Does School Choice Help Students in Overcrowded Schools? Evidence from a Centralized School Assignment

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Abstract: School overcrowding is a pressing issue faced by many large urban school districts. This study evaluates the role of an existing school choice program in alleviating overcrowding in Wake County, North Carolina. The Wake County magnet school program uses a centralized assignment to re-assign students to magnet schools in areas with large proportions of economically disadvantaged students. In addition to improving diversity and providing innovative education, Wake County leverages this system to address school overcrowding at traditional schools through prioritizing applicants from overcrowded schools. This paper fully exploits the random variation in offers of magnet seats at all magnet schools by conditioning on assignment propensity scores and causally identifies the effect of magnet attendance by overcrowding status of origin schools following Abdulkadiroğlu et al. (2017). Results suggest no evidence of differential gains in math and literacy skills from magnet attendance by students from overcrowded base schools. However, students with an overcrowded base school experience stronger magnet gains on reduced absenteeism than students with a non-overcrowded base school.

Keywords: school choice, achievement gap

JEL classification: I21, I24, I28

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1 Introduction

Rapid population growth and budget shortfalls have led to overcrowding in many urban school districts (?NCES, 2000, 2007). As existing facilities fail to keep up with student enrollment growth, school districts may choose to leverage existing school choice programs to solve overcrowding. The objective of maximizing existing facility utilization can be embedded in the assignment design, attracting students to less-crowded schools. This paper studies how students from overcrowded schools benefit in cognitive and non-cognitive outcomes from the magnet school programs in Wake County, North Carolina, and proposes a novel approach to estimating overcrowding effects.

Wake County is one of the fastest-growing urban areas in the nation and faces the challenge of keeping pace with student population growth while delivering quality learning environments. NCPS (2016) identifies Wake County as having the greatest need in North Carolina for new school construction between 2015 and 2020.[1] In Wake County, grade-entry students are assigned to a "base school" according to their home addresses. The Wake County magnet program allows students to apply to receive magnet seats in an annual centralized magnet reassignment. Apart from promoting diversity and boosting student performance, another essential purpose of the magnet program is to alleviate school overcrowding with school choice by "maximizing use of school facilities" (WCPSS, 2019b). Given this policy objective, this paper focuses on school overcrowding in traditional schools and not in magnet schools. The design of the magnet schools' priority structure over students reflects this intention with priorities given to students applying from an overcrowded base school, thus increasing their chances of a successful reassignment to magnet schools.

The empirical challenge in estimating the effect of school overcrowding on student achievement is that students sort into overcrowded schools. High- or low-performing students may enroll at overcrowded schools, depending on the reason for overcrowding. Parents may choose to move to areas where neighborhood schools have desirable characteristics, raising the demand for school seats and resulting in overcrowding. It is also possible that schools in areas with a higher proportion of low socioeconomic status students have more difficulty obtaining resources to build and maintain school facilities to accommodate student growth.[2]

[1] In 2015, 59 of the 107 elementary schools in Wake County had more enrolled students than the capacity of their permanent buildings and temporary classrooms combined.

[2] Prior to 2010, Wake County implemented large-scale reassignment policies with the purpose of reducing school overcrowding in areas experiencing high population growth and maintaining socioeconomic diversity. Students from

In the context of Wake County's magnet program, this paper evaluates whether students experience achievement gains from "escaping" overcrowded traditional schools and attending magnet schools. I separate magnet applicants from traditional schools into two groups by their base school overcrowding status. The group of applicants with an overcrowded traditional base school likely "fall back" to their overcrowded base school if they do not receive a magnet offer, while others "fall back" to a non-overcrowded traditional base school.

This paper adds to the few studies on school overcrowding effects (?Rivera-Batiz and Marti, 1995; Shirley, 2017). Two common solutions to school overcrowding have been examined by the literature—mobile classrooms and multi-track year-round school calendars. I present an alternative solution that utilizes an existing school-choice program to attract students away from overcrowded schools. I also propose a new approach to estimate the effect of school overcrowding. Although school overcrowding status is likely non-random for students, centralized assignment allows for random variation in magnet school offers. Taking advantage of the random variation in centralized school assignments, I provide causally identified estimates of the effect of magnet attendance by base school overcrowding status following the econometric method proposed by Abdulkadiroğlu et al. (2017). I then examine the differential gain from attending a magnet school by base school overcrowding status as a proxy of overcrowding effects among applicants to the magnet program. While I do not find evidence of overcrowding effects on math and literacy skills, the results show a large and statistically significant overcrowding effect on absenteeism. Compared to students with a high-performance, non-overcrowded base school, students with a high-performance, overcrowded base school experience a more than 40% reduction in the number of absences from attending magnet schools.

This paper contributes to a recent line of research that identifies magnet school effects using the methodology by Abdulkadiroğlu et al. (2017), which fully exploits the conditional random variation in assignment outcomes (Abebe et al., 2019; Abdulkadiroğlu et al., 2020; Dur et al., 2020; Winters, 2020). Abdulkadiroğlu et al.'s (2017) approach extracts an assignment probability or "propensity score" of each applicant based on their submitted preferences and priorities and the assignment mechanism applied for the centralized assignment. They show that conditioning on

both high- and low-income neighborhoods were reported to be reassigned and bused to attend less overcrowded schools, suggesting both types of overcrowded schools may exist in Wake County (Hoxby and Weingarth, 2005; Parcel and Taylor, 2015).

the propensity score alone is sufficient to ensure the independence of school offers with respect to student characteristics, making them valid instruments for school enrollment (Rosenbaum and Rubin, 1983). This approach fully utilizes the random variation in the assignment and allows for identifying school choice effects from a larger quasi-experimental sample. Dur et al. (2020) adopts Abdulkadiroğlu et al.'s (2017) propensity score conditioning method to evaluate the impact of magnet schools in the Wake County Public School System. This paper adopts the approach in Dur et al. (2020) to identify magnet effects for two subgroups of magnet applicants by their base school overcrowding status.

The remainder of this paper is organized as follows. Section 2 provides background information regarding the literature on school overcrowding and Wake County schools. Section 3 provides details on the Wake County centralized magnet school assignment, the assignment algorithm used in Wake County, and the assignment propensity scores. Section 4 explains the empirical methodology used in this paper, with data descriptions discussed in Section 5. Section 6 describes school overcrowding effects on student outcomes, and Section 7 concludes.

2 Background on Overcrowding and Wake County Assignment

2.1 Literature Review

2.1.1 School Overcrowding

There is little quantitative evidence on the direct effects of school overcrowding on student outcomes. Rivera-Batiz and Marti (1995) use school-level regression analysis and finds that overcrowding in New York City public schools has a negative effect on student achievement in schools with students from low socioeconomic status. For students with high socioeconomic status, school overcrowding is positively correlated with student achievement, which they explain is a result of better schools attracting more students. The positive correlation can be evidence of unobserved student characteristics, which likely correlate with both enrollment in an overcrowded school and academic outcomes. Shirley (2017) uses the fixed effects model to analyze school-level data of eleventh graders in Kentucky high schools and does not find evidence of negative correlations between ACT scores and three- to five-year school overcrowding indicators. **?** is the closest work to mine and analyzes student-level panel data from Wake County. They find that school overcrowding negatively affects students' reading achievement growth, but not students' mathematics achievement growth. They include student, school, and grade-by-year fixed effects in the regression model to control for time-invariant unobserved characteristics. However, their approach may overlook the effects of time-variant policies, such as annual reassignment plans that switch students to new schools to reduce the overcrowding of existing schools. While these students may experience less severe overcrowding at new schools, their achievement may suffer due to unfamiliar environments and longer commute times, resulting in overcrowding effects in the opposite direction (WRAL, 2018a).

Another implication of overcrowding is larger class sizes or slow implementation of class size reduction mandates. Research on multiple school districts reports that facility constraints due to overcrowding can be a significant obstacle to rolling out class size reduction initiatives (Bohrnstedt and Stecher, 1999; Green and Doran, 2000).[3] There has been extensive literature on the effect of class size on various outcomes, especially for the Tennessee STAR experiment. In general, studies have found strong and positive effects of smaller kindergarten class sizes on student test scores, high school completion, college attendance, wages, fewer arrests, and an array of other adult outcomes such as participation in retirement saving plans (Chetty et al., 2011; Finn and Achilles, 1990; Krueger, 1999; Krueger and Whitmore, 2001). Other studies have found mixed evidence of the effect of smaller class sizes on student outcomes, attributing the reduction in teacher quality to the dampening of small class effect (Hoxby, 2000; Jepsen and Rivkin, 2009).

It is common practice for schools to use temporary or mobile classrooms to address overcrowding (NCES, 2007). Descriptive research has shown this practice to be linked with questionable health and safety conditions and negative student attitudes, despite no significant reported effects in student achievements (Callahan et al., 1999; **?**; NCES, 2007).

The literature has examined two remedies for school overcrowding—mobile classrooms and multi-track year-round calendars. The body of evidence on mobile classrooms mainly comes from qualitative analyses or descriptive statistics. They suggest these classrooms have no effect on student test scores but are associated with negative student attitudes and concerns from teachers

[3] Table 1 on Wake County elementary school characteristics shows that overcrowded schools have slightly higher average class sizes.

and principals on health and safety conditions (?).

The effects of multi-track year-round calendars have been studied with more sophisticated quantitative methods. A multi-track year-round calendar allows more students to use facilities by operating on separate schedules with periodic breaks. On the one hand, the alternating schedules help maximize school facilities' utilization and serve more students. On the other hand, they disrupt traditional school schedules and add stress to teachers. Graves (2010) uses panel data methods to analyze school-level longitudinal data from California. She finds a negative impact of multi-track year-round calendars on student academic performance with a 1-2% drop in national percentile rank. While McMullen and Rouse (2012) find no discernible overall impact of year-round calendars on student test scores using fixed-effects models, McMullen et al. (2015) use quantile regressions and show small positive effects for the lowest-performing students.

2.1.2 Estimating School Choice Effects Using Centralized Assignments

A growing literature evaluates education programs by exploiting variation created through randomized lotteries at selective schools or in centralized assignments of a set of schools. Using assignment outcomes based on exogenous variation allows for causal identification of student achievement gains free of bias created by student sorting into schools. Several papers take advantage of random variation based on lotteries administered at the school level by selective schools and open-enrollment programs, using lottery outcomes at each school or program as instruments for student enrollment (?Cullen et al., 2006; Engberg et al., 2014).

On the other hand, many studies focus on district-wide centralized assignments comprised of multiple schools where students submit a ranked order of schools to the assignment system. A student's first-choice school is the school that she prefers to any other school. Studies of district-wide school choice plans have frequently used lottery outcomes at students' first-choice schools as instruments for first-choice school attendance. In general, attending the first-choice school in centralized assignments is found to result in positive test score impacts and, in some cases, better outcomes related to crime and college attendance (Hastings et al., 2012a; Deming, 2011; Deming et al., 2014). Other studies instrument exposure to charter schools with charter offers, with controls for every combination of charter school lotteries each student was subject to (Abdulkadiroğlu et al., 2011; Angrist et al., 2013, 2016). However, prior research only uses random variation generated at the first-choice schools or oversubscribed schools, limiting the representativeness of the estimates. In centralized assignments, students losing lotteries at oversubscribed schools can create random variations at lower-ranked schools, which are not fully exploited in the studies mentioned above.

Abdulkadiroğlu et al. (2017) provides a new method that fully exploits the random variation created by lotteries through propensity scores, which represents the probability of receiving an offer from any school on a student's submitted preference list. They suggest that conditioning on propensity scores sufficiently ensures that offers are independent of student characteristics. Using administrative data on Wake County's centralized assignment for magnet school seats, Dur et al. (2020) follow this new approach and causally identify the effect of magnet school attendance for Wake County applicants. They find robust evidence of positive magnet effects on math skills and attendance among magnet applicants. Abdulkadiroğlu et al. (2020) use this method to generate bias-free estimates of school effects on applicants to a minority of New York City high schools that are subject to random assignment. They use these estimates as benchmark results to test the accuracy of two other models developed based on the district-wide sample including non-applicants.

The majority of research on school choice evaluates the programs as a whole and estimates the school choice effects on all students regardless of their fallback options when they lose the lottery. Little research has been done to study policy-relevant aspects of school choice, such as differential effects related to overcrowding. This paper follows the econometric method in Dur et al. (2020) and adapts it to account for differential treatment effects for two student subgroups that vary by their base school overcrowding status.

2.2 School Overcrowding in Wake County

The Wake County Public School System is the 15th large school district in the United States, with 159,549 students enrolled in 187 schools as of the 2018-19 school year. Wake County has experienced rapid population growth in recent years. From 2004-2005 to 2015-2016, the student population in the district grew by 38% (NCPS, 2015a). NCPS (2016) concludes that Wake County is in the greatest need of new schools among all school districts in North Carolina. Elementary schools have been identified as the grade levels with the highest need for new construction or existing renovation. In this study, I focus on overcrowding in elementary schools, as it is more prevalent among a larger set of schools.

In 2015, 59 of the 107 (27%) Wake County elementary schools were above 100% of the school's capacity and 29 were above 106%, the threshold by which the National Center for Education Statistics deems a school overcrowded (WCPSS, 2015a; NCES, 2007). An increase in class sizes due to school overcrowding is less of a concern in Wake County, North Carolina. The current North Carolina class size mandate caps are set at 23 students per classroom for grades K-3. With the new state class-size mandate, which limits class size to 19 to 21, going into effect in the fall of 2019, the school district is under even more pressure to increase the number of classrooms. The school district has addressed overcrowding in several ways.

Despite the high costs, Wake County has been building new schools to address the rapid growth in student population. The Community Improvement Program (CIP) in Wake County was passed to allow for $565 million in bonds to be invested in the construction of new schools between 2013 and 2019. (WCPSS, 2019a). Utilizing facilities at new schools to alleviate overcrowding at existing schools often leads to students being reassigned to new schools. Many students and parents subject to reassignment have voiced their concerns, including longer commute times, unexpected changes in the school calendar, or adapting to a new environment(WRAL, 2018a,c,b).

In addition to building new schools, Wake County Public Schools have taken advantage of adapting existing spaces by using mobile/modular classroom units and multi-track year-round schools. As of 2009, there are more than 1,000 mobile units throughout the district. In the 2014-2015 school year, 17.3% of all capacity in elementary school is in temporary classrooms. In 2006, year-round schools were introduced as another remedy for school overcrowding. As of 2016, 37 elementary schools are year-round schools, and seven are multi-track. Multi-track year-round schools split students into four groups with three in class at all times as a way to increase the campus capacity.

Compared to the solutions discussed above, the existing magnet school program helps alleviate overcrowding on a smaller scale, but it has two advantages. First, participation in the magnet program is entirely voluntary—students are free to apply for reassignment at any magnet school or not apply at all. This feature minimizes controversy compared with one-size-fits-all plans to convert school calendars or reassign current students to newly built schools. Second, the assignment operates within the given capacities of each magnet school. Since no additional seats at magnet schools are required, the district can save on new school construction or new mobile classrooms.

3 Assignment, Deferred Acceptance, and Assignment Propensity Scores

3.1 Centralized Assignment in Wake County

In Wake County, all students are initially assigned to a neighborhood base school based on their home address. The base school is the default enrollment option if students do not apply to be reassigned to a magnet school, an alternative calendar school, or a charter school. Wake County conducts an annual centralized assignment that allows students of any grade to apply to be reassigned to a magnet school. The magnet school program is the most established diversity program in the school district, and is intended to "reduce high concentrations of poverty" and "promote diverse populations" (WCPSS, 2019b). The school district also intends to alleviate school overcrowding with school choice by "maximizing use of school facilities."

Since the 2015-2016 school year, Wake County has used the Deferred Acceptance (DA) algorithm to assign applicants to most district schools. In the assignment process, magnet seats are assigned up to schools' pre-determined capacities based on student preferences and school priorities. Students submit a list of up to five schools ranked by their preference over the schools. Schools also have "preferences" over students, called "priorities", which are functions of student characteristics. In addition to priorities, schools also use a single lottery number assigned to each student to break ties. The lottery numbers are unknown to applicants.

The school district designs the priority structure. At elementary schools, current magnet seat holders in grades K-4 have guaranteed seats in the next academic year. The highest priority at a school is assigned to those with siblings currently attending this school. Students residing in an area with high socioeconomic status receive the second-highest priority. Next, there are a set of facility utilization (or overcrowding) priorities granted to students with overcrowded base schools. The district's intention of addressing overcrowding with school choice is reflected in the utilization priorities. A student with an overcrowded base school has higher priorities at all magnet schools than a student with a non-overcrowded base school, holding sibling status and residence area the same. A student with a severely overcrowded base school is also granted higher priorities than a student whose base school is moderately overcrowded. Overcrowding is defined as having projected enrollment over 105% of projected capacity.[4]

3.2 Assignment algorithm: Deferred Acceptance (DA)

Deferred Acceptance (DA) is the most widely-used centralized assignment mechanism. DA is an algorithm with inputs of preferences, priorities, and school capacities coupled with lottery numbers for each applicant, and an output of a vector of assignment outcomes that specifies each student's assigned school (or lack thereof) among the set of schools subject to DA. The DA process is simple and shown as follows:

Step 1. Each applicant applies to the highest-ranked school on her preference list, i.e. the most preferred school.

Step 2. Each school receives the applications and ranks applicants by priorities. Students with the same priorities, if any, are then ranked by lottery numbers. According to the ranked list of all applicants, schools give temporary seats to the highest-ranked up to its capacity and reject others.

Step 3. Each rejected applicant applies to the next highest-ranked school on her list.

Step 4. Each school pools the new applicants together with all students currently offered a temporary seat and ranks them first by priority and then by lottery number. Schools give temporary seats to the highest-ranked applicants up to its capacity and reject others.

Repeat Step 1 through Step 4 until:

Step n. All students are either temporarily seated at a school or have been rejected by all schools on their preference lists. As a result, no one initiates new applications. Now, DA is terminated, and schools offer seats for those who were previously temporarily seated. Each student is seated at only one school since students cannot apply for other schools unless they are rejected at the one they have just applied to.

In Wake County, the school-student-specific priorities are coarse, meaning that many students can share the same priorities at a given school. Therefore, students can be subject to tie-breaking

[4]There are four categories of overcrowding priorities. The highest priority category is granted to students with base schools projected to be over 120% overcrowded. In 2015-2016, 30 elementary schools were projected to have an overcrowding percentage over 120%. Students with base school overcrowding measure between 115%, and 120% have the second-highest category of utilization priority. The third category is for those from base schools with overcrowding measures between 110% and 115%, and the fourth category for overcrowding measures between 105% and 110%. Many magnet applicants have overcrowding priorities in Wake County. In the 2015-2016 school year's magnet assignment, 44% of applicants have overcrowding priorities, while 62% of those receiving magnet offers have overcrowding priorities.

using lottery numbers in order to obtain a magnet seat. When a school is oversubscribed, students with the highest priorities will always be assigned regardless of their lottery numbers. Lottery tie-breaking takes place when a school has more applicants with the same priorities than the number of remaining seats. These applicants are conditionally seated, which means that their assignment is purely determined by lottery numbers. Therefore, conditionally seated applicants at a given school have the same probability of assignment to that school.

3.3 Assignment Propensity Scores

It is straightforward that DA allows for random variation for conditionally seated students at oversubscribed schools. Under different draws of random lottery numbers, these students can experience various assignment outcomes. More interestingly, DA also results in random variation at undersubscribed schools.

Imagine a simple assignment with three students and two schools. Students i, j, and k have the same priorities at both schools. All three students prefer school a over school b. School a has a capacity for only one student while school b has more seats available than the number of applicants. In DA, all students apply to the oversubscribed a, and each has a 33% chance of getting in. Two students are rejected and then apply to b, where they are automatically accepted. I can calculate the probability of being assigned to b for all students as $(1 - 33\%) * 100\% = 67\%$.

Thirty-three percent and 67% are examples of assignment propensity scores. A propensity score, or assignment probability, is defined as the probability of being assigned at a school. In the context of magnet assignments, it is useful to define a sector-specific propensity score over a set of schools $s = 1, ..., S$:

$$PS_i = \sum_{s=1}^{S} Pr(D_i(s) = 1)$$

with $D_i(s)$ indicating the assignment of student i to school s. The magnet propensity score for a student is the sum of her scores for each magnet school.

The propensity score can be calculated based on simulations using different random draws of lottery numbers. The simulated score of an applicant is equal to the proportion of simulations where lottery numbers are drawn in a way that allows the student to be seated at magnet schools. It is worth noting that simulations input preferences, priorities, and capacities in the *original* assignment algorithm that produces offers to students to consider. To generate propensity scores in this paper, I ran the assignment one million times, each time with a new set of random lottery numbers. I then count the number of times students were assigned to each magnet school and divide them by one million to calculate the school-specific propensity scores.

4 Empirical Strategy

I follow the econometric method proposed by Abdulkadiroğlu et al. (2017) and first implemented in the Wake County setting by Dur et al. (2020). This method fully exploits the conditional random variation in assignment outcomes by conditioning on assignment propensity scores, which group students together based on their preferences and priorities. As long as students have the same propensity score, their offer is independent of other characteristics. Compared to lottery indicators used in traditional approaches, such as the first-choice instruments approach, conditioning on propensity scores generates a richer sample, as lottery indicators only group students based on whether they are subject to the same lottery.

Imbens and Angrist (1994) have shown that the local average treatment effect (LATE) for those who comply with their assignment can be causally identified under the assumptions of independence, exclusion, and monotonicity. These assumptions are listed below for a variation of the potential outcomes model. Independence asserts that the assignment outcome must be independent of potential enrollment and outcomes. In the case of centralized school assignments described in Section 3, the assignment outcome is only conditionally random for students who are in the same lottery. Traditional methods only account for random variation at oversubscribed schools that are listed as students' first choice. However, it is embedded in the DA algorithm that undersubscribed schools are also subject to conditional random variation in student offers, since lottery losers apply to a lower-ranked school conditional on losing the tie-breaking with a set probability.

Rosenbaum and Rubin (1983) showed that offers are independent of potential individual characteristics conditional on propensity scores, thus eliminating omitted variable bias. The method in Abdulkadiroğlu et al. (2017) builds on this. It runs a classic IV model conditional on assignment propensity scores at magnet schools instead of lottery indicators. Propensity-score conditioning allows researchers to identify causal effects based on random variation even at undersubscribed magnet schools. Therefore, this method provides the largest sample size available in the dataset and identifies LATE for a larger and more representative complier sample. Under standard assumptions of LATE, an IV model that follows Abdulkadiroğlu et al. (2017) is:

$$Y = \mu + \beta D + G(PS) + X'\delta + \epsilon \tag{1}$$

with D, magnet attendance, instrumented by Z, an indicator for receiving an offer from any magnet school. $G(PS)$ indicates a function of assignment propensity scores. β is the average effect of magnet attendance on student outcomes for compliers.

In order to study differences in the effect of magnet attendance by base school overcrowding status, I first consider the potential outcomes model for two groups of students:

$$Y = Y_1 + (Y_1 - Y_{0A})(1 - D) * A + (Y_1 - Y_{0B})(1 - D)] * B \tag{2}$$

A is a binary variable that equals one if the student is from an overcrowded base school. $B \equiv 1 - A$ is a binary variable that equals one if the student is from an non-overcrowded base school. Y_{0A} denotes the potential outcome if a student does not attend a magnet school and has an overcrowded base school. Similarly, Y_{0B} represents the potential outcome for a student with a non-overcrowded base school without magnet attendance. Y_1 denotes the potential outcome if this student attends a magnet school. Let D_1 denote a student's potential magnet enrollment with a magnet offer. D_{0j} ($j \in A, B$) indicates her potential enrollment without a magnet offer that is specific to the overcrowding status of her base school..

I impose the standard LATE assumptions—independence, exclusion, and monotonicity. The independence assumption holds when the instrument, the assignment offer, is independent of student characteristics conditional on assignment propensity scores. Random tie-breakers ensure conditional independence in centralized assignments. The exclusion assumption suggests that the instrument cannot directly affect the potential outcome. This assumption holds if magnet offers only affect student outcome by changing student' magnet attendance status for each fallback option group. The monotonicity assumption holds as long as receiving a magnet offer weakly improves the chance of attending a magnet school. It is reasonable to assume that magnet offers do not deter students from attending.

Given that the three LATE assumptions hold, under the potential outcomes model in equation 2, the standard IV model presented by equation 1 identifies an average of two LATEs for two groups of students by their base school overcrowding status, weighted by their proportion in the complier population, ω_A and ω_B ($\omega_A + \omega_B = 1$):

$$\begin{aligned}\frac{E[Y|Z=1,G(PS)] - E[Y|Z=0,G(PS)]}{E[D|Z=1,G(PS)] - E[D|Z=0,G(PS)]} &= E[Y_{1A} - Y_{0A}|D_{0A} < D_{1A}]\omega_A \\ &+ E[Y_{1B} - Y_{0B}|D_{0B} < D_{1B}]\omega_B\end{aligned} \tag{3}$$

with

$$\omega_A = \frac{Pr(D_{0a} < D_{1a}|G(PS))}{Pr(D_{0a} < D_{1a}|G(PS)) + Pr(D_{0b} < D_{1b}|G(PS))}, \omega_B = 1 - \omega_A$$

In order to separately identify the two counterfactual-specific LATEs by students' base school overcrowding status, I further impose an additional assumption of constant effects, that is, $Y_{1i} - Y_{0Ai} = \beta_A$ and $Y_{1i} - Y_{0Ai} = \beta_B$ for each observation i. To model two fallback options for magnet applicants, I add an interaction of magnet attendance and an indicator base school overcrowding status in this IV model following the literature (Deming, 2014; Hastings et al., 2012b). Then, the model becomes:

$$Y = \mu + \beta_0 D + \beta_A D * A + \gamma A + G(PS) + X'\delta + \epsilon \tag{4}$$

with D and $D * A$ instrumented by Z and $Z * A$. A denotes a student's base school overcrowding status. In this model, β measures the mean magnet effect for complying students from a non-overcrowded base school, and β_A measures the differential gain from magnet attendance by base school overcrowding status.[5] While β_A cannot be interpreted as the true overcrowding effect, it provides a novel alternative measure of overcrowding effects on student achievements by evaluating

[5]Table A1 compares differences in student characteristics by magnet offers and base school overcrowding status with controls for assignment propensity scores. Propensity scores seem to provide sufficient control to allow for relatively balanced student characteristics for lottery losers and winners. Lottery losers with a non-overcrowded base school are more likely to be African American. Lottery winners with an overcrowded base are less likely to have siblings or having an older sibling that also attends Wake County public schools.

how students from overcrowded schools differentially respond to the magnet school program.

5 Wake County Data and Descriptive Statistics

This study proposes to estimate the causal impact of school overcrowding through student-level administrative data merged with student assignment outcomes and school-level indicators on overcrowding. I study school overcrowding effects in elementary schools, which has been identified by Public Schools of North Carolina as the school type most in need of new and renovated facilities (NCPS, 2016).

I use assignment and enrollment data on grade-entry students in the 2015-2016 school year, who submitted their magnet applications in February 2015. These students are followed through the end of their second grade in the 2017-2018 school year, where student outcome data are recorded. I focus on students who were kindergarteners in the 2015-2016 school year in order to allow the sample to contain the largest number of students in one grade. Twenty-two percent of applicants for magnet elementary schools were entering kindergarten, the most among all elementary grade levels. Restricting the sample to grade-entry magnet applicants likely results in estimating magnet effects based on a more representative sample of students. However, grade-entry students may have different characteristics and gains from magnet attendance compared to non-grade-entry students. Students in the latter group likely have prior experience at traditional schools or have recently moved into the Wake County school district.

5.1 School Characteristics

The school-level administrative data has information on actual overcrowding levels in the 2014-2015 school year and projected overcrowding levels in the 2015-2016 school year. The overcrowding measure is calculated by dividing the number enrolled students by the school's capacity. The planned facility utilization capacity is based on the number of permanent classrooms and the "optimal" number of temporary (mobile) classrooms.[6] The actual facility utilization capacity adjusts the planned capacity by accounting for the actual number of temporary classrooms used

[6]The optimum number of temporary units is defined as the number of mobile classrooms that meets a number of criteria, including being supported by dining and toilet facilities and specialized educational program spaces such as gym.

and other school-specific changes in its needs for classrooms. In this paper, I focus on the actual overcrowding level in the 2014-2015 school year, which is calculated by dividing each school's 2014-2015 enrollment by its actual capacity for the school year.[7] I construct a binary indicator for school overcrowding that equals one if a student's base school is over 105% overcrowded. To leave out the effect of mobile classrooms, my calculation is based on the capacity of permanent classrooms only by removing temporary classroom capacity from the total school capacity.[8] Throughout this paper, I consider all magnet schools as non-overcrowded schools, given the fact that the school district wishes to move students from overcrowded traditional schools to magnet schools.

The school-level data also contains information on school demographics and academic performance. Table 1 shows differences in school characteristics by overcrowding status. Magnet schools are listed separately in Column 3. Overcrowded schools are generally larger schools and have approximately one additional student in an average classroom. However, overcrowded schools also have slightly higher teacher-to-classroom ratios. It is important to note that overcrowded schools have higher teacher quality in terms of experience than non-overcrowded schools and magnet schools. Overcrowded schools also have substantially lower numbers of acts of violence and short-term suspensions in addition to slightly higher attendance percentages. Also, overcrowded schools score significantly higher on average in the school achievement scores calculated based on the average student EOG math and reading test scores in the 2014-2015 school year. This finding further motivates this paper's empirical methodology that allows Y_0 to differ based on base school overcrowding status. However, overcrowded schools have higher ratios of students to internet-connected computers, which may indicate old or deteriorating equipment.

5.2 Student Characteristics

The student-level assignment data has detailed information on all magnet applications, including student preferences, priorities at each school, lottery numbers, school capacities, and assignment outcomes. To calculate the propensity score for each student, I construct a new dataset using

[7]Projected overcrowding is calculated by dividing the projected enrollment in the next school year by the planned capacity. Projected overcrowding serves as the ground for assigning utilization priorities in the Wake County magnet assignment.

[8]Another overcrowding indicator was created for the case where the school is over 105% overcrowded even with temporary classrooms. I also considered projected overcrowding, overcrowding measures on high class size and temporary classrooms usage. Results using these overcrowding measures are reported in Table A4.

preferences, priorities, and capacities in the actual assignment and a set of lottery numbers that are randomly re-drawn from a uniform distribution between zero and one. I then use this dataset as the input to run the original assignment algorithm and obtain a new set of assignment outcomes for each student. Due to lottery numbers changes, a student may switch between assigned and unassigned status or receive a different magnet assignment in the simulation. I then repeat this process one million times using the High Performance Computing cluster, thus collecting 1 million assignment outcomes for each student. To aggregate simulation results, I calculate each student's "simulated propensity score" for magnet assignment by counting the number of simulations where they are assigned to any magnet school and dividing it by 1 million.[9] Students with simulated propensity scores strictly between 0 and 1 are subject to random variation in assignment outcomes.

The student-level administrative records also include detailed information on student demographics such as race and gender, enrollment, and non-cognitive outcomes such as absences. Based on students' home addresses, I create an indicator for whether students live in residence with other students attending a Wake County magnet school ("siblings"). By comparing grades of students living in the same address, I also record whether a student has older siblings attending a magnet school. As for cognitive outcomes, I focus on two test scores that measure early literacy and math skills in the data.[10]

The Number Knowledge Test (NKT) and the Dynamic Indicators of Basic Early Literacy Skills (DIBELS) are individually administered to grade K-2 students three times in the beginning, middle, and end of each academic year.[11]

The Number Knowledge Test (NKT) is an oral test designed to measure intuitive knowledge of numbers and basic arithmetic skills such as counting, adding, and subtracting that an average student has at each age level (Case et al., 1996). The test contains thirty questions in four levels corresponding to the knowledge acquired by a typical student at the age of 4, 6, 8, and 10, respectively.

[9] Unfortunately, the analytic DA propensity score proposed by Abdulkadiroğlu et al. (2017) is not applicable in the setting of the Wake County assignment. In the 2015-2016 school year magnet assignment, Wake County performs an assignment rule that only fills 90% vacant seats after assigning guaranteed seats to students with older sibling priorities. The remaining 10% of seats are assigned based on a lottery without accounting for student priorities. As a result, the Wake County assignment rule results in two lotteries at each school if capacities are not filled after assigning guaranteed seats to students with older sibling priorities. The analytic DA score is no longer applicable since it assumes that only one lottery is carried at each school to assign students.

[10] This is because the grade-entry cohort in elementary schools have not yet taken the end-of-grade standardized tests, which begins in the third grade.

[11] Since grade-entry students have no recorded cognitive outcomes before Kindergarten, I consider test scores at the beginning of Kindergarten as baseline test scores.

The student cannot proceed to the next level of questions if she has committed three consecutive errors in the current level. The NKT score is widely used to measure early math achievement in literature from various disciplines (Jerrim and Vignoles, 2016; Ribner et al., 2019; Zhang et al., 2019). Several studies have shown a strong positive correlation between the NKT score and later math and reading attainment and a negative correlation with behavioral problems such as physical aggression in elementary school (Cowan et al., 2011; **?**; Jordan et al., 2007; Romano et al., 2010). Gersten et al. (2005) finds that the NKT works well as a screening measure for students with math difficulties. Research using growth models shows students in low-increasing trajectories of early number knowledge consistently fall behind in math learning through elementary school, suggesting the importance of early identification and intervention for students with deficits in number sense following NKT test results (**?**Jordan et al., 2007). The raw test score is between 1 and 30. I create an indicator for students who score above 14, the cutoff for having math skills, not below the grade level of K-1.[12] This indicator of not scoring below grade level is interpreted as the student not being at-risk in terms of early math skills, as low NKT scores are predictive of low achievements in math learning as students progress to higher grades (**?**Jordan et al., 2007).

The Dynamic Indicators of Basic Early Literacy Skills (DIBELS) is designed to measure early literacy skills and identify students experiencing difficulty acquiring these skills to provide support early on (Good and Kaminski, 1996). Like the NKT, the DIBELS is also an individually administered oral test where students read out passages to teachers. For second graders, DIBELS consists of measures on students' speed and accuracy in reading connected text (Oral Reading Fluency, ORF) and comprehension of the text (Retell). DIBELS has gained widespread use in the United States, with numerous studies showing its predictive power for later reading attainment in elementary school and its effectiveness with identifying students at risk of reading difficulties (Good et al., 2001; Smolkowski and Cummings, 2016; Pears et al., 2016; Roehrig et al., 2008). More specifically, Barger (2003) find a strong correlation between the DIBELS ORF score and North Carolina end-of-grade reading scores when these two tests were taken one week apart. I create a binary indicator for not scoring well below the DIBELS test benchmark and focus on this outcome for literacy skills in this paper. This definition is consistent with the test's objective to identify students with literacy

[12]The developmental conversion chart that exhibits how raw scores are converted to grade levels is available at https://s3.amazonaws.com/ecommerce-prod.mheducation.com/unitas/school/explore/sites/number-worlds/number-worlds-number-knowledge-test.pdf.

skills "at-risk" of falling behind.

A large body of literature has examined non-cognitive skills that are not captured by standardized tests and shown that these skills have significant effects on long-term outcomes in students' adult lives (Heckman and Rubinstein, 2001; Borghans et al., 2008; Lindqvist and Vestman, 2011). Following the literature, I use one behavioral measure available in the dataset as a proxy for non-cognitive skills - the log of the number of absences between grade 0.[13]

Table 2 shows student characteristics for all students who applied for a Kindergarten seat in the magnet school program for the 2015-2016 school year. Column (2) and (3) show mean characteristics for subgroups by base school overcrowding status. Overcrowded schools have a slightly higher proportion of male students. Students from overcrowded schools are less likely to be African American and and more likely to be Hispanic students compared to those from non-overcrowded schools. Average NKT scores at the beginning of Kindergarten is slightly higher at overcrowded schools, while the proportion of students not at-risk in literacy skills is lower. I consider test scores recorded at the beginning of Kindergarten as baseline test scores that indicate student ability before any school influence. Hence, these results suggest that both positive and negative sorting into overcrowded schools depending on the subject. As for assignment outcomes, students from overcrowded base schools are more likely to receive an offer and have higher median priority at first choice school compared to students from non-overcrowded base schools. This result is consistent with the priority structure design that prioritizes the magnet assignment of these students.[14]

[13] In order to measure non-cognitive skills, Jackson (2018) constructs a behavior index with five behavioral variables, including log absences.

[14] Table A2 shows that lottery winners with an overcrowded base school are slightly more likely to attend an offered magnet school than lottery winners with a non-overcrowded base school. Lottery losers with an overcrowded base have a higher rate of compliance by attending their base school than lottery losers with a non-overcrowded base school. In general, students with an overcrowded base are also less likely to leave the school district. Figure 1 shows the relationship between three student outcomes and magnet attendance by base school's actual overcrowding intensity in the 2014-2015 school year. The outcome difference by magnet attendance for log absences increases as overcrowding measure reaches above 100%.

6 Results and Discussion

6.1 Overall effects

The estimation sample for Table 3 is all students with an assignment propensity score strictly between 0 and 1 who do not have a magnet as base school and are continuously enrolled between 2015-2016 and 2017-2018. School-level controls for base schools include binary indicators for below-median one-year teacher turnover rate, as well as average acts of violence and short-term suspensions. These measures are recorded in the 2014-2015 school year, prior to the enrollment of Kindergarten magnet applicants for the 2015-2016 school year.[15]

I measure math skills for second graders using scores from a shortened version of the Number Knowledge Test (NKT). The mean score is 25.2 for second graders at the end of the 2017-2018 school year in the sample. This score's chronological age equivalent is about seven to eight years old, and the grade level equivalent is about grade 2-3 (Case et al., 1996). Of the 973 children in the estimation sample, only 9 had missing NKT scores. I also create an indicator that equals one if a student has an NKT score above 14, suggesting a grade level equivalence of grade 1-2 and above.

I present in Part A, Table 3, the second-stage estimates of magnet effects on math skills by school overcrowding status based on the model shown in equation 4. Column (1) shows the differential magnet effect, which I consider as an alternative measure of overcrowding effects. If falling back to an overcrowded base school instead of a non-overcrowded base school results in worse outcomes, i.e. negative overcrowding effects, the magnet gain for students from overcrowded schools should be stronger. Column (2) and (3) show that magnet effects are positive and statistically significant regardless of applicants' base school overcrowding status. Results suggest that attending a magnet school increases NKT score by more than four points on average for applicants regardless of their base schools' overcrowding status. These points gain are equivalent to an improvement in math skills equivalent to approximately one grade level. Magnet effects are also positive and statistically

[15]Table A2 shows the enrollment status of magnet school applicants who are subject to lotteries. I have left out applicants with a magnet base school. Results are presented for four subgroups by whether they have won the lottery and their base school overcrowding status. A substantial proportion of lottery losers with non-overcrowded schools end up attending a magnet school, compared to the other groups. In addition, applicants with a non-overcrowded base school are more likely to leave the school district regardless of whether they received a magnet seat. Column (1), Table A3, shows the first-stage estimate of the effect of receiving a magnet offer on magnet school attendance in Kindergarten. Column (2) suggests some level of differential compliance by base school overcrowding status, as evidenced in Table A2.

significant on not receiving the at-risk status of math skills. Magnet attendance contributes to a 31 to 33 percent reduction in at-risk status in math skills, depending on base school's overcrowding status. The differential magnet gain for both math outcomes are small and not significantly different from zero, which indicates minimal overcrowding effects on students' math skills.[16]

Part B, Table 3, displays magnet effects on normalized Dynamic Indicators of Basic Early Literacy Skills (DIBELS) test scores and being identified as at-risk in the DIBELS test, which measures early literacy skills. Compared to the NKT test, there are around 30 more students with missing scores.[17] For students from both overcrowded and non-overcrowded base schools, attending a magnet school has no discernible effect on improving DIBELS scores or the chance of not being an at-risk student. These null results of magnet effects on literacy skills are consistent with the literature (**?**Dur et al., 2020). The gap in magnet effects by overcrowding status suggests overcrowding effects is not statistically significantly different from zero. These results, however, are also estimated with large noise.[18]

Part C, Table 3, shows results on the non-cognitive outcome of absences. The dependent variable, log absences, is calculated by taking the logarithm of one plus all absences of each student in the three school years between 2015-2016 and 2017-2018. Estimates in Column (2) show that students with an overcrowded base schools have a statistically significant reduction in the number of absences by more than 90% from attending a magnet school. Column (3) shows magnet effects of a 40% reduction in absences for students from non-overcrowded base schools. The differential gain is large and statistically significant, indicating strong negative overcrowding effects on student attendance. The effect size is an almost 50% increase in absences throughout the three school years observed in my sample, which is equivalent to attending around 10 days fewer than students in non-overcrowded base schools. Possible explanations for negative overcrowding effects on non-cognitive outcomes include reduced engagement with the school.[19]

[16]Table A4 and A5 show regression results under six alternative specifications that are largely consistent with results shown in Part A, 3. For specification checks, I switched to alternative measures of overcrowding status and changed the function form of propensity scores as well as the estimation sample. In general, the differential gains from magnet attendance by overcrowding status are reported as close to zero except for Column (3), Table A4.

[17]To obtain the most information from the WCPSS dataset, I use mid-of-year DIBELS test results in second grade.

[18]Table A4 and A5 presents regression results under five alternative specifications. Overcrowding effects can be positive or negative depending on the definition of overcrowding. Column (4), Table A4 suggests that the large average K-2 class size of a school is associated with negative effects on literacy skills.

[19]Table A4 and A5 show five alternative specifications for non-cognitive outcomes. The negative overcrowding effects on attendance are robust to various functional forms of propensity scores, but not to different definitions of overcrowding measures. Overcrowding effects are not observed for a few overcrowding measures including projected

6.2 Mechanisms

Table 4 further explores the path to overcrowding effects by examining two common arguments for negative overcrowding effects, higher class size and the use of temporary (mobile) classrooms. Model specifications are similar to those presented in Table 3. I interact measures of class size or mobile classrooms with magnet attendance for students from overcrowded base schools as well as its instrument, receiving a magnet offer for students from overcrowded base schools. Columns (1) and (2) present two overcrowding effects with respect to the overcrowded school's class size. I measure class size using each school's K-2 average class size in the 2014-2015 school year and create a binary indicator for schools with average class size above the district average of 21 students per class.[20] 14 out of 26 overcrowded schools are defined to have higher-than-average class sizes. Similar to Table 3, I do not observe any statistically significant overcrowding effects on math and literacy skills. The strong negative overcrowding effect on student attendance is only observed for overcrowded schools with above-average class size. Similarly, I estimate the 2SLS model using interactions with mobile classroom usage and present two overcrowding effects in Columns (3) and (4). I refer to the facility utilization report for the number of temporary classrooms used in each school in the 2014-2015 school year. Mobile classroom percentage is calculated by dividing the number of mobile classrooms by the sum of permanent and mobile classrooms. The median is 0.11, suggesting 11% of all classrooms in a school is a temporary unit. 5 out of 26 overcrowded schools did not employ mobile classrooms in this school year. Again, no overcrowding effects on math and literacy outcomes are observed. Despite the lack of power, the overcrowding effects on absences is larger for schools that uses mobile classrooms, especially those with an above-median mobile classroom percentage. These results suggest both school characteristics contribute the negative overcrowding effects on student attendance. However, I cannot disentangle the two effects due to lack of variation in mobile classroom usage - all but five overcrowded schools use mobile classrooms to accommodate students. It is also unknown whether the cohort observed were placed in any mobile classrooms between 2016 and 2018.

overcrowding, mobile classroom usage, or high class size.

[20] The state's class size mandate is 23 between 2014 and 2018.

6.3 School Performance and Overcrowding Effects

We may suspect that overcrowded schools have more enrolled students over their capacities because they have specific characteristics that are correlated with student achievement. Table 1 suggests that overcrowded schools have higher student performance levels than other schools in Wake County. To address this achievement gap by overcrowding status, I separate the sample into two subsamples by a binary indicator for high academic performance at the student's base school in the school year prior to her enrollment. The indicator equals one if the base school has school achievement scores of A or B for End-of-Grade (EOG) math and reading tests, as indicated by the school report card in the 2014-2015 school year.[21] To receive school achievement scores of A or B, the school must have at least 70% of students being grade-level proficient in the subject (NCPS, 2014, 2015b). School achievement scores are reported on North Carolina School Report Cards as core measures of each school's academic performance. The subsample analysis allows me to identify two sets of differential magnet effects for students based on base school overcrowding. This model also provides additional information on heterogeneity in achievement gains within students with an overcrowded base school.

I separately identify the model shown in Table 5 for two subgroups by base school achievement scores in the 2014-2015 school year. Descriptive statistics in Table 1 suggest that overcrowded schools, in general, have higher SPG scores, which motivates this subsample analysis to compare magnet effects by overcrowding status based on base school quality. Here, a high-performance school is defined as having received an "A" or "B" for both EOG math and EOG reading on the school report card in the 2014-2015 school year. In 2014-2015, 32 out of the 107 schools in Wake County have received an "A" or "B" for both subjects on the school report card, including 23 overcrowded traditional schools, three magnet schools, and six non-overcrowded traditional schools. The sample size for students with a high-performance base school is 331.

Table 5 shows heterogeneous overcrowding effects by base school's academic performance. Negative overcrowding effects on math skills are observed among students with a low-performance base

[21] The EOG math and reading tests are statewide assessments on student performances concerning the North Carolina Standard Course of Study (NCSCS). Elementary school students in grades 3-5 enrolled in public and charter schools participate in EOG tests administered by the North Carolina Department of Public Instruction's Accountability Services Division. An 80% weight is assigned to school achievement scores when calculating the overall School Performance Grade (NCPS, 2014).

school. However, these effects are measured with large noise. Overcrowding effects on math are positive among students with high-performance base schools, suggesting high quality of the set of eight overcrowded school among 30 high-performance schools. Both subsamples generate null overcrowding effects on literacy. Negative overcrowding effects on attendance are observed for both subsamples. Consistent with Part A, the effect size for students with a high-performance base school is smaller.

Tables 3 to 5 show the important aspect of overcrowding effects on non-cognitive outcomes, which is overlooked in the literature. The results also suggest a high degree of heterogeneity in overcrowding effects by base school performance. If policymakers are concerned about maximizing the level of magnet effect, results in this paper imply that they may consider granting higher priorities to students from an overcrowded school with low school achievement scores when designing the priority structure of the magnet reassignment.

7 Conclusion

In this study, I take advantage of the centralized magnet school assignment in Wake County, North Carolina, to examine the school choice effects on students who attempt to leave overcrowded magnet schools. I exploit the randomness created by assignment tie-breakers to disentangle school crowding effects for assignment lottery losers. The results suggest mixed effects of school overcrowding on student cognitive and non-cognitive outcomes. Having an overcrowded base school is not associated with stronger magnet effects on math skills measured by the Number Knowledge Test (NKT) and literary skills measured by the Dynamic Indicators of Basic Early Literacy Skills test (DIBELS). Since students from overcrowded base schools do not experience higher gains from "escaping" overcrowded traditional schools than others, I find no evidence of negative overcrowding effects on early cognitive outcomes for magnet applicants in Wake County.

Overcrowding effects on log absences are strong and negative. Students from overcrowded base schools experience significantly higher magnet gains in reducing absences, suggesting a substantial negative overcrowding effect on student attendance. I have examined two potential mechanism for this overcrowding effect. Although the second graders in my sample were subject to a statewide class size mandate of 23 students per classroom at the time, larger class sizes are still associated with large overcrowding effects on attendance. The use of temporary classrooms in overcrowded schools is also linked with strong overcrowding effects. The subgroup analysis of overcrowding effect by base school's academic performance indicates heterogeneity in both the quality of overcrowded schools and overcrowding effects.

Many studies have suggested a negative correlation between early absenteeism and academic achievement trajectory, including test scores and high school dropouts (Alexander et al., 1997; Brocato, 1989; Krohn and O'Connor, 2005; Lin and Chen, 2006). Overcrowding in elementary school can have long-term impacts on both cognitive and non-cognitive outcomes. Utilizing an existing magnet program to address overcrowding may be part of the solution.

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Table 1: Elementary School Characteristics by School Overcrowding Status

School characteristics	Overcrowded traditional schools	Non-overcrowded traditional schools	Magnet schools
	(1)	(2)	(3)
Number of students	837.462	684.500	565.360
	(198.350)	(194.577)	(120.878)
Average grade 0-2 class size	21.218	20.327	20.393
	(1.107)	(1.503)	(1.798)
Number of teachers per classroom	1.223	1.112	1.122
	(0.151)	(0.204)	(0.159)
Percentage of teachers with 11+ years experience	0.537	0.491	0.454
	(0.097)	(0.112)	(0.105)
Percent of teachers with masters or higher degree	0.365	0.362	0.368
	(0.075)	(0.074)	(0.056)
High math achievement scores	0.769	0.463	0.360
	(0.430)	(0.503)	(0.490)
High reading achievement scores	0.654	0.389	0.200
	(0.485)	(0.492)	(0.408)
Average daily attendance percentage	0.962	0.958	0.959
	(0.004)	(0.005)	(0.004)
Number of crimes or acts of violence per 100 students	0.052	0.146	0.146
	(0.074)	(0.184)	(0.230)
Short term suspensions per 100 students	2.111	3.392	5.766
	(4.097)	(3.290)	(7.853)
Observations	26	54	25

Note: Author's calculations based on the 2014-2015 School Report Card provided by the North Carolina Department of Public Instruction and the 2014-2015 Facility Utilization Report provided by the Wake County Public School System (WCPSS, 2015b). Information in School Report Cards include school-level data student performance and academic growth, school and student characteristics. High math or reading achievement scores refers to the school scoring an "A" or "B" on the School Report Card in the given subject.

Table 2: Applicant Characteristics by Base School Overcrowding Status

Applicant characteristics	Base school type Overcrowded traditional school	 Non-overcrowded traditional school	 Magnet school
	(1)	(2)	(3)
Received a magnet offer	0.660	0.424	0.475
	(0.475)	(0.495)	(0.500)
Median priority at 1st choice	23	8	16
Male	0.544	0.468	0.521
	(0.499)	(0.499)	(0.501)
African American	0.166	0.233	0.164
	(0.373)	(0.423)	(0.371)
Hispanic	0.127	0.088	0.063
	(0.334)	(0.283)	(0.244)
Other race	0.205	0.186	0.097
	(0.404)	(0.390)	(0.296)
Limited English Proficiency	0.046	0.047	0.021
	(0.211)	(0.212)	(0.144)
Has sibling	0.359	0.327	0.265
	(0.481)	(0.469)	(0.442)
Has older sibling(s) enrolled in the district	0.263	0.273	0.231
	(0.441)	(0.446)	(0.422)
Baseline NKT score	11.485	10.967	11.385
	(3.923)	(3.928)	(3.498)
Baseline DIBELS score not at-risk	0.872	0.901	0.887
	(0.335)	(0.298)	(0.318)
Observations	259	853	238

Note: 26 magnet school applicants have base schools that open in the 2015-2016 school year, Abbotts Creek Elementary School and Scotts Ridge Elementary School. They are removed from the sample.

Table 3: Estimates of Overcrowding Effects

Student Outcomes	Difference (Overcrowding effect) (1)=(3)-(2)	Overcrowded base (2)	Non-overcrowded base (3)
Part A: Math			
NKT Score	-0.184	4.796**	4.611***
	(1.619)	(2.186)	(1.294)
NKT Not At-risk	-0.020	0.328***	0.308***
	(0.091)	(0.117)	(0.068)
N		248	716
Part B: Literacy			
DIBELS Score	-0.107	0.224	0.117
	(0.308)	(0.484)	(0.307)
DIBELS Not At-risk	-0.071	0.026	-0.045
	(0.089)	(0.140)	(0.095)
N		243	692
Part C: Non-cognitive			
Log Absences	0.489*	-0.925**	-0.436*
	(0.281)	(0.401)	(0.235)
N		251	722

Note: Sample includes magnet school applicants who are recorded in the Wake County public school data continuously between the 2015-2016 school year and the 2018-2019 school year. Specifications include gender, race, siblings enrolled in the district, four base school characteristics, and nine propensity score controls indicating propensity score rounded to 0.1. Robust standard errors are reported. * $p<.10$, ** $p<.05$, *** $p<.01$.

Table 4: Overcrowding Effects by Class Size and Mobile Classroom Usage

	Class size		Mobile Classrooms		
Student Outcomes	Class size above district average	Class size below district average	Mobile classrooms percentage above median	Mobile classrooms percentage below median	No mobile classrooms
	(1)	(2)	(3)	(4)	(5)
Part A: Math					
NKT Score	-0.717	1.111	-1.947	0.541	-0.460
	(1.960)	(2.247)	(2.808)	(2.491)	(0.869)
NKT Not At-risk	-0.075	0.127	-0.262	0.122	0.013
	(0.110)	(0.126)	(0.177)	(0.134)	(0.049)
Part B: Literacy					
DIBELS Score	-0.210	0.232	0.284	-0.751	-0.050
	(0.374)	(0.408)	(0.560)	(0.458)	(0.137)
DIBELS Not At-risk	-0.068	-0.078	0.079	-0.224	-0.050
	(0.108)	(0.128)	(0.160)	(0.149)	(0.039)
Part C: Non-cognitive					
Log Absences	0.665*	0.025	0.771	0.539	-0.079
	(0.355)	(0.362)	(0.534)	(0.417)	(0.111)

Note: Results show the differential magnet gains by base school overcrowding status interacted with base school class size or mobile classroom measures. Sample includes magnet school applicants who are recorded in the Wake County public school data continuously between the 2015-2016 school year and the 2018-2019 school year. Specifications include gender, race, siblings enrolled in the district, four base school characteristics, and nine propensity score controls indicating propensity score rounded to 0.1. Robust standard errors are reported. * p<.10, ** p<.05, *** p<.01.

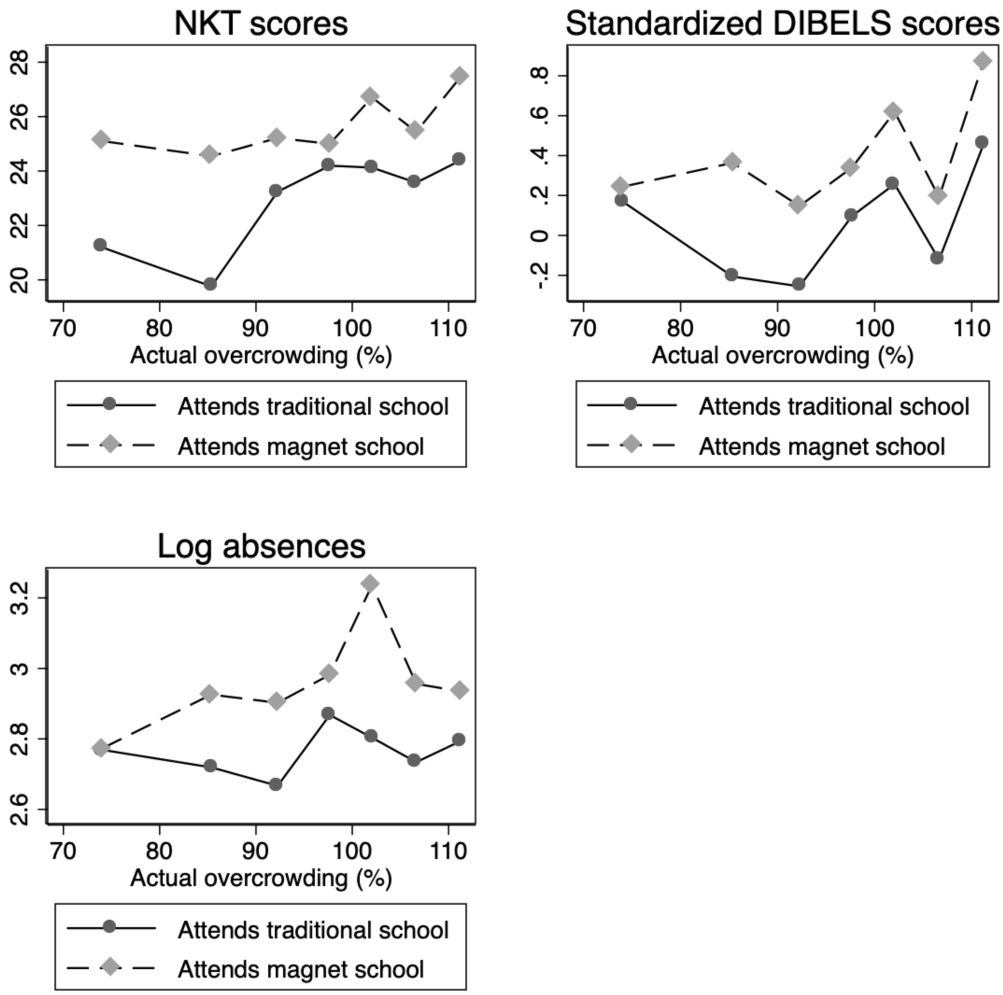
Table 5: Subgroup Overcrowding Effects by School Performance

Student Outcomes	Low-performance School (1)	High-performance School (2)
Part A: Math		
NKT Score	-3.990	2.567*
	(3.460)	(1.468)
NKT Not At-risk	-0.286	0.218**
	(0.179)	(0.093)
N	636	328
Part B: Literacy		
DIBELS Score	0.006	0.065
	(0.707)	(0.237)
DIBELS Not At-risk	-0.069	0.007
	(0.228)	(0.029)
N	610	325
Part C: Non-cognitive		
Log Absences	1.297*	0.227
	(0.694)	(0.250)
N	642	331

Note: Results are estimated for two subsamples based on base school's achievement score in the previous school year. High-performance school is defined as scoring an A or B for math and reading in school performance grade in 2015. Subsamples includes magnet school applicants who are recorded in the Wake County public school data continuously between the 2015-2016 school year and the 2018-2019 school year. The Specifications include gender, race, siblings enrolled in the district, four base school characteristics, and nine propensity score controls indicating propensity score rounded to 0.1. Robust standard errors are reported. * p<.10, ** p<.05, *** p<.01.

Appendices

Figure 1: Student Outcomes by Magnet Attendance and Base school Overcrowding Percentages



Note: Sample includes conditionally seated applicants who are recorded in the Wake County public school data continuously between the 2015-2016 school year and the 2018-2019 school year. Actual school overcrowding is calculated the actual enrollment over actual capacity in the 2014-2015 school year (WCPSS, 2015b).

Table A1: Statistical Tests for Balance

Student characteristics	Non-offered, Non-overcrowded mean (1)	Magnet offer * Overcrowded base (2)	Magnet offer * Non-overcrowded base (3)	Overcrowded base (4)
Base school is magnet	0.182	-0.004	-0.063	-0.130**
		(0.056)	(0.083)	(0.063)
Male	0.491	0.009	0.082	-0.020
		(0.075)	(0.110)	(0.083)
African American	0.270	0.128**	0.097	-0.078
		(0.059)	(0.087)	(0.066)
Hispanic	0.114	-0.000	-0.053	0.046
		(0.045)	(0.066)	(0.050)
Other race	0.114	-0.085	-0.108	0.254***
		(0.052)	(0.077)	(0.058)
Has sibling(s) enrolled in the district	0.211	0.035	-0.211**	0.107
		(0.067)	(0.099)	(0.074)
Has older sibling(s) enrolled in the district	0.128	0.058	-0.272***	0.188***
		(0.062)	(0.092)	(0.069)
Base school has below-median one-year teacher turnover rate	0.372	0.059	-0.049	0.451***
		(0.071)	(0.104)	(0.078)
Base school has below-median acts of violence	0.436	-0.038	-0.042	0.123
		(0.073)	(0.107)	(0.081)
Base school has below-median short-term suspensions	0.408	-0.030	0.073	0.242***
		(0.071)	(0.105)	(0.079)

Note: This table reports coefficients from regressions of student characteristics in each row on three variables shown in columns (2)-(4), as well as 9 propensity score controls indicating propensity score rounded to 0.1. The sample includes magnet school applicants who are recorded in the Wake County public school data continuously between the 2016-2017 school year and the 2018-2019 school year. * p<.10, ** p<.05, *** p<.01.

Table A2: Applicant Enrollment Destinies by Base Overcrowding Status

Student enrollment	All applicants subject to lottery (1)	Lottery winner, over-crowded base school (2)	Lottery winner, non-overcrowded base school (3)	Lottery loser, over-crowded base school (4)	Lottery loser, non-overcrowded base school (5)
Attend offered magnet school	0.129	0.776	0.688	0.000	0.000
Attend other magnet school	0.225	0.020	0.000	0.154	0.351
Attend non-magnet base school	0.420	0.102	0.042	0.687	0.365
Attend non-magnet non-base school	0.009	0.020	0.000	0.000	0.015
Attend non-magnet non-base school that is overcrowded	0.004	0.020	0.000	0.000	0.004
Attend non-magnet non-base chool that is non-overcrowded	0.005	0.000	0.000	0.000	0.011
Left WCPSS	0.215	0.082	0.250	0.159	0.269
Observations	550	49	48	182	271

Note: Proportions of applicants that enroll in each type of school in the 2015-2016 school year are shown in this table. Leaving WCPSS is defined as no school enrollment information in the Wake County Public School System administrative records.

Table A3: First-stage results

	Magnet attendance (1)	Magnet attendance * Overcrowded base (2)
Received magnet offer * Overcrowded base	0.430***	-0.190***
	(0.061)	(0.045)
Received magnet offer * Non-overcrowded base	0.007	0.437***
	(0.020)	(0.048)
Overcrowded base	0.501***	-0.340***
	(0.054)	(0.028)
Base school is magnet	0.044***	0.054*
	(0.016)	(0.028)
Male	-0.010	-0.009
	(0.011)	(0.020)
African American	0.019	0.003
	(0.016)	(0.027)
Hispanic	0.015	0.069**
	(0.018)	(0.035)
Other race	-0.016	0.012
	(0.018)	(0.029)
Has sibling(s)	0.058**	-0.110***
	(0.023)	(0.039)
Not oldest	-0.072***	0.108**
	(0.025)	(0.043)
Below median acts of violence	0.029**	-0.005
	(0.014)	(0.022)
Below median short-term suspensions	-0.017	-0.074***
	(0.014)	(0.022)
Observations	973	973
First-stage F-statistics	27.53	216.14

Note: First-stage results for Table 3 is presented. Sample includes magnet school applicants who are recorded in the Wake County public school data continuously between the 2015-2016 school year and the 2018-2019 school year. Specifications include gender, race, siblings enrolled in the district, four base school characteristics, and nine propensity score controls indicating propensity score rounded to 0.1. Robust standard errors are reported. * p<.10, ** p<.05, *** p<.01.

Table A4: Specifications Checks for Overcrowding Effects - Alternative Definition for Overcrowding

Student Outcomes	Actual Overcrowding $\geq$ 105% (1)	Projected Overcrowding $\geq$ 105% (2)	Mobile classroom percentage above median (3)	Class size above district average (4)
Part A: Math				
NKT Score	-0.130	0.405	-0.595	-0.251
	(1.673)	(1.189)	(1.238)	(1.161)
NKT Not At-risk	-0.026	-0.025	-0.122*	0.001
	(0.094)	(0.069)	(0.070)	(0.066)
Part B: Literacy				
DIBELS Score	-0.118	0.324	0.444*	-0.540**
	(0.318)	(0.212)	(0.245)	(0.223)
DIBELS Not At-risk	-0.065	0.118**	0.046	-0.117*
	(0.092)	(0.059)	(0.069)	(0.067)
Part C: Non-cognitive				
Log Absences	0.544*	-0.176	0.043	0.050
	(0.289)	(0.169)	(0.178)	(0.177)

Note: This table presents four specification tests for Table 3. Specifications include gender, race, siblings enrolled in the district, four base school characteristics, and nine propensity score controls indicating propensity score rounded to 0.1. Robust standard errors are reported. * p<.10, ** p<.05, *** p<.01.

Table A5: Specifications Checks for Overcrowding Effects - Alternative Propensity Score Specification

Student Outcomes	PS is linear (1)	PS rounded to 100th (2)
Part A: Math		
NKT Score	-0.093	0.029
	(1.590)	(1.570)
NKT Not At-risk	-0.018	0.015
	(0.092)	(0.092)
Part B: Literacy		
DIBELS Score	-0.108	-0.203
	(0.300)	(0.314)
DIBELS Not At-risk	-0.076	-0.085
	(0.087)	(0.088)
Part C: Non-cognitive		
Log Absences	0.367	0.498*
	(0.258)	(0.287)

Note: This table presents two specification tests for Table 3. Specifications include gender, race, siblings enrolled in the district, four base school characteristics, and propensity score controls. Robust standard errors are reported. * p<.10, ** p<.05, *** p<.01.