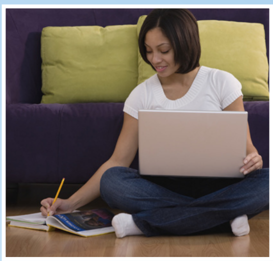
Some Economic Consequences of Improving Mathematics Performance

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Some Economic Consequences of Improving Mathematics Performance

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Some Economic Consequences of Improving Mathematics Performance

Improved mathematics achievement would likely raise high school completion rates substantially, and with especially strong impacts for lower socioeconomic groups and most minorities.

Summary

In this report, we examine how improving mathematics performance has economic consequences through raising high school graduation rates. We investigate the link between higher mathematics achievement in school and subsequent human capital and labor market outcomes. We then predict the effect of improving math skills in grades 8 and 10 on the yield of high school graduates per age cohort. Improved mathematics achievement would most likely raise high school completion rates substantially, with especially strong impacts for lower socioeconomic groups and most minorities.

We then present the lifetime economic consequences from a higher yield of high school graduates. In particular, we reviewed the impact on income and tax revenues, social productivity, and reductions in the costs of public health, crime, and public assistance. These lifetime consequences are calculated as gains to the individual students (private), as gains to the taxpayer (fiscal), and as gains to society (social). We simulate the total magnitude of these economic benefits if mathematics achievement in the U.S. were raised to equal that of other developed countries in the OECD, Canada, and a high performer, Finland.

Finally, we review the evidence on interventions that have demonstrated effectiveness in improving mathematics achievement in high schools and middle schools. Although this evidence is somewhat sparse, we identify several effective interventions and estimate their costs. Given the substantial economic benefits from raising mathematics skills in high school, these interventions have very high benefit-cost ratios.

1. Introduction

A series of recent publications depict a bleak nexus of poor education and declining economic outcomes across the U.S. population (Kirsch, Braun, & Yamamoto, 2007). New demographic forces – racial and ethnic diversification, a large foreign-born population, and the concentration of minority students in inner-city schools – will adversely affect educational outcomes (Tienda & Alon, 2007). Soon, the U.S. labor force will reflect this new demography. If we project this demography and its past educational performance into the future, we can anticipate a workforce with a declining average educational attainment relative to the present. In U.S. secondary schools, education levels are already stagnant and perhaps declining: After a century of growth, the high school graduation rate peaked at just under 80% by 1970; since then, it has trended downward toward 70% (Goldin & Katz, 2008, Figure 9.2; Heckman & LaFontaine, 2008). The college completion rate is also weaker. Although the college enrollment rate of high school graduates has risen since 1980, the time needed to complete college has also lengthened; the 5-year college graduation rate has remained static (Turner, 2007).

After a century of advantage, the rest of the world is catching up with the United States. On the basis of past educational performance, the United States leads the world in the proportion of the population aged 55-64 with a secondary school education. But for the younger population, aged 25-34, the proportions are already higher in Switzerland, Norway, Canada, Sweden, Japan, and Finland and much closer to the United States in all other countries in the Organization for Economic Co-operation and Development (OECD), (see Goldin & Katz, 2008, Figure 9.1). A comparison of current graduation rates for high school-age students is even more ominous: As of 2007, the United States was 14th among OECD countries in terms of high school graduation rates and 10 percentage points behind the OECD average of 82% (www.data360.org). Given the greater variability in high school completion requirements in the United States relative to other OECD countries, this quantitative difference may understate the substantial differences in favor of other nations.

The prognosis for future American students is not promising. To compound the challenge of securing an adequate supply of skilled workers, recent evidence indicates that the demand for skilled workers keeps growing (Autor, Katz, & Kearney, 2008). In his analysis of higher education in the United States, Bailey (2007, p. 92) concluded that "occupational forecasts, analyses of job content, trends in wages, and changes in international competition all point to an increasing need…for workers with high-level skills." In their analysis of tasks performed at work, Levy and Murnane (2004) charted the growth of "complex communication" and "expert thinking" tasks and the decline of routine cognitive and routine manual tasks. The relative supply shortage of workers with these skills and high demand are part of the explanation for widening economic inequality in the United States.

Thus, the need for further educational investments is pressing. At issue is what form those investments should take. Below, we outline the case for improving science, technology, engineering, and math (STEM) teaching and learning. This case is strong in part because existing investments appear inadequate. According to the 2005 National Academy of Sciences Committee on Prospering in the Global Economy of the 21st Century in their report *Rising above the Gathering Storm*, 68% of 8th graders receive mathematics instruction from a teacher who does not have either a degree or certification in math; the respective percentage for instruction in physical sciences is 93%. Nationally, fewer than one-third of 4th- and 8th-graders are proficient in math. Even for students taking a core mathematics curriculum, only half meet the ACT college readiness benchmark. At the college level, only 15% of undergraduate degrees are in natural sciences or engineering, and one-third of engineering majors switch to an alternative major. Over one-third of doctoral degrees in natural sciences awarded in the United States are obtained by foreign-born students. For engineering, the figure is over half.

In this paper, we focus on a key component of the STEM disciplines: mathematics skills at the elementary and secondary school level. Without adequate preparation of high school students in math, college-level reforms (in any STEM discipline) are unlikely to be successful. We begin by describing how mathematics skills in elementary and secondary school translate into attainment levels and college preparedness. Then we consider how improvements in mathematics skills translate into improved economic outcomes, such as earnings and labor market participation. We also review how other STEM subjects (studied in college) influence earnings. Our argument is straightforward: Mathematics skills are a very strong predictor of high school graduation, which in turn has a very clear relationship to adult economic well-being regardless of college major or occupation. Thus, raising math scores is a way to raise economic output independent of metrics such as the number of scientists or engineers. Next, we discuss K-12 mathematics programs with proven effectiveness and estimate the costs of these programs; then we compare the costs with the benefits to calculate a benefit–cost ratio.

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2. The Economic Importance of Mathematics Skills

Several strands of research emphasize the importance of raising mathematics (and science) skills. Research has examined how mathematics skills influence subsequent human capital (proxied by achievement and high school completion) and economic outcomes, such as earnings and growth in GDP. Most of the concern about improving mathematics performance of K-12 students centers on the importance of mathematics in determining labor force productivity and earnings as well as in preparing the young for postsecondary study and for scientific and technical careers. A comprehensive statement expressing this concern is *Rising Above the Gathering Storm,* the 2007 Report by the National Academy of Sciences.

In this paper, we emphasize a somewhat different aspect that can also provide a large economic payoff – the contribution of mathematics achievement to improving the prospects of high school completion. It is well known that high school graduates have far better economic prospects than high school dropouts as well as the possibility to undertake and succeed in postsecondary education. However, the role of mathematics achievement on high school completion has not been fully assessed as a path in itself for improving economic outcomes. This paper attempts to show the magnitude of this path as well as to assess its return on investment.

2.1 Mathematics skills and human capital accumulation

Early mathematics skills are a strong foundation for later achievement, not only in mathematics but across other subjects. Duncan et al. (2007) comprehensively studied the relationship between school-entry mathematics skills and subsequent achievement using six longitudinal datasets from three countries. Mathematics skills at school entry are strong predictors of later achievement as far as age 13. The effect size of early mathematics skills on subsequent mathematics skills is .34. Reading skills also exhibit a positive effect on later achievement. But early mathematics skills have more than double the effect on later achievement compared with early reading skills, and in fact school-entry mathematics performs as well as school-entry reading in predicting later reading achievement. Notably, other early indicators are much weaker at predicting later achievement; Duncan et al. (2007, p. 1437) found only "moderate predictive power for attention skills, and few to no statistically significant coefficients on socioemotional behaviors." Improving early mathematics should therefore have a strong payoff for all skills.

For high school students, recent research highlights the importance of course-taking sequences in mathematics on graduation. On the basis of the Education Longitudinal Study (ELS) of 2002, mathematics skills are highly correlated with graduation. Only 52% of the students who take no mathematics graduate from high school, only 61% of those who take basic mathematics graduate, and almost every single student who takes calculus graduates from high school (Bozick & Lauff, 2007). High school grades have a similarly powerful effect: 82% of students who do not score any Fs in mathematics graduate, but only 22% of students who score at least one F graduate. Further each failed course reduces the probability of graduating by 15 percentage points (Allensworth & Easton, 2007).

A number of microeconomic studies have revealed how test scores relate to graduation rates, controlling for individual and school-related characteristics.[1] Most studies use the data from the National Education Longitudinal Study of 1988 (NELS-88) and so focus on secondary school test scores (8th or 10th grade). The results are consistent. Lee and Burkam (2003) reported that a 1 standard deviation increase in math grade point average (GPA) reduces the odds of dropping out by 32% (although after controlling for potentially causal factors such as school characteristics and socioeconomic status, the effect is no longer statistically significant). Rumberger and Larsen (1998, Table 5) found that a 1 standard deviation increase in eighth grade (reading and mathematics composite) test scores reduces the probability of not graduating by 48%. So, if the initial dropout rate were 20%, the new rate would be 11% (see also Zvoch, 2006). However, within this overall relationship there is substantial subgroup heterogeneity by gender, socioeconomic status, and ethnicity.

2.2 Mathematics skills and high school graduation

To investigate subgroup differences in high school mathematics scores on graduation, we estimated the impact of mathematics scores on graduation rates using NELS-88 and ELS-2002. Unfortunately, both datasets have dropout rates significantly below nationally reported rates (in part because some GED students may self-report as graduates). Therefore, the reported impacts of test scores are probably conservative. Although the ELS is more recent, it does not have information before 10th grade and many students have already dropped out by then. Therefore, we focus on the results from NELS, with the complementary results from the ELS included in the Appendix.

Across the two datasets, the specifications are intended to be complementary, with differences reflecting grade levels and the variables available in each dataset. Four models were estimated, with control variables added cumulatively. Model 1 includes only gender and ethnicity covariates; added in Model 2 are peer characteristics (e.g., percentage of students receiving a free school lunch); added in Model 3 are individual family background measures; and added in Model 4 are baseline reading test scores. Separate estimations were performed by achievement quartile and by gender and ethnicity. For ease of interpretation, we report the percentage change in the dropout rate and the "yield" of new high school graduates assuming that math scores are increased by 1 standard deviation.[2] For NELS, the results are reported in Tables 1 and 2; corresponding results

1 Advanced math in high school is also strongly associated with completion of college, with an impact even greater than high school GPA and socioeconomic status (Adelman, 1999).

2 Math scores were standardized across the entire sample with a mean of zero and standard deviation of 1. Then a 1 standard deviation change in math scores was calculated for each subsample separately. For example, the white female subsample mean standardized math score was 0.3, so we set that math score 1 standard deviation higher, at 1.3.

…a one standard deviation increase in math scores would reduce the dropout rate by 70%, with a yield of 9.7 extra high school graduates per 100 students.

using ELS are in Tables A1 and A2. A full set of comparable estimates were made for reading (Tables A3-A6).

Looking across all four tables, math scores in 8th or 10th grade have a very significant impact on the probability of dropping out. The odds ratios (not reported here) are extremely high, in some cases almost 5. Indeed, for the full samples an increase of 1 standard deviation in mathematics scores has a larger effect than a 1 standard deviation increase in socioeconomic status. The conclusions are consistent whether we consider the NELS or ELS. The main difference is that the coefficients using the ELS are smaller, reflecting the fact that the dropout rate conditional on 10th grade attendance is much lower than that conditional on 8th grade attendance. It is also important to note that we are considering only the yield in terms of new graduates, not the impact on all students from higher mathematics scores regardless of whether they would graduate or not.

The first column of Table 1 presents effects for the full sample of 13,263 students. For the very simple specification in Model 1, a 1 standard deviation increase in eighth grade mathematics scores would reduce the dropout rate by 75%. This translates into 10.4 additional high school graduates per 100 students. Adding control variables reduces the impact of math skills, but not by much. In Model 4, which includes gender, ethnicity, school characteristics, family background information, and reading scores, a 1 standard deviation increase in math scores would reduce the dropout rate by 70%, with a yield of 9.7 extra high school graduates per 100 students.

The next four columns of Table 1 show the impacts split according to eighth grade math achievement quartiles. Looking at Model 4, we see evidence of a large difference between low- and high- achievement students. For students in the bottom quartile, a 1 standard deviation increase in math scores would reduce the dropout rate by 60%; this would yield 17.5 new high school graduates. For students in the second quartile, a 1 standard deviation increase in math scores would also reduce the dropout rate by 60%, yielding 9.7 new high school graduates. Raising math scores by 1 standard deviation for students who are below the median in math has a much more powerful effect than for students who are above the median. For students in the top two quartiles in eighth grade math, the fall in the dropout rate is not as large (39% and 58%), and the yield of new high school graduates is significantly smaller (2.9 and 1.5 new graduates) because there are far fewer dropouts from these quartiles and the effect of improved mathematics achievement is smaller.

Table 2 indicates the effects by gender and ethnicity. The impacts vary, as do the consequences in terms of yield of new high school graduates. As shown in Model 4, the smallest effect is for black males. The dropout rate falls by only 48%, but because of the high proportion of black male dropouts, the yield is relatively high at 9.1 new graduates. In contrast, the impact of raising math scores is highest for white females. It reduces the dropout rate by 74%, but the yield is relatively low, at 8.9 new graduates. Yields are particularly high for Hispanic males (13.7) and for black and Hispanic females (12.3 and 12.1, respectively).

Table 1. Percentage change in the dropout rate [extra graduates per hundred students] from a 1 standard deviation increase in math scores,by eighth grade math achievement

	Full sample	Sample split by eighth grade math achievement quartiles			
		First quartile (lowest)	Second quartile	Third quartile	Fourth quartile (highest)
Math score					
Model 1	-75	-74	-64	-45	-53
	[10.4]	[21.5]	[10.4]	[3.4]	[1.4]
Model 2	-75	-72	-64	-43	-60
	[10.4]	[21.0]	[10.4]	[3.2]	[1.6]
Model 3	-73	-70	-60	-42	-57
	[10.1]	[20.2]	[9.7]	[3.1]	[1.5]
Model 4	-70	-60	-60	-39	-58
	[9.7]	[17.5]	[9.7]	[2.9]	[1.5]
Dropout rate	15.2	28.9	16.2	7.4	2.6
Observations	*13,263*	*3,316*	*3,292*	*3,324*	*3,321*

Source: National Educational Longitudinal Survey, 1988-1994.
Notes: Percentage figure is the change in the dropout rate. The figure in square brackets is the increase in the number of high school graduates. Adjusted means based on logistic models for graduation (1,0) with all other variables set at the mean value. Model 1 controls for: gender, ethnicity. Model 2 controls for: Model 1 and free-school lunch populations, minority status, public school, urban school, and whether the school is dangerous or disruptive. Model 3 controls for: Model 2 and SES, mother's education. Model 4 controls for: Model 3 and 8th grade reading score.

Table 2. Percentage change in the dropout rate [extra graduates per hundred students] from a 1 standard deviation increase in math scores for eighth grade students, by gender and ethnicity

	Male			Female		
	Black	Hispanic	White	Black	Hispanic	White
Math score						
Model 1	-65	-70	-64	-78	-66	-77
	[12.7]	[14.2]	[7.5]	[13.8]	[14.6]	[9.2]
Model 2	-65	-71	-64	-78	-67	-78
	[12.7]	[14.5]	[7.6]	[13.8]	[14.8]	[9.3]
Model 3	-62	-71	-64	-77	-65	-75
	[12.0]	[14.4]	[7.6]	[13.8]	[14.3]	[9.0]
Model 4	-48	-67	-63	-69	-55	-74
	[9.1]	[13.7]	[7.4]	[12.3]	[12.1]	[8.9]
Dropout rate	20.4	20.9	12.0	17.2	22.3	14.9
Observations	*639*	*822*	*4,951*	*749*	*928*	*5,197*

Source: National Educational Longitudinal Survey, 1988-1994.
Notes: Percentage figure is the change in the dropout rate. The figure in square brackets is the increase in the number of high school graduates. Adjusted means based on logistic models for graduation (1,0) with all other variables set at the mean value. Model 1 controls for: gender, ethnicity. Model 2 controls for: Model 1 and free-school lunch populations, minority status, public school, urban school, and whether the school is dangerous or disruptive. Model 3 controls for: Model 2 and SES, mother's education. Model 4 controls for: Model 3 and 8th grade reading score.

Gains in math can improve economic outcomes in three ways: raising productivity through higher educational attainment, higher productivity at each level of attainment and a positive interaction between the two…

Similar results are seen with the ELS data. For model 4, the decline in the dropout rate is 54%, with a yield of 4 new high school graduates per 100 students (Table A1). Again, the impacts are much greater for students in the bottom quartiles of math achievement: yields are 3.5 and 6.3, whereas yields for the top two quartiles are 1 and 0.7, respectively. Heterogeneity by gender and ethnicity is also evident (Table A2). Specifically, improvements in math in Model 4 have the strongest impact on the dropout rates of white females (-62%), especially compared with those of black males (47%).

These NELS and ELS results may be contrasted with our parallel estimates for reading, as reported in Appendix A3–A6. The NELS data illustrate the greater significance of math over reading. Comparing the results from Model 4 in Table 1 and Table A3, an effect size gain in math reduces the dropout rate by 70%, with a yield of 9.7; an equivalent gain in reading reduces the dropout rate by 47%, with a yield of 6.5. For the bottom quartile, math gains are associated with a 60% fall in the dropout rate and a yield of 17.5; the respective figures for reading are 34% and 9.1. The primacy of math gains over reading gains is also evident in Tables A2 and A4, which show that only for one subgroup – black males – is the yield higher from raising reading scores by 1 standard deviation (12.1 versus 6.6). For the other five subgroups, math scores have a much greater impact than reading, with a yield that translates into 2 to 3 more high school graduates. The same conclusions can be drawn using ELS data. The effect size yield for math is 4 (Table A1) whereas the effect size yield in reading is 2.9 (Table A5). Again, the yield differences are much greater for students in the bottom two quartiles.

Overall, both absolutely and relatively effect size gains in math would reduce the high school dropout rate. The yield of new high school graduates – leaving aside the consequences for students who would graduate regardless – is between 10 (NELS, eighth grade) and 4 (ELS, 10th grade). If math interventions were targeted to students below the median, the effect size yield would be between 14 and 5. These yields are likely to generate significant economic gains.

2.3 Mathematics skills and economic outcomes

Gains in math can improve economic outcomes in three ways: raising productivity through higher educational attainment, raising productivity at each level of attainment, and producing a positive interaction when the economic impact of higher math achievement rises with each level of attainment. Separating these effects is particularly challenging (Heckman, Stixrud, & Urzua, 2006).

Unambiguously, the effect of math skills on earnings is both absolutely and relatively powerful. Using the National Longitudinal Survey of Youth, Blackburn (2004) found that the mathematics subtests of the Armed Forces Qualification Tests (AFQT) administered to teenagers have the strongest correlation with later earnings. A 1 standard deviation increase in the numerical operations score increases wages by 2.8%. Using High School and Beyond data, Rose and Betts (2004) estimated the effects of each mathematics course separately. Progressively stronger impacts were evident for more advanced math, with calculus credits having a very strong influence on earnings. Staying in school for an extra year but with a course load with no math adds only 2% to earnings; if the extra year includes calculus in the course load, earnings are 9% higher (Rose & Betts, 2004, Table 4).

But the magnitude of the gain from higher achievement is open to debate. Test score advantages in elementary school do not perfectly correlate with advantages by graduation, and these advantages are not uniform for each year of schooling. Also, models vary in how they control for attainment. Indeed, most recent estimates by Rose (2006) using NELS-88 show a mixed picture that reflects the heterogeneity of test scores on graduation probabilities. Improved high school math scores have almost no effect on male earnings, but females obtain a 9% advantage where test scores are 1 standard deviation higher. Rose (2006, Table 5) also reported significantly higher earnings as math scores of those in the bottom quartile of ability improve, with weaker gains for those with greater math skills. For females, there are strong effects on labor market participation as well as earnings. Hanushek (2006) argued that the impact of higher math achievement is greater, reporting four estimates suggesting that the earnings premium from a 1 standard deviation increase in test scores is 12%. However, approximately half these gains may be attributable to additional attainment associated with the higher math scores rather than the math scores themselves. Finally, recent estimates by Goodman (2008) show that higher math requirements for black males can explain almost the entire wage premium from a year of additional schooling.

In addition, college math credits – and engineering credits – have a significant impact on earnings relative to other subjects taken by college graduates (Thomas & Zhang, 2005). The effects even apply for those already in the workforce. From community college transcripts of displaced workers, Jacobson, LaLonde, and Sullivan (2005) calculated that a year of "more technically oriented vocational and academic math and science courses" raises earnings by 14% for males and 29% for females. In contrast, less technically oriented courses yield no payoff.

Earnings gains are only a fraction of the full returns to individuals from higher math skills. A number of studies have identified both monetary and non-monetary advantages from being more highly educated (for examples, see Wolfe & Zuvekas, 1997; for the range of powerful health-related effects, see Cutler & Lleras-Muney, 2006). The link between these non-monetary advantages and math skills per se has not been researched. But mediated through differences in either attainment or earnings, these other advantages should also be counted as the effect of higher math skills.

The strong influence of math and science across the U.S. economy is evident from an inventory of technological change over the last century (National Academy of Sciences, 2005, Chapter 2). This influence includes innovations and inventions related to infrastructure (e.g., water supply and distribution), transport (automotive, aeronautics, highways, aerospace), communications (telephony, television, internet), energy power (nuclear technology), health systems (imaging, laser optics, surgical technologies), and information processing (computers, semiconductors). The consequences have been improved infrastructure, higher productivity, disease reduction, greater product development, and more effective environmental protection. All these factors have played a role in the rapid growth in economic well-being over the last century.

Finally, international studies found that math and science scores are important for economic growth. Hanushek and Kimko (2000) found relatively large effects, such that a "one standard deviation increase in math and science skills translates into more than one percentage point in average annual real growth." This growth effect may incorporate not only direct increases in incomes, but also higher productivity in other economic and social domains. This empirical estimate is probably overstated, in part because cross-country regressions were prone to aggregation bias. Similarly large effects were found by Hanushek and Woessmann (2007), who also concluded that schooling attainment is less important than cognitive skills.

Even with some imprecision over the absolute effect of cognitive skills and some debate over the relative importance of educational quality and quantity, the collected evidence nevertheless suggests an important role for math and science skills in raising economic output.

3. The Economic Benefits of Higher Math Skills

…each additional male expected high school graduate will earn from $190,000 to $333,000 more than a dropout (net of all taxes), depending on race; for each female expected high school graduate the net earnings gain ranges from $90,000 to $172,000.

To calculate the lifetime economic consequences of enhanced math skills, we focused on five domains: labor market outcomes, tax payments, health status, criminal activity, and welfare receipt. Education is influential in each domain, with consequences for private individuals, for taxpayers, and for society.

For high school graduates, these influences have been well documented by Belfield and Levin (2007). We adapted their estimates of lifetime present value economic benefits at age 20 for an "expected" high school graduate.[3] The adapted estimates are in Tables A7 and A8. All figures are expressed in 2006 dollars. We briefly summarize the method before describing the economic benefits from a greater yield of high school graduates.

People with higher levels of education earn more and therefore pay more taxes. Accepted findings are that education causes higher earnings (rather than simply being correlated with them, see Rouse, (2007). Those with more education work more hours, have more stable employment, are employed in jobs with more generous benefits, and earn more. To calculate the gains in earnings from high school graduation we used earnings data from the Current Population Survey (CPS).[4]

3.1 Labor Market Outcomes

Cross-sectional CPS data reveals the extent of the labor force advantages for those with more education. Only one in three dropouts are employed, half the rate of those who have graduated from high school. Whereas one in seven dropouts who are working have health insurance, the rate is one in two for graduates and the college bound. Annual earnings are at least three times higher for high school graduates and five times higher for persons with at least some college education. These annual differences persist over the life course, leading to significant lifetime advantages for high school graduates.[5] Expressed as present values at age 20, earnings of each additional male expected high school graduate will be $190,000 to $333,000 more than those of a dropout (net of all taxes) depending on race; for each female expected high school graduate, the net earnings gain ranges from $90,000 to $172,000.

3 An expected high school graduate is a high school graduate for whom the probability of college enrollment is also incorporated. College enrollment and completion rates for additional high school graduates are based on the current rates for students in the bottom quartile of high school achievement.

4 The CPS is the best available data, but it is not perfect. First, it does not count people in prison. We adjusted for differences in incarceration rates by sex and race (although this adjustment does not substantially influence the results). Also, we could not separately identify persons with GEDs from high school graduates in the CPS. The evidence suggests that GED-holders experience considerably poorer success in labor markets in comparison with high school graduates (Cameron & Heckman, 1993). Finally, the CPS undersurveys high school dropouts. This, too, introduces a conservative bias because these excluded persons are likely to have lower incomes.

5 Lifetime incomes are calculated on the basis of the following assumptions: the current distribution of incomes persists for this cohort as it ages, productivity grows by 1.5% per annum, all individuals retire at age 65, and individuals discount future incomes at a rate of 3.5% per annum.

3.2 Tax Payments

The income gains for graduates are used to estimate the amount of extra tax they pay. To estimate the income tax payments we applied the TAXSIM model (version 8) developed by the National Bureau of Economic Research. TAXSIM simulates an individual's U.S. federal and state income taxes (excluding rents or expenses). We followed the same method as for the earnings gains. Specifically, we estimated total lifetime tax contributions by education level, then calculated the extra payments over dropouts, and finally combined these to estimate the extra payment per expected high school dropout. Additional federal income tax payments range between about $74,000 and $131,000 for males and $39,000 to $68,000 for females across racial groups. Differences in state income tax payments range up to $45,000 for males and $23,000 for females.[6]

3.3 Health Status

More education is associated with changes in health behaviors and better health.[7] These health gains have benefits at the individual level, but they also reduce fiscal pressure on government-supported health programs. Specifically, Medicaid eligibility is means tested, so increased education – simply through its positive effect on earnings – lowers eligibility for and enrollment in Medicaid. Whereas 15% of white male dropouts are enrolled in Medicaid, the rate is 5% for high school graduates, 3% for those with some college, and less than 1% for college graduates. The effects are even stronger for groups who enroll at high rates. For example, 51% of African American female dropouts are on Medicaid, compared with 22% of high school graduates and 3% of college graduates.

Medicare coverage rates are similarly stratified by education level. Medicare is available for persons under 65 who qualify for social security disability income (SSDI), and receipt of SSDI is more common among dropouts. Annually, 8% of dropouts are covered, compared with 4% of high school graduates and 1% of those with a college degree.

Therefore, raising the rate of high school graduation should reduce public expenditures on health programs. We adapted estimates calculated by Rouse (2007). Federal savings on health expenditures for each additional high school graduate are on average $29,050; state savings are only slightly higher, at $29,200.

3.4 Criminal Activity

People with less education are more likely to be involved in criminal activity and are disproportionately represented in the state prison system. The causal effect of education is twofold: Education directly reduces criminal behavior and, because it is associated with higher incomes, indirectly reduces the incentive to commit crime (Farrington, 2003). Using Census and FBI data Lochner and Moretti (2004) identified the causal effect of becoming a high school graduate: Graduation reduces murder, rape, and violent crime by 20%; property crime by 11%; and drug-related offenses by 12%. The effects are stronger for males and vary by race but are evident across all subgroups.

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6 Additional payments in state sales and excise taxes were not included in the analysis.

7 In an extensive review, Cutler and Lleras-Muney (2006) found education to be strongly negatively associated with diagnoses of a range of conditions (including heart conditions, strokes, hypertension, high cholesterol, and diabetes as well as depression and smoking).

The economic consequences of crime are substantial, both to victims and to the taxpayer. Victims bear large direct costs in lost property, impaired quality of life, insurance, and avoidance behaviors (Anderson, 1999). Taxpayer costs include the criminal justice system, corrections, and crime prevention agencies as well as restitution for victims, publicly provided medical care, and lost tax revenues from lower victims' earnings. Nationally, Ludwig (2006) estimated a total cost of crime at more than $2 trillion dollars, equivalent to 17% of annual GDP. A large fraction of crime is committed by young adults, so that the costs of crime are incurred almost immediately after an individual leaves school.

Applying the estimates from Lochner and Moretti (2004), along with corresponding effects on months of incarceration and months of parole, we calculated the state/local and federal savings per high school graduate. The federal savings are significant, ranging from $13,000 to $16,510 for males and approximately $3,500 for females. Even larger savings are accrued by states, reflecting the larger amount of spending at the state and local level on criminal justice system services. These savings average $10,300 at the federal level and $21,260 at the state level per new high school graduate. There are significant differences in gender and ethnicity, with females imposing a considerably smaller burden than males.

3.5 Welfare Receipt

Finally, greater educational attainment is associated with lower receipt of public assistance payments or subsidies (Grogger, 2004; Waldfogel et al., 2007). Education directly reduces the probability of attributes and characteristics that raise welfare eligibility, such as single motherhood. Education also raises incomes, which in turn reduces eligibility for means-tested programs. National data indicate that receipt of Temporary Assistance for Needy Families (TANF) cash assistance, housing assistance, and food stamps is strongly correlated with low education (Barrett & Poikolainen, 2006; Rank & Hirschl, 2005). Less than 4% of TANF recipients and less than 2% of housing assistance welfare recipients have some college education, and more than two-thirds of all high school dropouts will use food stamps during their working life. Using the CPS, Waldfogel et al. (2007) estimated welfare receipt by education level, controlling for other factors. Relative to a high school dropout, a graduate is 40% less likely and a college graduate is 62% less likely to receive TANF. Similarly, high school graduates are 1% less likely, and college graduates are 35% less likely, to receive housing assistance. For food stamps, the respective probabilities are 19% and 54% lower (Rank & Hirschl, 2005).

The largest proportion of the public assistance savings per high school graduate comes from reductions in TANF payments, although there are nontrivial savings in housing assistance and food stamps as well. Savings for male dropouts are approximately $2,000, but for female dropouts they are at least double. Federal savings are on average $3,800 per graduate, and state savings are about $3,700.[8]

8 Compared with the other domains, these total figures are low. Welfare is time-limited and children and the elderly are primary beneficiaries; males do not receive much welfare (but they are a large proportion of all dropouts). Also, we have omitted benefits for other federal welfare programs where we have insufficient empirical evidence on their links to education. Nevertheless, the cost savings are still significant, particularly for female dropouts.

From a state's perspective… the gains are $52,890 in fiscal benefits; $186,230 in earnings gains (net of taxes); $79,480 in savings to victims; and $68,910 in productivity externalities.

3.6 Total Fiscal Gains

The total effect of taxes and government savings on health, crime, and welfare are large (Table A7). For each new high school graduate, the total fiscal benefits are $112,720 for the federal government alone. Income tax payments are the main contributory factor ($73,090), with health and criminal justice system savings also important. In addition, the total fiscal benefits per new high school graduate are $52,900 for state governments. Here, there is almost an equal impact from tax payments, crime expenditures, and health expenditures. But the costs of providing school and college education are much greater also. From the taxpayer perspective, the federal government is the main beneficiary when education levels increase, yet it is state governments that are responsible for the majority of funding for education. Finally, significant differences exist between ethnicity and gender, but for all subgroups the fiscal benefits are large.

3.7 Social Gains

In addition, there are social benefits from higher education levels. These social benefits include the fiscal benefits calculated above, as well as post-tax earnings, crime costs imposed on victims, and productivity externalities. These benefits are reported in Table A8. The post-tax earnings gains were derived from the CPS, which was used to assess income tax payments. The crime costs were derived from Ludwig (2006) and expressed as a proportion of the government crime costs. Finally, the productivity externalities were adopted from estimates by McMahon (2006), who conservatively calculated these externalities at 37% of post-tax earnings.

Per new high school graduate over the lifetime, these social benefits are very large. From a state's perspective (i.e., excluding federal fiscal benefits), the gains are $52,890 in fiscal benefits; $186,230 in earnings gains (net of taxes), $79,480 in savings to victims, and $68,910 in productivity externalities. This amounts to $387,500 per new high school graduate. Clearly, increasing education levels has a strong economic payoff for the individual, the government, and society.

4. Total Economic Effects of Math Skills

Here, we relate these economic consequences of high school graduation to an assumed improvement in overall math skills. We use the relationship between math improvement and high school graduation, based on our estimates from NELS. The extra graduates will yield economic benefits as indicated by the figures in Tables A7 and A8. Our approach underestimated the benefits of higher math performance because it did not account for the advantages of improved math skills for students who would have graduated anyway (and even for those who still do not graduate). Because the largest effects are associated with the two bottom achievement quartiles, we assumed that policies to improve math achievement are targeted only at those below the median in eighth grade. However, we needed to account for the fact that gains in math skills are not consistent across subgroups of the population. Therefore, we calibrated the gains in math skills by gender and ethnicity. We also needed to express the benefits as present values for a student in eighth grade.

One can set benchmarks for mathematics improvement by comparing U.S. performance relative to that of other developed countries. The OECD in Paris reported comparisons of mathematics achievement for 15-year-olds for 57 nations or jurisdictions for 2006 (U.S. Department of Education, 2008). The U.S. performed about 0.25 of a standard deviation below the OECD average, a 0.5 standard deviation below Canada, and about 0.75 of a standard deviation below the highest performer, Finland. These might be alternative scenarios that the United States education system could attain.

Table 3 shows the estimates of economic benefits for the additional high school graduates[9] that would be expected if the United States were to meet the average levels of mathematics performance for these comparison countries. These benefits are per student, not per graduate, but they reflect only the benefits accrued from an increase in the yield of high school graduates. The benefits are expressed in eighth grade dollars and so can be equated to expenditures during that grade. Three potential improvements in test scores are specified, the most modest being the increase required to bring PISA math scores for the United States to the OECD average, the middle level bringing the United States to the average for Canada, and the highest level bringing the United States to the average for Finland. These figures assume linearity in the impact of math achievement. However, scenarios 1 and 2 differ as to whether the improvement is population-wide or targeted to those students below the median.

9 Each graduate generates benefits far in excess of these amounts. But in order to yield one new graduate, interventions have to be applied to a larger population of students.

Table 3. Fiscal and social benefits from yield of new high school graduates from an increase in math scores of 0.25, 0.5, and 0.75 standard deviations

	Male			Female		
	Black	Hispanic	White	Black	Hispanic	White
[A] Increase in math scores of 0.25 *sd* (rising to average for OECD)						
{1} Population-wide						
Federal benefits	$2,940	$3,020	$2,270	$2,040	$1,810	$1,670
State/local benefits	$1,700	$1,600	$910	$1,050	$810	$600
Social benefits	$11,640	$11,630	$8,700	$4,530	$4,500	$5,010
{2} Targeted to bottom two quartiles						
Federal benefits	$4,130	$4,230	$3,180	$2,860	$2,530	$2,350
State/local benefits	$2,380	$2,230	$1,270	$1,480	$1,140	$840
Social benefits	$16,320	$16,300	$12,200	$6,350	$6,310	$7,020
[B] Increase in math scores of 0.5 *sd* (rising to average for Canada)						
{1} Population-wide						
Federal benefits	$5,890	$6,040	$4,540	$4,090	$3,610	$3,350
State/local benefits	$3,400	$3,190	$1,810	$2,100	$1,620	$1,190
Social benefits	$23,290	$23,250	$17,410	$9,060	$9,000	$10,020
{2} Targeted to bottom two quartiles						
Federal benefits	$8,250	$8,470	$6,360	$5,730	$5,070	$4,690
State/local benefits	$4,760	$4,470	$2,540	$2,950	$2,270	$1,670
Social benefits	$32,650	$32,600	$24,410	$12,700	$12,610	$14,040
[C] Increase in math scores of 0.75 *sd* (rising to average for Finland)						
{1} Population-wide						
Federal benefits	$8,830	$9,060	$6,800	$6,130	$5,420	$5,020
State/local benefits	$5,100	$4,780	$2,720	$3,160	$2,430	$1,790
Social benefits	$34,930	$34,880	$26,110	$13,580	$13,500	$15,020
{2} Targeted to bottom two quartiles						
Federal benefits	$12,380	$12,700	$9,540	$8,590	$7,600	$7,040
State/local benefits	$7,150	$6,700	$3,820	$4,420	$3,410	$2,510
Social benefits	$48,970	$48,900	$36,610	$19,040	$18,920	$21,060

Source: Yields based on NELS in Tables 1 and 2.
Notes: Cost discounted back to eighth grade at a discount rate of 3.5%. Average fiscal benefits weighted according to gender and ethnicity demography separately for scenarios {1} and {2}. Cost estimates derived from Tables A7 and A8. Figures expressed in 2006 dollars rounded to nearest $10.

A population-wide increase in math scores of 0.25 standard deviation would generate a federal taxpayer benefit of $2,270 to $3,020 per male student and $1,670 to $2,040 per female student, a state taxpayer benefit of $910 to $1,700 per male student and $600-$1,050 per female student, and a social benefit of $8,700 to $11,640 per male student and $4,500 to $5,010 per female student. If the increase in math scores were targeted to only students below the median, the economic consequences would be even greater. The fiscal benefits would be approximately 1.3 times as large and the social benefits closer to 1.5 times as large. For male students, these social figures exceed annual per-student public spending on all educational programs in eighth grade (approximately $9,000 nationally). Finally, as shown in panels [B] and [C], the economic gains to the United States from having math scores equal to those of Canada or Finland would be extremely large.

As noted, Table 3 does not include the gains for those students who also had improvements in their mathematics achievement but would have graduated anyway or who did not graduate. Given the evidence reviewed above, these individuals are likely to experience an increase in income. Therefore, for each 0.25 standard deviation of improved math skills, we added a 2% increase in income for students who would already graduate and those who would not graduate. This increase was based on the coefficient estimates identified above by Rose and Betts (2004). We assumed no associative benefits in terms of health status, criminal activity, and/or welfare receipt for these persons.

The earnings gain and tax payments from a 0.25 standard deviation increase in math scores are reported in Table 4. As with the estimates in Table 3, these present value figures are per student (not per graduate). The earnings gains range from $8,650 to $13,640 for males and $6,250 to $8,200 for females (reflecting their lower labor market participation rates). The additional tax payments are approximately 25% of the earnings gains. They range from $1,250 to $2,730. As with the yield effects, these economic values are substantial when compared with education spending in eighth grade. If U.S. math scores are 0.5 or 0.75 standard deviations higher, the economic benefits are proportionately higher (panels [B] and [C]).

The amounts in Tables 3 and 4 should be added together for a full estimate of the economic cost of low achievement in mathematics. Table 5 presents the economic impacts for the federal and state/local government. These impacts are calibrated for the scenarios where math scores are 0.25, 0.50, and 0.75 standard deviations higher population-wide and where they are higher for students below the median.[10] From these per-student amounts it is possible to calculate the aggregate consequences of underachievement in math. All figures are weighted according to U.S. gender and race/ethnicity demography.

10 Calculating the social benefits is otiose: they are magnitudes larger than the fiscal benefits reported here.

Table 4. Earnings and income tax payments from an increase in math skills across all high school graduates

	Male			Female		
	Black	Hispanic	White	Black	Hispanic	White
[A] Increase in math scores of 0.25 *sd*						
Lifetime earnings gain	$8,650	$11,070	$13,640	$6,250	$6,510	$8,200
Additional income tax payments	$1,730	$2,210	$2,730	$1,250	$1,300	$1,640
[B] Increase in math scores of 0.5 *sd*						
Lifetime earnings gain	$17,300	$22,140	$27,280	$12,500	$13,020	$16,400
Additional income tax payments	$3,460	$4,420	$5,460	$2,500	$2,600	$3,280
[C] Increase in math scores of 0.75 *sd*						
Lifetime earnings gain	$25,950	$33,210	$40,920	$18,750	$19,530	$24,600
Additional income tax payments	$5,190	$6,630	$8,190	$3,750	$3,900	$4,920

Source: Impact on math scores based on Betts and Rose (2004).
Notes: Impact not applied to new high school graduates (see Table 3); earnings and tax payments calculated for entire cohort. Cost discounted back to eighth grade at a discount rate of 3.5%. Amounts weighted according to gender and ethnicity demography. Includes all persons (labor market active and inactive). Figures expressed in 2006 dollars rounded to nearest $10.

Table 5. Per-student and aggregate fiscal and social benefits from an increase in math scores of 0.25, 0.5, and 0.75 standard deviations

	Per student		Aggregate per age cohort (millions)	
	Federal	State	Federal	State
[A] Increase in math scores of 0.25 *sd*				
{1} Population-wide	$3,560	$1,700	$6,700	$3,310
{2} Targeted to bottom two quartiles	$4,200	$2,000	$3,410	$1,670
[B] Increase in math scores of 0.5 *sd*				
{1} Population-wide	$7,120	$3,400	$13,400	$6,610
{2} Targeted to bottom two quartiles	$8,420	$4,000	$6,830	$3,340
[C] Increase in math scores of 0.75 *sd*				
{1} Population-wide	$10,680	$5,100	$20,100	$9,920
{2} Targeted to bottom two quartiles	$12,640	$6,010	$10,240	$5,000

Source: Impact on math scores based on Betts and Rose (2004).
Notes: Impact not applied to new high school graduates (see Table 3); earnings and tax payments calculated for entire cohort. Cost discounted back to eighth grade at a discount rate of 3.5%. Amounts weighted according to gender and ethnicity demography. Includes all persons (labor market active and inactive). Figures expressed in 2006 dollars rounded to nearest $10.

Per student, an improvement in math scores of 0.25 standard deviation population-wide would generate $3,560 in federal benefits and $1,700 in state/local benefits for taxpayers. For a single age cohort of 4.3 million persons, the aggregate economic impact would be $11 billion in additional tax payments. If math scores equivalent to those in Canada or Finland were obtained, the taxpayer gains would be correspondingly larger. If interventions are targeted to the bottom two quartiles, the per-student gains are even greater: $4,200 in federal benefits and $2,000 in state/local benefits. The aggregate consequences – based on only half the age cohort – are $5.1 billion in additional tax payments.

Per student, an improvement in math scores of 0.25 standard deviations population-wide would generate $3,560 in federal benefits and $1,700 in state/local benefits for taxpayers.

Across 237 studies of math interventions for grades K through 5, only nine studies met quality standards.

5. Interventions to Improve Math Skills

The fiscal and social benefits we calculated are sufficiently large that interventions to raise math skills might be expected to yield a positive return. Unfortunately, few interventions have been demonstrated to be effective in raising math achievement. In part, this may be because newer cognitive science-based interventions have not been evaluated fully yet, such as SimCalc, even though early assessments appear promising with large effect sizes (Roschelle et al., 2007). Nevertheless, two recent syntheses by the What Works Clearinghouse (WWC, 2007a,b) illustrate the paucity of high-quality research on effective math programs.[11]

Across 237 studies of math interventions for grades K through 5, only nine studies met quality standards (WWC, 2007a). These studies related to only five curricula out of a pool of 74 available curricula. Of these five, only one curriculum – Everyday Mathematics – had potentially positive effects on math achievement; the other four had no identifiable effects. On the basis of four studies across 12,306 students in 171 schools, Everyday Mathematics was found to raise math achievement by 6 percentile points.

There are more definitive conclusions for middle school math curricula (WWC, 2007b). From 158 studies of 23 curricula, only 21 studies met quality standards, and these studies related to seven curricula. The review results for these studies are in Table A9. For the Saxon and I CAN LEARN curricula, there were clear positive effects. The effects were found in six separate studies, covering large numbers of schools and students. The percentile point improvements from these curricula were 8 and 6, respectively. For three more curricula, there are potentially positive effects. These curricula may have possibly greater percentile point achievement gains, although they have been evaluated with much smaller samples (and in only one school, in the case of The Expert Mathematician). Finally, for two curricula only mixed effects were reported, with no improvements on average.

To these we add Mathletics, a Harcourt School Publishers program in which students progress at their own rate with games, hands-on activities, and projects. It was implemented in 25 afterschool centers, and children were randomly assigned to intervention or control groups. Subsequent math scores were measured, with an evaluation by MDRC (Black, Doolittle, Zhu, Unterman, & Grossman, 2008). Mathletics students received on average 179 minutes of math instruction per week, amounting to 30% more math than the control group. The impact was 8.5% more growth in SAT 10 total math scores relative to the control group (an effect size of 0.06), with no countervailing deterioration in test scores in other subjects.

We discuss these interventions but are not endorsing any one specifically. They are presented here as illustrations of cost–benefit analyses. Alternatives can

11 Perhaps surprisingly, class size reduction is not differentially effective for minority students in math. Based on Project STAR, Nye, Hedges, & Konstantopoulos (2001) reported that: minority students gain most from smaller classes in reading but not math; girls gain most in math but not reading; and the effects do not vary by ability.

be inserted into the analysis as they are identified and evaluated. Indeed, these examples are far from ideal. We do not know whether the benefits from any of these interventions fade out over a period of time. This concern might be particularly strong for interventions that rely more on test preparation and memorization; Saxon is an example of this mode.

Other reforms may be effective. Corbett Burris, Heubert, and Levin, (2006) found that an accelerated middle school math curriculum, delivered through heterogeneous grouping of students, improved completion of advanced math courses; test scores and AP test-taking rates were also higher. Afterschool programs may also raise math competencies. An investigation of 10 afterschool programs showed moderate effectiveness in terms of academic gains (Baldwin Grossman et al., 2002). High-quality preschool programs may also raise math scores according to recent evidence from the United Kingdom (Melhuish et al., 2008). Effective preschool was associated with an effect size gain in math of 0.26 by age 10, slightly below the effect of home learning (0.40) and the quality of the elementary school attended (0.39). Smaller schools may also be effective in raising achievement (Kuziemko, 2006). An overview of other strategies that have low or moderate supporting evidence (e.g., changes in classroom behavior, personalized instruction, and use of data systems) is given in Dynarski et al. (2008).

Broader reforms may also enhance math skills. The National Academy of Sciences (2005) proposed six K-12 recommendations to improve math and science education: recruitment of 10,000 teachers; summer institutes; master's programs; AP/IB teacher and student incentives; and improvements to the science and math curriculum. Although these reforms are likely to be beneficial, they may be challenging to implement. For example, more qualified math and science teachers will require higher wages, assuming that higher quality teachers can be easily identified. And, as What Works Clearinghouse reviews illustrate, curriculum improvements are not easily identifiable. Further, these are general policy directions rather than concrete programs that have been tested and evaluated for specific gains in mathematics and resource requirements for which costs can be calculated.

Most important is the fact that the newer interventions based on the learning sciences have not been fully evaluated over an academic year, even though they show promise. A good example is the eighth grade intervention Visicalc which in a short-term random-assignment study showed an effect size of .79 overall and 1.27 on the most complex portion relative to the control group (Roschelle et al., 2007). If the costs for Visicalc are comparable to those of other curriculum changes in terms of teacher preparation, it is likely to have high cost-effectiveness and benefit-cost results.

Most of the interventions do not even report the complete picture of what it takes to implement them to be successful, and it is the ingredients of effective implementation that must be used to construct cost estimates.

6. The Cost of Interventions

Not only is limited evidence on effective intervention, but evidence on the costs of improving math and science skills is sparse. For most of the interventions, the complete picture of what it takes to implement them to be successful is not reported, and it is the ingredients of effective implementation that must be used to construct cost estimates (Levin & McEwan, 2001). The National Academy of Sciences (2005) estimated $6 billion over 5 years to implement its K-12 recommendations. However, its cost estimates are back of the envelope and cannot be easily related to specific gains in math achievement.[12] The only per-student cost estimate is for incentives for students to take the AP or IB, and these are estimated at only $140 per student.

Similarly at issue is how much the four effective math curricula cost relative to the next best alternative. Plausibly, the cost ingredients are likely to include (1) the price of the new curriculum materials (books, lesson plans, assignments, assessments), (2) training of teachers in the new curriculum, (3) reorganization of school and class facilities (e.g., for smaller class groupings), and (4) additional hours of instruction and assessment. Also fundamental to our costing out exercise are the duration of each intervention across grade levels, the depreciation of any required capital investments, and the source of funding.[13]

Drawing on technical reports on the interventions, we have compiled descriptions of the cost ingredients for each, along with consistent results for impacts. This information is reported in Table 6. Each intervention required a new curriculum, and most required at least 2 days of teacher training, although the interventions varied in the extent to which they required reorganization of classroom facilities. Clearly, because limited information is available, our estimates cannot be precise. Two interventions reported some cost data, but these reports omitted key information. For Everyday Math, the resource package does not include the costs of the textbooks, the training, or the management of parental involvement. For I CAN LEARN, it is unclear how many students over how many years are covered by the full installation expenditure of $335,000. Finally, rudimentary costs data were also collected for the range of afterschool programs evaluated by Baldwin Grossman et al. (2002). Typically, these programs were offered 4-5 days per week, with schools serving on average 63 students per day. The total operating cost per day of one youth slot was $23 (ranging from $12 to $56), not including the start-up costs of $78,000 per school (2006 dollars). However, costs varied significantly based on differences in implementation (e.g., in administration, staff-student ratios, and salaries for activity leaders).

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12 For example, the first recommendation is to recruit 10,000 teachers. This will almost certainly increase math achievement, but the impact in terms of test score gains is unknown.

13 For example, some of the money for afterschool programs was from redirected expenditures (including federal monies and administrative time of foundation-aid funded staff). In other cases, the cost figures represent additional amounts of money.

Table 6. Ingredients for effective math curricula

	Everyday Math	Saxon Middle School Math	I CAN LEARN	Mathletics	Afterschool math programs
(1) New curriculum materials	New (different) textbooks only	New (different) textbooks only	Instructional videos, interactive multimedia presentations, question bank	Harcourt School Publishers	Varied.
(2) Training of teachers in the new curriculum	40 hours of professional development, incl. conferences and on-site programs	Minimal	2 days of teacher training and access to support service	2 days of teacher training	NA
(3) Reorganization of school and class facilities	Some parental involvement	None	Full installation is 30 workstations per class, incl. curriculum software/ hardware, networking, furniture, 3 years on-site support	Required are 4 certified teachers; 10 students per instructor	Yes. Reorganization varied across staff-student ratios and administration.
(4) Additional hours of instruction and assessment	None	None	None. May save on assessment time.	After school program students had 49 more hours of instruction over school year.	Yes. After school program for 4-5 days per week.
Delivery in grades	K–6	9	9	2–5	Middle/high school
Effect size gain	0.16 over 3 years	0.21	0.15	0.06	NA
Reported estimate of costs	K core teacher resource package costs $210, for higher grades cost is $300	NA	$335,000 for full installation	NA	$38 per day per youth (range of $22 - $132), with start-up costs of $89,000 per school

Sources: Everyday Math, ies.ed.gov/ncee/wwc/pdf/techappendix04_207.pdf; Saxon, ies.ed.gov/ncee/wwc/pdf/techappendix03_17.pdf; I CAN LEARN, ies.ed.gov/ncee/wwc/pdf/techappendix03_14.pdf; Mathletics, www.mdrc.org/publications/480/full.pdf 2006 dollars.

The unit costs for these interventions are likely to be small.[14] First, the total costs are applied across large populations of students. For example, 2 days of teacher training costs approximately $840 in the opportunity cost of teacher time.[15] Assuming that this teacher then teaches math to 60 students annually for 3 years, the unit cost of teacher training per student is only about $3 per year. Second, even costs for small-scale reorganizations may be low when amortized over several years of implementation. Third, where an intervention requires a new textbook, it is reasonable to assume that the textbook market is reasonably competitive so that the price of the original textbook is close to that of the intervention textbook. Additional costs from implementing the new interventions might therefore be expected to be trivial. The exceptions here would be when a new textbook must be developed (e.g., Mathletics) or when the textbook is associated with computer-based infrastructure (e.g., I CAN LEARN).

However, costs may be significantly higher when the math intervention requires additional hours of math instruction. Labor costs associated with additional personnel can be substantial.

Table 7 provides a fiscal benefit–cost evaluation for effective math curricula. This evaluation is illustrative and imprecise because the information on the costs of these interventions is far from adequate. (Information on afterschool math programs is so weak – in relation to both costs and effects – that no benefit–cost evaluation is reported). Two scenarios are reported: an increase in math scores of 0.25 standard deviation population-wide and one targeted to the bottom two quartiles of math achievement. The benefits are reported in present values in eighth grade and per student (adjusted for demography); they can be compared directly with expenditures on interventions as these are also reported in eighth grade present values.

The first row of Table 7 gives the unit costs of each program: Mathletics is the most expensive because it requires 49 extra hours of instruction per student. Saxon purportedly requires only new textbooks, a claim that justifies skepticism considering that teachers need to be prepared to deliver instruction based on the materials that are provided. Thus, the cost for the Saxon results may be underestimated. The second row gives the cost per student to effect an increase of 0.25 standard deviation (see Table 6 for reported effect sizes). Although Everyday Math is relatively inexpensive, it takes 3 years to generate an effect size gain of 0.16 standard deviation, and this is produced in elementary school. In contrast, Saxon is reported to be highly effective and generates gains in ninth grade, but possibly not all the costs may have been documented. These unit costs range from $230 to $3,530, and they can be compared directly with the fiscal benefits reported in Table 5 and shown as {B1} and {B2}. Clearly, each intervention generates a positive net present value. The amounts vary from $1,730 to $5,030 across the interventions. The benefit-cost ratios all exceed 1. The highest benefit-cost ratio is for Saxon, at 23:1 or 27:1. However, as stated, there is reason to believe that the costs have been understated. Note that these ratios do not include any social benefits from higher math scores.

14 Another relevant comparison is total federal spending on STEM at the K-12 level by all government agencies. This was $574 million in 2006, which amounts to less than $50 per student (U.S. DOE, 2007, Appendix E).

15 Based on a teacher salary of $60,000 and benefits of 37% and a work year of 195 days. Also included is the cost of the trainer with an equal salary, training 10 teachers for 2 days.

Table 7. Fiscal cost-benefit evaluations for effective math curricula to increase math scores by 0.25 standard deviation (2006 dollars)

	Everyday Math	Saxon Middle School Math	I CAN LEARN	Mathletics	Afterschool math programs
Unit cost per student	$480	$190	$530	$850	~$2,300
Cost per student to increase math scores by 0.25 *sd* {C}	2,230	230	880	3,530	NA
Total fiscal benefits from an increase in math scores population-wide {B1}	5,260	5,260	5,260	5,260	$5,260
Net present value {B1-C}	3,030	5,030	4,380	1,730	–
Benefit-cost ratio {B1/C}	2.36	22.87	5.97	1.49	–
Total fiscal benefits from an increase in math scores targeted to bottom two quartiles {B2}	6,210	6,210	6,210	6,210	–
Net present value {B2-C}	3,980	5,980	5,330	2,680	–
Benefit-cost ratio {B2/C}	2.79	26.99	7.05	1.76	–

Sources: Unit costs are approximate, based on Table 6. Benefits are taken from Table 5. Present values at eighth grade using 3.5% discount rate. 2006 dollars.

…it appears that the benefits of even existing interventions exceed their costs when evaluating their impact on improving high school graduation rates.

7. Conclusions

Most economic arguments for improving mathematics instruction and increasing student mathematics achievement rely on the assumption that higher academic achievement will result in greater labor market productivity and payoffs. There are certainly studies that support this conventional wisdom. But an additional argument that may be even more powerful in terms of its economic consequences is that improved mathematics achievement raises high school graduation and post-secondary participation and success. In this study, we estimated the potential impact on increased high school completion and potential post-secondary continuation from higher mathematics achievement at grades 8 and 10. Of course, higher levels of performance at these grades would require interventions in the earlier grades and even at preschool levels. We found that the impact of improved mathematics achievement would most likely raise high school completion substantially, especially for lower socioeconomic groups and most minorities. Given future projections of U.S. school demography, the latter finding is particularly important.

We proceeded to estimate the economic consequences of increased graduation in terms of individual or private gains, fiscal gains to the public, and social benefits for all society. In particular, we reviewed the impact on income and tax revenues, social productivity, and reductions in the costs of public health, crime, and public assistance. We then estimated the total magnitude of these economic benefits and reviewed what they would be if mathematics achievement were raised to that of other developed countries, Canada, and high-performer Finland.

Finally, we reviewed the evidence on interventions that had demonstrated effectiveness in improving mathematics achievement in high schools and middle schools. We recognized that the formal evidence is less abundant than we had hoped. Nevertheless, we combined the economic gains from additional graduates estimated to be produced by these mathematics interventions with the costs of the interventions to review these investments from a benefit-cost perspective. Based on these analyses, it appears that the benefits of even existing interventions exceed their costs when evaluating their impact on improving high school graduation rates. We believe that a continuing search for powerful methods of raising mathematics achievement is called for and can be evaluated in terms of its economic results.

Our analyses indicate that there are substantial economic benefits from increasing math skills. Of the many different interventions for improving math skills, only a few have been demonstrated to be effective using high-quality research methods. A related approach would be to promote more course-taking in math, an approach that appears to be feasible and for which there is good evidence of improved economic outcomes. Finally, we need to be cognizant of the fact that raising mathematics achievement to improve high school graduation might also improve college graduation rates and that the strongest economic payoffs seem to be vested in those populations that are least well off educationally.

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Appendix

Table A1. Percentage change in the dropout rate [extra graduates per hundred students] from a 1 *sd* increase in math scores, by 10th grade math achievement

	Full sample	Sample split by 10th grade math achievement quartiles			
		First quartile (lowest)	Second quartile	Third quartile	Fourth quartile (highest)
Math score					
Model 1	-60	-26	-77	-42	-50
	[4.4]	[3.7]	[6.7]	[1.8]	[0.9]
Model 2	-59	-26	-76	-39	-49
	[4.4]	[3.7]	[6.6]	[1.7]	[0.9]
Model 3	-60	-27	-76	-34	-48
	[4.4]	[4.0]	[6.6]	[1.4]	[0.9]
Model 4	-54	-24	-72	-24	-38
	[4]	[3.5]	[6.3]	[1.0]	[0.7]
Dropout rate	7.3	14.5	8.7	4.2	2.1
Observations	*15,976*	*4,000*	*3,979*	*4,012*	*3,985*

Source: Educational Longitudinal Survey, 2002.
Notes: Percentage figure is the change in the dropout rate. The figure in square brackets is the increase in the number of high school graduates. Adjusted means based on logistic models for graduation (1,0) with all other variables set at the mean value. Model 1 controls for: gender, ethnicity. Model 2 controls for: model 1 and school-level SES. Model 3 controls for: model 2 and SES, mother's education. Model 4 controls for: model 3 and 10th grade reading score.

Table A2. Percentage change in the dropout rate [extra graduates per hundred students] from a 1 *sd* increase in math scores, for 10th grade students, by gender and ethnicity

	Male			Female		
	Black	Hispanic	White	Black	Hispanic	White
Math score						
Model 1	-47	-45	-54	-57	-54	-52
	[6.5]	[5.3]	[3.7]	[4.6]	[5.1]	[2.6]
Model 2	-53	-44	-55	-58	-58	-63
	[7.4]	[5.2]	[3.8]	[4.6]	[5.5]	[3.3]
Model 3	-53	-43	-54	-59	-49	-64
	[7.5]	[5.1]	[3.7]	[4.7]	[5.0]	[3.3]
Model 4	-47	-36	-51	-41	-52	-62
	[6.6]	[4.3]	[3.5]	[3.2]	[5.0]	[3.2]
Dropout rate	14.0	11.9	7.9	8.0	9.4	5.2
Observations	*1,009*	*1,105*	*6,163*	*1,018*	*1,122*	*5,559*

Source: Educational Longitudinal Survey, 2002.
Notes: Percentage figure is the change in the dropout rate. The figure in square brackets is the increase in the number of high school graduates. Adjusted means based on logistic models for graduation (1,0). Model 1 controls for: gender, ethnicity. Model 2 controls for: model 1 and school-level SES. Model 3 controls for: model 2 and SES, mother's education. Model 4 controls for: model 3 and 10th grade reading score.

Table A3. Percentage change in the dropout rate [extra graduates per hundred students] from a 1 *sd* increase in reading scores, for eighth grade students, by math achievement

	Full sample	Sample split by eighth grade reading achievement quartiles			
		First quartile (lowest)	Second quartile	Third quartile	Fourth quartile (highest)
Reading score					
Model 1	-62	-51	-64	-60	-35
	[8.6]	[13.7]	[10.0]	[5.3]	[1.5]
Model 2	-62	-51	-64	-60	-37
	[8.6]	[13.6]	[10.2]	[5.3]	[1.6]
Model 3	-60	-51	-62	-56	-34
	[8.3]	[13.6]	[9.8]	[4.9]	[1.4]
Model 4	-47	-34	-48	-44	-13
	[6.5]	[9.1]	[7.6]	[3.8]	[0.5]
Dropout rate	15.2	26.4	15.7	8.7	4.2
Observations	*13,263*	*3,326*	*3,305*	*3,315*	*3,305*

Source: National Educational Longitudinal Survey, 1988-1994.
Notes: Percentage figure is the change in the dropout rate. The figure in square brackets is the increase in the number of high school graduates. Adjusted means based on logistic models for graduation (1,0) with all other variables set at the mean value. Model 1 controls for: gender, ethnicity. Model 2 controls for: Model 1 and free-school lunch populations, minority status, public school, urban school, and whether the school is dangerous or disruptive. Model 3 controls for: Model 2 and SES, mother's education. Model 4 controls for: Model 3 and 8th grade math score.

Table A4. Percentage change in the dropout rate [extra graduates per hundred students] from a 1 *sd* increase in reading scores, for eighth grade students, by gender and ethnicity

	Male			Female		
	Black	Hispanic	White	Black	Hispanic	White
Reading score						
Model 1	-66	-54	-61	-64	-60	-62
	[12.7]	[11.2]	[7.2]	[11.5]	[13.3]	[7.4]
Model 2	-68	-56	-61	-66	-60	-62
	[13.0]	[11.6]	[7.3]	[11.9]	[13.4]	[7.5]
Model 3	-69	-55	-60	-69	-58	-59
	[13.2]	[11.3]	[7.0]	[12.2]	[12.8]	[7.1]
Model 4	-65	-38	-45	-61	-48	-45
	[12.1]	[7.7]	[5.3]	[10.8]	[10.7]	[5.3]
Dropout rate	20.4	20.9	12.0	17.2	22.3	14.9
Observations	*634*	*824*	*4,954*	*752*	*929*	*5,201*

Source: National Educational Longitudinal Survey, 1988-1994.
Notes: Percentage figure is the change in the dropout rate. The figure in square brackets is the increase in the number of high school graduates. Adjusted means based on logistic models for graduation (1,0) with all other variables set at the mean value. Model 1 controls for: gender, ethnicity. Model 2 controls for: Model 1 and free-school lunch populations, minority status, public school, urban school, and whether the school is dangerous or disruptive. Model 3 controls for: Model 2 and SES, mother's education. Model 4 controls for: Model 3 and 8th grade math score.

Table A5. Percentage change in the dropout rate [extra graduates per hundred students] from a 1 *sd* increase in reading scores, for 10th grade students, by math achievement

	Full sample	Sample split by 8th grade reading achievement quartiles			
		First quartile (lowest)	Second quartile	Third quartile	Fourth quartile (highest)
Reading score					
Model 1	-55	-21	-53	-73	-59
	[4.0]	[2.9]	[4.5]	[3.5]	[1.3]
Model 2	-54	-21	-51	-71	-58
	[4.0]	[3.0]	[4.3]	[3.4]	[1.3]
Model 3	-54	-25	-53	-69	-57
	[4.0]	[3.5]	[4.5]	[3.3]	[1.2]
Model 4	-39	-13	-33	-45	-46
	[2.9]	[1.9]	[2.8]	[2.2]	[1.0]
Dropout rate	7.3	14.0	8.5	4.8	2.5
Observations	*15,976*	*3,952*	*4,107*	*3,913*	*4,004*

Source: Educational Longitudinal Survey, 2002.
Notes: Percentage figure is the change in the dropout rate. The figure in square brackets is the increase in the number of high school graduates. Adjusted means based on logistic models for graduation (1,0). Model 1 controls for: gender, ethnicity. Model 2 controls for: model 1 and school-level SES. Model 3 controls for: model 2 and SES, mother's education. Model 4 controls for: model 3 and 10th grade math score.

Table A6. Percentage change in the dropout rate [extra graduates per hundred students] from a 1 *sd* increase in reading scores, for 10th grade students, by gender and ethnicity

	Male			Female		
	Black	Hispanic	White	Black	Hispanic	White
Reading score						
Model 1	-48	-46	-52	-58	-54	-55
	[6.7]	[5.5]	[3.6]	[4.6]	[5.1]	[2.9]
Model 2	-54	-45	-53	-59	-58	-65
	[7.5]	[5.3]	[3.7]	[4.7]	[5.5]	[3.4]
Model 3	-48	-44	-52	-59	-53	-54
	[6.7]	[5.3]	[3.6]	[4.7]	[5.0]	[2.8]
Model 4	-31	-32	-38	-51	-40	-33
	[4.3]	[3.8]	[2.6]	[4.1]	[3.0]	[1.7]
Dropout rate	14.0	11.9	7.9	8.0	9.4	5.2
Observations	*1,009*	*1,105*	*6,163*	*1,018*	*1,122*	*5,559*

Source: Educational Longitudinal Survey, 2002.
Notes: Percentage figure is the change in the dropout rate. The figure in square brackets is the increase in the number of high school graduates. Adjusted means based on logistic models for graduation (1,0). Model 1 controls for: gender, ethnicity. Model 2 controls for: model 1 and school-level SES. Model 3 controls for: model 2 and SES, mother's education. Model 4 controls for: model 3 and 10th grade math score.

Table A7. Lifetime fiscal savings per expected high school graduate (2006 dollars)

	Education expenditures	Tax payments	Health expenditures	Crime expenditures	Welfare expenditures	Total fiscal gains
Federal government						
Male						
White	(4,200)	131,340	19,920	13,000	1,390	161,440
Black	(3,870)	112,780	35,310	23,900	2,200	170,330
Hispanic	(3,920)	74,450	26,820	16,510	2,240	116,090
Female						
White	(3,700)	67,770	28,140	3,450	3,390	99,040
Black	(3,740)	35,100	44,520	3,570	8,010	87,460
Hispanic	(3,340)	38,720	33,020	3,460	6,770	78,630
Average	*(3,760)*	*73,090*	*29,050*	*10,530*	*3,820*	*112,720*
State/local government						
Male						
White	(28,430)	45,030	20,040	26,560	1,370	64,560
Black	(26,800)	38,660	35,520	48,850	2,110	98,340
Hispanic	(27,080)	25,520	26,980	33,700	2,150	61,270
Female						
White	(26,000)	23,240	28,290	6,550	3,260	35,340
Black	(26,180)	12,040	44,780	6,780	7,620	45,040
Hispanic	(24,210)	13,280	33,210	6,550	6,440	35,260
Average	*(26,300)*	*25,070*	*29,220*	*21,260*	*3,650*	*52,890*

Source: Adapted from Belfield and Levin (2007).
Notes: Lifetime values based on a 3.5% discount rate. Average savings are weighted for population in each group (other included in white category). Figures rounded to nearest $10 and expressed in 2006 dollars.

Table A8. Total lifetime social gains per expected high school graduate (2006 dollars)

	Fiscal savings to state and local government	Earnings (net of all taxes)	Crime (victim costs)	Productivity externalities	Total social gains
Male					
White	64,560	332,920	98,900	123,180	619,560
Black	98,340	287,350	181,880	106,320	673,880
Hispanic	61,270	189,940	125,530	70,280	447,010
Female					
White	35,340	172,270	25,000	63,740	296,350
Black	45,040	89,750	25,880	33,210	193,880
Hispanic	35,260	98,930	25,030	36,610	195,820
Average	*52,890*	*186,230*	*79,480*	*68,910*	*387,500*

Sources: Adapted from Belfield and Levin (2007). For column 1, Table A5. For column 2, earnings calculations from CPS. For column 3, Ludwig (2006). For column 4, McMahon (2006).
Notes: Lifetime values based on a 3.5% discount rate. Average savings are weighted for population in each group other included in white category). Female earnings estimates adjust for labor market participation rates. Figures rounded to nearest $10 and expressed in 2006 dollars.

Table A9. Effectiveness of math curricula in middle school

Intervention	Number of studies	Sample size (schools/ students)	Summary of effects	Average improvement in percentile points
Saxon Middle School Math	6	101/3,399	Positive effects	8
I CAN Learn® Pre-Algebra and Algebra	6	729/16,656	Positive effects	6
The Expert Mathematician	1	1/170	Potentially positive effects	14
University of Chicago School Mathematics Project (UCSMP) Algebra	2	4/225	Potentially positive effects	13
Cognitive Tutor® Algebra I	2	9/781	Potentially positive effects	8
Connected Mathematics Project (CMP)	3	100/14,696	Mixed effects: evidence of inconsistent effects	-2
Transition Mathematics	3	49/972	Mixed effects: evidence of inconsistent effects	0

Source: WWC (2007b). Study [5] has only 'small' evidence. For positive and potentially positive effects, overriding contrary evidence must not be found. Student-level effects only for students in grades 6-9.

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