Educational Evaluation and Policy Analysis
June 2017, Vol. 39, No. 2, pp. 333–360
DOI: 10.3102/0162373716685823

Are Expectations Alone Enough? Estimating the Effect of a Mandatory College-Prep Curriculum in Michigan

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This article examines the impacts of the Michigan Merit Curriculum (MMC), a statewide college-preparatory curriculum that applies to the high school graduating class of 2011 and later. Our analyses suggest that the higher expectations embodied in the MMC had slight impact on student outcomes. Looking at student performance in the ACT, the only clear evidence of a change in academic performance comes in science. Our best estimates indicate that ACT science scores improved by 0.2 points (or roughly 0.04 SD) as a result of the MMC. Our estimates for high school completion are sensitive to the choice of specification, though some evidence suggests that the MMC reduced graduation for the least prepared students.

Keywords: *standards, accountability, achievement, graduation, high school*

Over the past two decades, the academic achievement of elementary students in the United States has risen substantially, but that of high school students has stagnated. Reading and math scores of 9- and 13-year-olds rose from the early 1970s through 2012, whereas those of 17-year-olds barely budged (National Center for Education Statistics, 2013). Moreover, recent research indicates that, when calculated properly, the high school graduation rate of boys is flat over the past 40 years, whereas that of girls has increased only slightly (Murnane, 2013). The United States consistently lags behind other industrialized countries on international tests of the academic performance of high school students. On the 2009 Program for International Student Assessment (PISA) exam, 15-year-olds in the United States scored 17th in math and 12th in science relative to students in the other 33 Organization for Economic Cooperation and Development (OECD) countries.

Many states have responded to these trends, some of them implementing more rigorous course-taking standards. In this article, we focus on the efforts of one state to impose consistent curricular standards across high schools. In 2007, Michigan implemented the Michigan Merit Curriculum (MMC), which established an ambitious set of standards for the state's high school students. To graduate from high school, Michigan's students must now take a set of classes that includes Algebra II, chemistry or physics, 4 years of English, and 2 years of a foreign language. While this set of courses is standard for any student planning to attend a 4-year college, it is not at all typical of most high school graduates. In 2005, only 12% of Michigan's high schools required Algebra II, and even fewer required chemistry or physics. Among high school graduates nationwide in 2005, 68% completed Algebra II and only 31% completed physics.[1]

The intent of the MMC is to increase academic preparation for college and enhance career readiness. It is expected that students, teachers, and schools will rise to the higher expectations, leading to an increase in academic achievement and attainment. But the likely effects of this initiative are ambiguous. When graduation standards are raised, it is plausible that fewer students will meet the new, higher standards required to graduate.

This article evaluates the effect of the MMC on high school graduation rates and academic achievement.[2] Like many large education policy changes, the MMC was implemented statewide and affected virtually all students at the same time, making it difficult to convincingly estimate the causal impact of the reforms. We take several approaches to evaluating the policy. To begin, we employ student-level longitudinal data to estimate an interrupted time-series (ITS) analysis that identifies the impact of the policy from deviations in pre-existing trends. We use a rich set of student and school characteristics to help control for any time-varying factors that might confound our analysis. And based on extensive discussions with state education officials, we conclude that there were not any significant statewide policies implemented concurrently that might bias our results. We supplement this with an analysis of aggregate data that compare changes over time in Michigan with changes over the same time period in comparison states. This serves to account for any national changes in the economy or educational landscape that might be driving high school student outcomes during this time period.

Looking at student performance on the ACT, the only clear evidence of a change in academic performance comes in science. Our best estimates indicate that ACT science scores improved by 0.2 points (or roughly 0.04 *SD*) as a result of the MMC. Students who entered high school with the weakest academic preparation saw the largest improvement, gaining 0.35 points (0.15 *SD*) on the ACT composite score and 0.73 points (0.22 *SD*) on the ACT science score. Looking at student performance on the ACT, the only clear evidence of a change in academic performance comes in science.

With respect to graduation rates, our estimates for high school completion are very sensitive to the sample and methodology used. Overall, we find no clear evidence that the introduction of the new policy changed graduation rates. However, some of our analyses suggest that the new requirements may have had a small negative impact on the likelihood of high school graduation for students who entered high school with the weakest academic preparation.

These findings are consistent with much of the prior literature. A large body of research has found that increasing high school graduation requirements (whether in the form of additional courses or exit exams) results in lower graduation rates among the most disadvantaged students. There is less evidence on how such policies affect student achievement, but the existing research generally does not find large gains in student performance.

Our findings suggest several important lessons for policymakers. First, raising course-taking standards alone is likely insufficient to generate substantial improvements in student outcomes. Second, more rigorous course-taking standards may have a downside for the least prepared students, some of whom who drop out of school and others who fail to graduate on time.

The remainder of the article proceeds as follows: In Section “Background,” we describe the background of the MMC. In Section “Prior Literature,” we review prior literature on similar reform efforts. Section “Research Methodology” and “Data” describe the empirical strategy and data, respectively. Section “Results on High School Achievement” presents results, and we conclude in Section “Discussion and Conclusions.”

Background

The American Diploma Project, an advocacy organization, has tracked states’ adherence to their recommended high school curriculum, which includes math through Algebra II and 4 years of English. Since 2004, 36 states and the District of Columbia have raised graduation requirements to meet this set of standards, while an additional 14 states plan to do so in the next few years (Achieve, Inc., 2013).

The Michigan legislature passed a new set of high school graduation requirements called the MMC. The stated intent of the MMC was by increasing the rigor of secondary school, student would be better prepared for college and career (Cherry, 2004). The first students covered by the MMC started high school in the fall of 2007. Students who started high school before that date were not bound by these new rules. The first cohort of freshmen affected by the MMC graduated in the spring of 2011.

The MMC emphasized academic preparation in mathematics and science. Students were required to take Algebra I, geometry, and Algebra II, as well as biology and either chemistry or physics. Students had to take 4 years of English, 2 years of a foreign language, three courses in social studies, and one credit each of physical education, art, and online learning. The typical high school student devoted about half of his or her courses to meet the requirements of the MMC.

Before these requirements were passed, Michigan had largely left curricular decisions to the districts. For high school students, the only state requirement was a single course in civics.[3] The state still had influence on curricular content, however, in that it wrote and graded the standardized tests required by the federal No Child Left Behind (NCLB) Act. As schools and districts faced sanctions when students performed poorly on these tests (given in 11th grade, as well as Grades 3–8), they had a strong incentive to teach the material contained in those tests. But the state imposed no constraints on the curricula that schools used to teach the material contained in the required tests.

Before the MMC, districts varied considerably in the courses they required of high school students. According to a state-administered survey, only about a third of school districts required 4 years of math before the new curriculum was put in place; a similar proportion required 3 years of science. These requirements were reflected in students' choices: Only a quarter of high school students took physics, less than half took chemistry, and only one of eight took Algebra II. By contrast, about 60% of districts required 4 years of English even before the Merit Curriculum was implemented.[4] These statistics suggest that the new curriculum was particularly binding in the realms of science and math. Note that the new curriculum not only required students to take more rigorous classes but also required schools to provide them; thus, many schools needed to hire teachers and schedule the courses students would be required to take.

While the requirements of the MMC were extensive, state oversight of compliance was relatively limited. The state provided a detailed framework for each required course, including instructional guidelines. However, implementation of these standards and enforcement of the requirements of the curriculum remained local responsibility. A set of standardized, statewide, end-of-course exams was intended to accompany the new curriculum, but these were shelved in the face of budget constraints and district resistance. Districts and schools instead wrote and administered their own course assessments, which consisted of (for example) a final exam, a portfolio, a project, or a series of tests given throughout the course. The state did not audit these assessments or student transcripts to confirm that the MMC was followed.

The state also required that all students take the Michigan Merit Exam (MME) in 11th grade. The MME consisted of the ACT college-entrance examination, components of the ACT's WorkKeys job skills assessment, and Michigan-developed assessments in mathematics, science, and social studies. Graduation was not contingent on passing the MME.

Prior Literature

A long literature documents the correlation between the rigor of courses that students take in high school and their future academic success. Successful completion of rigorous math and science courses is associated with improved academic and social outcomes in the short term (Frank et al., 2008). Those who take math and science are also more likely to attend college, especially 4-year institutions (Adelman, 1999; Davis-Kean, Eccles, & Simpkins, 2006; Riegle-Crumb, 2006; Sadler & Tai, 2007; Schneider, Swanson, & Riegle-Crumb, 1997; Sells, 1973). In addition, a small but growing body of research shows that taking certain core courses, especially those in math and science, can have significant, positive effects on long-term labor-market outcomes (Betts & Rose, 2004; Cortes, Goodman, & Nomi, 2015; Goodman, 2012; Levine & Zimmerman, 1995).

Given this evidence, one might ask why students do not take such courses on their own. In other words, why is a state mandate such as the MMC necessary? Economic theory offers several explanations for such market failure. Students and/or parents may be unaware of the benefits of more rigorous course taking, a case of asymmetric information. Students may have high discount rates, and thus be unwilling to endure the short-term cost of taking more difficult courses for the long-term benefit of better economic outcomes. It is possible that school factors, such as a lack of courses or an unwillingness on the part of counselors to assign certain students to college-prep courses, operate to exclude many students from rigorous course taking. In the face of any of these barriers, a state-mandated policy such as the MMC can serve to increase rigorous course taking.

The extent to which such a requirement provides the benefits shown in prior research depends on several factors. Evidence based on courses students *choose* to take, however, may not predict the effects of a policy that *requires* all students to take those same courses. The effects of taking a given course are almost certainly heterogeneous. Standard economic theory would predict that those who choose to take a course are those who expect to benefit most from it, and that forcing others to take it would produce smaller benefits or even harm. However, if students did not take such courses because of poor information, those induced to take the classes by the MMC could actually benefit more than the students who took them voluntarily. Indeed, a large body of evidence now indicates that students forced to stay in high school by compulsory schooling and child labor laws benefit from the additional schooling (Acemoglu & Angrist, 2001; Angrist & Krueger, 1991; Oreopoulos, 2006, 2007).

It is also possible that the imposition of the curricular requirements could change the size and student mix within classes. Peer effects and class size are channels through which high-achieving students could be harmed, as their classes expand to include less-eager classmates. Depending on the nature of classroom peer effects and instruction, the lower achieving students, by contrast, could benefit from sharing more classes with their high-achieving classmates.

What is the evidence on the effect of requiring high school students to take more rigorous courses? The results to date are mixed. There is some evidence that increased course taking boosts student performance and high school completion (Achieve, Inc., 2013). But there is countervailing evidence that higher course requirements are associated with decreases in high school completion (DeCicca & Lillard, 2001). Moreover, there is substantial evidence that high school exit exams, a closely related policy, increase drop-out rates, particularly among low-income students (Dee & Jacob, 2007; Jacob, 2001; Jenkins, Kulick, & Warren, 2006; Papay, Murnane, & Willett, 2010), and little evidence that they improve student achievement (Dee & Jacob, 2007; Grodsky, Kalogrides, & Warren, 2009).

Two evaluations in Illinois are particularly relevant to the present article. In 1997, the Chicago Public Schools enacted a reform that mandated a college-preparatory curriculum, including a requirement that students take Algebra I and English I in their ninth grade (rather than lower-level math and English courses). Researchers at the Consortium on Chicago School Research find that this resulted in a convergence of course taking by students of differing race and baseline achievement (Allensworth, Lee, Montgomery, & Nomi, 2009; Allensworth, Nomi, Montgomery, Lee, & Mazzeo, 2010; Montgomery & Allensworth, 2010). However, grades in Algebra I went down, and more students failed the course. Furthermore, affected students were no more likely to take math courses beyond Algebra II. There was no effect on test scores or college attendance. In addition, the research documented a sharp decline in high school graduation rates in the first few years following the introduction of the policy, although graduation rates subsequently recovered and returned to prepolicy levels.[5]

In 2005, Illinois passed legislation requiring 3 years of math and 2 years of science for high school graduation. Buddin and Croft (2014) use cross-district variation in baseline requirements to implement a differences-in-differences strategy, with districts that had the requirements in place prior to the legislation serving as the control group and other districts as the treatment group. Their findings indicate that students took few more science courses as a result of the policy, but they find no impact on science score, math course-taking or math scores, or college attendance.

While these studies provide valuable insight, they have significant limitations. The Chicago studies by necessity focus on a single district. And because the district enacted a variety of reforms during this period, it is difficult to attribute the impacts to the course-taking policy alone. The Illinois study has the advantage of looking at a statewide policy, but the authors rely on student self-reports of course taking that come from the ACT students are required to take in 11th grade. As a result, the analysis only includes students who persisted through the end of 11th grade and took the ACT. The authors have data on college attendance from matched National Student Clearinghouse (NSC) data but do not actually have information on high school graduation. As a result, they cannot study whether the introduction of the new course requirements reduced the likelihood of high school graduation, a potentially important outcome. Finally, to designate treatment and control districts, they rely on district responses on a pre-intervention survey. However, they find no pre-intervention difference between treatment and control districts in a key measure of math course taking, suggesting that district-specific policies that existed prior to the state law may not have been enforced.

Relative to the prior literature then, our study makes several distinct contributions. First, we use administrative data, which provide us with highly reliable measures of test scores and educational attainment for all students in the state, including those who will later drop-out or move. Second, these data allow us to control for a rich set of student and school characteristics, which help us control for factors that can influence student outcomes that might have changed coincident to the introduction of the policy. Third, with the exception of the working paper by Buddin and Croft (2014), this article is (to the best of our knowledge) the first analysis of a state attempt to require college-preparatory courses for all students.

Research Methodology

The MMC was implemented statewide in a single year. Before the new legislation, Michigan had few school districts with requirements resembling those of the MMC. This precludes the construction of a straightforward within-state control group of schools that were not bound by the new requirements. Instead, we use several complementary methods to estimate the impact of the MMC on student outcomes.

Our primary approach is to estimate an ITS using the rich, student-level, state administrative longitudinal data. In the ITS approach, postpolicy deviations from prepolicy trends in outcomes are attributed to the policy.[6] Specifically, we estimate a model of the form:

$$\begin{aligned} y_{ics} = \beta_0 &+ \beta_1 PostYr1_c + \beta_2 PostYr2_c \\ &+ \beta_3 PostYr3_c + \gamma Cohort_c \\ &+ \mathbf{X}_{ics} + \mu_s + \varepsilon_{ics}. \end{aligned} \tag{1.1}$$

Here, subscripts index student i in school s in ninth-grade cohort c. The dependent variable is a measure of educational attainment or achievement. The variable *Cohort* is a continuous variable indicating the year a student starts high school, and serves to estimate our trend. The three *Post* variables are dummies that are set to 1 for the first, second, and third cohorts bound by the new policy. The coefficients on these dummies estimate cohort-specific deviations from the prepolicy trend in the dependent variable. We present the weighted average of the coefficients on these dummies as a summary measure of the policy impact.

The key identifying assumption of an ITS is that, absent the policy, the outcome of interest would have continued on its prepolicy trend. As we are undertaking a cohort analysis, the key threats to identification are cohort-specific shocks. These shocks could include changes in the composition of Michigan's students, economic shocks that affect labor-market prospects and family income, and other shifts in education policy affecting the same cohorts as the new curriculum. Our detailed longitudinal data allow us to control for a rich set of student, school, and district characteristics, included in the vector **X** in the equation above. These include student race, sex, eligibility for subsidized meals, and baseline test scores. In addition, we include fixed effects that indicate the school at which a student was a freshman, along with cohort-specific measures that capture the average characteristics of a school's freshman class.

During the first years of the MMC, economic conditions in Michigan (as in the rest of the country) were rapidly deteriorating. The effect of the Great Recession on educational attainment and achievement is ambiguous. Dismal labor-market conditions reduce the opportunity cost of schooling, but deteriorating family income may negatively affect the ability of children to succeed in school. To control for such variation in economic conditions across time, as well as across the state, we include measures of the local unemployment rate during the time a student was enrolled in high school. As these economic shocks may have affected schools' financial resources, we also control for annual, per-pupil expenditures at the level of the school and district.

One concern that we cannot address with such controls involves the context of the reforms in Michigan. The MMC legislation passed in 2006 incorporated tangible changes such as the mandate that all 11th graders take the ACT exam (see Hyman, 2016, for a discussion of this policy and its potential impact) along with the introduction of a new Michigan-specific high school assessment, the MME. These changes took place prior to the actual MMC requirements that are the focus of this article.

In a closely related study, we collect and analyze historical student transcript data for a random sample of Michigan high schools, which will allow us to study how the new requirements affected course-taking and student assignment to specific classes. Preliminary results from this work suggest that there were some increases in course taking after the passage of the legislation but prior to the actual mandate taking effect. Like other types of cohort-specific shocks, this type of "anticipatory" response to the new policy complicates the interpretation of the ITS results.

To the extent that we see improvements in student outcomes prior to the new requirements themselves, the ITS assumes that such improvements would have continued on the same trend. If we expect that the improvement generated by these noncurricular high school reforms would have declined (or accelerated) of their own accord, the ITS results might be misleading. For this reason, we present our results both with and without the pretrend.

This may be particularly relevant for examining ACT scores. It is well documented in the education literature that scores tend to fall after the introduction of a new exam, but then rise as teachers and students gain familiarity with its content and format (Koretz, 2002). The ACT was mandated statewide in Michigan just a few years before the implementation of the MMC. This would predict that ACT scores would rise sharply for a few years before the MMC and then flatten out, even if the curriculum had zero causal effect on scores. In this scenario, the inclusion of a pretrend in the ACT analysis would lead us to understate any benefits of the policy.

When analyzing high school graduation outcomes, we supplement the ITS analysis with a cross-state analysis. We present estimates from standard panel data models (with controls for state- and year-fixed effects as well as time-varying state-level controls) as well as from the synthetic control methods suggested by Abadie, Diamond, and Hainmueller (2010). We discuss the details of these data and analyses below.

When analyzing high school achievement, we take advantage of the national scope of the ACT exam to implement something like a comparative ITS approach. During our analysis period, Illinois required all 11th-grade public school students in the state to take the ACT.[7] While we do not have student-level data from Illinois, we obtained the distribution of ACT scores in Illinois by year. That is, for each year, we know the Illinois state percentile corresponding to each possible ACT score on each subtest. We use this information to normalize the ACT scores of Michigan students by year.[8] This normalization implicitly controls for changes in the scaling of the ACT as well as trends in student performance due to national economic or policy factors. We estimate Equation 1.1 using this Illinois-normalized ACT score. In all equations, standard errors are clustered by the school at which a student was a ninth grader.

Given the theory and prior research described above, we hypothesized that the introduction of the MMC would increase math and science performance among students who were least likely to take college-prep courses in prior years. However, we also suspected that it might increase high school graduation rates among the least prepared students, those who cannot (or are unwilling to) complete the more rigorous curriculum. For this reason, we look separately at students based on quintiles of their eighth-grade math scores, which is an extremely strong predictor of subsequent ACT scores and high school graduation.

Data

Our student-level, longitudinal data file includes multiple cohorts of Michigan public school students that we obtained and merged from the state's Center for Educational Performance and Information and its Department of Education. This yields a student-level, longitudinal file that includes information on student demographics and standardized test scores, high school attended, and time of graduation. We drop roughly 5% of students who attended a nontraditional school. In addition, for our main analyses, we focus on the subset of students with a non-missing eighth-grade test score in the year prior to high school entry. This provides us with a key covariate for our analysis but results in the exclusion of roughly 16% to 19% of each ninth-grade cohort, most of which stems from students who were not in the Michigan public school system prior to high school or took an alternative assessment for students with special needs. If we include this set of students and assign them imputed scores based on their own demographics and their peers eighth-grade scores, our results do not change (see the Appendix, available in the online version of the journal).

For the analysis of student achievement, our sample consists of six cohorts of students who entered high school in fall 2004 through fall 2009. The first three cohorts were not bound by the MMC, whereas the second three were. We will refer to these cohorts by the spring in which they were ninth graders the prepolicy cohorts are noted as 2005, 2006, and 2007, while the postpolicy cohorts are 2008, 2009, and 2010. The first cohort bound by the MMC would have been scheduled to graduate in spring 2011.

The relevant high school exam during our analysis period is the MME. As part of the MME, all students take the ACT, a nationally normed, college-entrance exam. The ACT includes subtests in math, science, reading, writing, and social studies. While the state provides each student with an overall MME score, students are able to use the resulting ACT score independently for purposes such as college admissions and scholarship applications. That is, the Michigan exam is structured so that the ACT score the students obtain is a complete and "regular" ACT score, comparable with what students would receive had they taken the exam outside of the state testing context. The MME replaced the older Michigan high school test, with both being administered to 11th graders in spring 2007, which corresponds to the ninth-grade cohort of 2005. We begin our analysis period with this cohort to avoid the need to equate across two quite different high school exams.

In the analysis that follows, we focus on the ACT scores rather than other components of the MMC as the ACT is nationally normed and highly relevant for critical student outcomes such as college admissions. In the small set of cases in which students have multiple ACT scores, we use the score from the first time the student took the exam.

For our analysis of high school completion, we are able to include two additional prepolicy cohorts—students entering high school in fall 2002 and fall 2003—although we have somewhat less confidence in the data for the fall 2002 cohort because the fraction missing eighth-grade scores is about 5 percentage points more than in subsequent cohorts.[9]

Graduation from a public high school in Michigan is captured by our longitudinal data, which follows students as long as they remain in the public school system. We are confident in the graduation data, as it is audited by the state for accountability purposes. We are less confident in other "exit code" values provided in the state data. The exit code represents a school's best guess of what a student will be doing the following year, for example, dropping out, transferring to a private school, or leaving the state. Inspection of the longitudinal data indicates that these exit codes are periodically wrong. For example, many students who were expected to reenroll or transfer to another public school in Michigan never again appear in the state data.

For most of the analysis, we focus on a three-category measure: graduated from a Michigan public high school, still enrolled in a Michigan public school, and everything else. The primary outcome is an indicator of high school graduation, which is set to 0 for all other students, who may have dropped out, transferred to a private school, or left the state.[10]

Students in Michigan take standardized tests in Grades 3 through 8, as well as in the junior year of high school. The high school test serves as our measure of academic achievement, whereas math scores from fourth and eighth grades serve as baseline controls. The choice of exams for use as baseline achievement controls is dictated by data availability. Given the rollout of standardized exams in different grades and subjects in the state, fourth- and eighth-grade math were the only cases in which we had consistent elementary test score measures for all cohorts in our sample.

We define all student-specific demographic variables, as well as variables indicating program participation, by their values when the student started high school. These include dummies indicating a student's eligibility for free and reduced-price lunch (FRPL), special education status, migrant status, and English-learner status.

Sample Statistics

Table 1 (demographics and school characteristics) and Table 2 (outcomes) provide sample means, reported separately for each student entering ninth-grade cohort. The size of the entering ninth-grade cohort in Michigan public schools varied during the period of analysis from 112,201 students starting high school in 2005 to 114,491 for those entering in 2010. This reflects the population loss experienced by the state during this period. The number of high schools in the analysis fluctuates across cohorts, from as few as 674 to as many as 717 schools.

Demographic shifts in the sample over this period were relatively minor, with the exception of the share of students eligible for FRPL, which increased from 22% for the 2003 cohort to 35% for the 2010 cohort, a result of the nationwide recession on Michigan's students.

We construct standardized scores across all cohorts by subtracting the 2005 mean score and dividing by the 2005 standard deviation, creating a measure that is standardized relative to the 2005 cohort. Fourth- and eighth-grade math scores appear to have been increasing somewhat throughout the time period, consistent with national trends and the findings of Dee and Jacob (2011) with regard to NCLB. However, there is an extremely large (0.31 *SD*) jump in eighth-grade scores for the ninth-grade cohort of 2009. Despite extensive investigations of the underlying data and conversations with state officials, we cannot find any explanation for what seems like an extremely large 1-year increase, although the fact that the 2010 cohort mean is even larger suggests that the 2009 value was not an anomaly.[11,12] The fraction of students taking the 11th-grade test increased during the sample period, likely reflecting the ramp-up of test taking in the first years of the new high school test, the MME, before the MMC took effect. Both MME and ACT scores increase over the sample period.

Graduation rates are also rising across time during the period before the MMC was put in effect. Among the cohort starting high school in 2003, 75% graduated high school within 4 years and 78% within five years; the corresponding statistics for those entering in 2007 are 76% and 79%, respectively.

Results on High School Achievement

The primary goal of the MMC was to ensure that students were prepared for college and a 21st-century labor market, with a focus on enhancing skills in math and science. To explore what, if any, impact the new course requirements had on student achievement, Figures 1 to 5 show trends in the ACT composite and subtest scores in Michigan from the 2005 cohort through the 2010 cohort.

The solid line in each figure shows the unadjusted trends, normalized to 0 in 2005. To control for other factors that might have changed over this time period, we estimate a variant of Equation 1.1 but include indicators for cohorts 2006 through 2010 instead of the linear trend or post-policy indicators. The dashed lines in each figure indicate the point estimates on these cohort indicators from regressions with all of the controls described above except for the prior test scores (both at the individual student and at the school-cohort level). The 2005 cohort serves as the omitted category, and hence all estimates are relative to this group. The dotted lines in each figure track the cohort effects from a regression that also controls for prior test scores. Specifically, we control for individual fourth- and eighth-grade math scores as well as the mean and

TABLE 1

Summary Statistics on Student and School Background Characteristics

	Year of Grade 9							
Variable	2003	2004	2005	2006	2007	2008	2009	2010
Demographics								
%Female	50.1	49.9	50.2	49.8	49.6	49.8	49.4	49.3
%White	76.4	75.5	74.6	73.8	73.5	73.2	72.9	73.2
%Black	17.0	18.1	19.0	19.4	19.4	19.3	19.3	18.4
%Hispanic	3.3	3.3	3.4	3.8	4.0	4.2	4.5	4.9
%Asian	2.0	1.9	1.9	1.9	2.1	2.1	2.2	2.4
%Migrant	.2	.1	.2	.2	.2	.2	.1	.2
%Free lunch (Grade 9)	21.6	22.5	24.7	27.2	29.0	30.3	32.8	34.5
%Subsidized lunch (Grade 9)	5.8	5.6	5.7	6.5	6.8	6.9	7.3	7.3
%In special education	11.3	11.7	10.7	11.2	11.2	11.5	11.8	11.5
%With limited English proficiency	1.7	2.2	2.6	2.4	2.5	2.8	2.8	2.6
Average age	14.50	14.49	14.49	14.50	14.51	14.50	14.50	14.51
School characteristics								
Enrollment	273.36	292.47	308.34	302.40	294.71	290.76	279.05	281.47
%Of students attending urban school	19.67	19.68	19.88	19.62	18.16	17.56	17.42	16.60
%Of students attending suburban school	45.12	45.26	45.83	46.03	47.43	47.68	47.94	48.96
%Of students attending school in a town	9.00	8.91	8.70	8.59	8.53	8.48	8.44	8.30
%Of students attending rural school	26.21	26.14	25.60	25.76	25.88	26.28	26.20	26.13
%Of students attending charter school	1.29	1.88	2.16	2.50	2.69	2.99	3.50	3.76
%Of students attending magnet school	6.21	7.38	9.32	10.43	11.08	11.99	14.02	13.74
Unemployment rate (%) in county (Grade 9)	7.36	7.70	7.70	7.38	7.55	7.94	12.25	14.18
District per-pupil expenditure (Grade 9)	10,129.29	10,152.35	10,076.07	10,006.60	10,072.56	9,877.53	10,153.53	10,080.25
School per-pupil expenditure (Grade 9)	6,376.35	6,444.65	6,376.83	6,277.96	6,349.03	6,231.83	6,555.39	6,433.25
Prior standardized achievement								
Eighth-grade std math score[a]	−0.23	−0.17	0.00	0.01	0.03	0.05	0.31	0.46
%Missing fourth-grade math score	17.89	19.55	20.40	20.70	20.10	15.96	13.50	12.00
Fourth-grade std math score[a]	−0.06	−0.10	0.00	−0.06	0.17	0.17	0.33	0.34
Sample								
Total students	112,201	120,853	126,974	126,443	122,890	120,770	116,208	114,491
Unique schools	705	706	698	711	674	717	701	705

Note. This table reports the mean of each variable for the sample, including students who first attended a traditional high school in Grade 9 during 2003–2010 with nonmissing eighth-grade math test scores.
[a]Standardized equated exam scores are determined based on the 2005 cohort score. Scores are “equated” to account for differences in the number of possible points.

TABLE 2

Summary Statistics on Student Outcomes

	Year of Grade 9							
Variable	2003	2004	2005	2006	2007	2008	2009	2010
High school tests								
% that take the ACT			83.46	84.66	85.48	86.33	87.52	87.59
Average ACT composite score			18.88	18.92	19.08	19.31	19.38	19.61
Average ACT math score			18.88	19.03	19.25	19.36	19.53	19.68
Average ACT science score			19.48	19.52	19.44	19.71	19.91	19.99
Average ACT reading score			17.64	17.71	18.07	18.32	18.35	18.73
Average ACT English score			18.99	18.93	19.04	19.36	19.21	19.54
Advanced placement exam outcomes								
%Took at least one exam[a]	11.58	14.75	16.28	16.95	18.42	19.70	20.97	22.02
%Took at least one exam (math)[a]	5.09	6.08	6.47	6.66	7.20	8.06	8.29	8.85
%Took at least one exam (science)[a]	3.49	5.35	6.16	6.29	6.90	7.54	7.69	8.32
Number of exams[a]	0.20	0.32	0.38	0.40	0.44	0.50	0.53	0.59
Number of exams (math)[a]	0.05	0.07	0.07	0.08	0.08	0.09	0.10	0.10
Number of exams (science)[a]	0.04	0.07	0.08	0.08	0.09	0.10	0.10	0.11
Average score	3.03	2.88	2.84	2.81	2.77	2.69	2.76	2.78
Average score (math)	3.15	3.06	3.13	3.14	3.06	2.90	3.04	3.01
Average score (science)	3.10	2.94	2.84	2.76	2.77	2.77	2.79	2.82
Maximum score	3.16	3.06	3.04	3.02	2.98	2.92	2.98	3.01
Maximum score (math)	3.16	3.09	3.17	3.18	3.11	2.96	3.10	3.08
Maximum score (science)	3.15	3.03	2.94	2.87	2.88	2.88	2.91	2.94
Minimum score	2.90	2.69	2.63	2.59	2.55	2.46	2.53	2.52
Minimum score (math)	3.14	3.03	3.09	3.09	3.00	2.85	2.98	2.95
Minimum score (science)	3.06	2.84	2.73	2.66	2.66	2.65	2.67	2.70
Score 3+ on at least 1 AP exam (%)[a]	4.59	5.59	5.94	5.95	6.40	6.83	7.14	7.83
Score 3+ on at least 1 AP math exam (%)[a]	3.41	3.94	4.25	4.41	4.70	4.92	5.36	5.70
Score 3+ on at least 1 AP science exam (%)[a]	2.34	3.38	3.71	3.60	3.95	4.35	4.46	5.14
High school outcomes								
%Graduating in 4 years or fewer	74.93	74.41	73.75	74.20	76.26	75.58	75.83	75.26
%Enrolled in high school after 4 years	9.18	9.31	9.45	9.48	8.91	9.86	9.14	7.83
%Drop-out within 4 years	2.56	2.73	2.82	2.91	2.75	2.64	2.38	2.45
%Left Michigan public within 4 years	1.66	2.10	2.36	2.70	2.90	2.87	2.64	2.52
%Unknown within 4 years	1.88	1.82	1.73	1.95	2.06	2.10	2.29	2.19
%Other within 4 years	9.79	9.63	9.89	8.76	7.13	6.95	7.73	9.75
%Graduating in 5 years or fewer	78.07	77.53	77.05	77.42	79.24	78.72	78.76	78.06
%Enrolled in high school after 5 years[b]	2.17	2.25	2.34	2.28	2.33	2.46	1.97	
%Drop-out within 5 years[b]	3.67	3.80	3.94	4.06	3.58	3.75	3.52	
%Left Michigan public within 5 years[b]	1.77	2.24	2.43	2.76	2.95	2.99	2.68	
%Unknown within 5 years[b]	2.57	2.78	2.85	3.07	3.12	3.48	3.45	
%Other within 5 years[b]	11.75	11.41	11.38	10.41	8.78	8.60	9.62	
Sample								
Total students	112,201	120,853	126,974	126,443	122,890	120,770	116,208	114,491
Unique schools	705	706	698	711	674	717	701	705

Note. This table reports the mean of each variable for the sample, including students who first attended a traditional high school in Grade 9 during 2003–2010 with nonmissing eighth-grade math test scores. AP = advanced placement.

[a]AP exam outcomes are unconditional, students who did not take an AP exam are coded to have 0 exam and 0 score in one exam. AP score is 1- to 5-point scale.

[b]We do not have the high school graduation information (except graduation) within 5 years for the 2010 cohort.

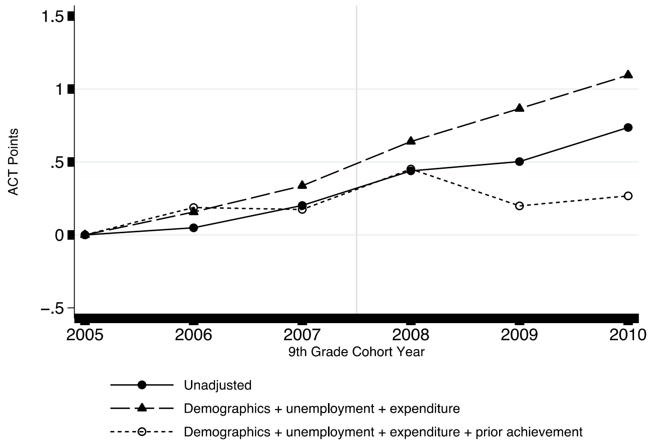

FIGURE 1. *Impact of MMC on ACT composite scores.*
Note. MMC = Michigan Merit Curriculum.

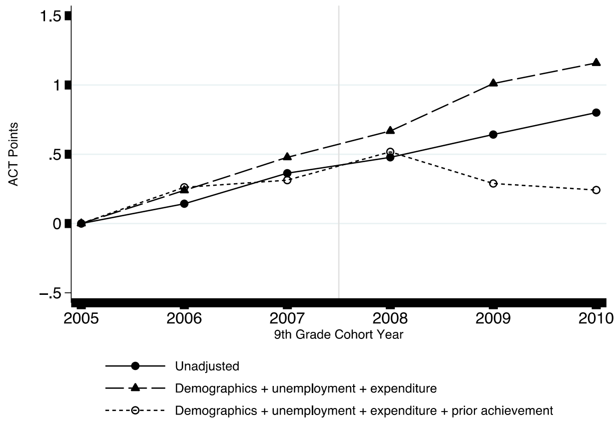

FIGURE 2. *Impact of MMC on ACT math scores.*
Note. MMC = Michigan Merit Curriculum; ACT = American College Testing.

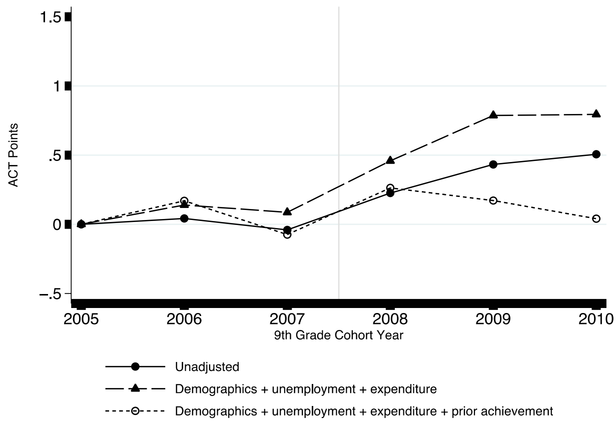

FIGURE 3. *Impact of MMC on ACT science scores.*
Note. MMC = Michigan Merit Curriculum; ACT = American College Testing.

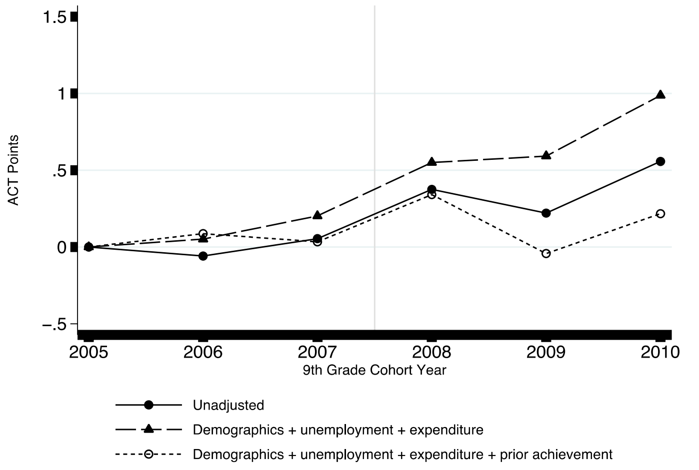

FIGURE 4. *Impact of MMC on ACT reading scores.*
Note. MMC = Michigan Merit Curriculum.

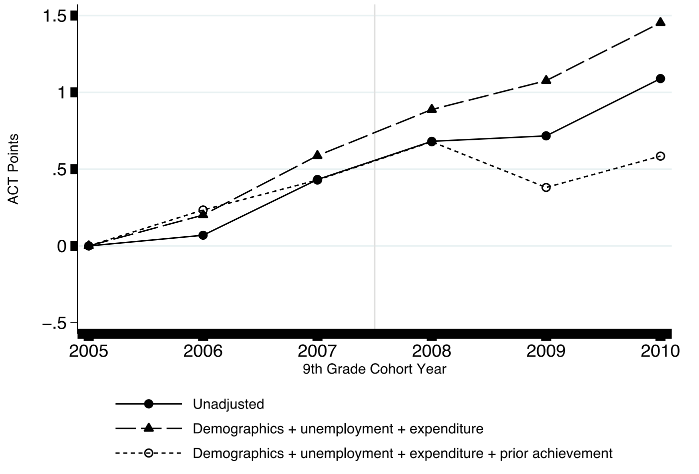

FIGURE 5. *Impact of MMC on ACT English scores.*
Note. MMC = Michigan Merit Curriculum.

standard deviation of fourth and eighth grades in the individual's school cohort (i.e., the student's high school peers).

Figure 1 shows that composite scores increased over the sample period. For example, students in the 2010 cohort scored roughly 1.1 points higher than students in the 2005 cohort. It is interesting to note that the dashed lines, which control for demographics, are notably steeper than the solid line, which shows the unconditional achievement trend. This difference reflects the fact that the student population in Michigan was becoming more disadvantaged over the recession period. Controls for prior achievement flatten the trend somewhat because, despite the economic conditions, student performance on fourth- and eighth-grade exams grew over this period. Most notably, we see a sharp drop in the dotted lines in 2009 and 2010, reflecting the substantially higher eighth-grade math scores for these cohorts.

While a simple before–after analysis would suggest a positive impact of the MMC, the growth we observe does not deviate sharply from the existing growth once the new curricular requirements are introduced. Scores on the math and English tests follow trends similar to the composite scores. In contrast, scores in science

TABLE 3

Impact of MMC on ACT Scores

Outcome	Prepolicy *M*/*SD*	(1)	(2)	(3)	(4)
Composite ACT score	[18.959]	0.400***	0.139***	0.167***	−0.096
	{4.890}	(0.057)	(0.053)	(0.062)	(0.059)
Number of students		624,316	624,316	624,316	624,316
Math ACT score	[19.052]	0.373***	0.068	−0.018	−0.333***
	{4.796}	(0.065)	(0.063)	(0.072)	(0.069)
Number of students		624,630	624,630	624,630	624,630
Science ACT score	[19.482]	0.407***	0.172***	0.432***	0.197***
	{4.914}	(0.058)	(0.060)	(0.065)	(0.065)
Number of students		624,354	624,354	624,354	624,354
Reading ACT score	[18.984]	0.357***	0.128**	0.295***	0.067
	{5.902}	(0.062)	(0.061)	(0.075)	(0.074)
Number of students		624,494	624,494	624,494	624,494
English ACT score	[17.803]	0.465***	0.191**	−0.046	−0.320***
	{6.019}	(0.087)	(0.083)	(0.090)	(0.087)
Number of students		624,696	624,696	624,696	624,696
Took ACT math	[0.846]	−0.012**	−0.013**	−0.027***	−0.027***
	{0.361}	(0.005)	(0.005)	(0.006)	(0.006)
Number of students		727,776	727,776	727,776	727,776
Prepolicy trend		No	No	Yes	Yes
Demographics, school characteristics, and school FE		Yes	Yes	Yes	Yes
Prior fourth-grade math test scores (individual and school levels)		Yes	Yes	Yes	Yes
Prior eighth-grade math test scores (individual and school levels)		No	Yes	No	Yes

Note. This table reports the coefficients and standard errors from regressions of interrupted time-series design of the impact of MMC on ACT outcomes. Each coefficient–standard error pair is obtained from a separate regression. Students for 2005–2010 cohorts without imputed eighth-grade test scores are included. "Took ACT math" is a dummy variable that is equal to 1 if a student has a nonmissing ACT composite score. All the ACT scores are the first-time ACT exam raw scores of each subject. All the control variable groups (demographics, school characteristics, prior fourth- and eighth-grade test scores at both individual and school levels) are corresponding to those listed in Table 1, except not controlling for the unemployment rates and school/district expenditures in Grades 11 and 12. Prepolicy mean/*SD* reports the mean/standard deviation of each outcome in 2005–2007. Robust standard errors in parentheses are clustered at high school level. MMC = Michigan Merit Curriculum; FE = fixed effects. *Significant at 10% level. **Significant at 5% level. ***Significant at 1% level.

and reading appear to increase more sharply, indicating that the policy may have had a positive impact on achievement in these subjects.

Table 3 presents regression estimates of the relationship between the MMC and ACT scores. To illustrate the importance of pre-existing trends, we show estimates without them (Columns 1, 2) as well as with them (Columns 3, 4). All estimates control for school-fixed effects, fourth-grade math scores, and a full set of student, school, and district covariates. The models in Columns 2 and 4 also control for eighth-grade math scores.[13]

Across the estimates in Table 3, several patterns emerge. First, as shown in the figures, the effects are stronger in science and reading than in math or English. Second, accounting for pre-existing trends and eighth-grade math scores both independently (and jointly) reduce the size of the estimates. Third, all of the estimates are quite small relative to the prepolicy level of ACT scores. For example, the coefficient estimate of 0.432 points for science in Column 3 corresponds to an increase of only 0.09 *SD*. Finally, conditional on observable student and school characteristics, the introduction of the new curriculum is associated with a slight reduction in the proportion of students taking the ACT.[14] In Appendix A and Appendix Table 4 we conduct sensitivity analyses following Lee (2009) that demonstrate this modest sample attrition does not meaningfully bias our estimates.

To account for changes in the scaling of the ACT over time, as well as any unobserved factors common to public schools in the Midwest, Table 4 shows results for ACT scores normed to the Illinois distribution (see Data section). While the estimates are slightly more positive than those in Table 3, the conclusions are similar. In Column 4, our preferred model, we see small but significant increases in science and reading scores. For example, the estimate of 2.1 for science indicates a 2-percentile-point increase (from a baseline of the 47th percentile). The math effect is very small (0.6 percentile points) and only marginally significant. The English effect is not significantly different than 0.

Table 5 shows results separately by the quintile of the student's eighth-grade math score, using the specification from Column 4 in Table 3. Appendix Figures 1 to 5 (available in the online version of the journal) show the trends in ACT scores by subject for each of the quintiles. Models that do not control for Grade 8 scores and/or use the Illinois percentiles of student ACT scores as the outcome yield comparable results and are shown in Appendix Tables 1 and 2 (available in the online version of the journal). The final row of Table 5 shows the difference between the impacts of the MMC on the top and bottom quintiles. Across each subject area in our models with a prepolicy trend, the impact on the lowest prepared students is larger than that on the highest prepared students by a statistically significant margin. These comparatively large effects mean that even when we lack clear evidence of growth in student scores, there is a clear narrowing of the achievement gap between the highest and lowest quintiles. Appendix Table 3 (available in the online version of the journal) shows comparable results using the standardized MME instead of the ACT as the outcome.

These results suggest that the set of students who entered high school with weak academic skills may have benefited from the new requirements, at least in terms of science and reading achievement. The estimate of 0.726 on science scores for bottom quintile students (from the model that includes a prepolicy trend) is equivalent to about 0.22 *SD*; the corresponding estimate for the composite score translates to an effect of roughly 0.15 *SD*. Conversely, there is some evidence that students who entered high school with the strongest academic skills experienced a decline in performance relative to what would have been expected in the absence of the policy. It should be noted, however, that these results are particularly sensitive to the inclusion of the prepolicy trend.[15]

To the extent that these high-achieving students were most likely to have been taking college-prep courses in earlier years, one might not have expected the policy to have a sizable impact on their performance. However, the introduction of the MMC necessitated staffing changes within schools that might have influenced the performance of higher achieving students. For example, principals may have shifted the most talented math or science teachers to courses taken by less well-prepared students who were newly required to take the college-prep courses. Or staffing shortages may have led class sizes in upper-level math and science courses to increase. We plan to explore both these potential pathways in subsequent research that utilizes individual student transcript data.

Advanced Placement (AP) Course Taking

Further evidence of the link between the slight rise in science ACT scores was analyzed by examining AP course taking. Table 6 shows impact on AP course taking separately for students in the top three quintiles of their cohort's eighth-grade math distribution.[16] As with the ACT estimates, these models include controls for fourth- and eighth-grade math scores at the student and school-cohort level. We see a very small increase in the number of AP exams taken among students in the top quintile (0.17 exams, which is equivalent to 0.09 *SD*). In the results not shown here, we document that there was no increase in AP math exams taken, but a small increase in science, although that was not

TABLE 4

Impact of MMC on ACT Scores, Relative to Illinois Score Trends

Outcome	Prepolicy *M*/*SD*	(1)	(2)	(3)	(4)
Composite ACT Illinois percentile	[43.528]	1.310***	−0.064	2.223***	0.886***
	{27.859}	(0.308)	(0.294)	(0.351)	(0.331)
Number of students		624,316	624,316	624,316	624,316
Math ACT score Illinois percentile	[45.220]	0.813**	−0.737**	0.878**	−0.650*
	{26.608}	(0.343)	(0.324)	(0.388)	(0.370)
Number of students		624,630	624,630	624,630	624,630
Science ACT score Illinois percentile	[47.391]	1.115***	−0.195	3.375***	2.111***
	{28.573}	(0.338)	(0.344)	(0.373)	(0.370)
Number of students		624,354	624,354	624,354	624,354
Reading ACT score Illinois percentile	[44.559]	1.512***	0.402	2.913***	1.841***
	{28.215}	(0.295)	(0.291)	(0.363)	(0.356)
Number of students		624,494	624,494	624,494	624,494
English ACT score Illinois percentile	[40.486]	1.812***	0.673*	0.644	−0.474
	{27.995}	(0.389)	(0.374)	(0.412)	(0.400)
Number of students		624,696	624,696	624,696	624,696
Prepolicy trend		No	No	Yes	Yes
Demographics, school characteristics, and school FE		Yes	Yes	Yes	Yes
Prior fourth-grade math test scores (individual and school levels)		Yes	Yes	Yes	Yes
Prior eighth-grade math test scores (individual and school levels)		No	Yes	No	Yes

Note. This table reports the coefficients and standard errors from regressions of interrupted time-series design of the impact of MMC on ACT outcomes. Each coefficient–standard error pair is obtained from a separate regression. Students for 2005–2010 cohorts without imputed eighth-grade test scores are included. The ACT outcome measures correspond to the percentile that the student's raw score would be in the distribution of Illinois test takers in the given year. See text for more discussion on this. All the control variable groups (demographics, school characteristics, prior fourth- and eighth-grade test scores at both individual and school levels) are corresponding to those listed in Table 1, except not controlling for the unemployment rates and school/district expenditures in Grades 11 and 12. Prepolicy mean/*SD* reports the mean/standard deviation of each outcome in 2005–2007. Robust standard errors in parentheses are clustered at high school level. MMC = Michigan Merit Curriculum; FE = fixed effects. *Significant at 10% level. **Significant at 5% level. ***Significant at 1% level.

significant at conventional levels (coef. = 0.047, *SE* = 0.031). However, passing rates on AP science exams increased somewhat at the same time. For example, among students in the top quintile, the fraction of students scoring at least a 3 on an AP science exam increased by 3.6 percentage points relative to a 16.3% prepolicy mean. For students in Quintile 3, the proportion scoring at least a 3 increased 0.005 percentage points from a baseline of 0.006.

Results for High School Attainment

The analysis above suggests that the introduction of the new course requirements had little impact on high school achievement for the average student but may have improved ACT scores for students entering high school with the weakest academic preparation. However, the concern with policies like the MMC is that by placing additional barriers to a high school diploma, these policies might lead the least prepared students to drop out.

To begin to explore this issue, we present a variety of figures that track high school completion for Michigan ninth graders in 2003 through 2010. Figure 6 shows 5-year rates for the full analysis sample.[17] As in the ACT figures, the solid lines show the unadjusted trends, normalized to 0 in 2003. The dashed lines show adjusted trends

TABLE 5

Impact of MMC on ACT Outcomes by Student Eighth-Grade Math Score Quintile

	Student eighth-grade math score quintile					Diff.
Outcome	1 (Low)	2	3	4	5 (High)	Q1 − Q5
ACT composite score						
All covariates, but no prepolicy trend	0.361***	0.120	0.122	0.148*	0.196*	0.165
	(0.062)	(0.073)	(0.081)	(0.086)	(0.112)	(0.122)
	[14.108]	[16.060]	[18.004]	[20.481]	[24.718]	
	{2.295}	{2.696}	{3.092}	{3.459}	{4.125}	
All covariates and prepolicy trend	0.354***	0.105	−0.035	−0.261***	−0.239*	0.593***
	(0.073)	(0.085)	(0.093)	(0.101)	(0.129)	(0.143)
Number of students	112,294	119,788	124,796	137,931	129,507	241,801
ACT math score						
All covariates, but no prepolicy trend	0.211***	0.094	0.184**	0.058	0.111	0.100
	(0.051)	(0.064)	(0.076)	(0.100)	(0.140)	(0.148)
	[14.766]	[16.042]	[17.698]	[20.304]	[25.128]	
	{1.709}	{2.061}	{2.734}	{3.479}	{4.337}	
All covariates and prepolicy trend	−0.119**	−0.084	−0.047	−0.428***	−0.562***	0.443***
	(0.055)	(0.074)	(0.090)	(0.113)	(0.147)	(0.153)
Number of students	112,429	119,861	124,850	137,965	129,525	241,954
ACT science score						
All covariates, but no prepolicy trend	0.391***	0.170*	0.105	0.168*	0.249**	0.142
	(0.081)	(0.096)	(0.090)	(0.096)	(0.122)	(0.142)
	[14.939]	[16.884]	[18.758]	[20.940]	[24.574]	
	{3.307}	{3.459}	{3.525}	{3.597}	{4.150}	
All covariates and prepolicy trend	0.726***	0.647***	0.337***	0.034	−0.314**	1.040***
	(0.099)	(0.111)	(0.104)	(0.110)	(0.133)	(0.163)
Number of students	112,312	119,799	124,800	137,934	129,509	241,821
ACT reading score						
All covariates, but no prepolicy trend	0.409***	0.147	0.072	0.210*	0.152	0.257
	(0.084)	(0.100)	(0.116)	(0.122)	(0.139)	(0.159)
	[14.140]	[16.153]	[18.106]	[20.528]	[24.587]	
	{3.413}	{4.071}	{4.627}	{5.093}	{5.577}	
All covariates and prepolicy trend	0.660***	0.154	−0.074	−0.119	0.145	0.515***
	(0.104)	(0.117)	(0.135)	(0.149)	(0.169)	(0.195)
Number of students	112,368	119,838	124,823	137,949	129,516	241,884
ACT English score						
All covariates, but no prepolicy trend	0.449***	0.015	0.137	0.175	0.288**	0.161
	(0.113)	(0.110)	(0.126)	(0.118)	(0.143)	(0.165)
	[12.079]	[14.652]	[16.946]	[19.642]	[24.066]	
	{3.569}	{4.025}	{4.337}	{4.589}	{5.168}	
All covariates and prepolicy trend	0.154	−0.346***	−0.367***	−0.512***	−0.217	0.371*
	(0.124)	(0.126)	(0.136)	(0.138)	(0.168)	(0.194)
Number of students	112,465	119,868	124,865	137,970	129,528	241,993
Took ACT math						
All covariates, but no prepolicy trend	−0.014	−0.014*	−0.011	−0.011*	−0.003	−0.011
	(0.011)	(0.008)	(0.007)	(0.006)	(0.005)	(0.012)
	[0.675]	[0.812]	[0.879]	[0.925]	[0.955]	
	{0.468}	{0.391}	{0.326}	{0.264}	{0.207}	
All covariates and prepolicy trend	−0.048***	−0.028***	−0.024***	−0.018**	−0.002	−0.046***
	(0.012)	(0.010)	(0.009)	(0.007)	(0.006)	(0.013)
Number of students	159,770	144,618	140,088	148,056	135,244	295,014

Note. This table reports the coefficients and standard errors from regressions identical to Columns 2 and 4 as shown in Table 2, but estimated separately for students in quintiles of eighth-grade math achievement. Each coefficient–standard error pair is obtained from a separate regression. Students for 2005–2010 cohorts with nonmissing eighth-grade test scores are included. The prepolicy mean (standard deviation) of the outcomes is reported in square brackets (braces). Robust standard errors in parentheses are clustered at high school level. MMC = Michigan Merit Curriculum.
*Significant at 10% level. **Significant at 5% level. ***Significant at 1% level.

TABLE 6

Impact of MMC on Advanced Placement Course Taking and Scores by Student Eighth-Grade Math Score Quintile

	Grade 8 math quintile		
Outcome	3	4	5 (High)
Number of AP exams taken			
Coefficient	0.028	−0.023	0.172**
SE	(0.020)	(0.037)	(0.081)
Prepolicy *M*	[0.166]	[0.429]	[1.434]
Prepolicy *SD*	{0.583}	{0.992}	{2.003}
Number of AP science exams taken			
Coefficient	0.000	−0.014	0.047
SE	(0.006)	(0.011)	(0.031)
Prepolicy *M*	[0.028]	[0.076]	[0.321]
Prepolicy *SD*	{0.178}	{0.300}	{0.680}
Average score on AP exams taken			
Coefficient	0.096	0.047	0.154**
SE	(0.144)	(0.106)	(0.071)
Prepolicy *M*	[1.738]	[2.195]	[3.179]
Prepolicy *SD*	{1.000}	{1.159}	{1.280}
Score 3+ on at least one AP exam			
Coefficient	0.004	−0.005	0.022
SE	(0.003)	(0.007)	(0.015)
Prepolicy *M*	[0.009]	[0.044]	[0.264]
Score 3+ on at least one AP science exam			
Coefficient	0.005**	0.001	0.036***
SE	(0.002)	(0.005)	(0.014)
Prepolicy *M*	[0.006]	[0.026]	[0.163]

Notes: This table reports the coefficients and standard errors from regressions of interrupted time-series design of the impact of MMC on advanced placement exam outcomes with full controls that are listed in Column 4 of Table 2, but estimated separately for students in quintiles of eighth-grade math achievement. Students for 2005–2010 cohorts with nonmissing eighth-grade test scores are included. Each coefficient–standard error pair is obtained from a separate regression. Robust standard errors in parentheses are clustered at high school level. MMC = Michigan Merit Curriculum; AP = advanced placement.

*Significant at 10% level. **Significant at 5% level. ***Significant at 1% level.

that control for all student and school characteristics with the exception of prior test scores. The dotted lines show adjusted trends that additionally control for fourth- and eighth-grade math scores at both the student and school-cohort levels.

Several patterns stand out. First, unadjusted graduation rates declined somewhat between 2003 and 2005, then grew slightly until 2007, and finally leveled out for cohorts after 2008 that were affected by the new course requirements. When we control for student demographics and economic conditions (dashed lines), completion rates look worse in the early years but better in the later years. This largely reflects the influence of the dramatically worsening economic conditions over the period, which would have been expected to decrease high school completion. The dotted trend line, which further adjusts for prior student achievement, accentuates this pattern. The reason is that elementary school achievement scores were increasing over this time period, which would have been expected to increase high school completion in the absence of other factors.

From the perspective of the ITS design, the nonlinearity of the prepolicy trend substantially complicates the analysis. If we limit the analysis to the 2005 to 2010 cohorts, in an effort to match the achievement sample, the sharp upward trajectory before 2008 implies that we will find a negative impact of the reforms using the ITS design. If we use the entire 2003 to 2007 period to estimate the prereform trajectory, these figures suggest that we will find zero or even slightly positive effects. However, the fact that the trend from 2003 to 2007 is clearly nonlinear implies that the ITS with a linear pretrend is misspecified. Finally, the existence of notable trends prior to the policy reform (at least in certain samples) suggests that the ITS estimates may differ substantially from simple difference-in-differences (DD) estimates.

Given the likely sensitivity of our results to the choice of sample and specification, Table 7 presents the full range of estimates. As suggested in the figure, estimated impact of the MMC on high school graduation ranges from negative 5 percentage points to positive 3 percentage points. We find a similar pattern of estimates for both 4- and 6-year graduation rates (results available on request). This suggests that any effects we find are not merely a result of students taking longer to graduate high school.

However, as discussed earlier, the prior literature and the details of the MMC in particular suggest that the reform should have affected students differently based on their prior academic preparation. We hypothesized that it would have little,

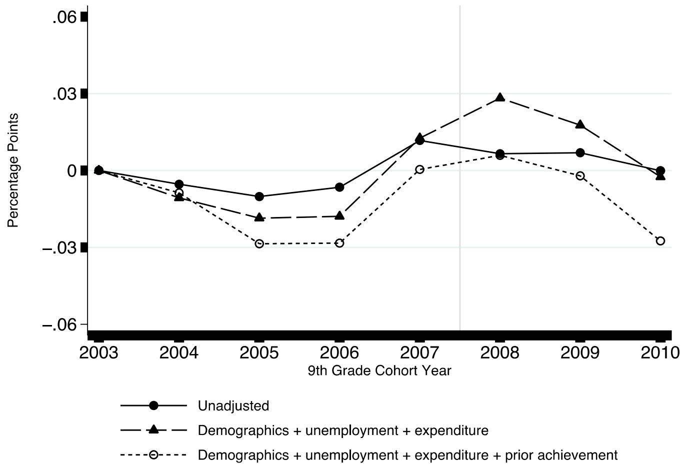

FIGURE 6. *Impact of MMC on 5-year graduation rates.*
Note. MMC = Michigan Merit Curriculum.

TABLE 7
Impact of MMC on 5-Year High School Completion Outcomes

	Outcome = graduated			Outcome = still enrolled		
	2003–2010	2004–2010	2005–2010	2003–2010	2004–2010	2005–2010
Approach	(1)	(2)	(3)	(4)	(5)	(6)
Difference-in-differences	0.005	0.008	−0.002	0.006***	0.006***	0.005***
	(0.011)	(0.011)	(0.011)	(0.002)	(0.002)	(0.002)
Interrupted time series	0.033**	0.013	−0.050**	0.004*	0.002	0.003
	(0.002)	(0.003)	(0.004)	(0.002)	(0.003)	(0.004)
Prepolicy mean	0.779	0.778	0.779	0.023	0.023	0.023
Number of students	960,830	848,629	727,776	960,830	848,629	727,776

Note. This table reports the coefficients and standard errors from difference-in-differences and interrupted time-series models, where the outcomes of graduation or enrollment are measured 5 years after high school entry. Each coefficient–standard error pair is obtained from a separate regression. Students with missing eighth-grade test scores are excluded. All regressions include the full set of control variables shown in Table 1, including demographics, school characteristics, prior fourth- and eighth-grade test scores at both individual and school levels. Robust standard errors in parentheses are clustered by high school.
*Significant at 10% level. **Significant at 5% level. ***Significant at 1% level.

if any, impact on highly prepared students, many of whom would have been taking the rigorous math and science courses prior to the new requirements and have always had extremely high graduation rates. However, we expect that it might have a negative impact on the least prepared students.

To examine this type of heterogeneity, Figures 7 to 11 show the 5-year graduation trends separately for quintiles of a student's eighth-grade performance on the standardized math exam. These quintiles are constructed separately by cohort, so they measure a student's relative position in the cohort's distribution and abstract from changes in the entire distribution over time. While there is some variation across the quintiles, each group shows a similar pattern whereby adjusted graduation rates decline over the first few years, rise sharply immediately before the reform, and then level off or drop for the cohorts to whom the new course requirements applied.

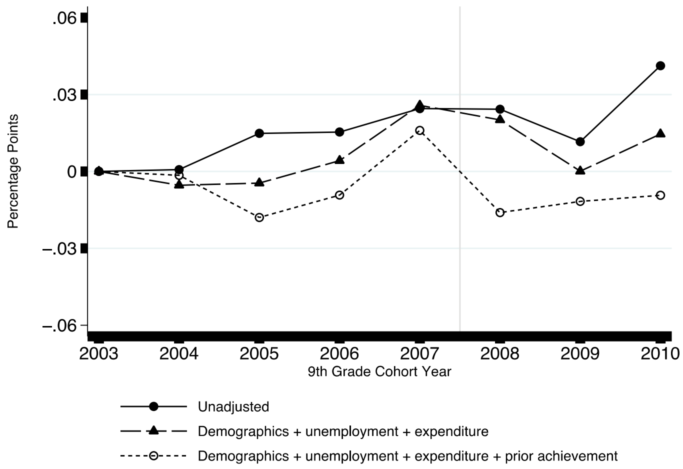

FIGURE 7. *Impact of MMC on 5-year graduation rates (Quintile 1).*
Note. MMC = Michigan Merit Curriculum.

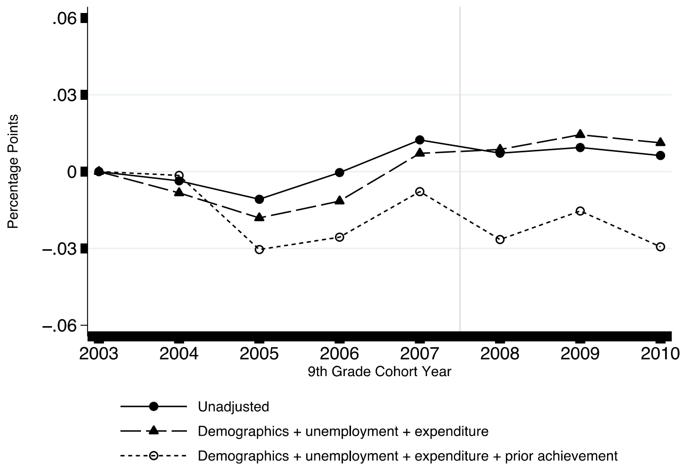

FIGURE 8. *Impact of MMC on 5-year graduation rates (Quintile 2).*
Note. MMC = Michigan Merit Curriculum.

Table 8 presents 5-year completion separately by quintile of eighth-grade score.[18] Looking across the quintiles and across the two specifications, we see that the graduation estimates are consistently smaller for the bottom quintiles. For example, the DD (ITS) estimates suggest that the new course requirements increased graduation rates for students in the top quintile by roughly 2.0 (4.8) percentage points (off a baseline of 91.8%), compared with −0.01 (0.00) percentage points for students in the bottom quintile. Again, we show the difference between the first and fifth quintile impacts in the final row of this table. In this case, the difference reveals a widening gap in high school completion rate that is statistically significant and substantively large, with the top students receiving a 4.9-percentage-point boost to their graduation rates from the MMC compared with no increase resulting from the policy for the lowest achieving group.

To the extent that one believes that the large positive coefficient for top quintile students is due to unobserved state-time specific factors unrelated to the MMC, one might consider the difference between top and bottom quintile students as the causal impact of the MMC from a comparative interrupted time-series (CITS)

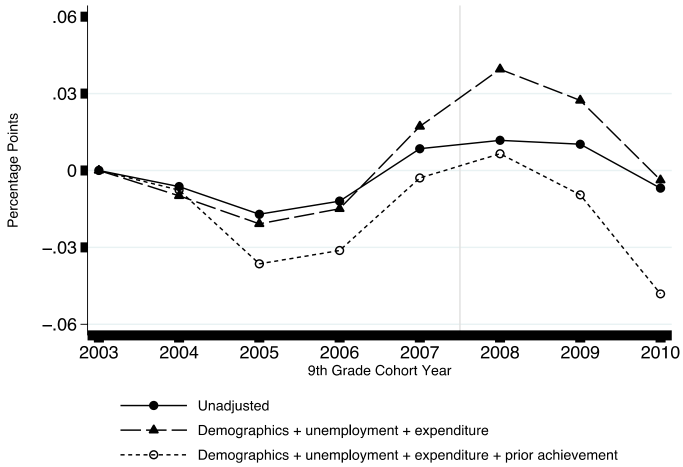

FIGURE 9. *Impact of MMC on 5-year graduation rates (Quintile 3).*
Note. MMC = Michigan Merit Curriculum.

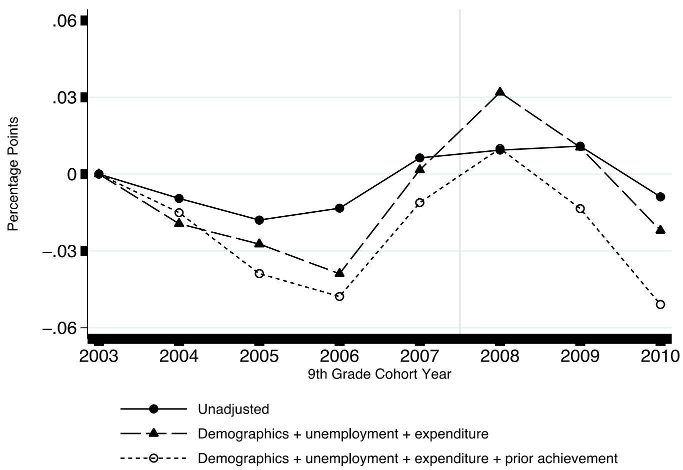

FIGURE 10. *Impact of MMC on 5-year graduation rates (Quintile 4).*
Note. MMC = Michigan Merit Curriculum.

design. This may be a reasonable assumption because the majority of students in this top quintile took MMC-mandated math and science courses prior to the new requirements, and nearly more than 90% of students in this group graduated high school prior to the reform. Using the top quintile as a counterfactual for each of the lower quintiles, we would conclude that the new policy led to a modest reduction in high school graduation among students in the bottom quintiles. For students in the bottom quintile, for example, difference-in-difference-in-differences (DDD) and CITS estimates are −0.029 and −0.049, respectively. Given the prereform completion rate of 58.6%, these effects are noticeable but modest.

Appendix Table 5 (available in the online version of the journal) shows comparable estimates for a sample that excludes 2003 and 2004 cohorts to match the sample for which we have ACT scores. As suggested in the figures, the impacts for this sample are considerably more negative. For example, the ITS model for this sample indicates that the MMC reduced graduation rates by 8.6 percentage points, and even the DD model indicates a reduction of 2 percentage points (though this estimate is not significantly different from 0).[19]

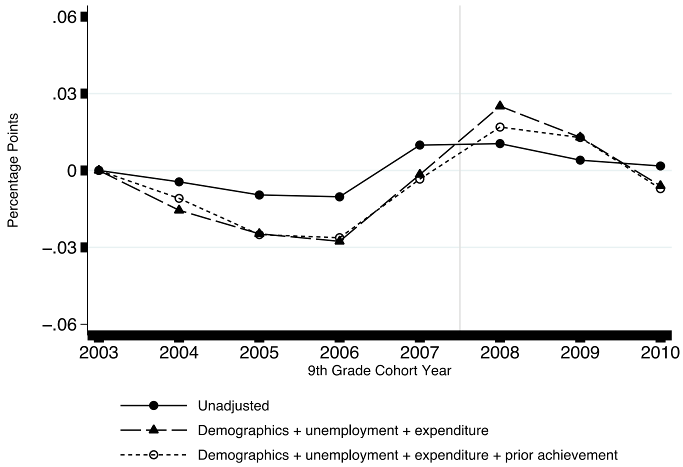

FIGURE 11. *Impact of MMC on 5-year graduation rates (Quintile 5).*
Note. MMC = Michigan Merit Curriculum.

TABLE 8
Impact of MMC on High School Outcomes by Student Eighth-Grade Math Score Quintile

	Student eighth-grade math score quintile					Diff.
Outcome	1 (Low)	2	3	4	5 (High)	Q1 − Q5
Graduated within 5 years						
All covariates, but no prepolicy trend	−0.010	−0.004	0.005	0.006	0.020	−0.029*
	(0.015)	(0.013)	(0.013)	(0.014)	(0.014)	(0.018)
	[0.586]	[0.726]	[0.809]	[0.870]	[0.918]	
All covariates, and prepolicy trend	−0.000	0.022	0.038**	0.050**	0.048**	−0.049**
	(0.016)	(0.017)	(0.019)	(0.021)	(0.021)	(0.021)
Still enrolled within 5 years						
All covariates, but no prepolicy trend	0.017***	0.010***	0.003	0.001	0.001	0.016***
	(0.004)	(0.003)	(0.003)	(0.002)	(0.001)	(0.004)
	[0.057]	[0.029]	[0.015]	[0.007]	[0.003]	
All covariates and prepolicy trend	0.013**	0.005	−0.002	−0.001	0.000	0.013**
	(0.006)	(0.004)	(0.003)	(0.002)	(0.002)	(0.006)
Number of students	207,058	192,876	186,639	195,378	178,879	385,937

Note. This table reports the coefficients and standard errors from regressions identical to those shown in Column 1 of Table 7 but estimated separately for students in quintiles of eighth-grade math achievement. Each coefficient–standard error pair is obtained from a separate regression. Students for 2003–2010 cohorts with nonmissing eighth-grade test scores are included. The prepolicy mean of the outcomes is reported in square brackets. Robust standard errors in parentheses are clustered at high school level. MMC = Michigan Merit Curriculum.
*Significant at 10% level. **Significant at 5% level. ***Significant at 1% level.

Cross-State Analysis

Given the sensitivity of the graduation results presented thus far, we turn to a cross-state analysis that allows us to control for common time effects that could confound the difference-in-differences and ITS analyses. In recent years, several states have adopted graduation policies similar to Michigan. We consider a state to have a comparable policy if its high school graduation requirements included both Algebra 1 and geometry, and at least two of the three core science classes (biology, chemistry, and physics)

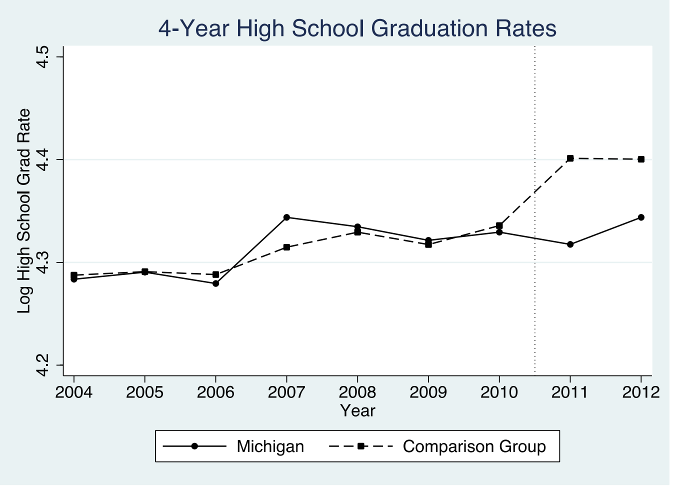

FIGURE 12. *Impact of MMC on 4-year graduation rates (synthetic control).*
Note. MMC = Michigan Merit Curriculum.

during our sample period. Appendix Table 7 (available in the online version of the journal) lists graduation requirements in each state during this period, and indicates those states with policies similar to Michigan.[20] We exclude all states with similar policies from our set of potential comparison states in the analyses described below.

A key challenge in this approach is to find a reliable state-year measure of high school graduation. Heckman and LaFontaine (2010) document a number of substantial biases inherent in the commonly used sources of data. They conclude that the decennial census (and more recently, American Community Survey) provides the most accurate estimates of educational attainment at a national level. Unfortunately, it is not possible to reliably link individuals to the state (or year) in which they attended high school with these data.

After exploring various options, we chose to use the log of the average freshman graduation rate (AFGR) calculated by the National Center for Education Statistics (NCES) and reported in the Common Core of Data (CCD). The AFGR is a proxy measure of the graduation rate created by using the diploma count to estimate the number of graduates (the numerator) and an estimated freshman class size to determine the number of possible graduates (the denominator). While less accurate than the adjusted cohort graduation rate (ACGR) that directly measures high school completion with student-level data, the AFGR is the only available national-level measure of state graduation rates covering the period in which we are interested. We use the AFGR data for the cohorts graduating in 2004 through 2012, which correspond to ninth-grade cohorts 2001 to 2009.[21] The CCD provides AFGRs for both the overall graduation rates and several subgroups. However, an inspection of the data suggested that the subgroup AFGR statistics were frequently missing and/or included implausible values in many states. For this reason, we limit our analysis to the state's overall AFGR.[22]

We adopt the synthetic control method of constructing a comparison group proposed by Abadie et al. (2010), which provides a formal method for constructing a comparison in cases where few units receive treatment. This approach uses information on prepolicy trends in the outcome measure as well as other covariates to create the best comparison for the treatment unit. State-year controls include racial composition, unemployment, logged median household income, average per-pupil expenditures for public K–12 schools, and fraction of elementary and secondary age children enrolled in private schools, along with the outcome measure (log AFGR) in 2004, 2006, 2008, and 2010.[23]

Figure 12 shows the trends in Michigan and the synthetic control group, which consists of

TABLE 9

Cross-State Analysis of High School Graduation Rates

	Outcome = log (average freshman graduation rate)					
	States selected using synthetic control method			All nonreform states		
	(1)	(2)	(3)	(4)	(5)	(6)
MMC requirement	−0.045	−0.045	−0.053	−0.073	−0.086	−0.031
RMSPE of control	0.012					
Number of valid placebos	29	29	29	29	29	29
Implied p value from placebo test	.000	.000	.170	.100	.100	.000
State- and year-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
State-year covariates	No	Yes	Yes	No	Yes	Yes
Prior trend	No	No	Yes	No	No	Yes
Control states (weight)	Alabama (0.42), Alaska (0.12), Connecticut (0.28), Vermont (0.18)			All 29 nonreform states listed in Appendix Table 6 (available in the online version of the journal) weighted equally		

Note. The AFGR is collected by the National Center of Education Statistics (NCES) and reported in the Common Core of Data. Synthetic control method described in Abadie, Diamond, and Hainmueller (2010). Covariates are listed in Appendix Table 8 (available in the online version of the journal). MMC = Michigan Merit Curriculum; RMSPE = root mean squared prediction error; AFGR = average freshman graduation rate.

Alabama (weight 0.42), Alaska (weight 0.12), Connecticut (weight 0.28), and Vermont (weight 0.18). Michigan and the control states track each other quite closely from 2004 through 2010, but then diverge in 2011, the first class affected by the new graduation requirements. The fact that the two trend lines are so similar prior to 2011 reflects the fact that the procedure was effective in finding a good “match” for Michigan.

Table 9 presents corresponding regression estimates. Columns 1 to 3 all utilize the synthetic control states (and weights) identified above (along with Michigan), with each column showing point estimates from a specification that includes different control variables. The point estimates indicate that the MMC is associated with a roughly 5% decline in the graduation rate in Michigan. As a further robustness test, Columns 4 to 6 show estimates from a more standard panel data regression in which all states are included and equally weighted. While the estimates vary a bit across specifications, the qualitative conclusion is the same—namely the introduction of the MMC was associated with a small reduction in high school graduation. Our preferred model, Column 6, indicates a roughly 3% reduction.

Given the small number of states and the fact that only one state (Michigan) is in the treatment group, standard methods of statistical inference are not appropriate. Instead, we adopt the exact inference test described by Abadie et al. (2010). We calculate the effect of a placebo treatment on all nontreated comparison states, and then produce p values for the likelihood of Type I error by calculating the percentage of these effects that are as or more extreme than the effect we estimate for Michigan. The point estimate for Michigan is smaller than all of the 29 other states in the first two specifications (Columns 1, 2), which translates to a p value of .000. For the third specification (Column 3), the point estimate for Michigan is smaller than 24 of the 29 other states, generating an implied p value of .17. The implied p values for the specifications using all nonreform states as controls (equally weighted) are .10, .10, and .00, respectively.

While the outcome of AFGR is imperfect and our estimates are necessarily imprecise given the modest number of control states, we believe that this analysis provides suggestive evidence that the introduction of the new course requirements in Michigan led to a small reduction in high school completion.

Discussion and Conclusion

The MMC implemented a standardized curriculum across the state, which closely resembled the core set of classes commonly required for college admittance. Among the changes the policy required was an increase in the number of math and science courses needed for graduation. The assumption of the policy was that having students take more rigorous courses would better prepare them for college and the workplace.

We find that the introduction of the policy had relatively slight impact on selected measures of student achievement and educational attainment. There is some evidence that the new course requirements led to an increase in science achievement, which is reflected in higher scores on both the ACT exam and AP courses. In science and other subjects, the evidence suggests that students who entered high school with the weakest academic preparation may have experienced the largest benefits of the policy. However, for the bottom quintile group in science, where we see the largest effects, the impact was modest: an increase of 0.73 ACT scale points, relative to a baseline of roughly 15 points.

Our results for high school completion are more sensitive to the choice of sample and specification. If we use ninth-grade cohorts from 2003 through 2010, the ITS estimate suggests a 3.3-percentage-point (4%) increase in graduate rates; if we focus instead on the 2005 to 2010 cohorts, we find a 5-percentage-point (6.4%) decline in graduation rates. The difference is due to the highly nonlinear prereform trend in high school completion, especially the sharp increase in graduation rates for the cohort immediately prior to the reform.

As with the achievement analysis, we find larger impacts among the students with the weakest academic preparation entering high school. In the case of completion, however, we find that these lower achieving students experience the largest reductions in the likelihood of graduation under the new policy. We suspect that this was caused by higher failure rates among low-performing students pushed into more difficult courses by the new requirement, a claim which we will investigate in subsequent analyses of student transcript data.

A sizable portion of the decrease in high school graduation rates can be explained by an increase in drop-out rates captured in the state administrative data. The remaining decrease in high school graduation rates may also be due to drop-outs that are not captured in the state data or due to a variety of other factors such as students obtaining a general education diploma (GED) and enlisting in the military. Unfortunately, the available state administrative data do not allow us to reliably explore these other outcomes.

Given recent trends in districts and states adopting more rigorous high school curriculum requirements (Domina & Saldana, 2012), it is critical to understand how such changes influence student outcomes. Our results suggest that higher standards alone will have, at best, a limited impact on student performance. Future research will allow us to examine if the policy did have an impact on college attendance and degree completion. It will also allow us to better pin down the mechanisms responsible for any reduction in high school graduation and the pattern of achievement effects across students with different initial achievement levels. With a deeper understanding of these mechanisms, policymakers will be able to adapt the policy to enhance its benefits and mitigate its costs.

Authors' Note

This research uses data structured and maintained by the Michigan Consortium for Educational Research (MCER). MCER data are modified for analysis using rules governed by MCER and are not identical to data collected and maintained by MDE and CEPI. Results, information, and opinions are the authors' and do not reflect the views or positions of MDE or CEPI.

Acknowledgments

Thanks to our partners at the Michigan Department of Education (MDE) and Michigan's Center for Educational Performance and Information (CEPI), especially Thomas Howell, Venessa Keesler, and Joseph Martineau. An army of research assistants worked to prepare these data, and we are eternally grateful to them all.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: The Institute of Education Sciences provided generous support through Grant R305E100008.

Notes

1. See https://nces.ed.gov/programs/digest/d13/tables/dt13_225.40.asp

2. In future work, as the affected cohorts age, we will also examine effects on postsecondary attainment, choice, and achievement.

3. See page 2 in http://www.michigan.gov/documents/mde/faq1_178592_7.pdf.

4. Authors' calculations based on data provided by the Michigan Department of Education.

5. In a related set of analyses, researchers studied a program of "double-dose" algebra that Chicago implemented in an effort to improve outcomes among low-performing students. In 2003, Chicago required students with below-average math scores to take two periods of algebra. Researchers found that test scores increased among students targeted for this "double dose" as well as those who were not. But, at the same time, failure rates increased among students who were not targeted for the double dose (Nomi & Allensworth, 2009; see also Cortes, Goodman, & Nomi, 2015). Subsequent research indicated that the double-dose policy led schools to sort students into math classes based on the ability to a greater extent than they had previously. As a result, some students who were just above the average were sorted into classes with higher performing peers and more rigorous standards. This contributed to the improvement in their scores but also led to higher failure rates for this group. Nomi (2012) documents that the double-dose policy led to more mixed-ability classes and a subsequent decline in high-performing students.

6. The interrupted time-series (ITS) approach has been used by a number of researchers to evaluate district- and state-initiated reforms, including comprehensive Accelerated Schools (Bloom, Ham, Melton, & O'Brien, 2001), Talent Development (Herlihy, Kemple, & Smith, 2005), and district-wide high-stakes testing (Jacob, 2005).

7. Colorado also had mandatory ACT over this period. We chose to focus exclusively on Illinois because it is more similar to Michigan on a variety of dimensions, and thus likely a better comparison. Several other states later adapted mandatory ACT policies. For more information on these, see Hyman (2016).

8. For example, a student who scored 23 on the ACT math would be at the 71st percentile of the Illinois distribution if he or she were in the 2005 cohort and the 67th percentile if he or she were in the 2010 cohort.

9. The student longitudinal data system (SLDS) officially began with the 2002–2003 academic year. We obtain the 2001–2002 eighth-grade test scores for the first cohort in our sample by matching older test score files to the longitudinal data via a fuzzy match using name, sex, race, and school district. Match rates were 93%, meaning that we were able to match 93% of students in the test score files to the SLDS. Note that we would not expect all to match because some students would have left the Michigan Public Schools between 2001–2002 and 2002–2003.

10. The state, when calculating its high school graduation rates for each cohort of freshmen, uses a federal formula that excludes students who transfer to private school or leave the state. We do not exclude such students from the analytic sample, so our measures will differ slightly from officially published graduation rates.

11. Relative to the 2008 cohort, the 2009 had higher scores in eighth-grade science (0.17 *SD*) and seventh-grade English (0.11 *SD*) and reading (0.19 *SD*) but lower scores in seventh-grade writing (0.07 *SD*).

12. As sensitivity analyses, we estimate all models excluding the eighth-grade test scores (but keeping the fourth-grade scores) and obtain comparable results.

13. As discussed above, we believe that eighth-grade scores should be a control in our model. However, Table 1 shows an extremely large (0.27 *SD*) increase in eighth-grade math scores between the 2008 and 2009 cohort. Given the strong relationship between eighth-grade test scores and ACT scores, the inclusion of eighth-grade controls has a noticeable influence on our estimates. For this reason, we show results with and without these Grade 8 controls.

14. This is not due to the policy-induced reduction in high school completion documented above. In results available upon request, we find comparable impacts on test taking if we limit the analysis to students who attended 11th grade and/or graduated from a Michigan public high school.

15. In an effort to determine the magnitude of any bias in our analysis, we adopt the approach outlined by Frank, Maroulis, Duong, and Kelcey (2013). We apply our analysis to the estimated effect of 0.726 and standard error of 0.099 from the first column of Table 5 for the lowest quintile of students for science, including covariates and pre-policy trends. Using statistical significance as a threshold for our sample of 112,312 (df = 111,611), and standard error of 0.099, $\delta^{\#} = SE \times t_{\text{critical},df = 7,600} = 0.099\ (1.96) = .194$. Given the estimated effect of 0.726, to invalidate the inference bias must have accounted for $1 - .194 / 0.726 = 0.733$, or

about 73% of the estimated effect. Drawing on Rubin's Causal Model, to invalidate our inference one would have to replace about 73% (about 82,294) of the cases, and assume the limiting condition of zero effect in the replacement counterfactual cases. For the estimate of 0.391 that does not account for the pre-policy trend, the bias would have to be roughly 59% of the estimated effect. These levels of robustness are greater than half to two thirds of the *EEPA* studies reviewed by Frank, Maroulis, Duong, and Kelcey (2013). Thus, while we concede that there are limitations to implementing the ITS design in this case, we would argue that limitations are likely not great enough to invalidate our inferences.

16. Essentially no students in the bottom two quintiles take advanced placement (AP) exams.

17. The trends in 4-year graduation results look virtually identical.

18. There are fewer than 100 unique values of the eighth-grade raw scores, which is the reason that the number of observations per quintile differs somewhat.

19. Given the large decline in graduation rates implied by the ITS estimates above, it is useful to examine what might have happened to the bottom quintile students under the Michigan Merit Curriculum (MMC). With the caveats regard data quality discussed above, Appendix Table 5 (available in the online version of the journal) presents estimates of how the reforms influenced the following outcomes: dropping out, leaving Michigan public schools, and a catch-all "other" category, which includes completion other than graduation (e.g., general education diploma [GED], completion of a special education track that does not result in a diploma), incarceration, enlistment in the military, enrollment in homeschooling, and death. These results indicate that the bulk of the decrease in graduation is accounted for by an increase in outcomes captured in the "other" category.

20. States other than Michigan that met this definition are Arizona, Arkansas, Delaware, District of Columbia, Georgia, Idaho, Illinois, Indiana, Kansas, Kentucky, Louisiana, Minnesota, Mississippi, Oklahoma, South Dakota, Tennessee, Texas, Utah, and West Virginia. Several of these states' requirements were implemented in different years for math and science. For example, the math requirement in Arkansas was binding for the graduating class of 2009, whereas the science requirement was binding for the class of 2010. In this case, the earlier year was coded as the beginning of the treatment period. In addition, nine states had policies that were similar to MMC for either math or science but not both.

21. The average freshman graduation rate (AFGR) is not available after 2012, which means that we cannot include our final cohort in the cross-state analysis.

22. AFGR was missing in seven state-year observations. In these cases, we use an interpolated value to replace the missing.

23. Appendix Table 8 (available in the online version of the journal) presents summary statistics.

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Manuscript received February 11, 2016
First revision received September 12, 2016
Second revision received October 30, 2016
Accepted November 16, 2016