Aiming High and Falling Short:

California's 8th Grade Algebra-for-All Effort

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Abstract: The U.S. is in the midst of an effort to intensify middle school mathematics curricula by enrolling more 8th graders in Algebra. California is at the forefront of this effort, and in 2008 the state moved to make Algebra the accountability benchmark test for 8th grade mathematics. This paper takes advantage of this unevenly-implemented policy to understand the effects of curricular intensification in middle school mathematics. Using district-level panel data from all California K-12 public school districts, we estimate the effects of increasing 8th grade Algebra enrollment rates on a 10th grade mathematics achievement measure. We find that enrolling more students in advanced courses has negative average effects on students' achievement, driven by negative effects in large districts.

U.S. students persistently trail their international peers in mathematics achievement, performing particularly poorly on the application of mathematical concepts (Organization for Economic Cooperation and Development, 2009; Gonzalez et al., 2008; Schmidt, 2012). This skills gap impedes U.S. economic growth and competitiveness (Goldin & Katz, 2008). Over the last several decades, U.S. schools have dramatically intensified high school mathematics curricula in an attempt to improve U.S. mathematics achievement (Domina & Saldana, 2012a). Central to this movement is the effort to enroll a greater proportion of students in Algebra while they are in middle school. Algebra serves a crucial gatekeeping function in U.S. schools. For students who fail to master Algebra in 8th or 9th grade, the path to advanced training in mathematics and, subsequently, many well-paid and high-status careers is blocked (Adelman, 1999; Attewell & Domina, 2008; Long, Conger, & Iatorola, 2012). Furthermore, it is a uniquely challenging course, drawing heavily upon the concrete procedural skills that students develop in elementary mathematics and requiring students to develop a new set of abstract reasoning skills (Carraher & Schliemann, 2007; Howe, 2005; Vogel, 2008).

In this paper, we take advantage of an ambitious but unevenly implemented effort to enroll all California 8th graders in Algebra to examine the consequences of curricular intensification for student achievement. Using district-level panel data from all California public K-12 school districts, we estimate the effects of increasing 8th grade Algebra enrollment rates on 10th graders performance on the mathematics portion of the California High School Exit Exam. Our analyses make two major contributions to the fledging literature on curricular intensification in middle and high schools: First, we provide a system-level view of the consequences of changing course placement practices, rather than the student-level effects of advanced courses course placement. Second, we explore the effects of changing mathematics course enrollment patterns for achievement in several mathematical content areas, including basic arithmetic, pre-algebraic functions, and algebra. Our findings are counter-intuitive, suggesting that enrolling more students in advanced math courses has negative consequences for mathematics achievement.

1. Context: 8th grade Algebra-for-all in California

Over the past three decades, California has been at the forefront of the national effort to universalize 8th grade Algebra (Loveless 2008). In 1987, California's State Superintendent of Public Instruction argued that detracking middle schools was a central step toward raising academic standards in high schools. In 1992, the state department of education called for "heterogeneous grouping and detracking as a goal" and the 1997 revision of the state's content standards called on middle schools to enroll all 8th graders in Algebra I. In 1999, the California State Senate passed the *Public School Accountability Act* (PSAA). By penalizing schools for enrolling 8th graders in pre-algebra or other general math courses, the law created powerful incentives for schools to place more 8th graders in Algebra (Domina, Penner, Penner & Conley, 2014). The adoption of these standards spurred rapid intensification in middle school mathematics. Between 1999 and 2008, the proportion of California 8th graders enrolled in Algebra more than tripled, from 16 percent to 51 percent (Rosin, Barondess, & Leichty, 2009).

In 2008, the state's Board of Education voted to make the Algebra California Standards Test (CST) the "sole test of record" for the state's 8th graders. This vote required 8th graders to demonstrate proficiency on the state's end-of-course Algebra standards exam in order to satisfy accountability expectations under the *No Child Left Behind Act* and California's *Public Schools Accountability Act* (Rosin, Barondess, & Leichty, 2009). However, California's 8th grade Algebra mandate was never fully implemented. Responding to a challenge from California school administrators and school boards, the courts postponed the policy's implementation in the spring of 2010. Later that year, under pressure from the Obama administration and teachers' unions, the California Academic Content Standards Commission adopted the Common Core State Standards, which recommend pre-Algebra content for 8th graders. While California's revised middle school math standards continue to encourage schools to enroll 8th graders in Algebra, state policy no longer mandates accelerated Algebra (Wurman & Evers, 2011).

California's decades-long effort to universalize 8th grade Algebra created a fluid policy environment. Over the last several years, districts across the state have moved to enroll more students in early Algebra. Many districts anticipated the 8th grade Algebra mandate and began to track greater proportions of 8th graders into Algebra courses long before the state attempted to mandate the course. Many district officials supported the mandate, viewing it as a tool to mitigate inequalities in the opportunity to learn. Other district officials, however, remained committed to the idea of sorting students into middle school mathematics courses based on their prior achievement, and were reluctant increase 8th grade Algebra enrollments even after the state created incentives to do so. Furthermore, after the state stepped away from its 8th grade Algebra mandate, 8th grade Algebra enrollment rates began to decline in some – but not all – California districts. As a result, patterns of 8th grade Algebra enrollment rates vary considerably across districts. This variation makes it possible to estimate the effects of increasing 8th grade Algebra on student mathematics achievement.

2. Curricular intensification and its consequences

The American curricular intensification movement is predicated on the notion that students learn more in academically challenging educational environments; a theory that is often referred to as "opportunity to learn" (Porter, 2002). Consistent with this theory, several studies indicate that students who are exposed to rigorous curriculum and instruction experience greater achievement gains on average than those who are not (e.g., Attewell & Domina 2008; Argys, Rees, & Brewer, 1996; Domina 2014; Gamoran et al., 1997; Gamoran & Hannigan, 2000; Long, Conger, & Iatarola, 2012; Schmidt et al., 2001, 2011). These studies employ a wide range of methods to isolate the effect of rigorous course enrollment for students' later outcomes. Taken together, their results suggest that efforts to enroll more students in accelerated Algebra courses should boost student achievement by influencing student exposure to rigorous academic content, effective instructional strategies, and high-achieving peers.

However, this literature is limited in two important regards: First, efforts to estimate the effects of curricular intensification using observational data are subject to considerable selection bias, since students who enroll in advanced courses differ from students who do not on a wide range of characteristics. Relatively few studies have attempted to estimate the effects of advanced course-taking in experimental or rigorous quasi-experimental settings, and those that do have returned sharply mixed results. Heppen et al. (2012) report the results of an experiment in which high-achieving 8th graders in 68 randomly-selected small, rural middle schools were offered access to an online Algebra course. In this case, access to online Algebra had a moderate positive effect on these high-achieving students' Algebra achievement as measured at the end of 8th grade (effect size=0.39), as well as their subsequent high school math course-taking. However, instrumental variable analyses taking advantage of rapid curricular intensification in 10 North Carolina school districts indicate that accelerated Algebra has a negative effect on student achievement (Clotfelter, Ladd & Vigdor, 2012a, 2012b).

Second, policy efforts like California's 8th grade Algebra push do more than change a handful of students' course-enrollment patterns. Rather, they aim to make broad systematic changes in school curricula and organization. These systematic changes may have spillover effects for students who enroll in 8th grade Algebra as well as their peers who enroll in less advanced mathematics courses, particularly when schools transition from highly differentiated systems of mathematics instruction to relatively untracked Algebra-for-all systems. As a result, studies that identify the effects of 8th grade Algebra enrollment for a given student may provide limited insight into the effects of an effort to accelerate Algebra enrollment for a large proportion of students. By reducing low-level courses and integrating students who once would have taken these courses into more advanced classrooms, these policies likely have a wide range of intended and unintended consequences on the content, pedagogy, and social organization of secondary schools (Gamoran & Hannigan, 2000). Policies that increase the number of students in advanced courses increase the demand for teachers in these courses, often leading schools to assign new teachers or teachers who had previously specialized in teaching lower-level courses to advanced courses (Clotfelter, Ladd & Vigdor, 2012a). Further, large-scale curricular intensification likely changes the distribution of student skills within advanced courses and less advanced courses alike. Increasing the proportion of students enrolled in 8th grade Algebra courses may lead to increases in the degree of skill heterogeneity and lower mean prior achievement scores in Algebra courses by adding more low-achieving students to these courses. At the same time, this policy shift likely *decreases* skill heterogeneity and lowers mean prior achievement scores in pre-Algebra courses, as the highest-skill students from pre-Algebra are promoted to Algebra, leaving behind only the students deemed most underprepared for Algebra in 8th grade. These changes in classroom composition may have independent consequences on student learning (Nomi 2012; Zimmer & Toma, 2000), as well as effects on teacher instructional content and methods (McPartland & Schneider, 1996). The net effects of curricular change thus include direct course enrollment effects for students who enroll in different courses under a given placement regime than they would have otherwise, as well as spillover effects for students whose course enrollments may not be affected by the shift but whose learning environments are.

Perhaps due to these spillover effects, evaluations of broad-based curricular intensification efforts return fewer positive results than analyses of the student-level effects of advanced course enrollment (Stein, Kaufman, Sherman, & Hillen, 2011). Allensworth et al. (2009) find no evidence to suggest that a Chicago Public Schools effort to enroll all 9th graders in Algebra I and college prep English improved student achievement, graduation rates, or college-going. While difference-in-difference analyses suggest that the "double-dose" Algebra curriculum that Chicago implemented as a part of this effort was effective for low-achieving students (Nomi & Allensworth, 2009), Nomi (2012) finds that curricular intensification in Chicago had unintended negative effects for high-achieving students.

Furthermore, preliminary evidence from California is similarly discouraging. Liang, Heckman & Abedi (2012) provide a descriptive analysis of state-wide student-level data indicating that approximately 60 percent of students who take Algebra in the 8th grade fail to score proficient on the end-of-course Algebra CST. Furthermore, they demonstrate that students who fail 8th grade Algebra and thus take the Algebra CST again at the end of their 9th grade year score lower on average than students who take the Algebra CST for the first time at the end of 9th grade. While this analysis does not control for differences between these two groups of students and the schools they attend, it indicates that accelerated Algebra may not boost achievement among California's students. Similarly, case-study data point to declines in student mathematics achievement in one California district that dramatically increased 8th grade Algebra enrollment rates (Domina, Penner, Penner, & Conley 2014).

3. Evaluating California's 8th grade Algebra-for-all effort

This paper provides a uniquely rigorous evaluation of the net effects of changing middle school mathematics placement policies. We use panel data from California public school districts between 2003-04 and 2009-10 to estimate the effects of increasing the percent of students enrolled in 8th grade Algebra on students' mathematics achievement, as measured by the California High School Exit Exam. Like students in middle and junior high schools throughout the United States, 8th graders in most California middle schools have the option of enrolling in one of several tiered mathematics courses, including remedial mathematics, general mathematics or pre-Algebra, Algebra, and, for a handful of particularly advanced students, Geometry or higher level mathematics. Since secondary math courses are nearly universally sequenced in American secondary schools, 8th grade course enrollments largely determine students' chances of enrolling in more advanced courses throughout high school. In particular, students must take Algebra in 8th grade in order to take Calculus before they graduate from high school.

Our analyses draw upon district-level data collected from the California Basic Educational Data System (CBEDS) and the California High School Exit Exam (CAHSEE), describing middle school math course enrollment patterns and subsequent mathematics achievement for students enrolled in all California public school districts that serve students from middle school to high school.[1] Our analyses use the district as the unit of analysis for two reasons: First, since California does not have a statewide student-level data system, student- or

[1] Unlike much of the United States, several California localities maintain separate elementary and secondary school districts. Since these districts report data separately, we are unable to link 8th grade math course enrollments in these districts with measures of student 10th grade mathematics achievement. Therefore, our analyses include only "unified" public school districts in California, or those that administer both elementary and secondary schools. In addition, the analyses exclude data reported separately by state boards of education (which often administer relatively small vocational schools and other special programs for "at-risk" youth") and charter schools. Approximately two-thirds of California 8th graders enroll in the districts that are included in our analyses.

even school-level data that include middle school mathematics course enrollments and 10th grade test scores are unavailable. Second, districts play a crucial role in determining math course placement practices in California, accounting for more than half of the variation in 8th grade Algebra enrollment rates among traditional middle schools. Table 1 reports descriptive data for 8th graders enrolled in California unified school districts in each cohort between 2003-04 and 2009-10. In each of these years, the 222 school districts that are at the focus of this study enrolled approximately 300,000 8th graders. In 2003-04, approximately 40 percent of these students enrolled in Algebra or a more advanced math course during their 8th grade year. By 2009-10, that percentage was more than 60 percent. This growth in 8th grade Algebra enrollment rates is equivalent to approximately a standard deviation in the pooled unweighted distribution of district-level 8th grade Algebra enrollment. By comparison, NAEP data indicate that 8th grade Algebra enrollment rates among public school students nationwide increased from 24 percent to 35 percent between 2000 and 2010.

The analyses that follow utilize a balanced panel that excludes approximately 100 districts that do not report data in at least one study year. Since these excluded districts are relatively small, our balanced panel accounts for over 85 percent of California 8th graders in unified school districts in any given year. Furthermore, as the descriptive data for all California districts reported in Table 1 indicate, the differences between districts that provide balanced data and those that do not are not pronounced.

[Insert Table 1 about here]

Predictors of 8th grade Algebra enrollment rates in California K-12 School districts

Prior to estimating the achievement effects of increasing 8th grade Algebra enrollment rates, we provide a descriptive look at district-level middle school math course placement trends.

We first do so by reporting trends in 8^{th} grade Algebra enrollment rates across the state and within the state's 12 largest school districts.

We then explore district variation in 8^{th} grade Algebra enrollment trends by providing an enrollment-weighted unconditional correlation matrix. The focal variable in this correlation matrix represents the proportion of 8^{th} graders in a given district (d) who completed the end-of-course CST in Algebra I or higher (e.g. Geometry, or Algebra II) in each year (t) between 2004 and 2010. We use CST course completion as a proxy for students' 8^{th} grade mathematics course completion. California students who take basic skills or pre-Algebra courses sit for the General Math CST in the spring of their 8^{th} grade year; while students who take Algebra courses sit for the Algebra CST and students who take Geometry sit for the Geometry CST. Nearly all students – including special education students and English-language learners – take these tests under California and federal accountability policy.[2] The correlation matrix reports the extent to which these district-level 8^{th} grade enrollment rates vary over time and with district demographics, including variables representing the proportion of 8^{th} graders who are black or Hispanic[3]; the proportion of 8^{th} graders who are classified as English language learners; and the natural log of

[2] End-of-course tests provide important advantages over course title as a measure of course completion. Since California school accountability policy requires all districts report data on end-of-course test-taking for all students using a common form, comparable data are available on this measure across districts and over time. While course enrollment data are not publicly available for California public school students, analyses of data from one large California public school district indicates that end-of-course tests provide a relatively reliable proxy for course content. In this district, approximately 99% of 8^{th} graders who enroll in pre-Algebra courses take the 8^{th} grade General Mathematics CST. Similarly, 99% of students in Algebra I courses enroll in the 8^{th} grade Algebra CST. In addition, several schools in this district offer a two-year Algebra course sequence. Approximately 95% of the 8^{th} graders who take the first year of this two-year Algebra course sequence take the 8^{th} grade General Mathematics CST. Analyses of data from another large California public school district point to a similarly high level of correspondence between course enrollment and end-of-course CST completion (Taylor 2011).

[3] We do not include a control for percent of students who are eligible for free or reduced lunch since this variable is highly correlated with the percent of minority students and the percent of ELL students (correlations between percent minority and both of these variables is roughly .7). It is also worth noting that socio-economic composition of California school districts changes very little during the study period, so that these district fixed effects largely account for these demographic characteristics.

district 8th grade enrollments. In addition, we correlate 8th grade Algebra enrollment rates against a lagged measure of the districts' Academic Performance Index (API) scores and a lagged measure of district 8th grade Algebra enrollment rates. The API is a composite measure of student achievement that is central to California's school accountability system. The composite reports the weighted average of students' Math, English, Science, and History CST scores within a district (or school), with Math and English accounting for 85 percent of the score. Under California accountability policy, 8th grade algebra enrollment rates are an input in the algorithm which generates districts' API scores. Districts receive API scores for test performance from time *t* in time *t+1*. The correlation between a school's API in time t-1, and 8th grade algebra enrollment rates in time *t* partially captures the extent to which districts respond to accountability pressures by increasing 8th grade Algebra rates. Finally, the bivariate correlation between contemporary and lagged 8th grade Algebra enrollment rates provides a sense of the extent to which middle school mathematics placement practices are path-dependent at the district level.

Panel analysis: California K-12 School Districts, 2004-2010 8th Graders

Following an examination of the patterns of Algebra enrollment across the timespan of our panel, we next estimate district fixed effects models to investigate the effects of changing 8th grade Algebra enrollment rates in California public school districts on student achievement. The most basic of these analyses takes the following form:

$$(1) \mathrm{Y}_{\mathrm{d,t+2}} = \beta_0 + \beta_1(\%\mathrm{Alg})_{\mathrm{d,t}} + \beta_2(\mathrm{X})_{\mathrm{d,t}} + \beta_3(\mathrm{API})_{\mathrm{d,t\text{-}1}} + \alpha_{\mathrm{d}} + \alpha_{\mathrm{t}} + \varepsilon_{\mathrm{d,t}}$$

In this model, the dependent variable, $Y_{d,t+2}$, is a district-level measure of student achievement on the mathematics portion of the spring 10th grade CAHSEE. This exam, which is designed under contract by ETS, addresses content covered California's standards for 6th and 7th grade mathematics and Algebra courses. It consists of 80 scored multiple choice questions (and an additional 12 unscored questions being tested for future use) covering Algebra, measurement and geometry, statistics, data analysis and probability, number sense, and mathematical reasoning.

The CAHSEE mathematics exam is particularly useful for this analysis since it is the only mathematics exam that nearly all California public school students take at the same time during the middle and high school years. State law requires all California public school students take this exam for the first time in the spring of their 10^{th} grade year. Students must pass this exam (as well as a parallel exam in English language arts) in order to earn a high school diploma.[4] Our analyses use CAHSEE data from two years after students in the panel completed 8^{th} grade (March 2006-March 2012 CAHSEE administration). By contrast, neither mathematics CSTs nor college admissions tests provide appropriately representative samples for our purposes. Fewer than half of California high school students take the SAT in a given year, and a smaller proportion takes the ACT. Even though nearly every student in California takes the Algebra CST at some point, the timing of when a student takes the exam varies from 8^{th} grade to 11^{th} grade depending on when he or she enrolled in Algebra. The same is true for higher level mathematics, although the share of students who complete higher level math courses also decreases as the course gets more difficult.

That said, the CAHSEE mathematics exam is not without its limitations. Since the exam is designed to ensure students have a minimal level of mathematics competency, it gives considerable weight to pre-Algebra mathematics topics and may not accurately capture achievement for students at the top of the skills distribution. Approximately 8 percent of California 10^{th} graders score the highest possible score on this exam. While this proportion has not changed appreciably over the study period, these ceiling effects may negatively bias our

[4] Although students may retake the CAHSEE multiple times after failing initially, we use only the first CAHSEE attempt in our analyses.

findings. Furthermore, if changing enrollments in 8th grade Algebra courses primarily influences student achievement in Algebra and more advanced mathematics topics, one might expect overall CAHSEE mathematics exam scores to understate the effects of changing 8th grade Algebra placements.

We address these measurement concerns in two ways: First, we have compiled evidence regarding the CAHSEE's validity from a variety of sources in an online Appendix.[5] Our own analyses as well as previously published reports point to a positive 0.70 correlation between student CAHSEE scores and mathematics CST scores that does not vary considerably over time. Notably, this correlation is particularly robust for 10th graders enrolled in relatively advanced mathematics courses. For example, the correlation between CAHSEE scores and Summative Mathematics CSTs is 0.74 in the 2011-12. Furthermore, CAHSEE scores correlate closely with students' postsecondary enrollment outcomes (HumRRO, 2012). Second, we conduct supplementary analyses of five CAHSEE sub-scales: probability and statistics, number sense, Algebra and functions, measurement and geometry, and Algebra I. Each of these subscales uses data from 12-17 test items that align closely with state content standards (Becker et al. 2008, 2010, 2012; Wise et al. 2004, 2006). These analyses make it possible to investigate heterogeneity in the effects of curricular intensification across different mathematical domains. The results of these analyses provide important insights into the CAHSEE's validity as a measure of mathematics achievement in this setting. If curricular intensification has different effects on high-level skills than low-level skills, the relatively weak coverage of high-level mathematics in the CAHSEE may lead to important biases. However, evidence of consistent effects of curricular intensification across CAHSEE sub-scales may serve to mitigate these measurement concerns.

[5] http://sites.uci.edu/tdomina/files/2013/07/Domina-McEachin-Penner-Penner-EEPA-Appendix.pdf

The model includes district fixed effects, α_d, to account for unobserved time-invariant differences between districts, and cohort fixed effects, α_t, to account for common trends across years. The fixed effects remove potential time-invariant changes between district differences as well as time-variant changes common to all districts that are related to both districts' Algebra enrollment rates and CAHSEE scores. We also include a vector of time-variant district characteristics to control for potential observable differences among districts, $X_{d,t}$. These include the proportion of 8th graders who are black or Hispanic, the share of English Language Learners, the natural log of district enrollment, and lagged Academic Performance Index (API) scores.[6]

The key predictor variable in this analysis is the percent of district 8th graders who enroll in 8th grade Algebra or higher. To ease interpretation, we standardize this measure on the 2004-05 distribution, so that zero is equal to the 2004-05 mean and -1 and 1 are equivalent to one standard deviation above and below that mean. Assuming that district CAHSEE test score averages change over time at a common rate after controlling for observed time-varying district characteristics, then β_1 in Equation 1 can be interpreted as an unbiased estimate of the change in district-level 8th grade Algebra enrollment rates on CAHSEE test scores. If, however, test score averages follow district-specific trends – and particularly if these district-specific trends correlate with 8th grade Algebra course placement trends – Equation 1 may provide biased estimates of the effects of increasing 8th grade Algebra enrollments. To address this concern, we additionally estimate a random-growth model (Papke 1994; Wooldridge 2002; Zimmer & Buddin 2006).

[6] During the time-span of our district-level panel, California included incentives for districts to enroll students in Algebra in its API calculation. It is therefore likely that the percent of students enrolled in at least Algebra in time *t*, is a function of a districts' API score from *t-1*. For this reason, we control for the districts' prior API score.

This model estimates district-specific intercepts (α_d) and district-specific time trends ($\alpha_d * \tau$), and can be represented as:

$$(2) Y_{d,t+2} = \beta_1(\%Alg)_{d,t} + \beta_2(X)_{d,t} + \alpha_d + \alpha_t + \alpha_d * \tau + \varepsilon_{d,t}$$

This random growth model controls for both time-invariant between district differences, as well as differences in districts' average growth rate.[7] It should also be noted that the relationship between the independent variables and the dependent variable in a random growth model is only identified off non-linear changes over time. The time fixed effects in this model account for year-to-year secular changes in achievement that deviate from the common linear in achievement. Equation 2 yields unbiased estimates of the effect of 8th grade Algebra enrollment on student achievement if changes in algebra enrollment are exogenous to the independent variables as well as unmeasured district characteristics that are time-invariant or linearly time-varying.

These analyses estimate a highly policy-relevant parameter that has largely been neglected elsewhere in the literature on accelerated Algebra and other forms of curricular intensification: The mean achievement effects of enrolling more students in advanced math courses. This parameter is the net effect of curricular intensification. In contrast to studies that estimate the effects of advanced course enrollment only for students at risk of moving into advanced courses, our analyses capture the important ways in which enrolling more students in advanced courses not only alters mathematics course experiences for students who change courses, but also alters experiences for their peers who are left in low-level courses, and their peers who would have taken high-level courses even prior to the change in placement practices.

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[7] To estimate this, we start with the model: $Y_{dt+2} = \beta_1(\%Alg)_{dt} + \beta_2 X_{dt} + \alpha_t + \alpha_t * \tau + \varepsilon_{dt}$. We take the first-difference of this equation to remove district-specific intercepts and are left with a constant trend for each district. We then estimate the first-difference of (2) using district and time fixed-effects to remove the district specific constant trends (see Papke 1994; Wooldridge 2002; Zimmer & Buddin 2006 for more detail about the RGM).

However, neither equation 1 or 2 addresses the potentially confounding consequences of short-term changes in district organization or management. If such changes systematically precede changes in middle school mathematics placement practices, estimates of the effects of 8th grade Algebra placement may be biased. One particularly troubling potential confounder is administrative turnover – the arrival of new administrative leadership might cause both 8th grade Algebra enrollment rates and later student achievement to shift. Since we do not have access to statewide panel data on district leadership, we are unable to evaluate this possibility. However, discussions with district administrators suggest that administrative turnover often occurs *after* districts intensify middle school mathematics curricula, rather than before.

All multivariate analyses are weighted by the mean of each district's 8th grade enrollment across the panel. In addition, we estimate a series of supplementary models in which we investigate the extent to which the effects of curricular intensification vary by district size. Prior to the 8th grade Algebra-for-all effort, relatively large districts may have provided more highly differentiated mathematics instruction than low-enrollment districts (where there were few students to split between tracked mathematics course sequences). These supplementary models thus consider the extent to which the effects of increasing 8th grade Algebra result from changes to the content, instruction, and peer composition of mathematics courses in complex and differentiated educational systems. We use district-level cluster-robust standard errors estimation throughout to address potential heteroskedasticity and serial correlation among observations.

4. Changes in 8th grade Algebra enrollment rates

California districts dramatically intensified middle school mathematics curricula over the last decade. This increase in 8th grade Algebra enrollment rates clearly predates the State Board of Education's attempt to make 8th grade Algebra the mathematics "course of record" for accountability purposes. However, 8th grade Algebra enrollment rates jumped in the year immediately after the state announced this policy shift, increasing from 54 percent in 2007-08 to 60 percent in 2008-09. Statewide 8th grade Algebra enrollment rates continued to rise after this announcement, despite legal efforts to overturn the 8th grade Algebra mandate.

California's 8th grade student body has remained relatively demographically stable during this period of rapid curricular change. Free and reduced lunch enrollment rates vary between 51 and 56 percent during this time period, fluctuating gradually with broader shifts in economic conditions. The racial and ethnic composition of California 8th graders also changed little during this time period, with approximately 54 percent of 8th graders identifying as black, Hispanic, Native American, or Pacific Islander.[8] The most striking demographic shift apparent in this table concerns the proportion of English-language learners in California schools. In 2003-04, 27 percent of California 8th graders were classified as English-language learners; by 2009-10, that number had dropped to 20 percent. More than three-fourths of these students are native Spanish speakers. This decline in ELL enrollment seems to be largely a function of changing practices for reclassifying non-native speakers as English-language proficient.

[Insert Figure 1 about here]

While Table 1 suggests that accountability pressures from the State Board of Education led districts and schools across the state to enroll more students in 8th grade Algebra, Figure 1 indicates that districts across the state took very different paths toward intensifying middle school mathematics curricula. This figure presents line graphs representing 8th grade Algebra enrollment rate trends between 2003-04 and 2009-10 for the twelve largest California unified school districts. Just one of these districts, Anaheim Union, seems to have responded directly to

[8] During this period, the Latino share of the California 8th grade population increased by approximately two percentage points, while the African-American share declined.

the state's Algebra accountability mandate, nearly universalizing 8th grade Algebra by doubling the proportion of 8th graders placed into Algebra or more advanced math courses in 2009-10. Other districts, including Corona-Norco, Garden Grove, and Los Angeles, seem to have responded to early signals from the state, increasing 8th grade Algebra enrollment rates by more than 20 percentage points in the years leading up to the passage of the 8th grade Algebra-for-all mandate. Several large California public school districts acted much more gradually to increase 8th grade Algebra enrollment rates. Capistrano is typical of this approach, gradually increasing 8th grade Algebra enrollment rates from approximately 20 percent to 40 percent over the study period. Middle school math enrollment trends follow a somewhat idiosyncratic pattern in the state's largest public school district, Los Angeles Unified, where 8th grade Algebra enrollment rates spiked at 67 percent in 2005 before decreasing to 49 percent in 2007 and increasing again to 60 percent by 2010. The degree of between-district heterogeneity is even more pronounced among smaller districts.

Table 2 provides a more systematic look at 8th grade Algebra enrollment rates in California school districts. These population-weighted unconditional correlations provide another way of understanding the secular increase in 8th grade Algebra enrollments, indicating that there is a positive 0.23 linear correlation between year and 8th grade Algebra enrollment rates. (Supplementary multivariate models, which are available by request, clearly indicate that this secular trend is significant even after controlling for demographic changes.) However, neither the size, nor the ethnic or language composition of California public school districts is associated with 8th grade Algebra enrollment. Similarly, although relatively high-performing districts tend to have higher rates of 8th grade Algebra enrollment than lower-performing districts, this correlation is weak. Indeed, the single district-level factor that is closely correlated with 8th grade Algebra enrollment rates is the lagged 8th grade Algebra enrollment rate; a finding that indicates that patterns in 8th grade Algebra enrollment are highly path dependent.

[Insert Table 2 about here]

5. Effects of increasing 8th grade Algebra enrollment on student achievement

The analyses reported in Table 3 take advantage of these uneven patterns in district 8th grade Algebra enrollment rates to estimate the effects of changes in the proportion of students enrolled in 8th grade Algebra or higher on mathematics achievement. The first model in Table 3 does so using a district fixed-effects approach. This model considers the relationship between district 8th grade Algebra enrollment rates in a given year and mean CAHSEE math scores for 10th graders in the district two years later. The negative and statistically significant "% 8th graders >= Algebra" coefficient in this model indicates that efforts to enroll more middle school students in advanced mathematics courses have unintended negative consequences for student mathematics achievement. This model indicates that a 1 standard deviation increase from mean 2004-05 8th grade Algebra enrollment rates (such as might occur if a district were to increase 8th grade Algebra enrollment from approximately 38 percent to 60 percent) decreases mean student CAHSEE math scores by approximately 0.07 standard deviations. By way of comparison, this estimated negative effect is approximately the same size as the average positive achievement effects associated with the federal *No Child Left Behind* Act (Dee & Jacob 2011) or about 15 percent of the Black-White achievement gap in mathematics (Reardon 2008).

[Insert Table 3 about here]

The internal validity of the district fixed effects identification strategy hinges on the assumption that the only time-varying within-district characteristics that systematically covary with both 8th grade Algebra placement patterns and CAHSEE math scores are captured by our controls for observable demographic characteristics and time fixed effects accounting for state-wide year-to-year changes. We relax this assumption by estimating a random growth model that, in addition to the district fixed-effects, allows for different district-specific linear time-trends. This model accounts for district fixed effects, district-specific time-trends, and time fixed effects, accounting for between-district variation in linear CAHSEE score trends. This random growth model returns coefficients similar in magnitude and direction as the main district fixed effects model. However, since these models only use the non-linear variation in the independent variables to identify causal effects, they are somewhat less precise.

The analyses reported in Table 4 test the appropriateness of these fixed effects and random growth models through a series of placebo tests designed to examine the possibility that unobserved changes coinciding with increases in Algebra enrollment confound our findings. We regress demographic variables, standardized ELA CAHSEE scores, and leads and lags of standardized math and ELA CAHSEE scores on the percent of students enrolled algebra or higher—the main coefficient of interest—and the other control variables. If the coefficient for algebra enrollment is statistically significant in these models, this suggests that our results in Table 3 may be confounded by omitted variables not captured by our analytic strategy.

The first column of Table 4 reports the results of analyses using the district fixed effects estimation strategy and the second column reports the results of analyses using the random growth modeling strategy. The first five rows assesses whether the percent of students in at least algebra is significantly related with districts' demographics and API scores. In most cases, the fixed effect and random growth model return marginally statistically insignificant results, with the exception of the percent of English Language Learners, grade 8 enrollment, and lagged API scores. However, these point estimates are quite small, especially in models that use the random growth specification. We next evaluate whether districts' ELA CAHSEE scores, and leads and lags of ELA and math CASHEE scores, are associated with districts' algebra enrollment rates. It does appear that in the fixed effects specification, the percent of students enrolled in at least algebra is associated with ELA CAHSEE scores and some leads and lags of math and ELA CAHSEE scores. This result calls into question the internal validity of Table 3's fixed effects specification. However, the random growth model specification does not return any significant relationships between the percent of students enrolled in at least algebra and ELA CAHSEE scores and the leads and lags of math and ELA CAHSEE scores. This indicates that there is a potentially linear time-varying confounder that is not controlled for in the fixed effects specification, but that is accounted for in the random growth model specification. This analysis highlights the random growth model's importance for generating unbiased estimates of the achievement effects of 8th grade Algebra enrollment rates.

[Insert Table 4 about here]

Although administered to students in the spring of their 10th grade year, the CAHSEE is a criterion-referenced test designed to measure students' mastery of basic Algebra and pre-Algebra mathematics content. Since this test is not designed to capture student proficiency with more advanced mathematics concepts, it is possible that the analyses reported in the first model of Table 3 may provide negatively biased estimates of the relationship between 8th grade Algebra enrollment rates and mathematics student learning. For example, redirecting students from grade-level 8th grade mathematics courses to 8th grade Algebra may have negative effects on their mastery of basic arithmetic and pre-algebraic mathematic content even as it boosts their algebraic understanding. In such a scenario, the summary CAHSEE test score might exaggerate the negative effects associated with increasing 8th grade Algebra enrollment.

The models reported in Table 5 use detailed CAHSEE subscale score results to consider the extent of this potential bias. These subscales measure the percent of CAHSEE test score items students answered correctly in several distinct mathematics domains ranging from the relatively simple (Number Sense) to the more advanced (Measurement and Geometry; Algebra I). These analyses indicate that the effects of increasing 8th grade Algebra enrollment rates are consistently negative across the five domains. For example, a one-standard deviation increase in district 8th grade Algebra enrollment rates is associated with a 0.05 standard deviation decline in the percentage of Number Sense questions students answer correctly. This result is not significantly different from the significant 0.04 standard deviation decline in Algebra I achievement. Similarly, a one standard-deviation increase in 8th grade Algebra enrollment rates is associated with a 0.04 standard deviation decline in Measurement and Geometry achievement. These results are quite similar across the fixed effects and random growth model specifications. The results reported in Table 5 thus provide some reassurance that the CAHSEE test adequately captures student mathematics achievement at least through basic Algebra and geometry, but also suggest that the declines in CAHSEE scores resulting from an increase in 8th grade Algebra enrollment are present and similar in magnitude in all major content areas assessed by the CAHSEE. These findings suggest that enrolling more students in 8th grade Algebra does not just undermine student achievement in pre-algebraic mathematic content, but also undermines achievement on a relatively wide range of mathematics areas. While it remains possible that increases in 8th grade Algebra enrollment rates could lead to downstream improvements in higher-level mathematics, these findings do not provide support for this argument.

[Insert Table 5 about here]

The district fixed effects analyses reported in Tables 3 through 5 identify the effects of curricular intensification off of within-district changes in the percent of 8th graders enrolled in Algebra or higher over time. In Table 6 we build on these results by examining: 1) whether the effects that we observe are driven by large year-to-year shifts in Algebra enrollment (such as the sharp increase that Figure 1 shows between 2008 and 2009 in Anaheim); 2) whether enrollment changes that occurred before and after the 2008 policy had similar effects; and 3) whether the effects that we see are short term implementation costs associated with curricular intensification. We examine each of these points in turn, first using the district fixed effects approach (Panel A) and second using the random growth modeling approach (Panel B).

[Insert Table 6 about here]

The first set of models we estimate in Table 6 (column 1) investigate whether large year-to-year changes in 8th grade Algebra enrollment rates have disproportionately large achievement consequences. These models add indicator variables for districts in the years in which 8th grade Algebra enrollment rates increased or decreased by more than a standard deviation (>1 SD incr. and >1 SD dcr.) and more than two standard deviations (>2 SD incr. and >2 SD dcr.) as defined in the 2004 district 8th grade Algebra enrollment rate distribution. Using both the fixed effects and the random growth approach, these models return coefficients that are consistent with our previous findings. The linear 8th grade Algebra enrollment rate term is negative in both models, although this coefficient is not statistically significant in the less efficient random growth model. Importantly, none of coefficients associated with districts that experienced relatively large year-to-year changes in 8th grade Algebra enrollment rates are statistically significant, indicating that the effects of changes in 8th grade Algebra enrollment rates are fairly linear. Although districts that make large increases in 8th grade Algebra enrollment rates tend to see larger achievement declines than districts that make change 8th grade Algebra enrollment rates more incrementally, large changes do not appear to have disproportionately large effects and do not drive negative 8th grade Algebra rate effects statewide.

The second set of models in Table 6 (column 2) test whether changes in 8th grade Algebra enrollment rates that occur prior to the California Board of Education’s attempt to mandate Algebra for all 8th graders have different achievement effects than changes that occur after the mandate. (The “post policy” indicator in this model takes a value of 1 for observations in the 2009 and 2010 school year and a value of 0 for all other years.) If the best-organized districts increased their 8th grade Algebra enrollment before the state’s 8th grade Algebra policy went into effect, one might expect the post-policy*8th grade Algebra interaction in this analysis to be negative. However, one might expect a positive interaction if the development of effective instructional practices accompanied the statewide move toward increased Algebra enrollment. The main effect of 8th grade Algebra enrollment rate is significant and negative, indicating that increasing 8th grade Algebra enrollments by a standard deviation in the pre-policy period decreased CAHSEE scores. These effects are consistent across the two modeling strategies, with the fixed effects model returning a -0.07 effect and the random growth model returning a -0.04 effect. In both models, the 8th grade Algebra*post-policy interaction returns a positive coefficient. Although not statistically significant, its sign indicates that post-policy increases in 8th grade Algebra enrollment rates may have had less pronounced negative effects on math achievement than pre-policy increases.

Models 3 and 4 add lagged 8th grade Algebra enrollment rate control variables to the basic fixed effects model to investigate the extent to which year-to-year changes in 8th grade Algebra enrollment rates have lasting negative consequences for CAHSEE math scores. If these lagged scores were significant and positive, they would suggest that observed negative effects of increases in 8th grade Algebra enrollment are short-lived and that average test scores tend to bounce back as districts design strategies to effectively educate a larger proportion of students in advanced middle school math courses. However, the coefficients for lagged 8th grade Algebra enrollment rates (in model 3) and twice-lagged 8th grade Algebra enrollment rates (in model 4) are both small and not statistically significant, suggesting that 8th grade Algebra enrollment rate changes have lasting consequences for district CAHSEE math test score trajectories. While controlling for the lagged score does not reduce the magnitude of the main effect for 8th grade Algebra enrollment rate, it does reduce the precision of this estimate in the random growth model. As a result, the random growth model estimate of the effect of 8th grade Algebra enrollment is not significant net of lags.

The findings reported thus suggest that efforts to intensify middle school mathematics curricula have unintended negative consequences for student mathematics achievement across a broad range of domains. However, the analyses reported in Table 7 provide a glimmer of hope, indicating that curricular intensification efforts do not *always* have negative effects on student achievement. To estimate these models, we split California unified public school districts into tertiles based on their 2004 8th grade enrollments and then estimate a district fixed effects analysis of the effects of curricular intensification on CAHSEE math scores for each of these subgroups. The resulting analysis suggests that the negative effects of increasing 8th grade Algebra occur exclusively in relatively large school districts (in this analysis, districts enrolling 850 or more 8th graders annually, a category that includes California's largest urban school districts as well as mid-sized suburban and rural districts).[9] These findings are nearly identical

[9] Districts in the lowest-enrollment tertile enroll fewer than 300 8th graders annually; districts in the middle tertile enroll between 300 and 850 8th graders annually; 8th grade enrollments in the top tertile

whether estimated using a fixed effects or random growth modeling strategy and are robust to alternate district size categorizations. In small and middle-sized districts, middle school mathematics curricular intensification has no effect on student achievement. In large districts, however, a 1 standard deviation increase in 8th grade Algebra enrollment decreases mean CAHSEE scores by 0.05-0.07 standard deviations, net of time-invariant district characteristics and controls. This result does not seem to be driven by any one large district. For example, the model returns nearly identical results if Los Angeles Unified or any other large district is excluded from the analysis. While we are unable to investigate the reasons underlying these differential effects, we suspect that curricular change entails particularly pronounced logistical challenges in large schools and districts. Since these have the capacity to offer highly differentiated middle school mathematics instruction, the decision to enroll more students in mathematics is likely require the reassignment of large numbers of teachers as well as profound changes to the organization and composition of both Algebra and less advanced mathematics courses. These bureaucratic challenges are important since more than 80 percent of the 8th graders enrolled in the analysis districts attended high-enrollment districts.

[Insert Table 7 about here]

In sum, the results of our district fixed effects analyses paint a very discouraging picture of the effects of intensifying middle school mathematics curricula by enrolling more students in 8th grade Algebra. Contrary to the common-sense predictions of "opportunity to learn" theory and the findings of previous observational studies, these analyses suggest that broad-based

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range from 850 to more than 50,000. The districts in the lower two tertiles are nearly all located in rural areas, and enroll somewhat fewer students of color and English language learners than the large districts. However, these demographic differences are not as pronounced as one might expect. 43 percent of students low-enrollment districts are black or Hispanic, compared to 47 percent of students in the middle enrollment districts and 59 percent of students in high enrollment districts.

efforts to enroll more students in 8th grade Algebra have negative effects on student achievement in large school districts and no benefits in small or medium districts.

6. Discussion

The push to increase Algebra taking rates among 8th graders is a prime example of a broader effort to improve U.S. educational and economic competitiveness by increasing the academic rigor of K-12 schools. While this push has increased Algebra enrollments for traditionally underserved students in California and nationally, it is less clear if it has improved student achievement. Our analyses of a panel of district-level data from California's school districts highlight a potentially serious unintended consequence of these efforts. We find that district-level increases in 8th grade Algebra enrollment rates correspond with declines in average CAHSEE scores, including scores on CAHSEE test items covering basic Algebraic skills.

While disappointing, these results may help to make sense of a puzzling set of findings that have emerged in recent research regarding the consequences of 8th grade Algebra. Using data from a randomly control trial involving rural New England middle schools that had previously not offered 8th grade Algebra, Heppen and colleagues find that enrolling relatively high-achieving students in 8th grade Algebra courses has positive consequences for student achievement. By contrast, in a series of instrumental variable analyses that take advantage of policy-driven changes in 8th grade Algebra placements in North Carolina middle schools, Clotfelter and colleagues find that 8th grade Algebra enrollment has negative effects for student mathematics achievement.

The contradiction between these two studies is difficult to resolve if one assumes that the treatment – 8th grade Algebra – is comparable across these two settings. However, that assumption may not be valid. In this paper, we suggest that changes in middle school mathematics placement regimes may have spillover effects for instruction and learning in middle school mathematics courses. Thus, when a district or school moves to enroll more students in 8th grade Algebra, it changes not just whether a given individual receives access to Algebra instruction, but also affects the teachers and peers that all individuals are likely to encounter, both in Algebra as well as in other classes. Put differently, we suspect that Algebra (and pre-Algebra) means something different in schools that enroll 80 percent of 8th graders in Algebra than in schools that enroll 40 percent of 8th graders in Algebra. Likewise, we suspect that intensifying the curriculum to put more students into 8th grade Algebra is a more challenging task in districts where course placement changes affect a large number of students and teachers.

As such, from a policy perspective, we believe it is important to understand not just the effects of placing any given individual into Algebra ceteris paribus, but also the effects of implementing a broad-based Algebra-for-All policy. By allowing for the possibility that curricular intensification policies may change the broader dynamics of peer and teacher interactions, our panel data models test the net effects of increasing 8th grade Algebra enrollments on student achievement. While we lack the data to provide a detailed account of the mechanisms through which these effects occur, our analyses clearly indicate that these net effects are negative. In particular, our results suggest that future work should carefully attend to the challenges associated with implementing curricular intensification policies in large districts, as these districts appear particularly vulnerable to iatrogenic effects.

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Table 1: Descriptive statistics, 8th graders enrolled in California unified public school districts, 2003-04 – 2009-10

	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10
Balanced Panel							
% in Algebra or higher	0.38	0.43	0.48	0.53	0.54	0.59	0.63
%in Algebra or higher (std)	0.01	0.22	0.43	0.64	0.70	0.93	1.07
% minority	0.50	0.51	0.51	0.52	0.53	0.54	0.54
% ELL	0.27	0.26	0.20	0.21	0.21	0.20	0.20
District API	702.0	708.8	725.5	735.8	741.1	752.7	764.9
N(districts)	222	222	222	222	222	222	222
Weighted N	301,892	300,552	292,629	292,185	291,754	286,736	279,175
All districts							
% in Algebra or higher	0.38	0.42	0.46	0.51	0.54	0.58	0.60
%in Algebra or higher (std)	0.00	0.17	0.37	0.56	0.70	0.90	0.97
% minority	0.49	0.50	0.52	0.53	0.53	0.53	0.54
% ELL	0.27	0.25	0.21	0.21	0.22	0.20	0.20
District API	700.1	706.9	718.9	732.2	737.3	748.1	760.8
N(districts)	282	285	293	288	296	309	300
Weighted N	336,084	336,010	341,332	336,131	333,089	337,277	317,902

Table 2: Unconditional correlation matrix, predictors of 8th grade Algebra enrollment rate, California public school districts 2003-04 – 2009-10

	8th Grade Alg (%)	Year	% Minority	% ELL	8th grade enrollment (ln)	District API (lag)	8th Grade Alg (lag)
8th Grade Alg (%)	1.00						
Year	0.23	1.00					
% Minority	0.06	0.03	1.00				
% ELL	0.03	-0.22	0.74	1.00			
8th grade enrollment (ln)	0.03	-0.02	0.45	0.38	1.00		
District API (lag)	0.09	0.29	-0.84	-0.73	-0.38	1.00	
8th Grade Alg (lag)	0.80	0.25	0.06	-0.01	0.05	0.11	1.00

Table 3: Fixed effects and random growth model coefficients, predictors of district mean CAHSEE math test scores, California public school districts 2003-04 – 2009-10 (balanced panel)

	Fixed effects	Random Growth
% 8th graders >=Algebra (std)	-0.07**	-0.05*
	(0.02)	(0.02)
2004 (8th)	-0.28**	--
	(0.10)	
2005 (8th)	-0.14+	0.06
	(0.08)	(0.04)
2006 (8th)	-0.10+	0.08
	(0.06)	(0.05)
2007 (8th)	-0.13**	-0.01
	(0.04)	(0.04)
2008 (8th)	-0.02	0.01
	(0.03)	(0.02)
2009 (8th)	--	--
2010 (8th)	0.00	-0.05+
	(0.03)	(0.03)
% black/Hispanic	-1.42	-0.54
	(1.04)	(1.00)
% ELL	0.18	0.2
	(0.36)	(0.51)
Ln(8th Grade Enrollment)	0.05	-0.13
	(0.28)	(0.22)
Lagged District API	0.47***	0.03
	(0.11)	(0.10)
Constant	0.82	0.12***
	(2.28)	(0.02)
Adj. R-squared	0.40	0.04
# of districts	220	213
Rho	0.84	0.33

+ p<0.10, * p<0.05, ** p<0.01, *** p<0.001

Table 4: Misattribution checks. Fixed effects and random growth model coefficients for the % of student enrolled in at least algebra predicting 8th grade % minority, logged enrollment, and contemporaneous mean CAHSEE scores, California public school districts 2003-04 – 2009-10 (balanced panel).

Dependent Variables	**Fixed Effects Model**	**Random Growth Model**
% black/Hispanic	0.00	0.00
	(0.00)	(0.00)
% ELL	0.02+	0.01*
	(0.01)	(0.00)
% FRPL	0.00	0.01
	(0.01)	(0.01)
Grade 8 Enrollment (ln)	-0.01+	0.000
	(0.01)	(0.00)
Lagged API	0.03*	0.01*
	(0.01)	(0.01)
ELA CAHSEE	-0.05*	-0.01
	(0.02)	(0.02)
Twice Lag CAHSEE Math	-0.05+	0.020
	(0.029)	(0.034)
Twice Lag CAHSEE ELA	-0.07*	0.020
	(0.030)	(0.030)
One Lag CAHSEE Math	-0.05*	0.020
	(0.021)	(0.026)
One Lag CAHSEE ELA	-0.06**	0.000
	(0.022)	(0.026)
One Lead CAHSEE Math	-0.030	0.020
	(0.021)	(0.015)
One Lead CAHSEE ELA	-0.04+	0.000
	(0.019)	(0.015)
Two Leads CAHSEE Math	-0.020	-0.010
	(0.021)	(0.021)
Two Leads CAHSEE ELA	-0.020	0.000
	(0.020)	(0.022)

+ p<0.10, * p<0.05, ** p<0.01, *** p<0.001

NOTE: All models include the cohort controls as well as demographic, enrollment, and API controls used in Table 3, with the exception of the independent variable when it is used as the dependent variable (e.g., % Minority).

Table 5: Fixed effects and random growth model coefficients, predictors of district mean % correct CAHSEE math test subscales, California public school districts 2003-04 – 2009-10 (balanced panel)

	Panel A: Fixed effects models					**Panel B: Random Growth Models**				
	(1) Prob & Stats % correct (std)	(2) Number Sense % correct (std)	(3) Algebra & Functions % correct (std)	(4) Geo % correct (std)	(5) Algebra I % correct (std)	(1) Prob & Stats % correct (std)	(2) Number Sense % correct (std)	(3) Algebra & Functions % correct (std)	(4) Geo % correct (std)	(5) Algebra I % correct (std)
% 8th graders >=Algebra (std)	-0.05***	-0.05***	-0.04**	-0.04**	-0.04*	-0.05**	-0.05**	-0.04*	-0.05**	-0.04*
	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
2004 (8th)	0.00	-0.28***	-0.1	-0.11	-0.20**	--	--	--	--	--
	(0.07)	(0.07)	(0.07)	(0.07)	(0.08)					
2005 (8th)	0.00	-0.18**	-0.08	0.02	-0.05	0.00	0.03	0.00	0.10***	0.10***
	(0.06)	(0.06)	(0.06)	(0.07)	(0.07)	(0.03)	(0.02)	(0.03)	(0.03)	(0.03)
2006 (8th)	-0.10**	-0.02	-0.07+	0.06	-0.12**	-0.08**	0.17***	0.00	0.15***	0
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.02)	(0.03)	(0.02)	(0.03)	(0.03)
2007 (8th)	-0.09**	-0.04	-0.01	0.04	-0.10**	-0.07**	0.09***	0.04+	0.10***	-0.02
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
2008 (8th)	0.02	-0.15***	0.04+	-0.01	-0.12***	0.01	-0.10***	0.05*	0.00	-0.10***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
2009 (8th)	--	--	--	--	--	--	--	--	--	--
2010 (8th)	-0.05*	-0.16***	0.03	0.10***	0.07**	-0.06*	-0.22***	0.01	0.07**	0.04
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.02)	(0.02)	(0.03)	(0.03)	(0.03)
% black/Hispanic	0.40	0.39	0.47	0.28	-0.16	-0.29	-0.03	-0.09	-0.55	-0.48
	(1.19)	(1.16)	(1.17)	(1.14)	(1.11)	(1.09)	(1.12)	(1.15)	(1.12)	(1.00)
% ELL	0.02	0.03	0.19	0.05	0.52*	0.39	0.39	0.14	0.38	0.37
	(0.23)	(0.27)	(0.23)	(0.29)	(0.21)	(0.36)	(0.33)	(0.33)	(0.37)	(0.38)
Ln(8th Grade Enrollment)	0.13	0.08	0.05	0.00	0.14	-0.25	-0.31	-0.27	-0.36+	-0.23
	(0.19)	(0.19)	(0.19)	(0.19)	(0.20)	(0.20)	(0.20)	(0.21)	(0.21)	(0.21)
Lagged District API	0.16*	0.17*	0.19*	0.20*	0.22**	-0.11	-0.13	-0.17	-0.14	-0.14
	(0.07)	(0.07)	(0.07)	(0.08)	(0.08)	(0.11)	(0.11)	(0.12)	(0.12)	(0.12)
Constant	-0.89	-0.41	-0.31	0.19	-0.66	0.05*	0.11***	0.08**	0.08***	0.09***
	(1.91)	(1.91)	(1.89)	(1.86)	(1.87)	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)
Adj. R-squared	0.06	0.19	0.12	0.14	0.17	0.04	0.15	0.02	0.04	0.07
# of districts	222	222	222	222	222	222	222	222	222	222
Rho	0.85	0.85	0.85	0.85	0.85	0.18	0.17	0.17	0.17	0.17

+ p<0.10, * p<0.05, ** p<0.01, *** p<0.001

Table 6: Fixed effects and random growth model coefficients, predictors of district mean CAHSEE math test scores, California public school districts 2003-04 – 2009-10 (balanced panel)

	Panel A: Fixed effects models				**Panel B: Random Growth Models**			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
% 8th graders >=Algebra (std)	-0.07*	-0.07**	-0.05**	-0.05*	-0.03	-0.04*	-0.04	-0.04
	(0.03)	(0.02)	(0.02)	(0.02)	(0.03)	(0.02)	(0.03)	(0.03)
>2 SD incr.	0.06	--	--	--	-0.00	--	--	--
	(0.05)				(0.04)			
>1 SD incr.	-0.01	--	--	--	-0.01	--	--	--
	(0.04)				(0.03)			
>2 SD dcr.	-0.02	--	--	--	0.02	--	--	--
	(0.05)				(0.04)			
>1 SD dcr.	0.05	--	--	--	0.10	--	--	--
	(0.08)				(0.09)			
Post-policy period	--	-0.02	--	--	--	-0.03	--	--
		(0.03)				(0.03)		
% Alg * Post-policy	--	0.03	--	--	--	0.04+	--	--
		(0.03)				(0.02)		
% 8th graders >=Algebra (lag, std)	--	--	-0.01	--	--	--	0.01	--
			(0.02)				(0.01)	
% 8th graders >=Algebra (2nd lag, std)	--	--	--	-0.02	--	--	--	0.00
				(0.02)				(0.02)
yr8th== 2005	-0.15	--	-0.16+	--	--	--	0.04	--
	(0.09)		(0.09)				(0.05)	
yr8th== 2006	-0.14*	--	-0.14*	-0.15*	0.04	--	--	--
	(0.06)		(0.06)	(0.07)	(0.05)			
yr8th== 2007	-0.15**	--	-0.15***	-0.16**	-0.04	--	-0.04	-0.06**
	(0.05)		(0.04)	(0.05)	(0.04)		(0.04)	(0.02)
yr8th== 2008	-0.04	--	-0.04	-0.04	-0.01	--	0.00	-0.01
	(0.03)		(0.03)	(0.03)	(0.02)		(0.02)	(0.02)
yr8th== 2009	--	--	--	--	--	--	--	--
yr8th== 2010	0.01	--	0.01	0.01	-0.03	--	-0.04	-0.03
	(0.03)		(0.03)	(0.03)	(0.03)		(0.03)	(0.03)
Controls	+	+	+	+	+	+	+	+
Constant	-0.54	0.51	0.19	0.47	0.10***	0.12***	0.10***	0.08***
	(2.55)	(2.29)	(2.43)	(2.44)	(0.02)	(0.02)	(0.02)	(0.02)
Adj. R-squared	0.34	0.38	0.34	0.29	0.04	0.01	0.03	0.03
# of districts	219	220	219	216	211	213	211	209
Rho	0.89	0.81	0.89	0.9	0.37	0.32	0.36	0.38

+ p<0.10, * p<0.05, ** p<0.01, *** p<0.001

Table 7: Fixed effects and random growth model coefficients, predictors of district mean CAHSEE math test scores by 2003-04 district enrollment tertile, California public school districts 2003-04 – 2009-10 (balanced panel)

	Panel A: Fixed effects models			**Panel B: Random Growth Models**		
	Low enrollment	Mid-enrollment	High-enrollment	Low enrollment	Mid enrollment	High enrollment
% 8th graders >=Algebra (std)	0.01	0.01	-0.07*	0.03	0.00	-0.05*
	(0.02)	(0.03)	(0.03)	(0.02)	(0.02)	(0.02)
2004 (8th)	-0.05	-0.17	-0.38*	0.00	0.00	0.00
	(0.13)	(0.11)	(0.15)	(0.00)	(0.00)	(0.00)
2005 (8th)	-0.03	-0.02	-0.19	0.03	0.07+	0.10*
	(0.11)	(0.09)	(0.13)	(0.06)	(0.04)	(0.04)
2006 (8th)	0.09	-0.05	-0.12	0.14*	0.08	0.14**
	(0.10)	(0.08)	(0.09)	(0.06)	(0.05)	(0.05)
2007 (8th)	-0.02	-0.10+	-0.16*	0.04	-0.02	0.01
	(0.08)	(0.06)	(0.07)	(0.05)	(0.04)	(0.05)
2008 (8th)	-0.05	-0.05	-0.01	0.00	-0.04	0.06*
	(0.06)	(0.05)	(0.04)	(0.05)	(0.04)	(0.03)
2009 (8th)	--	--	--	--	--	--
2010 (8th)	-0.01	0.02	-0.05	-0.01	0.00	-0.13**
	(0.06)	(0.06)	(0.04)	(0.07)	(0.06)	(0.04)
% black/Hispanic	1.58	-0.64	-2.6	1.93	-0.24	-2.50*
	(1.05)	(0.94)	(1.62)	(1.76)	(1.65)	(1.08)
% ELL	0.67	-0.4	0.96+	0.9	0.52	1.27
	(0.56)	(0.71)	(0.53)	(0.64)	(0.76)	(0.79)
Ln(8th Grade Enrollment)	0.2	0.1	0.07	0.04	-0.08	-0.32
	(0.18)	(0.22)	(0.54)	(0.19)	(0.27)	(0.51)
Lagged District API	0.16	0.40**	0.53*	0.18	-0.12	0.13
	(0.10)	(0.13)	(0.20)	(0.13)	(0.14)	(0.15)
Constant	-1.54+	-0.02	1.11	-0.02	0.11***	0.14***
	(0.90)	(1.34)	(4.17)	(0.03)	(0.03)	(0.03)
Adj. R-squared	0.07	0.25	0.35	0.02	0.00	0.05
# of districts	61	79	80	56	77	80

+ p<0.10, * p<0.05, ** p<0.01, *** p<0.001

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