(0.068)	(0.069)
Observations	913	1,612	1,358	1,332	743	1,947	941	875	874	933	898	859

Notes: Estimates of Attended - Assigned School Score by lottery outcome and moving decision. The omitted category is winners who complied with their assignment, for whom the outcome is zero by definition. All regression are conditional on application choice by year fixed effects, and all other controls. The *HS Quality* and *Avg HS Price (t)* heterogeneity refer to the level of test scores and mean home price at the student's application year neighborhood school. Standard errors clustered by lottery.

Table A5: School Quality - Heterogeneity - Sixth Grade

	Avg. Math & Read Score Difference (Attended - Assigned)											
	Ec. Disad.		Sex		Race		HS (t) Quality			Avg HS Price (t)		
	Yes	No	Male	Female	White	Non-white	Low	Middle	High	Low	Middle	High
Lottery Loser												
Change HS	0.424***	0.438***	0.413***	0.429***	0.487***	0.414***	0.386***	0.568***	0.280***	0.458***	0.421***	0.377***
	(0.030)	(0.050)	(0.057)	(0.046)	(0.085)	(0.030)	(0.053)	(0.058)	(0.100)	(0.053)	(0.057)	(0.103)
Same HS	0.253***	0.327***	0.296***	0.296***	0.238***	0.319***	0.343***	0.343***	0.191***	0.359***	0.291***	0.210***
	(0.054)	(0.059)	(0.058)	(0.049)	(0.056)	(0.054)	(0.074)	(0.048)	(0.041)	(0.073)	(0.050)	(0.040)
Lottery Winner												
Non-Complier X Change HS	-0.700***	-0.372***	-0.468***	-0.738***	-0.043	-0.591***	-0.586***	-0.638***	-0.313*	-0.494***	-0.811***	-0.371***
	(0.111)	(0.115)	(0.111)	(0.112)	(0.079)	(0.096)	(0.136)	(0.132)	(0.174)	(0.160)	(0.072)	(0.119)
Non-Complier X Same HS	-0.646***	-0.161	-0.279***	-0.420***	-0.159	-0.478***	-0.647***	-0.708***	-0.102	-0.830***	-0.605***	-0.003
	(0.089)	(0.107)	(0.096)	(0.119)	(0.140)	(0.088)	(0.102)	(0.147)	(0.109)	(0.090)	(0.113)	(0.106)
Observations	1,412	1,832	1,512	1,732	928	2,316	1,082	1,144	1,018	1,247	986	1,011

Notes: Estimates of Attended - Assigned School Score by lottery outcome and moving decision. The omitted category is winners who complied with their assignment, for whom the outcome is zero by definition. All regression are conditional on application choice by year fixed effects, and all other controls. The *HS Quality* and *Avg HS Price (t)* heterogeneity refer to the level of test scores and mean home price at the student's application year neighborhood school. Standard errors clustered by lottery.

Table A6: Test Score Het by Type and Win Prob (Kindergarten)

		School Type			*Win Probability*	
	Full Sample	Magnet	DL	Trad.	<0.5	>=0.5
Lottery Loser						
Change HS	0.224***	0.230***	0.211***	0.202***	0.215***	0.296***
	(0.023)	(0.023)	(0.059)	(0.036)	(0.024)	(0.067)
Same HS	0.099***	0.103***	0.135***	0.086***	0.104***	0.079**
	(0.014)	(0.014)	(0.026)	(0.020)	(0.014)	(0.030)
Lottery Winner						
Non-Complier X Change HS	-0.199***	-0.219***	-0.679**	-0.296***	-0.243**	-0.157**
	(0.063)	(0.067)	(0.268)	(0.080)	(0.106)	(0.070)
Non-Complier X Same HS	-0.199**	-0.201**	-0.369**	-0.072	-0.184	-0.212*
	(0.086)	(0.087)	(0.141)	(0.072)	(0.125)	(0.115)
Observations	2,690	2,535	599	890	1,940	750

Notes: School quality heterogeneity by program type and win probability (comparable with Table 4). Only displaying Magnet applicants, because that is the vast majority of applications, 2,535/2690 in estimation sample. Only displying the two most common magnet types for separate analyses, Dual Language and Traditional. Estimates of (Attended - Assigned) School Score by lottery outcome and moving decision. Scores are averages of math and reading scores. The omitted category is winners who complied with their assignment, for whom the outcome is zero by definition. All regression are conditional on application choice by year fixed effects, and all other controls. Standard errors clustered by lottery.

Table A7: Test Score Het by School Type and Win Prob (Sixth Grade)

		School Type			*Win Probability*	
	Full Sample	Non-Mag.	Magnet	IB	<0.5	>=0.5
Lottery Loser						
Change HS	0.426***	0.425***	0.416***	0.394***	0.420***	0.399***
	(0.031)	(0.056)	(0.036)	(0.041)	(0.044)	(0.080)
Same HS	0.292***	0.093**	0.342***	0.365***	0.283***	0.285***
	(0.052)	(0.039)	(0.057)	(0.062)	(0.072)	(0.081)
Lottery Winner						
Non-Complier X Change HS	-0.599***	-0.621***	-0.616***	-0.591***	-0.882***	-0.440***
	(0.103)	(0.185)	(0.122)	(0.136)	(0.098)	(0.125)
Non-Complier X Same HS	-0.361***	-0.572**	-0.330***	-0.335**	-0.649***	-0.234*
	(0.098)	(0.217)	(0.104)	(0.125)	(0.072)	(0.113)
Observations	3,244	660	2,584	2,142	1,907	1,337

Notes: School quality heterogeneity by program type and win probability (comparable with Table 4). Only displaying IB magnets on their own, because they are the vast majority of magnet applications, 2,142 of 2,584 magnet applications in the estimation sample. Only displying the two most common magnet types for separate analyses, Dual Language and Traditional. Estimates of (Attended - Assigned) School Score by lottery outcome and moving decision. Scores are averages of math and reading scores. The omitted category is winners who complied with their assignment, for whom the outcome is zero by definition. All regression are conditional on application choice by year fixed effects, and all other controls. Standard errors clustered by lottery.

Table A8: Differences in Attended and Assigned School Chars (Kindergarten)

	School Characterstics (Attended - Assigned)					
	Avg Test Score	School VA	Ec Disad.	Ac. Gifted	LEP	White (pct)
Lottery Loser						
Change HS	0.224***	0.031***	-0.126***	0.051***	-0.031***	0.128***
	(0.023)	(0.009)	(0.014)	(0.007)	(0.005)	(0.016)
Same HS	0.099***	0.027***	-0.044***	0.023***	-0.013***	0.028***
	(0.014)	(0.007)	(0.006)	(0.004)	(0.002)	(0.006)
Lottery Winner						
Non-Complier X Change HS	-0.199***	-0.030	0.084**	-0.075**	0.086***	0.004
	(0.063)	(0.030)	(0.032)	(0.031)	(0.017)	(0.037)
Non-Complier X Same HS	-0.199**	-0.104***	0.065*	-0.032*	0.046***	0.066**
	(0.086)	(0.029)	(0.035)	(0.019)	(0.011)	(0.028)
Dep Var Mean	0.059	0.012	-0.028	0.014	-0.006	0.027
Dep Var SD	(0.284)	(0.088)	(0.157)	(0.088)	(0.057)	(0.154)
Observations	2,690	2,690	2,690	2,690	2,690	2,690

Notes: Estimates for differences in school characterstics (assigned - attended) for kindergarten sample. Alternative measures, comparable with Table 4. Uses interaction terms between lottery outcomes and moving decisions. *School VA* = Estimated school level value-added, conditional on student level characteristics, including lagged test score. *Ec. Disad.* = proportion of economically disadvantaged students in school. *Ac. Gifted* = percent of students in school who are academically gifted. *LEP* = percent of students in school with limited English proficiency. *White* = percent of students in school who are white. Standard errors clustered by lottery.

Table A9: Differences in Assigned and Attended School Chars (Sixth Grade)

	School Characterstics (Attended - Assigned)					
	Avg Test Score	School VA	Ec Disad.	Ac. Gifted	LEP	White (pct)
Lottery Loser						
Change HS	0.429***	0.071***	-0.156***	0.105***	-0.034***	0.128***
	(0.031)	(0.007)	(0.018)	(0.009)	(0.004)	(0.030)
Same HS	0.294***	0.049***	-0.087***	0.090***	-0.022***	0.032***
	(0.052)	(0.010)	(0.011)	(0.017)	(0.004)	(0.009)
Lottery Winner						
Non-Complier X Change HS	-0.582***	-0.072***	0.181***	-0.165***	0.046***	-0.113*
	(0.101)	(0.021)	(0.054)	(0.024)	(0.008)	(0.066)
Non-Complier X Same HS	-0.360***	-0.028	0.076*	-0.146***	0.039***	0.062
	(0.097)	(0.026)	(0.039)	(0.028)	(0.009)	(0.041)
Dep Var Mean	0.124	0.022	-0.039	0.034	-0.009	0.022
Dep Var SD	(0.395)	(0.068)	(0.149)	(0.109)	(0.039)	(0.146)
Observations	3,244	3,244	3,244	3,244	3,244	3,244

Notes: Estimates for differences in school characterstics (assigned - attended) for kindergarten sample. Alternative measures, comparable with Table 4. Uses interaction terms between lottery outcomes and moving decisions. *School VA* = Estimated school level value-added, conditional on student level characteristics, including lagged test score. *Ec. Disad.* = proportion of economically disadvantaged students in school. *Ac. Gifted* = percent of students in school who are academically gifted. *LEP* = percent of students in school with limited English proficiency. *White* = percent of students in school who are white. Standard errors clustered by lottery.

Table A10: Price Residuals, Heterogeneity - Kindergarten

	Difference in Price Residuals, HS(t+1) - HS(t)											
	Ec. Disad.		Sex		Race		HS (t) Quality			Avg HS Price (t)		
	Yes	No	Male	Female	White	Non-white	Low	Middle	High	Low	Middle	High
Change HS X Score Diff												
Lost	0.096	0.150***	0.105**	0.173***	0.139***	0.142***	0.140**	0.124**	0.170**	0.264***	0.075	0.101***
	(0.099)	(0.030)	(0.044)	(0.047)	(0.036)	(0.049)	(0.058)	(0.051)	(0.071)	(0.073)	(0.048)	(0.035)
Won X Non-Complier	0.033	-0.012	-0.037	0.021	-0.038	0.005	-0.153	0.325***	-0.233	-0.017	-0.002	0.133
	(0.183)	(0.097)	(0.130)	(0.171)	(0.094)	(0.115)	(0.146)	(0.092)	(0.171)	(0.142)	(0.135)	(0.201)
1st Stage CBG Controls	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Observations	913	1612	1358	1332	743	1947	941	875	874	933	898	859

Notes: All regressions include application choice by year fixed effects, and other controls. The outcome variable is the difference in the average home price residual aggregated to the home school level and interacted with the change in school average test scores (Attended - Assigned) to scale the estimates according to a one standard deviation change in school quality (comparable to column 2 from Table 6). The omitted category is all applicants who had the same home school in both lotteries, i.e. they did not move and so have a difference in neighborhood school zone price residuals of zero by definition. The *HS Quality* and *Avg HS Price (t)* heterogeneity refer to the level of test scores and mean home price at the student's application year neighborhood school. Standard errors clustered by lottery.

Table A11: Price Residuals, Heterogeneity - Sixth Grade

	Difference in Price Residuals, HS(t+1) - HS(t)											
	Ec. Disad.		Sex		Race		HS (t) Quality			Avg HS Price (t)		
	Yes	No	Male	Female	White	Non-white	Low	Middle	High	Low	Middle	High
Change HS X Score Diff												
Lost	0.135**	0.137**	0.141***	0.123**	0.108*	0.134***	0.158**	0.180***	-0.066	0.195***	0.128**	0.049
	(0.051)	(0.055)	(0.036)	(0.054)	(0.057)	(0.036)	(0.068)	(0.034)	(0.044)	(0.049)	(0.059)	(0.064)
Won X Non-Complier	0.013	0.049	0.023	-0.012	-0.112	0.016	0.042	-0.071	0.100	0.008	-0.005	0.071
	(0.087)	(0.063)	(0.046)	(0.108)	(0.092)	(0.072)	(0.091)	(0.088)	(0.085)	(0.164)	(0.065)	(0.076)
1st Stage CBG Controls	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Observations	1412	1832	1512	1732	928	2316	1082	1144	1018	1247	986	1011

Notes: All regressions include application choice by year fixed effects, and other controls. The outcome variable is the difference in the average home price residual aggregated to the home school by CBG level and interacted with the change in school average test scores (Attended - Assigned) to scale the estimates according to a one standard deviation change in school quality (comparable to column 4 from Table 6). For students who did not change neighborhood schools, the outcome variable is zero. The omitted category is all applicants who had the same home school in both lotteries, i.e. they did not change school zones and so have a difference in neighborhood school zone price residuals of zero by definition. The school-CBG level residual difference is imputed using the neighborhood school level residuals when data are missing. The *HS Quality* and *Avg HS Price (t)* heterogeneity refer to the level of test scores and mean home price at the student's application year neighborhood school. Standard errors clustered by lottery.

Table A12: Price Heterogeneity by Type and Win Prob (Kindergarten)

		School Type			*Win Probability*	
	Full Sample	Magnet	DL	Trad.	<0.5	>=0.5
Change HS X Score Diff						
Lost	0.140***	0.152***	-0.000	0.270***	0.119***	0.293***
	(0.038)	(0.038)	(0.070)	(0.059)	(0.042)	(0.039)
Won X Non-Complier	-0.014	0.002	-0.473**	-0.093	-0.143	0.173
	(0.103)	(0.104)	(0.179)	(0.115)	(0.140)	(0.128)
1st Stage CBG Controls	✓	✓	✓	✓	✓	✓
Observations	2690	2535	599	890	1940	750

Notes: Price residual heterogeneity by program type and win probability (comparable with Table 6). Only displaying Magnet applicants, because that is the vast majority of applications, 2,535/2690 in estimation sample. Also, only displying the two most common magnet types for separate analyses, Dual Language and Traditional. All regressions include application choice by year fixed effects, and other controls. The outcome variable is the difference in the average home price residual aggregated to the home school level and interacted with the change in school average test scores (Attended - Assigned) to scale the estimates according to a one standard deviation change in school quality (comparable to column 2 from Table 6). The omitted category is all applicants who had the same home school in both lotteries, i.e. they did not change school zones and so have a difference in neighborhood school zone price residuals of zero by definition. Standard errors clustered by lottery.

Table A13: Price Heterogeneity by School Type and Win Prob (Sixth Grade)

		School Type			*Win Probability*	
	Full Sample	Non-Mag.	Magnet	IB	<0.5	>=0.5
Change HS X Score Diff						
Lost	0.132***	0.134***	0.130***	0.110*	0.110**	0.191***
	(0.032)	(0.034)	(0.044)	(0.054)	(0.042)	(0.040)
Won X Non-Complier	0.024	0.228***	-0.128	-0.125	-0.049	0.123**
	(0.073)	(0.055)	(0.081)	(0.080)	(0.116)	(0.056)
1st Stage CBG Controls	✓	✓	✓	✓	✓	✓
Observations	3244	660	2584	2142	1907	1337

Notes: Price residual heterogeneity by program type and win probability. Only displaying IB magnets on their own, because they are the vast majority of magnet applications, 2,142 of 2,584 magnet applications in the estimation sample (comparable with Table 6). All regressions include application choice by year fixed effects, and other controls. The outcome variable is the difference in the average home price residual aggregated to the home school by CBG level and interacted with the change in school average test scores (Attended - Assigned) to scale the estimates according to a one standard deviation change in school quality (comparable to column 4 from Table 6). For students who did not change neighborhood schools, the outcome variable is zero. The omitted category is all applicants who had the same home school in both lotteries, i.e. they did not change school zones and so have a difference in neighborhood school zone price residuals of zero by definition. The school-CBG level residual difference is imputed using the neighborhood school level residuals when data are missing. The omitted category is all applicants who had the same home school in both lotteries, i.e. they did not change school zones and so have a difference in neighborhood school zone price residuals of zero by definition. Standard errors clustered by lottery.