The Role of Vocational and Technical Education in Nigeria Economic Development

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Meta-analytic methods were used to examine the moderating effect of institutional factors on the relationship between high school mathematics curricula and college mathematics course-taking and achievement from a sample of 32 colleges. The findings suggest that the impact of curriculum on college mathematics outcomes is not generally moderated by institutional characteristics such as selectivity and educational profile, providing evidence that the relationships between curriculum and college mathematics outcomes generalize to a range of colleges. The results inform college policies and practices for advising students on mathematics course-taking including enrollment in developmental courses, and high school mathematics curriculum selection.

There is substantial evidence that many U.S. students enter college unprepared to succeed in mathematics (National Center for Educational Statistics [NCES], 2006, 2008, 2009), including the fact that 25%, and perhaps as many as 40%, of all college freshmen complete at least one developmental mathematics class (typically a non-credit bearing class that should have been completed in high school) (Attewell, Lavin, Domina, Levey, 2006; NCES, 2003). The large numbers of students whose preparation for college mathematics is unsatisfactory has prompted postsecondary institutions to invest significant resources in policies and practices that support students' mathematics learning (Bettinger & Long, 2009).

The lack of student preparation has also prompted research on the role of high school mathematics curricula in preparing students for college mathematics. This literature has generally shown that high school mathematics curriculum is related to the difficulty level of the first college mathematics course a student completes but not to the difficulty of subsequent mathematics courses, whereas evidence of the relationship between curriculum and college mathematics achievement reflected in course grades is mixed (Harwell et al., 2009; Post et al., 2010; Schoen & Hirsch, 2003).

An important next step in increasing our understanding of the relationship between high school mathematics curricula and college mathematics course-taking and achievement is examining the impact of college characteristics on these relationships (We define college as a postsecondary institution offering a bachelor's degree). Research has demonstrated that college characteristics and organizational climates impact a range of student outcomes (Berger & Milem, 1999), and that there is an ongoing need to develop and refine college policies that promote better student outcomes including mathematics outcomes (Bettinger & Long, 2009; Ratcliff, Lubinescu, & Gaffney, 2001). However, none of this work has examined the impact of institutional factors on the relationship between high school mathematics curriculum and college mathematics achievement and course-taking including developmental mathematics.

Rationale for the Study and Research Question

Understanding the impact of institutional factors on the relationship between high school mathematics curriculum and college mathematics outcomes is important for two reasons. First, it informs the use of high school mathematics curricula by college advisors who recommend mathematics coursework to students. Norman (2008) found evidence that high school mathematics curriculum plays an important role in the first college mathematics course recommended to students by advisors but the basis of this importance was unclear. For example, knowing whether completion of a particular high school mathematics curriculum increases or decreases the likelihood of enrollment in a developmental mathematics course in a more or less selective institution provides guidance to advisors charged with recommending an initial college mathematics course.

Second, the results inform the selection of mathematics curricula by high schools for college bound students. Specifically, the presence or absence of institutional moderators suggests that the relationship between high school mathematics curriculum and college mathematics outcomes does (or does not) generalize to a variety of institutions. The former implies that this relationship generalizes across a range of institutions and suggests that preparation for, and success in, college mathematics does not depend on these characteristics; the latter implies that this relationship is strengthened or weakened by institutional characteristics meaning that preparation for, and success in, college mathematics will be influenced by these characteristics. This information assists high schools in mathematics curriculum selection decisions for college bound students.

High School Mathematics Curricula

The most widely used mathematics curricula in the U.S. are commercially developed (CD) or traditional curricula that stress traditional algorithms and procedures (Education Market Research, 2006). The curricula in the CD category are typically organized as separate years of algebra, geometry, and advanced algebra, and within each year the texts are divided into chapters which focus on algorithmic development with problem solving that concentrates on solving word problems. Student communication is not a central focus of these texts and mathematical content is, in general, explained by the teacher.

A second category are National Science Foundation (NSF)-funded curricula that are designed to be aligned with the National Council of Teachers of Mathematics' (NCTM) *Curriculum and Evaluation Standards for School Mathematics (CESSM)* (NCTM, 1989, 2000). The mathematics curricula funded by NSF included: *Contemporary Mathematics in Context* (*CMIC* or Core-Plus) (Coxford et al., 1998), *Interactive Mathematics Program* (*IMP*) (Fendel, Resnick, Alper & Fraser, 1997), and *Mathematics: Modeling Our World* (*MMOW* or ARISE) (Garfunkel, Godbold, & Pollak, 1998). These curricula focus on algebra, geometry, probability, statistics and topics in discrete mathematics yearly, de-emphasize algorithmic manipulation, and emphasize the role of students as active participants in the learning process and the value of small groups (Schoenfeld, 2004). A third curriculum is the University of Chicago School Mathematics Project (UCSMP), which is often described as having attributes of both the CD and NSF-funded curricula (Schoenfeld, 2004).

Studies of the relationship between high school mathematics curricula and college mathematics performance have typically compared the impact of NSF-funded and CD curricula. The focus on NSF-funded curricula is in large part because of the intense criticism of these curricula as detailed in Schoenfeld (2004), and in part because of the unsatisfactory mathematics performance of U.S. high school students (NCES, 2006, 2008) most of whom completed a CD curriculum.

The Impact of College Characteristics and Organizational Climates

There is considerable empirical evidence of the impact of college characteristics and organizational climates on a range of student outcomes (Berger & Milem, 1999), and of the need to develop college policies that promote better student outcomes including mathematics outcomes (Bettinger &

Long, 2009; Ratcliff et al., 2001). There is also empirical evidence of the impact of institutional factors on developmental mathematics outcomes (e.g., Attewell et al., 2006; Fong, Huang, & Goel, 2008), but there are no theoretical models of this process.

The importance of understanding the role of postsecondary institutional factors on preparation for college mathematics (reflected in high school mathematics curricula) and college mathematics outcomes led us to pose the following research question:

What institutional factors moderate the relationship between high school mathematics curriculum and college mathematics course-taking and achievement as reflected in the likelihood of completing a (i) developmental mathematics course and the grade earned (ii) college algebra course and the grade earned (iii) calculus I course and the grade earned?

We limit our examination to the impact of CD and NSF-funded curricula because of the intense scrutiny and criticism the latter have received (Klein, 2001). Given our research question, institutional (aggregate) data rather than disaggregated (student) data were analyzed, a practice similar to coarsening data in epidemiological research to identify overall patterns (see, e.g., Iacus, King, & Porro, 2008). In this process data are rescaled to a more coarse form (e.g., student level to institutional level), which implies a change in inferences to aggregated units of analysis. Using institutional level data provided compelling and succinct representations of the impact of institutional moderators on the relationship between high school mathematics curricula and college mathematics outcomes. Of course, it is important to avoid the ecological fallacy discussed by Robinson (1950) in which inferences about disaggregated data (students) are made based on aggregated data (institutions). While such inferences are permissible under quite restrictive conditions (Schuessler, 1999) we limit our inferences to institutions.

We focused on the likelihood of enrolling in a college developmental mathematics course because of evidence that high school mathematics curriculum plays a key role in the first college mathematics course a student is advised to take (Norman, 2008), and the possibility that this relationship could be moderated by institutional factors. College algebra was included as an outcome due to the large numbers of students who enroll in these courses (Hofacker, 2006), and calculus I because it serves as a gateway to higher level mathematics and completion of a major in science, technology, engineering, or mathematics (STEM) (Tyson, 2011).

Methods

Research Design

A retrospective cohort cluster design was used in which postsecondary institutions (colleges) served as clusters. College mathematics outcomes for CD and NSF-funded curricula were compared for each institution, producing a quasi-experimental design.

Population and Sample

The target population consisted of colleges in the U.S. whereas the sampled population consisted of colleges in the upper Midwest of the U.S. that varied in several ways (e.g., educational profile). Following the purposive sampling arguments of Shadish, Cook, and Campbell (2002, pp. 354-372), the sample allows us to generalize our results at least approximately to similar institutions. Altogether 32 four-year institutions were sampled.

Students enrolling in college will generally be expected to have completed at least three years (Carnegie units) of high school mathematics, as reflected in the mathematics portions of the ACT and SAT tests (ACT, 2009; College Board, 2009). To be included in our study students enrolled at an institution must have completed at least three years of high school mathematics in a CD or NSF-funded curriculum and completed at least one college mathematics course.

Data Sources

Data were obtained from two sources. The first, college records, included the number of years of high school mathematics a student completed and titles of their high school mathematics courses which were used to identify a student's high school mathematics curriculum. College records also yielded the titles and grades of student's mathematics coursework across eight college semesters, demographic information, and a student's college major which was captured using a trichotomous variable: STEM, Humanities/Social Sciences, or Other.

The second data source reflected information about post-secondary institutions. Variables taken from institution websites and a State Department of Education website reflected important college characteristics and organizational climates: institutional size (captured by enrollment = number of full-time + part-time students), selectivity (ACT mathematics score of the freshmen class corresponding to the 25th percentile as reported on institution websites), percentages of African American students and STEM majors, institutional profile (publicly or privately supported), and educational profile. The latter variable combined selectivity and the nature of an institution's student body and was generated using information on the Carnegie Foundation website http://classifications.carnegiefoundation.org/lookup_listings/standard.php?key=783. For our sample the educational profile variable had three categories: (i) 1 = full-time = ≥ 80% students attend school on a full-time basis, selective (more selective = average ACT score in upper one-fifth of all colleges, selective = average ACT score in middle two-fifths of all colleges), and transfer rate (high transfer-in = ≥ 20%, low transfer-in rate = < 20%) (ii) 2 = full-time/more selective/high transfer-in rate (iii) 3 = mixture of full-time and part-time students/mixture of selective and less selective/high transfer-in rate.

The dependent variables were used to compute effect sizes corresponding to our research question. Dependent variables reflecting the difficulty level of a college mathematics course were created by examining the description of each mathematics course at each sampled institution. This process led to college mathematics courses being categorized as representing one of three difficulty levels: Level 1 reflected course that should have been completed in high school (developmental), Level 2 a course that a student who satisfactorily completed four levels (years) of mathematics in high school would not repeat in a college setting (e.g., college algebra, pre-calculus mathematics), and Level 3 calculus I. Seventy-five percent of the sampled institutions used a 12-point grading scale (A, A-, B+, …, F), 18.75% used a seven-point scale (A, AB, B, BC, C, D, F), and 6.25% used a five-point point grade scale (A, B, C, D, F). To reduce the impact of between-institution differences related to grades we rescaled all grades to a five-point scale (A = 5, B = 4, ...).

Data Analyses

Meta-analysis was used to study patterns in effect sizes to provide insight into the moderating effect of institutional factors on the high school mathematics curricula and college mathematics course-taking and achievement relationships. Both graphical and inferential analyses were used to explore patterns in the effect sizes and the impact of institutional factors. Data for each dependent variable were analyzed separately.

Course-taking

We focused our examination on the relationship between high school mathematics curriculum and college mathematics course-taking by creating three binary dependent variables corresponding to our research question: Completed a developmental mathematics course in college 1 = yes (difficulty level = 1), 0 = no; Completed college algebra in college 1 = yes, (difficulty level = 2), 0 = no; Completed calculus I in college 1 = yes (difficulty level = 3), 0 = no. The proportion of 1's reflected enrollment in a curriculum cohort (e.g., CD with proportion $\hat{p}_{CD_k}$) among students who subsequently enrolled in a developmental mathematics course at the kth institution. A similar quantity was generated for students in the NSF-funded cohort at the kth institution (e.g., $\hat{p}_{NSF_k}$). We then estimated an effect size for an institution ($\hat{\delta}_k$) as:

$$\hat{\delta}_k = \frac{(\hat{p}_{CD_k} - \hat{p}_{NSF_k})}{\hat{\sigma}_{\hat{p}_{CD_k} - \hat{p}_{NSF_k}}} \sim \text{Normal}(\delta_k, \sigma^2_{\delta_k}),$$

$$\hat{\sigma}^2_{\hat{p}_{CD_k} - \hat{p}_{NSF_k}} = \frac{\hat{p}_{CD_k}\hat{q}_{CD_k}}{N_{CD_k}} + \frac{\hat{p}_{NSF_k}\hat{q}_{NSF_k}}{N_{NSF_k}} \quad (1)$$

In equation (1) $\hat{\delta}_k$ is a standardized effect size similar to Cohen's d (Cohen, 1988), $\hat{\sigma}^2_{\hat{p}_{CD_k} - \hat{p}_{NSF_k}}$ is the variance of the difference in the proportions, N is a sample size, and $\hat{q} = 1 - \hat{p}$. A similar process was followed for the outcomes reflecting the likelihood of completing a college algebra course and calculus I, respectively.

Grades

The process to compute $\hat{\delta}_k$ for grades followed Konstantopoulos and Hedges (2009). For all outcomes we examined plots of effect sizes and used two-level hierarchical linear modeling to explore variation among effect sizes and to construct explanatory models.

Results

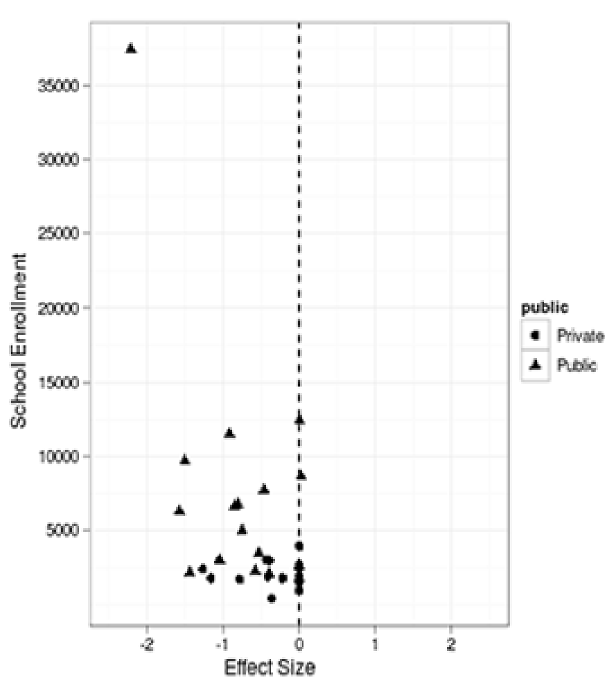
Descriptive Analyses

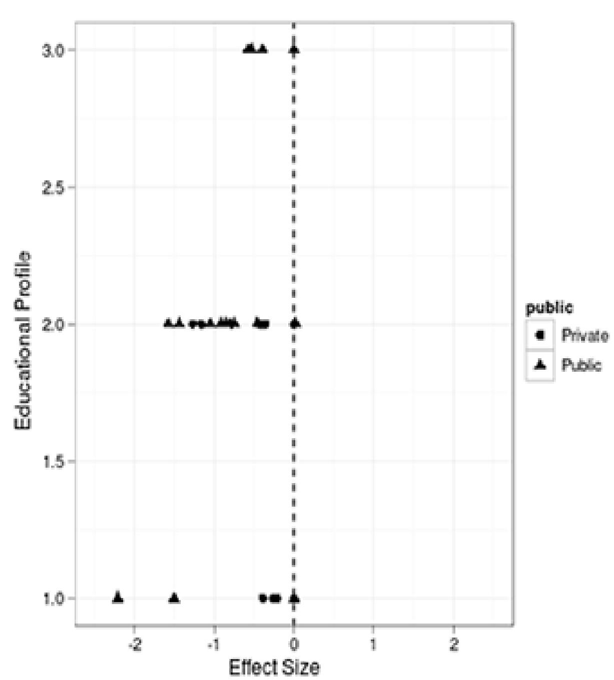
The average enrollment at the 32 institutions was 5,100 and ranged from 440 to 37,383 with first, second, and third quartile values of 1897, 2672, and 6655, respectively. The average institutional ACT mathematics score corresponding to the 25^{th} percentile was 21 and ranged from 15 to 29 in our sample (scores corresponding to the 50^{th} percentile were unavailable). The distribution of institutions in the three categories of the educational profile variable (full-time/more selective/high transfer-in rate, full-time/selective/high transfer-in rate, mixture of full-time and part-time students/mixture of selective and less selective/high transfer-in rate) was 28.1%, 59.4, and 12.5, respectively. The percentage of African American students enrolled at an institution was on average quite small (2.4%) and ranged from almost 0 to 12.73%, whereas the average percentage of STEM majors at an institution was 7.8% and ranged from almost 0 to 21.1%.

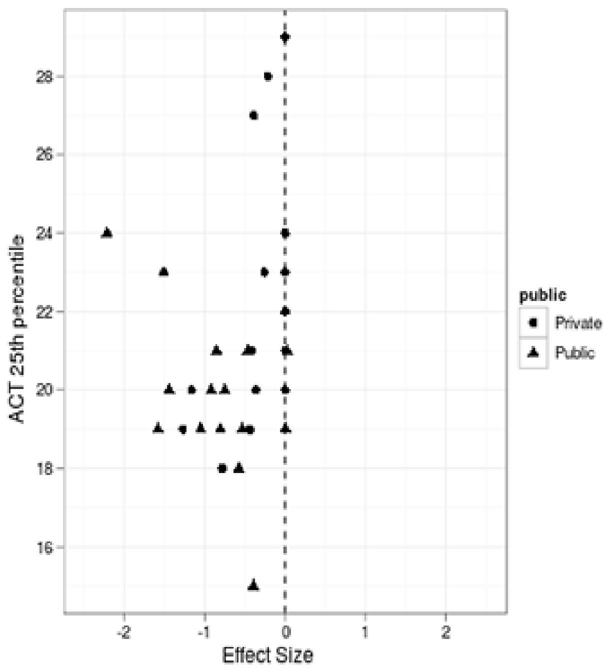
The institutional proportions for completing a developmental mathematics course in college for the CD and NSF-funded cohorts were .12 (N = 1,211) and .22 (468), respectively; for students completing three, four, or five years of high school mathematics the proportions completing a developmental mathematics course for the CD and NSF-funded cohorts were .12 (702) and .22 (265), .10 (453) and .19 (184), and .02 (56) and .04 (19), respectively. Institutional proportions for completing a college algebra course for the CD and NSF-funded cohorts were .53 (5,091) and .57 (1,216), respectively.

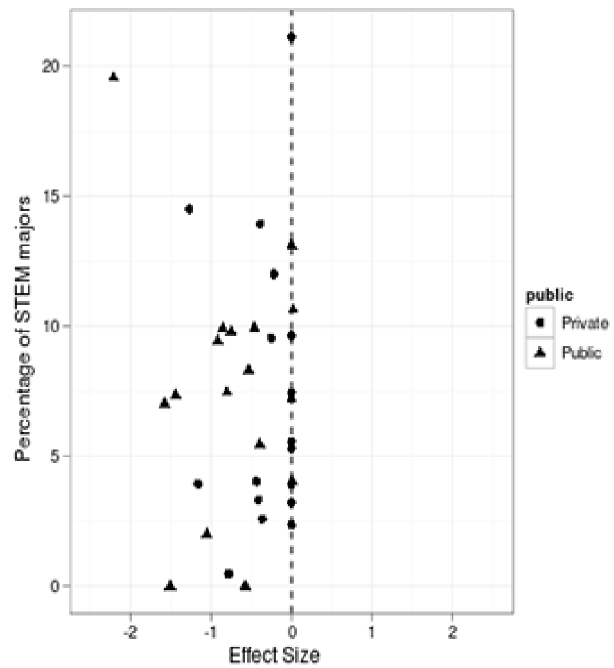
Plots of effect sizes ($\hat{\delta}_k$) computed using equation (1) are given for the likelihood of completing a developmental (Figures 1-5) and calculus I course (Figures 6-10). Patterns for college algebra were similar and are not reported. Figures 1-5 reflect the difference between the CD and NSF-funded cohorts at an institution in the likelihood of completing a developmental mathematics course by an institution's size (enrollment), educational profile, ACT mathematics 25th percentile, percentage of STEM majors, and percentage of African Americans as a function of financial profile (publicly or privately supported). The overwhelming majority of effect sizes are negative meaning that at most institutions the NSF-funded cohort was on average more likely to initially enroll in a developmental mathematics course compared to the CD cohort. An effect size of zero suggests that at that institution the CD and NSF-funded cohorts are equally likely to enroll in a developmental course.

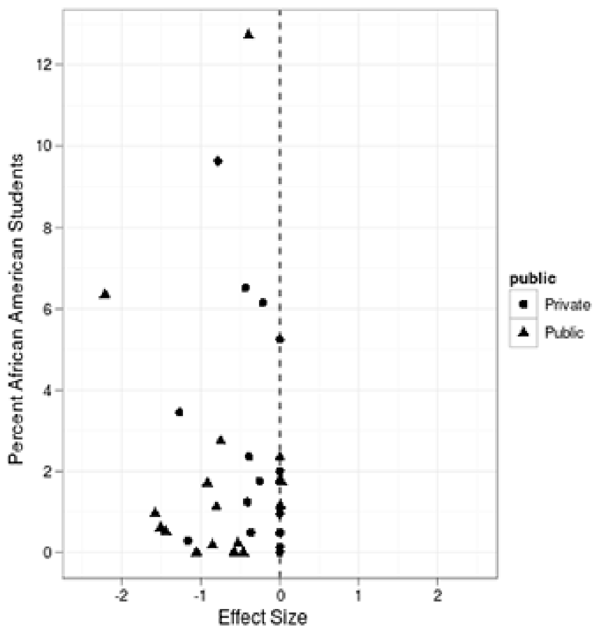
Educational profile, ACT 25th percentile score, and percentages of African American and percentage of STEM majors appeared to weakly moderate the relationship between curriculum and likelihood of taking a developmental mathematics course appearing in Figures 1-5.


School Enrollment
Effect Size
public
Private
Public
35000
30000
25000
20000
15000
10000
5000
-2
-1
0
1
2


Educational Profile
Effect Size
public
Private
Public
3.0
2.5
2.0
1.5
1.0
-2
-1
0
1
2

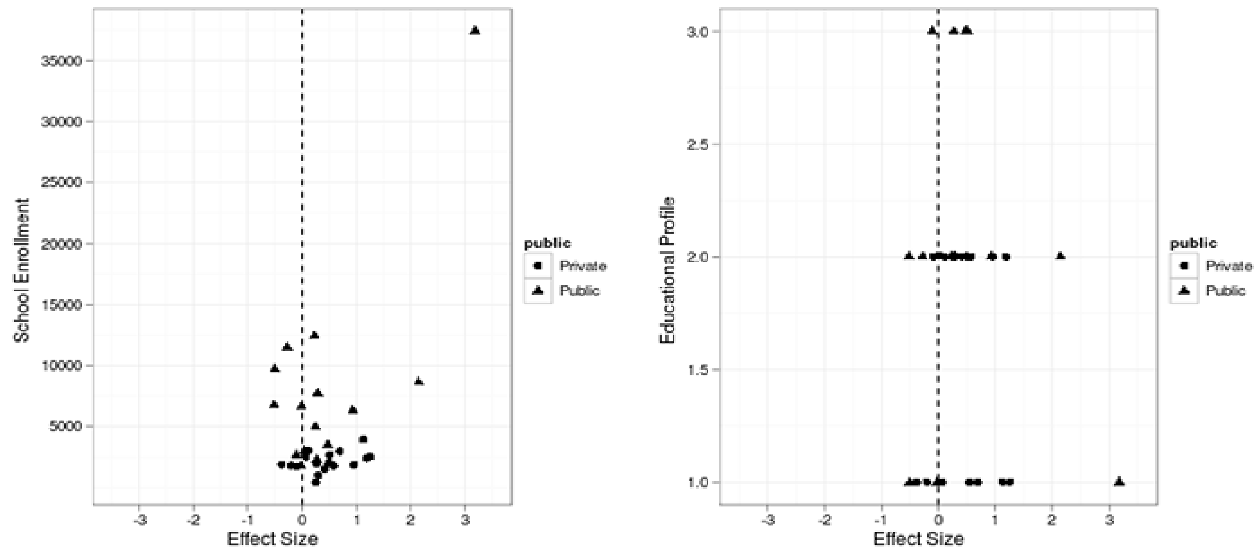

ACT 25th percentile
Effect Size
public
Private
Public

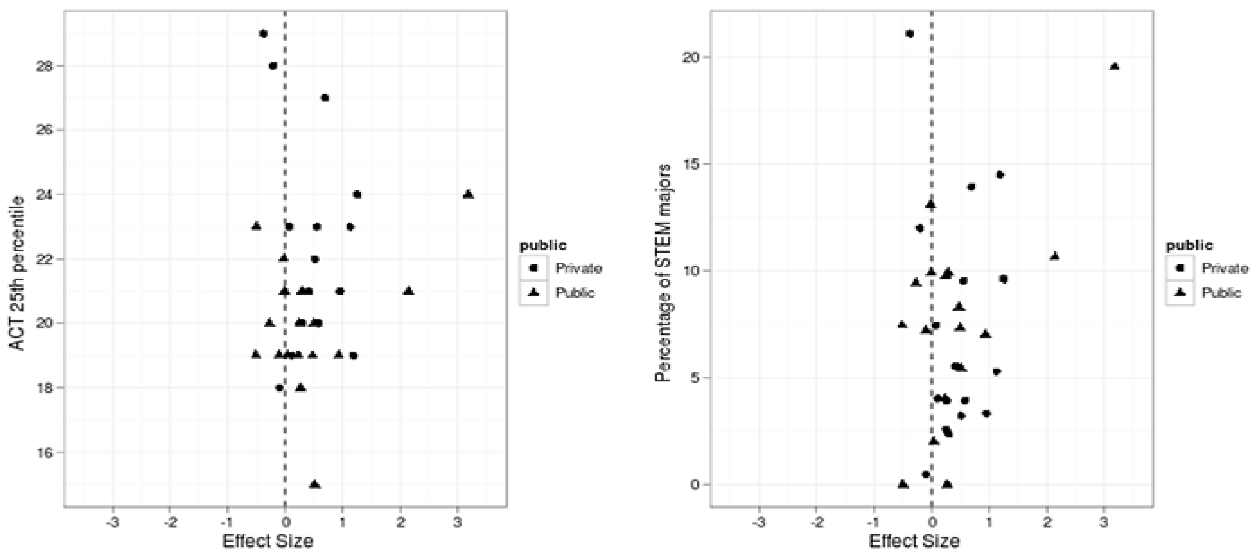

Percentage of STEM majors
Effect Size
public
Private
Public

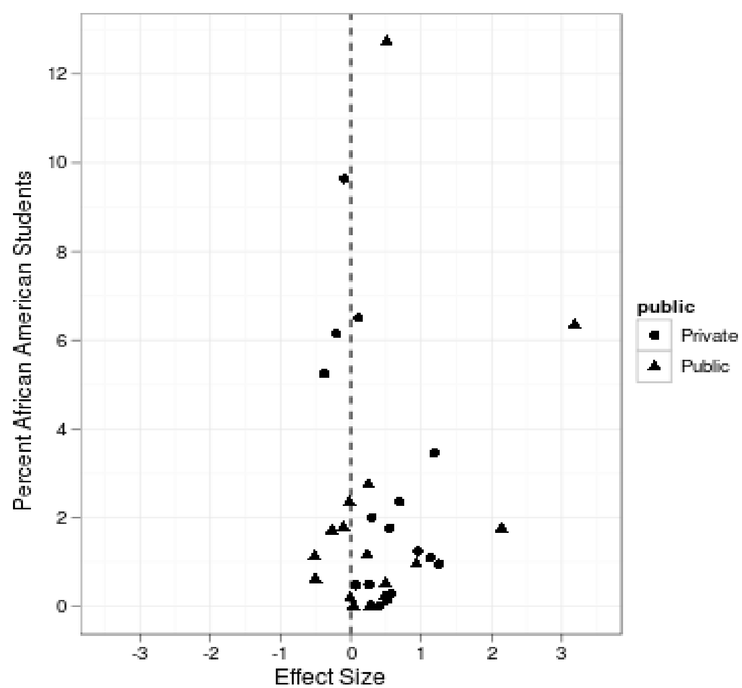


Figures 1-5. Plots of effect sizes reflecting the difference between the CD and NSF-funded cohorts in the likelihood of taking a developmental mathematics course.

Figures 6-10. Plots of effect sizes reflecting the difference between the CD and NSF-funded cohorts in the likelihood of taking calculus I.




ACT 25th percentile
28
26
24
22
20
18
16
-3
-2
-1
0
1
2
3
Effect Size
public
Private
Public
Percentage of STEM majors
20
15
10
5
0
-3
-2
-1
0
1
2
3
Effect Size
public
Private
Public


Percent African American Students
12
10
8
6
4
2
0
-3
-2
-1
0
1
2
3
Effect Size
public
Private
Public

Although enrollment did not appear to moderate this relationship, the institution with the largest enrollment also had the largest effect size, which could be due to factors such as the alignment between mathematics placement tests and high school mathematics curricula or the way that these curricula are used by advisors in recommending a student's first college mathematics course. Effect sizes appeared to increase somewhat for more selective/selective institutions (coded 1) compared to selective/less selective institutions. For higher percentages of STEM majors the effect sizes seemed to move toward zero, which might be expected because the mathematics requirements of many STEM majors results in a sample of mathematically able students for whom high school mathematics curriculum differences on college mathematics outcomes are negligible (Post et al., 2010).

Figures 6-10 reflect the likelihood of completing calculus I in college for the various institutional variables. On average the CD cohort was more likely to complete calculus I especially in institutions with higher concentrations of STEM majors. In general, educational profile seemed to mildly moderate the relationship between curriculum and likelihood of completing calculus I with positive effect sizes for more selective institutions (especially for a few public institutions) and near zero for less selective institutions.

Effect sizes showed an especially interesting pattern for the ACT 25th percentile moderator, with values of 18 -24 generally associated with positive effect sizes favoring the CD cohort. However, for ACT 25^{th} percentile values above 26 the effect sizes are close to zero and for two institutions the NSF-funded cohorts are more likely to complete calculus I. This is likely attributable to increasingly small differences among high school mathematics curricula for college mathematics outcomes for more mathematically proficient students. For quite small percentages of African American students at an institution there was no distinct pattern among effect sizes but for higher percentages the effect sizes centered on zero, with the exception of one public institution with approximately 6% African American students which had a large effect size favoring the NSF-funded cohort.

Similar figures for the average grade in a developmental, college algebra, and calculus I course were constructed. These figures (not reported) suggested that the CD cohort was somewhat more likely to earn higher grades than the NSF-funded cohort and that this pattern was not clearly moderated by any of the institutional factors.

Inferential Analyses

Hierarchical linear models in which the level one model (within institutions) did not have predictors and level two (between institutions) contained predictors reflecting institutional factors were fitted to effect sizes (see (Raudenbush & Bryk, 2002). The statistical shortcomings of proportions led us to transform each proportion using the arcsine transformation and to use the transformed values to compute effect sizes (Cox, 1970). We opted to first fit models to the proportions and then to the transformed values. Because the two sets of findings were very similar we report results for proportions.

Preliminary analyses with no predictors showed significant variation among effect sizes for each outcome. Further examination of the variance of the effect sizes for each outcome indicated medium variation among effect sizes (Hedges & Pigott, 2004), prompting us to construct explanatory models evaluating the presence of moderating effects. However, only a few statistically significant results emerged. One was the percentage of %STEM majors (rescaled to quartiles of the original variable to avoid implausible estimates) whose slope of .07 indicated that a one unit increase (i.e., from the first to the second quartile) was associated with a small expected increase in the likelihood that the NSF-funded cohort would enroll in a developmental mathematics course. Another significant meta-analytic finding was that the CD cohorts were more likely to complete college algebra relative to the NSF-funded cohorts.

Conclusions and Implications

This study sought to identify moderating effects of institutional factors such as educational profile and selectivity on the relationship between high school mathematics curricula and college mathematics course-taking and achievement. Two important findings emerged. First, there was significant variation among effect sizes in the likelihood that the NSF-funded and CD cohorts enroll in developmental mathematics, college algebra, or calculus I courses in college. In our view the result of greatest concern is for the likelihood of enrolling in a developmental course since it suggests differences between the NSF-funded and CD cohorts at the college entry point.

Second, the general lack of a significant relationship between effect sizes and institutional factors for most outcomes suggests that the NSF-funded and CD cohort differences (or lack thereof) generalize to a variety of post-secondary institutions (e.g., more or less selective institutions). More generally, our results suggests that variables reflecting organizational characteristics and climate had on average little or no impact on the relationship between high school mathematics curricula and college mathematics course-taking and achievement.

Implications

We think our findings have two important implications. One is that the absence of significant moderators suggests that the development of policies and practices that promote greater student mathematics learning regardless of the high school mathematics curriculum a student completed will not be informed by institutional selectivity, educational mission, enrollment, etc. For example, the similar enrollment rates in calculus I in college regardless of high school mathematics curriculum suggests that this factor be given less weight in recommending an initial college mathematics course. Put another way, the absence of moderating effects suggests that this issue is not affected by various characteristics of colleges and thus is applicable to a range of institutions. Second, our results suggesting that the relationship between mathematics curricula and college mathematics course-taking and achievement generalizes to a variety of colleges informs curriculum adoption decisions at the high school level for college bound students.

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