Abstract Title Page
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Title: The Aftermath of Accelerating Algebra: Evidence from District Policy Initiatives

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Abstract Body

Limit 4 pages single-spaced.

Background / Context:

Description of prior research and its intellectual context.

In 2008, the California State Board of Education voted to require all students to enroll in algebra by 8th grade. This policy initiative, yet to be actually implemented, represents the culmination of a decades-long movement toward offering algebra instruction before the traditional high school years. Nationally, the proportion of 8th grade students enrolled in algebra doubled between 1988 and 2007 (Perie, Moran and Lutkus, 2005; Walston and McCarroll 2010), reaching rates over 50% in three states and the District of Columbia. The movement to offer algebra instruction before high school has been inspired in large part by correlational research documenting significant differences in later-life outcomes between those students who enroll in algebra by 8th grade and those who do not. But correlation need not imply causation, and it is unclear whether accelerated algebra enrollment – particularly when not accompanied by complementary curriculum reform in earlier grades – yields positive or negative effects (Loveless, 2008).

Purpose / Objective / Research Question / Focus of Study:

Description of the focus of the research.

This paper provides a quasi-experimental estimate of the causal impact of accelerating the introduction of algebra coursework. We analyze policy initiatives introduced in two large North Carolina school districts in 2002/03. These initiatives caused many students to take Algebra I earlier than they would have before the initiative, with the increase being especially abrupt for students in the middle deciles of the initial math achievement distribution. After maintaining the acceleration policy for two years, one district reversed course, reverting almost entirely to its previous placement pattern, whereas the other district stuck with its policy throughout the sample period. We use the across-cohort variation in placement patterns created by these abrupt shifts in policy to infer the impact of acceleration, by comparing students with similar initial math achievement who were subjected to different placement policies solely on the basis of their year of birth. The analysis also incorporates, as an additional counterfactual, observations from eight additional large North Carolina school districts with no announced policy shift regarding the timing of Algebra I.

Setting:

As just described, the research is based on explicit policy initiatives in two large North Carolina school districts and it is supplemented with observations from eight additional large North Carolina Districts.

Population / Participants / Subjects:

We rely on the student level data for 6 cohorts of students enrolled in the ten largest North Carolina School Districts. The data include all students other than those for whom some data are missing.

Intervention / Program / Practice:

In the fall of 2002, two of the three largest school districts in North Carolina adopted unusually aggressive policies to accelerate placement of middle and high school students into Algebra I. The districts, Charlotte-Mecklenburg Schools (hereafter, CMS) and Guilford County Public Schools (encompassing the cities of Greensboro and High Point), were led by strong superintendents who championed a policy of increasing the number of 8^{th} graders taking Algebra I. The superintendent of CMS strongly believed as a matter of pedagogy that algebra should be offered to many, if not most, students in middle school, rather than waiting until they are in high school. Later described as "a bear on getting middle school kids in eighth grade to learn Algebra I," this superintendent announced at the beginning of the 2001/02 year that his goal would be to increase to 60% the portion of students in the district who were proficient in Algebra I by the end of eighth grade, as indicated by scoring at level 3 or above on the state's end-of-course test. In Guilford, a new superintendent began his tenure in May 2000 forcefully advocating a policy of enrolling as many 8^{th} graders as possible in Algebra I. These superintendents not only broke from past patterns of course-taking but also diverged significantly from policies followed by most other districts in North Carolina. To be sure, there was widespread interest in education circles at this time in the idea of accelerating the teaching of algebra. Adding additional impetus, the state of North Carolina had increased from three to four the number of math courses required for admissions to the University of North Carolina system.

Our descriptive analysis of algebra taking in middle school by cohort (disaggregated based on students' prior year test scores) clearly illustrate the magnitude of the policy change in both districts (see figures 1 and 2).

Research Design:

In our basic most basic specifications, Charlotte Mecklenburg and Guilford are considered to have adopted a "treatment" of accelerating algebra instruction for some of the cohorts, while the other eight are considered "controls" used to identify counterfactual trends in relevant outcome measures. The eight "control" districts themselves exhibit some degree of variation in algebra-taking patterns over time, and in additional specifications we use this variation as well to identify effects. The presence of policy variation in the "control" districts does not bias our main effect estimates so long as it is not perfectly correlated with changes in the "treatment" districts.

Thus, our basic estimation strategy is a version of differences-in-differences: we compare the outcomes of students stratified into deciles of initial ability level, as measured by the mean of 6th and 7^{th} grade math scores, across cohorts. In order to implement this strategy in a manner that produces local average treatment effects, we use instrumental variable estimators capturing the policy-induced variation in individual propensity to take Algebra I by 8^{th} grade.

Our main outcome variables are test scores in algebra 1, the probabilities of passing algebra I by 10^{th} grade, geometry by 11^{th} grade and algebra II by 12^{th} grade. Students who pass those courses meet the North Carolina State Board of Education's minimum standards for a college-preparatory course of study. We use standardized end-of-course tests designed by the state to assess performance in each course, rather than the grade assigned by the course instructor. We also provide some basic descriptive evidence on the likelihood of progressing to a calculus course in high school, the traditional culmination of a college-preparatory math course sequence beginning with Algebra I in 8^{th} grade, and on the likelihood of repeating Algebra I.

In addition to a modified strategy that explores implicit policy variation across all 10 districts, which has the advantage of allowing us to examine how the effects differ for students at different points in the prior year test score distribution, we also do various robustness checks and explore one of the possible mechanisms that might explain the negative effects, namely the substitution for less qualified teachers as schools needed to offer more algebra courses in middle school.

Although data limitations prevent us from using a comparable differences-in- differences strategy to examine the impacts of early algebra taking on calculus taking we are able to bound the effects on enrollment in that upper level course.

Data Collection and Analysis:

Our data are derived from North Carolina Education Research Data Center longitudinal records on students who entered 7^{th} grade between 1999/2000 and 2004/05 and spent the subsequent school year in any one of the state's ten largest districts – CMS, Guilford, and an additional eight districts we consider as "controls" in our basic specifications. We restricted the sample to students with valid scores on the state's standardized 6^{th} and 7^{th} grade mathematics assessment in order to stratify them by prior math performance. We then tracked progress through college-preparatory math courses using the state's end-of-course (EOC) examinations in Algebra I, Geometry, and Algebra II. When using ten districts and all available cohorts, our sample amounts to 194,425 students.

Our estimation strategy takes advantage of the large and abrupt policy changes undertaken in CMS and Guilford County beginning in the fall of 2001. We exploit these changes to estimate local average treatment effects for taking Algebra I by the time students reach 8^{th} grade, based on differences between the treated and untreated cohorts. To address concerns that differences across cohorts might reflect changes in the difficulty of standardized tests or other phenomena, we use the state's other eight largest districts as additional "control" observations. Although these districts may have implemented some form of policy change at some point during our sample period, our identifying assumption is that any such policy changes did not affect the exact same deciles and cohorts as were affected by the CMS and Guilford changes. Under this assumption controls for decile-by-cohort fixed effects, included in our main specifications, account for time-varying factors affecting all students at similar performance levels statewide.

Findings / Results:

The results contrast starkly with the basic patterns revealed in our own OLS analysis and previous, correlational analyses. Students accelerated into middle school algebra score 37% of a standard deviation lower on their Algebra I end-of-course tests. At the same time they are about 4 percentage points more likely to pass the course by the time they complete 10^{th} grade. The apparent contradiction between lower test scores and higher pass rates is explained by course retaking, a point we also examine in the paper. Moreover, two -stage least squares estimates indicate that accelerated students are neither more nor less likely to pass Geometry and Algebra II on a college-preparatory schedule. (See results in Table 4).

Based on our interaction models, we conclude that enrolling the lowest-performing students (based on prior year tests) in early Algebra introduces significant downside risks with little to no upside potential. For moderately-performing students, there are at best modest potential rewards and significant downside risk. Students in the top 40% of the initial test score distribution appear to suffer few ill effects beyond the first year, and may in fact benefit from the opportunity to access higher-level math coursework in high school. (See results in Table 6).

Finally, our analysis of teachers in one district shows that whatever declines in teacher quality that were associated with the introduction of the acceleration program are not sufficient to account for the declines in algebra 1 test scores.

Conclusions:

We find that acceleration initiatives lowered the Algebra I test scores of affected students. Moderately-performing students who were accelerated into Algebra I in 8^{th} grade scored one-third of a standard deviation worse on the state end-of-course exam, compared to otherwise similar students in seventh-grade cohorts that were not subjected to acceleration. Across numerous specifications, only one point estimate suggests a statistically significant positive effect on subsequent course performance; the vast majority of estimates are insignificant or significantly negative. Specifications examining apparent policy variation across the full set of 10 large North Carolina districts indicate more persistently negative effects for low-performing students, but benign or beneficial effects for high-performing students.

We find substantial evidence that introducing algebra in middle school, rather than serving to equalize student outcomes, exacerbates inequality. Students at or above the 60^{th} percentile of the initial achievement distribution appear to suffer few ill effects beyond the first year, and may be as many as 20 percentage points more likely to take a calculus course in high school when they are accelerated. At the lower end of the distribution, since calculus-taking rates are approximately zero regardless of Algebra I timing, the acceleration introduces costs without offering benefits. Patterns in the middle of the distribution are, not surprisingly, somewhere between these extremes.

One interpretation of these findings is that offering algebra for all 8^{th} graders would be a worthy standard if additional reforms raised the performance of all students to the level where the 60^{th} percentile North Carolinian middle school student lies today. More generally, this evaluation illustrates the hazards of basing policy initiatives on simple correlational evidence, without first taking steps to assess the validity of causal interpretation.

Appendices

Not included in page count.

Appendix A. References

References are to be in APA version 6 format.

Loveless, T. (2008) "The Misplaced Math Student: Lost in Eighth-Grade Algebra." Brookings Institution Brown Center Report on American Education, September.

Perie, M., R. Moran and A.D. Lutkus (2005) "NAEP 2004 Trends in Academic Progress: Three Decades of Student Performance in Reading and Mathematics." National Center for Education Statistics Publication 2005-464.

Walston, J. and J.C. McCarroll (2010) "Eighth Grade Algebra: Findings from the Eighth-Grade Round of the Early Childhood Longitudinal Study, Kindergarten Class of 1998-99 (ECLS-K)." National Center for Education Statistics Publication 2010-016.

Appendix B. Tables and Figures
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Table 4: Basic instrumental variables results

Independent variable	Algebra I Test Scores (IVQR)	Pass Algebra I by 10th grade	Pass Geometry by 11th grade	Pass Algebra II by 12th grade
Enrolled in Algebra I by 8th Grade	-0.370*** (0.038)	0.043* (0.022)	-0.023 (0.023)	0.027 (0.017)
Male	0.101*** (0.007)	0.037*** (0.005)	0.015*** (0.003)	0.053*** (0.005)
African-American	0.008 (0.009)	0.014*** (0.004)	-0.015*** (0.002)	0.046*** (0.005)
Hispanic	0.017 (0.017)	0.014*** (0.005)	-0.004 (0.004)	0.026*** (0.006)
Other Race	0.102*** (0.016)	0.017*** (0.005)	0.017** (0.005)	0.041*** (0.009)
Free/Reduced Lunch	-0.182*** (0.009)	-0.060*** (0.006)	-0.076*** (0.006)	-0.099*** (0.007)
N	194,425	194,425	194,425	194,425
Adjusted R^2	---	0.479	0.533	0.424

Note: Standard errors, corrected for clustering at the decile-cohort-district level, in parentheses. Estimation is by two-stage least squares except as indicated. Algebra I test score is taken from the student's first test administration. Course passage for Algebra I and Algebra II is defined as obtaining a standardized test score at or above the 20th percentile of the statewide distribution. Course passage for Geometry is defined as obtaining an achievement level at or above 3 on the test. Grade-retained students are kept with their original cohort. District, decile, cohort and decile-by-cohort fixed effects included but coefficients are not shown in this table. Sample consists of all available cohorts, deciles, and districts.
*** denotes a coefficient significant at the 0.1% level, ** the 1% level, * the 5% level.

Table 6: Instrumented Quintile Interaction Effects of the Impact of Acceleration into Algebra I in 8th Grade

Independent variable	Algebra I Test Score		Pass Algebra I by 10th grade	Pass Geometry by 11th grade	Pass Algebra II by 12th grade
	2SLS	RFQR w/imputation	2SLS	2SLS	2SLS
Quintile 1 Student * Enrolled in Algebra I by 8th Grade	-0.479*** (0.080)	-0.240*** (0.015)	0.221*** (0.037)	-0.108*** (0.031)	-0.0627 (0.048)
Quintile 2 Student * Enrolled in Algebra I by 8th Grade	-0.456*** (0.034)	-0.397*** (0.006)	0.0921*** (0.022)	-0.081*** (0.012)	-0.0401* (0.016)
Quintile 3 Student * Enrolled in Algebra I by 8th Grade	-0.429*** (0.034)	-0.398*** (0.006)	0.0356* (0.015)	-0.085*** (0.018)	-0.0174 (0.020)
Quintile 4 Student * Enrolled in Algebra I by 8th Grade	-0.324*** (0.048)	-0.260*** (0.006)	0.0462** (0.014)	-0.0129 (0.018)	-0.015 (0.017)
Quintile 5 Student * Enrolled in Algebra I by 8th Grade	-0.306*** (0.092)	-0.140*** (0.010)	0.096*** (0.022)	0.0687** (0.026)	0.011 (0.023)
N	113738	124505	124505	124505	124505
Adjusted R^2	0.712	0.376	0.424	0.568	0.436

Note: Standard errors, corrected for clustering at the decile-cohort-district level, in parentheses. Algebra I test score is taken from the student's first test administration. Course passage for Algebra I and Algebra II is defined as obtaining a standardized test score at or above the 20^{th} percentile of the statewide distribution. Course passage for Geometry is defined as obtaining an achievement level at or above 3 on the test. Grade-retained students are kept with their original cohort. All models control for average 6^{th} and 7^{th} grade math test score decile, cohort and district fixed effects, and instrument for Algebra I enrollment by 8^{th} grade using an indicator representing the probability of taking Algebra I by 8^{th} grade within your decile-cohort-district cell. Columns headed "2SLS" are estimated by two-stage least squares. Column headed "RFQR w/imputation" applies the Neal and Johnson (1996) method of imputing poor performance for 10,767 non-Algebra I-takers and estimating using the Chernozhukov and Hansen (2005) method. *** denotes a coefficient significant at the 0.1% level, ** the 1% level, * the 5% level.

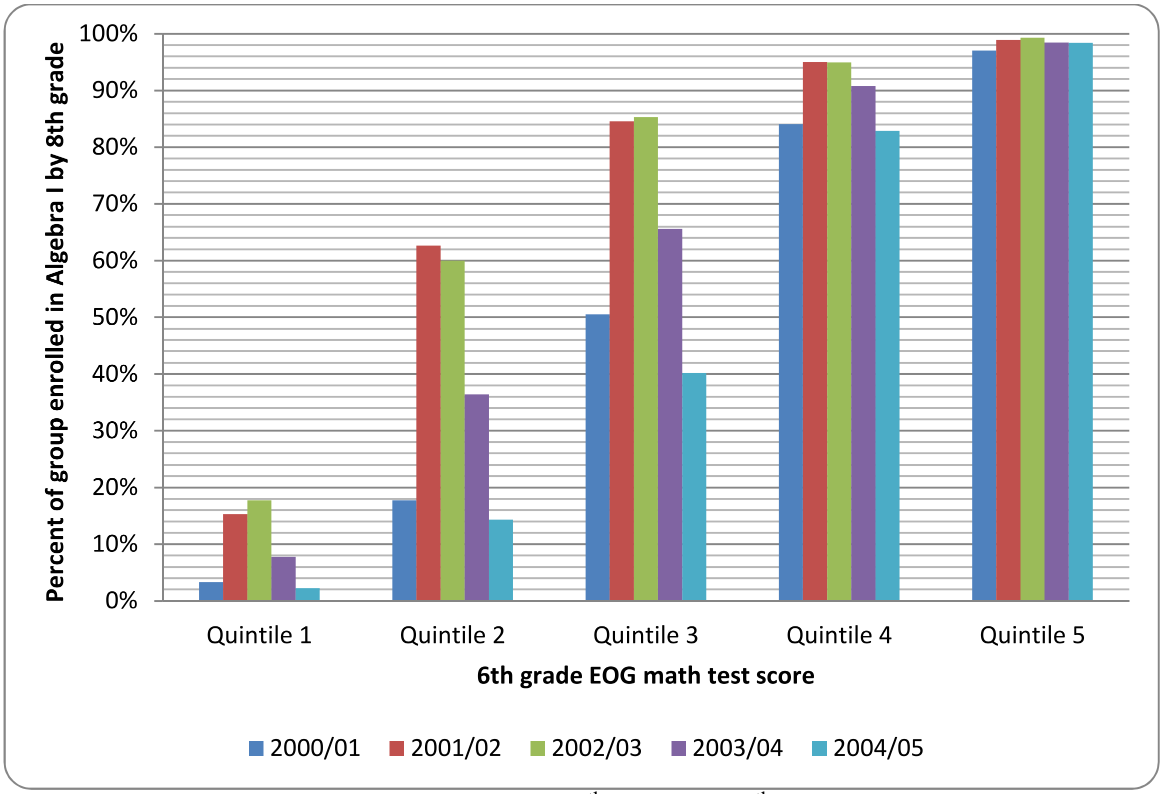

Figure 1: Probability of taking Algebra I by 8th grade, by 6th grade math test score quintile and year entering 7th grade, Charlotte-Mecklenburg Schools.

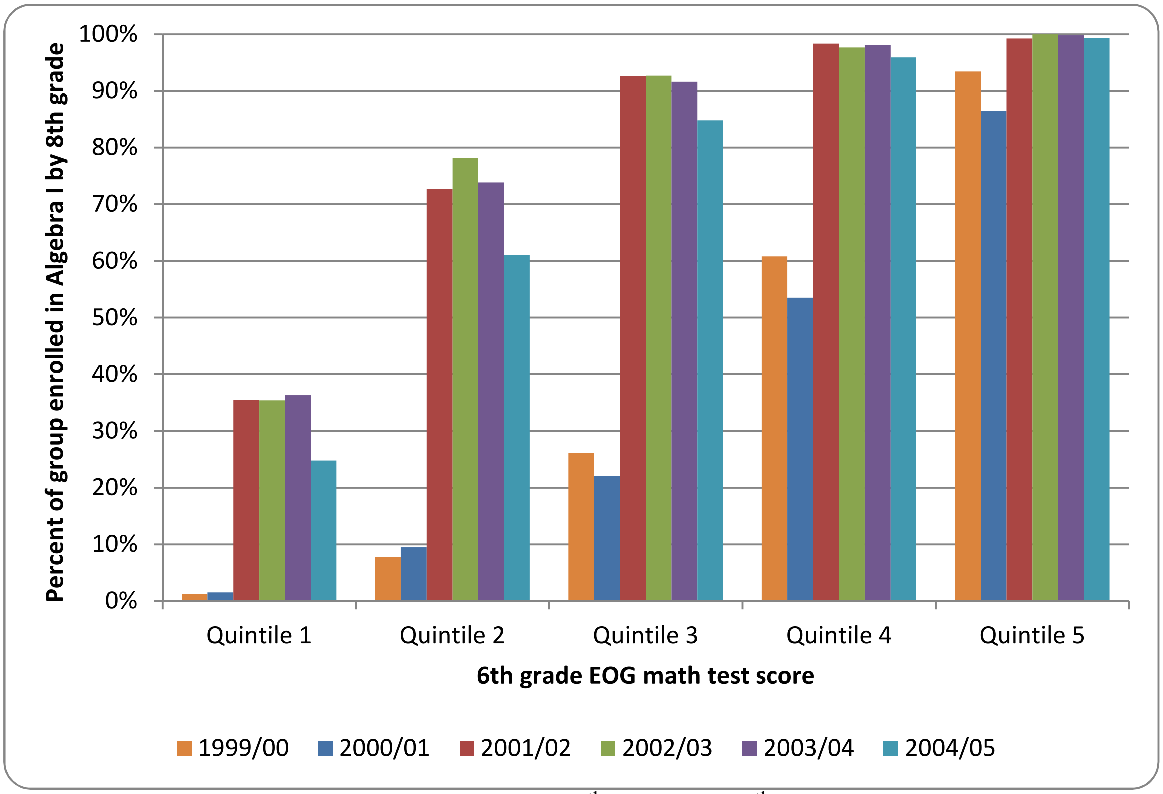

Figure 2: Probability of taking Algebra I by 8th grade, by 6th grade math test score quintile and year entering 7th grade, Guilford County Schools.