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# Middle School Math Acceleration and Equitable Access to 8th Grade Algebra: Evidence from the Wake County Public School System*

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## Abstract

School districts across the country have struggled to increase the proportion of students taking algebra by 8th grade, thought to be an important milestone on the pathway to college preparedness. We highlight key features of a research collaboration between the Wake County Public School System and Harvard University that have enabled investigation of one such effort to solve this problem. In 2010, the district began assigning middle school students to accelerated math coursework leading to 8th grade algebra on the basis of a clearly defined measured of prior academic skill. We document two important facts. First, use of this new rule greatly reduced the relationship between course assignment and student factors such as income and race while increasing the relationship between course assignment and academic skill. Second, using a regression discontinuity analytic strategy, we show that the assignment rule had strong impacts on the fraction of students on track to complete algebra by 8th grade. Students placed in accelerated math were exposed to higher-skilled peers but larger class sizes. We describe future plans for assessing impacts on achievement and high school course-taking outcomes.

**Key words:** Algebra, middle school mathematics, regression discontinuity, Wake County Public School System, Strategic Data Project

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## INTRODUCTION

Several years ago, the Wake County Public School System (WCPSS) in North Carolina sought a strategy to provide equitable access to appropriate and rigorous mathematics courses in the middle grades and to ensure access to Algebra I by the 8th grade for academically prepared students. In particular, the district hoped to increase the disproportionately low rates of enrollment in advanced math coursework among black students, Hispanic students, and students from low-income households. To support this goal, in the 2010-2011 school year, WCPSS enacted a mathematics course assignment policy based on a numeric criterion developed by the SAS Institute's Education Value-Added Assessment System (EVAAS) to determine student eligibility for an accelerated math curriculum in the 6th and 7th grades and for placement in Algebra I in the 8th grade. District officials believed that increasing students' access to such coursework prior to high school would, in turn, increase their subsequent academic opportunities and, specifically, their likelihood of completing a rigorous, college-preparatory sequence of high school mathematics.

While several educational agencies have recently attempted to address such goals through grade-specific, algebra-for-all policies, WCPSS leadership believed that mandating every student into an accelerated course would be inappropriate, as such a policy action might lead to certain students enrolling in courses for which they were not academically prepared. Instead, the district identified the EVAAS-generated measure, a predicted probability of success on the North Carolina End-of-Course assessment in Algebra I, as an objective measure with which to standardize the process of assigning students to mathematics courses in the middle grades. Such a measure would identify students who might be overlooked for the recommendation to take accelerated-level courses as a result of variation in course grading practices and subjective beliefs about which students are capable of success in these courses. These subjective practices and beliefs, district officials argued, rest with teachers or counselors who might otherwise make recommendations on the basis of student characteristics, such as race/ethnicity or socioeconomic status, even conditional on demonstrated ability (Hui, 2011).

In EVAAS, district leadership believed it found a measure that would reduce or eliminate such bias, increase overall enrollment in accelerated mathematics coursework in the middle grades, and importantly, increase enrollment specifically for students who were, up to that point, under-represented in such courses. They reasoned that students who had proven themselves capable of success based on their prior test scores would flourish academically, become more engaged in their schoolwork, and gain access to more accelerated mathematics courses while in high school. WCPSS also contended the structure of the policy would both encourage acceleration into Algebra I for appropriately prepared $8^{th}$ grade students (somewhat analogous to single-grade, algebra-for-all policies used in other districts) and improve the overall pipeline for advanced math by impacting the placement of rising $6^{th}$ and $7^{th}$ graders into advanced math courses, setting them on course for Algebra I in the $8^{th}$ grade.

By virtue of our team's collective connections to the Center for Education Policy Research (CEPR) at Harvard University and the Strategic Data Project, a research-education agency partnership housed at CEPR, we have built a partnership between WCPSS personnel and academic researchers in order to investigate the implementation of the district's middle grades mathematics assignment policy and its impact on student outcomes. This collaborative effort seeks to generate evidence that will inform both the WCPSS district leadership as well as the broader mathematics education policy community about the potential benefits and consequences of an assignment strategy such as that currently used in Wake County.

In this article, we describe the initial phase of this ongoing investigation, focusing on evidence about how the assignment rule was implemented, the extent to which it achieved the goal of improving equitable access to advanced math coursework, and how the rule establishes the opportunity for future study of the impact of accelerated coursework on student outcomes. We begin by describing the research and policy context related to math course and algebra assignment policies. We then describe the WCPSS assignment policy in detail. Given the focus of this issue, we next describe the broader Strategic Data Project partnership that has facilitated this investigation. Following this, we detail the data used in our exploration of the WCPSS math assignment strategy and discuss the identification strategy we employ for understanding the causal impacts of acceleration in middle grades mathematics on several student-level outcomes.

We find four main results. First, overall rates of math acceleration increased substantially after implementation of the assignment rule. Second, the policy succeeded in moving the district towards the goal of equalizing access to advanced math coursework, both by increasing enrollment among black students, Hispanic students, and students from lower-income families, and by reducing the role of these demographic factors in the course-assignment process. Third, relative to non-accelerated students, accelerated students' math classes had much more academically skilled peers and were substantially larger. Fourth, the discontinuity in coursework generated at the eligibility threshold is sufficiently large and precise to serve as an instrument for various student outcomes that will be explored in later work. After discussing these results, the final section concludes with discussions of next steps in this ongoing partnership between the school district and academic researchers.

**MOTIVATION**

In the United States, mathematics achievement is often regarded as essential for individual educational and economic success as well as national global competitiveness (Chazan, 2008; The College Board, 2000). Indeed, recent evidence suggests that increasing the number of years of mathematics required of students raises earnings, especially among students from minority or economically disadvantaged groups (Goodman, 2012). Beginning with Sputnik in 1957, continuing with *A Nation at Risk* (Gardner, 1983) and still in more recent reports (see, for example, National Mathematics Advisory Panel, 2008; Brown et al, 2013), policymakers have called for increased proficiency in math as a national imperative. Efforts thus have focused on increasing the amount and rigor of mathematics course taking, with a particular focus on exposure to algebra (Adelman, 2006). As a key prerequisite for a sequence of courses culminating in college-level classes such as calculus and statistics, Algebra I is considered a critical "gatekeeper" course (Adelman, 2006; Education Commission of the States, 2008; Rickles, 2013; Walston & McCarroll, 2010).

With this gateway status recognized, Algebra I enrollment rates have increased over the last two decades, with significant growth at the 8th grade level (Walston & McCarroll, 2010). Concurrently, algebra course-taking in later grades has declined, reflecting the push for algebra earlier in students' mathematics careers (Stein, Kaufman, Sherman, & Hillen, 2011). Yet, this shift has not been experienced uniformly. For example, among 8th graders, black students and Hispanic students continue to enroll in Algebra I at rates lower than their white counterparts (Domina, 2014; Gamoran & Hannigan, 2000; Stein et al, 2011), even conditional on prior achievement (Walston & McCarroll, 2010). This may be due to a combination of differences in mathematical preparedness and course placement practices. In addition, black students and

Hispanic students may disproportionately attend schools in which algebra is not offered in the middle school years. Nevertheless, concerns about the equality of access to algebra courses remain and have been foregrounded in recent years, particularly given evidence of the positive outcomes associated with taking algebra.

Research has documented the relationship between algebra enrollment and a variety of educational and economic outcomes (Adelman, 2006; NCTM, 1989; Gamoran & Hannigan, 2000; Ham & Walker, 1999, Ma, 2005; Stein et al, 2011). Yet, much of this research suffers from likely selection bias (Rickles, 2013; Stein et al, 2011) and therefore does not support causal claims about the impact of algebra. Typically, students are assigned to algebra coursework based on a combination of teacher or counselor recommendation, prior achievement, and student or parent preferences. A concern that arises from such course selection processes relates to those students who may be overlooked. Together with factors such as teacher expectations and school course offerings, students who are prepared for a course may nonetheless be excluded. Indeed, even among those sufficiently prepared, certain demographic groups are not proportionally represented in algebra courses (Domina, 2014; Stein et al, 2011; Stone 1998; Walston & McCarroll, 2010).

In response to concerns regarding equity in exposure to algebra, many policymakers have advocated for early and universal access to algebra, with some districts and states mandating Algebra I for all $9^{th}$ grade students (as in Chicago, see Allensworth, Nomi, Montgomery, & Lee, 2009 and Nomi, 2012) and others for all $8^{th}$ grade students (e.g. Burris, Heubert, & Levin, 2006; Silver, 1995; and, for an account of a statewide policy in California, see Bitter & O'Day, 2010). The "Algebra-for-All" movement has generated substantial debate (Loveless, 2008; Schneider, 2009; Silver, 1995), at the heart of which lies a tension regarding student readiness for algebra.

As was the concern in WCPSS, selective entry may deny access to those prepared for the course, placing unfair barriers to future opportunities. Yet, universal enrollment may force underprepared students into a course in which they may not be successful, particularly without additional supports. Additionally, universal policies may yield unintended or unanticipated adjustments by schools and teachers, undermining the aims of the policy. For example, while some schools may adapt pedagogy in rigorous ways to meet the needs of a more heterogeneous population, others may "water down" the curriculum and nevertheless perpetuate previous systems of inequality (Schneider, 2009). Universal policies also implicitly mandate changes to students' preparation for algebra, having curricular implications for the grades prior to those in which students take algebra. These changes may not occur in practice. Simply mandating that all students take algebra without giving attention to their preparation, what an algebra course entails, or how it is taught may be damaging to the very students the policy was intended to help.

Despite ongoing debates, limited causal evidence exists on universal algebra policies (Rickles, 2013; Stein et al, 2011). Researchers unsurprisingly find that universal policies increase algebra enrollment (Allensworth, et al, 2009; Burris et al, 2006; Everson & Dunham, 1996; Stein et al, 2011). Impacts on student achievement, however, are mixed (Stein et al, 2011). Clotfelter et al. (2012a, 2012b) find negative effects of accelerating low-skilled students into Algebra I in 9$^{th}$ grade. Ninth grade universal algebra in Chicago negatively impacted the mathematics achievement of high-skilled students placed in heterogeneous classes (Nomi, 2012). While the Chicago policy increased overall algebra credit accumulation, it also increased failure rates across ability groups, and it did not lead to improved standardized test scores (Allensworth et al, 2009). For low performing students assigned to a "double dose" of algebra,[1] the policy yielded positive short-term impacts on GPA and standardized test scores (Nomi & Allensworth, 2009)

[1] A "double dose" of algebra means that a student takes two periods of algebra per day.

but also an increase in course failure rates. In the longer term, the double-dose strategy yielded positive effects on ACT performance, high school graduation, and college entrance (Cortes, Goodman, & Nomi, forthcoming). Thus, there may be promise for algebra enrollment policies when combined with appropriate support for underprepared students, although care must be taken with how such policies are implemented (Nomi & Allensworth, 2013).

In the face of ongoing debates and mixed evidence on universal placement strategies, practitioners and policymakers have begun to seek alternative, objective mechanisms to advance students' mathematics trajectories and to identify policies that might best encourage early and equitable exposure for students who are prepared. The recent WCPSS policy relying on an objective measure to target students for acceleration provides an important opportunity to understand the benefits and consequences of alternative mathematics course assignment strategies.

## POLICY OVERVIEW AND CONTEXT

Historically, about 30 percent of WCPSS 8$^{th}$ graders have enrolled in Algebra I annually. Responding to concerns that the demographics of the 8$^{th}$ grade students enrolling in Algebra I did not reflect those of the district overall, the school board, along with a task force focused on economically disadvantaged students, sought to ensure that all students who demonstrated the potential to be successful in accelerated mathematics courses and Algebra I in the middle grades both had access to and were encouraged to enroll in the course.

As a result, the district designed and implemented a targeted middle-grades math enrollment strategy. Beginning in the 2010-2011 academic year, the district identified students for accelerated mathematics and pre-algebra in the 6$^{th}$ and 7$^{th}$ grades, respectively, and for

Algebra I in the $8^{th}$ grade utilizing a proprietary numeric criterion developed by the SAS Institute's Education Value-Added Assessment System (EVAAS). The EVAAS prediction model capitalizes on extant student test score information (e.g., standardized End-of-Grade test scores from all available prior grades) and specifically predicts each student's probability for each achievement level on the Algebra I end-of-course (EOC) exam.[2] For $6^{th}$ and $7^{th}$ grade students with a 70% or higher probability of achieving Level III on the Algebra I EOC exam, the policy recommends placement for $6^{th}$ grade accelerated math and $7^{th}$ grade Pre-Algebra, respectively, putting these students on track for Algebra I in the $8^{th}$ grade. For $8^{th}$ grade students with a 70% probability or higher of earning a Level III on the Algebra I EOC, the policy recommends placement in Algebra I in the $8^{th}$ grade.[3]

## PARTNERSHIP AND LONGITUDINAL DATA

Given the focus of this *Educational Evaluation and Policy Analysis* special issue on research partnerships that use data and rigorous analytic methods to inform educational practice, the details and structure of the relationship that paved the way for this investigation bear description. All of the authors on this paper are currently or were previously affiliated with Harvard University as students, faculty or staff researchers and are currently affiliated with the Center for Education Policy Research (CEPR) at Harvard. CEPR is the hosting entity of the Strategic Data Project (SDP).

The Strategic Data Project (SDP) was formed in 2008 with funding from the Bill and Melinda Gates Foundation. The goal of SDP is to transform the use of data in education to

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[2] The Algebra EOC exam is the North Carolina state standardized test that all students must complete at the end of Algebra I and is required of students who have taken the course. The exam is counted as part of the final course grade for each student.

[3] Level III represents a passing score on the North Carolina Algebra I end-of-course exam.

improve student achievement. Two fundamental and related challenges were at the heart of SDP's genesis. First, school districts are awash in data but often lack capacity to conduct analyses that have the potential to inform practice and decision making. Second, while educational research had contributed to our collective understanding on important topics such as teacher effectiveness and retention, alternative certification programs, and college-going outcomes, most districts lacked the opportunity to learn about these topics in their own contexts and with their own data (Hess & Fullerton, 2008). Seeking to address these challenges, SDP began as a pilot partnership between CEPR and two school districts: Charlotte-Mecklenburg Schools and the District of Columbia Public Schools and has since grown to include over 60 partner agencies, including school districts, state education agencies, charter management organization and non-profits.[4]

SDP utilizes several strategies in working towards this mission. The SDP research team utilizes data from each partner agency's administrative information systems to conduct detailed, descriptive analyses related to students' college readiness and success as well as human capital and teacher effectiveness to better inform that particular agency's strategic planning, management and decision making and to encourage its continued use of data for such purposes. These analyses are referred to as the SDP diagnostics. Data gathered to support the diagnostics includes detailed longitudinal information on students, such as demographic characteristics, courses taken, years enrolled and measures of academic achievement, including course grades and standardized test scores. Data also include teacher-level information, such as demographic characteristics, educational and licensure background, the number of years for which each teacher has been with the district, and the specific courses and groups of students each teacher teaches. While these data are typically pulled from a number of disparate data sources and

[4] For more information about the Strategic Data Project, please see www.strategicdataproject.org.

governing entities throughout an agency, the SDP research team works to bring the various elements into several unified files for analysis. Because of the research relationship that proceeded WCPSS joining SDP, the district and Harvard University had already established agreements and security protocols to enable the sharing of student- and teacher-level data between the two organizations. These agreements were then updated (and data refreshed) through the continuation of the SDP relationship.

In 2011, WCPSS joined on as a partnership district with SDP. Prior to becoming a formal SDP partner, WCPSS had contracted with CEPR to conduct a set of descriptive analyses focused on trends in achievement gaps by salient student characteristics, such as race / ethnicity and socioeconomic status. The district had undergone a leadership change, and then-incoming (now former) superintendent requested these analyses to provide a third-party look at academic achievement trends among the district's students. Through the process of conducting these analyses, members of our team had the opportunity to learn about the context and policy efforts underway in the district. These early conversations led to mutual interest in WCPSS signing on as a partner district in the Strategic Data Project and in investigating district efforts, such as the newly established middle-grades math assignment policy.

As the relationship was being established contractually, the SDP team was able to learn about the district's impetus for implementing the policy and was able to underscore the unique opportunity, given the structure of the policy, to investigate its impact with a rigorous, quasi-experimental research design. With the formation of the SDP relationship, the district and CEPR researchers agreed that understanding the impact of the middle-grades math assignment policy would be a focus of the ongoing research partnership.

Perhaps most critical to the success of this project, SDP places Strategic Data Fellows within each of its partner agencies. The SDP Fellows are skilled quantitative analysts selected through a national recruitment process to serve in a two-year fellowship in one of the SDP partner agencies. The role of the fellow in each agency is to improve data inquiry and data-driven decision making. Fellows contribute time to working on and facilitating the SDP diagnostics as well as conducting key projects that are both of import to the district and related to each fellow's substantive domains of interest. As part of his fellowship work within WCPSS, Darryl Hill, a member of this project's team, took on the WCPSS math placement policy as a key component of his portfolio of work for the district.

Hill's position within the district has been an integral aspect of this project for a number of reasons. First, he was able to learn, first hand, about the details and intricacies of the various WCPSS data systems. In addition to facilitating the assembly of the original data files required for the SDP diagnostics, he was also able to gather data elements required for this particular investigation that were not part of the diagnostic data sets. For example, he was able to gather the individual-level EVAAS probabilities for all students in WCPSS. He was able to develop an intimate understanding of the data's idiosyncrasies which he gained by working directly with the district's various data owners. Second, Hill was physically close and had direct access to the district staff members integrally involved in the development and implementation of the policy under exploration. This access afforded him the opportunity to talk regularly with district leaders about their intentions and visions for the WCPSS math assignment strategy. Third, his position as a researcher within the district afforded him access to school leaders and teachers responsible for responding to the district's charge of implementing the new strategy for math course placement. By traveling to many of the district's schools, Hill was able to talk directly with school leaders and mathematics teachers and learn about the on-the-ground context in which the policy was being implemented across schools. He learned about schools' site-specific approaches to the policy's implementation. This included learning about both the structures and services schools put in place to support students struggling in accelerated mathematics as well as the perceived needs the schools had for successful implementation. Much of what Hill learned has and continues to inform the group's analytic approach. For example, Hill was able to learn that compliance with the policy became stronger over time as a result of a powerful directive from the superintendent, and that some schools grouped their students into specially created sections of advanced math courses that corresponded to EVAAS scores. These details led our team to understand why compliance with the policy appeared more modest in its first few years and underscored the importance of including school-level fixed effects in our modeling strategy.

Fourth, Hill was able to represent the team's preliminary work not only internally to district leadership but also externally to interested parties and community members within Wake County. For instance, after the team presented preliminary results at an annual academic conference, community members learned about the ongoing work and were interested to discuss its meaning and implications for students in Wake County. Hill was able to facilitate these interactions with community members and utilized them as an opportunity to further educate about the findings to date. Finally, as the team's work moves forward, Hill will be able to lead dissemination of the study's findings within the district, for example, by presenting to bodies such as the district's school board, to the superintendent's leadership council, and to school leaders, teachers and community members throughout Wake County. In all of these ways, Hill's presence in WCPSS allows this investigation to serve as an example of research done *with* a district rather than *to* a district.

## DATA

To examine implementation of the enrollment policy, we utilize data from WCPSS's longitudinal student information system. This system assigns students unique identifiers that allow the district to follow their progress from primary school through secondary school. For our purposes, the data's longitudinal structure facilitates this research by tracking students from the end of fifth grade, when they are assigned EVAAS scores that determine whether they will be accelerated in math, through middle and high school, during which many of our outcomes of interest are measured. We can track students as long as they stay within WCPSS and will explore whether acceleration affected the rate of attrition from the district. Without the ability to link student records across years, this study would not be feasible.

Three major components of the data are critical to the current study. First, the data include student-level EVAAS scores, which provide an estimate of each student's predicted probability of success in algebra, as described above. New EVAAS scores are generated annually for rising $7^{th}$ and $8^{th}$ graders, as further standardized test scores are incorporated into the calculation.

Second, the data contain each student's complete middle school coursework transcript. We can therefore observe the math courses in which students enroll and thus whether they were accelerated in math. Because classrooms can be uniquely identified and linked to both students and teachers, we can construct measures of peer composition, such as class size or average prior achievement, and teacher characteristics, such as years of experience or value-added. These classroom-level measures will help us characterize in greater detail the various channels through which acceleration may have affected student outcomes.

Third, the data contain information on student demographics, such as gender, free/reduced price lunch status, and race/ethnicity. Such variables will serve as controls in some regression specifications and will allow us to explore heterogeneity in program impacts.

Finally, for future work, we are in the process of linking the transcript data to three important categories of outcomes that may be affected by math acceleration, namely standardized test scores, grades earned in middle school courses, and the high school coursework in which students later enroll. Standardized test scores will come from North Carolina's End-of-Grade (EOG) exams in math and reading comprehension, administered in the 3$^{rd}$ through 8$^{th}$ grades regardless of the specific courses in which the students were enrolled. That all students in a given grade receive a common assessment will allow us to explore whether acceleration affected math and reading achievement at the end of 6$^{th}$, 7$^{th}$ and 8$^{th}$ grade.

## SAMPLE DESCRIPTION AND EQUITY CONSIDERATIONS

Because the acceleration policy under study was first implemented in the 2010-11 school year, we focus largely on data for the 2010-11, 2011-12 and 2012-13 school years. Our main analytic sample consists of WCPSS students with valid EVAAS scores who entered 6$^{th}$ grade in the 2009-10 through 2012-13 school years. We refer to these students collectively as the 2010-13 cohorts, named for the spring of the academic year in which they first entered 6$^{th}$ grade. The 2010 cohort was subject to the new policy starting only in 7$^{th}$ grade, while the subsequent three cohorts were subject to it starting in 6$^{th}$ grade.

Table 1 contains summary statistics for the main analysis sample. Column 1, which contains all students in the sample, shows that 57% of WCPSS students in these grades are white or Asian and 38% are black or Hispanic. During this time period, 70% of middle school students are in accelerated math coursework, and the average EVAAS predicted probability is more than 10 percentage points higher than the 70% eligibility threshold set by the assignment rule. In fact, that EVAAS threshold represents roughly the 25th percentile of math skill in the district, so that the accelerated track should contain about 75% of WCPSS students if the acceleration rule were followed exactly.

Columns 2 and 3 divide the sample into students in accelerated math courses and those not. Accelerated students are substantially more likely to be white or Asian and less likely to be black or Hispanic. Accelerated students have much higher math skills, whether measured by EVAAS or by their 5th grade math exam z-score, the latter of which suggests a 1.3 standard deviation difference between the average performance of the two groups. Finally, accelerated students' math classes have much more highly skilled peers, are roughly five students larger, and have fewer black or Hispanic peers than do the math classes of non-accelerated students.

Before turning to a description of the empirical strategy we will use to estimate the impact of math acceleration on student outcomes, we first take a broad view of the overall impact of the new policy on the way in which students were assigned to accelerated coursework. Upon implementation, the policy immediately increased rates of enrollment in middle school accelerated math, and placement recommendations based on this policy have been followed with a high (and increasing) degree of fidelity. As Figure 1 shows, the share of students in accelerated math in the 6th through 8th grades during the 2007-08, 2008-09 and 2009-10 school years was about 40-44 percent. That share then jumped to 55 percent in the first year of policy implementation and up to nearly 70 percent in the subsequent two years. In 2010-11, 71 percent of EVAAS-eligible students enrolled in coursework leading to or called Algebra I. By 2012-13, this figure had risen to 94 percent. Rates of acceleration have been largely flat for students deemed ineligible by the new policy.

Figure 2 shows rates of math acceleration by low-income status. Acceleration rates rose substantially for both low income and non-low income students over this time period, though a large income gap in acceleration still persists in part because of the large income gap in EVAAS scores. Perhaps the most striking feature of these graphs is that EVAAS-eligible low-income students' rates of acceleration more than doubled from 40 percent to close to 90 percent over this time period. We see very similar patterns when comparing black and Hispanic students to white and Asian students. EVAAS-eligible black and Hispanic students' rates of acceleration also roughly doubled from about 45 percent to about 90 percent over this time period (not shown).

To study how the policy improved equitable access to accelerated math more rigorously, in Table 2 we regress for each cohort the fraction of students' observed middle school years spent in accelerated math coursework on EVAAS scores and income, race and gender indicators. We also include school-grade-cohort fixed effects so that all coefficients shown are within-school-and-cohort estimates and thus cannot be explained by student sorting across schools or differences across cohorts. Two patterns are striking. First, consistent with the use of EVAAS scores for assignment purposes, the relationship between EVAAS scores and acceleration monotonically increased over this time period, with the EVAAS coefficient increasing by more than half from the pre-policy 2009 cohort to the 2013 cohort.

Second, large income and race gaps in acceleration rates even conditional on skill (as measured by EVAAS) diminished greatly over this time period. Low-income students in the 2009 cohort spent 10.5 percentage points fewer of their middle school years in accelerated math coursework than did their non-low-income peers in the same school and of the same skill. For the 2012 and 2013 cohorts, this income gap had dropped to 2-3 percentage points. Black and Hispanic students in the 2009 cohort spent 7.4 percentage points fewer of their middle school years in accelerated math coursework than did their white and Asian peers in the same school and of the same skill. For the 2012 and 2013 cohorts, this race gap had dropped to a statistically insignificant 1-2 percentage points. There is little consistent evidence of a substantial gender gap in acceleration rates, conditional on skill. F-statistics associated with testing the joint significance of the income and race indicators dropped from 86 to 4-6 across these cohorts, although they remain statistically significant. Nevertheless, we interpret this substantial drop in F-statistics together with the patterns in regression coefficients as indication that the new EVAAS score-based assignment rule reduced the role of income and race in the math acceleration decision — the original goal of the policy — by increasing the role of academic skill in that assignment process over the time period examined.

## EMPIRICAL STRATEGY

The substantial differences in academic skill and other factors between accelerated and non-accelerated students would severely bias a simple comparison of these two groups' outcomes. To cleanly identify the impact of math acceleration on student standardized test performance, course grades, course-taking and other outcomes, we exploit the fact that WCPSS chose an EVAAS predicted probability of 70% as the cutoff for assignment to accelerated math coursework. This fact allows us to use a regression discontinuity (RD) design to compare outcomes of students just above and below that threshold. These two groups of students are nearly identical in all ways except that the former group was recommended for acceleration while the latter was not. As such, comparison of these two groups near the threshold should yield estimates unbiased by differences in prior academic achievement or other student characteristics. Of course, a limitation of this approach is that estimated impacts of acceleration that are derived from the regression discontinuity analysis are local to those students near the 70% cutoff, or those students who are around the 25$^{th}$ percentile of the achievement, as determined by the EVAAS measure.

The EVAAS predicted probability of success in Algebra I therefore serves as our forcing variable, the variable utilized to assign students exogenously to either the treatment group, those invited to accelerated math courses, or the control group, those not invited to such acceleration. Because EVAAS scores are recalculated after each grade to incorporate new standardized test scores and because math acceleration may affect such scores and thus subsequent EVAAS values, EVAAS scores calculated at the end of 6$^{th}$ and 7$^{th}$ grades may be partly endogenous to the policy itself. We therefore use as a forcing variable each student's EVAAS score as calculated at the end of 5$^{th}$ grade, prior to the point in time when middle school math acceleration could have affected that score.

Our use of RD is consistent with the guidelines presented by the What Works Clearinghouse (Schochet et al, 2010). First, the invitation to enroll in accelerated mathematics is based on a clear, clean assignment rule. Students with a predicted probability of 70% or greater are invited to take an accelerated math course and those with a probability below 70% are not. Second, the forcing variable is ordinal, as it is a probability predicted from a multivariate model, and therefore has numerous possible values on either side of the cutoff. Third, it is utilized by WCPSS only for assigning students to math courses, so that no other factors are confounded with the forcing variable.

For the RD approach to yield valid causal inference, subjects must not be able to manipulate the forcing variable. Given that the EVAAS probability is a predicted value based on a proprietary model with multiple inputs, manipulation would be difficult, if not impossible. Support for this supposition comes from the fact that, while WCPSS selected the cutoff criteria of 70%, SAS was responsible for generating the probability values, and the underlying model is not made public. Second, the cutoff scores are a function of prior standardized test performance and students likely have neither sufficient technical knowledge of the policy nor sufficient capability to manipulate their own test performance to impact their placement on the continuum of the forcing variable directly on either side of the cutoff. Additionally, for the earliest cohorts, students sat for standardized tests prior to the development of the prediction model or assignment policy and could not have anticipated it being implemented.

To confirm this reasoning, we examine the integrity of the forcing variable graphically. Figure 3 shows a histogram of the forcing variable for all students in the main analysis sample, with Panel A showing the full sample and Panel B showing the sub-sample that the RD analysis will focus on. The threshold value of 70% is marked with a vertical dashed line. We observe no discrete change in the density at the threshold, suggesting no obvious manipulation of the EVAAS scores. Though this figure presents the distribution for students across all grades and school years, tests and figures disaggregated by grade and school year look similarly smooth.

While students are recommended for accelerated mathematics if they have a 70% or higher EVAAS probability, not all eligible students enroll in the recommended course, and some ineligible students do manage their way into the accelerated courses regardless. The discrepancies between eligibility and take-up mean that the probability of a student enrolling in an accelerated mathematics course does not jump sharply from zero to one at the 70% threshold.

As a result, we will model the relationship between our outcome and the EVAAS probability as a "fuzzy" regression discontinuity (Imbens & Lemeiux, 2008; Murnane & Willett, 2011). We explain our strategy with respect to a generic outcome *Y*, such as a standardized test score or course grade.

We employ a two-stage approach using instrumental variables to estimate the effect of participating in accelerated mathematics on our outcome *Y*. We first use each student's position relative to the probability cutoff as an instrument for enrollment in accelerated mathematics. For the first stage, we use local linear regression to fit the following linear probability model for student *i* in cohort *c*, grade *g* and initial middle school *s*:

$$ACCEL_{icgs} = \beta_0 + \beta_1 ELIG_{icgs} + \beta_2 CEVAAS_{icgs} + \beta_3 (CEVAAS \times ELIG)_{icgs} + \mu_{cgs} + \varepsilon_{icgs}$$

.

where *ACCEL* is an indicator for enrollment in an accelerated math course, and *ELIG* is an indicator for a student's end of 5th grade EVAAS score exceeding 70%. *CEVAAS* is a student's EVAAS score re-centered around that threshold, such that $\beta_2$ represents the slope of the relationship between the probability of acceleration and EVAAS to the left of the threshold. The interaction between *CEVAAS* and *ELIG* allows that slope to differ to the right of the threshold. We include cohort-by-grade-by-school fixed effects, which improves the precision of our estimates but has little impact on their magnitude, as would be expected given that the threshold is the same throughout the district. The coefficient on the eligibility indicator, $\beta_1$, therefore represents the difference in math acceleration rates between students just above and just below the eligibility threshold in the same cohort, grade and school.

Because we are still in the process of obtaining data on student outcomes, we focus in this paper on documenting that first stage itself. In particular, we assess the extent to which the assignment rule was followed. We will show that the assignment rule was followed closely enough that *ELIG* is a strong enough instrument to allow us later to identify the impact of math acceleration on student outcomes. The second-stage model that we will use in future research is given by:

$$Y_{icgs} = \pi_0 + \pi_1 ACCEL_{icgs} + \pi_2 CEVAAS_{icgs} + \pi_3 (CEVAAS \times ELIG)_{icgs} + \gamma_{cgs} + \delta_{icgs}$$

where *Y* represents outcomes such as test scores and course grades, and *ACCEL* is instrumented by eligibility as in the first-stage equation above. Based on this model, the parameter of interest will thus be $\pi_1$, the effect of participating in accelerated mathematics for students who were accelerated because of the assignment rule. This estimate represents a local average treatment effect for "compliers", those students near the threshold who took accelerated math coursework only because of the cutoff rule and who would not have enrolled had the rule not existed (Angrist, Imbens & Rubin, 1996). These students would not have chosen themselves or been chosen by their schools to enroll in accelerated coursework but are induced to do so by the new eligibility rule. Our identification strategy thus relies on the fact that there are two nearly identical sub-groups of students on either side of the threshold who would not have taken accelerated math coursework in the absence of the new policy. The policy thus quasi-randomly induces one sub-group to enroll but leaves the other untouched. While there would be empirical advantages to a true randomized trial, in this context randomization would simply not be politically palatable for the district and therefore not feasible to implement.  Therefore, the regression discontinuity design provides a particularly attractive alternative.

**FIRST STAGE RESULTS**

Before turning to the first stage results, we note that our primary specification here uses local linear regression, a triangular kernel, a bandwidth of 15 EVAAS points, and clusters standard errors by initial middle school. Though not shown in detail here, the results presented below are robust to alternative weighting such as rectangular kernels (Imbens & Lemieux, 2008), a variety of bandwidths, including those suggested by other optimal bandwidth selection methods (Calonico et al., forthcoming; Imbens & Kalyanaraman, 2012; Ludwig & Miller; 2007) and inclusion of covariates. That inclusion of covariates does not affect our central estimates is unsurprising given that the inability to manipulate the EVAAS score theoretically suggests that students' demographic characteristics should be balanced across the threshold. We confirm this in Table 3, which tests for discontinuities in demographic characteristics at the threshold by running our first-stage specification with various covariates as outcomes. All of the available covariates appear balanced across the threshold, suggesting that our treatment and control groups look quite similar in terms of race, income, special education and LEP status, age and gender.

We first show the graphical representation of the first-stage relationship between students' EVAAS scores and the probability of enrolling in accelerated math coursework. Figure 4 show this relationship by grade and school year, with the top row representing the 2010-11 school year during which the new assignment policy was first implemented. The largely untreated 2009 cohort is thus represented in the upper right box, as they were 8$^{th}$ graders in the 2010-11 school year and show little evidence of a discontinuity in acceleration rates near the threshold.

The 2010 cohort, who were 7$^{th}$ graders in 2010-11 and 8$^{th}$ graders in 2011-12, show clearer discontinuities, with students just above the threshold noticeably more likely to be accelerated in both 7th and 8th grades compared to those just below the threshold. The subsequent 2011-2013 cohorts, all of whom started middle school under the new assignment rule, show substantial discontinuities in acceleration rates as well. These discontinuities seem particularly striking in 7th grade, though the most recent 2013 cohort shows a substantial discontinuity in 6th grade, the one year for which we can currently observe them. Overall, these graphs suggest that the new assignment rule has been more and more faithfully implemented over time and will serve as a strong source of exogenous variation in the probability of a given student being accelerated in math.

Figure 5 provides an alternative way of measuring the strength of the first stage. Here, we define the treatment as the fraction of each student's observed middle school years spent in accelerated math coursework. We then pool the 2010-13 cohorts, which yields a much less noisy figure than those separated by grade and school year. The discontinuity here is striking. Students just below the eligibility threshold spend less than 40% of their middle school years in accelerated coursework, whereas those just above the threshold spend about 55% of their time in such coursework, on average.

We confirm this graphical intuition in Table 4 by fitting the first-stage regressions described previously. The top row uses as an outcome the fraction of each student's observed middle school years spent in accelerated math coursework. The remaining rows use as an outcome an indicator for being accelerated in a given grade and year. The first column represents the untreated 2009 cohort, while the second through fifth columns represent the treated 2010-13 cohorts. The final column pools all four treated cohorts.

As expected, there is no evidence that the eligibility threshold affected math acceleration rates in the 2009 cohort's first two years, prior to the policy's introduction. In 8th grade, there is small and only marginally significant evidence of an impact for that cohort in the policy's first year. For the 2010 cohort, which was in 7th grade when the new policy began, eligibility increases the fraction of middle school years spent in accelerated math by 7.3 percentage points. This fraction rises monotonically across subsequent cohorts, so that eligibility increases the fraction of years accelerated by 28.3 percentage points for the 2013 cohort. Pooling all four treated cohorts leads to an average estimated first-stage effect of 13.4 percentage points. For the pooled sample, the F statistic for the eligibility coefficient is nearly 50, well beyond the threshold of 10 suggested by Bound, Jaeger and Baker (1995) for a strong instrument. The second through fourth rows show that much of the strength of this instrument comes from particularly strong impacts in 7th grade acceleration decisions, though smaller effects in 6th and 8th grade are still highly statistically significant.

Table 5 explores potential channels through which acceleration might impact later outcomes by estimating how acceleration affects the peers and teachers to which students are exposed in their primary math classes. Each coefficient shows the estimated impact of current acceleration status, where acceleration has been instrumented with eligibility. Relative to non-accelerated students, those accelerated because of the assignment rule end up with peers who are 1.1 standard deviations higher in math skill as measured by their 5th grade math scores. Interestingly, these two sets of classes have similar standard deviations in such math skill, so that acceleration does not change the heterogeneity of skill to which students are exposed. Accelerated students end up in classes that are 4.2 students larger. They have peers who are more than 20 percentage points less likely to be low-income, black or Hispanic, though gender composition is unchanged. There is little evidence that acceleration affects the quality of students' math teachers on average, though we do see suggestive evidence that accelerated students are less likely to be assigned teachers with value-added measures one standard deviation below the mean. In total, these results suggest that acceleration exposes students to higher skilled peers and possibly fewer low quality teachers, which might have positive effects, but also to larger class sizes, which might have negative effects. Based on these results, it is worth noting that because of the structure of the policy, students on different sides of the EVAAS threshold had mathematics classroom experiences that different not only in terms of curriculum and course content but also in terms of the composition of their classroom. In this respect, the treatment that we are assessing with our regression discontinuity design is multi-dimensional in nature and not necessarily the effect of a more advanced mathematics curriculum exclusively.

Finally, Table 6 replicates the first row of Table 4, interacting all right-hand side variables with income, race or gender indicators in order to study whether the district was enforcing the EVAAS threshold rule differently for different groups of students. The first and second panels suggest that the assignment rule is applied similarly across students of different income levels but slightly more strictly to black and Hispanic students than to white and Asian students. Consistent with Table 2, we see small differences in acceleration rates by income and race conditional on EVAAS scores.[5] The third panel suggests that the assignment rule is applied somewhat more strictly to male students than to female students, with the difference between the two discontinuity coefficients being marginally significant. Again consistent with Table 2, the female coefficient suggests that, conditional on EVAAS score, female students are no more likely to be accelerated than male students. Overall, these results suggest that the assignment rule is being applied fairly similarly across student subgroups.

[5] These coefficients are less precisely estimated than their equivalent coefficients in Table 2 because that table included the entire sample, whereas Table 4 includes only students near the eligibility threshold.

**CONCLUSION**

Findings from our initial investigation of the WCPSS math acceleration policy suggest that overall participation in accelerated mathematics courses has increased as a result, and that the assignment policy has been applied equally across student subgroups defined by gender and by race / ethnicity. In addition to increasing overall participation in accelerated mathematics, this assignment strategy has also resulted in girls being represented in accelerated math courses in proportion to their enrollment in the district. In contrast, however, while enrollment rates for black students and Hispanic students also improved substantially over their pre-policy levels, neither group of students has achieved representation in accelerated courses in way that is proportional to their overall share of district enrollment. This last fact underscores that policies that base assignment solely on demonstrated ability may not be sufficient to ameliorate long-standing imbalances in access to important academic steppingstones. Nevertheless, our analyses do reveal that policies such as these can serve to diminish the extent to which factors such as income and race relate to course placement, at least conditional on student achievement.

Yet to be known is whether the rule-based assignment policy in Wake County has a meaningful impact on student-level measures of school engagement and academic performance. In subsequent analyses, we will utilize course-taking, course-grades, standardized test scores, attendance, discipline, and college-going as policy-relevant outcomes of interest in both the short and long term. Earlier work in Chicago that provided algebra instruction for all $9^{th}$-grade students in the district suggests that accelerating students into algebra may result in mixed short-term academic benefits as measured by test scores (Allensworth et al., 2009; Nomi & Allensworth, 2009), but that there may be a long-term payoff in the way of college going for students impacted by this policy (Cortes et al., forthcoming). The continued work is especially important given that clear differences exist between the educational contexts of Chicago and Wake County and the potential usefulness of these outcome data for education policy in a variety of contexts. Our ongoing access to and use of the longitudinal data from WCPSS will add to the existing literature on math acceleration and algebra access policies, while providing relevant feedback on the policy's impact on student outcomes in its local context.

It is important to emphasize that without our research partnership with WCPSS, there would be no prospect for establishing or continuing this line of investigation. Further, the district's continued maintenance of its longitudinal data systems as well as its commitment to using these data to measure ongoing impact and to improve equity of both practice and outcomes make this work possible. Thus, the WCPSS policy and this research partnership through the Strategic Data Project serve as a compelling example of how cooperation among researchers and education agencies can leverage existing data to answer important questions about the impact of innovative policies. Our aim is that collaborative efforts such as these will yield fruit both for informing the broader research community as well as organization-level decision making in educational agencies which are often data rich but comparatively limited in terms of analytic capacity.

This issue of *EEPA* is a signal that the education policy research community strives to build stronger bridges to and partnerships with education agencies in order to apply rigorous analytic tools to policy questions of the highest importance. We believe that this is the right direction for the field. Yet, our own experience has reminded us collectively to remain cognizant of the potential risks and controversies that can be generated by education policies and efforts to assess their impact, such as our efforts with WCPSS. For example, though the incentive structure within the academic community clearly favors the presentation of work in progress, the risks associated with the potential misuse and misunderstanding of early findings is borne disproportionately by the partnering educational agency. If policy innovation, research partnerships, and the honest evaluation of educational policies using experimental and quasi-experimental methods are to be furthered, the utmost care must be taken to honor the interests and working realities of the students, community members, educators and agency leaders involved.

Finally, the WCPSS middle grades mathematics acceleration policy is emblematic of policies that are established in ways that allow for high-quality and causally identified impact analyses, and our subsequent analyses will seek to understand finer-grained variation in the implementation of the policy across school contexts and the impacts of this policy on student outcomes in both the short and long term. If our investigation suggests this as a broadly feasible and promising strategy for improving students' access to rigorous and appropriate coursework in mathematics, the WCPSS course assignment strategy will serve as an example for other districts considering similar policy goals and actions. WCPSS's use of the EVAAS measure, specifically, should not serve as a limiting factor for other districts considering ways to provide objective access to school resources or curricula. In addition to understanding impacts ultimately, research partnerships also serve as a potential opportunity for constructing measures analogous to the EVAAS predicted probability, or for finding ways to identify other approaches for implementing district- or school-level policies so that their impact on student outcomes can be rigorously understood.

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Figure 1: Fraction of Students Accelerated, By Year and Eligibility

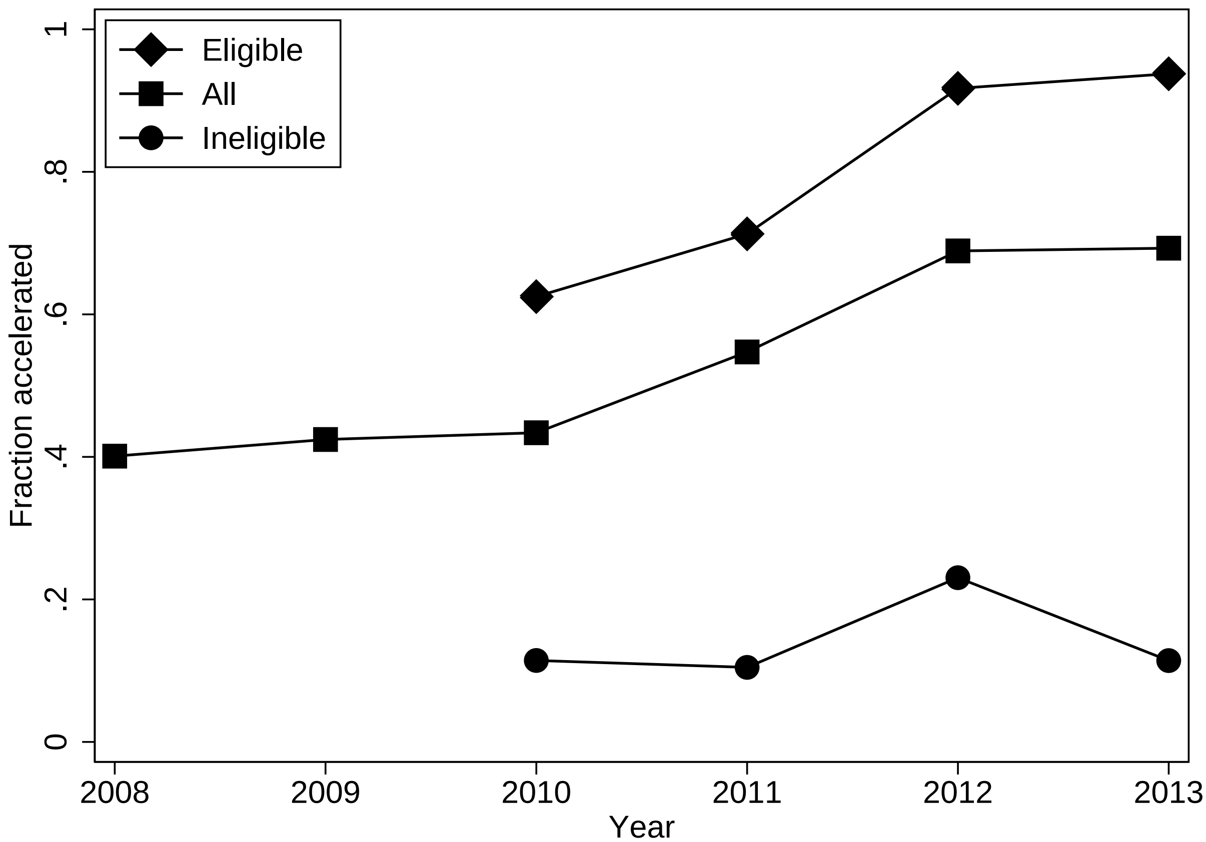

Figure 2: Fraction of Students Accelerated, By Income

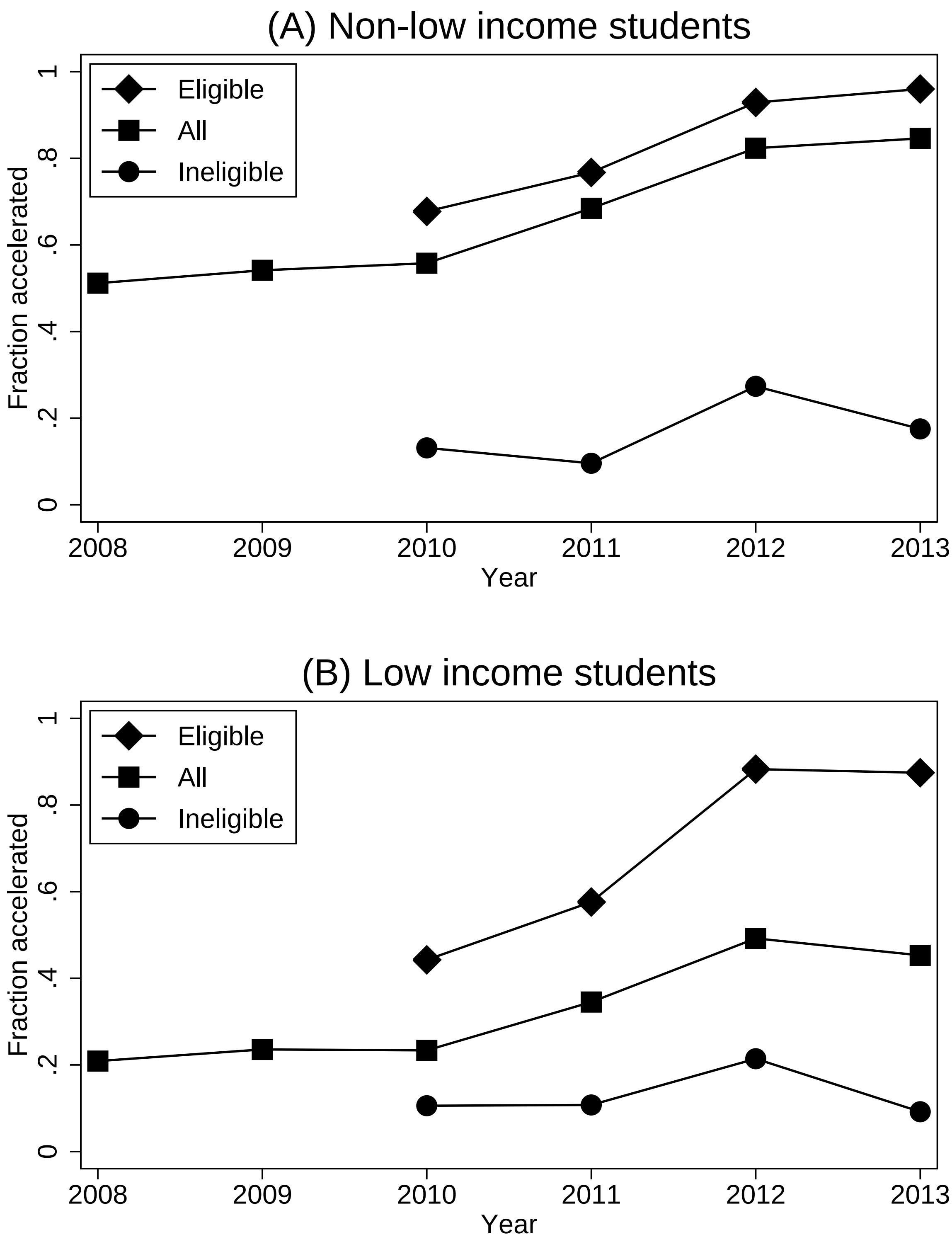

Figure 3: Distribution of EVAAS Scores

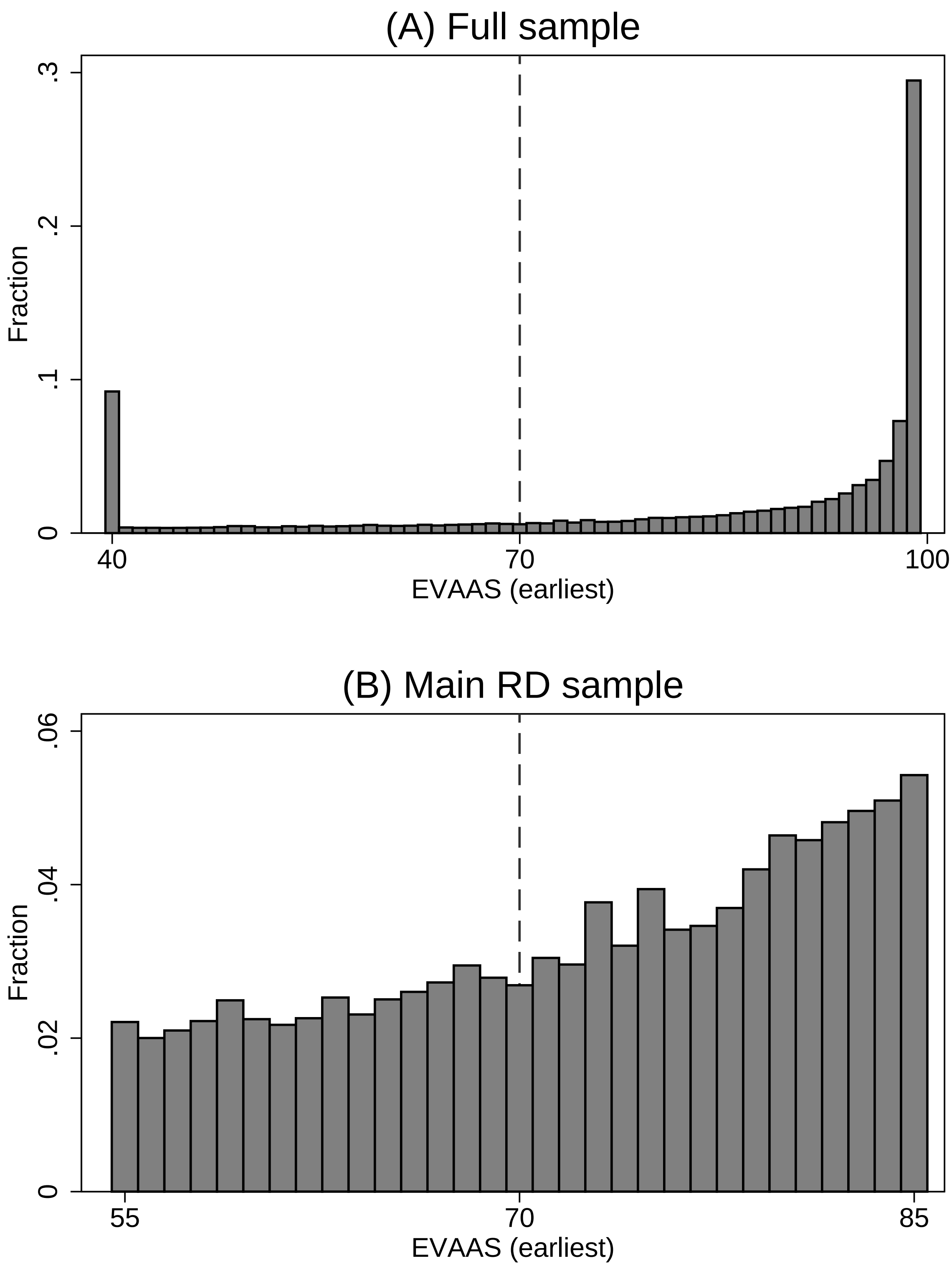

Figure 4: Placement in Accelerated Math

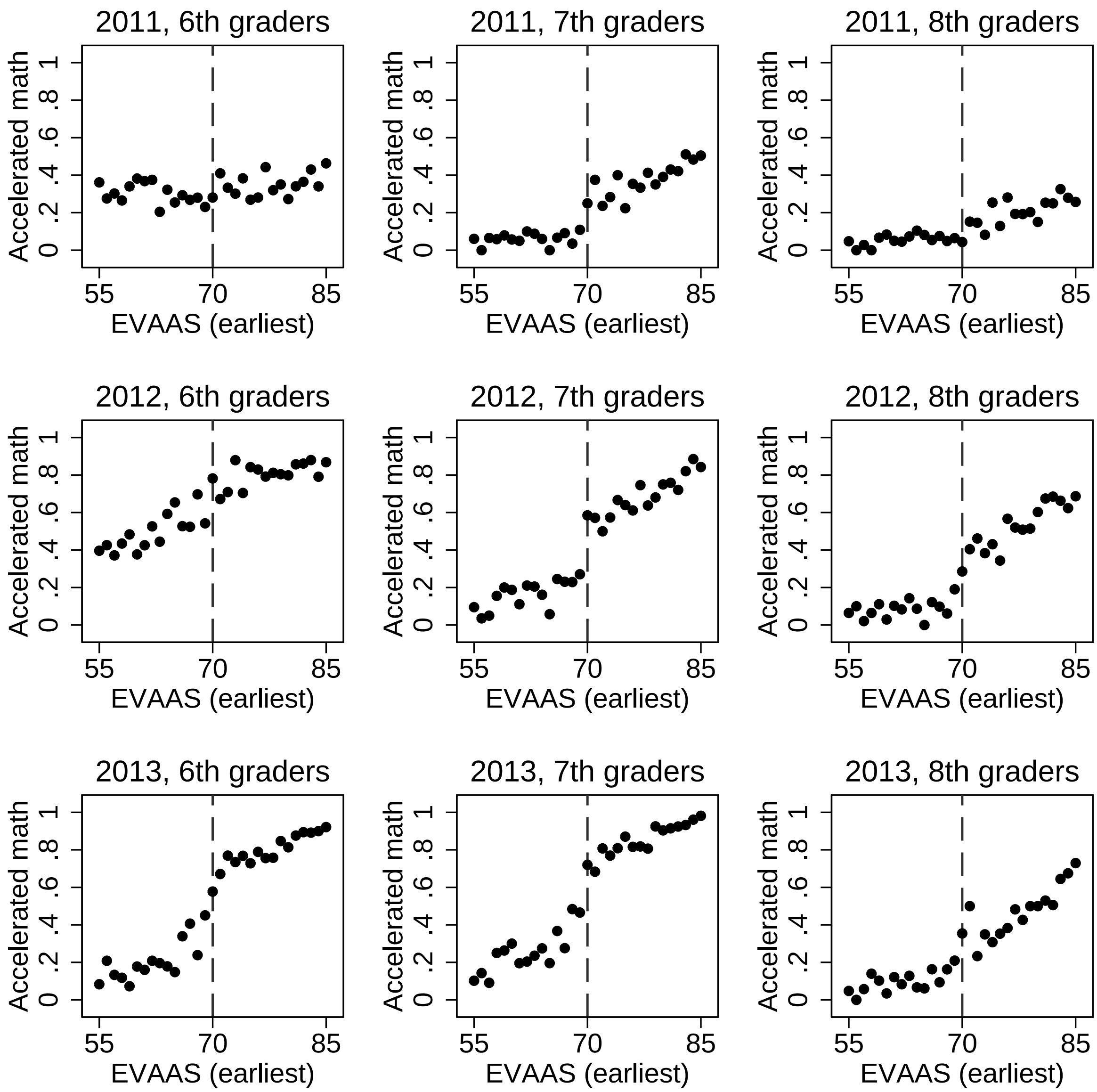

Figure 5: Fraction of Years in Accelerated Math

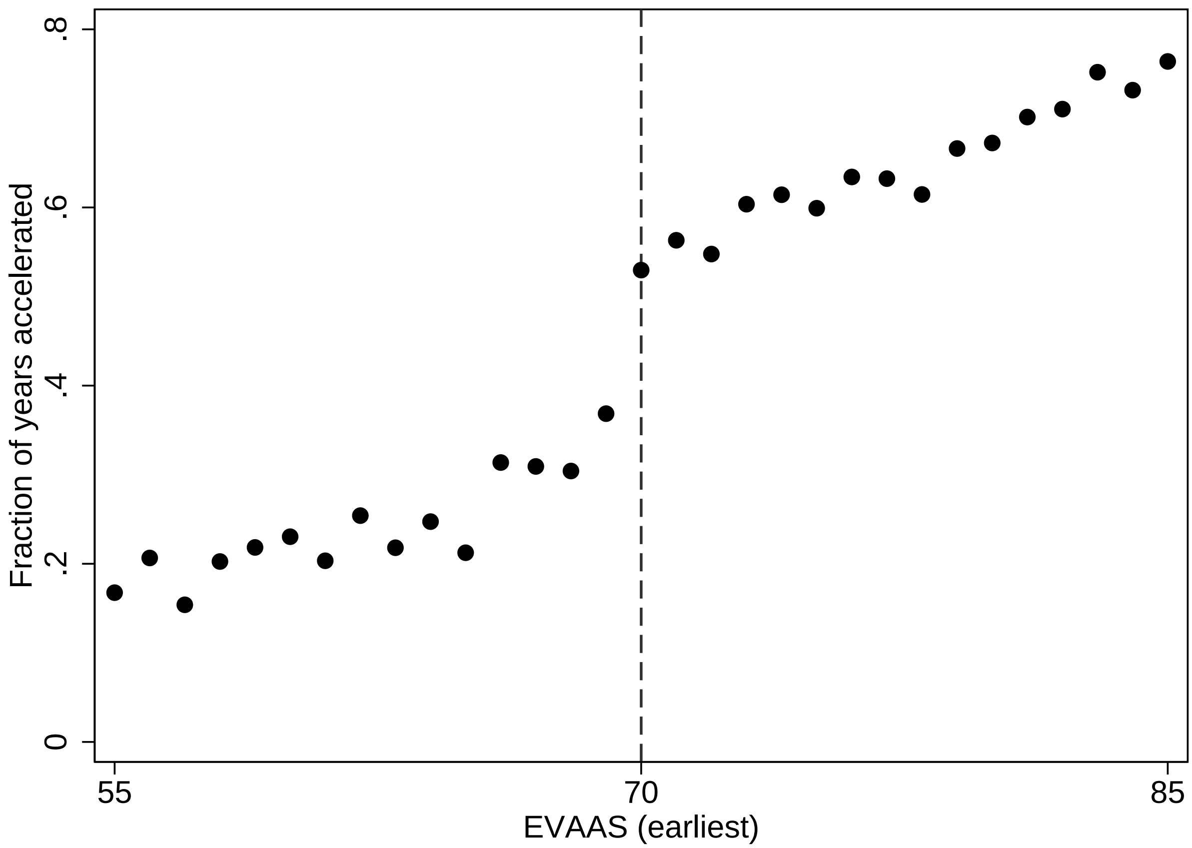

Table 1: Summary Statistics

| | (1) All students | (2) Accelerated | (3) Non-accelerated |
|---|---|---|---|
| (A) Controls | | | |
| Female | 0.501 | 0.504 | 0.495 |
| White | 0.509 | 0.598 | 0.304 |
| Asian | 0.062 | 0.079 | 0.024 |
| Black | 0.247 | 0.171 | 0.425 |
| Hispanic | 0.135 | 0.106 | 0.203 |
| Other race | 0.046 | 0.046 | 0.044 |
| Poor | 0.375 | 0.266 | 0.630 |
| Special education | 0.351 | 0.366 | 0.316 |
| Limited English proficiency | 0.161 | 0.138 | 0.213 |
| Age on September 1 | 13.299 | 13.262 | 13.386 |
| (B) Math course and skills | | | |
| Accelerated | 0.699 | 1.000 | 0.000 |
| EVAAS (most recent) | 80.671 | 91.824 | 54.171 |
| EVAAS (earliest) | 83.051 | 92.868 | 60.235 |
| 5th grade math z-score | 0.032 | 0.421 | -0.884 |
| (C) Math course peer composition | | | |
| Mean 5th grade math z-score | 0.018 | 0.412 | -0.898 |
| SD 5th grade math z-score | 0.629 | 0.617 | 0.655 |
| Class size | 26.243 | 27.719 | 22.811 |
| Fraction black or Hispanic | 0.429 | 0.327 | 0.666 |
| Fraction female | 0.499 | 0.502 | 0.492 |
| N | 82,359 | 57,584 | 24,775 |

Notes: Mean values of key variables are shown for all students in the 2010-2013 cohorts.

Table 2: Decreasing Role of Demographics in Math Acceleration Process

| | (1)<br>2009<br>cohort | (2)<br>2010<br>cohort | (3)<br>2011<br>cohort | (4)<br>2012<br>cohort | (5)<br>2013<br>cohort |
|---|---|---|---|---|---|
| EVAAS (earliest) | 0.009*** | 0.011*** | 0.012*** | 0.012*** | 0.014*** |
| | (0.000) | (0.000) | (0.000) | (0.001) | (0.001) |
| Low income | -0.105*** | -0.077*** | -0.077*** | -0.020*** | -0.032*** |
| | (0.010) | (0.009) | (0.010) | (0.007) | (0.011) |
| Black/Hispanic | -0.074*** | -0.044*** | -0.040*** | -0.005 | -0.017 |
| | (0.013) | (0.010) | (0.010) | (0.009) | (0.011) |
| Female | 0.003 | 0.008 | 0.016*** | 0.002 | 0.019*** |
| | (0.007) | (0.007) | (0.006) | (0.005) | (0.004) |
| Constant | -0.120*** | -0.256*** | -0.274*** | -0.188*** | -0.386*** |
| | (0.025) | (0.024) | (0.035) | (0.057) | (0.051) |
| $R^2$ | 0.41 | 0.58 | 0.60 | 0.65 | 0.62 |
| F(income,race) | 86.1 | 41.3 | 36.7 | 4.0 | 5.7 |
| N | 9,286 | 9,381 | 9,267 | 9,607 | 9,752 |

Notes: Heteroskedasticity robust standard errors clustered by initial middle school are in parentheses (* p<.10 ** p<.05 *** p<.01). Each column uses OLS to estimate the relationship between the fraction of middle school years spent in accelerated math coursework and earliest EVAAS score, income, race and gender. Each regression includes school-by-grade fixed effects. The sample consists of the last middle school year observed for each student in the listed cohort. Below each column are F-tests of the joint significance of the income and race coefficients. The p-values associated with those F-tests are all less than 0.01.

Table 3: McCrary and Covariate Balance Test

| | (1)<br>Count | (2)<br>Black/<br>Hispanic | (3)<br>Low<br>income | (4)<br>Special<br>ed. | (5)<br>LEP | (6)<br>Age on<br>Sept. 1 | (7)<br>Female |
|---|---|---|---|---|---|---|---|
| Eligible | -2.573 | 0.000 | -0.034 | -0.032 | 0.020 | 0.017 | -0.002 |
| | (2.600) | (0.025) | (0.028) | (0.025) | (0.018) | (0.031) | (0.027) |
| $\mu$ | 52.52 | 0.70 | 0.65 | 0.22 | 0.21 | 13.30 | 0.53 |
| N | 261 | 16,010 | 16,010 | 16,010 | 16,010 | 16,010 | 16,010 |

Notes: Heteroskedasticity robust standard errors clustered by initial middle school are in parentheses (* $p<.10$ ** $p<.05$ *** $p<.01$). Each coefficient is the reduced form estimate of the relationship between eligibility for acceleration and the list covariate. The coefficients shown are generated by local linear regression using a triangular kernel of bandwidth 15, including cohort-by-school-by-grade fixed effects. The first column uses as an outcome the number of observations in each year, grade and 1-point wide EVAAS bin. Also listed is the mean of the covariate for students just below the threshold (with EVAAS between 67 and 70). The sample includes the 2010-2013 cohorts.

Table 4: First Stage Estimates of Exposure to Accelerated Math Coursework

| | (1)<br>2009<br>cohort | (2)<br>2010<br>cohort | (3)<br>2011<br>cohort | (4)<br>2012<br>cohort | (5)<br>2013<br>cohort | (6)<br>2010-13<br>cohorts |
|---|---|---|---|---|---|---|
| Fractions of years accelerated | 0.012 | 0.073*** | 0.092*** | 0.186*** | 0.283*** | 0.134*** |
| | (0.022) | (0.024) | (0.029) | (0.034) | (0.072) | (0.019) |
| $\mu$ | 0.21 | 0.20 | 0.25 | 0.55 | 0.37 | 0.33 |
| F | 0.3 | 9.1 | 10.2 | 29.6 | 15.5 | 48.9 |
| N | 4,736 | 4,910 | 4,956 | 4,010 | 2,134 | 16,010 |
| | | | | | | |
| Accelerated in grade 6 | 0.016 | 0.004 | 0.012 | 0.158*** | 0.283*** | 0.125*** |
| | (0.033) | (0.023) | (0.025) | (0.053) | (0.072) | (0.027) |
| $\mu$ | 0.31 | 0.28 | 0.26 | 0.59 | 0.37 | 0.39 |
| F | 0.2 | 0.0 | 0.2 | 9.0 | 15.5 | 21.2 |
| N | 1,554 | 1,679 | 1,763 | 2,098 | 2,134 | 7,674 |
| | | | | | | |
| Accelerated in grade 7 | -0.005 | 0.189*** | 0.276*** | 0.291*** | | 0.252*** |
| | (0.023) | (0.069) | (0.065) | (0.050) | | (0.039) |
| $\mu$ | 0.06 | 0.08 | 0.24 | 0.42 | | 0.25 |
| F | 0.0 | 7.6 | 17.7 | 34.3 | | 41.6 |
| N | 1,594 | 1,669 | 1,676 | 1,912 | | 5,257 |
| | | | | | | |
| Accelerated in grade 8 | 0.049* | 0.189*** | 0.100* | | | 0.147*** |
| | (0.028) | (0.058) | (0.055) | | | (0.035) |
| $\mu$ | 0.06 | 0.11 | 0.16 | | | 0.14 |
| F | 3.2 | 10.8 | 3.2 | | | 18.0 |
| N | 1,588 | 1,562 | 1,517 | | | 3,079 |

Notes: Heteroskedasticity robust standard errors clustered by initial middle school are in parentheses (* $p<.10$ ** $p<.05$ *** $p<.01$). In the first row, first stage estimates show the impact of eligibility for acceleration on the fraction of middle school years spent in accelerated math coursework. The remaining rows show the impact of eligibility for acceleration on current acceleration status, by grade. The coefficients shown are generated by local linear regression using a triangular kernel of bandwidth 15, including cohort-by-school-by-grade fixed effects. Eligibility is measured by each student's earliest EVAAS score. Below each coefficient is the proportion of students just below the threshold enrolled in accelerated coursework, as well as the F-statistic associated with the excluded instrument.

Table 5: Peer and Teacher Characteristics in Primary Math Classroom

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| (A) Peers | Mean math skill | St. dev. math skill | Class size | Fraction female | Fraction low inc. | Fraction black/Hisp. |
| Accelerated | 1.079*** | -0.016 | 4.154*** | 0.007 | -0.241*** | -0.225*** |
| | (0.088) | (0.037) | (1.097) | (0.031) | (0.026) | (0.031) |
| N | 16,010 | 16,010 | 16,010 | 16,010 | 16,010 | 16,010 |
| (B) Teachers | VAM estimate | Low VAM | Years of exp. | Novice teacher | Female teacher | Missing teacher |
| Accelerated | 0.284 | -0.213** | 0.138 | 0.014 | 0.142 | -0.038 |
| | (0.298) | (0.100) | (1.223) | (0.040) | (0.086) | (0.056) |
| N | 14,110 | 14,110 | 12,649 | 12,649 | 12,713 | 16,010 |

Notes: Heteroskedasticity robust standard errors clustered by initial middle school are in parentheses (* p<.10 ** p<.05 *** p<.01). Each panel shows instrumental variables estimates of the impact of acceleration, where acceleration is instrumented with eligibility. The coefficients shown are generated by local linear regression using a triangular kernel of bandwidth 15, including cohort-by-school-by-grade fixed effects. In panel B, low VAM is defined as having an estimated VAM more than one standard deviation below average, and the final column's outcome is an indicator for missing information about a student's primary math teacher. The sample includes the 2010-13 cohorts.

Table 6: First Stage Impacts, By Gender, Income and Race

| | (1) 2010-2013 cohorts | (2) 2010 cohort | (3) 2011 cohort | (4) 2012 cohort | (5) 2013 cohort |
|---|---|---|---|---|---|
| (A) Income | | | | | |
| Non-poor * Eligible | 0.140*** | 0.124** | 0.049 | 0.185*** | 0.265*** |
| | (0.023) | (0.049) | (0.039) | (0.046) | (0.087) |
| Poor * Eligible | 0.129*** | 0.042* | 0.113*** | 0.187*** | 0.285*** |
| | (0.026) | (0.024) | (0.035) | (0.049) | (0.090) |
| Poor | -0.030 | -0.001 | -0.044 | -0.040 | -0.089 |
| | (0.025) | (0.027) | (0.031) | (0.058) | (0.080) |
| p | 0.75 | 0.14 | 0.18 | 0.97 | 0.86 |
| N | 16,010 | 4,910 | 4,956 | 4,010 | 2,134 |
| (B) Race | | | | | |
| White/Asian * Eligible | 0.097*** | 0.092** | 0.011 | 0.099** | 0.264*** |
| | (0.025) | (0.035) | (0.046) | (0.045) | (0.078) |
| Black/Hispanic * Eligible | 0.152*** | 0.066** | 0.124*** | 0.236*** | 0.286*** |
| | (0.024) | (0.031) | (0.033) | (0.047) | (0.094) |
| Black/Hispanic | -0.027 | 0.012 | -0.045 | -0.040 | -0.085 |
| | (0.026) | (0.022) | (0.046) | (0.062) | (0.070) |
| p | 0.10 | 0.57 | 0.04 | 0.05 | 0.85 |
| N | 16,010 | 4,910 | 4,956 | 4,010 | 2,134 |
| (C) Gender | | | | | |
| Male * Eligible | 0.160*** | 0.087*** | 0.131*** | 0.203*** | 0.314*** |
| | (0.018) | (0.031) | (0.037) | (0.052) | (0.068) |
| Female * Eligible | 0.111*** | 0.063* | 0.051 | 0.171*** | 0.259** |
| | (0.028) | (0.032) | (0.036) | (0.049) | (0.098) |
| Female | 0.035 | 0.004 | 0.037 | 0.017 | 0.128* |
| | (0.023) | (0.029) | (0.027) | (0.047) | (0.074) |
| p | 0.08 | 0.56 | 0.08 | 0.67 | 0.58 |
| N | 16,010 | 4,910 | 4,956 | 4,010 | 2,134 |

Notes: Heteroskedasticity robust standard errors clustered by initial middle school are in parentheses (* p<.10 ** p<.05 *** p<.01). First stage estimates show the impact of eligibility for acceleration on the fraction of middle school years spent in accelerated math coursework. The coefficients shown are generated by local linear regression using a triangular kernel of bandwidth 15, including cohort-by-school-by-grade fixed effects. These replicate the regressions from the top row of Table 4, interacting the independent variables with indicators for income, race or gender. Also shown is a p-value from an F-test of the equality of the two interaction coefficients shown. The sample includes the 2010-13 cohorts.