The Cost-Effectiveness of an Alternative Approach to Developmental Mathematics Education

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Abstract

Due to low success of traditional, postsecondary remediation mathematics, The Maryland Mathematics Reform Initiative First in the World Grant (MMRI–FITW) sought to develop and implement a statistics pathway as an alternative to traditional algebra-based math, to accelerate developmental mathematics students' progress into credit-bearing postsecondary mathematics courses. In this study, we use cost to students and cost to institutions to estimate the cost per student and assess the cost-effectiveness of MMRI–FITW statistics-based vs. traditional algebra-based approach to developmental mathematics education for increasing student enrollment in college credit-bearing mathematics. The results indicate participating in the MMRI–FITW statistics-based vs. traditional algebra-based approach, reduces education costs by approximately 7 percent and is 36 percent more cost-effective for increasing student enrollment in college-credit mathematics. The article concludes with the implications of the cost-effectiveness results for scaling the MMRI–FITW statistics-based approach to developmental mathematics education.

Keywords: developmental education, community colleges, cost effectiveness, educational policy, higher education, mathematics reform, quasi-experimental analysis.

Background

Earning general education mathematics credits early and performing well in mathematics is a strong predictor of completing a postsecondary degree (Adelman, 2006; Herzog, 2005; Zientek et al., 2020). Yet, almost two in five beginning college students are placed in remedial education (Snyder, De Brey, & Dillow, 2016), with mathematics being the most frequently assessed remedial need (Valentine, Konstantopoulos, & Goldrick-Rab, 2017). Researchers have indicated that remedial mathematics is the single largest academic barrier to increasing overall college graduation rates (Attewell, Lavin, Domina, & Levey, 2006), and in some cases, becomes an insurmountable barrier (Bryk & Treisman, 2010). Trends in U.S. institutions indicate that 30 percent of students referred to developmental education do not even enroll in a remedial course (Bailey, Jeong, & Cho, 2010), and only 50 percent of community college students who take at least one remedial mathematics course finish their mathematics remediation requirements (Chen & Simone, 2016). Results from a meta-analysis of developmental education studies demonstrate that placement in developmental education is associated with significant negative effects on credits earned, achievement in college-level courses, and degree attainment (Valentine, Konstantopoulos, & Goldrick-Rab, 2017).

Over the last two decades, researchers have presented many rationales and arguments for the poor success rates of traditional remedial approaches, including additional time and costs required for degree completion (see Bahr, 2008); psychological barriers, such as math anxiety (see Ma, 1999; Zientek et al., 2010); deferred enrollment in college-level mathematics (Zientek et al., 2018); and insufficient skill development to increase students' rates of college success (Scott-Clayton & Rodriguez, 2012). Nonetheless, extensive student participation in developmental education continues with each developmental course, costing students

approximately $1,500 per course. On average, students pay $3,000 and add $750 in loan debt for two developmental courses (Barry & Dannenberg, 2016). The result is college students in the U.S. pay approximately $1.3 to $1.5 billion for remediation annually (Barry & Dannenberg, 2016; Jimenez, Sargrad, Morales, & Thompson, 2016).

Due to the low success of traditional remediation mathematics in preparing students to succeed in college-level math and attaining degrees (e.g., Boatman & Long, 2018; Valentine et al., 2017) and substantial investments, recent redesign efforts have shifted the conversation toward developmental education approaches (see for example, Rutschow & Mayer, 2018; Whinnery & Pompelia, 2018). Developmental approaches often integrate multiple instructional methods, blending elements of *streamlining,* in which remedial work is condensed or combined with college-level work, and *alignment* in which quantitative requirements are organized around programs of study. For example, replacing algebra-calculus with statistics (Logue, Douglas, & Watanbe-Rose, 2019) for students pursuing social science or humanities credentials. Blending elements of these approaches is *corequisite remediation,* in which students may take college-level courses with academic support in select areas of need. Researchers argue that streamlining and alignment approaches may be more successful for improving students' postsecondary success because placing students in college-level courses that meet general math education requirements may be more motivating, and college-level courses (statistics) may be easier for students to understand because it is more concrete than algebra-based math (Logue, Douglas, & Watanabe-Rose, 2019) and more closely related to the mathematics they will need in their major. In a Randomized Control Trial (RCT), Logue et al. (2016) compared the effects of traditional and corequisite remediation and found a significantly higher pass rate with corequisite than traditional remediation. And, in a follow-up study, Logue, Douglas, and Watanabe-Rose (2019)

found a positive effect of corequisite remediation on graduation rates and concluded that policies requiring corequisite mathematics versus traditional remediation can result in greater student success.

While there are some promising positive effects of developmental education redesign efforts, most research focuses on the effects of developmental education, exclusive of the costs. An exception is Belfield, Jenkins, and Lahr (2016), which examined the cost-effectiveness of the corequisite remediation model as it was implemented across 13 community colleges in Tennessee, and found gains in cost-effectiveness from moving from prerequisite to corequisite remediation on students' rate of college-level gateway course completion. Using administrative interviews (in which respondents identified resources needed to create, implement, and provide prerequisite and corequisite remediation) and IPEDS data, the authors found the estimated cost per three-credit college-level course did not vary much under prerequisite versus corequisite remediation ($1,000 and $1,030, respectively). But the rates of college-level gateway math course completion among students placed in remedial math was 51 percent for the corequisite model compared to 12 percent for the prerequisite model, resulting in a cost per successful student of $3,840 (corequisite model) vs. $7,720 (prerequisite model), an efficiency gain of 50 percent in students' rate of college-level gateway course completion. The authors conducted a sensitivity test and found the findings robust to changes in the cost per course and varied student success rates.

Because traditional approaches to developmental education have not been successful, and because of the high personal and institutional costs of developmental education, it is a critical public policy issue for which policymakers need lower cost alternatives that yield equal or better results.

The Maryland Mathematics Reform Initiative

Statistics-Based Approach to Developmental Mathematics Education

Building on decades of statewide mathematics reform efforts with funds from a Department of Education First in the World (FITW) grant, The Maryland Mathematics Reform Initiative (MMRI) sought to "develop, implement, and evaluate a statistics pathway to accelerate developmental students' progress into credit-bearing postsecondary courses and help more students reach certificate or degree completion effectively and efficiently" (Shapiro, 2016).

Policymakers hypothesized that the MMRI–FITW alternative statistics pathway would be an effective strategy to reduce costs and time associated with taking multiple developmental-level math courses for college credit accumulation and successful completion of a postsecondary degree among students who mostly enroll in programs of study in the social sciences and humanities (Shapiro, 2016) and pursue majors that do not require algebra-based calculus. The aim was to address the "disconnect" between the mathematics content students are taught and the mathematics they need to be successful in social sciences and humanities majors (Shapiro, 2016). Each campus designed its own new developmental math course within guidelines that stipulated that courses focus on algebraic and numerical skills that prepare students for statistics (Morgan, Hall, & Shapiro, 2019; Shapiro, 2016). At most institutions the counterfactual condition, or traditional approach, consisted of a sequence of algebra-based developmental math classes that relied on use of baseline math test scores to decide how many and which courses students should take. (For more information on the MMRI–FITW approach see Feldman et al., [2020]).

Given the rapid influx of new approaches for addressing developmental mathematics education, the field must continue to examine the impact of such efforts. And, information about

the cost-effectiveness of alternatives is critical for policymakers and decisionmakers to make informed decisions about interventions or reforms that may be more efficient for improving outcomes among students who take developmental mathematics courses.

Purpose of This Study

This study addresses the gap in the literature on the cost-effectiveness of alternative approaches to developmental mathematics education. Most of the literature on developmental mathematics education has focused on the effectiveness of such approaches and not the costs (an exception includes Belfield, Jenkins, & Lahr, 2016). While some positive effects of the MMRI–FITW statistics-based approach to developmental mathematics education have been identified on students' passing rates in developmental math courses and enrollment in college, credit-bearing math courses (Feldman et al., 2020), these effects have not been assessed in combination with the cost to assess the cost-effectiveness. This study expands those findings by examining the cost-effectiveness of the MMRI–FITW statistics-based approach vs. the algebra-based traditional approach. CE analysis determines which intervention provides the highest level of effectiveness for a given cost (Levin et al., 2018). Specifically, our question is: Which approach to developmental mathematics education, MMRI–FITW statistics-based or traditional algebra, is more cost-effective for increasing postsecondary students enrollment in credit-bearing math courses?

This type of information is critical to support education agencies' in the adoption of programs, policies, and practices (IES, 2020). While CE analysis does not provide information about the overall worth of an intervention based on overall cost and benefits to society (as the cost-benefit analysis does) it is critical for determining which approach is more efficient in getting students to enroll in credit-bearing mathematics courses. For students, the results of this

CE analysis are useful for deciding which approach to developmental mathematics may be more cost-effective to participate in, to complete college mathematics requirements, and eventually receive a degree. For policy- and decisionmakers, the results of the CE analysis provide information about which approach is more efficient for increasing student enrollment in college-level credit-bearing math courses, which can be used to inform decisions about how to optimize resource allocation across comparable approaches. Ultimately, developmental mathematic education reforms may not be successful if they are not more cost-effective than traditional approaches.

Methodology

This retrospective CE analysis (Levin et al., 2018) compares the cost and effectiveness of the MMRI–FITW statistics-based approach to developmental mathematics education (treatment) with the traditional algebra-based approach (comparison) for increasing students' enrollment in college-level credit-bearing math courses. We compare students who enrolled in the new courses that focused on preparation for statistics (treatment group) with students who enrolled in traditional algebra-based preparation for calculus (comparison group) over four semesters during their enrollment in college-level credit-bearing math courses. To estimate the costs of the MMRI–FITW statistics-based vs. traditional algebra-based approaches, we used two different methods: 1) institutional student expenses (student costs) based on willingness-to-pay, and 2) ingredients method based on opportunity costs (Levin et al., 2018) (institutional costs). The two methods provide cost burden estimates from different perspectives. The institutional student expenses indicate the cost burden to students for participating in the MMRI–FITW statistics-based vs. traditional algebra-based developmental mathematics class. The ingredients method, however, captures the cost burden to the institutions to provide faculty, facilities, and general

overhead costs to implement the MMRI–FITW statistics-based alternative. For the ingredients approach, we conducted the following steps: identified primary program ingredients, priced the ingredients, calculated costs, and conducted a sensitivity analysis (IES, 2020; Levin et al., 2018). For the effectiveness measure, we used impact estimates on student's rates of passing developmental math, and enrollment in credit-bearing math from a previous quasi-experimental design (QED) with a matched sample (Feldman et al., 2020). We discuss the study sample, the approaches to estimating costs, effectiveness estimates, and estimating the cost-effectiveness ratio below.

Sample: Schools and Students

The eight institutions included in the study represent a range of institutions and include five community colleges and three 4-year institutions. The sample contained both large and small institutions, with the largest serving approximately 19,000 undergraduates per year and the smallest serving fewer than 700. The institutions are located in rural, suburban, and city settings. At four of eight participating institutions, non-white students represented at least half of enrolled undergraduates. The study used a QED since students, who participated in the MMRI–FITW statistics-based approach via a new course that focused on preparation for statistics, selected whether to enroll (and were not randomly assigned). Students from the eight institutions were matched on baseline math ability and socioeconomic status resulting in an analytic sample of 2,041 students: 748 treatment students and 1,293 comparison students. This analytic sample was used to generate cost estimates and the main effects. (For more information about the characteristics of the sample, see Feldman et al., 2020.)

Approaches to Estimating Costs

We estimated costs using two methods: 1) student expenses, and 2) the ingredients method (Levin et al., 2018). The two methods estimate the cost burdens to different stakeholders—that is, cost to students and cost to institutions. And, while there is uncertainty in either approach, and both capture different costs, estimating both provides a sensitivity check to assess whether each approach is within a reasonable range of each other (though they capture different costs), and whether the use of one or the other influences the results of the CE analysis. However, both approaches are limited to the extent that they include all possible start-up or marginal costs; for example, the additional costs of institutions transitioning from the traditional algebra-based approach to the MMRI–FITW statistics-based approach. Nonetheless, the approaches are indicative of how costs can be estimated for developmental education alternatives (e.g., Belfield, Jenkins, & Lahr, 2016).

For the student expense approach, we collected 2018-19 student expense data from the Integrated Postsecondary Education Data System (IPEDS) for the eight institutions. The estimated expenses for an academic year included the tuition and fees, and costs of living. For the tuition and fees, given all the institutions had a high percentage (> 70%) of in-state students, we weighted the institution fees by the in- and out-of-state student population for each institution and then averaged the weighted tuition and fees across all institutions. We added the average weighted tuition and fees to the average costs of living estimates across all campuses to estimate the average total student expenses for an academic year. Provided additional information was not available about student's living conditions (e.g., on- or off-campus, living at home), we did not weight these expenses accordingly. To estimate student expenses, we prorated the average total student expenses for an academic year for one 3-credit course, assuming 30 credits over an

academic year. We multiplied this amount by the number of unique attempts of taking the developmental course (using estimates from the impact study) for the treatment and comparison groups to estimate the per-student cost for each group (MMRI–FITW statistics-based vs. traditional algebra-based).

From the ingredients method to estimating costs, we identified and priced key program ingredients, and calculated the cost per student for the MMRI–FITW statistics-based and traditional algebra-based approaches. The primary ingredients were faculty salaries to faculty who provide developmental course instruction, facilities used to provide instruction, and institutional overhead rates. Key parameters used to estimate the costs of the ingredients included average faculty salary, average teaching load, average institution overhead rate, average student enrollment in mathematics courses, average square footage of institutions' classroom, and average faculty/student ratio. To identify the costs of faculty and facilities, we used costs from CostOut® (Hollands et al., 2015), which has a database of U.S. prices for common ingredients of educational programs. We also referenced institutional documents (e.g., student catalogs and faculty workload guidelines, Internal Budget and Operating Plans, and Maryland Community College Space Utilization Report) to estimate student academic loads, faculty workloads, and use of facilities. We used institutional overhead rates for on-campus instruction to estimate an average overhead rate across institutions. Given that the cost model uses the same averages for the parameters listed above for the treatment and comparison group, the cost parameter that varies between the two groups (besides sample size) is the number of unique attempts to pass a developmental mathematics course. Because all else is equal, this cost parameter drives the differences in the cost estimates between the two alternatives.

Effectiveness Estimates

The effectiveness estimates were obtained from an impact study that examined the impact of the MMRI–FITW statistics-based vs. traditional algebra-based approach to developmental mathematics education on students' enrollment rates in college-level credit-bearing math courses (see Feldman et al., 2020 for additional information regarding sample selection, data collection, and creating the matched analytic sample). We used the impact of MMRI–FITW statistics-based approach on student enrollment in a credit-bearing course as the effectiveness measure to calculate the cost-effectiveness ratio. The impact study found that the MMRI–FITW statistics-based approach to developmental mathematics education had a significant, positive effect size of .141 ($p<.001$) on students' enrollment in college-level credit-bearing math (Feldman et al., 2020). The authors found that 49 percent of treatment students enrolled in credit-bearing math, relative to 34 percent of comparison students. This represents a 15 percentage point gain in (adjusted) student enrollment in a college-level credit-bearing math course.

Estimating Cost-Effectiveness Ratio

To conduct the cost-effectiveness analysis, we combined the costs and effectiveness measures into a cost-effectiveness (CE) ratio (Levin et al., 2018) for the MMRI–FITW statistics-based (treatment) and traditional algebra-based (comparison) group. We divided the per-student cost of the MMRI–FITW statistics-based vs. traditional algebra-based approach by the effectiveness measure, that is, the percentage of students enrolling in credit-bearing math. The CE ratio is interpreted as the cost per student that results in a 1 percentage point increase in the percentage of students who enrolled. This metric can also be interpreted as the average cost per successfully enrolled student. The intervention with the lower CE ratio is more cost-effective.

Results

Costs of MMRI–FITW Statistics-Based (Treatment) vs. Traditional Algebra-Based (Comparison) Approaches

The student expenses for the MMRI–FITW statistics-based (treatment) vs. traditional algebra-based (comparison) approaches to developmental mathematics education are displayed in Table 1. The average expenses for course enrollment per student for MMRI–FITW statistics-based (treatment) approach to developmental mathematics education is $2,450 (rounded to the nearest ten) compared to $2,650 for the traditional algebra-based (comparison) approach. The cost per student indicate the MMRI–FITW statistics-based (treatment) approach costs 7 percent less than the traditional algebra-based (comparison) approach. The average number of unique attempts to pass developmental courses was multiplied by the number of students participating in each group to determine the total number of developmental mathematics courses in which students enrolled, which was multiplied by the average expenses per course to estimate the total expenses for courses students enrolled in. The total expenses was divided by the number of students in each group to estimate the average per student expenses for the treatment and comparison group.

Table 1

Student Expenses for MMRI–FITW Statistics-Based and Traditional Algebra-Based Approaches

Group	Number of developmental mathematics courses enrolled in	Average student expenses per course (prorated from the academic year)	Total student expenses for courses enrolled in	Average expenses for courses enrolled in per student
MMRI–FITW statistics-based approach (Treatment, n = 748)	838	$2,190	$1,833,960	$2,450
Traditional algebra-based approach (Comparison, n= 1,293)	1,565	$2,190	$3,424,940	$2,650

Note. The number of developmental courses enrolled in is rounded to the nearest whole number.

Expenses are rounded to the nearest ten. Discrepancies in estimates are due to rounding.

We also used the ingredients method to calculate the cost per student for MMRI–FITW

statistics-based vs. traditional algebra-based approaches. Table 2 displays the cost per student

derived from the total cost of personnel, facilities, and institution overhead used by the MMRI–

FITW statistics-based and traditional algebra-based approaches. Compared to the cost per

student based on student expenses, the cost based on the ingredients method is slightly less (6%)

for the treatment and comparison groups ($2,290 and $2,480 respectively). But, the results are

the same in that the MMRI–FITW statistics-based approach to developmental mathematics

education is 7 percent less expensive than the algebra-based approach (displayed in Table 2).

Though the cost per student estimates based on student expenses and the ingredients method

capture cost burdens to different stakeholders (students vs. institutions), they both fall within the

range provided in the literature on costs of developmental education courses (e.g., $830

[Belfield, Jenkins, & Lahr, 2016] to $3,000 [Barry & Dannenberg, 2016]).

Table 2

Costs of MMRI–FITW Statistics-Based vs. Traditional Algebra-Based Approach to

Developmental Mathematics Education Based on Ingredients Method

| | Costs using Ingredients Method | |
	MMRI–FITW statistics-based approach (Treatment)	Traditional algebra-based approach (Comparison)
Ingredients		
Personnel: Faculty	$755,540	$1,410,990
Facilities: Classrooms	$585,060	$1,092,610
Other: Institution overhead	$375,510	$701,260
Total	$1,7161,10	$3,204,860
Cost per student	$2,290	$2,480

Note. Dollar amounts rounded to the nearest ten. Discrepancies in estimates are due to rounding.

Given the results of the cost-effective analysis are the same using cost per student from

either method (discussed further in the sensitivity of costs section), we proceed with discussing

the CE results using the costs derived from student expenses. This frames the discussion as the

cost to students for the additional effect of MMRI–FITW statistics-based vs. traditional algebra-

based approach on enrollment in college-level credit-bearing math courses.

Cost-Effectiveness of MMRI–FITW Statistics-Based vs. Traditional Algebra-Based

Approach to Developmental Mathematics Education

Overall, we find that the MMRI–FITW statistics-based approach (treatment) is 36 percent

more cost-effective than the traditional algebra-based approach (comparison). Table 3 presents

the cost-effectiveness of the two approaches. Using the analytic sample, 367 of 748 (45%)

students in treatment enrolled in college-level credit-bearing math vs. 440 of 1,293 (34%) in the

comparison group. The total amount of costs allocated to the treatment and comparison group is

approximately $1.83 million and $3.42 million, respectively. Dividing the total cost by the

number of enrolled students provides an average cost of $5,000 (treatment) vs. $7,790

(comparison) for each successfully enrolled student in college-level credit-bearing math. The

MMRI–FITW statistics-based approach requires 36 percent fewer resources than the traditional

algebra-based approach to enable an academically underprepared student to enroll in a college-

level credit-bearing math course. Hence, the MMRI–FITW statistics-based approach to

developmental mathematics education is significantly more cost-effective than the traditional

algebra-based approach.

Table 3

Cost-Effectiveness of MMRI–FITW Statistics-Based vs. Traditional Algebra-Based Approach

Cost-effectiveness components	MMRI–FITW statistics-based approach (Treatment)	Traditional algebra-based approach (Comparison)
Number of participating students	748	1,293
Effectiveness measure: Enrollment rate in credit-bearing math	49%	34%
Number of students who enrolled in college-level credit-bearing math	367	440
Total cost (based on student expenses)	$1,833,960	$3,424,940
CE ratio: Average cost per successful student	$5,000	$7,790
Efficiency gain	+36%	—

Note. Dollar amounts rounded to nearest ten. Discrepancies in estimates are due to rounding.

Sensitivity of Costs

The findings are robust to sensitivity testing in the cost parameters. Since estimating costs

always involves uncertainty and estimates may vary (Briggs et al., 2012), we varied parameters

in the cost model (e.g., average student expenses, average faculty to student ratios, average

faculty salaries, average institutional overhead rates) to assess the implications for the CE ratio. We found efficiency gains from moving to MMRI–FITW statistics-based vs. the traditional algebra-based approach under the different scenarios. While variations in cost parameters in the model do not change the results of the cost-effective analysis, they do demonstrate the possible range in the per-student cost estimates. For example, prorating students' expenses using an academic load of 24-units instead of 30-units, increases the cost per student from $2,190 to $2,740 (a 25% increase). And, in the ingredients method, changing the faculty to student ratio from 1:21 to 1:18 (the average student-to-faculty ratio for public 2-year institutions in 2018 [Condition of Education, 2020]) increases the cost per student for the treatment group from $2,290 to $2,680 [a 17% increase]).

It is also important to note if there were differences between groups on key cost parameters that could affect the cost-effectiveness results. For example, if for any reason, the treatment group had a lower student to faculty ratio than 1:21 that would increase the total cost per student, and would lower the overall cost-effectiveness of the treatment compared to the comparison group. This is true for the cost parameters that would increase total cost (e.g., out of state students, taking fewer than 30 credits, living on campus, or using larger than the average classroom, higher paid faculty). Conversely, if there were differences between groups on cost parameters that lower the costs (e.g., paying in-district fees, living at home, taking more than full academic load, having a higher faculty to student ratio than 1:21, using smaller than the average classroom, or lower paid faculty) for one approach and not the other, that would lower the cost per student and increase the overall cost-effectiveness of the respective approach.

Discussion, Conclusions, and Recommendations

This study provides initial evidence of the cost-effectiveness of the MMRI–FITW statistics-based approach to developmental mathematics education and is intended to help college educators and policymakers think about how to assess alternative approaches for improving students' postsecondary progress. Given budget constraints, decisionmakers often have to consider how to optimize existing resources across a variety of programs or interventions. Cost-effectiveness analysis compares the cost of each alternative along with its impact on an outcome and provides decisionmakers with critical information for making informed decisions about program choices, budgets, and strategies (Hollands & Levin, 2017). This study provides initial evidence that the MMRI–FITW statistics-based approach to developmental education is 36 percent more cost-effective than the traditional algebra-based approach, representing a substantial increase in efficiency and contributing to the literature on the cost-effectiveness of different approaches to developmental mathematics education. Furthermore, the results of this CE analysis indicate that the MMRI–FITW statistics-based approach had a medium effect size (ES = .05 to <.20) and moderate cost ($500 to < $4,000) as indicated in Kraft's (2020) schema for interpretation of cost-effectiveness ratios.

These results also fall within the "reasonable to scale" range (Kraft, 2020, p. 10). The typology provides a way to incorporate scalability into the process of interpreting effects but only provides a high-level assessment. Decisionmakers need to consider whether the costs and effects of the MMRI–FITW statistics-based approach would be similar if it was offered across more institutions to potentially more diverse groups of students. For example, would the fidelity of implementation of the MMRI–FITW statistics-based approach be similar at new institutions (e.g., adoption of course components, staffs' knowledge, and skills regarding new components)?

Do current policies support adoption of the MMRI–FITW statistics-based approach across more institutions? All of these questions need to be considered, in addition to effect size and costs, to address the challenges of scaling the approach.

Some of the sensitivity analysis and limitations of this study are particularly pertinent to the scalability issues raised above. For instance, are cost estimates of the MMRI–FITW statistics-based approach reflective of the costs, if implemented, using different key ingredients? The results of the sensitivity analysis indicate that if there are differences between the groups on key cost parameters, then that can influence MMRI–FITW cost-effectiveness comparisons between the MMRI–FITW statistics-based alternative and the traditional algebra-based approach. For example, if the new approach is implemented with a lower student-to-faculty ratio, then that would substantially increase the cost and reduce the cost-effectiveness of the statistics-based approach. While this CE analysis is limited to enrollment in a college-level credit-bearing math course, given that the per student cost is less for the MMRI–FITW statistics-based approach, even if there is no long-term effect on student graduation (i.e., graduation rates between groups are equal), the statistics-based alternative would still be more cost-effective than the traditional algebra-based approach—given it costs less to achieve the same outcome.

As promising developmental mathematics reforms continue to be implemented across the nation, it will be critical to assess their effectiveness along with the relative cost of reforms to assess whether interventions are providing a higher level of effectiveness for a given cost. The results of this study suggest that alternative approaches to developmental mathematics education may yield significant increases in efficiency. Given the substantial investment in developmental education (Barry & Dannenberg, 2016), using results from CE analysis to allocate these

resources more efficiently could save millions of dollars and significantly improve students'

post-secondary success with the dollars invested.

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