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CHAPTER 1:

GAPS IN THE STEM PIPELINE: WHAT CAN WE LEARN FROM IMMIGRANT-NATIVE COMPARISONS?

1.1 Introduction

The improvement of Science, Technology, Engineering and Mathematics (STEM) education has been identified as a top national priority.[1] Since 2010, over $12 billion has been invested on distinct programs to promote students' participation and performance in STEM fields. The goal is to produce one million more U.S. college graduates with STEM degrees than what are expected at the current rates over the next decade. As stated by President Obama, "reaffirming and strengthening America's role as the world's engine of scientific discovery and technological innovation is essential to meeting the challenges of this century." [2]

When evaluating the current college educated workforce, we notice that immigrants are highly concentrated in STEM fields. Data from the National Science Foundation (NSF) reveal that 26 percent of the college educated STEM workers are foreign-born – twice their share in the total working population. About 60 and 27 percent

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[1] The White House, Office of the Press Secretary, November 23, 2009. "President Obama Launches 'Educate to Innovate' Campaign for Excellence in Science, Technology, Engineering & Math (Stem) Education."

[2] *Ibid.*

of foreign-born STEM workers are from Asia and Europe, respectively. While economists have examined the contribution of high skilled immigration on domestic innovation and invention, and the impacts on the employment and earnings of their native counterparts (Card, 2004; Hunt and Loiselle, 2010; Kerr and Lincoln, 2010; Peri, 2007), we currently know little about immigrant students in the STEM pipeline in U.S. postsecondary education. On the other hand, immigrants account for an increasingly larger share of the undergraduate student population in U.S. higher education. A recent report by the Education Department's National Center for Education Statistics (NCES) demonstrates that about 10 percent of the college students in 2007-08 are first-generation immigrants and 13 percent are second-generation immigrants with foreign-born parents.[3] Understanding immigrants' educational attainment in the STEM pipeline is important not only for its own sake, but could also provide unique insights into college STEM attainment of their native counterparts.

This paper documents the immigrant-native college STEM attainment gap by addressing several related questions: First of all, is the immigrant-native gap in the STEM workforce observed in the STEM pipeline in college? How do STEM enrollment and persistence patterns differ across immigration generations as well as racial and ethnic groups? Second, to what extent are the different patterns explained by the observable characteristics, including socioeconomic status (SES), individual preferences, and academic preparation in math and science? Most importantly, what can we learn from these comparisons? Using nationally representative student survey data from the

[3] National Center for Education Statistics, 2012. "New Americans in Postsecondary Education: A Profile of Immigrant and Second-Generation American Undergraduates."

Beginning Postsecondary Longitudinal Studies 2004/09 (BPS 2004/09), I classify the sample into four groups: native students to U.S.-born parents, second-generation immigrant students with foreign-born parents, 1.5-generation immigrant students who came to the U.S. before or in their early teens and were educated in the U.S. before college, and recent first-generation immigrant students who attended foreign K-12 schools. I focus on two measures of students' college STEM attainment: entry and persistence, because both measures are critical to strengthening the STEM pipeline.[4]

I find that immigrant students have significantly higher rates entering and persisting in STEM fields compared to natives. The college STEM attainment advantage is particularly large among recent first-generation Asian and white immigrant students, who are 16 percentage points more likely to enter and persist in STEM fields than natives. The likelihood of entering and persisting in STEM fields are about 11 and 19 percentage points higher for 1.5-generation immigrant students, and 6 percentage points higher for second-generation immigrant students. Taking advantage of detailed survey data, I explore the factors that are associated with immigrants' higher college STEM attainment, focusing on Asians and whites as an example of groups who are successful at both STEM entry and persistence. The findings suggest that accounting for socioeconomic status, including demographic characteristics, family backgrounds, and school characteristics, closes the gap between first generation immigrant students and natives by about 30 – 50 percent. The coefficients on second-generation immigrant

[4] For papers examining STEM entry and persistence, see Astin and Astin (1992), Kokkelenberg and Sinha (2010), Lowell et al. (2009), Mendez et al. (2008), Shaw and Barbuti (2010), Strenta et al. (1994), Huang, Taddese, and Walter (2000).

students are no longer statistically significant. Controlling for individual preferences, using data on students' claimed important goals, on the other hand, does not have much impact on the estimates. I demonstrate that the most important factor contributing to first-generation immigrants' higher college STEM attainment is their better academic preparation in math and science in high school. In particular, the estimates suggest that it is not the number of years, but the level of math courses, such as whether having taken calculus and SAT/ACT math scores that determine students' college STEM attainment. The estimated immigrant-native difference in entering and persisting in STEM fields becomes no longer statistically significant after including the full set of academic control variables. The findings indicate that strengthening the quality of high school math and science education is an important vehicle for improving students' college STEM attainment.

This paper draws on the existing literature on students' major choice. Previous studies have demonstrated that socioeconomic characteristics, including age, gender, race and ethnicity, family income, and parents' education, are important determinants of students' choice of a STEM major. For example, certain demographic groups, such as females, blacks, and Hispanics are underrepresented in STEM majors (Maple and Stage, 1991; Griffith, 2010). Studies also found that students from low-income families are significantly more likely to be interested in choosing STEM majors than students from wealthier (Saks and Shore, 2005; Caner and Okten, 2010; Lichtenberger and George-Jackson, 2013).[5] Next, individual preferences have also been found to a crucial factor in

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[5] Using data from Panel Study of Income Dynamics (PSID), Saks and Shore (2005) show large income variance for different careers. In particular, business, sales, and entertainment careers are more

students' choice of a STEM major. For example, using data from Baccalaureate and Beyond (B&B) Longitudinal Study, Hilmer and Hilmer (2012) demonstrated that students who reported being financially well-off as important were more likely to major in business and engineering. In contrast, students who considered family as important were more likely to major in education. Exploiting experimental data from Northwestern University sophomores, Zafar (2009) found that the gender gap in STEM fields is largely due to different preferences. In particular, when choosing a major, female students cared more about the non-pecuniary aspects in college, whereas male students cared more about the monetary return at the workplace. Finally, several papers have examined how pre-college academic preparation impacts students' college STEM attainment. In particular, it has been found that high school math and science courses, and SAT/ACT math scores, are highly related to students' decision to pursue STEM majors when they enter college (Ost, 2010; Rask, 2010; Crisp, Nora and Taggart, 2009). Using a dynamic structural model of major choice, Arcidiacono (2004) demonstrated that students with higher ability were more likely to sort into high paying majors such as science and engineering. Drawing data from the Berea Panel Study, Stinebrickner and Stinebrickner (2011) found that students were open to mathematics and science at the beginning of college, but many of them transferred to other majors after realizing their lack in academic ability.

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risky in terms of income stream than others. By matching the career specific risks to major choice, they found that students from wealthier families are more likely to choose riskier careers using data from National Postsecondary Student Aid Survey (NPSAS).

In this paper, I consider three potential channels that might lead to the immigrant-native educational attainment gap in STEM fields in college. First, immigrant students might differ from native students in terms of demographic characteristics and family backgrounds. If immigrant students have a larger share of males and students from low-income families, they might be more likely to major in STEM fields than natives. Second, immigrant students and natives might have different motivations and preferences. For example, it might be more important for immigrant students to have a steady job and be financially well-off whereas achieving political influence is more motivating for native students. As immigrant and native students choose the major that best matches their motivations and preferences, we might expect immigrant students more concentrated in STEM fields whereas native students more likely to be in non-STEM fields. Next, the immigrant-native college STEM attainment gap might arise from variation in students' academic preparation in math and science. In the latest Program for International Student Assessment (PISA), an international assessment on the skills and knowledge of 15-year-old students conducted by Orginisation for Economic Cooperation and Development (OECD), U.S. teens ranked only 31st in math and 24th in science among students from 65 education systems, lagging behind many of their peers from Asia and Europe.[6] Therefore, immigrant students, especially those who attended foreign K-12 schools, might have stronger academic preparation in math and science compared to natives, and this might contribute to higher college STEM attainment. Understanding

[6] PISA 2012 Results in Focus: What 15-year-olds Know and What They Can Do With What They Know: Key Results from PISA 2012, OECD, 2012

what is driving the immigrant-native college STEM attainment gap has important implications for effective policy intervention. For example, if the immigrants' college STEM advantage is mainly due to stronger academic preparation in math and science, then more efforts should be devoted to enhancing students' math and science skills in high school. Alternatively, if the immigrant-native college STEM attainment gap arises from different individual preferences, then the focus of policies should be to inspire and motivate native students to study STEM majors and pursue STEM careers.

1.2 Data and Sample

The main analysis sample is based on restricted-use data from the Beginning Postsecondary Students Longitudinal Study 2004/09 (BPS: 2004/09). Conducted by the National Center of Education Statistics (NCES), BPS: 2004/09 tracks the postsecondary educational experiences of a nationally representative cohort of students who first enrolled in college during the 2003-04 academic year. Follow-up surveys were conducted at the end of their third (2005-06) and sixth (2008-09) years after entering college. As one of the largest surveys among undergraduates in the U.S., BPS: 2004/09 contains comprehensive information on students' demographic characteristics, family backgrounds, academic preparation for college, as well as their academic experience and degree attainment in college.

I define students' immigrant generational status based on where they were born, where their parents were born, and where they were educated before college. As illustrated in Table 1, first-generation immigrants are foreign-born students, second-generation immigrants are U.S.-born students who have at least one foreign-born parent, and higher-generation are native students to U.S.-born parents. Since there might be considerable variation between first-generation who immigrated before or in early teens and those who immigrated later, I further classify the foreign-born students into two subgroups based on whether they attended foreign K-12 schools: 1.5-generation immigrants are those who came earlier and received all of K-12 education in the U.S. whereas recent first-generation immigrants are those who came to the U.S. in later years and were educated in their home country before college.[7]

TABLE 1.1

DEFINITION OF IMMIGRANT STATUS

	Parents Foreign-born	Foreign-born	Foreign K-12
Natives			
2nd Gen	Y		
1.5 Gen	Y	Y	
1st Gen	Y	Y	Y

NOTE: Classification of 1.5-generation from recent first-generation based on responses to the survey question on whether they had attended foreign K-12 school.

[7] I distinguish 1.5-generation from recent first-generation based on their response to the survey question on whether they had attended foreign K-12 school. BPS does not ask respondents about the specific number of years of foreign K-12 education.

STEM majors are defined according to the NCES, including biology, computer science, math, physics and engineering. I construct two measures of student STEM college attainment, that is, entry and persistence. STEM entry indicates whether the student ever majored in STEM in college. That is, they reported a STEM major in either the 2003/04 or the 05/06 academic years. STEM persistence denotes whether she remained in STEM throughout college. In other words, STEM persisters are a subgroup of STEM entrants who reported a STEM major in one or both of the first two waves and were either still enrolled as STEM majors in 2009 when the survey was last conducted or had attained a STEM degree by 2009.

TABLE 1.2

IMMIGRANT-NATIVE SHARE IN THE STUDENT POPULATION

	Native	*2nd Gen*	*1.5 Gen*	*1st Gen*
All	79.17%	11.91%	3.43%	5.49%
STEM				
Entry	74.83%	12.97%	4.21%	8.54%
Persistence	72.29%	13.25%	4.75%	9.71%
N	9,280	1,400	400	640

NOTE: Data from BPS 2004/09, for a sample of students with non-missing data on math and science preparation, including SAT scores, years of math, years of science, and highest level of math in high school. Sample sizes are rounded to the nearest ten to comply with the restricted-use data licensing requirements from NCES.
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Table 2 provides the immigrant-native share in the total student population and in STEM fields. I focus on students with non-missing data on demographic characteristics, SAT/ACT scores, high school academic preparation, and college major. The data suggest that about 12 percent of all undergraduates are second-generation students with foreign-born parents, and 9 percent are first-generation students. In particular, 5.5 percent of the foreign-born students are recent immigrants who attended foreign K-12 schools. Moving to the next two rows, I find that immigrant students have a higher proportion majoring in STEM fields compared to natives. Notably, the share of recent first-generation students is about 8.5 percent in the subsample of students who ever enrolled in STEM majors and 9.7 percent in the subsample of and students who persisted in STEM majors, almost twice as large as their share in the total student population. Second and 1.5-generation also see increases in their representation in the two subsamples.

Table 3 reports summary statistics by students' immigrant generational status. The top panel shows students' socioeconomic characteristics, including age, gender, race and ethnicity, family income, and parents' education. I find that first-generation immigrant students, especially those who came more recently, are more likely to be male, black, or Asian compared to students of other generations. For example, Asians make up about 23 and 29 percent of 1.5 generation and recent first-generation immigrant students, respectively, much higher than their share of natives and second-generation immigrant students. Immigrant students also tend to come from families with lower income and less educated parents. In particular, about 40 percent of first- and second-generation immigrant students are the first generation in their family to attend college, as compared to fewer than 30 percent of natives. Next, the middle panel explores individual

TABLE 1.3

SUMMARY STATISTICS

	Native	*2nd Gen*	*1.5 Gen*	*1st Gen*
Socioeconomic status				
Age	18.62	18.44	18.63	18.80
Male	0.44	0.42	0.46	0.53
Black	0.12	0.10	0.08	0.15
Hispanics	0.06	0.36	0.31	0.30
Asian	0.00	0.18	0.23	0.29
Income percentile	0.53	0.45	0.45	0.38
College degree	0.72	0.60	0.65	0.61
Claimed important goals				
Community leader	0.45	0.47	0.47	0.44
Political influence	0.24	0.27	0.26	0.21
Financial well-off	0.74	0.82	0.81	0.78
Steady work	0.88	0.88	0.89	0.86
Leisure	0.88	0.84	0.86	0.80
Having children	0.70	0.67	0.61	0.54
Close to relatives	0.43	0.46	0.47	0.47
Academic preparation				
Years: Math	3.44	3.44	3.57	3.49
Years: Science	3.26	3.15	3.25	3.25
Years: English	3.81	3.75	3.80	3.79
Years: Social	3.38	3.37	3.36	3.30
Had calculus	0.19	0.21	0.22	0.27
SAT math	495.07	494.45	491.49	500.16
SAT verbal	501.97	486.17	485.44	453.41

NOTE: Data from BPS 2004/09, for a sample of students with non-missing data on math and science preparation, including SAT scores, years of math, years of science, and highest level of math in high school. Parental educational attainment is measured as having any college degree, including an associate’s degree and above.

preferences of native and immigrant students based on their claimed important goals. Specifically, students were asked whether the following aspects were important to them, including being financially well-off; having steady work; being a community leader; influencing the political structure; having leisure time; having children, and living close to relatives. I create a set of preference dummy variables for each of the aspects that equals one for student *i* if she claims it as important. I find that second- and 1.5-generation immigrant students are more likely to value being a community leader, achieving political influence, and, being financially well off than natives and recent first-generation immigrant students. The data also suggest that natives put a higher value on leisure time and children more than immigrant students. About 70 percent of natives claim having children as important as compared to 61 and 54 percent among 1.5 and recent first-generation immigrant students. The lower panel demonstrates that, on average, immigrant students and native students have similar amount of math and science courses in high school. Despite of the similar number of years, immigrant students are more likely to take advanced math courses. The share of students who have taken calculus before college is about 27 percent among recent first-generation students, as compared to about 20 percent among natives and second-generation immigrant students. Finally, recent first-generation immigrant students also have higher SAT math scores but much lower verbal scores compared to others.

1.3 Empirical Strategy and Results

To empirically examine the immigrant-native gap in the STEM pipeline, I estimate the following linear probability model,

$$Y_i = \beta_0 + \beta_1 IM_i + X_i\beta_2 + \varepsilon_i, \quad (1)$$

where the outcome variable is the college STEM attainment of student *I*, that is, entering and persisting in STEM fields. The key variables of interest are the set of dummy variables indicating students' immigrant generational status *IM*, including recent first-generation students who attended foreign K-12 schools, non-recent first-generation (1.5-generation) students who attended U.S. K-12 schools, and second-generation students with at least one foreign-born parent. The native students are the omitted group. Without controlling for other covariates, the coefficients on the immigrant dummies demonstrate the raw gaps in STEM enrollment and persistence rates between immigrant and native students.

Table 4 presents the basic results on the immigrant-native college STEM attainment gap. Coefficients in each column are from a separate regression for the outcome listed above. Column 1 and 2 report the results for the full sample. Native means are reported at the bottom of the table to facilitate interpretation of the results. Starting with STEM entry, I find that recent first-generation immigrant students are 13.6 percentage points more likely to enter STEM fields compared to natives. The gap is particularly large when evaluated at the mean entry rate of natives. The gaps become smaller and no longer statistically significant for higher generations. The estimates suggest that non-recent first-generation and second-generation immigrant students are about 3.5 and 2.1 percentage points more likely than natives to enter STEM fields,

TABLE 1.4

IMMIGRANT-NATIVE COLLEGE STEM ATTAINMENT GAP

	Entry	*Persistence*	
	(1)	*(2)*	*(3)*
1st Gen	0.1360*** (0.0276)	0.0864*** (0.0189)	0.0491 (0.0529)
1.5 Gen	0.0348 (0.0283)	0.0358* (0.0215)	0.0714 (0.605)
2nd Gen	0.0206 (0.0157)	0.0062 (0.0109)	-0.0175 (0.0368)
Native mean	0.22	0.11	0.51
N	11720	11720	2750
R^2	0.0055	0.0039	0.0007

***p < .01, **p < .05, *p < .1
NOTE: Data from BPS 2004/09, for a sample of students with non-missing data on math and science preparation, including SAT scores, years of math, years of science, and highest level of math in high school. Parental educational attainment is measured as having any college degree, including an associate's degree and above. Column 2 reports estimates using the full sample whereas column 3 reports estimates from a subsample of students who have entered STEM fields. Regressions are weighted. Sample sizes are rounded to the nearest ten to comply with the restricted-use data licensing requirements from NCES.

respectively. Column 2 demonstrates that first-generation immigrant students are also much more likely to persist in STEM fields than natives. The likelihood of persisting in STEM fields is about 8.6 percentage points higher among recent first-generation and 3.6 percentage points higher among 1.5-generation immigrant students, respectively whereas the rate of STEM persistence seems to be similar between second-generation immigrant and native students. Column 3 compares the immigrant-native STEM persistence gap conditional on entry. The sample is limited to students who have ever entered STEM fields. The results suggest that immigrants' college STEM advantage mostly happen at entry. Conditional on entering STEM fields, the coefficient on recent first-generation immigrant students reduces to about 5 percentage points whereas the coefficient on 1.5-generation immigrant students rises to 7.14 percentage points. However, neither of the estimates is statistically significant. The coefficient on second-generation immigrant students even becomes negative.

As discussed earlier, there is a substantial amount of cross-country/ region variation in the college-educated STEM workforce, with about 90 percent of the immigrants from Asia and Europe. To explore whether this variation is reflected in the STEM pipeline in college, I divide the immigrant population into four groups: Asian, white, black, and Hispanic, and decompose the immigrant-native gap by race and ethnicity.[8] The results are presented in Table 5. The estimates on entry and persistence conditional on entry are reported in the upper and lower panels, respectively. The results demonstrate that consistent with the cross-country/region variation in the STEM workforce, Asian and white immigrant students are considerably more successful at both STEM entry and persistence. Compared to natives, the likelihood of entering and persisting in STEM fields is about 19 and 20 percentage points higher for recent first-generation Asian immigrant students, and 9 and11 percentage points higher for whites. By contrast, the immigrant college STEM attainment advantage is not found among blacks and Hispanics. In particular, the estimates suggest that although recent first-

[8] BPS 2004/09 does not contain information on the country of origin.

TABLE 1.5

IMMIGRANT-NATIVE COLLEGE ATTAINMENT GAP: BY RACE AND ETHINICITY

	Asian	*White*	*Black*	*Hispanic*
	(1)	*(2)*	*(3)*	*(4)*
		Entry		
1st Gen	0.2085***	0.0888*	0.3040***	0.0333
	(0.0431)	(0.0497)	(0.0911)	(0.0390)
1.5 Gen	0.1141*	0.11043*	-0.0757	-0.0134
	(0.0583)	(0.0557)	(0.0762)	(0.0476)
2nd Gen	0.1448***	0.0063	-0.0417	-0.0063
	(0.0394)	(0.0275)	(0.0393)	(0.0251)
N	11720			
R^2	0.0116			
		Persistence		
1st Gen	0.1876***	0.1085	-0.1883	0.0431
	(0.0595)	(0.0891)	(0.1189)	(0.0818)
1.5 Gen	0.0647	0.2964***	-0.3192*	-0.0734
	(0.1006)	(0.0837)	(0.1734)	(0.1163)
2nd Gen	0.1085*	-0.0020	-0.0387	0.1351**
	(0.0652)	(0.0692)	(0.1092)	(0.0602)
N	2750			
R^2	0.0148			

***p < .01, **p < .05, *p < .1

NOTE: Data from BPS 2004/09, for a sample of students with non-missing data on math and science preparation, including SAT scores, years of math, years of science, and highest level of math in high school. The top panel reports estimates using the full sample whereas the lower panel reports estimates from a subsample of students who have entered STEM fields. Regressions are weighted. Sample sizes are rounded to the nearest ten to comply with the restricted-use data licensing requirements from NCES.

generation black immigrants are significantly more likely to enter STEM fields, they are about 19 percentage points less likely to persist than natives conditional on entry. As column 4 demonstrates, there is no statistically significant difference in college STEM attainment between first-generation Hispanic immigrant students and natives, whereas STEM persistence rate is about 14 percentage points higher among second-generation Hispanics.

Why are Asian and white immigrant students more likely to enter and persist in STEM fields? What are the factors that contribute to their higher college STEM attainment? In Table 6 to 10, I consider three channels, including socioeconomic characteristics, individual preferences, and academic preparation in math and science, which might lead to college STEM attainment gap between Asian and white immigrant students versus natives.[9]

The analysis on STEM persistence gap is based on the subgroup of STEM entrants.[10] Table 6 first presents estimates on college STEM attainment gap between Asian and white immigrant students and natives. As demonstrated, Asian and white immigrant students are significantly more likely to enter and persist in STEM fields compared to natives. The coefficients on recent first-generation immigrant students are about 16 percentage points at both entry and persistence whereas the coefficients on non-recent first-generation immigrant students are about 11 percentage points at entering STEM fields and 19 percentage points at persisting. The estimated difference is smaller between second-generation and native students, at about 6 percentage points.

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[9] Results on blacks and Hispanics are listed in the appendix tables.

[10] Results on STEM persistence gap from the full sample are listed in the appendix table.

TABLE 1.6

IMMIGRANT-NATIVE COLLEGE STEM ATTAINMENT GAP

	Entry	*Persistence*
	(1)	*(2)*
1^{st} Gen	0.1597***	0.1614***
	(0.0331)	(0.0506)
1.5 Gen	0.1089***	0.1865***
	(0.0404)	(0.694)
2^{nd} Gen	0.0614***	0.0550
	(0.0231)	(0.0488)
Native mean	0.22	0.51
N	11720	2750
R^2	0.0098	0.0133

***p < .01, **p < .05, *p < .1

NOTE: Data from BPS 2004/09, for a sample of students with non-missing data on math and science preparation, including SAT scores, years of math, years of science, and highest level of math in high school. Parental educational attainment is measured as having any college degree, including an associate's degree and above. The estimates represent the immigrant-native college STEM attainment gap between Asian and white immigrant students and natives. Column 2 reports estimates from a subsample of students who have entered STEM fields. Regressions are weighted. Sample sizes are rounded to the nearest ten to comply with the restricted-use data licensing requirements from NCES.

TABLE 1.7

IMMIGRANT-NATIVE COLLEGE STEM ATTAINMENT GAP, CONTROLLING FOR SES

	Entry		*Persistence*	
	(1)	*(2)*	*(3)*	*(4)*
1st Gen	0.1597***	0.0870**	0.1614***	0.0896
	(0.0331)	(0.0367)	(0.0506)	(0.0646)
1.5 Gen	0.1089***	0.0510	0.1865***	0.1330*
	(0.0404)	(0.0429)	(0.694)	(0.749)
2nd Gen	0.0614***	0.0105	0.0550	-0.0043
	(0.0231)	(0.0245)	(0.0488)	(0.0587)
Age		-0.0056		-0.0260*
		(0.0055)		(0.0138)
Male		0.1886***		0.0525**
		(0.0106)		(0.0243)
Black		0.0200		-0.0388
		(0.0171)		(0.0448)
Hispanic		-0.0576**		-0.0301
		(0.0246)		(0.0838)
Asian		0.0936***		0.0884
		(0.0316)		(0.0590)
Parents' education		0.0053**		0.0306***
		(0.0022)		(0.0052)
Family income		0.0003		0.0008
		(0.0002)		(0.0005)
N	11720	11720	2750	2750
R^2	0.0098	0.0657	0.0133	0.0576

***p < .01, **p < .05, *p < .1

NOTE: Data from BPS 2004/09, for a sample of students with non-missing data on math and science preparation, including SAT scores, years of math, years of science, and highest level of math in high school. Parental educational attainment is measured as having any college degree, including an associate's degree and above. Regressions are weighted. Sample sizes are rounded to the nearest ten to comply with the restricted-use data licensing requirements from NCES.

Table 7 lists the results after controlling for students' demographic, family, and school characteristics.[11] Raw estimates on the immigrant-native college STEM attainment gap are displayed in column 1 and 3 for comparison. Consistent with the existing literature, the coefficients suggest that males, Asians, and students from highly educated families have significant higher college STEM attainment whereas black and Hispanic students are less likely to enter and persist in STEM fields. Adjusting for socioeconomic characteristics reduces the coefficients on recent first-generation immigrant students to 8.7 percentage points at entry and 9.0 percentage points at persistence. For non-recent first-generation immigrant students, the coefficient drops by about 5.8 percentage points, more than one-half from the base level, at STEM entry, whereas the coefficient reduces by about 5.3 percentage points at persistence. The coefficients on second-generation immigrant students drop considerably and become statistically insignificant, suggesting that their higher college STEM attainment is largely explained by socioeconomic characteristics.

In Table 8, I explore how individual preferences impact the different likelihood of majoring in STEM fields between immigrant and native students. I add to the specification a set of dummy variables indicating students' preferences according to their claimed important goals, including being a community leader; influencing the political structure; being financially well-off; having steady work; having leisure time; having children, and living close to relatives. The results suggest that students who are motivated by being a community leader, achieving political influence, and living close to relatives

[11] BPS 2004/09 does not provide information on parents' occupation.

TABLE 1.8

IMMIGRANT-NATIVE COLLEGE STEM ATTAINMENT GAP, CONTROLLING FOR PREFERENCES

	Entry		*Persistence*	
	(1)	*(2)*	*(3)*	*(4)*
1st Gen	0.0870**	0.0807**	0.0896	0.0785
	(0.0367)	(0.0366)	(0.0646)	(0.0644)
1.5 Gen	0.0510	0.0492	0.1330*	0.1295*
	(0.0429)	(0.0427)	(0.749)	(0.754)
2nd Gen	0.0105	0.0095	-0.0043	-0.0096
	(0.0245)	(0.0244)	(0.0587)	(0.0582)
Community leader		-0.0205*		-0.0464*
		(0.0108)		(0.0255)
Political influence		-0.0274**		-0.0088
		(0.0129)		(0.0306)
Financial well-off		0.0066		-0.0010
		(0.0121)		(0.0302)
Steady work		0.0219		-0.0392
		(0.0160)		(0.0390)
Leisure		-0.0088		0.0165
		(0.0174)		(0.095)
Having children		-0.0095		-0.0020
		(0.0116)		(0.0266)
Close to relatives		-0.0248**		0.0362
		(0.0102)		(0.0255)
SES	Y	Y	Y	Y
N	11720	11720	2750	2750
R^2	0.0657	0.0684	0.0576	0.0590

***p < .01, **p < .05, *p < .1

NOTE: Data from BPS 2004/09, for a sample of students with non-missing data on math and science preparation, including SAT scores, years of math, years of science, and highest level of math in high school. Parental educational attainment is measured as having any college degree, including an associate's degree and above. Regressions are weighted. Sample sizes are rounded to the nearest ten to comply with the restricted-use data licensing requirements from NCES.

are less likely to choose STEM fields. For example, claiming it important to be a leader in the community is associated with 2 percentage points lower STEM entry rate and 4.6 percentage points lower persistence rate conditional on entry. By contrast, the estimates indicate that students who value having steady work are about 2.2 percentage points more likely to enter STEM fields. Coefficients on the other aspects are relatively small and not statistically significant, suggesting they are less relevant to students' college STEM attainment. Comparing the coefficients on the immigrant generation dummies across two specifications, I find that adjusting for individual preferences in general has little impact on the immigrant-native college STEM attainment gap. The coefficients on recent first-generation immigrant students drop only slightly by about 1 percentage point. The declines in the coefficients on non-recent first-generation immigrant students are even smaller. This suggests that the immigrant-native college STEM attainment gap is not primarily due to different motivations and preferences between immigrant and native students.

In Table 9 and 10, I investigate how academic preparation in math and science contributes to immigrants' advantage in STEM entry and persistence. In column 2, I control for the number of years of math and the number of years of science courses in high school. Years of English and social sciences are also included in the specification. The results demonstrate that the years of high school courses in math and science significantly increases students' college STEM attainment. An additional year of high school math increases the likelihood of entering and persisting in STEM fields by 2.8 and 4.0 percentage points, respectively, whereas an additional year of science course raises STEM entry and persistence rate by 3.9 and 1.7 percentage points, respectively.

TABLE 1.9

IMMIGRANT-NATIVE COLLEGE STEM ENTRY GAP, CONTROLLING FOR ACADEMIC PREPARATION

	(1)	*(2)*	*(3)*
1st Gen	0.0807**	0.0767**	0.0518
	(0.0366)	(0.0351)	(0.0342)
1.5 Gen	0.0492	0.0475	0.0439
	(0.0427)	(0.0422)	(0.0402)
2nd Gen	0.0095	0.0116	0.0014
	(0.0244)	(0.0242)	(0.0232)
Years: Math		0.0276***	0.0027
		(0.0058)	(0.0060)
Years: Science		0.0391***	0.0229***
		(0.0077)	(0.0077)
Calculus			0.1177***
			(0.0151)
SAT Math			0.0579***
			(0.0081)
SAT Verbal			-0.0135*
			(0.0073)
SES	Y	Y	Y
Preferences	Y	Y	Y
N	11720	11720	11720
R^2	0.0684	0.0769	0.1029

***p < .01, **p < .05, *p < .1

NOTE: Data from BPS 2004/09, for a sample of students with non-missing data on math and science preparation, including SAT scores, years of math, years of science, and highest level of math in high school. Parental educational attainment is measured as having any college degree, including an associate's degree and above. SAT scores are converted into Z scores. Regressions are weighted. Sample sizes are rounded to the nearest ten to comply with the restricted-use data licensing requirements from NCES.

TABLE 1.10

IMMIGRANT-NATIVE COLLEGE STEM PERSISTENCE GAP, CONTROLLING FOR ACADEMIC PREPARATION

	(1)	*(2)*	*(3)*
1st Gen	0.0785 (0.0644)	0.0637 (0.0646)	0.0361 (0.0647)
1.5 Gen	0.1295* (0.754)	0.1286* (0.708)	0.0978 (0.734)
2nd Gen	-0.0096 (0.0582)	-0.0096 (0.0592)	-0.0326 (0.0549)
Years: Math		0.0397** (0.0172)	0.0018 (0.0179)
Years: Science		0.0186 (0.0217)	-0.0088 (0.0215)
Calculus			0.0540* (0.0302)
SAT Math			0.1038*** (0.0184)
SAT Verbal			-0.0075 (0.0166)
SES	Y	Y	Y
Preferences	Y	Y	Y
N	2750	2750	2750
R^2	0.0590	0.0663	0.0985

***p < .01, **p < .05, *p < .1

NOTE: Data from BPS 2004/09, for a sample of students with non-missing data on math and science preparation, including SAT scores, years of math, years of science, and highest level of math in high school. Parental educational attainment is measured as having any college degree, including an associate's degree and above. SAT scores are converted into Z scores. Regressions are weighted. Sample sizes are rounded to the nearest ten to comply with the restricted-use data licensing requirements from NCES.

However, controlling for the number of years of high school courses does not seem to have much impact on the estimates. For example, the coefficients on recent first-generation immigrant students drop slightly by about 0.4 and 1.5 percentage points at entry and persistence, respectively. To interpret the relatively small impact, remember that as demonstrated in the summary statistics the average number of years of high school math and science courses is similar across students of different immigrant generational status. On the other hand, despite the similar amount of courses, the data suggest that immigrant students have more advanced math courses and achieve higher scores on standardized tests compared to natives. To investigate the impact of math proficiency on immigrants' higher college STEM attainment, I further control for whether the student had taken any calculus class in high school and her SAT/ACT math scores in column 3 in table 9 and 10. The results demonstrate that the quality of math courses is crucial in determining students' college STEM attainment. Having taken calculus is estimated to increase the likelihood of entering and persisting in STEM fields by about 11.8 and 5.4 percentage points, respectively. A one standard deviation increase in standardized math test scores is related to about 5.8 and 10.3 percentage points' higher STEM entry and persistence rate, respectively. It is also important to notice that is that once controlling the level of math course and math test scores, the coefficients on the number of years of math courses become no longer statistically significant. This suggests that it is the quality, rather than the quantity of high school math courses, that determines students' college STEM attainment. The comparison of the coefficients on the immigrant dummies across columns demonstrates that high school math preparation plays an important role in explaining first-generation immigrant students' higher college STEM attainment. For recent first generation immigrant students, the coefficients reduce to 5.2 and 3.6 percentage points at STEM entry and persistence whereas the coefficients on 1.5-generation immigrant students drop to 4.4 percentage points at entry and 9.8 percentage points at persistence. None of the estimates is statistically significant, suggesting that the immigrant college STEM advantage is largely explained by the observable characteristics, particularly academic preparation in math and science in high school.

To illustrate the variation behind the data, Table 11 compares the knowledge and skills of 15-year-old students' in math and science from selected countries and regions according to students' academic performance in the latest Program for International Student Assessment (PISA).[12] The first and third columns present students' mean test scores whereas the second and fourth columns list the relative ranking. We see that students from Asia perform significantly better than those from other countries and regions, with students from Shanghai, China ranking the top in both math and science. Students from Europe also have solid performance, ranked immediately after their Asian peers. By contrast, the academic performance of U.S. teens is less satisfactory, with scores in math and science both below the OECD average. Finally, students from Latin America, such as Mexico and Argentina, are at or near the bottom of the ranking.[13] Table 12 further compares degree attainment in science and engineering for respective countries. Interestingly, the data demonstrates that Asian and European countries also have higher proportion of first university degrees awarded in science and engineering

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[12] PISA 2012 Results in Focus: What 15-year-olds Know and What They Can Do With What They Know: Key Results from PISA 2012, OECD, 2012

[13] No countries or regions from Africa participated in the 2012 PISA.

TABLE 1.11

STUDENTS' PERFORMANCE IN MATH AND SCIENCE, BY SELECTED REGIONS AND COUNTRIES

	Math		*Science*	
	Mean	*Rank*	*Mean*	*Rank*
Average	494		501	
United States	481	36	497	28
Asian				
China, Shanghai	613	1	580	1
Singapore	573	2	551	3
Japan	536	7	547	4
Korea	554	5	538	7
Europe				
Finland	519	12	545	5
Germany	514	16	524	12
France	495	25	499	26
Other				
Mexico	413	53	415	55
Brazil	391	58	405	59
Argentina	388	59	406	58

NOTE: Data from PISA 2012 Results in Focus: What 15-year-olds Know and What They Can Do With What They Know: Key Results from PISA 2012, OECD, 2012.

TABLE 1.12

FIRST UNIVERSITY DEGREES AWARDED, BY SELECTED REGIONS AND COUNTRIES

	All fields	*S&E*	*S&E (%)*
United States	1,668,227	525,374	31.5
Asian			
China	2,590,535	1,288,999	49.8
Singapore	12,451	5,552	44.6
Japan	541,428	321,168	59.3
Korea	308,162	123,658	40.1
Europe			
Switzerland	2,864	806	28.1
Germany	369,059	138,583	37.6
France	286,450	100,118	35.0
Other			
Mexico	372,997	131,518	35.3
Brazil	850,787	121,465	14.3
Argentina	85,925	22,905	26.7

NOTE: Data from Science and Engineering Indicators 2012, National Science Board, National Science Foundation, 2012.

fields. For example, in 2010 about half of bachelor's degrees in China were awarded in STEM fields, as compared to about one-third in the U.S. The consistency provides suggestive evidence of the link between the quality of K-12 math and science education and students' college STEM attainment.

1.4 Conclusion and Future Work

First and second-generation immigrant students are becoming a larger share of the student population in U.S higher education. Understanding immigrants' educational attainment in the STEM pipeline has important implications for policy-making. This paper compares immigrants' college STEM attainment with that of native students using detailed survey data from the Beginning Postsecondary Longitudinal Studies 2004/09 from the National Center for Education Statistics. The results demonstrate large variation in STEM enrollment and persistence patterns across immigrant generational groups. Compared to natives, first-generation Asian and white immigrant students, especially those who attended foreign schools for K-12 education are significantly more likely to enter STEM fields than natives. Conditional on entry, they are also more likely to persist. Exploring the factors leading to their higher college STEM attainment, I find that better academic preparation in math and science is the most important factor contributing to their college STEM advantage. The results also suggest that it is the level of the course, rather than the number of years, that determines students' college STEM attainment. This indicates that to improve students' college STEM attainment more policy efforts are needed to improving the quality of K-12 math and science education.

Motivated by the above findings, in the second chapter I examine the impact of stricter high school math curriculum requirements on STEM degree completion. Over the past three decades, there have been two waves of nationwide high school math reforms, the first in the 1980s, and the second in more recent years. During these reforms, many states increased the number of years of math courses required for high school graduation. Exploiting the variation in the timing of math reforms across states, I estimate whether stricter high school math curriculum requirements increased the number of STEM graduates in the population using most recent data from the 2009-2012 American Community Survey.

CHAPTER 2:

DO STRTICTER HIGH SCHOOL MATH CURRICULUM REQUIREMENTS RAISE COLLEGE STEM ATTAINMENT?

2.1 Introduction

In 2012, the Obama Administration announced the goal of producing, over the next decade, one million more U.S. college graduates with STEM degrees than are expected at the current rate.[14] This announcement came amidst growing concerns over American high school students' low academic achievement in math. In the 2012 Program for International Student Assessment (PISA), conducted by the Organisation for Economic Cooperation and Development (OECD) among sixty-five international education systems, U.S. teens ranked only 31st in their math knowledge and skills.[15] To address these issues, policy efforts have been directed toward strengthening high school math curriculum standards. The most common policy initiative has been increasing the years of math required for high school graduation, with the rationale that, with stricter

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[14] Preparing a 21st Century Workforce, Science, Technology, Engineering, and Mathematics (STEM) Education in the 2013 Budget, White House Office of Science and Technology Policy, February 13, 2012

[15] PISA 2012 Results in Focus: What 15-year-olds Know and What They Can Do With What They Know: Key Results from PISA 2012, OECD, 2012

math curriculum requirements, “students will be well prepared to pursue a STEM degree and more actually attain such a degree.”[16]

Despite the ambitions behind these policies, the likely impact of raising high school math curriculum requirements will have on students’ college STEM attainment remains ambiguous. First, stricter math curriculum requirements do not necessarily translate to better academic performances. For example, higher minimum requirements might have little impact on high-skilled students, and could discourage the academic engagement of students with relatively low math skills, particularly female and minority students, who are underrepresented in STEM fields. Second, stricter high school math curriculum requirements are likely to impact students’ educational attainment on other margins. On the extensive margin, if stricter requirements cause fewer students to graduate from high school and attend college, the number of STEM majors may drop proportionally. Alternatively, more years of high school math may, in fact, better prepare students for college, and in that case we would expect more students to graduate from college with a degree in STEM fields. On the intensive margin, increased math curriculum requirements might shift students away from non-STEM fields and into STEM fields. While some students might do better with this shift of focus, others might find themselves struggling, and either change to non-STEM majors, or drop out of college entirely.

This paper examines the impact of stricter high school math curriculum requirements on students’ college STEM attainment by exploiting the variation in the

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[16] *Ibid.*

timing of math curriculum requirement increases from two national waves of curriculum reforms. The first wave of reforms was prompted by a much-publicized 1983 government report titled, “A Nation at Risk.” In the years immediately following the release of this report, forty-one states increased, or imposed for the first time, the number of years of math courses required for high school graduation. The second wave of math reforms began with the “Improving America’s Schools Act (IASA)” in 1994, and has been accelerating since the “No Child Left Behind Act (NCLB)” in 2001. By 2008, twenty-three states had further increased the years of high school math courses required for graduation, and another ten states were in the process of increasing these requirements. I construct state high school math curriculum requirements for cohorts graduated between 1978 and 2008, based on the Digest of Education Statistics from the Institute of Education Sciences (IES) and the historical documents from the Education Commission for the States (ECS). Exploiting the cross-state variation in the timing of requirement increases, I investigate the impact of math reforms on students’ college STEM attainment with data from the 2009-2012 American Community Survey (ACS).

In this paper, I address the following questions: First, did stricter high school math curriculum requirements increase the share of the population with a college degree in STEM fields? I estimate the impacts of the two waves of math reforms separately, since they differed qualitatively in the reforms they advanced and therefore, might have led to different impacts. Second, was there heterogeneity in treatment effects across the population? Understanding this question is particularly relevant given the substantial variation in college STEM attainment across demographic groups and the increasing concerns about the underrepresentation of females and minorities in STEM fields. Next, how did stricter high school math curriculum requirements impact student educational attainment on other margins? On the extensive margin, I examine whether math reforms affected the number of students graduating from high school and attending college. On the intensive margin, I estimate the effect of math reforms on completing a college degree in non-STEM fields. Finally, taking advantage of transcript data from the National Center for Education Statistics (NCES), I examine the direct impact of stricter state math curriculum requirements on how many math courses students are taking in high school.

I find that on average, the share of the population with a college degree in STEM fields increased by 0.24 percentage points after the first wave of math reforms, which is about four percent of pre-reform value. The more recent reforms, on the other hand, increased STEM degree completion by 0.26 percentage points. The increase is statistically significant at the 5 percent level. Despite the similar average impacts, I demonstrate a considerable amount of variation in treatment effects across the population between the two waves of math reforms. The earlier reforms statistically significantly raised college STEM attainment of traditionally underrepresented groups: among white females, black and Hispanic males, degree completion rates in STEM fields increased by about 10 percent. In contrast, the more recent reforms had a large and statistically significant impact on college STEM attainment among white males, and little effect on other groups.

Exploring the composition effect of stricter high school math curriculum requirements, I find no statistically significant changes in the pool of students graduating from high school and attending college during either wave of math reforms. However, individuals were less likely to complete an associate's degree following the earlier requirement increases, and the negative impact is strongest on white females. On the intensive margin, I find both waves of math reforms reduced degree completion in non-STEM fields, which suggests that stricter high school math curriculum requirements had shifted some students away from non-STEM fields and into STEM fields.

Relating the above findings to the changing nature of math reforms, this suggests that adopting stricter high school math curriculum requirements is potentially an important policy vehicle for improving students' college STEM attainment. The effectiveness of such policies depends crucially on the specific features of reforms. Reforms that focused on adding minimum year requirements mostly benefit students with low initial college STEM attainment, whereas more challenging standards-based curriculum reforms largely impact high-skilled students. To effectively improve college STEM attainment for all groups, different policy interventions might be necessary.

This paper builds on the following literatures. The first examines the impact of high school math preparation on college STEM attainment. Many studies have demonstrated that students who completed more math and science classes in high school, had advanced math courses, and scored higher on standardized tests are more likely to pursue STEM majors when they enter college (Maple and Stage, 1991; Crisp, Nora and Taggart, 2009; Jia, 2014). Exploiting the immigrant-native gap in college STEM attainment, Jia (2014) demonstrated that, compared with the native-born students, immigrant students are much more likely to major in STEM fields, and that better academic preparation in high school math seems to be the most important factor contributing to their higher college STEM attainment. However, it remains unclear whether the established correlations represent a causal relationship, largely because course-taking is not random. Students who take more math courses in high school might have other characteristics that contribute to college STEM attainment. For example, using a dynamic structural model, Arcidiacono (2004) demonstrated that students with higher math ability are more likely to sort into high paying majors such as science and engineering. To overcome the selection bias, in this paper I adopt a quasi-experimental approach to identify the impact of high school math preparation on students' college STEM attainment. In particular, I exploit the exogenous variation in students' course-taking from state-level high school math curriculum reforms. The findings are therefore, not biased by other individual student's characteristics that are correlated with both their course-taking in high school and later educational attainment in STEM fields in college.

The second body of literature examines the impact of high school math coursework on labor market outcomes. Using data from the National Longitudinal Survey of Youth (NLSY) and the senior cohort from High School and Beyond (HS&B), Levine and Zimmerman (1995) estimated OLS models and demonstrated that taking additional math in high school increased wages for female college graduates. By contrast, employing data from the National Longitudinal Study of 1972 (NLS-72), Altonji (1995) used the average number of courses taken in a student's high school as the instrument for the individual student's coursework. The instrumental variables estimates indicated that additional years of high school math had little effect on labor market earnings. Rose and Betts (2004) adopted both OLS and IV models to investigate the effect of specific high school math courses on earnings. Using detailed information on students' coursework from HS&B sophomore cohort, they found that high school math courses – particularly algebra and geometry – are important determinants of later labor market earnings. Two more recent studies estimated the returns to high school math courses by exploiting the variation from curriculum reforms. Taking advantage of a high school pilot curriculum scheme in Demark, Joensen and Nielsen (2006) found a positive causal relationship between high school math courses and later earnings. In another study, exploiting high school math reforms in the U.S. in the 1980s, Goodman (2012) estimated a two sample instrumental variable model using combined data from several high school transcript studies from NCES and the 2000 Census. He found that more years of math in high school induced large earning increases among blacks, particularly black males, but had little impact on whites.

I make two contributions to this literature. First, previous studies largely focus on the earlier cohorts who graduated from high school in the 1970s and 1980s. By contrast, I expand the sample to individuals who graduated from high school between 1978 and 2008 and examine the effect of high school math courses on both the earlier cohorts and the more recent graduates. This expansion is important because both high school math courses and the labor market conditions have changed substantially since the 1980s, which might have significantly altered the returns to high school math courses. Second, despite the mixed evidence from the above studies, little is known about the underlying mechanisms through which additional high school math courses impact labor market outcomes. In this paper, I fill in this gap by identifying one important channel – an increase in individuals' college attainment in STEM fields and greatly enhance our understanding of how high school math courses impact individuals' later outcomes.

Finally, this paper also relates to the growing body of literature on the impact of exit exams which students must take and receive a passing score to graduate from high school. Using data from the National Center for Education Statistics' Common Core of Data (CCD), Warrant, Jenkins, and Kulick (2006) demonstrated that more difficult exit exams decreased high school completion rates among 16- to 19-year-olds by about 2.2 percentage points and increased rates of GED test taking by about 0.12 percentage points. Another study by Dee and Jacob (2006) suggested that exit exams had large and statistically significant negative effects on high school graduation, particularly for blacks. The likelihood of completing high school dropped by over 7 percent and 10 percent among black males and black females, respectively. From a policy perspective, both exit exams and curriculum requirements are means to improve students' educational outcomes, the optimal policy crucially depends on understanding the impacts of both interventions. This work fills the gap in the literature on the impact of stricter curriculum requirements on high school graduation and GED taking, and the results provide important implications for policy making.

2.2 The Changing Nature of State High School Math Requirements

State efforts towards raising high school math requirements started in the early 1980s. In 1981, concerned by the unsatisfactory academic achievement of American high school students, particularly in math and science, President Reagan created the National Commission on Excellence in Education to investigate the state of education in the country. In 1983, the Commission issued the final report titled "A Nation at Risk. " In this report, the Commission attributes the unsatisfactory situation largely to the declining quality of school curriculum, pointing out: "This curricular smorgasbord, combined with extensive student choice, explains a great deal about where we find ourselves today. We offer intermediate algebra, but only 31 percent of our recent high school graduates complete it."[17] To address this issue, the Commission pressed for strengthened high school curriculum requirements and graduation standards "which tell students which subjects are most important."[18]

As demonstrated by Figure 1, most states responded quickly to the calls from "A Nation at Risk". In the years immediately following, thirty-four states increased curriculum requirements, usually by one year over the existing level; seven states imposed for the first time graduation requirements on the number of years of math courses to be completed. Figure 2 compares state requirements on the number of years of high school math courses over the years. As indicated by the columns in the left, before "A Nation at Risk," the majority of states either had no requirements, or required only one year of math for high school graduation. In contrast, the columns in the center of the figure show that by 1990, most states required students to complete at least two years of math courses in order to graduate from high school. While this represents a substantial improvement from the early 1980s, it is important to point out that the new requirements were still relatively low. For example, only eleven states required three years of math courses for graduation, the level proposed by the Commission. Another limitation of the earlier reforms is that, other than raising year requirements, states devoted little efforts to improving the quality of math curriculum. According to data from the National Center for

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[17] A Nation at Risk: The Imperative for Educational Reform, National Commission on Excellence in Education, U. S. Department of Education, 1983

[18] In particular, the Commission recommended three years of math for a standard high school diploma.

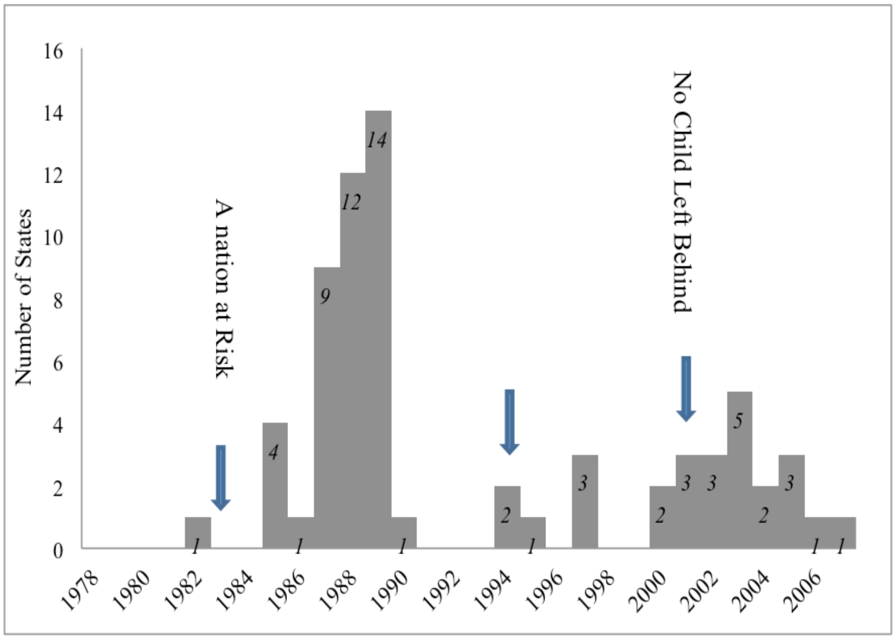

Figure 2.1: Timing of State High School Math Requirement Increases, Education Commission for the States (ECS) and the Digest of Education Statistics from Institute of Education Sciences (IES).

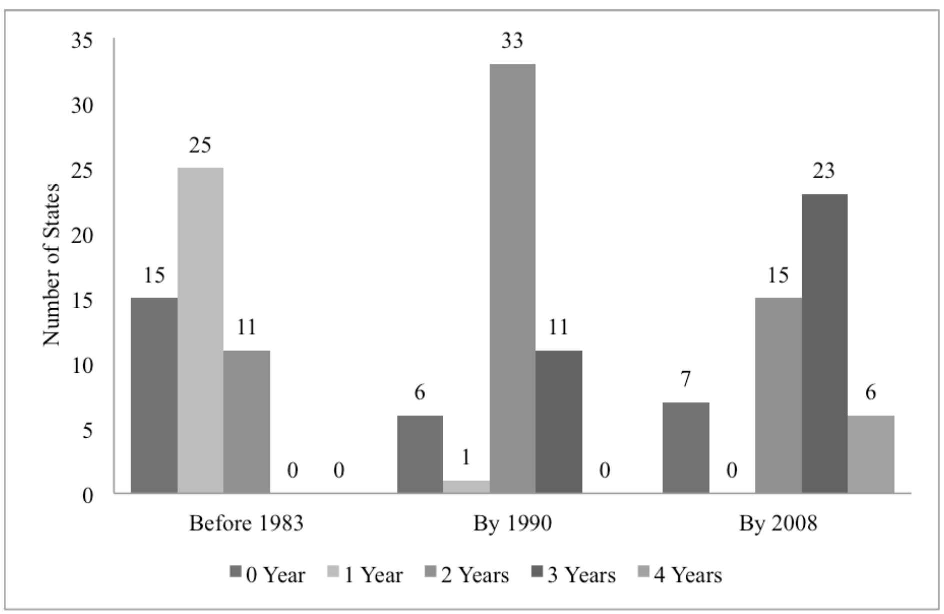

Figure 2.2: State Requirements on Years of High School Math Courses, Education Commission for the States (ECS) and the Digest of Education Statistics from Institute of Education Sciences (IES).

Education Statistics (NCES), during this period, only six states had developed curriculum standards that specify the topics to be covered in either elementary or secondary school.

A second wave of math reforms started in 1994 following the passage of "Improving America's Schools Act (IASA)" during the Clinton administration. This act reauthorized the "Elementary and Secondary Education Act (ESEA)," and was intended to support standards-based education reform at the state level. Eight pioneering states further increased their requirements on the number of years of math courses for high school graduation. In 2001, the Bush administration again reauthorized ESEA with the "No Child Left Behind Act (NCLB)". This further accelerated state high school math curriculum reforms. By 2008, twenty-three states further increased the number of years of math courses required for high school graduation. Another ten states are currently in the process of increasing requirements. As indicated by the columns in the left of Figure 2, at the end of the recent reforms, about thirty states required more than three years of math courses for high school graduation. A distinguishing feature of the recent reforms is that, in response to the federal calls for standards-based curriculum and measurable improvement in students' academic achievement in both IASA and NCLB, states have been moved beyond simple year requirements to developing course standards and articulating learning goals. In addition to raising the year requirements, most states have also specified particular math courses to be completed for high school graduation, such as Algebra I, Geometry, and Algebra II.[19]

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[19] High School Mathematics: State-Level Curriculum Standards and Graduation Requirements, Center for the Study of Mathematics Curriculum, 2007

2.3 Description of Data and Sample Construction

I collect data on states' required years of math for high school graduation from two sources: the Institute of Education Sciences (IES), and the Education Commission for the States (ECS). The Digest of Education Statistics, the annual report from IES, contains information on state high school curriculum requirements. The 1993, 1996, and 2004 digests are particularly relevant for the purpose of this project. In addition to state requirements on the number of years of math for high school graduation, they also specify the first cohort impacted by the reforms. Such information is not available in the earlier years' reports. I therefore supplement IES data with data collected from the Education Commission for the States (ECS). ECS is an interstate research compact in public education with a clearing-house rich in information on a broad range of education topics compiled from state legislations, policy reports, newsletters, and surveys. Researchers at the ECS generously shared with me the historical documents on state high school math curriculum requirements in the 1980s. Based on the above information, I construct complete state profiles on high school math curriculum requirements from 1978 to 2008.

The main data for estimation are pooled from the American Community Survey (ACS) 2009 to 2012 from IPUMS (Ruggles et al. 2010). The sample includes U.S.-born population with an age between 22 and 52 in 2012, and at least 22 years old at the year of the survey, with non-imputed data on age, state of birth, educational attainment, and field of bachelor's degree.[20] Assuming 18 to be the high school graduation age, those

[20] As I demonstrate later in the paper, the results are robust to including these observations.

individuals correspond to high school cohorts who graduated between the years 1978 and 2008. I focus on the post-1978 period, since information on state high school math curriculum requirements in the earlier years is not available. I then drop those who graduated from high school after 2008, because by the year of the survey, most of them are still too young to complete college.

As discussed earlier, the nature of curriculum requirement increases has changed between the two waves of math reforms. In particular, math reforms in the 1980s focused only on adding minimum years of requirements, whereas the recent reforms emphasized on developing standards-based math curriculum. The two types of reforms might have led to heterogeneous impacts on students' college STEM attainment. To separately examine the impacts from the two waves of math reforms, I further divide the sample into two subsamples: sample 1 for the first wave of math reforms includes individuals who graduated from high school before 1993 and sample 2 for the second wave of math reforms comprises of those who graduated after. The 1993 cohort is chosen as the cutoff mainly based on the timing of state math reforms indicated in Figure 1. In addition, as discussed in more detail later in the paper, it also allows for direct estimation of how math reforms affected students' course-taking in high school. [21]

Starting in 2009, the ACS began asking respondents with at least a bachelor's degree to identify their college major. Based on this information, I classify STEM majors as those with a bachelor's degree in biology and life science, physical sciences, nuclear

[21] In particular, I examine the effect of the more recent math reforms using restricted use data from the Beginning Postsecondary Students Longitudinal Study (BPS) 1996 and 2004. In a relevant study, Goodman (2012) employs transcript data on the earlier cohorts from HS&B and NEAP and estimates the impact of the first wave of math reforms on students' course-taking.

science, industrial radiology, computer and information science,[22] engineering, engineering technologies, mathematics, and statistics, plus those with a teaching degree in math, science, and computer education.[23]

Summary statistics for the analysis sample are presented in Table 1. The first column includes all individuals in the sample. In the next four columns, I present descriptive statistics by gender, and then for whites and non-whites including blacks and Hispanics. Beginning with the first column, we see that on average about 65 percent of the population in the sample has ever attended college. The second row indicates that about 40 percent has completed at least an associate's degree. Since major information is not available for respondents with an associate's degree, I focus on the STEM majors with a bachelor's degree. The third row shows about 30 percent of the population holds a bachelor's degree or above. However, as reported below, only five percent have a degree in STEM fields. Breaking down into the specific fields, we can see that most of the STEM degrees are in science and engineering fields. Next, columns 2 through 5 reveal a considerable amount of variation across the subgroups. In particular, females, blacks, and Hispanics are underrepresented in STEM fields. For example, only about two percent of non-white females have a STEM degree, whereas the share is over eight percent among white males. Cross-group variation also exists within STEM fields. Specifically, females

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[22] Specifically, computer and information science includes computer programming and data processing, computer information management and security, computer networking and telecommunications.

[23] I check the robustness of the results to alternative classification excluding teaching fields from STEM majors later in the paper.

TABLE 2.1

SUMMARY STATISTICS

	Whole Sample	*Female*		*Male*	
		White	*Non-White*	*White*	*Non-White*
College Attendance	0.6515	0.7218	0.6133	0.6341	0.4840
AA and above	0.4021	0.4722	0.2936	0.3888	0.2037
BA and above	0.3052	0.3606	0.1983	0.3034	0.1354
STEM Degree	0.0575	0.0420	0.0221	0.0840	0.0315
Science	0.0226	0.0247	0.0115	0.0252	0.0084
Computer	0.0099	0.0051	0.0051	0.0162	0.0087
Engineering	0.0207	0.0072	0.0038	0.0385	0.0131
Math	0.0043	0.0039	0.0015	0.0052	0.0016
Population Share		40.51%	10.06%	39.96%	9.48%
N	3,376,784	1,367,862	339,601	1,349,220	320,101

NOTE: Data are from the 2009 to 2012 American Community Surveys (ACS). The sample includes high school cohorts from 1978 to 2008 who are at least 22 years old at the year of the survey with non-imputed data on age, state of birth, educational attainment, and degree field. Race and ethnicity are divided into White and Non-white, where the latter includes blacks and Hispanics.

tend to concentrate in science, whereas males are more likely to major in computer and engineering.

2.4 Empirical Strategy and Results

2.4.1 Estimating the Average Effect

Exploiting the variation in the timing of math reforms across states, I separately estimate the effects of the two waves of math reforms using the following equation:

$$Y_{isc} = \beta_0 + \beta_1 Reform_{sc} + \theta X_{isc} + \delta_s + \delta_c + \delta_y + \varepsilon_{isc}, \qquad (1)$$

where the outcome variable is the educational attainment of individual *i* from state *s* of high school graduating cohort *c*. The key variable of interest is the treatment dummy *Reform*. It equals one if the individual is from a reform state and graduated from high school after the state increased math curriculum requirements, and zero otherwise. Since the Census does not report where and when respondents went to high school, I assign treatment status based on state of birth and age, assuming that people attend high school in their birth state and graduate when they are 18 years old. The vector *X* measures individual characteristics including gender, race, and ethnicity and the variables δs, δc, and δy are fixed state, cohort, and survey effects, respectively. Including the fixed effects is particularly important for identification in this context. In particular, the state fixed effects account for cross-state differences that are persistent over time such as geographical variation in educational attainment and STEM employment. The cohort fixed effects account for any other shocks to college STEM attainment that are the same across states, such as technology change and information innovation which might have induced more students to enter STEM fields in college. The final term *ε* is the idiosyncratic error term and in all models, I allow errors to be correlated across observations within the same state.

The key identification assumption to the above difference-in-differences estimation equation is that, absent math reforms, the underlying trends in college STEM attainment are the same across states. However, this assumption might be invalid. For example, if states experiencing slower growth rate in the share of the population with a STEM degree were more likely to raise their high school math curriculum requirements, the estimates β_1 would be biased downwards. Alternatively, if states increased curriculum requirements as a response to an influx of highly educated workers, perhaps in STEM fields, who demanded stronger high school math curriculum, the estimates would be biased upwards. To address this concern, I account for state-specific linear trends in college STEM attainment and estimate the following equation,

$$Y_{isc} = \beta_0 + \beta_1 Reform_{sc} + \theta X_{isc} + \lambda Trend_{sc} + \delta_s + \delta_c + \delta_y + \varepsilon_{isc}, \qquad (2)$$

where *Trend* is a set of interaction terms of cohort trend and state dummies.[24]

[24] I also account for quadratic trends as robustness checks.

2.4.2 Estimating Heterogeneity in Treatment Effects

In the above equation, β_1 identifies the average impact of stricter high school math curriculum requirements. However, as demonstrated in the summary statistics, there is a considerable amount of variation in college STEM attainment across demographic groups. Given the increasing concerns over the underrepresentation of females and minorities in STEM fields, I explore how math reforms affect college STEM attainment across demographic groups. I divide the sample into four mutually exclusive groups by gender and race/ethnicity. The four groups are white females, non-white females, white males, and non-white males. The non-whites include blacks and Hispanics, whereas the whites include Asians.[25] I estimate the following equation:

$$Y_{isc} = \beta_g Reform_{sc} + \theta_g X_{isc} + \lambda Trend_{sc} + \delta_{sg} + \delta_{cg} + \delta_{yg} + \varepsilon_{isc}, \qquad (3)$$

where *g* indicates each demographic group. δsg, δcg, and δyg are group-specific state, cohort dummies, and year fixed effects. *Trend* accounts for state/cohort specific trends. The vectors of estimated coefficients, βg, identify the effect of stricter high school math requirements on college STEM attainment of each subgroup.

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[25] The results are robust to grouping Asians separately. The estimates are listed in the appendix table.

2.5 Regression Results

2.5.1 The Effects of Math Reforms on STEM Attainment

Table 2 presents estimates on the impact of stricter high school math curriculum requirements on completing a college degree in STEM fields. Results on the first and second wave of math reforms are reported in the top and bottom panels, respectively. Column 1 begins with the basic specification, in which STEM degree completion is regressed on the reform dummy, with control variables for individual characteristics, state, cohort, and survey fixed effects. The estimates on both waves of math reforms are positive, implying an increase of 0.23 and 0.18 percentage points in college STEM attainment, respectively. However, as discussed earlier, the estimates are potentially biased due to time-varying, state-level unobservables, although the direction of the bias is unclear. Column 2 therefore reports results from the preferred specification, equation (2), in which I account for state-specific linear trends in college STEM attainment. As we can see, adding trends has no impact on the estimates on the first wave of reforms, but raises the magnitude and precision of the estimates on the second wave. The latter becomes significant at the five percent level. The results indicate that the share of the population graduating from college with a bachelor's degree in STEM fields increased by 0.24 and by 0.26 percentage points respectively after the first and second waves of math reforms.[26] To understand the magnitude of the effects, I calculate the size of the effect by dividing the coefficient estimates by the average rates of STEM degree completion before the reforms. As reported below, the increases are over 4 percent.

[26] The results are also robust to quadratic trends.

TABLE 2.2

EFFECTS OF STRICTER HIGH SCHOOL MATH REQUIREMENTS ON STEM DEGREE COMPLETION

	Pre-reform Mean	(1)	(2)
1st Reform	0.0528	0.0023 (0.0016)	0.0024 (0.0016)
Effect Size		4.29%	4.49%
N		1,838,730	1,838,730
2nd Reform	0.0585	0.0018 (0.0011)	0.0026** (0.0012)
Effect Size		3.12%	4.40%
N		1,538,054	1,538,054
Trends			Y

***p < .01, **p < .05, *p < .1

NOTE: Data are from the 2009 to 2012 American Community Surveys. The sample includes U.S.-born population who are at least 22 years old at the year of the survey with non-imputed data on age, state of birth, educational attainment, and degree field. Subsample for the first wave of reforms includes high school cohorts from 1978 to 1992; subsample for the second wave of reforms includes high school cohorts from 1993 to 2008. Standard errors are clustered by state and are listed in parentheses. Each coefficient is from a separate regression, controlling for gender, race and ethnicity, state fixed effects, cohort fixed effects, and year fixed effects. Column (2) controls for linear trends.

In Table 3, I conduct several robustness checks on the main results. First of all, the main estimation excludes observations with any imputed data on age, state of birth, educational attainment, or field of degree. This practice reduces the sample size by about ten percent. To examine whether the results are affected by data imputation, I re-estimate the models with those observations added back to the sample. As column 2 demonstrates, the estimates are largely the same across the two samples. In column 3 I consider alternative classifications of STEM degrees. As discussed earlier, I classify teacher education in math, science, and computer as STEM majors in this paper. While relevant from a policy perspective, this classification is potentially problematic if we think the knowledge and skills required for these teaching fields are essentially different from the technical STEM majors. I therefore estimate the effect of math reforms with STEM education classified as non- STEM majors. The results suggest that the alternative definition has relatively little impact on the estimates on the first wave of math reforms while raised the estimate on the second wave of math reforms to 0.28 percentage points. Finally, I examine whether the estimates are sensitive to the choice of control groups. During the two waves of math reforms, five states--Colorado, Iowa, Massachusetts, Michigan, and Nebraska--did not have any specific requirements on the number of years of math courses for high school graduation at the state level. In these states, curriculum requirements are usually determined by the local school districts. One might be concerned that the educational systems in these states are fundamentally different from the other states. Therefore, it is not appropriate to use them as the comparison group. Another issue with including these states is that they might have experienced increases in high school math curriculum

TABLE 2.3

EFFECTS OF STRICTER HIGH SCHOOL MATH REQUIREMENTS ON STEM DEGREE COMPLETION, ROBUSTNESS CHECKS

	(1)	(2)	(3)	(4)
1st Reform	0.0024 (0.0016)	0.0021 (0.0014)	0.0022 (0.0016)	0.0011 (0.0015)
N	1,838,730	2,028,375	1,838,730	1,643,062
2nd Reform	0.0026** (0.0012)	0.0026* (0.0014)	0.0028** (0.0012)	0.0024* (0.0012)
N	1,538,054	1,695,035	1,538,054	1,392,998
Drop Imputed Data		N		
Education Majors			N	
Locally Set States				N

***p < .01, **p < .05, *p < .1

NOTE: Data are from the 2009 to 2012 American Community Surveys. The sample includes U. S.-born population who are at least 22 years old at the year of the survey with non-imputed data on age, state of birth, educational attainment, and degree field. Subsample for the first wave of reforms includes high school cohorts from 1978 to 1992; subsample for the second wave of reforms includes high school cohorts from 1993 to 2008. Each column is from a separate regression, controlling for gender, race, ethnicity, state, age, cohort fixed effects, and state-specific trends in STEM attainment. Standard errors are clustered by state and are listed in parentheses. Column 2 adds observations with imputed data on age, state of birth, educational attainment, or degree field. In Column 3, math and science education are not classified as STEM majors. Column 4 excludes states where graduation requirements are determined by the local school districts..

requirements at the local district level, which are not observed in the data. To address these concerns, I re-estimate the model with the non-requirement states excluded from the sample. As demonstrated in column 4, estimates on the second wave of reforms are quite stable. However, the size of the point estimate on the earlier reforms reduced by more than half. This is potentially because that during the 1980s only ten states did not increase math curriculum requirements at the state level, including the five non-requirement states. The estimated effects of math reforms therefore are more sensitive to the choice of states in the control group.

Table 4 further demonstrates the impact of stricter high school math curriculum requirements on degree completion in each specific STEM field. Starting with the top panel, I find the first wave of math reforms had a large and statistically significant effect on degree completion in computer and information science fields. The share of the population getting a computer degree increased by 0.11 percentage points, or more than 10 percent, after the first wave of math reforms. By contrast, estimates in the other columns are small and not statistically significantly different from zero, suggesting that the earlier reforms did not significantly affect degree completion in those fields.

The bottom panel demonstrates a quite different pattern. As we can see, the impact on degree completion from the second wave of math reforms was concentrated in science and engineering fields. For example, degree completion in science fields increased by 0.27 percentage points. The estimate is large and statistically significant, with the size of the increase over 11 percent. Interestingly, the recent math reforms seem to have a negative impact on computer degree completion. The estimate is negative and large, although not statistically significant. Finally, similar to the earlier math reforms, I find little impacts on degree completion in mathematics.

TABLE 2.4

EFFECTS OF STRICTER HIGH SCHOOL MATH REQUIREMENTS ON STEM DEGREE COMPLETION

	Science (1)	Computer (2)	Engineering (3)	Math (4)
1st Reform	0.0006	0.0011**	0.0007	-0.0001
	(0.0008)	(0.0005)	(0.0007)	(0.0004)
Mean	0.0171	0.0101	0.0219	0.0039
Effect Size	3.51%	11.16%	3.26%	-3.36%
N	1,838,730	1,838,730	1,838,730	1,838,730
2nd Reform	0.0027***	-0.0011	0.0009*	0.0001
	(0.0010)	(0.0009)	(0.0005)	(0.0003)
Mean	0.0243	0.0120	0.0182	0.0040
Effect Size	11.01%	-9.01%	4.98%	2.19%
N	1,538,054	1,538,054	1,538,054	1,538,054

***p < .01, **p < .05, *p < .1

NOTE: Data are from the 2009 to 2012 American Community Surveys. The sample includes U.S.-born population who are at least 22 years old at the year of the survey with non-imputed data on age, state of birth, educational attainment, and degree field. Subsample for the first wave of reforms includes high school cohorts from 1978 to 1992; subsample for the second wave of reforms includes high school cohorts from 1993 to 2008. Standard errors are clustered by state and are listed in parentheses. Each coefficient is from a separate regression for the outcome variable listed at the top. All regressions control for gender, race and ethnicity, state fixed effects, cohort fixed effects, year fixed effects, and linear state specific trends. Effect size is calculated by dividing the estimate by the pre-reform mean.

2.5.2 Heterogeneous Effects of Math Reforms on STEM Attainment

Table 5 presents the impacts of math reforms on STEM degree completion for each demographic group. Estimates on the first wave of math reforms are reported in columns 1 to 3. In addition to the coefficient estimates, I also report the pre-reform STEM degree completion rate and the size of the effect calculated by dividing the estimates by the pre-reform mean. I find there is a large and statistically significant impact on white females, whose degree completion in STEM fields increased by 0.36 percentage points after requirement increases. The increase is economically important given white females' traditional underrepresentation in STEM fields. As reported in row 1, column 3, the size of the increase is over 10 percent. Next, the estimated effect on black and Hispanic males is also positive and large, though it is less precisely measured. By contrast, STEM degree completion rate among white males and non-white females responded little to the requirement increases.

Column 4 to 6 demonstrate a quite different scenario. In particular, the impact of the second wave of math reforms is substantially stronger on white males than on other groups. The share of STEM majors among white males increased by 0.46 percentage points, or about 5 percent, after the recent curriculum reforms. Row 1, column 4 suggests that in stark contrast to the first wave of math reforms, the recent reforms had no significant impacts on STEM degree completion among white females. The last two rows show economically large impacts on blacks and Hispanics. However, the estimates are not statistically significantly different from zero.

TABLE 2.5

EFFECTS OF STRICTER HIGH SCHOOL MATH REQUIREMENTS ON COLLEGE STEM ATTAINMENT

	1st Wave			2nd Wave		
	(1)	(2)	(3)	(4)	(5)	(6)
Reform_WF	0.0036*			0.0015		
	(0.0019)	0.0343	10.61%	(0.0017)	0.0476	3.10%
Reform_WM	0.0011			0.0046***		
	(0.0022)	0.0853	1.31%	(0.0016)	0.0863	5.33%
Reform_NWF	0.0005			0.0015		
	(0.0019)	0.0200	2.63%	(0.0023)	0.0271	5.59%
Reform_NWM	0.0028			0.0022		
	(0.0027)	0.0331	8.38%	(0.0024)	0.0347	6.27%
N	1,838,730			1,538,054		

***p < .01, **p < .05, *p < .1

Notes: Data are from the 2009 to 2012 American Community Surveys. The sample includes U.S.-born population who are at least 22 years old at the year of the survey with non-imputed data on age, state of birth, educational attainment, and degree field. Subsample for the first wave of reforms includes high school cohorts from 1978 to 1992; subsample for the second wave of reforms includes high school cohorts from 1993 to 2008. Standard errors are clustered by state and are listed in parentheses. Each coefficient is from a separate regression for the outcome variable listed at the top. All regressions control for gender, race and ethnicity, state fixed effects, cohort fixed effects, year fixed effects, and linear state specific trends. Effect size is calculated by dividing the estimate by the pre-reform mean.

2.5.3 Composition Effects of Math Reforms

The impact of stricter high school math curriculum requirements on students' college STEM attainment could be driven by both the intensive and extensive margin. To better understand the how stricter high school math curriculum requirements impact college STEM attainment, I explore the composition effects of math reforms. On the extensive margin, I examine the impact of math reforms on high school graduation, GED taking, college attendance, associate's degree completion, and bachelor's degree completion. On the intensive margin, I estimate how math reforms impacted degree completion in non-STEM fields.

I first present estimates on the extensive margin in Table 6 to 8. Table 6 reports the average impacts, whereas Table 7 and 8 report the heterogeneity in treatment effects across the demographic groups. Beginning with the top panel of Table 6, I find that, on average, the first wave of math reforms had no significant impacts on high school graduation or GED taking. Consistent with the average effect, estimates on each subgroup, as listed in the first two columns in Table 7 are also small and not statistically significantly different from zero. The next two columns in Table 6 suggest that individuals were less likely to attend college and complete an associate's degree after high school math curriculum requirement increases. For example, the share of the population getting an associate's degree dropped by 0.31 percentage points, which is about four percent of the pre-reform value. Table 7 shows that the decline in associate's degree completion happened to all subgroups, and the negative effects were particularly

TABLE 2.6

EFFECTS OF STRICTER HIGH SCHOOL MATH REQUIREMENTS ON

EDUCATIONAL ATTAINMENT

	HS (1)	GED (2)	Attendance (3)	AAonly (4)	BA (5)
1st Reform	-0.0018 (0.0022)	0.0009 (0.0015)	-0.0046 (0.0030)	-0.0031* (0.0017)	-0.0011 (0.0041)
Mean	0.8637	0.0465	0.5992	0.0921	0.2696
Effect Size	-0.21%	2.02%	-0.78%	-3.40%	-0.40%
N	1,838,730	1,838,730	1,838,730	1,838,730	1,838,730
2nd Reform	0.0000 (0.0020)	-0.0016 (0.0013)	-0.0019 (0. 0030)	0.0013 (0.0017)	-0.0023 (0.0034)
Mean	0.8688	0.0500	0.6755	0.0967	0.3290
Effect Size	0.00%	-3.19%	-0.28%	1.32%	-0.69%
N	1,538,054	1,538,054	1,538,054	1,538,054	1,538,054

***p < .01, **p < .05, *p < .1

NOTE: Data are from the 2009 to 2012 American Community Surveys. The sample includes U.S.-born population who are at least 22 years old at the year of the survey with non-imputed data on age, state of birth, educational attainment, and degree field. Subsample for the first wave of reforms includes high school cohorts from 1978 to 1992; subsample for the second wave of reforms includes high school cohorts from 1993 to 2008. Standard errors are clustered by state and are listed in parentheses. Each coefficient is from a separate regression for the outcome variable listed at the top. All regressions control for gender, race and ethnicity, state fixed effects, cohort fixed effects, year fixed effects, and linear state specific trends. Effect size is calculated by dividing the estimate by the pre-reform mean.

TABLE 2.7

EFFECTS OF STRICTER HIGH SCHOOL MATH REQUIREMENTS ON

EDUCATIONAL ATTAINMENT, FIRST WAVE

	HS (1)	GED (2)	Attendance (3)	AAonly (4)	BA (5)
Reform_WF	-0.0001 (0.0021)	-0.0009 (0.0014)	-0.0068* (0 0038)	-0.0045 (0.0029)	-0.0052 (0.0054)
Reform_WM	-0.0022 (0.0028)	0.0030 (0.0018)	-0.0013 (0.0042)	-0.0030 (0.0021)	0.0040 (0.0047)
Reform_NWF	-0.0061 (0.0059)	-0.0004 (0.0021)	-0.0061 (0.0089)	-0.0015 (0.0054)	-0.0061 (0.0061)
Reform_NWM	-0.0062 (0.0065)	0.0033 (0.0046)	-0.0113 (0.0079)	-0.0005 (0.0036)	-0.0014 (0.0051)
N	1,838,730	1,838,730	1,838,730	1,838,730	1,838,730

***p < .01, **p < .05, *p < .1

NOTE: Data are from the 2009 to 2012 American Community Surveys. The sample includes U. S.-born population who are at least 22 years old at the year of the survey with non-imputed data on age, state of birth, educational attainment, and degree field. Subsample for the first wave of reforms includes high school cohorts from 1978 to 1992. Standard errors are clustered by state and are listed in parentheses. Each coefficient is from a separate regression for the outcome variable listed at the top. All regressions control for gender, race and ethnicity, state fixed effects, cohort fixed effects, year fixed effects, and linear state specific trends. Effect size is calculated by dividing the estimate by the pre-reform mean.

TABLE 2.8

EFFECTS OF STRICTER HIGH SCHOOL MATH REQUIREMENTS ON

EDUCATIONAL ATTAINMENT, SECOND WAVE

	HS (1)	GED (2)	Attendance (3)	AAonly (4)	BA (5)
Reform_WF	0.0013 (0.0028)	-0.0015 (0.0018)	-0.0009 (0.0036)	0.0021 (0.0022)	-0.0050 (0.0041)
Reform_WM	-0.0015 (0.0025)	-0.0005 (0.0016)	-0.0033 (0.0034)	0.0022 (0.0025)	0.0029 (0.0047)
Reform_NWF	0.0015 (0.0066)	-0.0003 (0.0024)	-0.0051 (0.0084)	-0.0061 (0.0054)	-0.0039 (0.0051)
Reform_NWM	0.0015 (0.0058)	-0.0072* (0.0038)	0.0036 (0.0083)	0.0030 (0.0030)	-0.0012 (0.0069)
N	1,538,054	1,538,054	1,538,054	1,538,054	1,538,054

***p < .01, **p < .05, *p < .1
NOTE: Data are from the 2009 to 2012 American Community Surveys. The sample includes U. S.-born population who are at least 22 years old at the year of the survey with non-imputed data on age, state of birth, educational attainment, and degree field. Subsample for the second wave of reforms includes high school cohorts from 1993 to 2008. Standard errors are clustered by state and are listed in parentheses. Each coefficient is from a separate regression for the outcome variable listed at the top. All regressions control for gender, race and ethnicity, state fixed effects, cohort fixed effects, year fixed effects, and linear state specific trends. Effect size is calculated by dividing the estimate by the pre-reform mean.

strong among white females and white males. For the second wave of math reforms, I find that stricter high school math curriculum requirements had no effect on high school graduation, with the estimated average effect being zero. Next, column 2 in Table 6 demonstrates that individuals were less likely to take GED test after the second waves of reforms. Table 8 further shows that among black and Hispanic females, the decline is 0.72 percentage points and is statistically significant. Finally, as we can see, estimates in column 3 to 5 are all relatively small and not statistically significant, suggesting that the recent reforms had no significant impacts college attendance, and degree completion. Notably, relating the findings to the exit exams literature, the results suggest that unlike exit exams, raising curriculum requirements seem to have no negative impacts on high school graduation.[27]

Next, I explore the impact of math reforms on the intensive margin. I estimate the effect of stricter high school math curriculum requirement on degree completion in the following non-STEM fields: education, liberal arts and humanity, English and foreign languages, and social science including economics, anthropology, criminology, geography, international relations, political science, and sociology.[28] On the one hand, one might expect stricter high school math curriculum requirements to have no impacts on degree completion in these fields. On the other hand, with strengthened math curriculum in high school some students might be shifted away from non-STEM majors

[27] Studies have demonstrated that exit exams decreased high school completion rates and increased rates of GED test taking (Warrant, Jenkins, and Kulick 2006; Dee and Jacob, 2006).

[28] Education does not include teaching fields in math, science, and computer.

and into STEM majors, in which case we would expect decreases in degree completion in non-STEM fields.

The results are listed in In Table 9 to 11. The top panel of Table 9 indicates that the first wave of math reforms had a negative impact on degree completion in social science but not the other fields. Column 4 in Table 10 further demonstrates that the declines were mostly among females and minorities. For example, the share of social science majors decreased by 0.46 percentage points among white females. The estimate is economically large and statistically significant, implying a nearly 10 percent decline in degree completion in social science fields. Black and Hispanics also experienced large declines, although the estimates are less precisely measured. Interestingly, the opposite scenario happened to white males. As listed in row 2, column 4, white males were about 0.3 percentage points more likely to completion a degree in social science fields with stricter high school math requirements. The second wave of math reforms, on the other hand, statistically significantly reduced degree completion in education fields, particularly for females. Column 1 in Table 13 indicates that among black and Hispanic females, the share of education majors decreased by over 15 percent in the wake of the recent reforms. White females were also less likely to complete degrees in social science. The size of the decline is about five percent.

TABLE 2.9

EFFECTS OF STRICTER HIGH SCHOOL MATH REQUIREMENTS ON NON-STEM DEGREE COMPLETION

	Education (1)	Liberal arts, Humanity (2)	English, Language (3)	Social science (4)
1st Reform	-0.0001	0.0000	0.0000	-0.0015
	(0.0013)	(0.0004)	(0.0004)	(0.0011)
Mean	0.0311	0.0047	0.0109	0.0418
Effect Size	-0.41%	0.31%	-1.63%	-3.58%
N	1,838,730	1,838,730	1,838,730	1,838,730
2nd Reform	-0.0025*	-0.0001	-0.0002	-0.0001
	(0.0012)	(0.0003)	(0.0007)	(0.0010)
Mean	0.0396	0.0047	0.0166	0.0605
Effect Size	-6.22%	-9.01%	-1.00%	-0.11%
N	1,538,054	1,538,054	1,538,054	1,538,054

***p < .01, **p < .05, *p < .1

NOTE: Data are from the 2009 to 2012 American Community Surveys. The sample includes U. S.-born population who are at least 22 years old at the year of the survey with non-imputed data on age, state of birth, educational attainment, and degree field. Subsample for the first wave of reforms includes high school cohorts from 1978 to 1992; subsample for the second wave of reforms includes high school cohorts from 1993 to 2008. Standard errors are clustered by state and are listed in parentheses. Each coefficient is from a separate regression for the outcome variable listed at the top. Column (3) includes English, Linguistics and Foreign Languages, Linguistics and Foreign Languages. Social science in Column (4) includes economics, anthropology, criminology, geography, international relations, political science, and sociology. All regressions control for gender, race and ethnicity, state fixed effects, cohort fixed effects, year fixed effects, and linear state specific trends. Effect size is calculated by dividing the estimate by the pre-reform mean.

TABLE 2.10

EFFECTS OF STRICTER HIGH SCHOOL MATH REQUIREMENTS ON NON-STEM DEGREE COMPLETION, FIRST WAVE

	Education (1)	Liberal arts, Humanity (2)	English, Language (3)	Social science (4)
Reform_WF	-0.0019	0.0003	-0.0012	-0.0046**
	(0.0024)	(0.0005)	(0.0010)	(0.0020)
Effect Size	-3.57%	4.36%	-7.38%	-9.64%
Reform_WM	0.0000	-0.0006	0.0009	0.0027*
	(0.0012)	(0.0005)	(0.0010)	(0.0015)
Effect Size	0.07%	-14.73%	10.33%	6.14%
Reform_NWF	0.0030	0.0009	0.0003	-0.0035
	(0.0020)	(0.0008)	(0.0011)	(0.0032)
Effect Size	11.75%	24.21%	4.25%	-10.71%
Reform_NWM	0.0031*	0.0003	-0.0002	-0.0042
	(0.0015)	(0.0006)	(0.0007)	(0.0026)
Effect Size	35.55%	10.73%	-6.70%	-18.98%
N	1,838,730	1,838,730	1,838,730	1,838,730

***p < .01, **p < .05, *p < .1

NOTE: Data are from the 2009 to 2012 American Community Surveys. The sample includes U. S.-born population who are at least 22 years old at the year of the survey with non-imputed data on age, state of birth, educational attainment, and degree field. Subsample for the first wave of reforms includes high school cohorts from 1978 to 1992. Standard errors are clustered by state and are listed in parentheses. Each coefficient is from a separate regression for the outcome variable listed at the top. Column (3) includes English, Linguistics and Foreign Languages, Linguistics and Foreign Languages. Social science in Column (4) includes economics, anthropology, criminology, geography, international relations, political science, and sociology. All regressions control for gender, race and ethnicity, state fixed effects, cohort fixed effects, year fixed effects, and linear state specific trends. Effect size is calculated by dividing the estimate by the pre-reform mean.

TABLE 2.11

EFFECTS OF STRICTER HIGH SCHOOL MATH REQUIREMENTS ON NON-STEM DEGREE COMPLETION, SECOND WAVE

	Education (1)	Liberal arts, Humanity (2)	English, Language (3)	Social science (4)
Reform_WF	-0.0033	0.0002	-0.0006	-0.0022*
	(0.0020)	(0.0005)	(0.0013)	(0.0013)
Effect Size	-4.53%	3.77%	-2.26%	-4.61%
Reform_WM	-0.0015	-0.0003	0.0001	0.0013
	(0.0012)	(0.0004)	(0.0007)	(0.0015)
Effect Size	-7.30%	-7.60%	1.14%	2.39%
Reform_NWF	-0.0041*	0.0002	0.0004	0.0027
	(0.0022)	(0.0008)	(0.0011)	(0.0025)
Effect Size	-15.15%	5.45%	3.61%	5.21%
Reform_NWM	0.0000	-0.0007	-0.0002	0.0010
	(0.0011)	(0.0005)	(0.0008)	(0.0021)
Effect Size	0.42%	-28.35%	-3.61%	4.17%
N	1,538,054	1,538,054	1,538,054	1,538,054

***p < .01, **p < .05, *p < .1

NOTE: Data are from the 2009 to 2012 American Community Surveys. The sample includes U. S.-born population who are at least 22 years old at the year of the survey with non-imputed data on age, state of birth, educational attainment, and degree field. Subsample for the second wave of reforms includes high school cohorts from 1993 to 2008. Standard errors are clustered by state and are listed in parentheses. Each coefficient is from a separate regression for the outcome variable listed at the top. Column (3) includes English, Linguistics and Foreign Languages, Linguistics and Foreign Languages. Social science in Column (4) includes economics, anthropology, criminology, geography, international relations, political science, and sociology. All regressions control for gender, race and ethnicity, state fixed effects, cohort fixed effects, year fixed effects, and linear state specific trends. Effect size is calculated by dividing the estimate by the pre-reform mean.

2.6 Conclusion and Future Work

Policy makers often view raising high school math curriculum requirements as an important vehicle for improving students' college STEM attainment. Such initiatives started in the early 1980s after Reagan's influential report "A Nation at Risk," continued in the 1990s and 2000s with the standards-based education reforms, and have been accelerated by the Obama administration's recent campaign, "Educate to Innovate."

In this paper, I examine the impact of stricter high school math curriculum requirements on degree completion in STEM fields by exploiting two waves of nationwide math reforms. I find that the earlier reforms that focused on adding minimum year requirements had strong impacts on traditionally underrepresented groups, particularly white females and black and Hispanic males, but had limited impacts on white males. In contrast, the recent standards-based curriculum reforms substantially increased STEM degree completion among white males, with no significant impacts on others. I demonstrate that the impacts are not primarily driven by changes in the composition of students graduating from high school and attending college. Instead, degree completion in non-STEM fields decreased after math reforms, suggesting that stricter high school math curriculum requirements had shifted students away from non-STEM fields into STEM fields. Overall, the findings suggest that the specific features of math curriculum reforms are important and would lead to heterogeneous impacts across the population. Reforms with relative low requirements have stronger impacts on college STEM attainment on traditionally underrepresented groups, whereas more challenging, standards-based reforms mostly benefit student with more advanced math skills, but could potentially negatively impact others. When adopting stricter curriculum requirements, it is crucial for policy makers to consider the heterogeneity. Different interventions might be necessary for effectively improving college STEM attainment of different populations.

In addition to academic preparation, stricter high school math curriculum requirements could impact students' college STEM attainment though the preference channel. By being exposed to more math in high school, students might become more interested in STEM fields and thus more likely to enter such fields in college. As stated in the 2010 report by the President's Council of Advisors on Science and Technology, "Prepare and Inspire," one important focus of recent policies is to "inspire students so that all are motivated to study STEM subjects in school and many are excited about the prospect of having careers in STEM fields."[29] Unfortunately, there is a general lack of interest in STEM fields among high school students, even among those who were math proficient.[30] As an important next step, I would like to examine the impact of stricter high school math curriculum requirements on students' preference and how this, in turn, affects their college STEM attainment. The question could be explored with the available data on students' interests in STEM fields or intended college major, such as the CIRP Freshman Survey (TFS) conducted by the Higher Education Research Institute at the University of California, Los Angeles.[31]

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[29] Prepare and Inspire: K-12 Science, Technology, Engineering, and Math (STEM) Education for America's Future, President's Council of Advisors on Science and Technology (PCAST), 2010

[30] Meeting the STEM Workforce Demand: Accelerating Math Learning Among Students Interested in STEM, Business-Higher Education Forum, 2011

[31] More information about TFS is available at http://www. heri. ucla. edu/cirpoverview. php , Higher Education Research Institute, University of California, Los Angeles

Finally, data from the Census suggest that over 70 percent of STEM graduates are not employed in STEM occupations and that women are especially less likely to be employed in STEM occupations. [32] While not addressed in the current paper, I view the labor market outcomes as an important question for further research. Are individuals also more likely to work in STEM fields after graduating from college? What did the heterogeneous impacts on college STEM attainment imply for the wage inequality across demographic groups? Understanding these questions are particularly policy relevant given that the ultimate goal driving high school math curriculum reforms is to build up a college-educated workforce in STEM fields.

[32] The Relationship Between Science and Engineering Education and Employment in STEM Occupations, American Community Survey Reports, 2013

APPENDIX A:

SUPPLEMENTAL TABLES

TABLE A.1

IMMIGRANT-NATIVE GAP: PERSISTING IN STEM FIELDS, UNCONDITIONAL

	(1)	*(2)*	*(3)*	*(4)*
1st Gen	0.1420***	0.0870***	0.0832***	0.0595**
	(0.0279)	(0.0302)	(0.0301)	(0.0287)
1.5 Gen	0.1164***	0.0691*	0.0685*	0.0648*
	(0.0356)	(0.0392)	(0.0390)	(0.0371)
2nd Gen	0.0465***	0.0048	0.0048	-0.0025
	(0.0175)	(0.0185)	(0.0185)	(0.0173)
SES		Y	Y	Y
Preference			Y	Y
Academic				Y
N	11720	11720	11720	11720
R^2	0.0091	0.0491	0.0507	0.0939

***p<.01. **p<.05, *p<.1

NOTE: Data from BPS 2004/09, for a sample of students with non-missing data on math and science preparation, including SAT scores, years of math, years of science, and highest level of math in high school. Parental educational attainment is measured as having any college degree, including an associate's degree and above. Regressions are weighted. Sample sizes are rounded to the nearest ten to comply with the restricted-use data licensing requirements from NCES.

TABLE A.2

IMMIGRANT-NATIVE GAP BY RACE AND ETHINICITY, ENTERING STEM FIELDS

	(1)	*(2)*	*(3)*	*(4)*
Asian				
1st Gen	0.2085***	0.2472***	0.2357***	0.2029**
	(0.0431)	(0.0711)	(0.0704)	(0.0677)
1.5 Gen	0.1141*	0.1615*	0.1563*	0.1766**
	(0.0583)	(0.0831)	(0.0825)	(0.0749)
2nd Gen	0.1448***	0.1778**	0.1740**	0.1643**
	(0.0394)	(0.0710)	(0.0700)	(0.0674)
Black				
1st Gen	0.3040***	0.2699***	0.2647***	0.2443**
	(0.0911)	(0.0801)	(0.0770)	(0.0776)
1.5 Gen	-0.0757	-0.0956	-0.0952	-0.0757
	(0.0762)	(0.0768)	(0.0768)	(0.0761)
2nd Gen	-0.0417	-0.0422	-0.0386	-0.0320
	(0.0393)	(0.0436)	(0.0431)	(0.0411)
Hispanics				
1st Gen	0.0333	0.0892*	0.0954**	0.0695
	(0.0390)	(0.0466)	(0.0458)	(0.0467)
1.5 Gen	-0.0134	0.0530	0.0576	0.0498
	(0.0476)	(0.0578)	(0.0576)	(0.0566)
2nd Gen	-0.0063	0.0860**	0.0879***	0.0746**
	(0.0251)	(0.0339)	(0.0341)	(0.0340)
White				
1st Gen	0.0888*	0.0645	0.0605	0.0415
	(0.0497)	(0.0489)	(0.0489)	(0.0453)
1.5 Gen	0.11043*	0.0807	0.0789	0.0535
	(0.0557)	(0.0541)	(0.0539)	(0.0532)
2nd Gen	0.0063	-0.0047	-0.0063	-0.0116
	(0.0275)	(0.0266)	(0.0266)	(0.0254)
SES		Y	Y	Y

TABLE A.2 (CONTINUED)

Preference			Y	Y
Academic				Y
N	11720	11720	11720	11720
R^2	0.0116	0.0661	0.0687	0.1031

***p<.01. **p<.05, *p<.1

NOTE: Data from BPS 2004/09, for a sample of students with non-missing data on math and science preparation, including SAT scores, years of math, years of science, and highest level of math in high school. Parental educational attainment is measured as having any college degree, including an associate's degree and above. Regressions are weighted. Sample sizes are rounded to the nearest ten to comply with the restricted-use data licensing requirements from NCES.

TABLE A.3

IMMIGRANT-NATIVE GAP BY RACE AND ETHINICITY, PERSISTING IN STEM FIELDS

	(1)	*(2)*	*(3)*	*(4)*
Asian				
1st Gen	0.1876***	-0.1942*	-0.1823*	-0.2200*
	(0.0595)	(0.1077)	(0.1082)	(0.1168)
1.5 Gen	0.0647	-0.2878**	-0.2714**	-0.3106**
	(0.1006)	(0.1354)	(0.1369)	(0.1434)
2nd Gen	0.1085*	-0.2762**	-0.2644***	-0.2653**
	(0.0652)	(0.1078)	(0.1082)	(0.1158)
Black				
1st Gen	-0.1883	-0.0830	-0.0973	-0.1466
	(0.1189)	(0.1130)	(0.1161)	(0.1147)
1.5 Gen	-0.3192*	-0.2634	-0.2565	-0.1828
	(0.1734)	(0.2117)	(0.2123)	(0.1718)
2nd Gen	-0.0387	0.0012	-0.0075	-0.0364
	(0.1092)	(0.1150)	(0.1176)	(0.1140)
Hispanics				
1st Gen	0.0431	0.1148	0.1182	0.1080
	(0.0818)	(0.1153)	(0.1156)	(0.1176)
1.5 Gen	-0.0734	0.0051	-0.088	0.0013
	(0.1163)	(0.1441)	(0.1408)	(0.1359)
2nd Gen	0.1351**	-0.0274	-0.0258	-0.0228
	(0.0602)	(0.0995)	(0.0967)	(0.0935)
White				
1st Gen	0.1085	0.0680	0.0505	0.0185
	(0.0891)	(0.0878)	(0.0876)	(0.0909)
1.5 Gen	0.2964***	0.2478***	0.2438***	0.2279***
	(0.0837)	(0.0859)	(0.0864)	(0.0805)
2nd Gen	-0.0020	-0.0273**	-0.0302	-0.0657
	(0.0692)	(0.0704)	(0.0695)	(0.0645)
SES		Y	Y	Y

TABLE A.3 (CONTINUED)

Preference			Y	Y
Academic				Y
N	2750	2750	2750	2750
R^2	0.0148	0.0591	0.0604	0.1005

***p<.01. **p<.05, *p<.1

NOTE: Data from BPS 2004/09, for a sample of students with non-missing data on math and science preparation, including SAT scores, years of math, years of science, and highest level of math in high school. Parental educational attainment is measured as having any college degree, including an associate's degree and above. Regressions are weighted. Sample sizes are rounded to the nearest ten to comply with the restricted-use data licensing requirements from NCES.

TABLE A.4

STATE HIGH SCHOOL MATH REQUIREMENT INCRESES, FIRST WAVE

First Cohort	States and Types of Change
1985	AL (1 to 2), AK (1 to 2), DC (1 to 2), ND (1 to 2)
1986	NV (1 to 2)
1987	AZ (1 to 2), CA (0 to 2), DE (1 to 2), FL (0 to 3), KY (2 to 3), NC (1 to 2), OK (1 to 2), SC (2 to 3), TN (1 to 2)
1988	AR (0 to 3), CT (0 to 3), GA (1 to 2), ID (1 to 2), IL (0 to 2), MO (1 to 2), NJ (2 to 3), OH (1 to 2), OR (1 to 2), TX (2 to 3), UT (1 to 2), VA (1 to 2)
1989	IN (1 to 2), KS (1 to 2), LA (2 to 3), ME (0 to 2), MD (2 to 3), MS (1 to 2), NH (1 to 2), PN (1 to 3), RI (1 to 2), SD (1 to 2), VT (1 to 2), WA (0 to 2), WI (0 to 2), WV (1 to 2)
1990	NM (2 to 3)

NOTE Data on state math course requirements for each high school graduation cohort are collected from the Education Commission for the States (ECS) and the Digest of Education Statistics from Institute of Education Sciences (IES).

TABLE A.5

STATE HIGH SCHOOL MATH REQUIREMENT INCRESES, SECOND WAVE

First Cohort	States and Types of Change
1994	NC (2 to 3), TN (2 to 3)
1995	DC (2 to 3)
1997	GA (2 to 3), HI (2 to 3), WY (0 to 2)
2000	AL (2 to 4), DE (2 to 3)
2001	MN (1 to 3), GA (3 to 4), SC (3 to 4)
2002	MS (2 to 3), VT (2 to 3), VA (2 to 3)
2003	NV (2 to 3), OK (2 to 3), WV (2 to 3), WY (2 to 3), PA (3 to NA)
2004	NC (3 to 4), OH (2 to 3)
2005	AR (3 to 4), NY (2 to 3), IL (2 to 3)
2006	RI (2 to 4)
2007	IN (2 to 3)

NOTE: Data on state math course requirements for each high school graduation cohort are collected from the Education Commission for the States (ECS) and the Digest of Education Statistics from Institute of Education Sciences (IES).

TABLE A.6

EFFECTS OF STRICTER HIGH SCHOOL MATH REQUIREMENTS ON COLLEGE STEM ATTAINMENT

	1st Wave			2nd Wave		
	(1)	(2)	(3)	(4)	(5)	(6)
Reform_WF	0.0037** (0.0018)	0.0336	10.94%	0.0016 (0.0018)	0.0449	3.62%
Reform_WM	0.0012 (0.0027)	0.0841	1.48%	0.0045*** (0.0016)	0.0827	5.40%
Reform_ASNF	0.0085 (0.0253)	0.1474	5.75%	-0.0123 (0.218)	0.1783	-6.88%
Reform_ASNM	0.0091 (0.0246)	0.2572	3.55%	0.0106 (0.0146)	0.2479	4.29%
Reform_NWF	0.0002 (0.0018)	0.0199	1.24%	0.0011 (0.0023)	0.0271	4.10%
Reform_NWM	0.0025 (0.0028)	0.0331	7.56%	0.0018 (0.0024)	0.0347	5.08%
N	1,838,730			1,538,054		

NOTE Data are from the 2009 to 2012 American Community Surveys. The sample includes U. S. -born population who are at least 22 years old at the year of the survey with non-imputed data on age, state of birth, educational attainment, and degree field. Subsample for the first wave of reforms includes high school cohorts from 1978 to 1992; subsample for the second wave of reforms includes high school cohorts from 1993 to 2008. Standard errors are clustered by state and are listed in parentheses. Each coefficient is from a separate regression for the outcome variable listed at the top. All regressions control for gender, race and ethnicity, state fixed effects, cohort fixed effects, year fixed effects, and linear state specific trends. Effect size is calculated by dividing the estimate by the pre-reform mean.

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