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Is U.S. Science in Decline?

The nation's position relative to other countries is changing, but this need not be reason for alarm.

"Who are the most important U.S. scientists today?" Our host posed the question to his guests at a dinner that I attended in 2003. Americans like to talk about politicians, entertainers, athletes, writers, and entrepreneurs, but rarely, if ever, scientists. Among a group of six academics from elite U.S. universities at the dinner, no one could name a single outstanding contemporary U.S. scientist.

This was not always so. For much of the 20th century, Albert Einstein was a household-name celebrity in the United States, and every academic was familiar with names such as James Watson, Enrico Fermi, and Edwin Hubble. Today, however, Americans' interest in pure science, unlike their interest in new "apps," seems to have waned. Have the nation's scientific achievements and strengths also lessened? Indeed, scholars and politicians alike have begun to worry that U.S. science may be in decline.

If the United States loses its dominance in science, historians of science would be the last group to be surprised. Historically, the world center of science has shifted several times, from Renaissance Italy to England in the 17th century, to France in the 18th century, and to Germany in the 19th century, before crossing the Atlantic in the early 20th century to the United States. After examining the cyclical patterns of science centers in the world with historical data, Japanese historian of science Mitsutomo Yuasa boldly predicted in1962 that "the scientific prosperity of [the] U.S.A., begun in 1920, will end in 2000."

Needless to say, Yuasa's prediction was wrong. By all measures, including funding, total scientific output, highly influential scientific papers, and Nobel Prize winners, U.S. leadership in science remains unparalleled today. Containing only 5% of the world's total population, the United States can consistently claim responsibility for one- to two-thirds of the world's scientific activities and accomplishments. Present-day U.S. science is not a simple continuation of science as it was practiced earlier in Europe. Rather, it has several distinctive new characteristics: It employs a very large labor force; it requires a great deal of funding from both government and industry; and it resembles other professions such as medicine and law in requiring systematic training for entry and compensating for services with financial, as well as nonfinancial, rewards. All of these characteristics of modern science are the result of dramatic and integral developments in science, technology, industry, and education in the United States over the course of the 20th century. In the 21st century, however, a debate has emerged concerning U.S. ability to maintain its world leadership in the future.

The debate involves two opposing views. The first view is that U.S. science, having fallen victim to a new, highly competitive, globalized world order, particularly to the rise of China, India, and other Asian countries, is now declining. Proponents of this alarmist view call for significantly more government investment in science, as stated in two reports issued by the National Academy of Sciences (NAS), the National Academy of Engineering, and the Institute of Medicine: *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* in 2007, and *Rising Above the Gathering Storm: Rapidly Approaching Category 5* in 2010.

The second view is that if U.S. science is in trouble, this is because there are too many scientists, not too few. Newly trained scientists have glutted the scientific labor market and contribute low-cost labor to organized science but are unable to become independent and, thus, highly innovative. Proponents of the second view, mostly economists, are quick to point out that claims concerning a shortage of scientific personnel are often made by interest groups—universities, senior scientists, funding agencies, and industries that employ scientifically trained workers—that would benefit from an increased supply of scientists. This view is well articulated in two reports issued by the Rand Corporation in 2007 and 2008 in response to the first NAS report and economist Paula Stephan's recent book, *How Economics Shapes Science.*

What do data reveal?

Which view is correct? In a 2012 book I coauthored with Alexandra Killewald, *Is American Science in Decline?*, we addressed this question empirically, drawing on as much available data as we could find covering the past six decades. After analyzing 18 large, nationally representative data sets, in addition to a wealth of published and Web-based materials, we concluded that neither view is wholly correct, though both have some merit.

Between the 1960s and the present, U.S. science has fared reasonably well on most indicators that we can construct. The following is a summary of the main findings reported in our book.

First, the U.S. scientific labor force, even excluding many occupations such as medicine that require scientific training, has grown faster than the general labor force. Census data show that the scientific labor force has increased steadily since the 1960s. In 1960, science and engineering constituted 1.3% of the total labor force of about 66 million. By 2007, it was 3.3% of a much larger labor force of about 146 million. Of course, between 1960 and 2007, the share of immigrants among scientists increased, at a time when all Americans were becoming better educated. As a result, the percentage of scientists among native-born Americans with at least a college degree has declined over time. However, diversity has increased as women and non-Asian minorities have increased their representation among U.S. scientists.

Second, despite perennial concerns about the performance of today's students in mathematics and science, today's U.S. schoolchildren are performing in these areas as well as or better than students in the 1970s. At the postsecondary level, there is no evidence of a decline in the share of graduates receiving degrees in scientific fields. U.S. universities continue to graduate large numbers of young adults well trained in science, and the majority of science graduates do find science-related employment. At the graduate level, the share of foreign students among recipients of science degrees has increased over time. More native-born women now receive science degrees than before, although native-born men have made no gains. Taken together, education data suggest that Americans are doing well, or at least no worse than in the past, at obtaining quality science education and completing science degrees.

Finally, we used a large number of indicators to track changes in society's general attitudes toward science, including confidence in science, whether to fund basic science, scientists' prestige, and freshmen interest in science research careers. Those indicators all show that the U.S. public has remained overwhelmingly positive toward scientists and science in general. About 80% of Americans endorse federal funding for scientific research, even if it has no immediate benefits, and about 70% believe that the benefits of science outweigh the costs. These numbers have stayed largely unchanged over recent decades. Americans routinely express greater confidence in the leadership of the scientific community than that of Congress, organized religion, or the press.

Is it possible that Americans support science even though they themselves have no interest in it? To measure Americans' interest in science, we also analyzed all cover articles published in *Newsweek* magazine and all books on the *New York Times* Best Sellers List from 1950 to 2007. From these data, we again observe an overall upward trend in Americans' interest in science.

Sources of anxiety

What, then, are the sources of anxiety about U.S. science? In *Is American Science in Decline?*, we identify three of them, two historical and one comparative. First, our analysis of earnings using data from the U.S. decennial censuses revealed that scientists' earnings have grown very slowly, falling further behind those of other high-status professionals such as doctors and lawyers. This unfavorable trend is particularly pronounced for scientists at the doctoral level.

Second, scientists who seek academic appointments now face greater challenges. Tenure-track positions are in short supply relative to the number of new scientists with doctoral training seeking such positions. As a result, more and more young scientists are now forced to take temporary postdoctoral appointments before finding permanent jobs. Job prospects are particularly poor in biomedical science, which has been well supported by federal funding through the National Institutes of Health. The problem is that the increased spending is mainly in the form of research grants that enhance research labs' ability to hire temporary research staff, whereas universities are reluctant to expand permanent faculty positions. Some new Ph.D.s in biomedical fields need to take on two or more postdoctoral or temporary positions before having a chance to find a permanent position. It is the poor job outlook for these new Ph.D.s and their relatively low earnings that has led some economists to argue that there is a glut of scientists in the United States.

Third, of course, the greatest source of anxiety concerning U.S. science has been the globalization of science, resulting in greater competition from other countries. Annual news releases reveal the mediocre performance of U.S. schoolchildren on international tests of math and science. The growth of U.S. production of scientific articles has slowed down considerably over the past several decades as compared with that in other areas, particularly East Asia. As a result, the share of world science contributed by the United States is dwindling.

But in some ways, the globalization of science is a result of U.S. science's success. Science is a public good, and a global one at that. Once discovered, science knowledge is codified and then can be taught and consumed anywhere in the world. The huge success of U.S. science in the 20th century meant that scientists in many less developed countries, such as China and India, could easily build on the existing science foundation largely built by U.S. scientists and make new scientific discoveries. Internet communication and cheap air transportation have also minimized the importance of location, enabling scientists in less developed countries to have access to knowledge, equipment, materials, and collaborators in more developed countries such as the United States.

The globalization of science has also made its presence felt within U.S. borders. More than 25% of practicing U.S. scientists are immigrants, up from 7% in 1960. Almost half of students receiving doctoral degrees in science from U.S. universities are temporary residents. The rising share of immigrants among practicing scientists and engineers indicates that U.S. dependence on foreign-born and foreign-trained scientists has dramatically increased. Although most foreign recipients of science degrees from U.S. universities today prefer to stay in the United States, for both economic and scientific reasons there is no guarantee that this will last. If the flow of foreign students to U.S. science programs should stop or dramatically decline, or if most foreign students who graduate with U.S. degrees in science should return to their home countries, this could create a shortage of U.S. scientists, potentially affecting the U.S. economy or even national security.

What's happening in China?

Although international competition doesn't usually refer to any specific country in discussions of science policy, today's discourse does tend to refer, albeit implicitly, to a single country: China. In 2009, national headlines revealed that students in Shanghai outscored their peers around the world in math, science, and reading on the Program for International Student Assessment (PISA), a test administered to 15-year-olds in 65 countries. In contrast, the scores of U.S. students were mediocre. Although U.S. students had performed similarly on these comparative tests for a long time, the 2009 PISA results had an unusual effect in sparking a national discussion of the proposition that the United States may soon fall behind China and other countries in science and technology. Secretary of Education Arne Duncan referred to the results as "a wake-up call."

China is the world's largest country, with a population of 1.3 billion, and grew economically at an annualized growth rate of 7.7% between 1978 and 2010. Other indicators also suggest that China has been developing its science and technology with the intention of narrowing the gap between itself and the United States. Activities in China indicate its inevitable rise as a powerhouse in science and technology, and it is important to understand what this means for U.S. science.

The Chinese government has spent large sums of money trying to upgrade Chinese science education and improve China's scientific capability. It more than doubled the number of higher education institutions from 1,022 in 1998 to 2,263 in 2008 and upgraded about 100 elite universities with generous government funding. China's R&D expenditure has been growing at 20% per year, benefitting both from the increase in gross domestic product (GDP) and the increase in the share of GDP spent on R&D. In addition, the government has devised various attractive programs, such as the Changjiang Scholars Program and the Thousand Talent Program, to lure expatriate Chinese-born scientists, particularly those working in the United States, back to work in China on a permanent or temporary basis.

The government's efforts to improve science education seem to have paid off. China is now by far the world's leader in bachelor's degrees in science and engineering, with 1.1 million in 2010, more than four times the U.S. number. This large disparity reflects not only China's dramatic expansion in higher education since 1999 but also the fact that a much higher percentage of Chinese students major in science and engineering, around 44% in 2010, compared to 16% in the United States. Of course, China's population is much larger. Adjusting for population size differences, the two countries have similar proportions of young people with science and engineering bachelor's degrees. China's growth in the production of science and engineering doctoral degrees has been comparably dramatic, from only 10% of the U.S. total in 1993 to a level exceeding that in the United States by 18% in 2010. Of course, questions have been raised both in China and abroad about whether the quality of a Chinese doctoral degree is equivalent to that of a U.S. degree.

The impact of China's heavy investment in scientific research is also unmistakable. Data from Thomson Reuters' InCites and Essential Science Indicators databases indicate that China's production of scientific articles grew at an annual rate of 15.4% between 1990 and 2011. In terms of total output, China overtook the United Kingdom in 2004, and Japan and Germany in 2005, and has since remained second only to the United States. The data also reveal that the quality of papers produced by Chinese scientists, measured by citations, has increased rapidly. China's production of highly cited articles achieved parity with Germany and the United Kingdom around 2009 and reached a level of 31% the U.S. rate in 2011.

Four factors favor China's rise in science: a large population and human capital base, a large diaspora of Chinese-origin scientists, a culture of academic meritocracy, and a centralized government willing to invest in science. However, China's rise in science also faces two major challenges: a rigid, top-down administration system known for misallocating resources, and rising allegations of scientific misconduct in a system where major decisions about funding and rewards are made by bureaucrats rather than peer scientists. Given these features, Chinese science is likely to do well in research areas where research output depends on material and human resources; i.e., extensions of proven research lines rather than truly innovative advances into unchartered territories. Given China's heavy emphasis on its economic development, priority is also placed on applied rather than basic research. These characteristics of Chinese science mean that U.S. scientists could benefit from collaborating with Chinese scientists in complementary and mutually beneficial ways. For example, U.S. scientists could design studies to be tested in well-equipped and well-staffed laboratories in China.

Science in a new world order

Science is now entering a new world order and may have changed forever. In this new world order, U.S. science will remain a leader but not in the unchallenged position of dominance it has held in the past. In the future, there will no longer be one major world center of science but multiple centers. As more scientists in countries such as China and India actively participate in research, the world of science is becoming globalized as a single world community.

A more competitive environment on the international scene today does not necessarily mean that U.S. science is in decline. Just because science is getting better in other countries, this does not mean that it's getting worse in the United States. One can imagine U.S. science as a racecar driver, leading the pack and for the most part maintaining speed, but anxiously checking the rearview mirror as other cars gain in the background, terrified of being overtaken. Science, however, is not an auto race with a clear finish line, nor does it have only one winner. On the contrary, science has a long history as the collective enterprise of the entire human race. In most areas, scientists around the world have learned from U.S. scientists and vice versa. In some ways, U.S. science may have been too successful for its own good, as its advancements have improved the lives of people in other nations, some of which have become competitors for scientific dominance.

Hence, globalization is not necessarily a threat to the well-being of the United States or its scientists. As more individuals and countries participate in science, the scale of scientific work increases, leading to possibilities for accelerated advancements. World science may also benefit from fruitful collaborations of scientists in different environments and with different perspectives and areas of expertise. In today's ever more competitive globalized science, the United States enjoys the particular advantage of having a social environment that encourages innovation, values contributions to the public good, and lives up to the ideal of equal opportunity for all. This is where the true U.S. advantage lies in the long run. This is also the reason why we should remain optimistic about U.S. science in the future.

Recommended reading

J. M. Diamond, *Guns, Germs and Steel: The Fates of Human Societies* (New York: W.W. Norton & Company, 1999).

Thomas Friedman, *The World Is Flat: A Brief History of the Twenty-First Century* (New York: Farrar, Straus, and Giroux, 2005).

Titus Galama and James R. Hosek, eds., *Perspectives on U.S. Competitiveness in Science and Technology* (Santa Monica, CA: RAND, 2007).

Titus Galama and James R. Hosek, eds., *U.S. Competitiveness in Science and Technology* (Santa Monica, CA: RAND, 2008).

Claudia Dale Goldin and Lawrence F. Katz, *The Race between Education and Technology* (Cambridge, MA: Belknap Press of Harvard University Press, 2008).

Alexandra Killewald and Yu Xie, "American Science Education in its Global and Historical Contexts," *Bridge* (Spring 2013): 15-23.

National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* (Washington, DC: National Academies Press, 2007).

National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, *Rising Above the Gathering Storm: Rapidly Approaching Category 5* (Washington, DC: National Academies Press, 2010).

Organisation for Economic Co-operation and Development, *PISA 2009 Results: Executive Summary (2010)*; available online at www.oecd.org/pisa/pisaproducts/46619703.pdf.

Paula Stephan, *How Economics Shapes Science* (Cambridge, MA: Harvard University Press, 2012).

Yu Xie and Alexandra A. Killewald, *Is American Science in Decline?* (Cambridge, MA: Harvard University Press, 2012).

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