EXPLAINING GAPS IN READINESS FOR COLLEGE-LEVEL MATH: THE ROLE OF HIGH SCHOOL COURSES

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Abstract

Despite increased requirements for high school graduation, almost one-third of the nation's college freshmen are unprepared for college-level math. The need for remediation is particularly high among students who are low income, Hispanic, and black. Female students are also less likely than males to be ready for college-level math. This article estimates how much of these gaps are determined by the courses that students take while in high school. Using data on students in Florida public postsecondary institutions, we find that differences among college-going students in the highest math course taken explain 28–35 percent of black, Hispanic, and poverty gaps in readiness and over three-quarters of the Asian advantage. Courses fail to explain gender gaps in readiness. Low-income, black, and Asian students also receive lower returns to math courses, suggesting differential educational quality. This analysis is valuable to policy makers and educators seeking to reduce disparities in college readiness.

1. INTRODUCTION

Despite substantial increases over the past several decades in the number of courses required to graduate from a U.S. high school, many of today's graduates are still unprepared for college-level coursework. An estimated 28 percent of students who entered college in 2000 required remediation in reading, writing, or mathematics, with the highest need for remediation in mathematics (Parsad and Lewis 2003). Students who are low income, Hispanic, and black are least likely to be prepared for college-level coursework, and females are slightly less likely to be ready than males. Prior research on race and income gaps in educational performance suggests a number of explanations, such as differences in parental human capital, the quality of peers and resources across and within schools, and the treatment of students by their teachers (e.g., Fryer and Levitt 2004). Yet little of the prior research has taken a close look at the contribution of high school courses to demographic and socioeconomic gaps in secondary and postsecondary success. The lack of rigorous research on this topic is notable given the scrutiny that policy makers, educators, and testing entities, such as the American College Testing (ACT) program, have given to the course-taking patterns of American high school students.

This article examines the contribution of the highest math course taken in high school to racial, socioeconomic, and gender gaps in readiness for college-level math, controlling for students' academic achievement prior to entering high school, and other characteristics. With data on students in Florida public high schools who continue on to a Florida public postsecondary institution, we first examine sociodemographic gaps in readiness for college-level math. We then decompose the readiness gaps into the portions explained by the following differences across subgroups of students: (1) sociodemographic characteristics (for instance, the extent to which black-white gaps are explained by differences in family poverty, proxied by free or reduced-price lunch eligibility);[1] (2) educational needs (limited English proficiency [LEP] and special needs); (3) parental tastes for education (proxied by the choice of eighth-grade school); (4) knowledge gained prior to high school (performance on the eighth-grade math exam); and (5) highest math course taken in high school. We focus our analysis and discussion on comparing the contribution of the first four factors (characteristics of students and quality of education received prior to high school) to the fifth factor (courses that students take while in high school).

Increasing the number and level of courses required for high school graduation seems a straightforward policy remedy for better preparing students for

1. Free and reduced price lunch status may not be a perfect proxy for poverty because some students may not apply for the public subsidy. Our ability to explain college readiness gaps will be weakened to the extent that certain demographic groups (e.g., white students) are less likely to apply for the subsidy.

college, but we take a deeper look at this assumption by also exploring whether the returns to these courses are the same for all demographic and socioeconomic groups. There is widespread agreement, for instance, that students should be required to take more math courses and, in particular, courses beyond Algebra 2 in order to be prepared for college-level math (Adelman 2006; ACT 2007), yet it is not clear that all students benefit equally from the same courses.

Although there is no evidence that remedial coursework lowers postsecondary success relative to similar students who do not take remedial courses (Bettinger and Long 2005), focusing on the drivers of remedial education is important because the costs to reteach high school–level material in college are high. In Florida, an estimated $118.3 million was spent to provide remedial education to underprepared college entrants in 2003–4 (OPPAGA 2006). These financial costs were shared almost equally between the state and the students who took the courses that did not count toward their final degrees. Furthermore, the higher costs of college due to remedial coursework disproportionately fall on community college students who tend to be lower income. The tuition spent and time invested in remedial coursework may also delay or prevent entry into four-year institutions.[2]

We find that even among the select group of Florida high school students who enter a Florida public postsecondary institution, there are substantial racial, socioeconomic, and gender gaps in readiness for college-level math. Between 28 and 35 percent of black-white, Hispanic-white, and poverty gaps can be explained by differences in the math courses students take in high school, while differences in students' educational needs, eighth-grade scores, and eighth-grade campuses explain much of the rest. Black and poor students also receive smaller gains from taking higher-level math courses than those received by white and nonpoor students. The role of high school courses in explaining the high Asian readiness rates relative to whites is substantial: over three-quarters of the gap is explained by the higher rates of math course–taking among Asians relative to whites. In fact, Asians obtain higher readiness rates than whites even though they earn lower returns for the same courses. In contrast, gender gaps in college readiness are largely driven by the fact that females are more likely to attend college than males; as a result, the female college-goers tend to be less prepared than the male college-goers. These results suggest that equalizing race and poverty gaps in course taking can have profound effects on narrowing gaps in college readiness but that gender gaps

2. In many states, including Florida, community colleges are responsible for providing remedial coursework. Florida state law prohibits four-year institutions, with the exception of Florida Agricultural and Mechanical University, from offering remedial courses. Florida universities may, however, have arrangements with the community colleges to remediate their students (OPPAGA 2006).

in readiness are being driven by something other than the courses students take in high school.

While the results of this study are of clear relevance to Florida educators and state policy makers, the size and diversity of the state render the results important to the nation. Florida's 1.9 million students account for 4.6 percent of the nation's public school enrollment, and thirteen of the state's sixty-seven school districts are in the top one hundred of the largest school districts in the country. Florida also educates large percentages of black and Hispanic students (24 percent and 22 percent, respectively), which gives us the opportunity to draw conclusions about course taking and readiness for population subgroups that are large majorities in some school districts and states.[3] One additional advantage that Florida offers, aside from richly detailed student-level data, is the fact that there is a statewide college placement test to determine readiness that is the same across institutions. Earlier work on college readiness relied on institutional-level tests that varied in terms of content and cutoffs.

2. PRIOR RESEARCH ON THE EFFECTS OF HIGH SCHOOL COURSES

Though causality has not been entirely established, several studies suggest that taking more credits in math and more advanced math courses increases: (1) proficiency on high school standardized mathematics exams (Gamoran 1987; Bryk, Lee, and Smith 1990; Cool and Keith 1991; Stevenson, Schiller, and Schneider 1994; Rock and Pollack 1995; Berkner and Chavez 1997; Shettle et al. 2007); (2) the likelihood of high school graduation (e.g., Schneider, Swanson, and Riegle-Crumb 1998); (3) entry into and performance while in college (Schneider, Swanson, and Riegle-Crumb 1998; Adelman 2006); and (4) choice of college major (Federman 2007). For example, Adelman (2006) concludes that coursework above Algebra 2 significantly increases the likelihood of college completion.

Another line of research documents large demographic and socioeconomic disparities in high school course taking (Catsambis 1994; Stevenson, Schiller, and Schneider 1994; Davenport et al. 1998; Klopfenstein 2004; Riegle-Crumb 2006), and these course-taking disparities are found to partially explain racial and gender disparities in high school achievement and graduation (Hoffer, Rasinski, and Moore 1995; Rose 2004). There is also some evidence that the returns to courses differ for demographic and socioeconomic subgroups. Recent research on Texas public school students, for example, indicates that

3. It is worth noting that Florida's Hispanic students may be different than Hispanics in the rest of the nation given the large Cuban population. Cubans, 68 percent of whom live in Florida, tend to be more educated and have higher incomes than other Hispanics, making our estimates of Hispanic gaps in readiness likely smaller than might be observed elsewhere (Pew Hispanic Center 2006).

low-income and minority students who take and receive credit for advanced placement (AP) courses are more likely to fail state exit and AP exams than their higher-income, white peers (Dougherty, Mellor, and Jian 2006). One concern is that the title of the advanced courses offered in predominantly low-income, minority schools does not reflect the actual content and rigor of the curriculum, a problem referred to as “course credit inflation” (Dougherty, Mellor, and Jian 2006). Other explanations for return differences include differences across demographic groups in the importance of the quality of teachers and peers that may be associated with higher-level math course taking; differences in the rates at which students are receiving passing grades (and thus course credit) without having learned the material; and differences in retaining the material (perhaps caused by differences in expectations regarding the value of retaining the material).

There are possible gender disparities in returns as well. A recent report by the National Center for Education Statistics (NCES) (Shettle et al. 2007) on the course-taking patterns and performance (as measured by high school grade point average [GPA] and scores on the National Assessment of Educational Progress [NAEP]) of high school graduates in 2005 shows that females now take more challenging math and science courses and receive higher grades for those courses than males (a reverse in the course-taking disparities observed in an earlier report on 1990 high school graduates). Yet the study also shows that males who take advanced math courses still score higher on the NAEP than females who take the same courses. Since there is less across-school segregation by gender than by race or socioeconomic status, differences in the quality of the courses offered to females and males are unlikely to explain these findings.

Our article focuses on the relationship between course taking and the need for remedial coursework in college, a subject that has received relatively less attention. Some studies have found a positive correlation between course taking and achievement on national college admissions examinations, including the Scholastic Achievement Test (SAT) and the ACT program (Sebring 1987; Schneider 2003; ACT 2005, 2007). Yet these studies focus on the higher end of the high school distribution—students who take the SAT or the ACT—and as a result may generate biased estimates of the effect of high school courses on readiness. In addition, these studies rarely control for prior performance and are unable to disentangle the effect of the courses on college preparedness from the effect of motivation or other unobserved traits, a distinction we attempt to establish more definitively.

We could find only two studies that examine the relationship between high school courses and the need for college-level remediation among college entrants (not restricted to those who took the ACT or SAT). Hoyt and Sorenson

(2001) examine college remediation and high school courses of students from two Utah school districts who attended Utah Valley State College in 1998. The study finds that students who take higher-level courses in high school require less remediation in college. Yet many of the students who earned passing grades in higher-level math courses in high school also needed remedial courses in college. The authors suggest that students are not retaining the material they learn in their high school courses or that they are not motivated to study for the tests that determine whether they require remediation. A final possibility is that students are receiving passing grades despite having never learned the material.

Using similar data to ours, Roth et al. (2001) analyze the high school transcripts and college readiness rates of a cohort of 19,736 Florida public school students who graduated in 1994 and entered a Florida community college. The study operationalizes math course taking with an index that scores each course according to its rigor from one (e.g., basic or consumer math) to three (precalculus), then multiplies the rigor by the grade earned by the student.[4] While Roth and colleagues find significant differences in readiness by race and gender, their aggregation of math course taking into an index masks critical information on the relative importance of particular courses and the highest level of course taking. Moreover, the analysis does not take into account other factors that are likely to matter for a student's readiness for college, such as socioeconomic status, educational needs, prior academic achievement, and quality of the middle school attended.

To summarize, the prior research suggests a strong effect of math course taking on high school achievement and college completion that varies for subgroups of students. The research on the effect of high school courses on the need for remedial coursework in the first year of college is limited to two studies that do not control for prior achievement.

3. MODEL, ESTIMATION, AND DECOMPOSITION

Readiness for college-level math depends on the actions and characteristics of parents, students, and schools. Our effort is to distinguish the direct effect of high school course taking on readiness, net of other influences. We estimate the following empirical model of college readiness:

$$\text{Prob}(R_{ims} = 1) = \Phi(Q_j) = \Phi(\boldsymbol{D}_i\boldsymbol{\delta}_1 + \boldsymbol{E}_i\boldsymbol{\delta}_2 + \boldsymbol{A}_i\boldsymbol{\delta}_3 + \boldsymbol{M}_i\boldsymbol{\delta}_4 + \nu_m + \varepsilon_i). \quad (1)$$

R_{ims} is the math college readiness for student i who was enrolled in middle school m during eighth grade and who begins ninth grade in high school s in

4. For example, a student who took precalculus and earned an A would have a value equal to 12 (3 level *4.0 GPA), while a student who took consumer math and earned a B would have a value of 3 (1*3).

the 1999–2000 academic year. $\boldsymbol{D}_i$ is a vector of demographic characteristics, $\boldsymbol{E}_i$ is a vector of educational needs, $\boldsymbol{A}_i$ is a vector reflecting pre–high school math achievement, $\boldsymbol{M}_i$ is a vector of indicator variables for the highest math course student i took while in high school, ν_m is a vector of indicator variables of the student's eighth-grade campus, and ε_i is an error term for student i. The equation is estimated using a probit specification, where $\Phi()$ represents the cumulative normal distribution.

To elaborate on our specification, D includes the student's race/ethnicity, gender, and participation in the free or reduced price lunch (FRPL) program. E includes indicators for whether the student was ever designated as LEP during grades 8–12; whether the student ever exited LEP status; and whether the student was exceptional, indicating a physical, learning, or mental disability. A includes the student's eighth-grade Florida Comprehensive Assessment Test (FCAT) math score[5] and an indicator variable for having a missing score. M includes the following math levels: Calculus or Precalculus; Advanced Algebra, Trigonometry, or other math course designated by the Florida Department of Education (FDOE) as Level 3; Algebra 2; and Geometry (course coding is further explained below in section 4). Students whose highest course was Algebra 1 or lower level are the reference group.[6] Our vector of fixed effects for eighth-grade school (ν_m) and eighth-grade achievement scores (A) helps to minimize any omitted variable biases associated with the influence of prior experiences or middle schools on high school course taking, such as parental taste for education and early investments in education. That is, our operative assumption is that most of the influence of parents, students, and schools is captured by the variables included in equation 1 and that direct effects of parents, students, and schools on college readiness are minor. We discuss the possibility of failure of this assumption later in the appendix.

We then use a Blinder-Oaxaca variance decomposition technique to parcel the relative contribution of $\boldsymbol{D}$, $\boldsymbol{E}$, ν_m, $\boldsymbol{A}$, and $\boldsymbol{M}$ to the variation in R. To exemplify the technique, consider a parsimonious version of equation 1 where the right-hand side includes only a dichotomous measure of highest math course (e.g., $M =$ took high-level math) and one additional independent

5. The FCAT is a criterion-referenced statewide exam. We have normalized this score to have a mean of zero and a standard deviation of one, and set the score to zero if it is missing. Those who had missing eighth-grade FCAT math scores have slightly lower rates of math readiness (62 percent) than those who have the test scores (64 percent). In the appendix we explore the sensitivity of the results to include these students.

6. Most students (81 percent) in this reference group stopped at Algebra 1. Those who stopped at levels of math below Algebra 1 have higher rates of math readiness (24 percent) than those who stopped at Algebra 1 (8 percent). We suspect that those who appear to have stopped at levels of math below Algebra 1 and nonetheless enrolled in a Florida public postsecondary institution are highly unusual in ways that we cannot observe. Thus we chose not to have this unusual group of students be the reference category.

variable (P for poverty). Assume this specification is estimated separately for each subgroup (e.g., white/black).[7] The steps for decomposing the readiness gap between white and black students are as follows:

Step 1: Estimate separate regressions for white and black students and calculate means of the variables.

$$\text{Prob}\left(R_i^w = 1\right) = \Phi\left(\alpha^w + M_i\beta_1^w + P_i\beta_2^w + \varepsilon_i\right). \tag{1a}$$

$$\text{Prob}\left(R_i^b = 1\right) = \Phi\left(\alpha^b + M_i\beta_1^b + P_i\beta_2^b + \varepsilon_i\right). \tag{1b}$$

α^w = white intercept

α^b = black intercept

β_1^w = estimated effect of highest math course on white readiness

β_1^b = estimated effect of highest math course on black readiness

β_2^w = estimated effect of poverty on white readiness

β_2^b = estimated effect of poverty on black readiness

Step 2: Decompose the total achievement gap into component parts.

$$\bar{R}^w - \bar{R}^b = \left\{\sum_{i=1}^{N^w} \frac{\Phi\left(\beta_1^b M_i^w + \beta_2^b P_i^w + \alpha^b\right)}{N^w} - \sum_{i=1}^{N^b} \frac{\Phi\left(\beta_1^b M_i^b + \beta_2^b P_i^b + \alpha^b\right)}{N^b}\right\} + \left\{\sum_{i=1}^{N^w} \frac{\Phi\left(\beta_1^w M_i^w + \beta_2^w P_i^w + \alpha^w\right)}{N^w} - \sum_{i=1}^{N^w} \frac{\Phi\left(\beta_1^b M_i^w + \beta_2^b P_i^w + \alpha^b\right)}{N^w}\right\}, \tag{2}$$

where $\bar{R}^w$ is the average readiness of white students, $\bar{R}^b$ is the average readiness of black students, and the total readiness gap is given by $\bar{R}^w - \bar{R}^b$. The term in the first set of brackets gives the portion of the gap that can be explained by white and black students' different rates of taking the course and white and black students' different rates of poverty.[8] The term in the second

7. We estimate these models using a probit specification and use the decomposition formula provided by Fairlie (2005).

8. As explained in Fairlie (2005, p. 308), "The contribution of each variable to the gap is . . . equal to the change in the average predicted probability from replacing the black distribution with the white distribution of that variable while holding the distributions of the other variable constant." When the sample sizes of the two groups are not the same, this procedure requires selecting a random subsample of the larger group (e.g., whites) to match the sample size of the smaller group (e.g., blacks). We follow Fairlie (2005) in repeating this procedure one thousand times and using the average value of the average change in readiness. We also randomize the order of the variables

set of brackets gives the portion of the gap that remains unexplained. This unexplained portion captures several possible explanations, such as differential returns to the same courses and/or omitted parent/student/school characteristics that affect readiness. We do not further decompose the second set of terms because Jones (1983) demonstrates that changes in the definition of the reference category (the math level that is omitted) can substantially change the share that is attributed to differences in returns and the share that is attributed to other factors.

Instead, we take two alternative approaches to identifying possible returns differentials. First, we reestimate equation 1 adding interactions between each of the highest course indicator variables and indicators for each demographic and poverty subgroup. We compute the marginal effects for each student and present the average and standard deviations for each demographic and socioeconomic subgroup.[9]

Note that the black students' coefficients are used in both terms included in the first set of parentheses in equation 2. The decomposition shown in this equation can be rewritten such that white students' coefficients are used in the first bracket instead of black students' coefficients. When the white coefficients are used, the contribution of courses to the explained gaps tells us how much the readiness gap between blacks and whites would change if blacks took the same courses as whites *and earned the same return on those courses*. The difference between the variation explained using the two sets of coefficients is important because it gives insight into how much of the gap is explained by differential course taking versus differential returns on course taking. We present the decomposition results using the coefficients for the group whose readiness levels are lowest (i.e., the "disadvantaged" group) and discuss substantial differences in the results when we use the coefficients for the higher readiness group. In other words, we present the results that inform policy makers on the potential impact of graduation requirements (for instance, mandating that all students take more rigorous courses). We discuss

in the decomposition because the results may be sensitive to the ordering of variables. See Fairlie (2005) for additional information.

9. Note that neither the sign nor the significance of the interacted probit coefficients can be directly interpreted as the sign and significance of the marginal effect on the probability of being ready for college. Rather, depending on the individual student's characteristics, the marginal effect of the interaction term on the probability of readiness can be negative for some students, while positive for others (Ai and Norton 2003; Norton, Wang, and Ai 2004). The interaction terms provide the marginal effect of the interaction term on the value of Q_j in equation 1. For example, a negative value for the coefficient on geometry × black indicates that the boost in Q_j for students taking geometry is smaller for black students, but it does not necessarily indicate that the boost in the probability of being ready for college-level math is smaller for black students. We therefore compute the marginal effects for each student as follows: $\Phi(Q_j \mid M_i = 1) - \Phi(Q_j \mid M_i = 0)$, where M is the relevant highest math course, and $M_i = 0$ indicates having the highest math course be Algebra 1 or lower level.

in the text how much could be further gained if students took the same classes and received the same quality of learning, a more difficult outcome to achieve with conventional policy levers.

4. DESCRIPTION OF DATA

We use data from the FDOE's Education Data Warehouse (EDW), a highly sophisticated longitudinal database that collects extensive records on all students enrolled in Florida's public schools and colleges, including information on students' sociodemographics, educational needs, academic performance, high school course taking, and college readiness. Data on college readiness or need for remediation are available for those students who enter a public Florida college on graduation from high school. The need for remediation is determined by a student's score on the Florida Common Placement Test (CPT), the cutoff of which is set at an elementary algebra level for all institutions in the state. Students are exempt from the CPT if they scored above 440 on the math portion of the SAT-I or above 19 on the math portion of the ACT (see FDOE 2002 for more information on the CPT and the cutoff scores).

Of key importance to our study, the EDW contains detailed records of students' high school course taking. For each student, the data record the course code and name as well as the term in which the course was taken and the number of credits the student earned in the course. All schools in the state adhere to a common course code, with the FDOE maintaining a course code directory of authorized courses along with course descriptions that allow us to determine the level of each course. Most of the courses can be easily categorized into the common math course hierarchy: Below Algebra 1, Algebra 1, Geometry, Algebra 2, Trigonometry, Precalculus, and Calculus. For other courses, we relied on the FDOE's classification scheme that identifies whether a course is at level one, two, or three, where the higher number indicates greater difficulty. For example, courses with titles such as Pacesetter Mathematics and Probability and Statistics were coded as "Other Level Three" courses.

Our sample of students includes those who were enrolled in the eighth grade in 1998–99, along with students who entered the cohort in subsequent years and grades, assuming normal progression for an eighth grader in 1998–99, those students first observed in the ninth grade in 1999–2000, tenth grade in 2000–1, and so on (N = 372,860). For this analysis, we restrict our sample to 77,646 students who entered a postsecondary institution in Florida. We then drop 3,802 students who were not observed in at least three of the four high school grades[10] and 583 students whose highest math course was not

10. By restricting the sample to those who were observed in at least three grades, we ensured comparability in students' opportunities for course taking. These 3,802 students were far more likely to have a missing eighth-grade math score (89 percent), had lower scores (when observed), stopped

categorizable,[11] for a final analytic sample of 73,261 students. Table 1 lists the means of each of the variables used in the analysis for the sample (column 1) as well as separately by demographic and socioeconomic group. Consistent with reports published by the FDOE, approximately 64 percent of our sample is ready for college-level mathematics. There are also large demographic gaps in readiness by race and poverty and a modest advantage for male students over female students (FDOE 2002).

The demographic characteristics, educational needs, and eighth-grade test scores of the eight subgroups also vary substantially. Hispanics, Asians, and poor students have the highest rates of being LEP, while males are more likely than females to have some form of nongifted exceptionality. The gaps in readiness are paralleled by sizable gaps in eighth-grade math FCAT scores, with whites, Asians, nonpoor, and male students having higher scores than black, Hispanic, poor, and female students. There is only a modest relationship between demographics and having missing eighth-grade FCAT scores.

The bottom panel of the table shows differences in the highest math course students take in high school. Most of the students in the sample reach at least Algebra 2; however, there are nontrivial percentages of students who end their high school math course taking at Geometry, Algebra 1, or some lower level. Black and poor students are more likely to have their highest math course be at these lower levels. Asian students take much higher math courses than other students, with 75 percent of Asian students having their highest math course be in the top two levels. Male students are more likely to take Calculus or Precalculus than are female students; however, male students are also more likely to stop at lower levels (with female students more likely to stop at the middle levels).

The data do not permit us to examine enrollment in postsecondary institutions outside the state of Florida or private institutions within Florida. However, there is little evidence that our postsecondary sample is missing a high share of the most able Florida high school students. Only 10 percent of Florida resident freshmen who were enrolled in a degree-granting institution in the fall of 2002 and 2004 were enrolled in another state (Snyder and Tan 2005; Snyder, Tan, and Hoffman 2006). Furthermore, Florida's Bright Futures scholarship program, initiated in 1998, offers scholarships to high-achieving high school graduates to attend Florida postsecondary institutions and is likely to keep many high-ability students in the state of Florida (Dynarski 2004). Consistent with this prediction, we observe that the share of Florida

at lower levels of math, and were more likely to be Hispanic (23 percent) and/or LEP (19 percent) than the full analytic sample.

11. These 583 students were more likely to be white (73 percent), less likely to be poor (19 percent) and/or LEP (4 percent), and had higher eighth-grade math scores on average.

Table 1. Readiness for College Math and Means of Covariates, by Sociodemographic Group

			Sociodemographic Group							
		All Students	**White**	**Black**	**Hispanic**	**Asian**	**Nonpoor**	**Poor**	**Male**	**Female**
	Percent Ready for College Math	**64%**	**72%**	**42%**	**56%**	**81%**	**71%**	**48%**	**67%**	**62%**
Demographics	White	60%	100%	0%	0%	0%	76%	25%	62%	58%
	Black	18%	0%	100%	0%	0%	9%	36%	16%	20%
	Hispanic	18%	0%	0%	100%	0%	10%	33%	18%	18%
	Asian	3%	0%	0%	0%	100%	3%	3%	4%	3%
	Free or reduced price lunch (i.e., poor)	32%	13%	64%	60%	34%	0%	100%	30%	33%
	Male	43%	44%	37%	43%	49%	44%	40%	100%	0%
Educational needs	Limited English proficient (LEP)	14%	2%	12%	54%	30%	5%	32%	14%	13%
	Exited LEP status	12%	2%	10%	49%	25%	5%	29%	13%	12%
	(Nongifted) exceptional	6%	7%	6%	6%	3%	6%	7%	9%	5%
Eighth-grade math test	Standardized score	0.57	0.77	0.08	0.34	0.85	0.73	0.23	0.64	0.52
	Missing eighth-grade math test	19%	18%	17%	22%	21%	19%	18%	20%	18%
Highest math course	Calculus or Precalculus	22%	25%	14%	19%	45%	25%	16%	24%	21%
	Adv. Algebra/Trig./other level 3 course	30%	33%	25%	28%	30%	33%	25%	28%	32%
	Algebra 2	31%	28%	38%	35%	17%	28%	36%	30%	31%
	Geometry	9%	7%	13%	11%	4%	7%	12%	10%	8%
	Algebra 1 or below	8%	7%	11%	7%	3%	6%	10%	8%	7%
	Number of observations	73,261	43,779	13,204	12,924	2,308	50,039	23,222	31,316	41,945

Notes: Sample consisted of a progressive cohort of Florida public school students who started eighth grade in the 1998–99 school year, restricted to those (1) who were observed in at least three of the four high school grades (ninth, tenth, eleventh, twelfth); (2) whose highest math course was categorizable; (3) who entered a Florida public postsecondary institution by 2003–4; and (4) who had data on their college math readiness.

high school students in our cohort who are enrolled in a Florida postsecondary institution rises with the student's eighth-grade FCAT math score throughout the distribution up until the 95th percentile (with a peak entry rate of 62 percent), declines slightly through the 99th percentile (with an entry rate of 60 percent), and then drops down to an entry rate of 55 percent for the top 1 percent of Florida's students.

5. RESULTS

Explanations of Sociodemographic Gaps in Readiness

Table 2 shows how differences in educational needs, eighth-grade test scores, eighth-grade schools, and high school course taking explain gaps in readiness for college math. The first column shows that black students are less likely to be ready for college math than white students by 22.5 percentile points, controlling for FRPL status and sex. Note that the raw gap in readiness of 30.0 percentile points shown in table 1 is already partially explained by differences in poverty and sex composition between white and black students. Hispanic and poor students are at smaller disadvantages than black students (−8.9 and −15.2 percentile points, respectively). Asian students have a sizable advantage over white students (+13.8), while males have a modest advantage over females (+4.0).

The second column of table 2 adds educational needs to the specification. Since LEP students are less likely to be ready for college math, this partially explains Hispanic students' disadvantage, reducing the marginal effect of being Hispanic by one-quarter. Due primarily to male students' higher rates of nongifted exceptionality, once this characteristic is held constant, the male advantage over females increases.

Surprisingly, the inclusion of eighth-grade campus fixed effects has little impact on the demographic readiness gaps (see column 3 of table 2).[12] The one notable exception is for poverty, where the poverty disadvantage is reduced by over one-fifth with the inclusion of eighth-grade campus fixed effects. The campus fixed effects modestly raise the pseudo R^2 from 0.081 to 0.112.

12. These campus fixed effects were determined using only "regular" eighth-grade campuses, excluding juvenile justice facilities and other alternative institutions. If the student attended multiple regular eighth-grade campuses, we randomly selected one of the campuses. Students who were never enrolled in a regular eighth-grade campus were assigned to one group for the purpose of computing the eighth-grade fixed effect. We conducted a robustness check allowing the alternative institutions to be included as legitimate enrollments in determining the students' fixed effects, and the results are highly robust to this alternate choice. We also dropped all students who never attended a regular eighth-grade campus and students who are missing an eighth-grade math FCAT score. These results are discussed in the appendix.

Table 2. Explanations of Gaps in Readiness for College Math

		(1)	(2)	(3)	(4)	(5)	(6)
		Marginal Effect [Robust Standard Error]					
Demographics	Black	−0.225* [0.009]	−0.234* [0.009]	−0.237* [0.006]	−0.066* [0.007]	−0.087* [0.007]	−0.087* [0.007]
	Hispanic	−0.089* [0.009]	−0.068* [0.008]	−0.071* [0.007]	−0.031* [0.007]	−0.037* [0.008]	−0.038* [0.008]
	Asian American	0.138* [0.010]	0.142* [0.009]	0.129* [0.010]	0.108* [0.011]	0.015 [0.014]	0.015 [0.014]
	Poor	−0.152* [0.005]	−0.136* [0.005]	−0.107* [0.005]	−0.066* [0.005]	−0.038* [0.005]	−0.039* [0.005]
	Male	0.040* [0.004]	0.054* [0.004]	0.053* [0.004]	0.024* [0.004]	0.062* [0.004]	0.061* [0.004]
Educational needs	LEP		−0.135* [0.029]	−0.121* [0.017]	−0.077* [0.018]	−0.028 [0.019]	−0.031* [0.019]
	Exited LEP status		0.068* [0.020]	0.064* [0.016]	0.092* [0.016]	0.038** [0.017]	0.040** [0.017]
	Exceptional		−0.322* [0.010]	−0.333* [0.008]	−0.160* [0.010]	−0.057* [0.010]	−0.058* [0.010]
Eighth-grade math test	Standardized score				0.565* [0.008]	0.366* [0.008]	0.369* [0.008]
	Missing score				0.208* [0.006]	0.147* [0.006]	0.145* [0.006]
Highest HS math course	Calculus or Precalculus					0.489* [0.004]	0.484* [0.004]
	Adv. Algebra/Trig./ level 3 course					0.473* [0.006]	0.468* [0.006]
	Algebra 2					0.331* [0.007]	0.323* [0.007]
	Geometry					0.075* [0.010]	0.070* [0.010]
	Year taken						0.013* [0.003]
	With campus fixed effects?	No	No	Yes	Yes	Yes	Yes
	Number observations	73,261	73,261	73,048	73,048	73,048	73,039
	Pseudo R^2	0.061	0.081	0.112	0.315	0.442	0.443

Notes: Probit specification. Dependent variable equals one if ready for college math. Results above show marginal effects computed at the means. Sample size drops by 213 between specifications 2 and 3 because attendance at some eighth-grade campuses perfectly predicts students' readiness for college math (and thus leads to these students being dropped).
*Significant at 1%; **significant at 5%

Differences in the eighth-grade test scores go a long way in explaining demographic gaps in readiness for college math (see column 4 of table 2).[13]

13. The size and significance of the coefficient on "Missing Using Eighth-Grade Math Test" are expected. The estimated marginal effect (0.208) suggests that the average student having a missing score

Nearly three-quarters of the black disadvantage is explained by differences in eighth-grade math scores. The Hispanic and female disadvantages are cut by more than half, and the poor disadvantage is cut by more than a third. However, the Asian advantage over white students is only reduced from 12.9 to 10.8 percentile points, controlling for differences in eighth-grade math scores.

In column 5 of table 2, we add high school course taking, which proves to be a strong, positive predictor of readiness. For a student with mean characteristics, taking Calculus or Precalculus raises the likelihood of readiness by 48.9 percentile points relative to stopping at Algebra 1 or below. Consistent with earlier work on course taking and college completion (Adelman 2006) and performance on the ACT (ACT 2007), the largest gains occur at Algebra 2; readiness rates increase by 25.6 percentage points for students who take Algebra 2 relative to Geometry. The next largest increases occur between Algebra 2 and Advanced Algebra/Trigonometry and other level 3 courses (+14.2). Also consistent with prior work (Hoyt and Sorenson 2001), taking Algebra 1 or a higher level course does not guarantee readiness for college level math.

The last specification adds the year when the student took his or her highest math course. One might expect that part of the reason for the apparent effects of taking higher math courses is due to those courses being taken more recently (i.e., closer to the time of assessment for needing remediation). If so, the course-taking coefficients might be reduced once we control for the year in which that course was taken. As shown in column 6 of table 2, students who take the course in more recent years are more likely to be ready for college math (as expected). However, the inclusion of the year when the last math class was taken has almost no effect on the other included coefficients.

The change in the coefficients on the demographic variables between columns 4 and 5 is intriguing and requires further analysis. While the poverty gap is further reduced by courses and the Asian advantage is eliminated, the Hispanic coefficient shows no significant change, the black coefficient becomes more negative, and the male coefficient becomes more positive. The interpretation is that if black and female students took the same courses as similarly situated white and male students, they would be worse off. If Hispanic

in our sample of postsecondary school entrants would have had a score of roughly 0.37 (i.e., 0.208/0.565) standard deviations above the average of all eighth-grade students in Florida. As shown in table 1, for those in our sample with eighth-grade FCAT scores, the average student in our sample has a score 0.57 standard deviations above the average of all eighth-grade students in Florida. These results are consistent with the slightly lower rates of readiness for those in our sample with missing FCAT scores (discussed in note 5). When we use a linear probability model to estimate the specification shown in column 4 of table 2 (results not shown), the results suggest that those having a missing score in our sample would have had a score of roughly 0.50 (i.e., 0.185/0.367) standard deviations above the average of all eighth-grade students in Florida.

Table 3. Effect of Demographics, Educational Needs, and Eighth-Grade Math Achievement on Highest Math Course Taken

		Coefficient [Robust Standard Error]
Demographics	Black	0.037* [0.012]
	Hispanic	−0.005 [0.013]
	Asian American	0.423* [0.019]
	Free or reduced price lunch	−0.140* [0.009]
	Male	−0.087* [0.007]
Educational needs	Limited English proficient	−0.208* [0.038]
	Exited LEP status	0.281* [0.039]
	(Nongifted) exceptional	−0.408* [0.017]
Eighth-grade math test	Standardized score	0.956* [0.007]
	Missing eighth-grade math test	0.396* [0.015]

Notes: Regression includes eighth-grade campus fixed effects. $N = 73{,}261$. Adjusted $R^2 = 0.35$.
Dependent variable = highest math course taken in high school, coded as follows:
5 = Calculus or Precalculus
4 = Advanced Algebra/Trigonometry/other level 3 course
3 = Algebra 2
2 = Geometry
1 = Algebra 1 or below
* Significant at 1%.

students took the same courses as whites, they would experience no change in readiness.

To shed light on this finding, we estimated a linear probability model of course taking (where the dependent variable ranges from 1 = Algebra 1 or below to 5 = Calculus or Precalculus) with the demographic and educational characteristics of students as explanatory variables (see table 3). This analysis clarifies the direction of the changes in the demographic gaps in readiness between columns 4 and 5 of table 2. Controlling for eighth-grade test scores and other factors, Asian students' highest math course is nearly one-half level higher than otherwise similar white students. In addition, blacks and females take higher levels of math than otherwise comparable whites and males, respectively. Hispanics take the same courses as whites with the same characteristics. Logically, whites would reach the readiness levels of Asians if they took the same courses. But blacks and females would fare worse because they already take more advanced courses than otherwise comparable whites and males, respectively. Put differently, blacks and females are currently closing some of the readiness gaps by taking higher level courses, but wide gaps remain because they are behind on other drivers of readiness. Hispanics would experience no gains because their course-taking behavior is currently equivalent to that of whites with the same characteristics.

These results do not mean that the black-white, Hispanic-white, and gender readiness gaps cannot be closed by further changes in course-taking patterns. Rather, the current level of the black/female advantage in course taking (e.g., controlling for test scores) is not sufficiently great enough now to completely offset the gaps arising from differences in eighth-grade achievement, etc. The subsequent decompositions reveal the relative contribution of each of these factors to readiness gaps and shed light on the potential for equalizing course-taking patterns to remedy gaps. Before we reach that stage, an important step is to explore whether students from different groups are earning different returns on the same courses.

Variation in the Effects of Course Taking

We test for differences in returns by interacting the student's highest math course with demographic and educational needs characteristics. As described in section 4, we compute the marginal effects by first estimating a probit specification equivalent to that in column 5 of table 2, adding interactions between the highest math course indicators and the demographic indicators.[14] We then compute the marginal effect for each student and present the means and standard deviations in marginal effects for each racial, socioeconomic, and gender subgroup (see table 4).

In the first column of table 4, we show the distribution in the marginal effects of course taking for each racial group. Black and Asian students receive significantly smaller returns from course taking at all levels relative to otherwise comparable white students. For instance, the average black student who takes Algebra 2 is 23.3 percentage points more likely to be ready for college-level math than the average black student who stops at Algebra 1 or lower. The gain for white students from taking Algebra 2 is 14.6 percentage points higher than for black students and 12.7 percentage points higher than for Asian students, both statistically significant differences. Interestingly, Hispanic students earn significantly higher returns than whites from taking Precalculus or higher (6.4 percentage point return difference) and lower returns from taking Algebra 2 (3.3 percentage point return difference). The differences in returns between Hispanics and whites are small for the other two courses.

14. Appendix table 2 provides the results from these interacted models. The final column in the table shows the fully interacted model.

Table 4. Marginal Effect of Highest Math Course by Sociodemographic Group

Highest HS Course	Group	Race		Poverty		Gender	
		Mean Marginal Effect [Standard Deviation]					
Calculus or Precalculus	White	0.663	[0.176]				
	Black	0.572	[0.174]				
	Hispanic	0.727	[0.151]				
	Asian American	0.545	[0.205]				
	Nonpoor			0.663	[0.177]		
	Poor			0.644	[0.167]		
	Male					0.635	[0.189]
	Female					0.670	[0.162]
Adv. Algebra / Trig. / other level 3 course	White	0.569	[0.143]				
	Black	0.448	[0.166]				
	Hispanic	0.562	[0.152]				
	Asian American	0.450	[0.151]				
	Nonpoor			0.564	[0.146]		
	Poor			0.497	[0.165]		
	Male					0.529	[0.159]
	Female					0.549	[0.151]
Algebra 2	White	0.378	[0.098]				
	Black	0.233	[0.116]				
	Hispanic	0.345	[0.127]				
	Asian American	0.251	[0.072]				
	Nonpoor			0.372	[0.102]		
	Poor			0.281	[0.125]		
	Male					0.346	[0.112]
	Female					0.335	[0.118]
Geometry	White	0.072	[0.026]				
	Black	0.016	[0.011]				
	Hispanic	0.075	[0.040]				
	Asian American	0.052	[0.014]				
	Nonpoor			0.065	[0.025]		
	Poor			0.047	[0.029]		
	Male					0.066	[0.027]
	Female					0.056	[0.027]

Notes: Marginal effects were computed by first estimating a probit specification equivalent to that in column 5 of table 2, with interactions of the highest math course with demographic group dummy variables added. The marginal effects were then computed for each student as follows: $\Phi(Q_i|M_i = 1) - \Phi(Q_i|M_i = 0)$, where M is the relevant highest math course and $M_i = 0$ indicates having the highest math course be Algebra 1 or lower level. Note that all the differences in means between whites and other racial groups, between poor and nonpoor, and between males and females are significant.

The next set of columns shows that poor students receive significantly smaller gains in the likelihood of college readiness at all course levels, with the largest differences in returns at the middle-level courses (e.g., Advanced Algebra and Algebra 2). Male students receive lower returns than female students from completing Precalculus and Calculus. Though the remaining male-female return differences are statistically significant, they are small in magnitude (1–2 percentage points each).

In the next section, we identify the contribution of course-taking differentials to readiness gaps. We further explore how much the readiness gaps would be reduced if returns were equalized.

Decompositions of Gaps in College Readiness

Table 5 identifies the direct contributions of course taking and other characteristics to the gaps in readiness for college mathematics. We begin by discussing the effects of course taking and then work backward through the temporal ordering of the variables.[15] The first two columns of table 5 show the decomposition of the 30 percentage point black-white gap in college readiness. Column 2 shows the contribution of each characteristic (e.g., Male), while column 1 shows the sum of the contributions of characteristics within categories (e.g., Demographics). As shown toward the bottom of column 1, roughly 8 percentage points of the black-white gap can be explained by differences in course taking. That is, if the black-white course-taking gap were closed, holding test scores and other factors constant, the readiness gap could be reduced by 28 percent (8.3/30.0). However, for this result to be correct, the benefits of course taking would have to exist for all students, including those with lower levels of eighth-grade math achievement. We return to this question below.

Moving up column 1, we see that gaps in eighth-grade test scores *directly* explain an additional 13 percentage points of the black-white readiness gap. It is important to note that the eighth-grade test score additionally affects readiness through its strong effect on course taking; as shown in table 3, a 1 standard deviation increase in students' eighth-grade test scores leads students to increase their highest math course by nearly one full level. Thus the total effect of gaps in eighth-grade test scores on the black-white readiness gap is greater than 13 percentage points. The same observation holds as we consider the contributions made by eighth-grade campuses (2.9), educational needs (−0.3), and demographics (1.8); these all reflect the direct contributions only. As shown in table 3, the combinations of demographics, educational needs, eighth-grade campuses, and eighth-grade test scores explain 35 percent

15. Demographics, educational needs, eighth-grade campus, and eighth-grade FCAT scores all precede high school course taking and can be temporally ordered (roughly) as follows: $\boldsymbol{D}$, $\boldsymbol{E}$, ν_m, $\boldsymbol{A}$, and $\boldsymbol{M}$.

Table 5. Decompositions of Gaps in Readiness for College Math

		Black-White		Hispanic-White		Asian-White		Poor-Nonpoor		Male-Female	
		(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Demographics	Black	1.8%		1.1%		−0.3%		2.1%	1.5%*	0.3%	0.2%*
	Hispanic								0.5%*		0.0%**
	Asian								0.0%		0.0%
	Poor		1.5%*		1.0%*		−0.4%*				0.1%*
	Male		0.3%*		0.1%*		0.1%*		0.2%*		
Educational needs	LEP	−0.3%	−0.2%	−0.1%	−0.6%	−0.3%	−2.6%*	−0.5%	−0.4%	−0.2%	0.0%
	Exited LEP		−0.1%		0.5%		2.2%*		−0.1%		0.0%
	Exceptional		0.0%		0.0%*		0.1%*		0.0%*		−0.2%*
Campus	8th-grade FE	2.9%	2.9%*	3.8%	3.8%*	0.8%	0.8%*	1.8%	1.8%*	0.3%	0.3%*
Eighth-grade test score	Std. Score	13.0%	13.0%*	7.7%	7.8%*	0.9%	0.3%*	8.1%	8.0%*	2.0%	1.7%*
	Missing Score		0.0%		−0.1%*		0.6%*		0.1%*		0.3%*
Highest HS math course	Calc./Precalc.	8.3%	4.7%*	5.4%	3.5%*	7.5%	8.2%*	7.9%	4.0%*	−0.7%	0.9%*
	Trig., etc.		5.4%*		4.4%*		1.7%*		5.6%*		−1.2%*
	Algebra 2		−1.7%*		−2.1%*		−2.1%*		−1.4%*		−0.5%*
	Geometry		−0.1%		−0.4%*		−0.3%*		−0.3%*		0.1%**

Raw gap	30.0%	15.5%	9.7%	22.9%	5.2%
Explained gap	25.8%	17.8%	8.6%	19.4%	1.7%
Unexplained gap	4.2%	−2.3%	1.1%	3.5%	3.4%
Percent of gap explained	28%	35%	77%	34%	−13%
by highest HS math course					

Notes: Effects of differences in mean characteristics computed using the method proposed by Fairlie (2005) using the coefficient estimates from a probit specification applied to the group with the lower rate of readiness (i.e., the "disadvantaged" group). Columns headed by "(1)" reflect the sum of the effects of individual characteristics, as shown in columns headed by "(2)."

* Significant at 1%; ** significant at 5% (for the contributions of the individual characteristics)

of the variation in highest-math course level. Thus the indirect effects of the components via their effects on course taking are large. In combination, differences in these characteristics explain nearly all the black-white readiness gap (25.8 of 30 percentage points).

The drivers of Hispanic-white and poverty readiness gaps are very similar to the drivers of black-white readiness gaps. First, a similarly large role is played by course-taking differentials; 35 percent of the Hispanic-white gap and 34 percent of the poverty gap in readiness can be attributed to high school math courses. Second, the direct effects of other demographic characteristics and educational needs are small, given the large share that is explained by eighth-grade achievement scores. Third, the characteristics and courses that we have observed explain nearly all the poverty gap in readiness and slightly over-explain the Hispanic-white readiness gap. This result suggests that if Hispanics shared white students' course taking, test scores, eighth-grade campuses, demographics, and educational needs, Hispanics would have higher rates of readiness than white students.

The decomposition results for the Asian-white and gender gaps tell very different stories. Differences in eighth-grade test scores and other characteristics contribute little directly to the Asian-white disparity. Instead, over three-quarters of the gap is explained by Asian students' higher levels of course taking in high school. Again, nearly all the Asian-white disparity is explained by the characteristics and course-taking patterns that we have observed.

In contrast to all the other results, high school courses do not explain the gender gap in readiness. In fact, the net effect of differences in the patterns of male and female course taking would tend to produce a female advantage in readiness. Thus the female disadvantage in readiness is caused by factors other than course taking. One explanation is that female students are much more likely to attend a Florida public postsecondary institution than are male students. Though female and male high school students have similar distributions of math test scores among all eighth-grade students, males have much higher eighth-grade math scores among those who continue on to enroll in a Florida postsecondary institution. Thus male college-goers are a much more select sample than female college-goers. The linear control for eighth-grade test scores may not fully capture the extent to which gender gaps in readiness are due to less prepared female students being more prone to enroll. To investigate the possibility that such differential selection affects the analysis, we constructed a sample consisting of all male enrollees and a subsample of female students with similar eighth-grade math FCAT scores.[16] To construct

16. We thank an anonymous referee for suggesting this analysis.

the female subsample, we matched each male student with his nearest female neighbor counterpart (i.e., the female student with the most similar test score). This matching was done without replacement (i.e., each female student in the subsample is used only once). This procedure constructed a sample of 31,316 males and an equal number of females. Females in this matched sample had, by construction, comparable test scores (with an average gap of 0.01 standard deviations). Among this matched sample, 65.7 percent of females were college ready, compared with 66.9 percent of males. Thus the readiness gap in the full sample of 5.2 percent was reduced to 1.2 percent by matching in this manner. That is, 77 percent of the male-female gap can be explained by differences in the propensity to enroll conditional on eighth-grade scores.

Note that the decomposition formulas use the coefficients for the lower readiness group under the assumption that increasing course requirements would not necessarily alter the returns to courses for different groups. When we use the coefficients on courses of the higher readiness group, we obtain relatively similar results. The shares of the respective readiness gaps that are explained by course-taking gaps are as follows: black-white (30 percent), Hispanic-white (30 percent), Asian-white (66 percent), poor-nonpoor (34 percent), and male-female (−15 percent). The only notable change is the effect on the Asian-white readiness gap. Since Asian students earn lower returns to courses than whites, using the Asian coefficients lowers the contribution of courses in explaining the Asian-white disparity from 77 percent to 66 percent. The relative similarity of the results using both the advantaged and disadvantaged groups' coefficients suggests that differences in course-taking patterns are more important than differences in returns in producing the readiness gaps.

Are we correct in arguing that a sizable portion of the race and poverty readiness gaps could be closed by changes in course taking even with no changes in students' eighth-grade achievement, rates of poverty, etc.? For this argument to be convincing, the benefits of course taking would have to exist for all students, including those at the lower levels of the eighth-grade test score distribution. In figure 1, we graph the percent of students who are ready for college math by students' highest math course and students' decile on the eighth-grade math FCAT. Note that the deciles were computed for this sample of college-goers, so the results should be generalized only to this population.

Figure 1 shows several results of interest. First, readiness rises sharply by the student's highest math course, controlling for eighth-grade achievement. Second, the largest marginal gains are found for students in the middle deciles (3–6), while students in the top deciles are mostly college ready regardless of their courses. Students in the bottom two deciles, while receiving smaller returns to course taking than students in the middle deciles, nonetheless

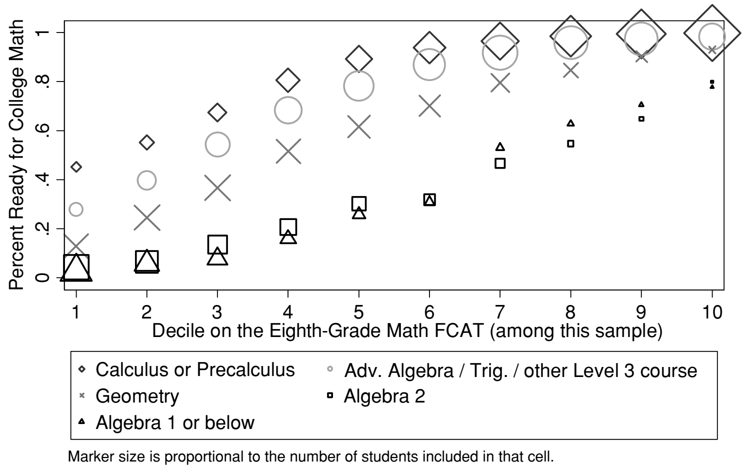

Figure 1. Readiness by Highest Math Course and Eighth-Grade Math FCAT Score Decile

received a good degree of benefit from their course taking.[17] Thus we feel relatively confident in saying that closing the race and poverty course-taking gaps, even with no other changes, would have a sizable effect on race and poverty college readiness gaps. At the same time, closing the eighth-grade achievement gaps holds more promise for closing the college readiness gaps given the large direct and indirect effects of eighth-grade achievement.

6. CONCLUSIONS

Racial, socioeconomic, and gender gaps in high school and postsecondary outcomes are well known, but less is known about the reasons for these gaps. Our findings provide some explanations for the large differences in the preparedness for college-level math.

For the cohort of Florida public school students in our sample who enter a Florida postsecondary institution, less than half of the black and poor students and just over half of the Hispanic students were prepared for college-level math—far below the readiness rates for white, Asian, and nonpoor students. These large disparities are troubling and suggest that more can be done to increase preparedness on postsecondary entry.

17. Of course, this conclusion needs to be tempered by the fact that some of the apparent returns to course taking for students in these lowest quintiles who took advanced math courses might reflect nonrandom selection of these lower achievement students into the higher math courses. Thus we separately estimated marginal effects computed using the same computation from the interacted probit models described in section 3 and presented in table 4. This specification includes interactions of course taking with quintiles on the eighth-grade FCAT and controls for demographics, educational needs, and eighth-grade campus fixed effects (which should mitigate some of the concerns regarding nonrandom selection). With this method, we found very similar results, with sizable returns at all achievement levels but the highest returns for students in the middle quintiles.

Our analysis reveals that the courses students take in high school contribute significantly to their college readiness, with the largest gains occurring at Algebra 2. These gains in readiness are found for students with both lower and higher levels of academic preparation (as measured by their eighth-grade test scores) and for students who attend the same high school. The ACT and others have been arguing for years that college-level mathematics requires at a very minimum knowledge of Algebra 2. Though many states have increased their high school graduation requirements, only twelve have set the bar this high (ACT 2007). In 2006, the Florida legislature enacted the “A++ Plan,” which increased the requirements for middle school graduation and revised high school graduation requirements to, among other things, include an additional year of mathematics. However, the minimum level of math required to graduate even with a college preparatory diploma in Florida remains fixed at Algebra 1.

While high school graduation requirements could be better aligned with postsecondary expectations, greater steps could also be taken to ensure that traditionally disadvantaged students take math courses beyond the minimum expected to graduate. Our analysis shows that simply ensuring that black, Hispanic, and poor students take the same math courses as white and nonpoor students could lower the college readiness gaps by 28, 35, and 34 percent, respectively. White students, who lag Asian students in readiness by 10 percentage points, could also nearly reach Asian students’ readiness rates by taking more advanced math courses. Yet we find that the slight male advantage in college math readiness is not explained by course-taking differentials because female students already take more advanced math courses than males. This is consistent with other work on gender disparities (Shettle et al. 2007) and suggests further study.

Precisely how educators can eliminate socioeconomic and race gaps in course taking is another matter. Our preliminary work suggests that much of the difference in highest math course taken is driven by differences in the characteristics of students before they enter high school, including their sociodemographic characteristics, educational needs, eighth-grade test scores, and eighth-grade campuses. In fact, students’ eighth-grade test scores have a larger effect on both highest math course taken and college readiness than any other characteristics that we observe. Clearly, efforts to improve the quality of K–8 education, whereby students are better prepared for high school, could contribute substantially to lowering subsequent disparities in high school and beyond. In addition, some caution is warranted in attempting to improve students’ course taking by raising curriculum standards, given the possibility that such higher standards may lead to higher dropout rates (Costrell 1994; Betts 1998).

Finally, when we examine the relationship between highest math course and college readiness separately by sociodemographic group, we find that not all students benefit equally from taking Algebra 2 and other math courses in high school. In particular, black, Asian, and poor students earn lower returns to the same courses than white and nonpoor students, possibly due to differences in the quality and rigor of the instruction or learning environments. Nevertheless, our decomposition analysis shows that the differences in the returns to the courses do not substantially minimize the potential benefit that equalizing course-taking patterns can have on sociodemographic gaps in college readiness. That is, most of the gaps in readiness are driven simply by the courses that students are taking and not by differences in the returns to those courses.

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APPENDIX

There are two tables in this appendix. In table A.1, we consider potential threats to the validity of the results shown in column 5 of table 2. For instance, we may be overstating the effects of course taking to the extent that high school actions (e.g., by a guidance counselor) have effects on both course taking and readiness. We address this with a variety of alternate specifications (see table A.1). First, we replace the eighth-grade campus fixed effect with a high school campus fixed effect[18] and alternatively with a composite eighth-grade × high school campus fixed effect (columns 5-Alt1 and 5-Alt2). The results of both specifications are similar to the specification with the eighth-grade fixed effects, indicating that the middle school and high school fixed effects are capturing a similar set of influences. Given the strong feeder relationships between eighth-grade schools and high school campuses, these results are not surprising.

Second, we use an instrumental variable, similar to the approach taken by Altonji (1995) and Rose and Betts (2004), who each used the average number of credits taken in math by student *i*'s classmates as an instrument for student *i*'s number of credits in math. We adapt this approach by replacing the individual math courses in specification 5 with a single index of highest math course (as described in table 3 and in section 4) and then instrumenting for this index using the average of the index for student *i*'s classmates. This approach could, in principle, mitigate the omitted variable bias caused by the effects of a high school as discussed above. It could also mitigate the omitted variable bias that could be caused by unobserved parental/student characteristics that affect course taking and readiness. In column 5-Alt3b, the noninstrumented results show that a one-unit increase in the index (i.e., going up one level in math) raises the average student's readiness by 23.9 percentage points. The IV-probit results shown in column 5-Alt3b show a smaller marginal effect of 14.9 percentage points. Since the IV estimate is smaller, it suggests some upward bias in the noninstrumented specification.

18. The campus for the high school fixed effect is based on the campus at which the student had the most terms of enrollment.

Table A.1. Robustness Checks for Explanations of Gaps in Readiness for College Math

		(5)	(5-Alt1)	(5-Alt2)	(5-Alt3a)	(5-Alt3b)	(5-Alt4)	(5-Alt5)
		Marginal Effect [Robust SE]						
Demographics	Black	−0.087* [0.007]	−0.072* [0.007]	−0.084* [0.008]	−0.087* [0.007]	−0.081* [0.007]	−0.044* [0.008]	−0.098* [0.009]
	Hispanic	−0.037* [0.008]	−0.044* [0.008]	−0.036* [0.008]	−0.038* [0.008]	−0.037* [0.007]	−0.037* [0.009]	−0.047* [0.010]
	Asian American	0.015 [0.014]	0.007 [0.014]	0.009 [0.014]	0.016 [0.013]	0.049* [0.013]	0.001 [0.016]	−0.004 [0.020]
	Poor	−0.038* [0.005]	−0.022* [0.005]	−0.032* [0.006]	−0.039* [0.005]	−0.050* [0.006]	−0.024* [0.006]	−0.014** [0.007]
	Male	0.062* [0.004]	0.062* [0.004]	0.064* [0.004]	0.060* [0.004]	0.051* [0.004]	0.048* [0.005]	0.088* [0.006]
Educational needs	LEP	−0.028 [0.019]	−0.019 [0.019]	−0.038* [0.020]	−0.032* [0.018]	−0.050* [0.019]	0.114* [0.034]	0.039* [0.021]
	Exited LEP status	0.038** [0.017]	0.022 [0.018]	0.047* [0.018]	0.042** [0.017]	0.063* [0.017]	−0.110** [0.051]	−0.002 [0.022]
	Exceptional	−0.057* [0.010]	−0.051* [0.010]	−0.059* [0.011]	−0.057* [0.010]	−0.094* [0.012]	−0.022** [0.011]	−0.052* [0.011]
Eighth-grade math test	Standardized score	0.366* [0.008]	0.349* [0.008]	0.374* [0.008]	0.370* [0.008]	0.444* [0.014]	0.375* [0.008]	0.375* [0.009]
	Missing score	0.147* [0.006]	0.144* [0.005]	0.145* [0.007]	0.147* [0.006]	0.172* [0.007]		0.152* [0.010]

Highest HS math course	Calculus or Precalculus	0.489* [0.004]	0.504* [0.004]	0.500* [0.004]			0.446* [0.005]	0.646* [0.005]
	Adv. Algebra / Trig. / other level 3 course	0.473* [0.006]	0.489* [0.006]	0.485* [0.006]			0.424* [0.007]	0.592* [0.009]
	Algebra 2	0.331* [0.007]	0.348* [0.007]	0.342* [0.007]			0.289* [0.008]	0.411* [0.010]
	Geometry	0.075* [0.010]	0.089* [0.010]	0.084* [0.010]			0.048* [0.013]	0.110* [0.014]
	Highest math course index (See table 3 for coding)				0.239* [0.003]	0.149* [0.014]		
Including eighth-grade campus fixed effects?		Yes	No	No	Yes	Yes	Yes	Yes
Including HS campus fixed effects?		No	Yes	No	No	No	No	No
Including composite eighth/HS fixed effects?		No	No	Yes	No	No	No	No
Instrumental variable used for course taking?		No	No	No	No	Yes	No	No
Restricted to those with nonmissing eighth-grade FCAT and nonmissing regular eighth-grade campus?		No	No	No	No	No	Yes	No
Restricted to community college students?		No	No	No	No	No	No	Yes
	Number of observations	73,048	72,995	69,138	73,048	73,031	54,588	42,795
	McFadden's pseudo R^2	0.442	0.456	0.462	0.440		0.467	0.335

Notes: Probit specification. Dependent variable equals one if ready for college math. Results above show the marginal effects computed at the means.
* Significant at 1%; ** significant at 5%

However, the estimated effect size in specification 5-Alt3a (+0.239) is larger than the average gains found in specification 5 (i.e., Geometry = +0.075; Algebra 2 = +0.256; Trigonometry, etc. = +0.142; and Calculus/Precalculus = +0.016), while the IV-Probit effect (+0.149) is reasonably consistent with the average effect size in specification 5—suggesting that little would be gained using an IV approach.[19] Second, and more important, we are not confident in the validity of this instrumental variable because it seems reasonable to believe that the course-taking patterns of student *i*'s classmates could have direct effects on student *i*'s readiness for college math aside from the effect on student *i*'s course taking. For example, having a classmate *j* who took Calculus could directly influence student *i*'s readiness if they study together. This direct effect of the instrument on the outcome invalidates the instrument. Thus we prefer the specification shown in column 5 of table 2 and assume that the effects of any unobserved parental/student characteristics are already mostly captured by the eighth-grade campus choice and eighth-grade FCAT scores.

Since eighth-grade campuses and eighth-grade FCAT scores are important variables in our specification in establishing the causal effects of course taking, in column 5-Alt4 of table A.1 we show the results restricted to those with nonmissing eighth-grade FCAT test scores and nonmissing regular eighth-grade campus. Notably, the estimated course-taking effects are only modestly attenuated for this selected sample. The readiness gaps for black, poor, and female students are also still significant but attenuated. Because dropping students with missing test scores and missing eighth-grade campuses could result in sample selection bias, we have included them in the results discussed in the main text.

Finally, we also test the model restricted to students who attended community college (see 5-Alt5). This subsample is interesting because 92 percent of those students who are not ready for college-level math are attending community colleges. For this subsample, the remaining readiness gaps for blacks, Hispanics, and females are slightly larger than for the full sample, while the remaining gaps for poor students are attenuated. The marginal effects of course taking are larger for this group, with Calculus or Precalculus providing a 64.6 percentile increase in the likelihood of being college ready relative to stopping at Algebra 1 or lower for a student with mean characteristics.

Table A.2 shows the results from the interacted probit models. These models are used to compute the distribution in marginal effects for subgroups of students that are shown in table 4.

19. A more direct test of bias in the results would be to instrument for the course-taking vector in specification 5 with a vector of shares of student *I*'s classmates who took Geometry, . . . , . . . , and Calculus/Precalculus. One could do this with a first-stage ordered logit, for example. However, given the econometric complexity and our skepticism of the validity of the instrument (which is subsequently discussed), we have chosen not to pursue such a strategy.

Table A.2. Variation of the Effect of Highest Math Course in High School on Readiness for College Math by Sociodemographic Group

		(1)	(2)	(3)	(4)
			Coefficient		
Demographics	Black	0.045	−0.250***	−0.249***	0.011
	Hispanic	−0.128*	−0.109***	−0.108***	−0.155*
	Asian American	0.375**	0.046	0.044	0.353*
	Free or reduced price lunch	−0.114***	0.024	−0.113***	−0.042
	Male	0.185***	0.186***	0.192***	0.196***
Educational needs	Limited English proficient	−0.089*	−0.090*	−0.082	−0.091*
	Exited LEP status	0.118**	0.125**	0.117**	0.121**
	(Nongifted) exceptional	−0.161***	−0.164***	−0.164***	−0.162***
Eighth-grade math test	Standardized score	1.094***	1.093***	1.094***	1.094***
	Missing eighth-grade math test	0.480***	0.484***	0.488***	0.479***
Highest HS math course	Calculus or Precalculus	2.697***	2.684***	2.564***	2.715***
	* Black	−0.576***			−0.492***
	* Hispanic	0.076			0.154
	* Asian American	−0.245			−0.194
	* Free or reduced price lunch		−0.274***		−0.171**
	* Male			0.059	0.036
	Adv. Algebra/Trig./level 3 course	2.014***	2.000***	1.948***	2.044***
	* Black	−0.339***			−0.295***
	* Hispanic	−0.029			0.009
	* Asian American	−0.376*			−0.347*
	* Free or reduced price lunch		−0.182***		−0.099
	* Male			−0.025	−0.030
	Algebra 2	1.237***	1.229***	1.191***	1.258***
	* Black	−0.269***			−0.236***
	* Hispanic	0.027			0.053
	* Asian American	−0.436**			−0.413**
	* Free or reduced price lunch		−0.129**		−0.069
	* Male			−0.010	−0.013
	Geometry	0.254***	0.236***	0.235***	0.242***
	* Black	−0.163*			−0.185*
	* Hispanic	0.092			0.068
	* Asian American	−0.089			−0.099
	* Free or reduced price lunch		0.000		0.045
	* Male			0.006	0.008
	Number of observations	73,048	73,048	73,048	73,048
	McFadden's pseudo R^2	0.443	0.442	0.442	0.443

Notes: Probit specification, with coefficients, rather than marginal effects shown. All specifications include eighth-grade campus fixed effects. Standard errors are available on request.
* Significant at 10%; ** significant at 5%; *** significant at 1%