Although American science education is facing increasing international competition, US science and economic growth can reap the benefits of globalization.

American Science Education in Its Global and Historical Contexts

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In 2009, students in Shanghai topped their peers around the world in math, science, and reading scores on the Program for International Student Assessment (PISA), a test administered to 15-year-olds in 65 countries, while American schoolchildren placed near the middle of the group (OECD 2010). The release of the disappointing PISA results (and other international comparisons) has been a source of national angst and the stimulus for rapid policy response in many countries (see, e.g., Engel et al. 2012; Feuer 2012), and prompted a wave of alarm in the United States: Why did American children not fare better? What could be done to improve results? Secretary of Education Arne Duncan referred to the results as "a wake-up call" (Dillon 2010), and a *USA Today* (2010) headline announced, "In ranking, US students trail global leaders."

Yet the relatively mediocre performance of American adolescents compared with their Asian peers on the 2009 PISA was not new. The 2007 Trends in

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International Mathematics and Science Study (TIMSS) showed similar results and met with a similar reaction (IEA 2008). Francis Eberle, executive director of the National Science Teachers Association, asked, "Do we want to be average?" (Toppo 2008). In 2008 Ina V.S. Mullis, codirector of the center that administers TIMSS, noted with concern the gap between the performance of American schoolchildren and children in the highest-performing Asian countries (Dillon 2008), and the 2010 issue of *Science and Engineering Indicators* reported that 70 percent of adult Americans said they were dissatisfied with the quality of math and science education in US schools (NSB 2010, Chapter 7, p. 7-42).

Many fear that, in an increasingly globalized world, the United States may not be improving fast enough to keep up.

The news coverage of these test results highlights that, for many Americans, performance in math and science is important both as a measure of ground gained relative to the performance of earlier cohorts of Americans and as an indicator of the United States' ability to remain dominant in an increasingly competitive global landscape. In the words of Arne Duncan, "We live in a globally competitive knowledge based economy, and our children today are at a competitive disadvantage with children from other countries.… [T]hat puts our country's long term economic prosperity absolutely at risk" (USA Today 2010). Many other policymakers, educators, and journalists have also raised the concern that, in an increasingly globalized world, the United States may not be improving fast enough to keep up. Thus concerns about the competitive position of American science education are related to fears for the economic future of the United States, particularly in comparison with China and other emerging Asian economies.

However, this pessimistic view is only one way of looking at the state of US science education (see also Feuer 2012). In this article, we present a more balanced view. We begin with a brief review of the relative performance of American schoolchildren on international tests of achievement in science and mathematics. While our results in this area support the conclusion that US students perform about average on standardized tests, they also document gains compared to earlier cohorts of Americans, showing that US science and math education has improved over its past.

After looking at test scores as indicators of the quality of future American scientists, we shift our attention to quantity. We find no evidence that American college students are turning away from the pursuit of math and science majors. We also find that counterclaims of a surplus of US scientists are overblown. Finally, we present an alternative view of globalization and science, explaining the ways global scientific collaboration may benefit the United States even if America is no longer the top performer.

American Students' Performance from a Global Perspective

To examine the performance of American schoolchildren in the international context, we use scores from the 2006 administration of PISA, in which 57 countries participated, and the 2007 administration of the 4th grade TIMSS, which involved 36 countries (Gonzales et al. 2009; OECD 2007).[1]

In comparing countries' educational outcomes, it is useful to consider test scores in the context of each country's level of economic development (e.g., based on per capita GDP in the same year). If the United States is performing at mediocre levels despite considerable economic resources, the implication is that the government is either investing less than other countries' governments in math and science education (at least as measured by these tests) or using its resources less effectively.

To measure economic resources across countries in comparable terms, we use Penn World Table Version 6.3, which adjusts for differences across countries in the goods and services that can be bought with one unit of currency (Heston et al. 2009). The results for 4th graders' TIMSS scores in math and science are shown in Figure 1.[2] Each dot represents a country or place, with

[1] This section draws on the results of our analysis reported in Xie and Killewald (2012).

[2] Because of Kuwait's very high GDP and poor test results, we excluded it from the dataset to avoid unduly influencing the results.

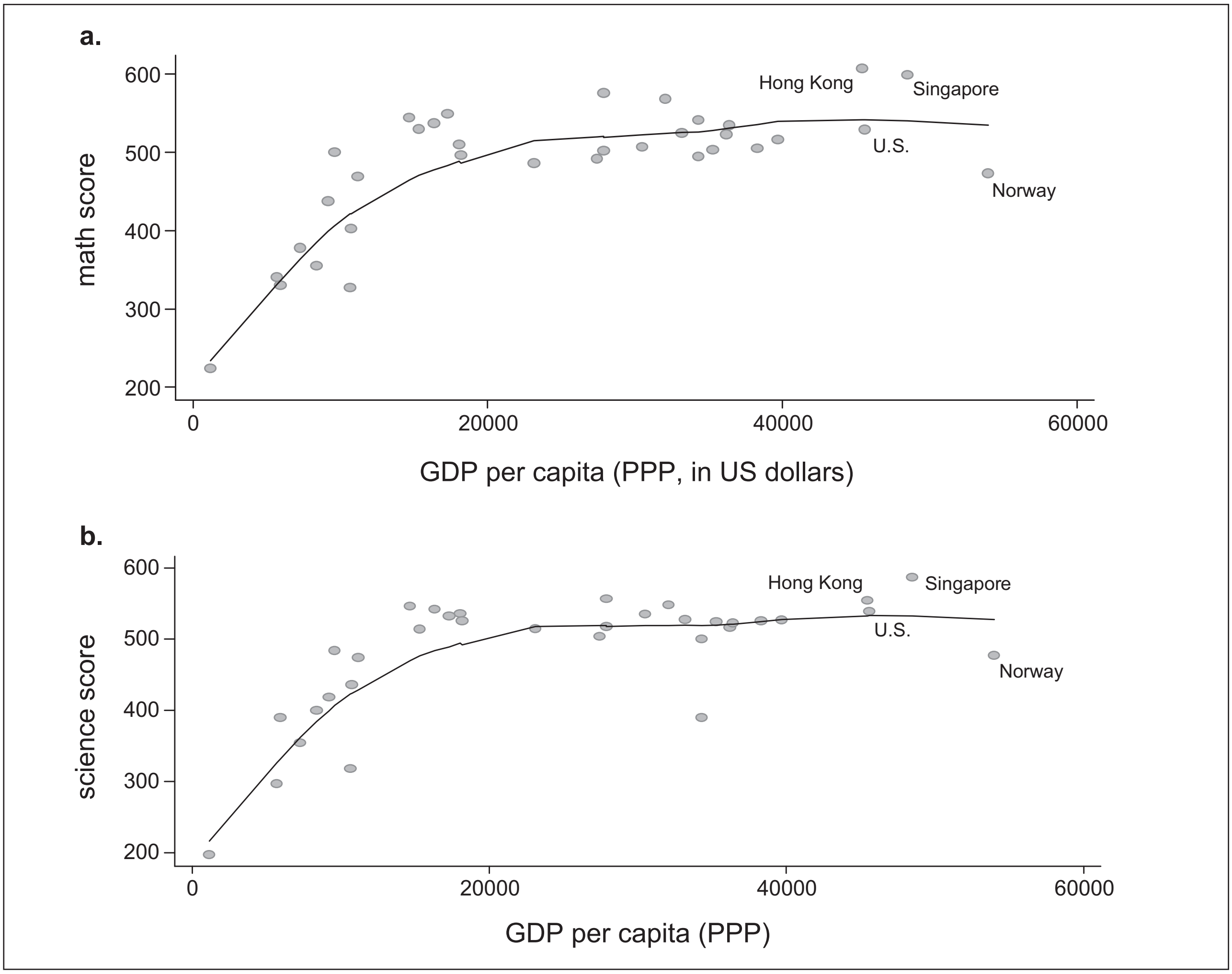

FIGURE 1 (a) TIMSS 4th grade math scores by annual GDP per capita (PPP), 2007. (b) TIMSS 4th grade science scores by GDP per capita (PPP), 2007. *Source:* Reprinted with permission from Xie and Killewald (2012). *Notes:* TIMSS = Trends in International Mathematics and Science Study. Individual scores range from 0 to 1000. Gross domestic product (GDP) per capita is adjusted for purchasing power parity (PPP) using Penn World Table Version 6.3. The GDP of the United Kingdom is used for England and Scotland. Kuwait is an outlier and removed from the analysis.

the United States and several other notable countries identified. In addition to Hong Kong and Singapore, other, unlabelled countries with higher scores than those of the United States (i.e., with dots above the line) are Japan, England, and the Russian Federation. In each figure, we present a flexible but smooth regression line that best describes the relationship between the TIMSS scores and GDP. For both math and science, the line of best fit shows that, at lower levels of per capita GDP, increasing financial resources are associated with sharp increases in test scores, but the subsequent flattening out of the line shows that further increases in resources lead to little additional gain in scores.

The United States falls just below the line in math and just above it in science, performing about as expected given its economic prosperity. But Hong Kong and Singapore, whose GDP per capita is similar to that of the United States, are above the line in both subjects, exceeding the performance of American youth. The TIMSS results for 8th graders indicate that students in the United States perform slightly worse than expected, given their financial resources, although the difference is larger in math.[3]

[3] For a discussion of the differences between the TIMSS and PISA samples and content, see *Science and Engineering Indicators 2010* (NSB 2010, p. 1-16).

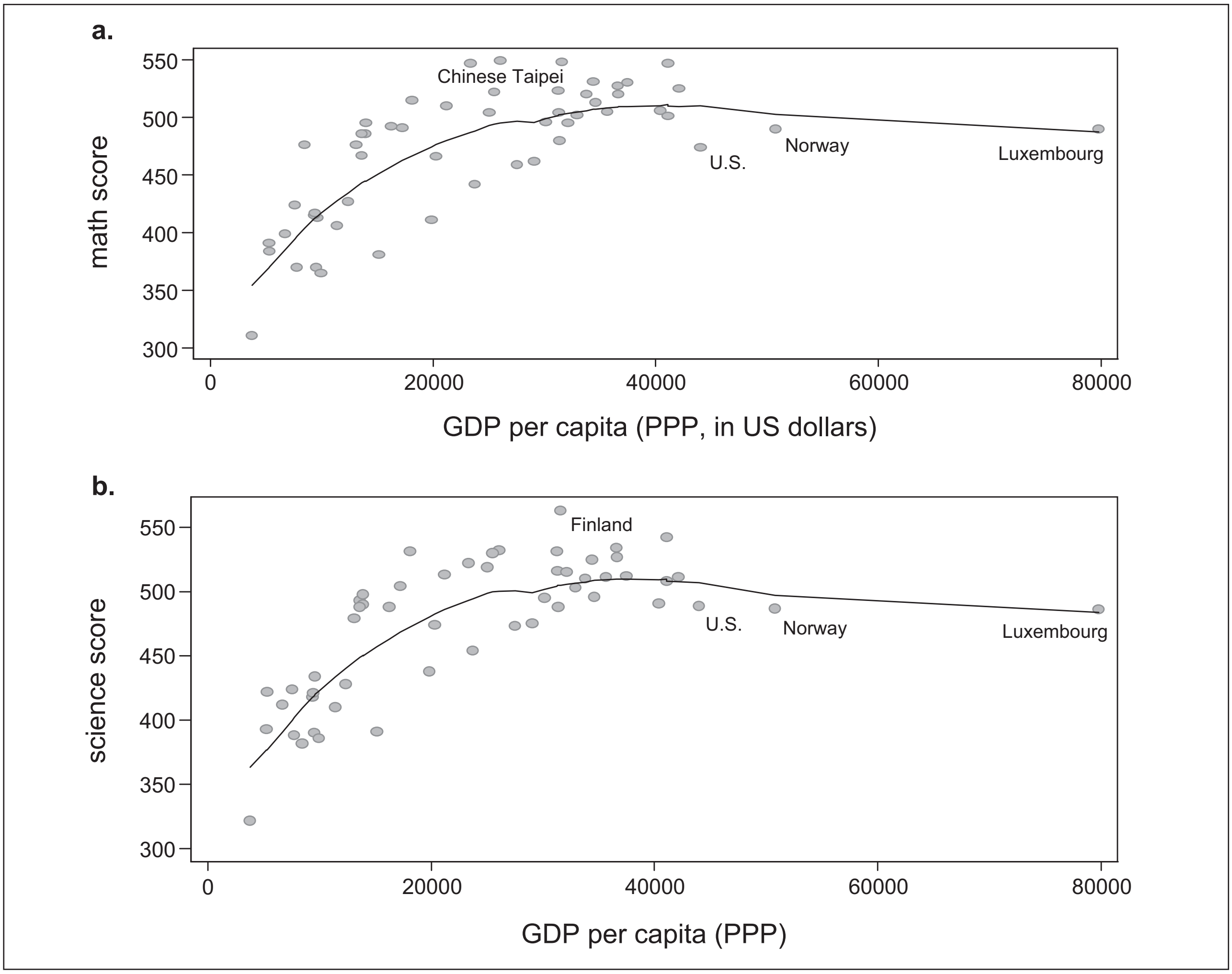

FIGURE 2 (a) PISA math scores by GDP per capita (PPP), 2006. (b) PISA science scores by GDP per capita (PPP), 2006. *Source:* Reprinted with permission from Xie and Killewald (2012). *Notes:* PISA = Program for International Student Assessment. Individual scores range from 0 to 1000. GDP per capita is adjusted for purchasing power parity (PPP) using Penn World Table Version 6.3. Serbia and Liechtenstein were excluded from the analysis because their GDP per capita for 2007 was not available from Penn World Table 6.3. Kuwait and Qatar are outliers and removed from the analysis.

Results from PISA in 2006, shown in Figure 2, are somewhat less favorable for US students: they fall below the line of best fit in both math and science, although the disparity is greater in math. The top spots went to Taiwan (designated Chinese Taipei in the PISA data) in math and Finland in science. Other countries whose students outperformed their US peers on this test are Japan, Australia, and Hungary.[4]

Thus the pattern that emerges from these figures is one of comparatively mediocre performance by American students despite access to considerable economic resources.

American Science Education from a Historical Perspective

Concern about US students' rather poor performance in math and science relative to that of youth in selected other countries must be distinguished from the concern that American youth may not be performing as well as in the past. In this section, we change the comparison group for contemporary American schoolchildren to previous cohorts of Americans. We find little evidence that US math and science education is worse today than in past decades. If anything, it may be better, especially in math.

[4] For this analysis, we excluded Kuwait and Qatar, both outliers because of their very high GDP and poor test results, to avoid their exerting undue influence on the regression line.

The National Assessment of Educational Progress (NAEP) has tracked trends in US students' knowledge of various academic subjects since the 1970s. From 1973 to 2008, the average math scores of both 9- and 13-year-old students increased significantly, while those of 17-year-olds remained flat. Furthermore, gains have been larger for African American and Hispanic students than for white students during this period, reducing the racial gap in math achievement (NCES 2009).

No assessment of the trend in US students' average achievement in math is, however, fully informative about trends in the potential pool of scientists, who are disproportionately drawn from the top part of the academic distribution. Has there been a decrease in the performance of American students with the highest levels of academic achievement in science-related subjects? Again, this does not appear to be the case. The math scores of students at the 90th percentile rose significantly between 1978 and 2008 for 9- and 13-year-olds, while remaining flat for 17-year-olds (NCES 2009).

Furthermore, among 17-year-olds, in 2008 19 percent had taken precalculus or calculus, compared with only 6 percent in 1978 (NCES 2009). And the number of students both taking and passing Advanced Placement (AP) exams in math and science subjects rose rapidly between 1997 and 2008 (NSB 2010, Chapter 1, p. 1-37).

In summary, the data show that today's American schoolchildren are better prepared than their counterparts of three decades ago to enter advanced training in scientific fields.

Pursuit of Higher Education in Science

International competition is not the only area of concern for those who view American science education as troubled. In 1990, former University of California president and National Science Foundation director Richard Atkinson, in a well-publicized article in *Science* magazine, projected "significant shortfalls" of scientists "for the next several decades" (Atkinson 1990, p. 425). This concern about recruitment of talented young adults to scientific education and careers has been echoed numerous times, leading to a popular view that there has been "a growing aversion of America's top students—especially the native-born white males who once formed the backbone of the nation's research and technical community—to enter scientific careers" (Benderly 2010). However, the claims of a current or impending shortage have also been challenged (Butz et al. 2003; Galama and Hosek 2008; Lowell and Salzman 2007).[5]

To address these concerns, we document trends in American undergraduates' pursuit of college-level scientific studies using longitudinal data on three cohorts of school-aged youth collected by the National Center for Education Statistics (NCES). Each cohort was followed through high school graduation and for at least eight years thereafter, with several follow-up interviews during this period. The NCES datasets provide information about the high school graduating classes of 1972, 1982, and 1992.[6]

We break down the process of degree attainment into two sequential steps: (1) attainment of a degree regardless of field and (2) attainment of college-level science education given a degree. In this way, we are able to distinguish trends in the pursuit of higher education more generally from trends in the pursuit of a science degree among all who receive a bachelor's degree.

US schoolchildren today are better prepared than their counterparts of three decades ago to enter advanced training in scientific fields.

The first two rows of Table 1 show the unadjusted trends across the three cohorts in the likelihood of receiving a bachelor's degree. The fraction of men receiving a bachelor's degree rose modestly, from 27.8 percent in the 1972 cohort to 30.5 percent in the 1992 cohort. For women, the rise was more substantial, from 23.9 percent to 36.9 percent. Students with high

[5] Atkinson's *Science* article has been widely criticized, and he himself later admitted that some of its assumptions were flawed, especially where immigration was concerned (Atkinson 1996).

[6] The data for each cohort are from the National Longitudinal Study of the Class of 1972 (NLS-72), High School and Beyond (HS&B), and the National Education Longitudinal Study (NELS:88, which tracked a cohort of students from their 8th grade year in 1988 through their senior year of high school in 1992). Information about these surveys is available at the NCES website, http://nces.ed.gov/.

TABLE 1 Bachelor's Degree and Science Major Attainment, by Gender and Cohort (percent)

	Male			Female		
	1972 cohort (NLS-72)	1982 cohort (HS&B)	1992 cohort (NELS)	1972 cohort (NLS-72)	1982 cohort (HS&B)	1992 cohort (NELS)
Bachelor's degree	27.8	30.7	30.5	23.9	29.8	36.9
Among top 25% in math achievement	54.5	61.2	64.3	53.5	70.4	75.9
Science major given bachelor's degree	28.7	31.4	28.3	10.2	13.7	13.2
Among top 25% in math achievement	36.9	41.5	38.8	15.7	20.9	19.3
Science subfields given bachelor's degree						
Physical science	7.4	3.4	3.1	3.6	1.3	1.6
Life science	9.6	5.0	8.1	4.6	5.3	8.3
Mathematical science	1.3	2.1	1.6	1.6	1.1	0.9
Computer science	1.1	5.6	3.2	0.1	4.1	0.8
Engineering	9.4	15.6	12.4	0.3	2.1	1.7

Note: The sum of percentages across the science subfields does not exactly equal the percentage of science major due to double-majoring and rounding. HS&B = High School and Beyond, class of 1980; NELS = National Education Longitudinal Study of 1988; NLS-72 = National Longitudinal Study of the Class of 1972.

Source: Reprinted with permission from Xie and Killewald (2012).

mathematical aptitudes (defined as having scored in the top 25 percent on the mathematics test given in each survey) generally had high rates of completing a bachelor's degree (above 50 percent). Men in this category increased their completion rates from 54.5 percent in 1972 to 64.3 percent in 1992, and women increased their rates by a larger margin, from 53.5 percent for the 1972 cohort to 75.9 percent for the 1992 cohort.

The next two rows present trends in the likelihood of receiving a bachelor's degree in science or engineering (S/E) conditional on having received a bachelor's degree in some field. For men, there is no clear trend: the fraction of college graduates receiving an S/E degree is between 28.3 percent and 31.4 percent. For women, there is an increase in the pursuit of science across cohorts, from 10.2 percent of college graduates in the 1972 cohort to 13–14 percent in the later cohorts. Even so, although women made slight inroads in scientific training over this period, male college graduates in the most recent cohorts were still more than twice as likely as their female counterparts to receive degrees in S/E fields.

There is little evidence that science suffers a "leaky pipeline" during the college years that steers students away from scientific fields and toward nonscientific studies. Using data from the same sources on 12th grade students' expectations regarding their major in college, we find that, for the 1992 cohort, the share of actual S/E majors among bachelor's degree recipients is slightly higher than the share of expected S/E degrees among youth expecting a bachelor's degree. Among 12th grade boys expecting to attain a college degree, 27.5 percent expected it to be in science and 28.3 percent of male college graduates actually received a degree in science. For women the numbers are 10.5 percent and 13.2 percent, respectively. Thus actual science majors account for about the same share of graduates as expected science majors do of expected degree recipients.[7]

[7] Students who expect to major in a nonscience field are less likely to complete *any* degree than their peers who plan to major in an S/E field. Some nonscience students also shift to an S/E major in college.

These patterns of science study among young men and women also hold true among students with high mathematical aptitudes. The likelihood of high-achieving men receiving S/E degrees was 36.9 percent in the 1972 cohort and 38.8 percent in the 1992 cohort; for high-achieving women the likelihood rose from 15.7 percent for the 1972 cohort to 19.3 percent for the 1992 cohort.

We further disaggregate the trend data on S/E degrees by field and present them in the last panel of Table 1. There is evidence of declining pursuit of physical science degrees among both men and women. In the 1972 cohort, 7.4 percent of male college graduates and 3.6 percent of female college graduates received a degree in physical science, but the comparable percentages in the 1992 cohort were only 3.1 percent and 1.6 percent. Offsetting this decline was an increase during the same period in the fraction of bachelor's degrees in engineering: among males it rose from 9.4 percent in the 1972 cohort to 15.6 percent and 12.4 percent in the later two cohorts, respectively, and for women the analogous numbers are 0.3 percent, 2.1 percent, and 1.7 percent. While engineering is the largest subfield of S/E majors for men, accounting for more than 10 percent of all male college graduates in the later two cohorts, it remains a far less common pursuit for women, never capturing more than 2.1 percent of a graduating cohort. Women's gains in attaining S/E degrees were concentrated in life science, the most popular scientific field for women: the fraction of female college graduates that received a degree in life science rose from 4.6 percent in the 1972 cohort to 8.3 percent in the 1992 cohort. Pursuit of math degrees has always been less common among students of either sex, and the share of math degrees declined across the cohorts for women, while showing no clear trend for men.

Beyond High School and College

Whereas we found little evidence that the supply of trained young scientists has declined in recent decades, critics of the shortfall argument contend that the United States in fact faces a crisis of a surplus of scientists, with too few jobs to employ them (Benderly 2010; NRC 2005). "The S&E [science and engineering] employment of S&E graduates is…a fairly consistent one-third of S&E graduates," claimed a 2007 report of the Urban Institute (Lowell and Salzman 2007, p. 30) in response to the 2007 report *Rising Above the Gathering Storm* (NAS/NAE/IOM 2007). A government-sponsored official publication series, *Science and Engineering Indicators*, commonly considered the most authoritative source on scientific workforce statistics, has released estimates that seem to bolster this claim. The 2010 edition, for example, reported a large discrepancy (a ratio of about one to three) between the size of the S/E workforce and the number of individuals with a bachelor's degree or higher in science or engineering—"between 4.3 million and 5.8 million" for the workforce versus "16.6 million" individuals with science or engineering degrees (NSB 2010, Chapter 3, p. 3-6).

We evaluated this claim using both direct and indirect measures and summarize our results here. Most critically, we find that the aforementioned numbers are sensitive to the inclusion of social science majors as scientific majors. At the undergraduate level, social science majors are not tightly linked to a career in the social sciences but are similar to a liberal arts degree. The fact that many social science graduates do not pursue careers in the social or natural sciences pulls down the average transition rate for all scientists. This is important because, as an undergraduate major option, social science is much bigger than other S/E fields and has grown rapidly in recent years (NSB 2010, Figure 2-5). When we exclude social scientists, we find that the ratio between the numbers of actual and potential scientists is between 45 percent and 60 percent, more than the 1:3 ratio. Given that the outcry about the state of American science has mostly been about natural science rather than social science, we believe that ours is a more appropriate description of transition rates from S/E undergraduate education to scientific employment.

International collaborations facilitate scientific achievements that benefit the entire world.

Impacts of Globalization

If current global trends continue, it is certainly possible that America will lose its long-standing dominance in world science. However, globalization does not necessarily come at the expense of American well-being.

Science increasingly requires collaborative efforts across national boundaries (NSB 2008, Chapter 5, pp. 5-2, 5-7), and such collaborations facilitate scientific achievements that benefit the entire world. Indeed, history shows that human societies have, for the most part, made significant advances in economy and culture only when technological knowledge was shared over different regions (Diamond 1999). Thus, rather than harming science in any one country, globalization may benefit scientific progress broadly.

To cite one high-profile recent example, the construction of the Large Hadron Collider at the European Organization for Nuclear Research (CERN) brought together scientists from nearly 60 countries to seek experimental evidence for the Higgs boson, a key prediction of the Standard Model of particle physics.[8] The international collaboration enabled countries to both pool personnel and share the more than $4 billion cost of building the world's largest particle accelerator (Brumfiel 2008).

There is also ample evidence that innovative ideas are most likely to emerge when people with different perspectives interact (Page 2007). The experiences and perspectives of scientists from different countries can make international collaboration highly productive for all. Furthermore, as with trading, comparative advantages can be exchanged for mutual benefits between scientists in different countries. Not least, participation in science by more nations means greater government investment in research overall and a larger science labor force worldwide.

Because a scientific discovery needs to be made only once but often has long-lasting and widespread benefits, globalization is certain to speed up scientific progress, for at least two reasons. First, there may be efficiency gains via complementarity, as scientists in different parts of the world may hold distinct advantages due to either unique natural resources (e.g., particular weather patterns or unusual plants) or unique intellectual traditions. Second, the sheer expansion of the scientific labor force means more opportunities to produce fruitful scientific results. Hence, globalization of science is beneficial to both science and humanity, and has the potential to benefit American science and society as a whole.

[8] Information about the project is available from the National Science Foundation and US Department of Energy, "The US at the Large Hadron Collider," available online at www.uslhc.us/.

Conclusion

American science education is the very foundation for US science, economy, and security. For this reason, policymakers and the public alike have good reason to be concerned about its welfare. However, in evaluating its state, it is useful to keep a balanced and holistic perspective.

In aspects that we could measure with data, we did not find evidence that US science education has deteriorated. To the contrary, we see that it has improved over time. It is true, however, that in comparison with other countries, particularly some Asian countries, US students' performance on international tests is mediocre, especially relative to America's rich economic resources. However, this comparison reflects improvements in students' academic performance in these successful countries more than a decline or failure of American science education. To be sure, America has a lot to learn from other countries, but this point is different from condemning US science education altogether. Finally, we posit that learning from other countries that are more successful in science education is actually a benefit of globalization, which can enhance the well-being of the United States in the long run.

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