Alternative Indicators of College Readiness in Math: Can We Better Identify Who Needs Developmental Education?

Working Paper

THE NEW YORK CITY
PARTNERSHIP FOR COLLEGE
READINESS & SUCCESS
City University of New York
NYC Department of Education
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March 2017

Find this report online at:
http://steinhardt.nyu.edu/research_alliance/publications/alternative_college_readiness_math_indicators

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ABSTRACT

Understanding which factors accurately predict college readiness and deciding on corresponding criteria to assign students to developmental education is a critical task for universities. Recent research has shown that many students assigned to developmental math courses would be capable of passing regular college-credit math courses. Moreover, research has shown that taking remedial mathematics significantly reduces the likelihood of graduation for four-year college entrants. The City University of New York (CUNY) currently relies on several standardized tests to assign students to developmental courses, but these tests have proven to be relatively weak indicators of college performance.

Alternative indicators or multiple measures of readiness have potential to improve the accuracy of placement, as demonstrated by research in California. Drawing on administrative data available through The New York City Partnership for College Readiness and Success, we assess the use of alternative indicators of college readiness in the New York City context by incorporating several additional measures of preparation other than test scores into predicting college math performance: high school GPA, high school math course grades, and math course-taking in grade 12. The population of study are 2006 entering ninth-graders who graduated from New York City public high schools in 2010, enrolled at CUNY immediately, and took a credit-bearing math course without needing prior remedial work (N=8,094).

We estimate logistic regression models predicting whether or not a student passes their first credit-bearing college math course as a function of our indicators of interest and a set of demographic and course-related controls. Results show that both overall GPA and math grades are significant predictors of passing college math, above and beyond current placement criteria and other control factors. Taking a math course in grade 12, on the other hand, does not play a significant role in predicting who passes. These findings suggest that including grades could improve decisions of whether students start in credit-bearing or remedial math courses.

INTRODUCTION

Each fall, approximately 20,000 students—more than half of all freshmen who start college at City University of New York (CUNY)—are assigned to developmental education in at least one subject, most often mathematics. In associate programs, where most developmental education courses are offered, 74 percent of freshmen were assigned to developmental education in math in fall 2015. CUNY is not unique in the scale of its developmental education courses: researchers estimate that half of all American undergraduates take one or more remedial courses in college and that remedial education is the second most common and expensive intervention aimed at improving college completion rates, after financial aid (Scott-Clayton, Belfield, & Crosta, 2012).[1]

Developmental education policy has high stakes for students. Despite the prevalence of remedial education, recent evidence has mounted at CUNY and nationally that remedial courses may not benefit many of the students assigned to them. Traditional developmental courses do not advance students toward a degree, but they do take time and consume financial resources. Several studies have found that developmental courses do not improve students' college outcomes, and may even make them less likely to persist and earn a degree (CCRC, 2014; Attewell et. al, 2006). Studies have also shown that many of the students assigned to remediation could have earned passing grades if placed directly into credit-bearing courses (Scott-Clayton, Crosta, & Belfield, 2014; Logue, Watanabe-Rose, & Douglas, 2016).[2] Furthermore, because Black and Hispanic students at CUNY are almost twice as likely as White and Asian students to be assigned to developmental education, developmental policies can contribute to racial gaps in access to bachelor's programs and in educational attainment.[3]

In October 2015 CUNY's Office of Academic Affairs launched a task force to review the University's developmental education policies. One of its key recommendations, inspired by emerging research and practices in other university systems, was that CUNY revisit the criteria it uses to assign students to developmental education and consider the incorporation of grades and academic indicators other than standardized test scores into placement decisions.

Drawing on a unique data set compiled by the Research Alliance for New York City Schools that links extensive information from the high school records of students enrolled in New York City Department of Education high schools to college

enrollment records, this study investigates the relative power of several pieces of evidence from a students' high school record to predict whether he or she will pass a credit-bearing college course, which can inform future placement policies. Specifically, we ask: to what extent do high school GPA, math GPA in grade 11, and taking math in grade 12 predict whether or not a student will pass his or her first college math course? We focus on these indicators because they would already be available on a student's high school record for use in college placement policy and because they are "malleable," that is, can be controlled by students and high schools. Our main data limitation is that we do not have information on the content of high school math courses, but rather only indicators of when they were taken.

PRIOR RESEARCH

Motivation for Multiple Measures

Studies of the predictive validity of standardized placement tests have generally found weak correlations with performance in college courses. Armstrong (2002) examined the predictive validity of scores on a commonly-used college placement test with respect to grades in college courses, and observed a correlation of 0.25 for English and 0.14 for math courses. Armstrong attributed the low predictive validity to the fact that course performance depends on traits not measured by placement tests, including motivation, perseverance, and attendance.

Several recent Community College Research Center (CCRC) studies have attempted to quantify how many students are "misplaced" into developmental courses based on placement test scores and demonstrate that the misplacement rates could be reduced by incorporating grades into placement decisions.[4] Belfield and Crosta's (2012) study of a statewide community college system found that one third of entering community college students were either "overplaced" in college-level courses and failed or "underplaced" in developmental courses when they could have gotten a B or better in a college-level course. Using students' high school GPA instead of placement testing to make placement decisions was predicted to cut severe placement error rates in half (to 17 percent).

Similarly, Scott-Clayton's (2012) study of a large, urban community college system that used a different placement test found that more than one-third of all tested students who placed into developmental English and almost a quarter of all tested students who placed into developmental math were severely underplaced. Using high

school transcript information instead of test scores was predicted to lower severe placement errors by 10 to 15 percent. Using the best of either placement test scores or high school transcript information was predicted to lower the remediation rate by 8 to 11 percentage points while reducing placement errors and increasing college-level success rates.

Current Use of Multiple Measures

Partly inspired by Scott-Clayton's research, more colleges across the country have begun to use "multiple measures" of student proficiency to place students in credit courses (Smith, 2016). Multiple measures have long been the norm in California Community Colleges, which have been required by law since 1992 to use more than standardized test scores to place students in developmental education. Despite these trends, there is still little rigorous, publicly-available research underpinning or validating various placement schemes (Academic Senate for California Community Colleges, 2014) and different colleges have adopted different measures for placement, including standardized tests, high school grades, and student self-reports of readiness and goals (REL, 2011).

Ngo et al. (2014) used data from the Los Angeles Community College District and found that use of multiple measures in the remediation placement process increased access to higher-level courses without decreasing student chances of success in their first math course. Colleges in the study awarded, and sometimes detracted, points from students' standardized placement test scores based on the students' high school GPA or other prior math background measures. For example, one college awarded a bonus point for each of the following: highest level of math previously taken with a C or better, number of years of math taken in high school, if the student had taken a math course within the previous year, and if the student had taken algebra. These findings support the use of multiple measures generally, but do not explain which specific factors are most useful for placement decisions.

Alternative Indicators of College Readiness

Belfield and Crosta (2012) tested the impact of several different predictors on college course outcome more directly. They found that, in contrast to placement test scores, high school GPA has a strong association with college GPA and college credit accumulation. However, other information from high school transcripts, including number of math courses taken in high school, did not explain any of the variation in college grades above and beyond that explained by high school GPA alone.

Jaffe (2014) tested various predictors of "college-readiness" in math among community college students in California and found that not taking mathematics in grade 12 was a significant factor in failing to be college-ready. However, her measure of "college readiness" was a passing score on the college placement test, which is only weakly correlated with actual college grades. Furthermore, she found significant variation in placement test scores among students who did and did not take math in grade 12 based on what kind of courses the students took and how strong their standardized test scores were.

Using data from the Education Longitudinal Study of 2002, Bozick & Owings (2008) reviewed student transcripts and the results of assessments administered to students to determine the level of mathematics proficiency acquired in high school. The study found that students who took more advanced courses generally gained more advanced skills, and that depth in the curriculum seemed to matter more than timing of courses. There were no difference in knowledge between students who took geometry in grade 11 followed by algebra II and those who took algebra II in grade 11 followed by no mathematics course, but students who reached algebra II in their junior year and then continued on to pre-calculus in their senior year had the largest learning gains.

In an analysis of the long-term outcome of completing a bachelor's degree, Adelman (2006) finds that when it comes to the subject matter/level of math courses, there is a "critical boundary," at which taking a higher level of mathematics is associated with increased odds of earning a bachelor's degree. For instance, for 12th-graders, students who took a course in trigonometry had 3.05 times the odds of earning a bachelor's degree as students who did not take trigonometry.

The current analysis tests the importance of some of the above-studied indicators in the context of New York City. Specifically, we examine whether high school GPA, math GPA in grade 11, and taking math in grade 12 are significant predictors of how students will fare in college math.

CONTEXT: CUNY

The CUNY system encompasses 18 distinct community and senior college campuses spread throughout New York City's five boroughs. During the time period of study, six community colleges and three senior colleges offered open-access associate degree programs that admitted any high school graduate.[5] Eleven senior colleges offered baccalaureate programs with varying degrees of selective admission standards. Each

four-year college sets its own criteria for freshman admission based on high school grades, credits, and SAT scores, but CUNY operates a largely centralized admissions system, in which candidates can complete a single form to apply to up to six CUNY colleges.

The University's central office sets common standards for determining placement into developmental education at all schools. Students who do meet "proficiency" requirements in math, reading, or writing are assigned to non-credit remedial interventions which they must successfully complete before enrolling in most college-credit courses.[6] Most students assigned to developmental education enroll in semester-long courses at their college that require the same amount of class time and tuition as regular college courses, although they contribute no credits towards a student's degree.[7]

Freshman applicants can meet the University-wide proficiency requirements and avoid developmental courses based on scores on any one of the following standardized tests:

1. New York State Regents high school exit exams in mathematics and English
2. SAT or ACT tests
3. Placement exams administered by the college before matriculation

Each test type listed above is evaluated on its own and given equal weight; students place into credit-bearing courses if they meet the cut point on any one test, regardless of their scores on the others.

CUNY has changed the cut scores needed to demonstrate proficiency on each of these exams multiple times in recent years, especially in mathematics (see Appendix 1 for a history of recent changes). The changes, mostly increases in cut scores, have been motivated by administrators' intentions to improve pass rates in credit-bearing courses, communicate high standards to applicants and local high schools, and standardize criteria across colleges. In 2011 CUNY added the requirement that to demonstrate proficiency using Regents exam scores, students must also have passed an algebra II or more advanced math course by the end of grade 11. The addition of that requirement increased the percentage of freshmen assigned to math remediation by nearly 10 percentage points. Our current analyses focus on students placed into courses before the course passage requirement was added and before cut scores on Regents and placement exams were last increased to allow us to observe course performance from a larger group of students.

DATA

We draw on an extensive longitudinal database compiled by the Research Alliance for New York City Schools that links administrative data from the New York City Department of Education and CUNY. The data include information on high school transcripts, as well as detailed college enrollment and course performance for students at CUNY colleges. This unique source allows us to test the predictive power of aspects of a student's high school record that have not been systematically captured in CUNY's own freshman application records.

The current analysis includes records for students who entered the ninth grade in 2006, graduated in four years, enrolled at CUNY in fall 2010, and took a credit-bearing math course.[8] Given that the analysis population is limited to students who did not need remediation and went directly into credit-bearing math courses at CUNY, our findings pertain to students who are relatively strong in math.[9]

Starting with 8,094 observations, we apply listwise deletion for the 1.6 percent of cases missing high school GPA, 1.4 percent of cases missing grade 11 math GPA, and 1.4 percent of cases missing lower Regents score. We perform multiple imputation to estimate values for the 21.7 percent of students who are missing upper Regents score and the 25.4 percent of students who are missing SAT score. We have 7,763 observations for analysis.

Table 1 shows characteristics of students in the analysis population. Students earn, on average, a 78.3 in their grade 11 math course[10]—slightly below their overall GPA of 81.6—with about three quarters of students taking math through grade 12. Average scores are 82.7 (out of 100) on the lower Regents and 64.9 (out of 100) on the upper Regents.[11,12] The average SAT math exam score is 513.[13] Thirty-two percent of the analysis population are Asian and another 32 percent are Hispanic, followed by 19 percent White and 17 percent Black. As for college performance, 70 percent of students passed their initial course (i.e. received a C or higher), and 88 percent of students persisted in college for three semesters. The first math course was most commonly algebra (31 percent) or an algebra alternative (19 percent).[14]

Table 1. Characteristics of Analysis Population (N=8,094)

	Mean
College math course	
Passed first college math course (C or higher)	70.0
Persisted in college for three semesters	88.0
High school indicators	
High school GPA	81.6
Math GPA grade 11	78.3
Took math grade 12	0.77
Test scores	
Lower Regents score	82.7
Upper Regents score	64.9
Math SAT	513
Demographic	
Female	53.0
White	19.4
Asian	31.6
Black	16.9
Hispanic	31.6
Other	0.50
Algebra	31.3
Algebra alternative	18.9
Statistics	16.3
Pre-calculus	16.6
Calculus	13.7
Other	3.30

RESULTS

Associations

Both overall GPA and grade 11 math GPA at the high school level are correlated with passing first college math course, with correlation coefficients of 0.28 and 0.21, respectively. Figure 1 illustrates differences in passing rates by overall GPA. Among students with a GPA between 60 and 69, 47 percent pass their first college math course, whereas among students with a GPA between 80 and 89, 74 percent do so.

Figure 1. Percentage of Students Passing First College Math Course, by High School GPA

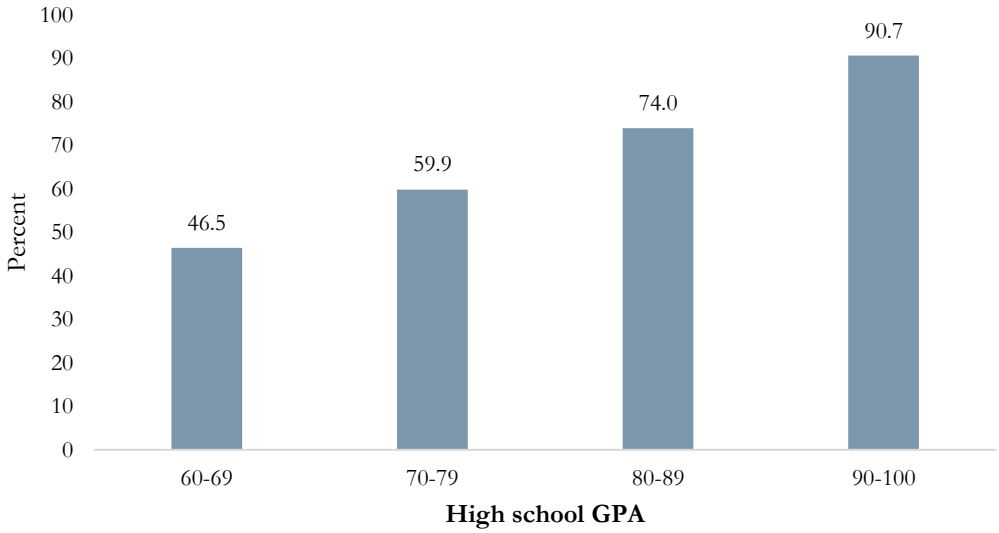


Figure 2 shows differences in passing rate by grade 11 math GPA. Among students whose GPA is between 60 and 69, 57 percent pass their first college math course, whereas among students with a GPA between 80 and 89, 75 percent do so.

Figure 2. Percentage of Students Passing first College Math Course, by Math GPA Grade 11

There are no significant difference in college math pass rates for students who took math in grade 12 vs. those who did not take math in grade 12 overall (70 vs. 69 percent, respectively). These rates, however, group all levels of grade 12 math together, as the data do not allow for identification of different course content.[15] To address this issue, we use information on timing of upper Regents exams to divide students into three groups that likely correspond to different levels of grade 12 math for those who took it: 1) students who never took an upper Regents exam, 2) students who took an upper Regents exams in grade 12, and 3) students who took an upper Regents exam before grade 12. We then explore the relationship of taking a grade 12 math course with passing college math for groups 1 and 3 separately (group 2 by design had almost no variation in grade 12 math-taking), under the assumption that grade 12 math courses for group 1 are of more basic content and grade 12 math courses for group 3 are more advanced. As shown in Table 2, group 1 students who take math in grade 12 have lower passing rates in college math than those who do not take math in grade 12, though this difference is not statistically significant. Group 3 shows an opposite pattern: students who took math in grade 12 do better in college math than those who did not take math in grade 12.

Table 2. Percentage of Students Passing First College Math

	No upper Regents	Upper Regents before grade 12
No math grade 12	58.3	73.6
Math grade 12	52.3	78.0

Regression Analyses

We turn to multivariate analysis to examine whether the above associations hold when standardized test scores (SAT score, lower Regents score, upper Regents score), student demographic characteristics (gender and race), and college course characteristics (content, college level) are taken into account. Table 3 presents odds ratios for a series of models predicting the likelihood of passing first college math course. The baseline Model 1 includes only those criteria currently used in placement (Regents and SAT scores). Models 2 to 4 add one of the high school math indicators each to test whether it provides additional information in explaining college math performance. Lastly, Model 5 includes all three high school indicators.

Both overall GPA and math GPA grade 11 are positively and significantly associated with passing college math, all else equal. In Model 2, an increase in one standard deviation of GPA (7.1 points) is associated with 77 percent higher odds of passing college math. In Model 3, an increase in one standard deviation of grade 11 math GPA (11.6 points) is associated with 37 percent higher odds of passing college math.

As for taking math in grade 12, it is not surprising that the coefficient in Model 4 is not significantly associated with passing college math, given that we did not find a simple association between the two variables. However, we do find that the association we observed for subgroup 1 (students who never took an upper Regents exam) holds with controls (results not shown), in that students who take math in grade 12 have lower passing rates in college math than those who do not take math in grade 12. This suggests that for weak math students, either taking grade 12 math is harmful to college math performance or such unobserved factors as poor motivation result in students having to take math in grade 12 *and* perform poorly in college.

In the full Model 5, overall GPA and grade 11 math GPA are independently and significantly associated with passing college math. This indicates that performance overall captures a different aspect of a student's propensity to do well than performance in math courses specifically. The content of the college math course is significantly associated with the likelihood that a given student passes the course.

Relative to students in college algebra, those in an algebra alternative have 1.38 times the odds of passing and students in pre-calculus and calculus only have about 0.40 times the odds of passing, all else equal. This suggests that these courses have systematic variation in grading standards, keeping in mind the limitations of our course groupings, as discussed in the data section.

Table 3. Odds Ratios from Logistic Regression Predicting Likelihood of Passing First College Math Course

	Model 1		Model 2		Model 3		Model 4		Model 5	
High school GPA			1.77	***					1.67	***
Math GPA grade 11					1.37	***			1.13	**
Took math grade 12							1.04		1.02	
Lower Regents score	1.16	***	1.08		1.16	***	1.65	***	1.09	*
Upper Regents score	1.72	***	1.55	***	1.59	***	1.72	***	1.52	***
Math SAT	1.20	**	1.31	***	1.22	**	1.20	**	1.31	***
Female	1.37	***	1.18	**	1.32	***	1.37	***	1.19	**
Asian	1.17		1.22	*	1.14		1.16		1.20	*
Hispanic	0.79	**	0.81	*	0.77	**	0.79	**	0.80	**
Black	0.77	**	0.82	*	0.75	**	0.77	**	0.81	*
Other	1.0		1.21		1.05		1.02		1.20	
Algebra alternative	1.3	**	1.38	***	1.34	**	1.30	**	1.38	***
Statistics	1.12.		1.09		1.10		1.11		1.09	
Pre-calculus	0.52	***	0.5	***	0.49	***	0.52	***	0.40	***
Calculus	0.47	***	0.4	***	0.41	***	0.47	***	0.38	***
Other	1.71	***	1.66	**	1.64	**	1.70	**	1.64	**
Constant	1.56	**	1.35	*	1.59	**	1.52	**	1.36	*
N	7763									

*** p<0.001 ** p<0.01 * p<0.05
Models control for college at which math course was taken.

For easier interpretation of results, Figures 3 and 4 show predicted probabilities of passing first college math course by high school GPA and math GPA grade 11, respectively, based on Model 5. At a high school GPA of 70, the predicted probability of passing college math is 0.54, compared to 0.69 at a high school GPA of 80.

Figure 3. Predicted Probability of Passing First College Math Course, by High School GPA

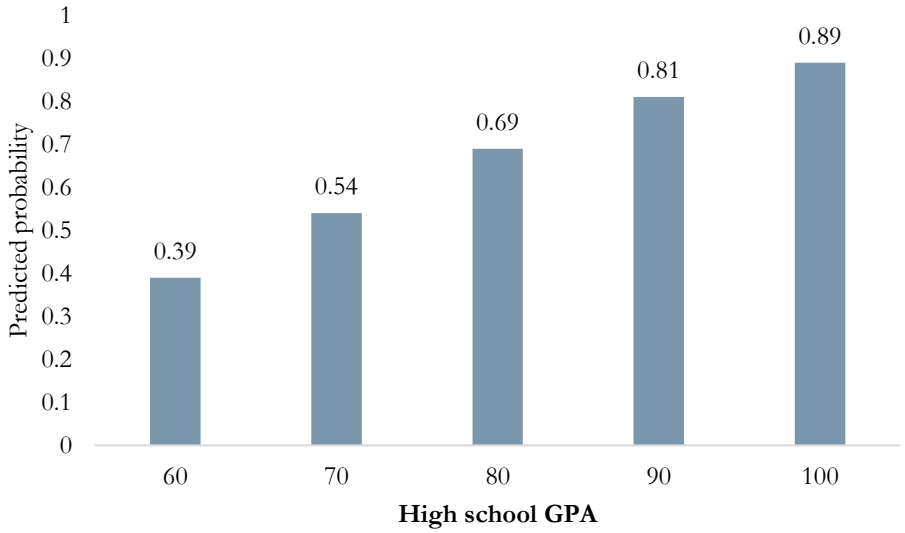
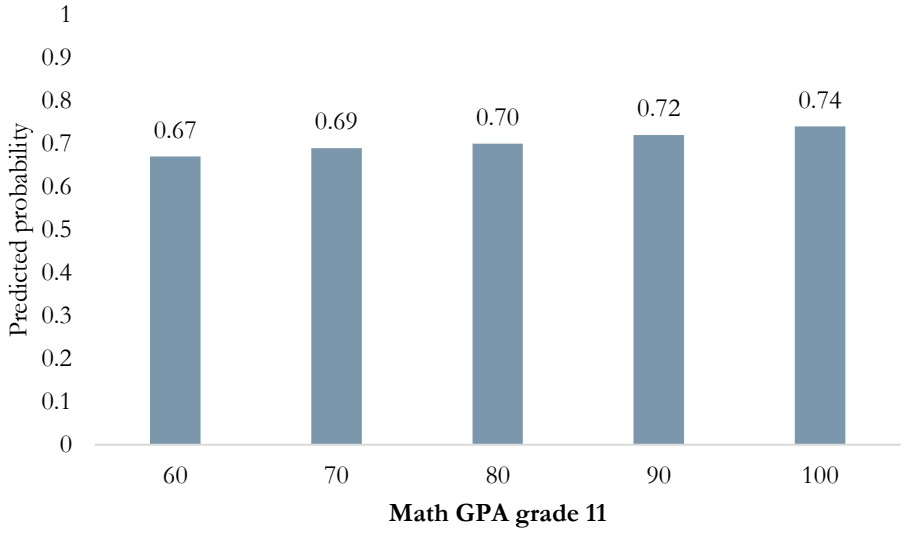


Figure 4. Predicted Probability of Passing First College Math Course, by Math GPA Grade 11



Given the importance of high school grades for passing college math, we test whether they continue to be important in explaining such longer-term college outcomes as persistence to semester 3. The unadjusted correlation of persisting to semester 3 is 0.22 for overall GPA and 0.14 for math GPA. The association with math GPA does not hold once control are added, but the one with overall GPA does. As seen in Table 4, an increase in one standard deviation of GPA is associated with 54 percent higher odds of persisting in college until semester 3.

Table 4. Odds Ratios from Logistic Regression Predicting Likelihood of Persisting to Semester 3

High school GPA	1.54	***
Math GPA grade 11	1.01	
Took math grade 12	1.04	
Lower Regents score	1.00	
Upper Regents score	1.17	*
Math SAT	0.98	
Female	1.15	
Asian	1.36	*
Hispanic	0.92	
Black	1.04	
Other	0.83	
Constant	14.01	***
N	7,763	

*** p<0.001 ** p<0.01 * p<0.05
Model controls for college at which math course was taken.

DISCUSSION

In order to inform future policies for placing students into developmental education, we tested the relative power of several pieces of evidence from a students' high school record to predict whether he or she will pass a credit-bearing college math course. High school grades seem to provide additional information above and beyond current placement criteria (and other control factors) in explaining both passing first math course and persisting to the third semester of college, and CUNY should explore incorporating them into placement decisions. Our finding on the importance of grades is in line with Belfield and Crosta (2012) and other research (e.g. Bowen, Chingos, and McPherson, 2009). Students who receive good grades in high school math not only pass their initial college math course at higher rates, but also stay in college longer. This lends further support to the consideration of grades in placement policy, which over time could also incentivize high school students to work hard in their math courses.

Taking a math course in grade 12 does not seem to explain additional variation in college math passing rates. In and of itself, it is therefore not a good candidate for inclusion in a multiple measures placement scheme. Our results are not conclusive because our current analysis is limited by the absence of information on the content of individual high school courses. We rely on a summary measure of the number of math courses attempted for each grade level, and inferences based on the exams that students took. Using inferences based on the timing of Regents exams, it does not appear that students receive any additional advantage from taking a math course in grade 12 regardless of whether it is a higher or lower level course when their background characteristics and other measures of achievement are controlled for, but if we had more consistent and reliable information about the content of courses we could address the role of course content more directly.

The current analysis does not address logistical requirements of incorporating new indicators into existing admission and placement systems, though a view to those practical implications informed the indicators we studied. As a next stage of this research, we plan to explore how the incorporation of high school grades into CUNY's placement algorithm might look in practice, including combining the new indicator with information that is currently used. At this next stage we will also be able to simulate how the algorithm changes would affect actual numbers of students placed into developmental vs. regular courses.

The New York City public schools have recently committed to a policy of "Algebra for All" that would enable all students to complete algebra no later than grade 9 by 2022. The policy aims to enable more students to succeed in higher-level high school math through better teaching in middle school (NYC DOE, 2016). In future research, it will be very interesting to observe what impact, if any, this change in curriculum has on students' proficiency in mathematics, and resulting access to and performance in college math courses.

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Appendix 1: History of CUNY Math Developmental Exemption Criteria

Effective Date	Applicable School Tier*	SAT Scores	Regents Scores and Course Completion	Compass Placement Test	
				Elementary Algebra	Arithmetic
March 2015	All	500	70 on Common Core-aligned regents + Algebra 2	40**	45**
March 2014	All	500	80 + Algebra 2	40**	45**
March 2012	1	510	80 + Algebra 2	45	45
	2	500	80 + Algebra 2	40	35
	3	480	80 + Algebra 2	40	35
March 2011	1	510	75 +Algebra 2	45	45
	2	500	75 +Algebra 2	40	35
	3	480	75 +Algebra 2	40	35
October 2008	1	510	75	45	45
	2	500	75	30	35
	3	480	75	30	30
October 2007	All	480	75	30	30
March 2004	All	480	75	27	27
March 2000	All	480	75	*CMAT*	*25*

*Tier 1: Baruch, Brooklyn, City, Hunter, Lehman, Queens, and York (as of Fall 2012)
Tier 2: John Jay, Medgar Evers, NYCCT, Staten Island and York (until 2012)
Tier 3: BMCC, Bronx, Hostos, Kingsborough, LaGuardia, and Queensborough

APPENDIX 2: GROUPING OF COLLEGE MATH COURSES BY COURSE NAME

College Algebra:

ALGBRA COLLEG STUDEN
COL ALGEBRA FOR TECH
COLL ALG & TRIG
COLL ALG FOR PRECALC
COLL ALG W/MODELING
COLL ALGEBRA & TRIG
COLLEGE ALGEBRA
COLLEGE ALGEBRA-TRIGON
COLLEGE ALGEBRA/TRIG
COLLEGE TRIGONOMETRY
COMP ALGEBRA SYSTEM
ELEMENTARY TRIGONOMETR
FUND OF MATH
INT ALGEBRA/TRIG
MODERN MATH 3
PACED MODERN MATH
TECHNICAL MATH 1

Algebra Alternative:

APPLIED FINITE MATH
BASIC IDEAS 1
BASIC STRUCT OF MATH
EL MATH ADV STDPT
FINITE MATHEMATIC
FINITE MATHEMATICS
FOUND OF MATH
FUND OF MATH I
FUNDAMENTALS OF MATHEM
HISTORY OF MATH
IDEAS IN MATHEMATICS
IDEAS IN MTH & APPLC
INTRO COLLEGE MATH
LIBERAL ARTS MATH
MATH & APPLICATIONS
MATH & ENVIRONMENT
MATH & MODERN WORLD
MATH ANALYSIS 1
MATH CONCEPTS/APPLIC
MATH EVERYDAY LIFE
MATH FOR CONTMP WRLD
MATH FOR LIBERL ARTS
MATH FUNDAMENTALS I
MATH IN COMT SOCIETY
MATH LITERACY
MATH. AND QUANT. REASO
MATHEMATICAL IDEAS
MATHEMATICAL THOUGHT
MTH & QUAN REASONING
PRACTICAL MATH
PRINCIPLES OF MATH
QUANT MTH DECS MKNG
QUANT.REASONING
QUANTITATIVE REASNG
QUANTITATIVE REASONING
SOCIAL SCI MATH
SURV MATH/COMP CNCPT
SURVEY OF MATH 1
THEORY OF INTEREST
THINKING MATHEMTCLLY
TOPICS IN MATH SCI"

Statistics:

BUSINESS STA I
BUSINESS STAT II
BUSINESS STAT HONORS
COMPTR ASST STATS
ELEM PROB & STAT
ELEM STATISTICS
ELEM STATISTICS 1
ELEM STATISTICS I
ELEMENTARY PROB&STAT
ELEMENTARY STATISTIC
ELEMENTS/STATISTICS
INTRO APPLIED STAT
INTRO APPLIED STAT(H
INTRO PROB/MATH STAT

INTRO STAT
INTRO STATISTICS
INTRO TO PROB & STAT
INTRO TO STATISTICS
INTRO: BIOSTATISTICS
INTRODUCTION TO STATIS
PROB AND STAT
PROBAB/STATISTICS
PROBABILITY & STAT
PROBABILITY THEORY
PROBABLTY & STA 1
STAT & PROBABILITY
STAT FOR SOCIAL SCI
STAT-PRIN/METHODS
STATISTCS/COMPUTERS
STATISTICS

Pre-Calculus:

ANAL GEOM & PRE CALC
PRECAL & ELEM OF CAL
PRECALC FOR BUSINESS
PRE CALCULUS MATH
PRE-CALCULUS
PRECALCULUS MATH A
PRECALCULUS MATH B
PRECALCULUS
PRECALCUS

Calculus and higher:

ANAL GEOM & CALC 1
ANAL GEOM CAL I
ANAL GEOM CAL II
ANAL GEOM CAL III
ANAL GEOM-CALC II
ANAL GEOM-CALC III
ANALYT GEOM CALC 1
ANALYT GEOM CALC 2
ANL GEOM & CALC 1
ANL GEOM & CALC I
ANL GEOM & CALC II
ANL GEOM & CALC III
APPL CALC/MATRIX APP
APPLIED CALCULUS II
CALC ANAL GEOM1 (H)
CALC APPLC SOC SCI I
CALC COMPUTER LAB
CALC COMUTER LAB
CALC I WITH PRECALC
CALC WITH ANAL GEOM1
CALC WITH ANAL GEOM2
CALC WITH ANAL GEOM3"
CALC WITH ANALYTIC GEO
CALC/ INFINITE SERIE
CALC/DIFF & INTEGTN
CALC/DIFFERENTIATION
CALC/INTEGRTN & INFI
CALCULUS 1
CALCULUS 2
CALCULUS 2 LAB
CALCULUS 3
CALCULUS FOR TECH
CALCULUS I
CALCULUS I - HONORS
CALCULUS I LAB
CALCULUS II
CALCULUS/INTEGRATION
COMBINATORICS
DIFF EQUATIONS
ELEM OF CALC & STAT
ELEM OF CALCULUS 1
ELEMENTS LINEAR ALG
ELEMENTS OF CALCULUS
HONORS CALCULUS I
INTERMED CALCULUS 1
INTERMEDIATE CALC
INTR MATH PROOF WRKS
LINEAR ALG&MTRX METH
LINEAR ALGEBRA
LINEAR ALGEBRA 1
LNR ALG-VCT ANL:ENGR
MATRIX ALGEBRA
METH DIFF EQUATNS
MULTIVARIABLE CALC
NUMBER SYSTEMS

ORDIN DIFF EQUATIONS
MATH FOUND FOR CALC
VECTOR CALCULUS

Other:

ALGORITHMS/COMP PROG
BUSINESS MATHEMATICS
COMPUTER LITERACY
DATA STRUCT/ALGOR
DISCRETE MATH CSCI
DISCRETE MATHEMATICS
DISCRETE PROBABILITY
EVENING THE ODDS
INTRO COMPUT&PROG
INTRO DISCRETE STRUC
INTRO. DISC MATH
INTRO:SYMBL CMPUTATN
MATH ELEM SCH TEACH
MATH ELEMENTARY ED
MATH FOR ALLIED HLTH
MATH FOR CHILDREN
MATH FOR ELEM EDUC I
MATH FOR ELEM TEACH
MATH FOR HEALTH SCI
MATH FOR RESP THERA
MATH MEDICAL DOSAGE
MATH OF FINANCE
MATH/ELEM SCH TEACH
MEDICAL DOSAGE CALC
PRB SOLV MGT,ECO&SCI

NOTES

[1] We use the terms "developmental" and "remedial" interchangeably to refer to pre-requisite course or intervention requirements that do not count for college credit.

[2] Logue et al. (2016) conducted a randomized controlled trial at CUNY, randomly assigning students with remedial needs into three different math courses: noncredit remedial algebra, noncredit remedial algebra with an additional weekly workshop, and regular, college-credit introductory statistics with a weekly workshop. Pass rates were highest for the credit-bearing statistics course, followed by the remedial course with a workshop, and lowest for the standard remedial algebra course without a workshop.

[3] In fall 2015, 70.1 percent of black and Hispanic first-time freshmen across CUNY were assigned to developmental education, compared to 36.4 percent of Asian and white freshmen.

[4] Studies focused on college placement tests complement the numerous other studies that have found that high school grades are better predictors of college grades and graduation than standardized tests such as the SAT or ACT (e.g., Bowen, Chingos, and McPherson, 2009).

[5] A seventh community college opened in fall 2013, but it is not included in the analysis.

[6] These standards also serve as de facto second layer of admissions requirements for 4-year colleges because most students assigned to any developmental education must start in associate degree programs.

[7] Students may also enroll in intensive-study workshops during the summer or delay their matriculation to take intensive workshops during the fall or spring term.

[8] We used information on performance in this math course regardless of when they took it, though the majority took it during their first year at CUNY (65 percent in semester 1 and 16 percent in semester 2).

[9] Of the 46,531 students who were ninth-graders in 2006 and graduated high school in four years, 18,449 enrolled at CUNY immediately. Of these, 8,094 took a first math course that was credit-bearing at some point upon enrollment.

[10] Math GPA is the average grade received for math courses in grade 11. If a student only took one math course during this school year, it is the grade for that course.

[11] There have been two or three different Regents exams, depending on the year. Lower Regents includes Sequence Math I, Math A, Regents Integrated Algebra. Upper Regents includes Sequence Math II, Sequence Math III, Math B, Regents Geometry, Algebra II/Trigonometry.

[12] This is the multiply imputed average score. The average score among the 78 percent who took the exam was 67.7.

[13] This is the multiply imputed average score. The average score among the 75 percent who took the exam was 517.

[14] College courses were grouped into these categories based on course name (see Appendix 2). In many cases, the decision was straightforward; however, in some cases we had to make an assumption as to the most likely course content. The courses that were the most difficult to categorize were those that fell either under "Algebra Alternative" or "Other". In general, we attempted to label foundational, introductory courses for a wide audience (e.g. "Math and Modern World" or "Foundations of Math") under "Algebra Alternative" and basic courses designed for a specific direction of study (e.g. "Math for Allied Health" or "Math for Elementary School Teachers") under "Other". The "Other" category also includes computer and programming courses (e.g. "Algorithms/Computer Programming"). These did not fit well into any other category, but

their inclusion here adds heterogeneity to the "Other" category, making it less meaningful for interpretation. The "Statistics" category may also have heterogeneity in that some courses may be introductory, while others may be more advanced and even have pre-calculus or calculus prerequisites.

[15] Course names and codes are not consistent across DOE high schools. Therefore we are not able to account for the content/level of math course a student took.