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U.S. Scientific Research and Development 202

A Critical Look at the Federal Research and Development Funding System

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On the cover: The Solenoidal Tracker at RHIC (STAR) is a detector which specializes in tracking the thousands of particles produced by each ion collision at RHIC. Weighing 1,200 tons and as large as a house, STAR is a massive detector. It is used to search for signatures of the form of matter that RHIC was designed to create: the quark-gluon plasma. It is also used to investigate the behavior of matter at high energy densities by making measurements over a large area.

Abstract

As a new Congress begins to deal with the federal budget, it is useful to review the budget setting process in the United States as it applies to research and development (R&D). The federal R&D budget process is a complex, often confusing, procedure characterized by a series of lengthy and frequently contentious negotiations between Congress, the Executive Office of the President, and numerous cabinet-level departments and federal agencies, all attempting to respond to an abundance of expectations and conflicting demands. Here we focus on the parts of the federal budget that deal with science and technology R&D funding in particular.

Introduction

While science and technology's importance is often buried under everyday political struggles, it plays an integral part in the creation of new knowledge and tools as well as driving the world economy. Science and technology positively impacts the economy in a multitude of ways by increasing productivity and improving the quality and variety of available goods. Although tangible returns for science and engineering R&D can be somewhat nebulous, economists over the past half-century have consistently characterized private returns to R&D as "strongly positive," while social returns are even higher.[1] Not only does U.S. R&D serve to improve the lives of Americans, but it also remains essential in maintaining a strong economy both domestically and worldwide.

Science and engineering R&D in the United States is a complex system of performers, those who do the research, and supporters, those who fund the research. Industry funds the largest share (about two-thirds) of national R&D—most of which is done in its own laboratories and is focused on applied R&D, leaving most basic research to be supported by the federal government. Federal support of R&D is provided by a number of federal agencies (cabinet level departments, agencies within departments, and independent agencies) through annual budget appropriations negotiated by the U.S. Congress and the White House.

With a total federal R&D budget of an estimated $144.4 billion in FY 2011, hundreds of thousands of programs and projects are sponsored in federal laboratories, universities, and industries. Funding for R&D has traditionally enjoyed bipartisan support, particularly in connection with defense (mostly applied research and weapons development) and health (biomedical research). However, making the case for increased funding of long-term, basic science and engineering research has become increasingly difficult, in part due to the intrinsic uncertainties about the ultimate impacts of the research such as religious and ideological concerns about certain kinds of research, (e.g., embryonic stem cells) and inadequate communication between scientists and the public and policymakers at all levels. In present times, when reducing annual deficit spending is high on the list of national priorities, the situation is particularly dire. In the innovation-driven economy of the 21st century, funding R&D is more important than ever. Indeed, basic research can simply get lost in the contentious budget debates and partisan squabbles. With new conservative leadership in the U.S. House of Representatives, following the FY 2010 election, the coming budget negotiations are proving to be especially difficult.

By examining some of the general characteristics of R&D funding and the annual federal budget process, one can get a sense of the inter-related parts that must come together to form the federal R&D effort.

The budget process for science and engineering R&D

The budget process for each federal agency begins roughly two years in advance of the final approval of the budget. The president sets out his overarching priorities, which are sent to all federal agencies in the early fall (e.g., the fall of 2010 for the FY 2012 budget, that covers the period October 1, 2011 to September 30, 2012) and which the president will submit to Congress in February 2011. For agencies dealing with science and technology, the president's priorities are detailed in a joint memorandum co-signed by the directors of the Office of Management and Budget, or OMB, and the Office of Science and Technology Policy, OSTP.[2] The agencies are expected to take the president's priorities into consideration in preparing their budget proposals, which include funding for all of their activities for a given fiscal year.

Next, OMB initiates a series of negotiations with each federal agency, resulting in a final draft that becomes part of the President's Budget Request and sent to Congress, usually in early February. Once in Congress, the House and Senate Appropriations Committees disaggregate the President's Budget Request into bundles of agencies that along with a bottom-line allocation, are sent to 12 (nine involving R&D funding) appropriations subcommittees, each of which then prepares a funding bill covering the agencies under its jurisdiction.

The National Science Foundation, or NSF, and National Aeronautics and Space Administration, NASA, are in the same appropriations bill as the Departments of Commerce and Justice. The Department of Energy, DOE, is in a bill that includes energy and water development projects. The National Institutes of Health, or NIH, resides in a bill with the Departments of Education and Labor. And the Department of Defense (DOD) is considered alone.

This disaggregated system of R&D appropriations means that most R&D funding agencies do not compete directly with one another but, rather, with nonscience programs, many of which are popular with the public and special interest groups. These congressional subcommittees wield considerable power over the operations of the agencies. If, at any time during a fiscal year, an agency wishes to deviate from the original budget, even moving relatively small amounts of money from one activity to another, it must obtain approvals from its appropriations subcommittees (House and Senate) as well OMB before proceeding. Thus one often hears agency officials complain about being micromanaged by Congress and spending all of their time on the hill.

The Senate and House must agree on the final 12 funding bills and send them to the president for signature into law by the start of the following fiscal year. Unless an agency "has an appropriation," i.e., the bill including its funding has been signed into law, by the end of a fiscal year, it cannot spend money and must cease operations, except for a small number of specified essential services.

In recent years, including FY 2011, the federal budget was not approved in time for the start of the fiscal year. Delays typically occur due to partisan discord within Congress or between Congress and the president. This requires the enactment of one, or several consecutive, continuing resolutions, which extend the deadline for negotiations beyond October 1.

Delayed budget approvals can cause severe problems for agencies, which usually must continue to work under the guidelines of their previous budgets and have no way of knowing when their budget will be approved or what it will look like. In order to avoid a chain of continuing resolutions, Congress will occasionally bundle the unresolved budget requests together as a single piece of legislation, known as an omnibus appropriations bill. Omnibus bills, which are becoming progressively more common, tend to contain a diverse set of unrelated legislative items. With specific regard to R&D funding, these last-resort bills provide a convenient platform for members of Congress, often with the encouragement of constituents (e.g., universities) to include earmarks.

Earmarks, also known as "pork-barrel spending" or "carve-outs" are defined as "funds provided by Congress for projects or programs where the congressional direction (in bill or report language) circumvents the merit-based or competitive allocation process or specifies the location or recipient, or otherwise curtails the ability of the Administration to control critical aspects of the funds allocation process."[3] Proponents of this practice argue that the money supports excellent research or facilities that would otherwise go unfunded or be delayed by bureaucratic procedures. While that may be true, these earmarks reduce funding available for competitive programs that are held to a higher standard of excellence and are open to proposals from researchers and universities across the country.

In his 2011 State of the Union speech (January 25, 2011), President Obama stated that he would veto any bill that comes to his desk containing an earmark. While many members of Congress agree with him in principle, earmarks have been popular with members of Congress, Democrats and Republicans, for many decades. Even if earmarks can be avoided in the FY 2012 budget, it will require an unprecedented degree of discipline to eliminate them in future years.

In the United States, in contrast to many other countries, there is no central mechanism to assess the nation's progress in science and technology and coordinate annual R&D budgets across the federal government. Only OSTP in the White House focuses on the nation's overall science and technology enterprise and federal R&D programs, but OSTP's role is an advisory one, and it does not have funding authority for these efforts. Large interagency R&D efforts (e.g., the National Nanotechnology Initiative) are coordinated by committees of the cabinet-level National Science and Technology Council, or NSTC, and often have small coordination offices to help track progress. However, funding for such programs is provided through the agencies according to each agency's process and priorities.

Current status of federal R&D funding

While the level of total nondefense federal R&D funding in the United States has been relatively stable in recent decades at approximately 10 percent of total nondefense discretionary federal spending, science and technology is not routinely a high priority and does not have privileged status with regard to funding. One notable exception in recent decades, has been NIH funding, which grew from 14 percent of the total federal R&D budget in 1970, to 26 percent in 1990, and doubled between FY 1998 and FY 2003 making it half of the total nondefense R&D budget. But the doubling was followed by an extended period of flat funding afterward.

In FY 2011, the federal government allocated $62 billion for nondefense R&D. For research alone (including defense but not development expenditures) this total was $61 billion. Eighty-six percent of federal research funding is divided among five agencies: NIH (50 percent), DOD (13 percent), DOE (12 percent), NSF (8 percent), and NASA (3 percent). (see Figure 1) The remaining 14 percent went to research programs led by a diverse set of federal agencies including the Departments of Agriculture, Interior, Commerce, Homeland Security, and the Environmental Protection Agency, or EPA.

Of the primary R&D funding agencies, NSF is the only one that supports all areas of basic nonmedical science and engineering, as well as science, technology, engineering and mathematics, or STEM, education and outreach. NIH supports biomedical research, with an overarching goal of improving human health. NASA predominately supports development-stage research, but its research focuses on space-based science, earth observations from space, and aeronautics. DOE funds research in the physical and mathematical sciences, including nuclear and high-energy physics, chemistry, basic energy research, and environmental science.

In recent years, there has been a growing concern in Congress, the White House, and the science and technology community and industry that the United States is losing its competitive edge in global science and technology. Reports such as the National Academies's "Rising Above the Gathering Storm" (and its 2010 update "Rapidly Approaching Category Five") have made a compelling case for increased investments in research.[45] In particular, there is a need to promote the physical and mathematical sciences as well as many areas of engineering that have been neglected for decades. One reason for some urgency is the rapidly increasing competition from abroad, especially from Asia, in all areas related to science, technology, innovation, and economic competitiveness.

In 2007 and again in 2011, Congress passed the "America COMPETES Act" with the stated purpose "to invest in innovation through research and development, and to improve the competitiveness of the United States." Increased funding for research also figured prominently in the "American Recovery and Reinvestment Act", with approximately $20 billion added to the FY 2009 budget for in nondefense R&D, primarily research funded by NIH ($10 billion), NSF ($3 billion), DOE ($4 billion), and NASA ($1 billion). These funds were to be spent in FY 2009 and FY 2010 with no expectation that they would increase the agencies' base budgets, hence would not contribute to increases in the budgets for FY 2011 and beyond.

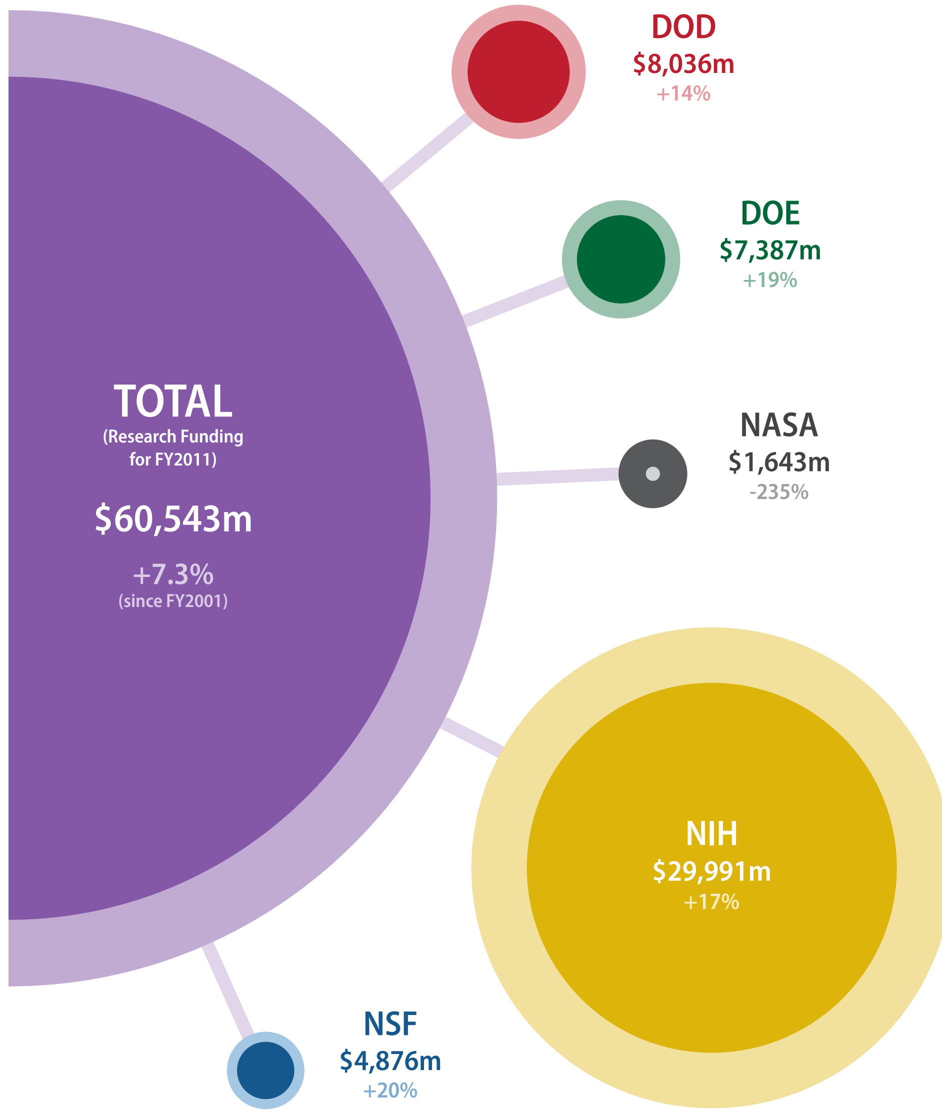
In President Obama's FY 2010 and 2011 budget requests, he emphasized the importance of basic research. Unfortunately, Congress's failure to send the president any appropriations bills for FY 2011 produced a string of continuing resolutions, the last of which appropriated funding for the remaining months of FY 2011 and resulted in an average of 1 percent cuts relative to the previous year in funding for the major research agencies, including NIH (down $300 million from $30.7 billion in the FY 2010 enacted budget), NSF (down $65 million from $6.8 billion), and DOE's Office of Science (down $30 million from $4.88 billion).

FIGURE 1

U.S. federal research funding*

Comparison of 2001 and 2011 levels in the five major S&T agencies (in constant 2011 dollars)

* These data are basic and applied research only. They do not include R&D facilities and capital equipment or development funds.



Sources: www.aaas.org/spp/rd/tbres09p.pdf and www.aaas.org/spp/rd/rdreport2012/tblii01a.pdf.

President Obama's FY 2012 budget request is an effort to rescue science budgets by raising overall R&D roughly to the FY 2010 levels and providing significant increases for research funding. The proposed budget would increase total R&D funding to $149.1 billion, up by $4.7 billion from the FY 2011 enacted budget. The proposed budget includes a 10 percent increase (or $6.0 billion) for total research, specifically, a 15.9 percent increase for the NSF budget (to $5.7 billion), a 22.3 percent increase to DOE (to $9 billion) and a 3.4 percent increase for NIH (to $31 billion). Additionally, President Obama's FY 2011 budget request emphasizes energy efficiency and renewable energy as well as climate change initiatives; it includes a 21 percent increase (to $2.6 billion) for multi-agency climate change research, and a 5 percent increase (to $2.4 billion) for DOE's Energy Efficiency and Renewable Energy R&D programs.[6]

Unfortunately, the political divide between the Republicans in Congress, especially in the House of Representatives, and the White House as well as the upcoming 2012 presidential election make it unlikely that President Obama's budget will pass without major cuts to R&D. This is unwise because R&D leads innovations that help drive the economy. Without steady support for science and technology, the economy is likely to stagnate. There continues to be bipartisan support for basic research funded by agencies such as NSF, DOE's Office of Science, the National Institute of Standards and Technology, NIST, and NIH. But even for these agencies, an optimistic scenario would be very modest increases relative to FY 2011, perhaps only slightly above inflation. If basic research is treated favorably in the budget negotiations, this would signal that concerns raised about American innovation and competitiveness are resonating with the public and the elected representatives in Washington, even in difficult economic times.

International comparisons of R&D spending

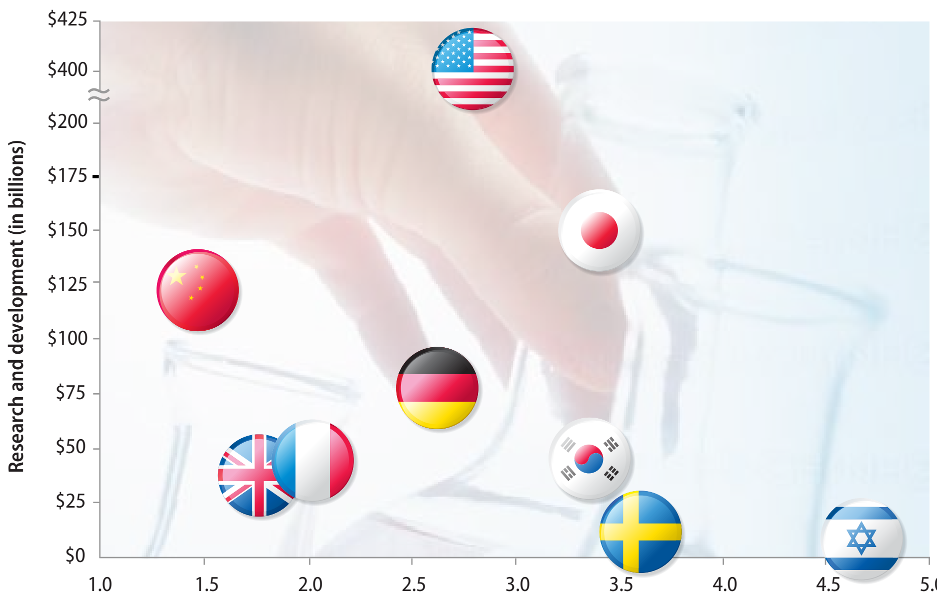
While the United States wrestles with its funding priorities, other nations are showing greater resolve to move ahead. According to the Organisation for Economic Co-operation and Development, or OECD, in 2008, the United States led the world in total national R&D spending (public and private) with $398 billion (see Table I and Figure 2), accounting for 35 percent of the approximately $1.1 trillion total global R&D expenditures followed by Japan, China, and Germany.[7]

Including public and private sources, the United States invested 2.8 percent of its gross domestic product, GDP, in R&D in 2008. This figure ranks the United States behind a number of other countries including Israel, Japan, and Switzerland which all have R&D-to-GDP ratios above 3 percent (Figure 2).[8] There is no rigorous basis for arguing that a particular percentage of GDP is optimal, however, such comparisons can provide an indication of relative spending priorities among nations. In a recent review from the National Bureau of Economic Research, returns from investments in R&D, both from public and private sources, are "strongly positive" and can be higher than other types of investments.[9] Furthermore, in 2007, knowledge and technology intensive industries provided almost 30 percent of global economic output.[10]

The increased globalization of science and technology and the growth of national investments in R&D in many parts of the world are also evidenced by the steady increase in research publications worldwide. From 1995 to 2007, the world has seen an average annual increase of 2.5 percent in published research articles.[11] International co-authorship has also markedly increased during this time period, from 13 to 22 percent. Historically the United States has dominated R&D

FIGURE 2

International R&D expenditures and percentage GDP



Source: OECD Factbook 2010: Economic, Environmental and Social Statistics; OECD Main Science and Technology Indicators, 2010.

output, but the U.S. percentage of total publications worldwide has fallen from 34 to 28 percent during this same 12-year period, while the number in East Asia has nearly doubled.[12]

In his April 27, 2009 speech to the National Academy of Sciences, President Obama announced his goal to "devote more than 3 percent of our GDP to research and development," and specifically to "promote breakthroughs in energy and medicine." Realizing this objective would require an increase in federal R&D spending, as well as a significant increase in R&D investment by U.S. industry. In the same speech, Obama committed to a 10-year plan to double the amount of funding going to three key federal research agencies and organizations that focus on research in the physical sciences and engineering: NSF, DOE's Office of Science, and NIST. The president's budget requests for FY 2010, 2011, and 2012 have been consistent with this plan. However, especially in FY 2011, Congress has chosen to fund R&D at lower levels than the presidential request and, with the slow pace of economic recovery in the United States, it will very difficult to grow federal R&D funding in the near-term. The arguments for long-term investment in R&D tend to get lost in budget battles over issues that have nothing to do with science and technology, as has often happened in the past.

TABLE 1

International R&D expenditures and percentage GDP

Country	R&D (in billions)	% Share	% GDP
China	$121.30	11%	1.49
United Kingdom	$38.70	3.4%	1.77
France	$42.90	3.8%	2.02
Germany	$76.80	6.8%	2.64
United States	$398.20	35%	2.77
Korea	$45.40	4.0%	3.37
Japan	$149.20	13%	3.42
Sweden	$12.08	1.1%	3.6
Israel	$8.85	0.8%	4.68
All other	$233.87	21%	--
Total world	$1,127.30	--	--

Source: OECD Factbook 2010: Economic, Environmental and Social Statistics; OECD Main Science and Technology Indicators, 2010.

The future of U.S. science and technology–Bright or cloudy?

America's continuing leadership in science and technology is largely due to 60 years of investment in long-term, basic and applied scientific research following WWII, especially following the launch of Sputnik in 1957.[13] But, over the last four decades, federal funding for the physical, mathematical, and engineering sciences has declined by one-half as a percent of GDP from 0.25 percent to 0.13 percent, while other countries such as China and Japan have emphasized these fields (EOP, 2010).[14]

Even funding for NIH has experienced little fiscal growth over the last eight years, in spite of the American public's strong support of biomedical research. The lack of a coherent government strategy for evaluating the impact of federal programs and setting R&D funding priorities across the federal government, combined with sometimes dramatic "feast to famine" swings in funding, particularly for NIH, should raise the question of whether the American people are getting their money's worth from federally funded R&D. Many programs and projects start and stop—sometimes abruptly—with the availability of government-funded grants. Such inconsistencies waste money and interrupt careers. The balance between funding for biomedical research and other fields is also an important policy issue in need of high-level discussions.

On the matter of assessing impacts of research investments, the federal government's implementation of the Government Performance and Results Act, specifically its process of evaluation, is uneven and tends to favor applied areas that have short-term objectives and quantitative metrics. Basic research investments are difficult to evaluate and increasingly difficult to justify. While scientists appreciate that the government has to be accountable to the public, Congress has no process to engage the scientific community to evaluate the impacts and benefits of research, and instead relies on hearings and ad hoc consultations for its external advice.

Science and technology policy actions, including federal R&D budgets, are further complicated by religious, ideological, or political concerns and agendas that often come across as antiscience. While most science-related matters are politically neutral, some recent national issues related to science, such as human embryonic stem cell research, climate change, and evolutionary biology have become highly politicized. When controversial science issues develop into Constitutional dilemmas, which require action from the judicial branch, or into contentious partisan disputes, policy decisions are often made without regard for the scientific evidence. In some instances, research funding for related scientific research suffers as well. There have even been documented efforts by members of Congress to deny funding for specific research grants that have gone through the peer-review process.[15]

In an effort to insure objectivity in these debates, scientists are needed to help clarify the scientific and technical aspects of the issues and to counter false assertions and misrepresentation of facts. This requires that scientists actively engage policymakers and the public in open dialogues, by talking with students, community groups, and legislators when they have the opportunity. But outreach presents a conundrum for scientists who want to stay out of the fray. Getting involved is not without personal and professional risk—all the more reason we should support those in our community who take on the challenge.

Of the many challenges we have touched on facing the United States science and technology effort, some could be mitigated by improved communication, or more accurately, conversation, between scientists, policymakers, and the American public. The current lack of mutual understanding about scientific and technical matters is, we believe, one of the greatest challenges facing science in the United States, especially during these times of national economic stress and budget cutting.

Fortunately, the general public continues to value science, even if most people have little understanding of science or the scientific process. According the 2010 Science and Engineering Indicators, the majority of U.S. citizens strongly support federal R&D funding and appreciate the positive impact science has on their lives. However, many Americans have not had any formal education in math and science beyond high school and "cannot provide correct answers to basic questions about scientific facts and do not apply appropriate reasoning strategies to questions about selected scientific issues".[16]

It is not clear what can be done about this in the short-term or even how a lack of understanding of mathematics and science influences how people feel about their importance. That said, as science, particularly biomedical science, continues to advance at a rapid pace, there will be many more findings that challenge the comfort level of the average American and citizens of other countries as well. It is risky to assume that the American people will continue to support science, which they do not understand, regardless of the perceived implications. They will need information they can understand provided by people they can trust.

Scientists also need to have a better understanding of the public. Often the message scientists think they are sending out is very different from the message the public hears. The American Academy of Arts and Sciences report, "Do Scientists Understand the Public," suggests that if we are going to be more effective in convincing the public of the unique importance of investments in R&D, we need to listen to the American people, hear the same voices that their elected political leaders hear, and gain a better appreciation of arguments used by various groups advocating more funding for one cause or another.

Sherwood Boehlert, former chairman of the House Science and Technology Committee and strong supporter of science, stated that "The argument that science funding is a long-term investment does nothing to set scientists apart. All that sets [them] apart is that scientists are the only group that thinks it's making a unique argument."[17] There are many strong advocates for science, but they need our help. Words like investment, exploration, discovery, innovation, competitiveness, security, and health are appropriate and sound good—but they are not enough. We will have to be more specific. The American public is well aware that spending 50 percent of all federal research dollars on biomedical research has not resulted in affordable health care. We might start by demonstrating that we intend to do something about that dilemma. Most Americans understand that climate change is a problem, but they are not hearing realistic solutions that they can understand and support. True, there are well-funded organizations dedicated to confusing the public on this topic. But that just means we will have to work harder and smarter.

Scientists who step outside their traditional roles as researchers and practitioners to engage the public and policymakers in a dialogue are often referred to as "civic scientists." Thousands of "civic scientists" are working with K-12 schools; lecturing to Rotary Clubs and other community organizations; giving interviews to the media,' writing books, articles, and blogs for the pubic; advising governments at all levels; and even spending time working in government agencies and in Congress. All of them need and deserve our support for their efforts. And they could use some company.

Endnotes

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