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Does Mathematics Remediation Work?: A Comparative Analysis of Academic Attainment among Community College Students

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Abstract Postsecondary remediation is a controversial topic. On one hand, it fills an important and sizeable niche in higher education. On the other hand, critics argue that it wastes tax dollars, diminishes academic standards, and demoralizes faculty. Yet, despite the ongoing debate, few comprehensive, large-scale, multi-institutional evaluations of remedial programs have been published in recent memory. The study presented here constitutes a step forward in rectifying this deficit in the literature, with particular attention to testing the efficacy of remedial math programs. In this study, I use hierarchical multinomial logistic regression to analyze data that address a population of 85,894 freshmen, enrolled in 107 community colleges, for the purpose of comparing the long-term academic outcomes of students who remediate successfully (achieve college-level math skill) with those of students who achieve college-level math skill without remedial assistance. I find that these two groups of students experience comparable outcomes, which indicates that remedial math programs are highly effective at resolving skill deficiencies.

Keywords Remediation · Remedial education · Developmental education · Basic skills · Mathematics · Community college · Transfer · Attainment · Achievement · Degree · Certificate

Introduction

Postsecondary remediation is a "hot button" topic on educational policy agendas. On one hand, it fills an important niche in U.S. higher education by providing opportunities to rectify race, class, and gender disparities generated in primary and secondary schooling, to develop the minimum skills deemed necessary for functional participation in the economy and the democracy, and to acquire the prerequisite competencies that are crucial for negotiating college-level coursework. On the other hand, critics argue that taxpayers should not be required to pay twice for the same educational opportunities, that

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remediation diminishes academic standards and devalues postsecondary credentials, and that the large number of underprepared students who are enrolling in college demoralizes faculty. Following from these critiques, some have argued for a major restructuring of remediation or even the elimination of remedial programs altogether.

In the midst of this debate, surprisingly few methodologically sound, comprehensive, large-scale, multi-institutional evaluations of postsecondary remedial programs have been put forward. While numerous small-scale (or otherwise limited) studies have been published over the last several decades, nearly all of these evidenced important weaknesses and produced findings of questionable value. Thus, despite longstanding controversy and much rhetoric, we have comparatively little dependable information about whether remediation is accomplishing the purpose for which it is intended. This is a critical oversight as decisions are being made about the role that remediation is to play in the future of higher education in the U.S.

The research I present here represents a step forward in rectifying this deficit in the literature, with particular attention to the prevailing area of remedial need, namely mathematics. In this study, I test the efficacy of remedial math programs in community colleges by comparing the long-term academic outcomes (credential attainment and transfer) of students who remediate successfully in mathematics (achieve college-level math skill) with those of students who achieve college-level math skill without the need for remedial assistance. To accomplish this test, I use hierarchical multinomial logistic regression to analyze data that address the entire population of first-time college freshmen who began college attendance in the Fall of 1995 at any of the 107 semester-system community colleges in California. I tracked the mathematics progress of these students for 6 years and their academic attainment for 8 years.

I find that students who remediate successfully experience outcomes that effectively are equivalent to those of students who do not require remediation, indicating that remedial math programs are highly effective at resolving skill deficiencies. However, the majority of remedial math students do not remediate successfully, and the outcomes of these students are not favorable. Thus, while remediation is efficacious for those who remediate successfully, further research is needed to identify the obstacles that hinder the remedial process for so many.

Background

Situating Postsecondary Remediation

Postsecondary remediation—variously referred to as “developmental,” “basic skills,” “compensatory,” or “preparatory” education (Tomlinson 1989)—has been described as “the most important educational problem in America today” (Astin 1998, p. 12). This declaration is not without merit; remediation is as remarkable for its sheer scale as for its unique function. For example, Parsad et al. (2003) estimate that, nationwide, 28% of first-time college freshmen enrolled in remedial coursework during the Fall of 2000. Adelman (2004a), employing a larger window of observation and somewhat different measures, estimates that 41% of students enroll in remedial coursework at some point during attendance. Consistent with these figures, estimates place the national *direct* cost of public postsecondary remedial programs at 1–2 billion dollars annually, and the total *direct* and *indirect* public and private costs at nearly 17 billion dollars annually (Breneman and Haarlow 1998; Greene 2000; Phipps 1998; Saxon and Boylan 2001).

Further supporting Astin's declaration, postsecondary remediation fills a critical niche in U.S. higher education (McCabe 2003). In a democratic society and a free economy, functional participation depends upon minimum levels of reading, writing, and math skill. Remediation embodies a collective societal endeavor to provide these minimum skills (Day and McCabe 1997; McCabe 2003; Phipps 1998; Roueche et al. 2001).

Equally important, remediation is a lifeline in the ascent to economic stability for individuals who lack minimum competencies in fundamental subjects (Day and McCabe 1997). Given that educational attainment is a principal determinant of socioeconomic outcomes (Kerckhoff et al. 2001), remediation opens the door to economic progress by ameliorating deficiencies that obstruct success in acquiring (or, in some cases, even access to) postsecondary credentials (Brothen and Wambach 2004; McCusker 1999; Tomlinson 1989). In light of the self-evident impracticality of sending adults back to high school to acquire necessary skills, remediation is an indispensable bridge to postsecondary credentials over the chasm of inadequate preparation (McCabe 2000; Roberts 1986).

Finally, postsecondary remediation is unique relative to other aspects of the educational system in that it is *not* designed to sort individuals into strata of attainment (Spring 1976). Rather, it is intended ostensibly to equalize attainment, reducing disparities between the disadvantaged and advantaged (Mills 1998; Roueche et al. 2001). This function is made all the more important by the fact that the funding structure of public primary and secondary education (based, in part, on local taxes) ensures substantial inequities in the quality of education provided to students (Cohen and Johnson 2004; Condron and Roscigno 2003; Walters 2001). Thus, remediation is, by definition, a "remedy" intended to restore opportunity to those who otherwise may be relegated to meager wages, poor working conditions, and other consequences of socioeconomic marginalization (Day and McCabe 1997; Roueche and Roueche 1999).

However, postsecondary remediation is a controversial topic (McMillan et al. 1997; Mills 1998). Critics contend that taxpayers should not be required to pay twice for the same learning opportunities, first in high school and then in college (Boylan 1999; Grimes and David 1999; Ignash 1997; Kozeracki 2002; McCabe 2000; Reising 1997; Roueche et al. 2001; Saxon and Boylan 2001). Some argue that providing secondary-level coursework in postsecondary institutions diminishes academic standards and devalues postsecondary credentials (Brothen and Wambach 2004; Costrell 1998; Immerwahr 1999; Oudenhoven 2002; Mazzeo 2002; Roueche and Roueche 1999; Steinberg 1998).[1] Others assert that the large number of underprepared students who are enrolling in college demoralizes faculty (Hadden 2000; Pitts et al. 1999; Trombley 1998). In light of these critiques, some states are shifting the burden of remediation solely to community colleges, while even more drastic proposals have been put forward, including requiring high schools to pay for remediation or the elimination of remediation altogether (Bastedo and Gumport 2003; Bettinger and Long 2005; Boylan et al. 1999; Breneman and Haarlow 1998; Day and McCabe 1997; Jenkins and Boswell 2002; Phipps 1998; Trombley et al. 1998).

Prior Evaluations of Postsecondary Remediation

Given the scale of postsecondary remediation, its core function in higher education, and the mounting controversy surrounding it, empirical evaluations of the relative success or

[1] An alternative interpretation suggests that remedial coursework actually protects academic standards by allowing college-level courses to address college-level material (McCabe 2000).

failure of remediation would seem to be a matter of first-order importance. Yet, it is only in the last few years that several methodologically sound, comprehensive, large-scale, multi-institutional evaluations have been published. Prior to this, most evaluative efforts were small in scale, limited in scope, or methodologically weak in other respects. As Phipps (1998, p. 10) observes, "[r]esearch regarding the effectiveness of remedial education programs has been sporadic, typically underfunded, and often inconclusive…the fact remains that there is a dearth of information regarding how well remedial education students perform." Roueche and Roueche (1999, p. 26) echo this assessment, "[p]rogram evaluation has been and remains the weakest component of the remedial effort," as do Koski and Levin (1998, p. 3), "…there is little or no comprehensive and reliable research regarding the efficacy of remedial education…". Even more strongly, Grubb and Gardner (2001, p. 4) state, "…there have been relatively few evaluations of remedial programs, and many existing evaluations are quite useless…".

The numerous small-scale (or otherwise limited) evaluations published over the last several decades paint a varied picture of the efficacy of remediation (Koski and Levin 1998). Some studies indicate that remedial students exhibit academic performance and experience academic outcomes that are comparable to those of students who do not require remediation (Boylan and Saxon 1999a; Crews and Aragon 2004; Kolajo 2004; Kulik et al. 1983; Overby 2003; Purvis and Watkins 1987; Southard and Clay 2004; Waycaster 2001). Other studies suggest the opposite conclusion: remedial students exhibit academic performance and experience academic outcomes that are less favorable than those of their college-prepared counterparts (Bickley et al. 2001; Curtis 2002; Grimes and David 1999; Illich et al. 2004; Tennessee Higher Education Commission 2001; Weissman et al. 1997b; Worley 2003). Still other studies present mixed or inconclusive findings regarding the efficacy of remediation (Gray-Barnett 2001; Seybert and Soltz 1992).

Unfortunately, nearly all of these studies have been plagued with methodological problems of various sorts, resulting in questionable internal validity, external validity, or both (Boylan and Saxon 1999a; Koski and Levin 1998). Among the most common problems evident in prior work are: reliance on simple bivariate analyses or other analytical methods involving minimal statistical controls (e.g., Crews and Aragon 2004; Overby 2003), reliance on data drawn from a single college (e.g., Bickley et al. 2001; Worley 2003), small sample size (e.g., Purvis and Watkins 1987; Southard and Clay 2004; Weissman et al. 1997b), failure to distinguish remedial students who remediate successfully from those who do not (e.g., Curtis 2002; Tennessee Higher Education Commission 2001), failure to address long-term outcomes in a comprehensive fashion (e.g., Gray-Barnett 2001; Grimes and David 1999), short observation periods (e.g., Illich et al. 2004; Seybert and Soltz 1992), and selection on the dependent variable (e.g., Kolajo 2004; Waycaster 2001). Put simply, *most* prior evaluative research cannot speak clearly concerning the efficacy of remediation.

However, two recent large-scale, comprehensive, multi-institutional studies do offer solid evidence concerning the efficacy of remediation. In the first, Bettinger and Long (2004) found that remedial math students in public 4-year colleges in Ohio who remediate successfully are only slightly less likely, on average, to complete a 4-year degree than are college-prepared students. In the second, Attewell et al. (2006), using data from the National Educational Longitudinal Study, found that students in community colleges who remediate successfully in English experience an increased likelihood of graduation compared with students who do not require remediation. Attewell and his colleagues otherwise found no differences between underprepared students who remediate successfully and college-prepared students in the likelihood of graduation, in either community or 4-year colleges. Taken together, these two studies constitute the beginning of an accumulation of empirical support for the efficacy of postsecondary remediation. It is to this body of work that I seek to contribute with this study.

This Study

The purpose of this study is to evaluate the relative success or failure of one aspect of remediation, namely remedial math in community colleges. Math is of particular interest because more students require remedial assistance with math than with any other subject (Adelman 2004a; Boylan and Saxon 1999b; Parsad et al. 2003). Community colleges are of interest because they constitute the primary venue in which postsecondary remediation is performed (Adelman 2004b; Day and McCabe 1997; Parsad et al. 2003). The question I pose here is, does mathematics remediation work? Said another way, does remediation in math resolve the academic disadvantage faced by mathematically underprepared students? The fundamental principle of remediation is equality of opportunity, and one definitive manner in which this can be demonstrated is equality of outcomes. In other words, students who remediate successfully in math should exhibit academic outcomes that are comparable to those of students who do not require remediation in math, all else being equal.

Among the complexities that have hampered efforts to test the efficacy of remediation is a lack of consensus regarding which "academic outcomes" are the most appropriate to analyze (Bers 1987; Boylan 1997). For example, some studies have examined the rate of success of underprepared students in remedial coursework, and a handful of studies have compared this rate to the rate of successful completion of all students in courses that address a particular subject matter (e.g., Boylan and Saxon 1999a; Curtis 2002; Illich et al. 2004; Waycaster 2001; Weissman et al. 1997a). However, this measure actually does not address the efficacy of remediation because the goal of remediation is to prepare students for success in college-level coursework, and passing a single remedial course is not necessarily indicative of this state.

Another common evaluative measure is persistence or retention (e.g., Grimes and David 1999; Kulik et al. 1983; Purvis and Watkins 1987; Weissman et al. 1997b). These studies ask whether remedial students persist in college at a similar rate to that of college-prepared students. However, this measure also is not informative concerning the efficacy of remediation because simply "sticking around" from semester to semester is not an objective of remediation (Boylan and Bonham 1992; Boylan and Saxon 1999a).

Many studies have compared the mean grade point average of underprepared students with that of college-prepared students, or of underprepared students who enrolled in remedial coursework with that of underprepared students who did not enroll in remedial coursework (e.g., Bickley et al. 2001; Kolajo 2004; Worley 2003). Unfortunately, this method of evaluation is complicated by the fact that not all remedial courses contribute "countable" credits and by the high rate of attrition among poor performing students (Koski and Levin 1998; Shults 2000).

Some studies have compared the pre-test and post-test scores on standardized exams of underprepared students (e.g., Grubb and Gardner 2001; Koski and Levin 1998; Seybert and Soltz 1992). There are problems with this method of evaluation as well. In particular, the goal of remediation is preparation for college-level coursework, and even sizeable gains on standardized exams may not reflect adequate preparation in a given subject matter (depending on the degree to which test scores reflect thresholds of preparation for college-level coursework).

Alternatively, some have compared the rate of success or average performance of college-prepared and underprepared students, or of underprepared students who enrolled in remedial coursework versus those who did not, in the first college-level course for which a given remedial sequence is intended to prepare a student (e.g., Crews and Aragon 2004; McCabe 2000; Southard and Clay 2004). This evaluative measure is among the most widely accepted because, as Boylan and Saxon (1999a, p. 6) argue, "[t]he most essential purpose of remedial courses is to prepare students to be successful in the college curriculum."

Lastly, some studies have compared the long-term academic outcomes (e.g., credential attainment, transfer to 4-year institutions) of students who require remediation with those of students who do not require remediation (e.g., Gray-Barnett 2001; Overby 2003; Tennessee Higher Education Commission 2001). This measure arguably is the most robust because, as Grubb and Gardner (2001, p. 23) explain, it is an outcome that has "intrinsic value."

In this study, I focus on the last of these measures: credential attainment and transfer Given the equalizing aim of remediation, I hypothesize that students who require remediation in math, negotiate successfully the remedial math sequence, and achieve college-level math skill, exhibit patterns of credential attainment and transfer that are comparable to those of students who achieve college-level math skill without the need for remediation. Conversely, although not specifically relevant to testing the efficacy of remediation, I anticipate that students who remediate successfully in math exhibit patterns of credential attainment and transfer that are superior to those of students who do not remediate successfully in math.

Data and Measures

Data

To test this hypothesis, I draw upon data collected by the Chancellor's Office of California Community Colleges. The Chancellor's Office, under mandate by the California Legislature, collects data each term via electronic submission from the 112 community colleges and affiliated adult education centers in California. The data maintained by the Chancellor's Office represent a census of community college students in California and include transcripts, demographics, financial aid awards, matriculation records, degree/certificate awards, etc. Additionally, the database is cross-referenced periodically against the enrollment records of all California public 4-year postsecondary institutions and the National Student Clearinghouse database (Boughan 2001) in order to identify students who transferred to public and private 4-year institutions, both in-state and out-of-state (Bahr et al. 2005).

I selected for this analysis the Fall 1995 cohort of first-time college freshmen who enrolled in any of California's 107 semester-based community colleges ($N = 202{,}484$). Valid course enrollment records were available for 93.9% of these students ($N = 190{,}177$). I observed the course enrollments of these students across all semester-based colleges for 6 years, through the Spring of 2001, and retained only those students who enrolled in at least one substantive, nonvocational math course ($N = 87{,}613$).[2] I, then, dropped 1,719

[2] It is possible that some students may begin at one community college and then transfer to another community college, or may simultaneously complete courses at two or more community colleges. To account for these possibilities, course enrollments for each student were observed across all semester-based community colleges without regard to the first institution of attendance.

students (2.0%) who were missing data on sex, age, or the ID variable used to track student records across colleges, resulting in an analytical cohort of 85,894 students. Finally, in 2003, I refreshed the data with updated information concerning credential awards and transfer to 4-year institutions through the Spring of 2003. Thus, the data offer detailed records through the Spring of 2001, while the aspects that address credential awards and transfer encompass an additional 2 years.

Outcome Variable: Academic Attainment

The primary outcome of interest in this study is a given student's long-term academic attainment in the community college system. Within the context of the community college, essentially two expressions of long-term attainment are readily measurable: the award of a credential and transfer to a 4-year institution. Two basic categories of credentials are available: associate degrees and certificates. The associate's degree typically requires the completion of a major program of study, general education coursework, and a minimum number of credits. In contrast, the certificate typically requires only the completion of a major program of study. Thus, the associate's degree is considered to be a higher-level credential than the certificate, although not all degree and certificate programs overlap. When these credentials are combined with the possibility of transfer, five mutually exclusive attainment outcomes can be derived, based upon the highest credential earned and whether transfer occurred:

1. *none*—student did not complete a credential and did not transfer;
2. *certificate only*—student completed at least one certificate, but did not complete a degree and did not transfer;
3. *degree with or without certificate*—student completed at least one degree, with or without a certificate, but did not transfer;
4. *transfer without credential*—student transferred, but did not complete a credential prior to transfer; and
5. *transfer with credential*—student completed at least one credential and then transferred.

Explanatory Variable: Math Status

The primary explanatory variable of interest in this study is a student's entry to, and exit from, math coursework. Ideally (methodologically speaking), entry to math would be operationalized using placement exams given at the time of admission. Unfortunately, matriculation processes at the 107 colleges are quite varied, and the only consistent means of classifying students is the skill-level of a given student's first math course. Likewise, exit from math is operationalized using the skill-level of the highest, successfully completed math course.

To categorize math courses, I used course catalogs and course characteristics in the data to determine the skill-level of each math course in which any member of the cohort enrolled at any time during the observation period. In total, I collapsed 2,750 math courses into two categories: remedial and college-level. Remedial math includes basic arithmetic, pre-algebra, beginning algebra, intermediate algebra, and geometry. College-level math includes all courses that address topics of a skill-level equal to, or greater than, college algebra. I ignored nonsubstantive math courses (e.g., math labs) and vocational math, except when a given vocational math course was part of a remedial math sequence or otherwise categorized as college-level.

Using this coding scheme, I classified each student in the cohort as either a remedial math student or a college math student based upon a given student's first math course. As noted earlier, students who enrolled exclusively in vocational math were dropped from the cohort. However, students whose first math course was vocational, but who subsequently initiated the remedial math sequence or enrolled in college-level math, were retained in the cohort and classified based on the skill-level of their first nonvocational math course. The rationale, in this case, is that a sizeable percentage (31.6%) of students whose first math course was vocational subsequently enrolled in remedial or college math. Moreover, whereas a first math enrollment in remedial or college math has value as an indicator of math competency at college entry, a first enrollment in vocational math is not indicative of competency.

My hypothesis predicts that students who negotiate successfully the remedial math sequence and attain college-level math skill exhibit patterns of credential attainment and transfer that are comparable to those of students who attain college-level math skill without the need for remediation. On the other hand, I anticipate that students who do *not* negotiate the remedial math sequence successfully exhibit outcomes that are significantly less favorable. While this suggests a three-category nominal variable, in fact four categories are necessary to account for each of these three conditions *plus* the cases in which students enroll initially in college math but ultimately do *not* complete a college math course successfully. Thus, the primary explanatory variable includes the following four attributes:

1. *college math "completer"* (CC)—student enrolled initially in a college math course and ultimately completed a college math course successfully,
2. *college math "noncompleter"* (CN)—student enrolled initially in a college math course but ultimately did *not* complete a college math course successfully,
3. *remedial math "completer"* (RC)—student enrolled initially in a remedial math course and ultimately completed a college math course successfully, and
4. *remedial math "noncompleter"* (RN)—student enrolled initially in a remedial math course but ultimately did *not* complete a college math course successfully.

For the purpose of this analysis, a *successful* math course enrollment is one resulting in a grade of A, B, C, D, or Credit.

Student-Level Control Variables

I include a number of student-level control variables found in prior research to be predictors of academic outcomes among remedial students (Bahr 2007, n.d.; Burley et al. 2001; Hagedorn et al. 1999; Hoyt 1999). Among the controls included here are: sex, race/ethnicity, age, three proxies of socioeconomic status (SES), three measures of enrollment patterns, academic goal, grade in first math course, English competency at college entry, and two measures of interaction with academic advising services. Details concerning the operationalization of each of these variables follow. Frequency distributions for each of these variables, as well as long-term academic attainment and math status, are provided in Table 1.

Sex is treated as a dichotomous variable. Race/ethnicity includes nine nominal categories and is treated as a set of dummy variables, with "White" excluded. Age is

Table 1 Frequency distributions of the student-level variables addressed in this study ($N_{students} = 85{,}894$)

Variable	Values	*N*	%
Academic outcome	No credential and no transfer	50,996	59.37
	Certificate only	1,897	2.21
	Associate's degree with or without certificate	6,060	7.06
	Transfer without credential	16,092	18.73
	Transfer with credential	10,849	12.63
Math status	College math "completer"	13,391	15.59
	Remedial math "completer"	17,182	20.00
	College math "noncompleter"	2,664	3.10
	Remedial math "noncompleter"	52,657	61.30
Academic goal	Transfer	19,774	23.02
	Transfer with associate's degree	36,730	42.76
	Associate's degree	5,033	5.86
	Vocational degree	2,170	2.53
	Vocational certificate	1,488	1.73
	Other job-related goal	6,307	7.34
	Abstract	3,755	4.37
	Remediation	1,838	2.14
	Undecided	7,935	9.24
	Unreported	864	1.01
English competency	College-level	26,996	31.43
	Remedial writing	36,967	43.04
	Remedial reading	5,386	6.27
	ESL	7,670	8.93
	None	8,875	10.33
First math grade	A	12,236	14.25
	B	13,587	15.82
	C	14,037	16.34
	D	6,200	7.22
	F	9,807	11.42
	Withdrawal	21,030	24.48
	Credit	3,816	4.44
	No credit	2,067	2.41
	Ungraded	587	0.68
	Missing/unreported	2,527	2.94
Persistence	1–2 Semesters	12,172	14.17
	3–5 Semesters	21,882	25.48
	6–8 Semesters	23,673	27.56
	9–11 Semesters	17,658	20.56
	12–14 Semesters	8,751	10.19
	15–17 Semesters	1,758	2.05
Enrollment inconsistency	<20.1%	31,670	36.87
	20.1–40.0%	28,473	33.15

Table 1 continued

Variable	Values	*N*	%
	40.1–60.0%	16,261	18.93
	60.1–80.0%	7,918	9.22
	>80.0%	1,572	1.83
Delay of first math	Fall 95–Spring 96	61,683	71.81
	Summer 96–Spring 97	12,555	14.62
	Summer 97–Spring 98	5,382	6.27
	Summer 98–Spring 99	3,001	3.49
	Summer 99–Spring 00	1,856	2.16
	Summer 00–Spring 01	1,417	1.65
Advising	Referred for advising	76,458	89.01
	Not referred for advising	9,436	10.99
	Received advising	63,543	73.98
	Did not receive advising	22,351	26.02
Fee waiver	Received fee waiver	29,311	34.12
	Did not receive fee waiver	56,583	65.88
Total $ value of grant(s)	Did not receive grant(s)	66,845	77.82
	<$501	1,187	1.38
	$501–1,000	2,300	2.68
	$1,001–1,500	3,312	3.86
	$1,501–2,000	2,544	2.96
	$2,001–2,500	5,097	5.93
	$2,501–3,000	1,971	2.29
	>$3,000	2,638	3.07
Race	White	37,128	43.23
	Black	7,661	8.92
	Hispanic	23,776	27.68
	Asian	10,132	11.80
	Pacific Islander	621	0.72
	Filipino	3,517	4.09
	Native American	830	0.97
	Other	983	1.14
	Unreported	1,246	1.45
Sex	Male	40,127	46.72
	Female	45,767	53.28
Age (years)	<18	8,096	9.43
	18–20	60,750	70.73
	21–25	7,318	8.52
	26–30	3,518	4.10
	31–35	2,439	2.84
	36–40	1,698	1.98
	41–50	1,613	1.88
	>50	462	0.54

measured in years, was collected at the time of application for admission, and is treated as continuous.

The three proxies of SES include a dichotomous indicator of receipt of a fee waiver during the first year of attendance, a dichotomous indicator of receipt of any grants during the first year of attendance, and a continuous indicator of the total monetary value of any grants received during the first year of attendance. Students who did not receive any grants were assigned a value of zero for the latter variable.[3]

The three measures of enrollment patterns include: persistence, enrollment inconsistency, and delay of first math course enrollment. Persistence is operationalized as the number of terms (including summer terms, but excluding winter intersessions) in which a given student enrolled in courses from Fall 1995 through Spring 2001. Enrollment inconsistency is operationalized as the percentage of terms in which a given student did not enroll in courses from Fall 1995 through the last term that the student was observed in the system. Delay of first math is operationalized as the term number of first math enrollment, with Fall 1995 assigned a value of one and Spring 2001 assigned a value of seventeen. All three of these variables are treated as continuous.

Academic goal is a self-reported measure of a student's primary objective, collected at the time of application, which I collapsed into ten nominal categories: transfer to a 4-year institution as an exclusive objective; transfer to a 4-year institution with an allied objective of a nonvocational associate's degree; nonvocational associate's degree as an exclusive objective; vocational associate's degree as an exclusive objective; vocational certificate as an exclusive objective; other job-related goals (e.g., acquiring or advancing job skills, maintenance of a professional license); abstract educational goals (e.g., discovering educational interests, personal development); remediation in fundamental academic subjects (including seeking credit for a high school diploma or GED); undecided; and unreported. Academic goal is treated as a set of dummy variables, with "transfer to a 4-year institution as an exclusive objective" excluded.

Grade in first math course includes ten nominal attributes: A, B, C, D, F, Withdrawal, Credit, No Credit, Ungraded, and missing/unreported. It is treated as a set of dummy variables, with "A" excluded.

English competency, like math competency, is set to the skill-level of a student's first English course. Through a process similar to that used to categorize math, I collapsed 6,625 substantive English courses into four categories: remedial reading, remedial writing, English-as-a-Second-Language (ESL), and college-level English. To these four categories, I added a fifth to account for students who did not enroll in any English coursework. English competency is treated as a set of dummy variables, with "college-level English" excluded.

Finally, interaction with academic advising services is measured using two dichotomous indicators of a given student's experience of being referred to, and/or receiving, advising at any point during the 6-year observation period.

College-Level Control Variables

In addition to the student-level controls, I control for several variables measured at the level of the college, including: the size of each college, the degree of math competency of

[3] While the data do not contain direct measures of SES, the receipt of financial aid serves as an indirect measure and is not without precedent as an indicator of SES in research on remediation (Koski and Levin 1998). DesJardins et al. (2002) offer a persuasive argument for using *offered* financial aid as an indicator of SES, but these data were not available.

entering students, and the goal orientation of each college. Size is operationalized as the number of first-time freshmen who enrolled in a given college in the Fall 1995 term. Degree of math competency is operationalized as the percentage of the Fall 1995 first-time freshmen cohort at a given college whose first nonvocational math enrollment was remedial in nature. Goal orientation is operationalized using four variables, each of which measures the percentage of the Fall 1995 first-time freshmen cohort at a given college who indicated one of the following four goals: transfer, associate's degree, job-related goals, and abstract goals. All six of these contextual variables are treated as continuous.[4]

Strengths and Weaknesses of the Data

The data I assembled for this study have a number of strengths and weaknesses. Among the strengths are access to a population (rather than a sample), a population that is larger than any used in prior studies of this topic, the length of time over which academic careers are observed, the capacity to distinguish between temporary breaks in enrollment and long-term exit from the postsecondary system, and the capacity to observe course enrollments despite student movement across colleges. However, five weaknesses of the data also must be noted.

First, the definitions of "remedial math student" and "college math student" employed in this study assume perfect placement into remedial or college-level coursework. In other words, in these data the only consistent method of classifying students across the colleges is course-taking behavior. This is an unavoidable consequence of the absence of high school transcripts in the data and variation in matriculation processes across the colleges.

While there is no clear solution for this weakness of the data, it is of less serious concern than it might appear. To elaborate, students whose math skills are deficient, but who do not enroll in any math coursework, really are not of interest (methodologically speaking) in answering the question posed in this study. The problem arises when a student who needs remedial assistance with math instead enrolls in a first math course that is college-level and, thereby, is classified as a "college math student." Logically speaking, the most likely outcome for such a student is failure of, or withdrawal from, the math course. If the student does not pursue further math coursework, then the student is captured in the category of CN, which does not pose a problem for this study because the CN category is not central to the hypothesis tested here. On the other hand, if the student drops backwards into remedial math (where the student should have begun) and ultimately works his/her way up to complete successfully a college math course, then the student is identified as a CC when, in fact, he/she should be classified as an RC. This could be problematic because the hypothesis tested in this study compares the outcomes of CCs and RCs.

To explore the scope of this problem, I examined the data for such patterns and found that, of the 16,579 students classified as "college-level," only 847 exhibited the pattern of enrolling initially in a college math course, failing, withdrawing, or receiving "no credit" for that course, and then enrolling in remedial math. Of these 847 students, only 388 eventually achieved college-level math competency. Thus, methodologically speaking, any problem generated by classifying math status on the basis of first math course appears to be minor.

Second, in terms of completing a college math course, the data do not account for academic progress accomplished outside of California's semester-based community colleges. More specifically, students who enter one of the 107 colleges included in this

[4] The contextual variables were transformed as necessary to approximate a normal distribution.

analysis, enroll in a remedial math course (or enroll in and then fail, or withdraw from, a college math course), and subsequently transfer to one of the five quarter-system community colleges, to a private 2-year college, or to a community college outside of California, effectively are treated as "noncompleters" in these data because academic progress that occurs outside of the 107 colleges is unobserved. Although such unobserved progress is expected to represent only a small fraction of the total progress, due consideration should be given to the possible impact on the findings.

Third, because the observation period for course enrollments is truncated at 6 years, some remedial math students may delay their first math course so long that remediating successfully within the observation period effectively is impossible. However, such a condition characterizes only a small percentage of this cohort. More specifically, 96.5% of the students enrolled in a first math course within the first 4 years following admission, allowing more than sufficient time to remediate successfully even for those who faced severe math deficiencies.

Fourth, the data do not address two control variables found to be important in prior studies of educational outcomes, namely employment intensity (e.g., hours worked per week) and credit course load (e.g., part-time versus full-time enrollment). Employment intensity has been found to be moderately negatively correlated with degree expectations, persistence, and other desirable outcomes (American Council on Education 2003; Carter 1999; Hoyt 1999; Toutkoushian and Smart 2001), although this finding is not entirely consistent across studies (Titus 2004). The findings concerning the effects of course load on academic outcomes are clearer and generally indicate that part-time students are somewhat less likely to experience desirable outcomes than are full-time students (Hoyt 1999; O'Toole et al. 2003; Stratton et al. 2007; Szafran 2001). While a variable measuring course load could be constructed from the transcript data, it would face the same problems and complications described by Adelman (2004a, p. 96).

The fifth weakness of the data concerns the generalizability of findings. While the use of a population has substantial advantages over the use of a sample, the population addressed here was drawn exclusively from California's community colleges. Although California's community college system, which has an annual enrollment of 2.9 million students (Turnage 2003), is the largest postsecondary system in the world, and while remediation in California is much like remediation in other states' systems in that placement procedures and exit standards vary from college to college (Boylan et al. 1999; Dougherty and Reid 2007; Hadden 2000; James et al. 2002; Jenkins and Boswell 2002; Kozeracki 2002; Oudenhoven 2002; Shults 2000), the generalizability of the findings of this analysis to other states is uncertain.

In addition, it should be noted that the population addressed in this study includes only first-time college freshmen, who constitute a segment of a larger population of first-time *and* returning students who enroll in remedial and/or college math. Consequently, any inferences drawn from this study are limited to first-time students, an important, but not all encompassing, segment of the population served by community colleges.

Method

I use two-level hierarchical multinomial logistic regression (Raudenbush and Bryk 2002) to model natural variation in the probability of each of the five possible outcomes. This model is specified according to the equations below, in which the left-hand side of the first equation represents the natural log of the odds of the probability of individual i, who is enrolled in college j, experiencing outcome 2, 3, 4, or 5, versus outcome 1. This outcome varies from the intercept for college j (B_{0j}) as a function of a set of three dummy variables that represent students' math status (*RC*, *CN*, and *RN*, with *CC* excluded as the comparison category), the corresponding coefficients for college j (B_{1j}, B_{2j}, B_{3j}), a set of k student-level control variables, and the coefficients associated with these control variables (B_{kj}). In turn, the intercept for college j (B_{0j}) varies from the intercept for all colleges (C_{00}) as a function of a set of q college-level control variables, the coefficients associated with these college-level variables (C_{0q}), and a random college-level error term (ε_{0j}). The coefficients associated with students' math status (B_{1j}, B_{2j}, B_{3j}) vary randomly and unconditionally at the college level (ε_{1j}, ε_{2j}, ε_{3j}), relieving the model of the assumption that the effect of math status is the same for all colleges. The coefficients associated with the student-level control variables (B_{kj}) are fixed across colleges. Students are assigned to the college in which they are observed to be enrolled in the Fall term of 1995, or, in the case of multiple institutions, to the college in which a given student enrolled in the greatest number of courses in that term.[5]

$$\ln\left(\frac{P(y_{ij}=m)}{P(y_{ij}=1)}\right) = \beta_{0j} + \beta_{1j}(RC)_{ij} + \beta_{2j}(CN)_{ij} + \beta_{3j}(RN)_{ij} + \beta_{kj}(Student\ Level\ Controls)_{ij}$$

$$\beta_{0j} = C_{00} + C_{0q}(College\ Level\ Controls)_j + \varepsilon_{0j}$$

$$\beta_{1j} = C_{10} + \varepsilon_{1j}$$

$$\beta_{2j} = C_{20} + \varepsilon_{2j}$$

$$\beta_{3j} = C_{30} + \varepsilon_{3j}$$

$$\beta_{kj} = C_{k0}$$

Analyses

Bivariate Analysis

As discussed earlier, the ameliorative objective of remediation implies that the academic outcomes of successful remedial math students (RCs) should be comparable to the outcomes of students who attain college math skill without the need for remedial assistance (CCs). Conversely, one would expect that students who do not remediate successfully in math (RNs) experience outcomes that are much less favorable than either "completing" group. To begin the exploration of this hypothesis, I present in Table 2 a cross-tabulation of the outcomes of these three categories of students, plus the fourth category of students who enrolled initially in college math but did not complete a college math course successfully (CNs).

The most noteworthy finding presented in this table is the overall similarity of the outcomes of CCs and RCs. These two groups are approximately equally likely to complete only a certificate and approximately equally likely to transfer, although RCs are more likely to transfer *with* a credential, while CCs are more likely to transfer *without* a credential. RCs are somewhat more likely to complete an associate's degree (without transfer) than are CCs, but the absolute magnitude of the difference is small (approximately 4%

[5] Although movement from one college to another is not uncommon among community college students (Bach et al. 2000), this model cannot capture these changes. An alternative specification using a cross-classified data structure would allow the college in which a given student is enrolled to vary, but would treat a student enrolled in multiple colleges as different students (Raudenbush and Bryk 2002).

Table 2 Cross-tabulation of academic outcome and math status (cell sizes are provided in parentheses)

Math status		Academic outcome					
		No credential and no transfer	Certificate only	Associate's degree with or without certificate	Transfer without credential	Transfer with credential	Total
"Completer"	College math	21.77% (2,915)	0.69% (93)	6.53% (874)	45.16% (6,047)	25.85% (3,462)	100.00% (13,391)
	Remedial math	18.89% (3,246)	0.79% (136)	10.51% (1,805)	32.62% (5,604)	37.20% (6,391)	100.00% (17,182)
"Noncompleter"	College math	71.66% (1,909)	1.43% (38)	3.23% (86)	21.73% (579)	1.95% (52)	100.00% (2,664)
	Remedial math	81.52% (42,926)	3.10% (1,630)	6.26% (3,295)	7.33% (3,862)	1.79% (944)	100.00% (52,657)
Total		59.37% (50,996)	2.21% (1,897)	7.06% (6,060)	18.73% (16,092)	12.63% (10,849)	100.00% (85,894)

points). Slightly more than one-fifth of CCs do not complete a credential and do not transfer, as compared with slightly less than one-fifth of RCs.

In contrast to the two successful groups, RNs experience outcomes that are much less favorable. In fact, more than four-fifths of RNs do not complete a credential and do not transfer. CNs have a more favorable transfer rate than do RNs, and a less favorable credential attainment rate (without subsequent transfer), but, globally speaking, the outcomes of CNs are relatively poor.

Regression Analysis

While the bivariate analysis supports my hypothesis that RCs exhibit patterns of credential attainment and transfer that are comparable to those of CCs (suggesting that remedial math programs are quite effective at resolving skill deficiencies for those who complete remediation), the internal validity of conclusions drawn from bivariate analyses is weak at best (Grubb and Gardner 2001). In particular, the absence of statistical controls makes it impossible to determine if the similarity of the outcomes of the two "completing" groups is a product of remediation working as intended or, alternatively, of average differences between the two groups on other predictors of attainment. Thus, it is important in this case to employ a comprehensive set of statistical controls in order to disentangle the effect of remediating successfully from the effects of behaviors and experiences that promote successful remediation. To this end, I present in Table 3 estimated coefficients and standard errors for the hierarchical multinomial logistic regression of academic attainment on math status and selected controls.

In reviewing Table 3, one finding is immediately obvious. Although RCs *do* differ significantly from CCs in the relative likelihood of experiencing one of the four outcomes, the difference between these two groups is quite small, net of controls. For RCs, the odds of transferring *with* a credential versus neither completing a credential nor transferring are approximately one-seventh (15%) *greater* than the odds for CCs, all else being equal. Otherwise, RCs do not differ significantly from CCs in the odds of transferring without a credential, in the odds of completing an associate's degree (without transfer), or in the odds of completing a certificate only, versus neither completing a credential nor transferring. Thus, on the whole, the two "completing" groups experience outcomes that are nearly identical to one another, once other variables are controlled.

In contrast, it is not surprising to find that the outcomes of the two "noncompleting" groups differ substantially and negatively from the two "completing" groups. For example, the odds of transferring *with* a credential versus neither completing a credential nor transferring for CCs are 31 times (3,136%) greater than the odds for RNs and 20 times (2,041%) greater than the odds for CNs, net of controls. Smaller, but still sizeable, gaps are noted in the likelihood of transferring *without* a credential and in the likelihood of completing an associate's degree without transfer. Taken as a whole, it is clear that students who do not attain college math skill are at an enormous disadvantage in terms of academic outcomes within the community college, and remedial math "noncompleters" experience the worst outcomes of the two "noncompleting" groups.

Predicted Probabilities

While odds ratios are useful for interpreting nonlinear statistics, they are of little help in visualizing the practical size of differences in attainment. Therefore, I calculated the

Table 3 Estimated coefficients and standard errors for the hierarchical multinomial logistic regression of academic outcome on math status and selected student-level and college-level control variables ($N_{students} = 85{,}894$; $N_{colleges} = 107$; control variables not shown)

Math status		Academic outcome				
		No credential and no transfer	Certificate only	Associate's degree with or without certificate	Transfer without credential	Transfer with credential
"Completer"	College math	Comparison category				
	Remedial math		−0.269 (0.143)	−0.048 (0.061)	−0.061 (0.050)	0.137** (0.044)
"Noncompleter"	College math		−0.114 (0.222)	−0.746*** (0.147)	−1.532*** (0.070)	−3.064*** (0.166)
	Remedial math		0.230 (0.119)	−1.027*** (0.061)	−2.460*** (0.050)	−3.477*** (0.063)

Note: ** $p \leq 0.01$; *** $p \leq 0.001$; standard errors provided in parentheses

Table 4 Predicted probabilities of each of the five academic outcomes for the "typical" student who is enrolled in the "average" community college, conditional on math status (calculated based upon the estimated coefficients of the model presented in Table 3)

Math status		Academic outcome					
		No credential and no transfer	Certificate only	Associate's degree with or without certificate	Transfer without credential	Transfer with credential	Total
"Completer"	College math	0.301	0.007	0.043	0.325	0.324	1.000
	Remedial math	0.294	0.005	0.040	0.298	0.363	1.000
"Noncompleter"	College math	0.729	0.015	0.049	0.170	0.037	1.000
	Remedial math	0.830	0.024	0.042	0.076	0.028	1.000

Note: The "typical" student, in this case, is a White female who was 20.46 years of age at the commencement of postsecondary attendance, whose first English course was a remedial writing course, who did not receive any financial aid, who indicated an academic goal of transfer in combination with achieving a nonvocational associate's degree, who was enrolled for 6.83 semester terms, who had an inconsistency of enrollment of 30.06%, whose first math enrollment occurred 2.89 semester terms into attendance, but who withdrew from her first math course, and who was both referred to, and received, academic advising

predicted probability of each outcome based upon the model presented in Table 3. These calculations were accomplished by setting all of the student- and college-level controls to their respective means (for continuous variables) or modes (for categorical variables), and then adjusting math status systematically. Consequently, these predictions are based on what one might think of as the "typical" student who is enrolled in the "average" college. The results are detailed in Table 4 and summarized in Fig. 1.

While the results presented in Table 4 further illustrate the comparability of outcomes of CCs and RCs, they also demonstrate the favorable distribution of outcomes for these two groups. The "typical" CC and RC have roughly a 65% chance of transferring (with or without a credential), a 5% chance of completing a credential without subsequent transfer, and a 30% chance of neither completing a credential nor transferring. In contrast, the "typical" RN has a 10% chance of transferring, a 7% chance of completing a credential without transfer, and an 83% chance of neither completing a credential nor transferring. The "typical" CN has a greater chance of transferring, and a lesser chance of neither completing a credential nor transferring, but otherwise does not differ substantively from the "typical" RN.

Alternative Model Specifications

In the interest of thoroughness, three alternative specifications of the model were examined. In the first alternative specification, I removed from the model all control variables that address concepts that occurred subsequent to enrollment in college. I retained math status, sex, race, age, the three proxies of SES, English competency at college entry, academic goal, and the college-level controls. The purpose, in this case, is to ensure that I do not "over control" the outcome by including variables that might be influenced by the experience of remediating successfully itself. The results are presented in Table 5.

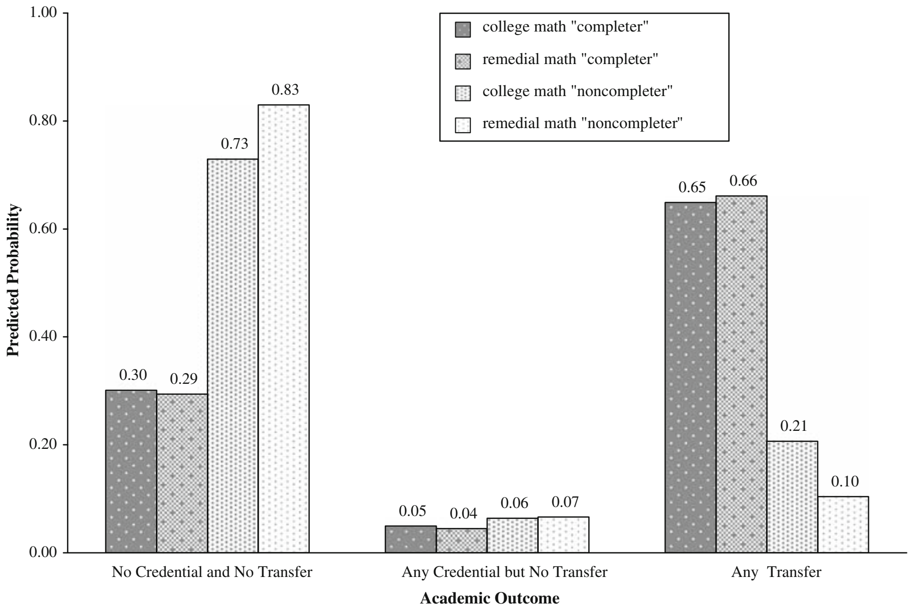

Fig. 1 Summary of the predicted probabilities of the various academic outcomes for the "typical" student who is enrolled in the "average" community college, conditional on math status (collapsed from the figures presented in Table 4)

The primary differences between the full model (Table 3) and the simplified model (Table 5) involve increases in the magnitudes of the estimated effects of math status. For example, RCs have a greater estimated advantage over CCs in the likelihood of transfer with a credential, while the RNs and CNs have a greater estimated disadvantage. A similar change is noted in the completion of an associate's degree without transfer, for which RCs now have a statistically significant advantage, while CNs and RNs face a greater estimated disadvantage. Concerning the likelihood of transfer without a credential, RCs and CCs remain equal, while RNs and CNs experience a greater estimated disadvantage. Only on the certificate-only outcome are the findings inconsistent, as the simplified model indicates that CNs face a significant disadvantage relative to CCs, while the full model indicates no significant differences. However, this coefficient barely reaches the threshold of statistical significance in the simplified model, which itself is a meaningful observation given the size of the analytical cohort, so this difference between the full and simplified models is not of great consequence.

By and large, these differences between the two specifications make sense in light of the variables that are excluded in the simplified model. For example, consider that first math grade is positively associated with the likelihood of achieving college math skill (Bahr n.d.; Wang 2001). In turn, achieving college math skill is positively associated with the outcomes examined here. Thus, in the simplified model, part of the estimated total effect of not achieving college math skill (CN and RN) includes the effect of first math grade, as one would expect that "noncompleters" performed more poorly, on average, in first math than did "completers." Likewise, some of the increased advantage of RCs over CCs observed in the simplified model likely is a product of greater average persistence among RCs (Kolajo 2004), which increases the likelihood of completing a credential of some sort (whether or

Table 5 Estimated coefficients and standard errors for a *simplified specification* of the hierarchical multinomial logistic regression of academic outcome on math status and selected student-level and college-level control variables ($N_{students} = 85{,}894$; $N_{colleges} = 107$; control variables not shown)

Math status		Academic outcome				
		No credential and no transfer	Certificate only	Associate's degree with or without certificate	Transfer without credential	Transfer with credential
"Completer"	College math	Comparison category				
	Remedial math		0.202 (0.141)	0.538*** (0.055)	0.028 (0.048)	0.473*** (0.041)
"Noncompleter"	College math		−0.533* (0.215)	−1.752*** (0.131)	−1.798*** (0.065)	−3.641*** (0.152)
	Remedial math		0.020 (0.116)	−1.380*** (0.057)	−2.618*** (0.048)	−3.837*** (0.061)

Note: * $p \leq 0.05$; *** $p \leq 0.001$; standard errors provided in parentheses not this is followed by transfer). Thus, on the whole, the results detailed previously in the full model (Table 3) appear to be logically consistent and fairly robust against this particular modification to the specification.

Concerning the second alternative specification, prior research indicates that the likelihood of successful remediation in math declines sharply with increasing skill deficiency at college entry (Bahr 2007, n.d.; Hagedorn and Lester 2006). Although not related directly to this pattern, one also might anticipate that students who exhibit the poorest math skills at college entry benefit less from remediating successfully in math than do remedial math students who exhibit stronger math skills at college entry. One might ask, does remediating successfully in math benefit students equally across the varying levels of initial math skill deficiency? For example, do basic arithmetic students who remediate successfully experience academic outcomes that are comparable to those of intermediate algebra students who remediate successfully, and do both of these groups achieve the various academic outcomes at rates that are similar to those of successful college math students? In other words, is remediation equally efficacious at every level of mathematical underpreparation?

To test the efficacy of remediation across levels of initial deficiency, I modified the operationalization of math status to include separate categories for each level of initial math skill, based upon a given student's first math course enrollment. This modified variable includes 10 categories, one for each of five levels of initial math skill multiplied by the two possible outcome conditions of achieving college math skill successfully or not. I then replicated the model presented in Table 3, replacing the simpler four-category indicator of math status with this new 10-category indicator. The pertinent results are presented in Table 6.

The results presented in Table 6 generally support the findings of the previous models. Although several statistically significant differences between CCs and the various categories of RCs emerge, no clear pattern of disadvantage for the poorest skilled RCs is evident, and all differences between CCs and RCs are comparatively small in magnitude. This suggests that, generally speaking, remediation is equally efficacious in its effect on academic outcomes across levels of initial math deficiency, net of controls.

In contrast, a progressive decline in the likelihood of achieving an associate's degree (without subsequent transfer) and transferring (with or without a credential) is observed among RNs as math skills at college entry decline. In other words, although it appears that the benefits of remediating successfully are fairly equal across levels of initial math skill deficiency, the consequences of *not* remediating successfully grow increasingly worse as math skills at college entry decline. This is an intuitively reasonable finding as one would anticipate that, in the absence of successful remediation, declining math skills progressively foreclose academic opportunities.

In the third and final alternative specification, I replicated the model presented in Table 6 using a different threshold of *successful* college math skill attainment. In particular, I treated a grade of "D" in a college math course as *unsuccessful*, in contrast to the inclusion of grades of "D" as *successful* in the models presented in Tables 1–6. In Table 7, I compare the distributions of college math skill attainment as a function of math skill at college entry under these two competing definitions of success. In Table 8, I present the pertinent coefficients and standard errors for this third alternative regression model specification.

Regarding the overarching pattern of outcomes, the results presented in Table 8 parallel those presented in Table 6. Although RCs, relative to CCs, are slightly advantaged in some respects and slightly disadvantaged in other respects, the overall pattern of

Table 6 Estimated coefficients and standard errors for the hierarchical multinomial logistic regression of academic outcome on an *expanded math status variable* and selected student-level and college-level control variables ($N_{students} = 85{,}894$; $N_{colleges} = 107$; control variables not shown)

Math status		Academic outcome				
		No credential and no transfer	Certificate only	Associate's degree with or without certificate	Transfer without credential	Transfer with credential
"Completer"	College math	Comparison category				
	Intermediate algebra/geometry		−0.176 (0.174)	−0.127 (0.074)	−0.178** (0.056)	0.015 (0.054)
	Beginning algebra		−0.397* (0.185)	−0.085 (0.074)	−0.035 (0.070)	0.164** (0.058)
	Pre-algebra		−0.462 (0.334)	−0.303* (0.149)	0.052 (0.125)	0.207 (0.111)
	Basic arithmetic		−0.249 (0.284)	−0.460** (0.148)	−0.358* (0.145)	−0.003 (0.131)
"Noncompleter"	College math		−0.081 (0.214)	−0.684*** (0.145)	−1.487*** (0.069)	−3.028*** (0.166)
	Intermediate algebra/geometry		0.117 (0.146)	−0.699*** (0.081)	−2.023*** (0.063)	−3.139*** (0.092)
	Beginning algebra		0.287* (0.126)	−0.842*** (0.065)	−2.407*** (0.050)	−3.303*** (0.071)
	Pre-algebra		0.091 (0.139)	−1.475*** (0.091)	−2.806*** (0.068)	−3.838*** (0.103)
	Basic arithmetic		0.148 (0.135)	−1.783*** (0.095)	−3.070*** (0.080)	−4.128*** (0.106)

Note: * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$; standard errors provided in parentheses

Table 7 Percentage of students at various levels of initial math skill who successfully achieved college-level math skill under two competing definitions of *success* ($N_{\text{students}} = 85{,}894$; $N_{\text{colleges}} = 107$)

Initial math skill	*N*	Minimum "D" threshold (%)	Minimum "C" threshold (%)	Difference	Odds ratio
College-level math	16,055	83.41	79.59	−3.82	0.776
Intermediate algebra/geometry	15,119	50.13	47.36	−2.77	0.895
Beginning algebra	26,315	26.35	24.83	−1.52	0.923
Pre-algebra	11,417	13.36	12.56	−0.80	0.932
Basic arithmetic	16,988	6.74	6.23	−0.51	0.919
Total	85,894	35.59	33.72	−1.87	0.921

Note: Values in "Odds Ratio" column were calculated by dividing the odds of success under the "minimum C" definition of successful remediation by the odds of success under the "minimum D" definition. Thus, the values in this column gauge the *relative* change in the likelihood of successful remediation when switching from the "minimum D" threshold to the "minimum C" threshold. The odds ratio is useful in this case because it allows comparisons between the various levels of initial math skill. For example, although the absolute decrease in the likelihood of success under the "minimum C" definition for Basic Arithmetic students is one-third that of Beginning Algebra students, the relative decrease for the two categories of initial math skill is nearly equal

comparable outcomes for RCs and CCs is preserved. Likewise, as in Table 6, a similar pattern of increasing disadvantage with decreasing math skill is observed among RNs. Thus, neither of the two alternative thresholds of successful remediation appears to be more or less informative than the other with respect to the questions addressed in this study.

Discussion

This paper poses the question, "Does mathematics remediation work?" To answer this question, I used hierarchical multinomial logistic regression to model natural variation in a five-category nominal outcome measure of long-term student attainment as a function of a four-category nominal measure of student's entry to, and exit from, math and a set of student- and college-level control variables. In addition, I replicated this model using a more complex 10-category nominal measure of math status and two competing definitions of college-level math skill attainment. The answer to the question posed here clearly is affirmative, yet with one important caveat.

Within the context of the community college, students who remediate successfully in math exhibit attainment that is comparable to that of students who achieve college math skill without the need for remediation, and this finding generally holds true even across the various levels of initial math skill deficiency. In fact, the two groups effectively are indistinguishable from one another in terms of credential attainment and transfer, with the minor exception of small differences in the likelihood of completing a credential prior to transfer. This is a remarkable finding, as it indicates that remediation has the capacity to fully resolve the academic disadvantage of math skill deficiency, at least as far as these outcomes are concerned. Thus, as it pertains to students who remediate successfully in math, the primary goal of remediation clearly *is* being achieved.

However, the caveat is large and troubling. Three out of four (75.4%) remedial math students do not remediate successfully (Table 1), and the academic attainment of these

Table 8 Estimated coefficients and standard errors for the hierarchical multinomial logistic regression of academic outcome on an expanded math status variable and selected student-level and college-level control variables, *using an alternative definition of successful college-level math skill attainment* ($N_{students} = 85{,}894$; $N_{colleges} = 107$; control variables not shown)

Math status		Academic outcome				
		No credential and no transfer	Certificate only	Associate's degree with or without certificate	Transfer without credential	Transfer with credential
"Completer"	College math	Comparison category				
	Intermediate algebra/geometry		−0.193 (0.184)	−0.099 (0.076)	−0.146* (0.061)	0.043 (0.055)
	Beginning algebra		−0.427* (0.199)	−0.068 (0.078)	−0.004 (0.075)	0.191** (0.061)
	Pre-algebra		−0.388 (0.351)	−0.315* (0.159)	0.114 (0.130)	0.259* (0.114)
	Basic arithmetic		−0.214 (0.299)	−0.442** (0.154)	−0.317* (0.140)	0.024 (0.139)
"Noncompleter"	College math		−0.104 (0.199)	−0.796*** (0.132)	−1.480*** (0.072)	−2.956*** (0.142)
	Intermediate algebra/geometry		0.078 (0.144)	−0.799*** (0.078)	−2.089*** (0.062)	−3.128*** (0.083)
	Beginning algebra		0.245 (0.129)	−0.910*** (0.066)	−2.459*** (0.050)	−3.324*** (0.065)
	Pre-algebra		0.046 (0.141)	−1.529*** (0.094)	−2.883*** (0.069)	−3.847*** (0.094)
	Basic arithmetic		0.124 (0.138)	−1.843*** (0.096)	−3.139*** (0.080)	−4.161*** (0.101)

Note: * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$; standard errors provided in parentheses students is abysmal: more than four in five (81.5%) do not complete a credential and do not transfer (Table 2). So, one must conclude that the answer to the question posed here is, "Yes, remediation does work for *some* students," or, perhaps, "*When* remediation works, it works extremely well."

Why does mathematics remediation work for some and not for others? Said another way, why do the majority of remedial math students *not* attain college-level math skill? In answer to this question, several strong correlates of successful remediation in math have emerged in the literature: grade in first math, depth of remedial need at college entry, and breadth of remedial need at college entry. The first of these—grade in first math—is a strong, positive predictor of the likelihood of successful remediation in math (Bahr n.d.; Wang 2001). The underlying reasons for this association are debatable, as a student's math grade is a product of a number of factors, including prior math preparation and the degree of effort applied to the topic by the student (Farkas 2003). It seems certain, however, that academic self-efficacy plays a role, as the relationships between performance, self-efficacy, and outcomes are well articulated (Britner and Pajares 2001; Chen and Kaplan 2003; Robbins et al. 2004; Santiago and Einarson 1998). More specifically, one would expect that poor performance in first math would discourage further pursuit of mathematical competency through the impact of the performance disappointment on academic self-efficacy.

Concerning the latter two correlates, depth of remedial need refers to the degree of deficiency in a given subject, while breadth of remedial need refers to the number of subjects in which a given student requires remedial assistance (Bahr 2007). A number of studies indicate that depth and breadth of remedial need are strongly and inversely associated with the likelihood of successful remediation (Bahr 2007, n.d.; Easterling et al. 1998; Hagedorn and Lester 2006; McCabe 2000; Weissman et al. 1997b). The effect of depth of remedial need, in particular, is startling evident in Table 7. For example, in this study only 1 in 15 basic arithmetic students achieved college-level math skill, while approximately one in two intermediate algebra and geometry students did so. Thus, the likelihood of successful remediation in math declines sharply as degree of deficiency (depth of remedial need) increases.

However, the mechanisms that underlie the relationships between depth/breadth of remedial need and successful remediation are, as of yet, unclear. For example, some have suggested that the stigma of placement in low ability groups influences negatively students' perceptions of themselves and the subject matter, and, thereby, academic outcomes (Hadden 2000; Maxwell 1997). One might extrapolate from this argument that the lower is a student's placement in the remedial hierarchy, the greater is the stigma attached to that placement, and, therefore, the lower is the likelihood that the student will remediate successfully. Yet, this explanation conflicts with Deil-Amen and Rosenbaum's (2002) finding of a shift toward "stigma-free" remediation in community colleges that tends to hide from underprepared students their remedial status. Alternatively, McCusker (1999) suggests that remedial students become discouraged at the prospect of taking numerous courses that do not result in credit towards a degree and/or lengthen the time required to achieve educational objectives, which is a problem that worsens the further down the remedial ladder one begins. Conversely, Rosenbaum (2001) suggests that some underprepared students view community college attendance as a personal educational "experiment," which contributes to undisciplined behavior with respect to coursework. One might reason that the students who are least prepared for college-level coursework are the most likely to view college attendance as an "experiment," which would contribute to the negative correlations between depth and breadth of remedial need and the likelihood of favorable outcomes. While these all appear to be plausible explanations, further research is needed to elaborate fully the relationships between depth and breadth of remedial need and successful remediation.

Policy Implications

At least three important implications for educational policy may be drawn from this work. First, as noted earlier, when mathematics remediation works, it works extremely well. Thus, although critics of remediation might continue to argue that this "second chance" is a "waste" of resources (Reising 1997), they may not argue that remedial math programs are failing to meet their objective for students who remediate successfully.

Nevertheless, critics legitimately may question the global success of programs in which three-quarters of the students who start a journey towards college-level math never arrive at that destination. Moreover, as noted earlier, it is those students who have the greatest deficiencies who are the least likely to remediate successfully. Thus, criticism of remedial programs may be justified on two fronts: comparatively few remedial math students remediate successfully, and those students who do remediate successfully are disproportionately those who require the least assistance.

Note, however, that the focus of the analysis presented here is *not* on the effect of remedial math coursework in general, but on the effect of remediating *successfully* in math. Therefore, one implication that should *not* be drawn from these findings is that remedial coursework is detrimental to the academic outcomes of some students. This distinction between the effect of remedial coursework and the effect of remediating successfully is an important one because studies that examine the effect of remedial coursework face a quagmire of problems associated with controlling confounding background characteristics of students.

In contrast, the only instance in which questions about unaddressed confounding variables would become prominent in a study such as this one is when the findings suggest that remediating successfully does *not* lead to outcomes that are comparable to those of college-prepared students. That is not the finding of this study. Rather, I find only negligible differences in outcomes between successful remedial math students and students who do not require remediation. Given that students who require remedial assistance disproportionately face other (additional) obstacles to academic success (including the many confounding background characteristics), this finding of only minor differences runs contrary to what one would anticipate if confounding background characteristics were analytically problematic in this study. Thus, a high level of confidence may be placed in the finding of this study, but this confidence extends only to the focus of this study (the effect of remediating successfully), and any inference drawn concerning some "general effect" of remedial math coursework likely would be erroneous.

Second, in this population more than four in five (81.3%) first-time freshmen who enrolled in nonvocational math enrolled specifically in remedial math (Table 1). Given this high rate of enrollment in remedial math coursework, one can see clearly that remediation is not simply one of many functions of the community college. Rather, it is so fundamental to the activities of the community college that significant alterations in remedial programs would change drastically the educational geography of these institutions. This should give pause to those who advocate the elimination of remediation or other substantial changes in the availability of remedial programs, as the implications of such changes would be profound indeed.

Finally, it is important to note that 59% of the first-time freshmen who enrolled in nonvocational math did not complete a credential and did not transfer, and 84% of the students who did not complete a credential and did not transfer were remedial math students who did not remediate successfully (Table 2). My analysis suggests that, all else being equal, assisting all remedial math students to remediate successfully may reduce the number of students who enroll in nonvocational math, but do not complete a credential and do not transfer, by as much as two-thirds (65%).[6] Thus, postsecondary remediation plays an indisputably central role both in the educational trajectories of students who require assistance with basic skills *and* in the "bigger picture" of educational attainment in the community college system. Given the growing attention on the performance of, and performance standards for, community colleges (Bahr et al. 2004, 2005; Bastedo and Gumport 2003; Boylan 1997; McMillan et al. 1997; Roueche and Roueche 1999; Roueche et al. 2002), it is exceedingly apparent in light of this analysis that identifying methods of increasing the rate of successful remediation in math should be a topic of central concern to all stakeholders in the community college system.

Conclusion

Postsecondary remediation is a hotly contested topic. Yet, remarkably few large-scale, comprehensive, multi-institutional evaluations of remediation have been put forward, leading to an astonishing lack of empirical evidence to inform this debate. In this study, I tested the efficacy of postsecondary remedial math programs, using data that address a population of 85,894 first-time college freshmen enrolled in 107 community colleges. I found that students who remediate successfully (achieve college-level math skill) exhibit long-term academic attainment (credential completion and transfer) that is comparable to that of students who achieve college-level math skill without the need for remedial assistance. Conversely, students who do not remediate successfully, who constitute both the majority of students who enroll in remedial math coursework and the majority of students who enroll in any nonvocational math coursework (remedial or college-level), experience outcomes that are considerably less favorable. Thus, it is clear that mathematics remediation is extremely effective for students who remediate successfully. However, further research is needed to elaborate the obstacles that are hindering successful remediation for so many.

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[6] As this is a counterfactual argument, it is only a supposition based upon the evidence.

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