School Choice, School Quality and Postsecondary Attainment

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We study the impact of a public school choice lottery in Charlotte-Mecklenburg (CMS) on postsecondary attainment. We match CMS administrative records to the National Student Clearinghouse (NSC), a nationwide database of college enrollment. Among applicants with low-quality neighborhood schools, lottery winners are more likely than lottery losers to graduate from high school, attend a four-year college, and earn a bachelor's degree. They are twice as likely to earn a degree from an elite university. The results suggest that school choice can improve students' longer-term life chances when they gain access to schools that are better on observed dimensions of quality.

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Today's urban schools face increasing pressure to matriculate students who are ready for college. Growing returns to post-secondary education and shrinking middle-wage employment make college degree completion necessary for upward mobility into the American middle class (Goldin and Katz 2007; Autor, Katz and Kearney 2008). While the racial achievement gap in math and reading for elementary and middle school students has steadily decreased since 1990, there has been no such decline in the achievement gap for 17-year-old students.[1] Overall, the U.S. high school graduation rate is actually lower than its peak in the late 1960s, and while college enrollment rates have increased, degree completion has not kept pace. Importantly, racial gaps in educational attainment remain large. Over 40 percent of African American and Latino students in the United States attend high schools that graduate less than 60 percent of incoming 9th graders (Balfanz and Legters 2004). Thus improving the quality of education in these high school "dropout factories" (Balfanz and Legters 2004) is a first-order issue for economic growth, national competitiveness (U.S. Department of Education 2006; Roderick, Nagaoka and Coca 2009), and equality of economic opportunity in light of the increasing wage returns to higher education (Turner 2004; Dynarski 2008; Heckman and LaFontaine 2010; Acemoglu and Autor 2010).

Yet, with a few exceptions, progress in urban high schools has been disappointing compared to elementary and middle schools (Murnane 2008). A series of recent studies of school choice policies such as intra-district open enrollment, charter schools and vouchers for private school tuition have found impacts on test scores for disadvantaged students from urban areas that range from modest to large (Rouse 1998; Howell and Peterson 2002; Krueger and Zhu 2004; Hoxby and Rockoff 2004; Cullen and Jacob 2009; Hastings, Kane and Staiger 2008; Hoxby and Murarka 2009; Wolf et al. 2008 Abdulkadiroğlu et al. 2011; Dobbie and Fryer 2011; Angrist et al. 2011; Hastings, Neilson and Zimmerman 2011). These studies, while promising, focus almost entirely on elementary and middle school students, and as a result they are largely limited to test score gains as outcome measures.

In this paper we study the impact of winning a lottery to attend a public high school in Charlotte-Mecklenburg Schools (CMS) on college matriculation and degree completion.

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[1] Authors' calculations using the National Assessment of Educational Progress (NAEP) Long-Term Trend data.

CMS implemented an open enrollment public school choice program in the Fall of 2002. Students were guaranteed admission to their neighborhood school but were allowed to choose and rank up to three other schools in the district, including magnet schools. When demand for school slots exceeded supply, allocation was determined by lottery. Unlike many other studies, school choice in CMS was broad-based. Nearly half of all rising 9th graders listed a non-guaranteed school as their first choice. Furthermore, lottery applicants came disproportionately from the inner-city neighborhoods of Charlotte, and there is no evidence of "cream skimming" of the best students from these neighborhoods into the applicant pool, resulting in a sample of applicants with similar observable characteristics to those typical for large urban school districts.

We match student-level administrative data from CMS to the National Student Clearinghouse (NSC), a national database of postsecondary enrollment. The match is done directly using personal identifying information, so dropouts and transfers can be followed and attrition from the sample is limited only by the coverage of the NSC.[2] Rising 9th graders in the Fall of 2002, the first year of new school choice assignments, could have completed up to five years of post-secondary enrollment, enabling us to measure both matriculation and degree completion over a reasonable horizon.

Our central finding is that students from low-quality neighborhood schools benefit greatly from choice. Lottery winners are more likely to graduate from high school, attend a four-year college and earn a bachelor's degree. They are about twice as likely to earn a degree from an elite institution such as UNC-Chapel Hill or Duke. For these students, the impact of winning the lottery is large; closing nearly 75 percent of the black-white gap in high school graduation and 25 percent of the gap in bachelor's degree completion. We also estimate the impact of winning a school choice lottery on high school test scores, graduation, and other school outcomes. We find no impact on 9th grade test scores, but relatively large improvements in other school outcomes such as grade point average, math course-taking, and absences.

We measure school quality and performance using a value-added approach. We estimate a variety of school value-added measures and in our preferred specification, we

[2] The NSC covers over 90 percent of 4-year college enrollment nationwide and in North Carolina. CMS sent every student who had ever been enrolled in any grade to the NSC for matching.

cannot reject the hypothesis that school quality estimates equal the lottery-based treatment effects for the main educational attainment outcomes in the paper. Thus in addition to providing the first evidence of the impact of school choice on the college achievement gap, our results suggest an additional validation of the value-added approach using lottery-based evidence in a broad and highly-subscribed school choice program (Raudenbush and Bryk 2002; Kane and Staiger 2008). [3]

Our results show that access to a higher-quality school can improve students' longer-term educational attainment. Importantly, the pattern of results is consistent with real and persistent skill gains among lottery winners from low-quality neighborhood schools. For example, we find large improvements in math-course completion and grades for lottery winners, consistent with real gains in college preparedness rather than better application assistance among students moving from low- to high-performing high schools. Increased college matriculation and degree completion also point to increased preparedness rather than simply decreased costs of applying as the primary channel through which higher-performing schools benefit the long-term outcomes for their students. Taken together, the results suggest that attending a better high school increases long-run educational attainment primarily through improved preparation for college-level coursework.

I. Background and Data Description

Charlotte-Mecklenburg is the 20th largest school district in the nation. The school district encompasses all of Mecklenburg County, which includes both the inner city areas of Charlotte and the more affluent suburbs surrounding it. Thus neighborhoods in CMS vary widely by race and income. In 1971, the Supreme Court (in *Swann v. Charlotte-Mecklenburg Board of Education)* ruled that this variation resulted in neighborhood schools that were *de facto* segregated, and for over 30 years CMS schools were desegregated under a court order that bused students all over the district to preserve racial balance in the schools. Particularly at the high school level, this meant in practice that

[3] Evidence of the benefits of high school choice on academic outcomes is scant. Cullen, Jacob and Levitt (2006) and Deming (2011) use lottery assignments and find some evidence of choice on crime and misbehavior. Booker et al. (2011) and Lavy (2010) uses difference-in-difference, instrumental variable and regression discontinuity approaches to estimate the impact of public school choice on high school graduation. We are aware of no study that examines the impact of choice on postsecondary attainment using a lottery-based design.

inner-city and largely African American neighborhoods were divided up and bused out to more affluent and white suburbs or to "midpoint schools" in different parts of the county.

After several years of legal challenges, the historic court order was overturned and the busing plan was terminated. In December of 2001 the CMS School Board voted to move forward with district-wide open enrollment for the 2002-2003 school year. Because CMS was no longer allowed to use race explicitly in student assignments, the school boundaries were redrawn as contiguous neighborhood school zones. Children who lived within each zone received guaranteed access to their neighborhood school, which was usually (but not always) the closest to their home address. This resulted in a change in assigned neighborhood high school for about 35 percent of households.

The school choice lottery took place in the spring of 2002. To maximize the number of parents that exercised choice, CMS conducted an extensive information campaign. They held a well-advertised fair at the Charlotte convention center, set up "choice booths" in local shopping malls, and sent volunteers door-to-door in low-income and non-English speaking neighborhoods to talk to families about the plan (Hastings, Kane and Staiger 2008). CMS also developed a comprehensive booklet with information about each school, as well as smaller brochures for individual schools. As a result, over 95 percent of parents submitted a choice application in the spring of 2002.

Parents were allowed to submit up to three choices, which included schools as well as special programs within schools.[4] Students were assigned to their neighborhood school by default, and admission for all other students was subject to grade-specific capacity limits that were set by the district beforehand but were not known to families at the time of the lottery (Hastings, Kane and Staiger 2008).[5] Children with siblings already in enrolled in a school also received guaranteed access. CMS was also divided into four "choice zones" and free transportation was provided by the district only within each zone, although families could provide their own transportation to any school.[6] The district

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[4] Parents who listed three non-guaranteed choices were automatically assigned their "home school" as a 4th choice.

[5] Indeed, the fact that the home school was guaranteed even if one did not submit an application was not clear. The district communicated to parents that if they did not submit a choice form, it was unclear which school their child would be assigned to. Thus parents who wanted their child's home school submitted a choice form with the home school listed as their first choice.

[6] The choice zones were constructed so that there was at least one predominately white suburban and at least one predominantly black inner-city school in each zone.

expanded capacity at schools where they anticipated high demand in an attempt to give everyone their first choice. Still, many high schools were oversubscribed.

When demand for slots among non-guaranteed applicants exceeded supply, admission was allocated by random lotteries that occurred within the following lexicographic priority groups:

(i) Students that attended the school in the previous year and their siblings.

(ii) Free- or reduced-price-lunch-eligible (i.e. low-income, "FRPL") students applying to schools where less than half of the previous year's school population was FRPL.

(iii) Students applying to a school within their own choice zone.

Applicants were sorted by priority group according to these rules, and then assigned a random lottery number. Slots at each school were first filled by students with guaranteed access, and then remaining slots were allocated within each priority group according to students' lottery numbers. If all members of a priority group could be offered admission, slots were allocated to the next priority group in the order of lottery numbers. CMS administered the lottery centrally and applied an algorithm known as a "first choice maximizer" (Abdulkadiroğlu and Somnez 2003). This meant that CMS first allocated slots to all those who listed a school as their first choice and only then moved to second choices. As the name indicates, this maximized the percentage of students who received their first choice, but it also meant that students who lost the lottery to attend their first choice school often found that their second choice had already been filled up in the previous round. While there is the potential for strategic choice with this type of lottery mechanism, Hastings, Kane and Staiger (2008) show that this is not likely to have been a large problem in CMS, at least in the first year of the choice plan.

We match these files to information on college attendance from the National Student Clearinghouse (NSC), a non-profit organization that maintains enrollment information for over 90 percent of colleges nationwide. In collaboration with CMS, we provided each student's full name, date of birth and (when applicable) high school graduation date, which the NSC used to match to its database. Rather than restricting to CMS graduates, we matched all students who were old enough to have been enrolled in college, regardless of the last grade they been enrolled in CMS. The NSC data contain information on enrollment spells and degrees for all covered colleges that a student attended. Information is available on full or part-time status and degree receipt in some cases. Unfortunately, we have no information about college experiences such as grades or choice of major. Although not all colleges provide information to the NSC, the coverage is very good in North Carolina and the surrounding states. The Data Appendix contains a list of colleges by coverage and a detailed analysis of the match process using data from the Department of Education's Integrated Postsecondary Data Source (IPEDS) as a reference.[7] Students who leave CMS are followed in these data. Attrition is subject only to the NSC's coverage and the quality of the match. Unless coverage is differential for lottery winners and losers, the results may be attenuated but will not be biased.

We match the lottery applicant file, with individual lottery numbers and priority groupings, to a panel of administrative data from CMS. Our data span the years 2000 to 2009 and contain detailed information on students' enrollment histories, test scores, course-taking and other outcomes of interest. The North Carolina Department of Public Instruction requires all school districts to assemble and send them a standardized set of files under the state's accountability regime. In addition to enrollment records, this includes students' scores on standardized End-of-Grade (EOG) exams in math and reading for grades 3-8 and End-of-Course (EOC) exam scores in high school subjects such as Algebra I and II, Geometry, English I, Biology and Chemistry. These tests are administered to all public school enrollees and schools are required to use the scores as some component of students' grades. Importantly, these reporting requirements help to ensure that CMS's records are of high quality, with longitudinally linked and consistent student records.

[7] The major two-year college in Charlotte, Central Piedmont Community College (CPCC), did not provide information to the NSC until 2006. To fill in this gap, we obtained enrollment data directly from CPCC for all years. This data was more detailed than what colleges typically provide to the NSC. The data from CPCC contain information on type of enrollment (i.e. degree-seeking or correspondence course), credit accumulation and GPA. We also used the CPCC data to verify the NSC's match process. See the Data Appendix for details.

II. Sample Characteristics and School Quality Measures

CMS received high school lottery applications from 29,584 high school students. We first limit the sample to students who were enrolled in any CMS school in the previous year. About six percent of applicants come from outside the district, and these students are much less likely to be enrolled in CMS the following fall. Since previous enrollment status is fixed at the time of the lottery, this sample restriction does not affect the validity of the randomization. We also exclude from the sample the small number of students who apply to special education programs. Finally, about five percent of this remaining sample does not show up in any CMS school in the fall of 2002. Although these students can still be matched to the NSC data and are included in those analyses, we have no other outcome information for them. This restriction results in a sample of 25,564 rising 9th-12th graders, or 86 percent of the original sample. Finally, we exclude rising 12th graders from the analysis sample because of concerns about correct randomization.[8] This leaves an analysis sample of 20,021 students.

Table 1 presents descriptive statistics for the 14 neighborhood school zones in CMS. School zones vary widely in income, demographic composition, average student test scores and postsecondary attainment. Median household income ranges from $94,799 (in 2000 dollars) in Providence to $27,278 in West Charlotte.[9] Similarly, the share of nonwhite students and those receiving lunch-subsidies (an indicator of poverty) ranges from less than 10 percent to over 90 percent. Average 9th grade test scores in math and English have a range of around 1.5 standard deviations. Most strikingly, the share of students attending a college that is judged as "very competitive" or better by the 2009 Barron's Profile of American Colleges ranges from nearly 50 percent in the highest income neighborhood to 2 percent in the poorest neighborhood.[10]

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[8] We have analyzed the individual choice lotteries to confirm that random numbers determine offers of admission, and have found that they hold perfectly except for in the 12th grade. In reviewing the historical documentation and in conversation with CMS, we have some concern that additional slots may have been made available at schools for rising 12th grade applicants. Thus we exclude from the analysis the 85 rising 12th grade applicants who were in marginal priority groups (about 4 percent of the lottery sample).

[9] We assign each student the median household income in their 2000 census tract and calculate the school measures as the average of each student's median tract household income.

[10] School in North Carolina with a rating of "very competitive" or higher include Appalachian State University, Duke University, Elon University, North Carolina State University, UNC-Asheville, UNC-Chapel Hill, UNC-Wilmington, and Wake Forest University. Four year colleges in North Carolina that are less than "very competitive" include East Carolina University, Fayetteville State University, North Carolina A&T University, North Carolina Central University, UNC-Charlotte, UNC-Greensboro, UNC-Pembroke, Western Carolina University and Winston-Salem State University. "Most competitive" schools in North Carolina are Davidson, Duke, UNC-Chapel Hill and Wake Forest.

The last three rows show the same measures for students who attend one of the three magnet high schools in CMS. Since these schools have no neighborhood zones, they are attended by students from one of the other 14 school zones in CMS. Magnet high schools serve predominately nonwhite students in the lower end of the income distribution. This is due in part to their location in the central city, whereas many of the higher-income schools are located in the surrounding suburbs. Magnet schools rank around the district average on measures such as average test scores, high school graduation and college attendance.

Despite having higher average test scores and higher rates of college attendance, schools in higher-income neighborhoods are not necessarily better. Families that choose to live in these neighborhoods are likely to make other investments in their children that improve academic outcomes. Thus a simple comparison of mean outcomes across neighborhood school zones will overstate differences in school quality. We estimate each school's contribution to student outcomes using a general value-added framework:

(1) $$A_{ij} = \beta X_{ij} + \nu_{ij}\ , \quad \text{where} \quad \nu_{ij} = \mu_j + \varepsilon_{ij}.$$

The X_{ij} vector includes basic demographic controls and third-order polynomials in state-standardized 8th grade math and reading EOG exams.[11] The residual υ_{ij} is a linear combination of a school effect μ_j (which is constant for all students in the school by assumption) and an idiosyncratic student-level error term (ε_{ij}). Under the strong assumption that there is no sorting on the unobserved determinants of A_{ij} after conditioning on X_{ij}, the parameter μ_j is a causal estimate of a school's mean impact on the academic achievement of its students (Raudenbush and Willms 1995, Kane and Staiger 2008, Rothstein 2010).

We estimate equation (1) by ordinary least squares (OLS) and take the mean residual across students as our estimate of μ_j.[12] We estimate equation (1) separately for two

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[11] The demographic covariates are median household income in Census tract, and indicators for race (African American, Asian, Latino, white), gender, free or reduced price lunch, special education and limited English proficiency. All covariates are collected in the 8th grade year.

[12] In principle, a more efficient alternative to OLS would be to use a hierarchical linear model (HLM) that accounts for the nested random effects implicit in our error structure (Raudenbush and Bryk, 2002). Because of the large number of students in each school, HLM and OLS yield virtually identical estimates.

cohorts of first-time 9th graders in Fall 2002 and 2003,[13] and we take the average of the two estimates as our measure of school quality. [14] We attribute each student only to the first high school that they attended, and we exclude students from grades 10-12 from the estimates to prevent bias from differential rates of grade attainment and dropout. Finally, we exclude the approximately 1,800 students who are in our lottery sample to avoid any mechanical correlation between μ_j and the lottery treatment effects.

Our estimates of school quality (value-added) for the five main outcomes of the paper are in columns 2 through 6 of Table 2. The test score measures are state standardized performance on End-of-Course (EOC) Math and English exams. While these exams are required for graduation, not all students take them at the same time. Among rising 9th graders in the Fall of 2002, 50 percent took the Algebra I exam, 33 percent took Geometry, 7 percent took Algebra II, and 10 percent did not take an exam (either because they were enrolled in some other course, or because they were no longer in CMS) in the Spring of 2003. To construct the 9th grade Math score variable, we assign each student the (standardized) score for the exam they took and we include fixed effects for the prior year's exam (i.e. the student's math "track") in our models. Since about 92 percent of 9th graders took the English exam, tracking is not an issue for that outcome. We also estimate school value-added for three educational attainment measures: high school graduation rates (measured as the percent of first-time 9th grade students who obtain a diploma from a CMS high school), the fraction who go on to attend any four-year college, and the fraction who attend a four-year college that is defined as very competitive by the 2009 Barron's Profile of American Colleges. If the value-added estimates are unbiased, they can be interpreted as the expected change in each outcome for a randomly chosen student attending that school, relative to the average school in CMS. Column 7 reports the average of the five school quality measures, scaled to have a mean of zero and standard deviation of one. The neighborhood school zones are sorted by the average quality measure in Column 7.

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[13] In principle, we could use data from earlier cohorts of 9th grade students to make our value-added estimates more precise. However, the school choice program introduction was accompanied by the opening of a new high school and sharp capacity and staffing changes at many schools in addition to student compositional changes from the large-scale neighborhood rezoning and choice. Thus our preferred specification is based only on the post-rezoning cohorts of 2003 and 2004, as school effects may have changed pre- to post-redistricting.

[14] For the remainder of the paper, we will refer to our value-added estimates as measures of "school quality". We recognize that there are many different dimensions of quality that we cannot measure.

The correlation between median household income of families assigned by default to each zone school and the average quality measure in Column 7 is 0.49.[15] Column 8 shows the average of standardized outcomes of students without regression adjustment. The correlation between income and mean unadjusted outcomes is higher – at 0.86. Interestingly, there is a positive correlation of 0.57 between unadjusted mean outcomes and our value-added measure of quality. This could reflect remaining bias from failure to fully adjust for differences in student characteristics across schools, but it could also be evidence that higher-income families sort into neighborhoods with better schools, or schools in such neighborhoods are able to attract better inputs.

A final way we consider measuring school quality is by using parent's revealed preferences, under the assumption that parents know school's value-added, and uniformly place high weights on this school characteristic. Column 9 shows the share of students assigned to each neighborhood school that list that school as their first choice. Families who are already guaranteed access to a high-quality school will be less likely than others to want to leave it.[16] Reassuringly, the probability that a student will choose their neighborhood school is positively correlated (0.27) with the school's average quality estimate. However, choosing one's neighborhood school is much more strongly correlated with both income (0.86) and the standardized measure of average outcomes (0.79) in Column 8. This raises the question of how much parents actually observe about quality and their motivations for choice. Recent evidence indicates that providing information on basic measures of quality can have a significant impact on parental decision-making (Hastings and Weinstein 2008; Andrabi et al. 2009).[17]

In this first year of choice, many families in underperforming schools used the opportunity to move their children to different high schools. Table 3 presents descriptive statistics on the types of students who exercised choice. Column 1 presents coefficients from a single linear regression of the probability of choosing a non-guaranteed school on

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[15] As in Table 1, the median household income measure for magnet schools is among attendees, not assigned students, since magnet schools do not have catchment areas.

[16] It is not a perfect measure of quality, for 3 reasons: 1) If a family lives much closer to the neighborhood school than to any other, they may find it too costly to switch to a better school; 2) Families may care about factors other than quality when selecting a school (friends, sports teams, etc.) 3) Families may not observe school quality – in fact, they may sort directly on observed but imperfect proxies for quality such as income.

[17] In fact, in modeling school choice, Hastings, Kane and Staiger (2008) test several measures of elementary and middle school achievement within their choice model and find no impact of traditional value-added calculations on choice, though parents do place significant implicit weights on average test scores and racial composition of schools.

each independent variable of interest (labeled in each row). The first column of results pools all students, while the second column examines students who are assigned to one of the four lowest-performing schools on the value-added measures in Table 2. These four schools (Waddell, West Mecklenburg, Olympic and Vance) rank at the bottom on both the average quality measure in Column 7 of Table 2 and an average of our two main educational attainment quality measures – high school graduation and four year college attendance value-added (Columns 4 and 5 of Table 2). The patterns of sample selection are very similar across the two columns. Lottery applicants live significantly farther away than students who choose their neighborhood school - each mile of distance decreases the probability that a student will choose their neighborhood school by 2.6 percentage points in the pooled sample, and 5.5 percentage points in the "low-quality" subsample. Applicants are much more likely to be African American and FRPL, indicating that choice in CMS is serving families that cannot afford to vote with their feet (Epple and Romano 2003). The pattern of results is nearly identical when we include neighborhood school fixed effects rather than restricting the sample to low-quality neighborhood schools. Overall, while there is clear sample selection on race and income, lottery applicants in both groups have very similar prior test scores as well as disciplinary outcomes such as absences and suspensions.

III. Empirical Strategy

Of the 20,021 students in the analysis sample, about 48 percent (9,719) chose a school other than the neighborhood school to which they were assigned. About 49 percent (4,736) of these students applied to schools that were not oversubscribed, and thus were automatically admitted. Another 32 percent (3,118) were in priority groups where no one was admitted. That leaves the remaining 19 percent (1,865) of students who applied to schools where admission was determined by random lottery numbers. Our main results are based on this sample of students.

We begin by following the standard approach in lottery-based studies of school choice, which estimate the average impact of winning the lottery across multiple schools and grades (Rouse 1998; Hoxby and Rockoff 2004; Cullen, Berry, Jacob and Levitt 2006;

Hastings, Kane and Staiger 2008; Hoxby and Murarka 2009; Abdulkadiroglu et al. 2011; Deming 2011; Hastings, Neilson and Zimmerman 2011). We estimate:

$$A_{ij} = \delta W_{ij} + \beta X_{ij} + \Gamma_j + \varepsilon_{ij} \quad (2)$$

where W_{ij} is an indicator variable that is equal to one if student i has a winning lottery number for admission to school j, X_{ij} is a vector of pre-lottery covariates that is included only for balance, Γ_j is a set of lottery fixed effects, and ε_{ij} is a stochastic error term.[18] We use only first choices in the model, so the number of observations in the regression is simply equal to the number of students in the sample. In principle we could estimate a nested model that incorporates multiple choices and accounts for students' "risk sets" (Abdulkadiroglu et al. 2011). However, since students who lost the lottery to attend their first choice school were generally shut out of other oversubscribed schools, there is almost no randomization on 2nd and 3rd choices.

Lottery fixed effects Γ_j are necessary to ensure that the *ex ante* probability of admission to a first-choice school does not differ between lottery winners and losers (Rouse 1998). If, for example, savvy families had some prior knowledge about the chance of admission, they might apply to schools with a higher probability of acceptance. Thus comparing winners and losers across lotteries might induce bias. In equation (2), δ gives the weighted average of outcome differences summed over each individual lottery, with weights equal to $N * [p(1-p)]$ where N is the number of applicants and p is the probability of admission (Cullen, Berry, Jacob and Levitt 2006). We can test the validity of the randomization by replacing the outcomes A_{ij} in equation (2) with predetermined covariates such as race, gender and prior test scores. If the randomization was conducted correctly, winners and losers should be balanced on all characteristics that are fixed at the time of the lottery. We test this in Appendix Table 1 and find that only 2 of 20

[18] The lotteries were actually conducted at the school-grade-priority group level, so the number of lotteries is greater than the number of schools. We suppress subscripts for grade and priority group for notational convenience. The X_{ij} vector includes controls for race, gender, free or reduced price lunch, 8th grade math and reading test scores, and indicators for the level of math taken in 8th grade (since some students are already enrolled in advanced math).

coefficients are significant at the 10 percent level, which is consistent with sampling variability.[19]

In Table 4 we show estimates from equation (2) for our five key outcomes of interest – 9th grade Math and English test scores, high school graduation, and college attendance and persistence.[20] Column 1 shows the mean value of each outcome for students who lost the lottery (the "control mean"), and Column 2 shows the mean effect of winning the lottery on each outcome with the standard error below in brackets. Standard errors are clustered at the individual lottery level. We find no average impact of winning the lottery on math or English test scores. Imputing the (standardized) 8th grade math score for students who did not take a 9th grade exam results in a point estimate of 0.000 with a standard error of 0.039. Thus we can rule out even relatively small (0.05σ) impacts on test scores of winning the lottery. We also find no difference in English test-taking by lottery. However, lottery winners are significantly more likely than lottery losers to take an end-of-course (EOC) math exam at all, an important step in preparation for taking further advanced math courses and matriculation into post-secondary institutions.[21]

Turning to impacts on post-secondary educational attainment, we find small, positive, but only marginally significant impacts of winning the lottery on various measures of attainment. Lottery winners are 3.6 percentage points more likely to graduate from high school, but this impact is only marginally significant (at the 10% level). Lottery winners are 3.2 percentage points more likely to attend a 2-year college, and 2.4 percentage points more likely to ever attend a four-year college, but neither estimate is statistically significant. However, when we examine the impact on quality of college attended, we do we see a relatively large proportional impact on college quality. Lottery winners are 2.4 percentage points more likely to attend a very competitive college. That estimate is a 25% increase from the control mean baseline of 9.6 percentage points, and is statistically significant at the 5 percent level. Although the 0.8 percentage point increase in most

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19 In addition, because we have the lottery numbers, priority groups, and admission outputs from the lottery computer algorithm, we are able to verify lottery-by-lottery that indeed lottery numbers were randomly assigned and admission complied with the lottery procedures.

20 We only estimate test score impacts for rising 9th graders (N=1,146), but we show results for educational attainment outcomes for the full sample (N=1,865) of rising 9th through 11th grade students.

21 Lottery winners are only about 2.5 percentage points more likely to remain in a CMS school, so selective attrition can only explain about 25% of the difference in test-taking. The remainder is explained by students who are enrolled but not taking math, or taking math in a non-standard (usually remedial) course such as pre-Algebra.

competitive college attendance is small and statistically insignificant, it is a 33% increase from the 2.4 percentage point baseline among lottery losers.

This impact carries through to matriculation through college as well as degree completion. We have college attendance data from the NSC through the Spring of 2011. This means that rising 9th grade students who progress normally through high school would be able to attend a maximum of 10 semesters (Fall 2006 to Spring 2011) of college. Thus for rising 9th grade students in 2002 our outcome is completion of a degree within 5 years of high school graduation, with additional years available for 10th and 11th graders. We construct two measures of college persistence – 1) enrollment in at least 4 semesters; 2) completion of a degree by the Spring of 2011. In the third panel of Table 4 we examine impacts of winning the lottery on these two measures of persistence. The results are similar to the attendance outcomes. The impacts on persistence are proportionally very similar to the impacts on attendance for very competitive colleges, while the impact of winning the lottery on persistence in any 4 year college is near zero and statistically insignificant.

Next we examine the impact of winning the lottery for different groups of students. We estimate equation (2) for the five main outcomes in the paper, and we add interactions between winning the lottery and indicator variables for race (nonwhite/white), free or reduced price lunch, and gender. Table 5 presents those results in a similar format to Table 3, with the addition in Column 5 of an F-test for equality of coefficients across groups. The point estimates for all five outcomes are greater for white students than for nonwhite students, although only the difference for 9th grade English score is significant at even the 10 percent level. The two measures of college attendance are positive and significantly different from zero for free-lunch-eligible students. Interestingly, free-lunch-eligible students gain on all three measures of educational attainment despite negative impacts on both Math and English test scores. Finally, we note the large and statistically significant difference in impacts on four-year college attendance for girls versus boys. Girls who win the lottery are about 7 percentage points more likely to attend a four year college. In contrast, boys are actually slightly less likely (but not significant) to attend a four year college. This matches the growing body of evidence that girls benefit academically more than boys from educational interventions (Hastings et al. 2006;

Anderson 2008; Angrist, Lang and Oreopoulos 2009; Deming 2009; Jackson 2010; Lavy, Silva and Weinhardt 2009). Overall, while there are some interesting differences in outcomes across groups, most do not pass the threshold of statistical significance.

Moreover, interpreting the pattern of results across outcomes and groups of students is difficult absent a theory linking demographics to reasons for school selection, to school characteristics to academic outcomes. If parents choose schools for both academic and non-academic outcomes (e.g. graduation rates versus proximity or athletics), then choice can lead to gains or losses in academic outcomes (Hastings, Kane and Staiger 2008). In a simple selection model of school choice based on expected gains on academic and non-academic dimensions, if student academic gains are increasing in school quality, we would expect to see gains among students who choose to attend much higher quality schools. More generally, since the impact of winning the lottery can be thought of as the difference in quality between a student's choice school and the quality of their outside option, significant treatment effects may be hard to detect if the treatment size is small. In other words, if students who lose the lottery to attend a high quality school are able to find another comparable alternative, the estimated impacts will be small even if the school itself is quite good.

For these reasons we split the sample of lottery applicants by the quality of their neighborhood school, where quality is defined by the value-added estimates in Table 2. Because every student who applies to the same school (within a given priority group) has the same *ex ante* chance of admission, the quality of an applicant's neighborhood school is a valid covariate on which to split the sample, similar to race or prior test scores. Furthermore, this setup allows us to compare treatment effects for students who applied to the same school but had outside options of different quality. Specifically, we estimate:

(3) $$A_{ij} = \delta\left(W_{ij} * S_{in}^{LQ}\right) + \theta\left(W_{ij} * S_{in}^{HQ}\right) + \eta S_{in}^{LQ} + \beta X_{ij} + \Gamma_{\mathrm{j}} + \varepsilon_{\mathrm{ij}}.$$

S_{in}^{LQ} and S_{in}^{HQ} are indicator variables equal to one if a student is zoned to neighborhood schools of "low" and "high" quality respectively, and the rest of the notation is identical to equation (2). Since equation (3) controls for lottery fixed effects, allowing the impact of winning the lottery to vary with S_n is equivalent to allowing it to vary with $\left(S_j - S_n\right)$.

We stratify every school into one of the two categories based on several different metrics, including our value-added estimates of school quality and revealed preference. We classify the four lowest-ranked schools on the average value-added "quality" measure in Column 7 of Table 2 as the "low quality" sample. Students from all other neighborhood school zones are in the "high quality" sample. Notably, the bottom four schools on the overall quality measure are also the bottom four on the two main measures of matriculation – high school graduation and four-year college attendance, and they are near the bottom in terms of revealed preference as well. We can interpret $(\delta - \theta)$ as a differences-in-differences (DID) estimate of the relative impact of coming from a low quality neighborhood school on winning the lottery. Since equation (9) includes lottery fixed effects, we are comparing applicants *to the same school and in the same grade* who came from different neighborhood schools. Thus, the results allow for a direct test of the differential impact of choice for students whose neighborhood schools do a poor job of graduating their students and sending them to college. In addition to stratifying the analysis by neighborhood school quality, we can allow the lottery treatment effect to vary continuously with our estimate of the school quality differential $(\widehat{S_j} - \widehat{S_n})$:

$$(4) \qquad A_{ij} = \delta W_{ij} + \eta(\widehat{S_j} - \widehat{S_n}) + \theta[W_{ij} * (\widehat{S_j} - \widehat{S_n})] + \beta X_{ij} + \Gamma_j + \varepsilon_{ij}.$$

Intuitively, if the estimated school quality difference is a good approximation of the impact that each school has on its students, then the impact of winning the lottery should be larger for applicants with a larger estimated quality difference. If all students were randomly assigned to schools, then the impact of switching a student from school j to school n would be $S_j - S_n$. In that case the specification in equation (4) would yield a coefficient of zero on the main effect and one on the interaction term. On the other hand, if the quality differential does not do a good job of explaining the lottery treatment effect, the slope coefficient θ will be close to zero and δ in equations (2) and (4) will be similar. This specification will also address whether school choice programs can effectively raise matriculation rates for students slated to attend schools with poor matriculation records.[22]

[22] We also estimate similar specifications where winning the lottery is interacted with the probability that students choose their neighborhood school. We could think of this as an alternative "revealed preference" measure of school quality that is robust to misspecification of *S*, and find similar results.

IV. Results

The four lowest-ranked schools on the measure of average quality in Column 7 of Table 2 are Waddell, West Mecklenburg, Olympic and Vance. Students who live in one of these four schools' neighborhood catchment areas are in the "low quality" sample, and all other students are in the "high quality" sample. In Appendix Tables 2 we report results for the four lowest-ranked schools on the revealed preference measure of quality. Overall, the pattern of results is not sensitive to small changes in the choice of schools.

Table 6 shows the impact of winning the lottery on enrollment and school characteristics. The first row examines selective attrition from the lottery sample. We find that lottery winners in both samples are about 2.5 to 3 percentage points more likely to still be enrolled in a CMS school in the Fall of 2002. Neither coefficient is statistically significant. While the impact on selective attrition is small, it could bias our results. However, we find that the main results are relatively robust to a variety of assumptions about attrition.[23] In the second row we see that the first stage impact of winning the lottery on fall enrollment is strong in both samples, suggesting that the offer of admission was relatively attractive. As indicated by the control means, however, a significant share of lottery losers still managed to enroll in their chosen school. This could happen because the student moved into the neighborhood over the summer, or because they were admitted subsequently off of a waitlist that we do not observe. Among lottery losers, students who subsequently enroll in their chosen school ("always takers" in the terminology of Angrist, Imbens and Rubin (1996)) have higher family incomes, are more likely to be white, and have substantially higher average test scores and rates of high school graduation and college attendance. This holds even with the low quality neighborhood school sample. Lottery winners with low-quality neighborhood schools are about 36 percentage points more likely to attend a magnet school, compared to about 25 percentage points in the "high quality" sample. This helps to explain why there is little change in the demographic composition of lottery winners' schools, in either group.

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[23] We re-estimate the results in Table 7 assuming values of zero for students who were missing in the Fall of 2002. The impact on high school graduation drops by about 35 percent but is still statistically significant in the "low-quality" sample. This assumption is probably too restrictive, especially since we possess information on the college-going of students who leave prior to the Fall of 2002 and we still find impacts on four-year college attendance.

Finally, we examine the impact of winning the lottery on school quality. In the last five rows of Table 6, the outcome is the “value-added” school quality estimate from Table 2 for each of the five main outcomes in the paper. If these measures were unbiased estimates of school quality, they would represent the average impact of the school on student outcomes. Overall, lottery winners in the “low-quality” sample attend schools with similar math and English value-added but significantly higher value-added on measures of educational attainment compared to their peers who lost the lottery. In contrast, lottery winners in the “high-quality” sample did not attend schools with higher value-added on any of the five measures, and the impact on 9th grade math value-added is negative and statistically significant. This may suggest that by high school, parents are focused more on matriculation from high school and to college than on standardized test scores as a measure of school quality.

Recall that because these are value-added measures, we would expect the impact for a randomly chosen (not self-selected) student to be simply equal to the coefficient on each outcome if the assumptions under which the value-added is calculated hold. Thus the estimates in Table 6 predict that lottery winners in the low-quality sample will be about 5 percentage points more likely to graduate from high school and attend a four-year college, but will score no higher on math and English tests. They also predict that in the “high-quality” sample, lottery winners will have modestly lower test scores and show no gains on measures of educational attainment.

Table 7 presents the results from estimation of equation (3) for the main outcomes of the paper. The pattern of results is striking. Nearly all of the impacts are larger in the low quality neighborhood school subsample, and the difference between the samples is statistically significant for over half of the outcomes and all of our main measures of educational attainment – high school graduation, four-year college attendance and degree completion. The impact of winning the lottery on 9th grade test scores is indistinguishable from zero for students in both samples. The main findings of this paper are that lottery winners from low quality neighborhood school zones are 8.7 percentage points more likely to graduate from high school, 6.6 percentage points more likely to attend a four-year college, and 5.7 percentage points more likely to earn a four-year college degree. However, unlike the results for high school graduation and college attendance, lottery winners from high-quality neighborhood schools are actually more likely to attend a very competitive college, although we cannot reject that the two coefficients are equal. Furthermore, the gap between the two samples for very competitive colleges narrows for the persistence measure and actually reverses for degree completion.

While the impact on four-year college attendance and degree completion for lottery winners from low-quality neighborhood school zones is proportionally fairly large (about 20 percent and 35 percent of the respective control means), the impacts for most competitive colleges are an order of magnitude larger. The point estimates for attendance, persistence and completion are small (between 1.7 and 2.1 percentage points), they represent more than a doubling of the probability that a student will attend and obtain a degree from one of these elite institutions. Lottery winners in the high quality sample are about 3.5 percentage points less likely to complete a four-year college degree and 2.1 percentage points more likely to complete a two-year degree, although neither estimate is significantly different from zero.

While we have limited evidence on the things that schools did to increase the educational attainment of their students, we find that lottery winners from low-quality neighborhood schools had better performance in high school on a range of mediating outcomes. We investigate these outcomes in Table 8. When looking at course-taking, we restrict our attention to math since the courses were more likely to have a standard curriculum, and because of recent evidence that mathematics courses may increase earnings later in life (Goodman 2009). Lottery winners from low-quality neighborhood schools had significantly higher grade point averages overall and in math and science courses, and they took more math courses overall. They also had significantly fewer absences from school in the first school year after the lottery. We find some evidence of reductions in absences in later years, but the estimates are imprecise. In contrast, we found no evidence of any impacts on mediating outcomes in the "high quality" sample. Notably, the differences across the two samples on the mediating outcomes are fairly large, which makes sense because schools have much more control over outcomes such as course-taking and academic preparation than over the college selection and attendance process.

The evidence on mediating outcomes in Table 8 suggests that lottery winners in the low-quality sample experience real human capital gains that make them more college-ready. We investigate this further in the bottom panel of Table 8 by estimating impacts on persistence and degree completion, conditional on enrollment. All else equal, we might think that students who are on the margin of college enrollment would have lower rates of persistence since they are on average less prepared. Thus, if "better" schools raise college enrollment by shepherding more marginal students into college, we might expect to see lower conditional persistence rates among lottery winners in the "low quality" sample. In fact, we find the opposite. Among students who attend a four-year college, lottery winners in the "low-quality" sample are about 7.5 percentage points *more* likely to complete a degree, although the estimate is not significantly different from zero. Among very competitive college attendees, however, lottery winners are nearly 30 percentage points more likely to earn a bachelor's degree, although the standard error is large because of the small sample. Interestingly, conditional completion rates are lower in the high-quality sample, although the estimates are imprecise.

Finally, we formalize the comparison between school value-added and the lottery treatment effects by allowing for a continuous relationship between the estimated school quality difference and the impact of a randomly assigned offer of admission. We estimate equation (4), where the impact of winning the lottery is interacted with $\widehat{S_j} - \widehat{S_n}$, the difference between the value-added of the school to which a student applies and their neighborhood school. If all students were randomly assigned to schools, then the impact of switching a student from school j to school n would be $(S_j - S_n)$. In that case the specification in equation (4) would yield a coefficient of zero on the main effect δ, and one on the interaction term θ. A rejection of this "random assignment" joint hypothesis can be interpreted in two related ways: 1) that our estimates of school quality are biased by unobserved sorting, or 2) that the impact of winning the lottery for applicants differs from the impact for non-applicants. This would be true if, for example, students apply because they expect to have a particularly good idiosyncratic match with their choice school that would not generalize to a randomly selected student in CMS.

One potential complication is that students who lose the lottery to attend their first choice often attended another school that was not oversubscribed (as explained in Section

I, virtually no students were admitted to oversubscribed schools unless they listed that school as their first choice). Since we are interested in the school quality lottery winners would have experienced had they lost, we construct an estimate of counterfactual school quality by using applicants' second and third choices. If their second choice was not oversubscribed (or if it was their neighborhood school), then we use the quality difference between their first and second choice in equation (4). Similarly, if their second choice was oversubscribed, and no one was admitted, we move to their third choice, and then to their neighborhood school (the implicit fourth choice for all students). In the small number of cases where there was a lottery in the 2nd or 3rd rounds, we use a weighted average quality difference where the weights are the probability of admission.[24]

In Table 9 we estimate versions of equation (4) that differ only in the covariates used to adjust the estimates of $\widehat{S_n}$ that we produced in equation (1) and Table 2. Column 1 contains the baseline model without any interaction term and is identical to the results in Table 4. Column 2 interacts an indicator for winning the lottery with unadjusted school-level means for each outcome, which are just demeaned versions of the descriptive statistics in Table 1. The coefficients on the interactions are significantly different from zero only for the 9th grade math and high school graduation outcomes, and the "random assignment" hypothesis is strongly rejected for all five outcomes.

Column 3 shows results where winning the lottery is interacted with the school quality estimates in Table 2, which include demographic covariates and polynomials in 8th grade math and reading test scores. The performance of the model improves dramatically, and we fail to reject the "random assignment" hypothesis for 9th grade math, high school graduation and four-year college attendance. The school quality estimates do a particularly good job of predicting gains in high school graduation and four-year college attendance. The coefficients on the main effects are 0.015 and 0.005 respectively, and the interaction terms are 0.937 and 0.866. This says that students who win the lottery to attend a school with identical estimated quality to the school they would have attended if they lost are 1.5 percentage points more likely to graduate and 0.5 percentage points more

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24 Formally, we estimate the school quality differential as VA(W)-VA(L) where VA(L) = p2*(VA2) + (1-p2)*[(p3*VA2) + (1-p3)*VA(n)]. VA(W) and VA(L) are value-added if the students wins and loses the lottery respectively, p2 and p3 are the probability of admission to the students' 2nd and 3rd choices, and VA2, VA3 and VA(n) are value-added for the 2nd choice, 3rd choice and neighborhood schools respectively. Because students list their choices prior to randomization, examining treatment effect heterogeneity by variation in pre-lottery choice sets does not bias the results. Estimates using just the neighborhood school as the counterfactual are very similar.

likely to attend a four-year college (so some self-selection on match quality or misspecification or remains). However, for every 1 percentage point of value-added gained, lottery winners are 0.94 and 0.87 percentage points more likely to graduate from high school and attend a four-year college. The fact that both are significantly different from zero is a rejection of the null hypothesis that value-added estimates have no power to predict the treatment effect of winning the lottery.

Column 4 makes use of a richer model of value-added that controls for 3rd through 8th grade test scores plus absences, out-of-school suspensions and grade repetition in middle school. Perhaps surprisingly, these additional covariates have very little impact, suggesting that a basic set of controls adequately controls for selection for three of the five main outcomes. Column 5 presents estimates from a model where winning the lottery is interacted with the share of students assigned to a neighborhood school that apply to attend another school. Here we measure school quality by relying on applicants' revealed preferences for schools other than their own. The pattern of results closely mirrors Columns 3 and 4, suggesting that our estimates of school quality conform closely to parental preferences for schools.

While school value-added does a good job of predicting treatment effects for 9th grade math, high school graduation and four-year college attendance, it does a very poor job of predicting 9th grade English scores and very competitive college attendance. This could be because other factors such as family influence or an idiosyncratic match between the student and the school are important, or because we cannot adequately control for the determinants of those outcomes, and so $\widehat{S_n}$ is misspecified. More generally, families that choose schools which appear no better on our measures of school quality may benefit from choice in ways that we do not observe.

For our main results, we interpret the within-lottery difference in outcomes for students who are assigned to "low-quality" neighborhood schools as evidence of the importance of school quality. One possible problem with this interpretation is that students from low-quality neighborhood schools might also have much better idiosyncratic matches than students from high-quality neighborhood schools, *within each lottery*. Since about 43 percent of first choices were one of the three magnet schools located in the inner city, we might be concerned that applicants from low-quality neighborhood schools had particularly good potential matches in these schools and programs, compared to the other students from their neighborhoods. However, nearly all the main results in the paper hold up when we exclude magnet applications from the analysis.[25] A related concern is that 10th and 11th grade applicants might be more likely to sort on idiosyncratic matches, yet we find that the pattern of results holds when we restrict everything to rising 9th grade applicants.

V. Discussion and Conclusion

In this paper we study the impact of winning an admissions lottery to attend a public high school in Charlotte-Mecklenburg. Students who exercised choice were more likely to come from minority and low-income backgrounds, and from low-performing home-school neighborhood assignment zones. We match school choices and lottery outcomes to data on college enrollment and degree completion from the National Student Clearinghouse (NSC), and we estimate the impact of winning the lottery to attend a student's first choice school on long-term measures of educational attainment. We find that lottery winners who are assigned to low-quality neighborhood schools are more likely to graduate from high school, attend a four-year college, and earn a bachelor's degree. They are about twice as likely to earn a degree from an elite institution such as UNC-Chapel Hill or Duke. In contrast, we find no evidence of benefits for lottery winners from higher-quality neighborhood schools. This represents the first evidence of the causal impact of a school choice policy on long-run postsecondary attainment.

Furthermore, we find that value-added measures of school quality which control for a prior test score and a basic set of demographic covariates do a good job of predicting the treatment effects from lottery-based random assignment. If it can be replicated in other settings, this finding has important implications for the external validity of studies of school choice that exploit lottery-based randomization. The focus on students with low-quality neighborhood schools may also have important implications for the patterns of heterogeneity in other studies. The quality of a student's default option matters just as much as the quality of the school they choose.

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[25] Results are available upon request. The only difference is in selective college enrollment and degree completion, where excluding the magnets makes the estimates in the low quality sample insignificant but still significantly larger than for the HQ sample in many cases.

The results show that school choice can have an important and long-lasting impact on educational attainment, but only when students gain access to schools that are better on observed dimensions of quality. In this setting, switching disadvantaged youth from one of the lowest quality high schools in a large urban district to an average-quality high school closed about 75 percent of the black-white gap in high school graduation and about 23 percent of the gap in bachelor's degree completion. This shows that improving the quality of urban high schools, while difficult to accomplish in practice, would lessen racial and socioeconomic inequality and generate potentially large gains in the stock of college-educated labor.

Unfortunately, we cannot say much about the underlying explanation for the gains experienced by lottery winners from low-quality neighborhood schools. Because the choice schools were often magnet schools, with specialized programs such as career academies, arts education, and intensive college prep, the benefits could come primarily from improved student engagement in high school. It is possible that having demographically similar but more able peers led to increased student learning and engagement inside the classroom. Better peers could also have an impact on behavior inside and outside of the classroom. The impacts on mediating variables as early as 9th grade are inconsistent with a scenario where "better" schools are simply more organized at getting students to surmount administrative hurdles such as accumulating enough credits in the right high school courses, or filling out college applications and financial aid forms. That could generate increases in educational attainment, but would be unlikely to raise grade point averages, increase math course-taking, reduce absences and increase college persistence conditional on enrollment.

For students with low-quality neighborhood schools, winning the lottery amounts to moving them from one of the lowest-quality public schools to an average-quality school within a large urban district. The schools had access to similar levels of resources and were managed under the same set of rules and constraints. Remarkably, the change in student racial composition and measures of peer quality such as average test scores was quite small. While we cannot eliminate the possibility that lottery applicants are different in unobserved ways from other students in CMS, the strong correlation between observational value-added measures and the lottery treatment effect suggests that the results might generalize to students outside of the applicant pool.

Interestingly, the performance of value-added measures of school quality is best for high school graduation and four-year college attendance, middling for math, and very poor for competitive college attendance and English test scores. Provided that these results could be replicated in other settings, they have important implications for the design of school accountability policies. It makes little sense to hold schools accountable for outcomes that they cannot control. School quality estimates that approximate impacts from random assignment are less likely to be biased by unobserved determinants of achievement, and thus may serve as better candidates for judging performance.

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TABLE 1 - DESCRIPTIVE STATISTICS BY NEIGHBORHOOD SCHOOL

	Median HH Income	Nonwhite	Free Lunch	9th Grade Math	9th Grade English	HS Graduate	College Attendance: Any 4 Year	College Attendance: Very Competitive	College Attendance: Most Competitive	N
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Panel A. Neighborhood School										
Providence	94,799	0.06	0.03	0.41	0.79	0.82	0.75	0.49	0.15	1,364
South Mecklenburg	72,830	0.15	0.16	0.24	0.58	0.79	0.66	0.39	0.10	1,590
North Mecklenburg	68,275	0.31	0.24	-0.26	0.25	0.76	0.58	0.27	0.09	1,303
Hopewell	67,473	0.31	0.27	-0.31	0.19	0.73	0.54	0.24	0.07	1,410
Butler	66,843	0.13	0.16	0.07	0.58	0.76	0.57	0.27	0.08	1,272
Myers Park	61,782	0.32	0.33	0.02	0.36	0.74	0.60	0.38	0.12	1,422
Olympic	50,914	0.52	0.50	-0.40	-0.15	0.69	0.41	0.12	0.03	1,148
East Mecklenburg	50,806	0.45	0.47	-0.20	0.15	0.64	0.44	0.19	0.06	1,376
Vance	50,394	0.66	0.54	-0.51	-0.08	0.69	0.44	0.12	0.05	1,979
Independence	48,664	0.58	0.53	-0.51	0.04	0.69	0.41	0.10	0.03	1,804
Waddell	45,536	0.58	0.61	-0.53	-0.22	0.63	0.31	0.08	0.02	842
Garinger	38,359	0.73	0.71	-0.60	-0.25	0.64	0.35	0.07	0.03	1,331
West Mecklenburg	38,305	0.70	0.71	-0.53	-0.43	0.60	0.29	0.06	0.02	1,923
West Charlotte	27,278	0.91	0.92	-0.83	-0.67	0.52	0.22	0.02	0.01	1,257
Panel B. Magnet Schools										
Harding University	43,643	0.68	0.55	-0.28	0.15	0.75	0.53	0.14	0.07	1,016
Berry Academy	41,568	0.79	0.76	-0.61	-0.42	0.68	0.41	0.07	0.02	691
Northwest Arts	52,654	0.39	0.38	-0.69	0.15	0.72	0.48	0.17	0.06	454
Correlation with Income		-0.94	-0.96	0.87	0.91	0.86	0.92	0.93	0.90	

Notes: All data are based on the students that are assigned to each neighborhood school in the Fall of 2002, not the students that actually attend. Column 1 is the average value of median household income for families in each neighborhood school zone, based on the 2000 Census and calculated at the tract level. Columns 4 and 5 show students' average 9th grade math and English end-of-course (EOC) exams. College competitiveness measures are defined by the Barron's Rankings. See the text of the paper for details.

TABLE 2 - NEIGHBORHOOD SCHOOL QUALITY ESTIMATES

		School Quality Measures (Value-Added)							
	Median HH Income	9th Grade Math	9th Grade English	HS Graduate	4 Year College	Very Competitive	Avg. Standardized Value-Added (Quality)	Avg. of Standardized Outcomes (in levels)	Chose Neighb. School
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A. Neighborhood School									
South Mecklenburg	72,799	0.112	0.057	0.053	0.042	0.050	1.388	1.037	0.70
North Mecklenburg	68,319	-0.008	0.032	0.047	0.056	0.037	0.967	0.940	0.51
Myers Park	61,891	0.027	-0.020	0.011	0.013	0.055	0.532	1.266	0.59
Providence	94,801	0.004	-0.030	0.002	0.032	0.049	0.465	1.758	0.92
Garinger	38,359	0.059	-0.011	0.020	0.006	-0.004	0.232	-1.065	0.18
Independence	48,669	-0.039	0.082	0.005	-0.005	-0.028	0.110	-0.384	0.59
West Charlotte	27,267	0.075	-0.097	-0.024	0.015	0.023	0.061	-1.372	0.22
East Mecklenburg	50,838	0.078	0.039	-0.045	-0.017	-0.011	0.019	-0.049	0.45
Hopewell	67,493	-0.085	-0.039	0.004	-0.013	-0.031	-0.466	0.346	0.69
Butler	66,871	-0.003	0.029	0.003	-0.043	-0.071	-0.480	0.634	0.57
Vance	50,487	-0.111	-0.034	-0.041	-0.026	-0.014	-0.589	-0.648	0.55
Olympic	50,942	-0.044	-0.096	-0.022	-0.046	-0.046	-0.845	-0.480	0.42
West Mecklenburg	38,320	0.046	-0.117	-0.046	-0.052	-0.034	-0.898	-1.179	0.28
Waddell	45,537	-0.146	-0.092	-0.066	-0.049	-0.025	-1.386	-1.242	0.53
Panel B. Magnet Schools									
Harding University	43,643	0.054	0.039	0.016	0.053	-0.005	-0.754	0.639	
Berry Academy	41,568	-0.091	-0.114	0.006	0.007	-0.013	-0.669	-0.567	
Northwest Arts	52,654	-0.055	0.159	0.004	0.029	0.004	-0.176	0.523	
Correlation with Income		-0.01	0.30	0.43	0.28	0.36	0.49	0.86	0.90

Notes: Column 1 is the average value of median household income for families in each neighborhood school zone, based on the 2000 Census and calculated at the tract level. Columns 2 through 6 contain value-added measures of school quality for the five main outcomes in the paper. See equation (1) in the paper and the accompanying discussion for details. The table is sorted by Column 7, which is the normalized average of the five quality measures in columns 2 through 6. Column 9 is a "revealed preference" measure of school quality - the probability that students assigned to each neighborhood school will choose to attend it.

TABLE 3 - SELECTION INTO THE LOTTERY SAMPLE

Outcome is chose non-neighborhood school	All		Low Quality	
	(1)	(2)	(3)	(4)
Distance to Neighborhood School	4.102	0.026***	4.169	0.055***
		[0.001]		[0.003]
Male	0.509	-0.021***	0.514	-0.016
		[0.007]		[0.013]
African-American	0.308	0.206***	0.544	0.111***
		[0.010]		[0.017]
Latino	0.035	0.047**	0.047	0.019
		[0.022]		[0.037]
Free/Reduced Lunch	0.332	0.140***	0.564	0.035**
		[0.010]		[0.016]
8th Grade Math	0.094	0.011*	-0.283	0.035***
		[0.006]		[0.011]
8th Grade Reading	0.139	0.009	-0.250	-0.006
		[0.006]		[0.010]
8th Grade Days Absent	8.681	0.001	9.534	0.001
		[0.001]		[0.001]
8th Grade Days Suspended	1.139	-0.001	1.566	-0.001
		[0.001]		[0.002]
Sample Size	17,881		5,320	

Notes: Columns 1 and 3 are mean values of the covariate in each row for students who listed their neighborhood school as their first choice, in the high and low quality neighborhood school samples respectively. Columns 2 and 4 are coefficients from one regression of the probability of choice on the covariates in the indicated rows, interacted with an indicator variable for whether the student lives in a neighborhood that is zoned to a "low quality school" - see the text for details in this definition.

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

TABLE 4 - IMPACT OF WINNING THE LOTTERY ON MAIN OUTCOMES

	Control Mean	Estimate
	(1)	(2)
Panel A. High School Outcomes		
9th Grade Math Score	-0.441	-0.025
		[0.051]
9th Grade English Score	-0.152	-0.017
		[0.044]
Taken 9th Grade Math Exam	0.815	0.089***
		[0.022]
Grad from CMS High School	0.601	0.036*
		[0.020]
Panel B. College Attendance		
Any 2 year college	0.530	0.032
		[0.031]
Any 4 year college	0.367	0.024
		[0.029]
Very Competitive	0.096	0.024**
		[0.011]
Most Competitive	0.024	0.008
		[0.007]
Panel C. Persistence (4+ sems)		
Any 2 year college	0.197	0.018
		[0.029]
Any 4 year college	0.283	-0.005
		[0.026]
Very Competitive	0.080	0.022*
		[0.012]
Most Competitive	0.021	0.005
		[0.006]
Panel D. Earned a Degree		
Any 2 year college	0.026	0.011
		[0.013]
Any 4 year college	0.177	0.005
		[0.015]
Very Competitive	0.065	0.014*
		[0.017]
Most Competitive	0.020	0.002
		[0.007]
Sample Size	1865	

Notes: Columns 1 is the mean value of the outcome in each row for students who lost the lottery. Column 2 is an estimate of the effect of winning the lottery from equation (2) in the paper, with lottery fixed effects and basic covariates for balance. Standard errors are below each estimate in brackets and are clustered at the lottery level. "Very Competitive" and "Most Competitive" colleges are defined by the Barron's rankings. See the text for details.

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

TABLE 5 - IMPACT OF WINNING THE LOTTERY BY SUBGROUPS

	Nonwhite		White		F(equal)
	(1)	(2)	(3)	(4)	(5)
9th Grade English Score	-0.389	-0.063*	0.224	0.090	0.078
		[0.035]		[0.082]	
9th Grade Math Score	-0.657	-0.043	-0.133	0.014	0.708
		[0.055]		[0.126]	
Grad from CMS High School	0.597	0.022	0.607	0.063*	0.389
		[0.028]		[0.033]	
Attended a 4 Year College	0.333	0.013	0.411	0.044	0.311
		[0.032]		[0.037]	
Very Competitive	0.035	0.019	0.175	0.034	0.714
		[0.017]		[0.029]	
	Free Lunch		Not Free Lunch		
9th Grade English Score	-0.378	-0.084	0.218	0.121*	0.007
		[0.050]		[0.064]	
9th Grade Math Score	-0.655	-0.055	-0.124	0.032	0.255
		[0.038]		[0.087]	
Grad from CMS High School	0.537	0.055	0.683	0.003	0.407
		[0.032]		[0.043]	
Attended a 4 Year College	0.258	0.042**	0.506	-0.009	0.193
		[0.020]		[0.053]	
Very Competitive	0.028	0.028**	0.182	0.017	0.637
		[0.010]		[0.021]	
	Male		Female		
9th Grade English Score	-0.227	-0.036	-0.073	0.009	0.586
		[0.052]		[0.065]	
9th Grade Math Score	-0.465	-0.036	-0.415	-0.010	0.595
		[0.053]		[0.059]	
Grad from CMS High School	0.541	0.030	0.669	0.044	0.763
		[0.024]		[0.036]	
Attended a 4 Year College	0.342	-0.014	0.395	0.071***	0.008
		[0.035]		[0.025]	
Very Competitive	0.078	0.021	0.116	0.028*	0.804
		[0.018]		[0.016]	
Sample Size	1865				

Notes: Columns 1 and 3 are mean values of the outcome in each row for students who lost the lottery. Columns 2 and 4 are estimates from a form of equation (2) in the paper, with a full set of indicator variables for lottery status and low or high quality neighborhood school. Standard errors are below each estimate in brackets and are clustered at the lottery level. Column 5 contains the p-value for an F-test that columns (2) and (4) are equal. "Very Competitive" College is defined by the Barron's rankings - see the text of the paper for a list of NC colleges that apply.

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

TABLE 6 - IMPACT OF WINNING THE LOTTERY ON ENROLLMENT AND SCHOOL CHARACTERISTICS

	HQ Neighborhood School		LQ Neighborhood School		F(equal)
	(1)	(2)	(3)	(4)	(5)
Panel A. Enrollment in Fall 2002					
In Any CMS School	0.922	0.027	0.918	0.029	0.933
		[0.020]		[0.023]	
In 1st Choice	0.370	0.545***	0.353	0.564***	0.753
		[0.080]		[0.057]	
Neighborhood School	0.382	-0.365***	0.463	-0.397***	0.501
		[0.052]		[0.039]	
Magnet School	0.121	0.252*	0.127	0.365***	0.195
		[0.125]		[0.117]	
Distance to Fall 2002 school	6.38	1.65***	6.07	1.25*	0.464
		[0.56]		[0.63]	
Percent African-American	0.406	0.054	0.535	-0.022	0.065
		[0.046]		[0.048]	
Percent Free Lunch	0.448	0.029	0.587	-0.053	0.024
		[0.042]		[0.044]	
Avg. 8th Grade Math Score	0.042	-0.022	-0.215	0.146**	0.003
		[0.072]		[0.070]	
Panel B. School Quality Measures					
9th Grade Math	0.044	-0.086***	-0.046	-0.003	0.011
		[0.022]		[0.043]	
9th Grade English	0.020	-0.049	-0.060	0.011	0.015
		[0.032]		[0.037]	
High School Graduation	0.001	0.007	-0.033	0.048***	0.000
		[0.006]		[0.008]	
4 Year College Attendance	-0.002	0.001	-0.032	0.050***	0.000
		[0.010]		[0.007]	
Very Competitive College	-0.005	-0.013	-0.026	0.025***	0.001
		[0.008]		[0.008]	
Sample Size	1,070		795		

Notes: Columns 1 and 3 are mean values of the outcome in each row for students who lost the lottery. Columns 2 and 4 are estimates from equation (3) in the paper, with a full set of indicator variables for lottery status and low or high quality neighborhood school. Standard errors are below each estimate in brackets and are clustered at the lottery level. Column 5 contains the p-value for an F-test that columns (2) and (4) are equal. The quality estimates for each school come from Table 2.

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

TABLE 7 - IMPACT OF WINNING THE LOTTERY BY NEIGHBORHOOD SCHOOL QUALITY

	HQ Neighborhood School		LQ Neighborhood School		F(equal)
	(1)	(2)	(3)	(4)	(5)
9th Grade English Score	-0.124	-0.009	-0.164	-0.023	0.896
		[0.062]		[0.074]	
9th Grade Math (impute 8th)	-0.629	-0.061	-0.606	0.057	0.087
		[0.045]		[0.047]	
Graduated from CMS High School	0.623	-0.003	0.568	0.087**	0.079
		[0.025]		[0.037]	
Attended a 2 Year College	0.533	0.005	0.525	0.066	0.211
		[0.035]		[0.042]	
Attended a 4 Year College	0.382	-0.014	0.345	0.072*	0.043
		[0.034]		[0.038]	
Very Competitive	0.089	0.028**	0.106	0.020	0.532
		[0.011]		[0.015]	
Most Competitive	0.027	-0.002	0.019	0.021**	0.079
		[0.007]		[0.010]	
Persistence (4+ sems)					
Any 2 year college	0.199	0.010	0.194	0.037	0.502
		[0.039]		[0.026]	
Any 4 year college	0.300	-0.012	0.259	0.031	0.144
		[0.029]		[0.027]	
Very Competitive	0.077	0.022*	0.084	0.037**	0.304
		[0.012]		[0.013]	
Most Competitive	0.023	-0.003	0.017	0.018**	0.078
		[0.006]		[0.009]	
Earned a Degree					
Any 2 year college	0.023	0.021	0.029	-0.003	0.211
		[0.013]		[0.017]	
Any 4 year college	0.194	-0.035	0.151	0.057**	0.008
		[0.022]		[0.021]	
Very Competitive	0.070	-0.003	0.058	0.035***	0.007
		[0.009]		[0.011]	
Most Competitive	0.023	-0.010	0.014	0.017*	0.027
		[0.007]		[0.009]	
Sample Size	1,070		795		

Notes: Columns 1 and 3 are mean values of the outcome in each row for students who lost the lottery. Columns 2 and 4 are estimates from equation (3) in the paper, with a full set of indicator variables for lottery status and low or high quality neighborhood school. Standard errors are below each estimate in brackets and are clustered at the lottery level. Column 5 contains the p-value for an F-test that columns (2) and (4) are equal. Competitive colleges are defined by the Barron's rankings - see the text of the paper for details.

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

TABLE 8 - IMPACT OF WINNING THE LOTTERY ON MEDIATING OUTCOMES

	HQ Neighborhood School		LQ Neighborhood School		F(equal)
	(1)	(2)	(3)	(4)	(5)
Grade Point Average	2.047	0.066*	2.098	0.142***	0.157
		[0.034]		[0.047]	
GPA -Math and Science	1.690	0.005	1.680	0.125**	0.026
		[0.034]		[0.056]	
Number of Math Courses	2.652	0.022	2.679	0.217**	0.165
		[0.073]		[0.093]	
Took Math Every Year	0.633	0.001	0.600	0.079*	0.273
		[0.041]		[0.039]	
Absences in 2002-2003	11.65	-0.11	11.88	-1.75*	0.122
		[0.75]		[0.96]	
Suspensions in 2002-2003	2.20	-0.75*	2.09	-0.79	0.939
		[0.39]		[0.53]	
College Persistence (conditional)					
Any 4 Year College	0.785	0.007	0.750	-0.052	0.325
N=636		[0.048]		[0.057]	
Very Competitive college	0.868	0.063	0.745	0.322*	0.164
N=151		[0.097]		[0.176]	
Degree Completion (conditional)					
Any 4 Year College	0.496	-0.084	0.424	0.075	0.033
N=636		[0.055]		[0.049]	
Very Competitive College	0.755	-0.150	0.545	0.297**	0.010
N=151		[0.107]		[0.139]	
Sample Size	1,070		795		

Notes: Columns 1 and 3 are mean values of the outcome in each row for students who lost the lottery. Columns 2 and 4 are estimates from equation (3) in the paper, with a full set of indicator variables for lottery status and low or high quality neighborhood school. Standard errors are below each estimate in brackets and are clustered at the lottery level. Column 5 contains the p-value for an F-test that columns (2) and (4) are equal. Competitive colleges are defined by the Barron's rankings - see the text of the paper for details.

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

TABLE 9 - COMPARISON OF SCHOOL VALUE-ADDED TO THE IMPACT OF WINNING THE LOTTERY

		Measured School Quality Difference (S_j - S_n)			
		Unadjusted	8th Grade Xs	All Covariates	Pr(choice)
Main Outcomes	(1)	(2)	(3)	(4)	(5)
9th Grade English Score	-0.017	0.035	0.052	0.056	-0.104
	[0.044]	[0.030]	[0.033]	[0.039]	[0.154]
Interaction Term		0.083	0.482	0.549	0.240
		[0.077]	[0.354]	[0.439]	[0.214]
F(main effect = 0, interaction = 1)		*0.000*	*0.002*	*0.001*	
9th Grade Math Score	-0.025	0.003	0.023	0.028	-0.470**
	[0.051]	[0.052]	[0.065]	[0.068]	[0.188]
Interaction Term		0.296**	0.756	0.803	0.773**
		[0.132]	[0.520]	[0.538]	[0.237]
F(main effect = 0, interaction = 1)		*0.000*	*0.464*	*0.447*	
Graduated from CMS	0.036*	-0.002	0.015	0.023	-0.127
	[0.020]	[0.026]	[0.026]	[0.024]	[0.103]
Interaction Term		0.522**	0.937*	0.979**	0.289
		[0.209]	[0.463]	[0.428]	[0.187]
F(main effect = 0, interaction = 1)		*0.023*	*0.808*	*0.431*	
Attended a 4 Year College	0.024	0.018	0.005	0.007	-0.072
	[0.029]	[0.037]	[0.028]	[0.028]	[0.082]
Interaction Term		0.095	0.866*	0.974	0.172
		[0.196]	[0.459]	[0.611]	[0.120]
F(main effect = 0, interaction = 1)		*0.000*	*0.954*	*0.967*	
Very Competitive College	0.024**	0.020**	0.020**	0.020**	0.032
	[0.011]	[0.009]	[0.009]	[0.009]	[0.029]
Interaction Term		0.068	0.301	0.320	-0.019
		[0.077]	[0.344]	[0.409]	[0.046]
F(main effect = 0, interaction = 1)		*0.000*	*0.001*	*0.003*	
Sample Size	1865				

Notes: Column 1 is the δ coefficient from equation (2) for each of the five main outcomes in the paper. Columns (2) through (4) estimate equation (4), where winning the lottery is interacted with the estimated difference in quality between the school that applicants attend if they win the lottery and the school they attend or would have attended had they lost. Column 5 interacts winning the lottery with the probability that students in each neighborhood school zone apply to another school. "Very Competitive" College is defined by the Barron's rankings - see the text of the paper for a list of NC colleges that apply.

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

TABLE A1 - IMPACT OF WINNING THE LOTTERY ON PRE-LOTTERY COVARIATES

	High Quality Neighborhood School	Low Quality Neighborhood School
	(1)	(2)
Median HH Income	-1319	-149
	[2,136]	[902]
Male	0.013	0.012
	[0.046]	[0.025]
Black	0.064*	0.033
	[0.037]	[0.026]
Latino	-0.014	-0.015
	[0.015]	[0.016]
FRPL	0.022	0.014
	[0.029]	[0.036]
Special Education	0.018	-0.024
	[0.030]	[0.025]
8th Grade Math	-0.067	0.069
	[0.088]	[0.052]
8th Grade Reading	-0.113	0.030
	[0.076]	[0.045]
Distance to Home	0.23	0.10
	[0.26]	[0.20]
Distance to Choice	1.07**	-0.51
	[0.41]	[0.41]
Sample Size	1865	

Notes: Columns 1 and 2 are estimates from a form of equation (8) in the paper, with a full set of indicator variables for lottery status and low or high quality neighborhood school. Standard errors are below each estimate in brackets and are clustered at the lottery level.

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

TABLE A2 - MAIN RESULTS, ALTERNATE SCHOOL QUALITY DEFINITION

	HQ Neighborhood School		LQ Neighborhood School		F(equal)
	(1)	(2)	(3)	(4)	(5)
	Bottom 4 Schools on Revealed Preference				
9th Grade Math (impute 8th)	-0.387	-0.074	-0.712	0.070*	0.008
		[0.054]		[0.039]	
Graduated from CMS High School	0.639	0.004	0.547	0.076**	0.143
		[0.025]		[0.038]	
Attended a 4 Year College	0.432	0.008	0.277	0.043	0.288
		[0.032]		[0.034]	
Very Competitive	0.126	0.031*	0.054	0.016	0.338
		[0.016]		[0.011]	
Most Competitive	0.034	0.004	0.009	0.012	0.539
		[0.011]		[0.007]	
Earned a Degree					
Any 2 year college	0.029	0.013	0.021	0.007	0.735
		[0.018]		[0.012]	
Any 4 year college	0.233	-0.017	0.099	0.033*	0.129
		[0.023]		[0.019]	
Very Competitive	0.094	0.003	0.026	0.027***	0.123
		[0.011]		[0.009]	
Most Competitive	0.029	-0.008	0.007	0.013*	0.067
		[0.009]		[0.007]	
Sample Size	1006		859		

Notes: Columns 1 and 3 are mean values of the outcome in each row for students who lost the lottery. Columns 2 and 4 are estimates from equation (3) in the paper, with a full set of indicator variables for lottery status and low or high quality neighborhood school. Standard errors are below each estimate in brackets and are clustered at the lottery level. Column 5 contains the p-value for an F-test that columns (2) and (4) are equal. Competitive colleges are defined by the Barron's rankings - see the text of the paper for details.

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.