Federal R&D Budget Trends: A Short Summary

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The following is intended as a brief summary of some major trends in federal R&D expenditures over the past several years.

Why Does Government Fund R&D?

Government has historically had a major hand in science and technology. There are a few simple rationales for why. The most immediate are government missions like national security, agriculture, environmental health, or infrastructure. To successfully fulfill these public missions requires interaction with science and technology.

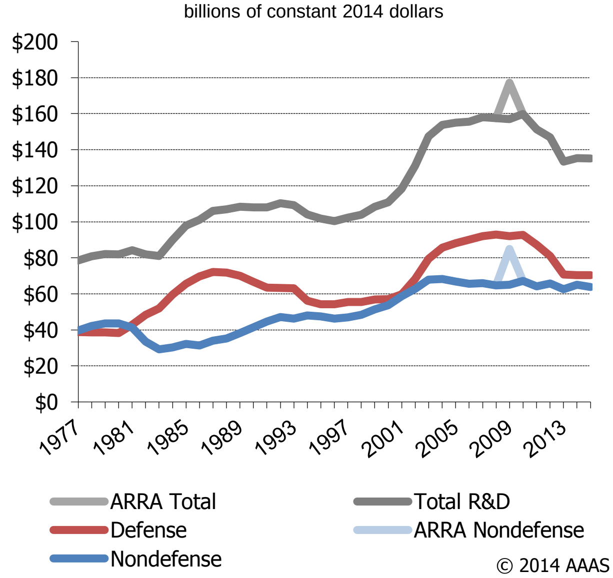
But there is a broader rationale for discovery science and advanced technology. Generally, the societal benefits of R&D are greater than the private benefits of R&D. Due to knowledge spillovers, it's difficult for the creator of new knowledge to reap all the benefits of that knowledge. This creates an allocation problem. As economist Joseph Stiglitz writes, "Knowledge can be viewed as a public good, and the private provision of a public good is essentially never optimal."[i] Additionally, many worthy research projects are risky, with uncertain prospects for success or future utility, and may require a long-term commitment of resources and infrastructure. These qualities of the science enterprise lead to underinvestment by private industry, which *in general* is more focused on lower-risk research and product development with the promise of short-term results. This is why industry spends 80 cents of every R&D dollar on development, and only 20 cents on basic and applied research (for civilian science agencies, the ratio is reversed).

As a result, writes a recent National Academies panel on the American research enterprise, "Increasingly, government is called upon to fund high-risk, long-term research and some types of applied research, particularly proof-of-concept research, at least to the point where the risks of investment in such research are reduced to attract private-sector funding."[ii] In this sense, the public research enterprise lays a foundation of knowledge, tools, and skills. At its best, it forms part of an ecosystem with universities and industry, contributing to progress in pharmaceuticals, semiconductors, food, aerospace, and other sectors through research output, human capital, and infrastructure and instrumentation.[iii] There is a track record of productive government interaction with outside actors, especially from within the defense system.[iv] With the globalization of science and the rise of R&D capacity in East Asia and elsewhere, such public-private interaction will become more important over time from a competitiveness perspective.

Major Budget Trends

In the past 15 years, federal appropriations for total R&D have experienced three approximate phases (see Figure 1, which brings the data back to 1977). In the "first phase," up to FY 2004, federal R&D increased rapidly, by

Figure 1: Federal R&D Since 1977
billions of constant 2014 dollars



38.5 percent. The "second phase" ran from FY 2004 to about FY 2010, and was marked by little change in the overall budget, but a divergence between defense and nondefense R&D. The end of the second phase was marked by the one-time funding boost in the American Recovery and Reinvestment Act, in FY 2009. Since FY 2010, funding has entered a jagged third phase of decline and recovery.

Each of these phases reflects the politics of the day, to varying degrees. The first-phase increase, coinciding with the end of the Clinton years and the first few years under George W. Bush, had two major drivers. First, Department of Defense (DOD) R&D accelerated following the September 11 attacks. Second, the period marked the completion of the bipartisan budget doubling at the National Institutes of Health (NIH), which began in 1998 over concerns for public health. In addition, R&D budgets expanded at the National Science Foundation (NSF), the National Nuclear Security Administration (NNSA), the Office of Science in the Department of Energy (DOE), and the Departments of Agriculture (USDA) and Veterans Affairs (VA). R&D investment no doubt benefited from a federal surplus and a loosening of Congress's position on discretionary spending limits at the time. Defense R&D increased by 49.7 percent over this time, while nondefense R&D grew by 26.6 percent.

In the second phase, funding for agencies and missions clearly diverged. The DOD R&D budget remained elevated and growing given national security concerns of the time. Meanwhile, the nondefense R&D budget began to erode. Funding did increase for some agencies, especially NSF, DOE Science, and the National Institute of Standards and Technology (NIST). All three of these agencies were targeted for budget doubling by America COMPETES, which placed the spotlight on the physical sciences, math, and engineering following the NIH doubling.[v] But even for agencies that gained budget ground, the rate of increase slowed appreciably from the earlier first phase. And some agencies, most notably NIH, lost ground due to sub-inflation appropriations, if not outright cuts, over this time. Total federal R&D in this period grew by only 2.9 percent after inflation. Defense R&D grew by 7.2 percent, while nondefense R&D declined by 2.4 percent.

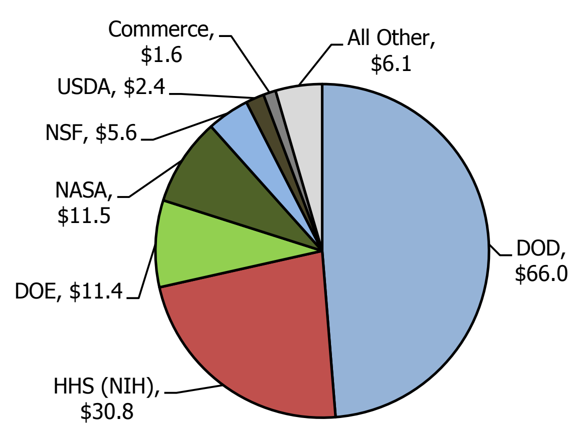
In FY 2009, the American Recovery and Reinvestment Act (ARRA) contributed $20.2 billion to federal R&D, in FY 2014 dollars. This included $3 billion for NSF, $11.2 billion for NIH, and $3.2 billion for DOE, with other civilian science agencies dividing the remainder.

FY 2010 was the high water mark for inflation-adjusted federal R&D. In FY 2011, with deficits becoming a major political issue, Congress began cutting discretionary spending, and R&D was not immune. Thus, in the third phase, the R&D budget has declined by an estimated 15.4 percent, a more than $24 billion drop. Reductions in spending for downstream technology development at DOD have played a big role in this decline; the decline in civilian science and technology has been much smaller. Sequestration in FY 2013 has also played a big role in the decline, though R&D budgets had already been coming down for two years at that point. The overall reductions up to FY 2013 were larger than any other three-year period since the end of the space race.

Following sequestration, there has been a very modest recovery in most nondefense science and technology accounts. As a result, since FY 2010, nondefense R&D is only down by an estimated 4.9 percent, while defense R&D has declined by an estimated 24.1 percent. DOD science and technology specifically has declined by 11.8 percent.

The estimated distribution of R&D by agency in FY 2014 is shown in Figure 2. This distribution doesn't tend to change radically year-to-year.

Figure 2: R&D by Agency, FY 2014
budget authority in billions of dollars

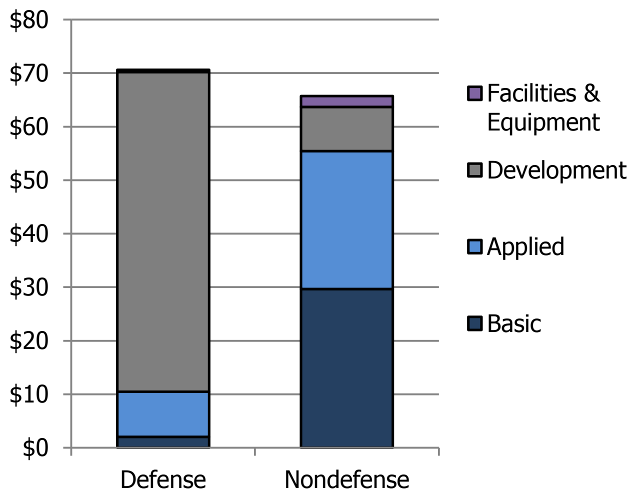


Source: OMB R&D data, agency budget justifications, and other agency documents and data. R&D includes conduct of R&D and R&D facilities.

Federal R&D by Character

R&D budget data is recorded in five categories: basic research, applied research, development, facilities, and equipment (the latter two are combined as "R&D plant"). The definitions for these activities are provided in OMB Circular A-11, Section 84 (see box). Agencies do their best

Figure 3: R&D by Character in the FY 2015 Budget
budget authority in billions



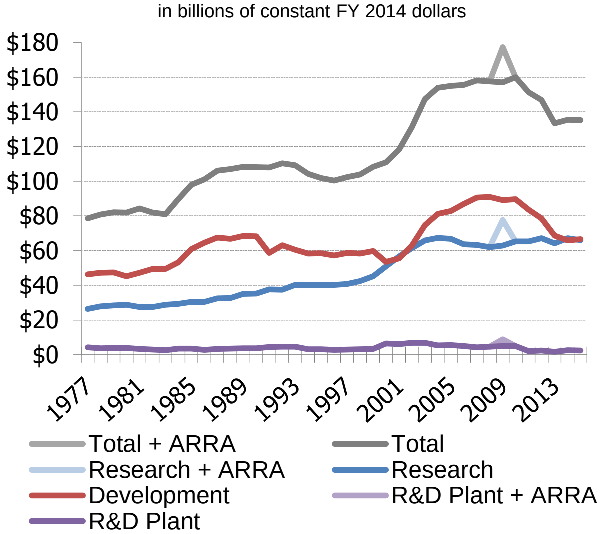
Source: OMB R&D data and agency budget documents. © 2014 AAAS

to accurately and consistently apply these definitions, but there will always be a level of subjectivity, especially between basic and applied research. Indeed, the idea of jettisoning the entire basic/applied dichotomy has its proponents.[vi]

Different parts of the federal R&D enterprise focus on different classes of R&D. Generally, basic and applied research is a pursuit for the civilian science agencies. Development is mostly funded by DOD, as part of its efforts to acquire advanced weaponry, vehicles, and medical and communications technologies, and by NNSA, through its stockpile and naval reactor programs. But this division isn't perfect. Civilian science agencies do fund substantial developmental activities, mostly at NASA, but also DOE, DHS, and elsewhere; and the defense apparatus maintains a sizable research enterprise through the military branches and defense agencies like DARPA (see Figure 3).

Historical budget authority for R&D by character is shown in Figure 4. Note that in this chart, "Research" refers to basic plus applied research. In recent decades, development has tended to run ahead of research, though the gap has closed of late. The trends track defense and nondefense spending (Figure 1) fairly closely.

Figure 4: Federal R&D by Character
in billions of constant FY 2014 dollars



Source: AAAS analyses of OMB and agency data. © 2014 AAAS

OMB R&D Definitions

"**Basic research** is defined as systematic study directed toward fuller knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications towards processes or products in mind. Basic research, however, may include activities with broad applications in mind."

"**Applied research** is defined as systematic study to gain knowledge or understanding necessary to determine the means by which a recognized and specific need may be met."

"**Development** is defined as systematic application of knowledge or understanding, directed toward the production of useful materials, devices, and systems or methods, including design, development, and improvement of prototypes and new processes to meet specific requirements."

R&D facilities spending "includes the acquisition, design, and construction of, or major repairs or alterations to, all physical facilities for use in R&D activities. Facilities include land, buildings, and fixed capital equipment, regardless of whether the facilities are to be used by the Government or by a private organization, and regardless of where title to the property may rest. Includes fixed facilities such as reactors, wind tunnels, and particle accelerators."

Lastly, **R&D equipment** spending "includes acquisition or design and production of movable equipment, such as spectrometers, research satellites, detectors, and other instruments. At a minimum, this line should include programs devoted to the purchase or construction of R&D equipment."

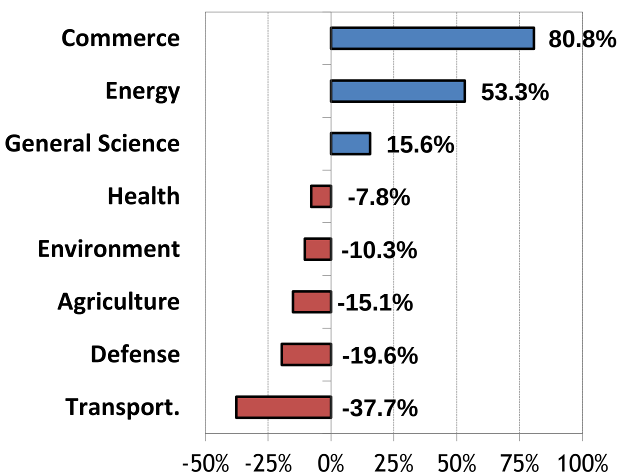
Source: OMB Circular A-11, Section 84

Federal R&D by Budget Function

Yet another way to evaluate changes in R&D is by budget function, the 20 or so spending categories used to classify government outlays. While almost all functions have some R&D spending, only ten contain $1 billion or more, and most is concentrated in four: defense, health, general science, and space (the latter two are technically part of the same function, but are broken out for our purposes). Energy, environment, and agriculture also usually contain at least $2 billion in R&D spending each. Transportation, commerce, and justice are the remaining three in the neighborhood of $1 billion.

Since budget functions group spending by category, comparing across functions can help show where the broad funding priorities have been for Congress and the executive branch over time. Figure 5 below shows changes in R&D spending by budget function over ten years, from FY 2005 to FY 2014.

Figure 5: R&D Changes by Select Budget Functions, 2005 - 2014
constant dollars



Source: AAAS analysis of historical data and current R&D data. Adjusted for comparability. © 2014 AAAS

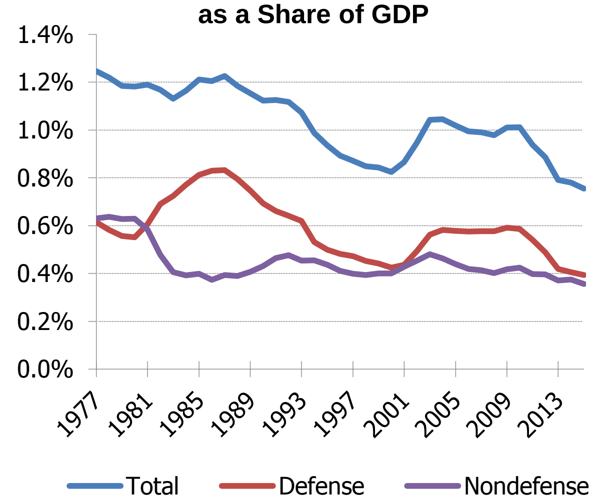
This chart warrants a few notes. The apparent growth in the **commerce** function is somewhat overstated. The function is dominated by NIST R&D, which has grown, but it also includes the Census Bureau, which in FY 2014 reported a relatively large and apparently one-time uptick in research spending associated with the periodic census. The **energy** function only covers applied energy programs, of which nuclear energy R&D has by far grown the most since FY 2005. **General science** includes NSF and DOE Science, both COMPETES agencies. The **health** function is dominated by NIH, but also includes other Health and Human Services agencies, and AAAS includes the VA in this function. The **environment** function includes several programs and agencies, notably EPA, the Department of the Interior, the National Oceanic and Atmospheric Administration (NOAA), and the Forest Service. The **defense** function includes NNSA and DOD.

Note that the space function has been left out of this comparison. Multiple changes in NASA's R&D reporting and account structure over the years make cross-year comparisons difficult (NASA's aeronautics research is housed in the **transportation** function above, and cuts to that program's funding help explain the overall transportation decline). NASA's discretionary budget, however, has declined by 7.7 percent since FY 2005.

R&D As a Share of the Economy

R&D as a share of gross domestic product (GDP), a metric known as "research intensity," is a commonly-used descriptor of a nation's competitive health. It is far from a definitive metric, but it does say something about the extent to which a given country is able and willing to prioritize public investment, or induce private investment, in science and technology relative to other activities.

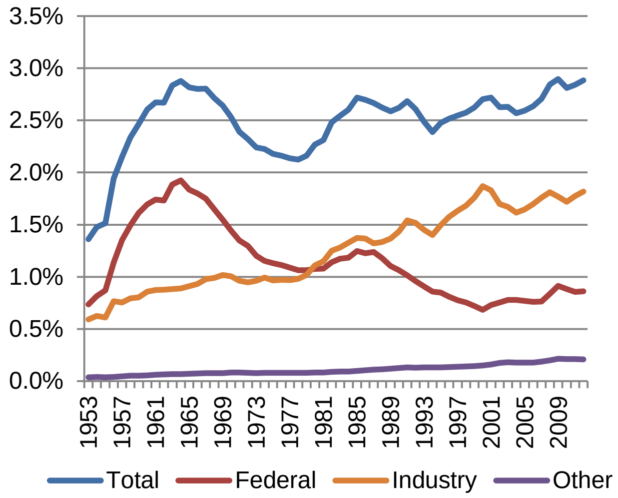
Figure 6: Federal R&D as a Share of GDP



Based on AAAS analysis of historical R&D and GDP data. © 2014 AAAS

Figure 6 uses R&D budget authority data compiled by AAAS over the years, and GDP data from OMB. Clearly, the overall trend since the 1970s has been downward. During the space race in the 1960s (not shown above), federal R&D outlays peaked above two percent. As of FY 2014, the R&D budget had declined to an estimated 0.78

Figure 7: R&D as a Share of GDP by Funder



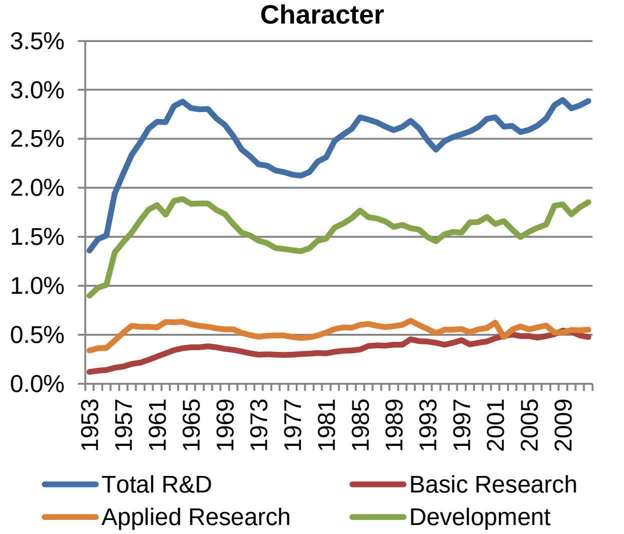
Source: National Science Foundation, *National Patterns of R&D Resources* survey series. © 2014 AAAS

percent of GDP. This decline is likely to continue as discretionary spending continues to shrink.

Nondefense R&D has remained fairly steady as a share of GDP since steep cuts in the 1980s. In most years, the economy only moderately outpaces nondefense R&D. Defense R&D has declined more clearly. Note that these trends mean development has also dropped more quickly than basic and applied research relative to GDP.

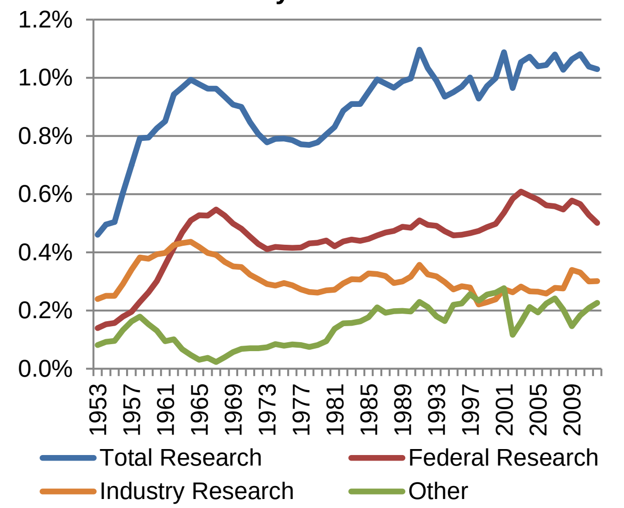
While the federal share of R&D has come down, it has been more than offset by increasing contributions from industry, and to a much lesser extent universities, state

Figure 8: R&D as a Share of GDP by Character



Source: National Science Foundation, *National Patterns of R&D Resources* series. © 2014 AAAS

Figure 9: Research as a Share of GDP by Funder



Source: National Science Foundation, *National Patterns of R&D Resources* series. © 2014 AAAS

governments, and research foundations. Figure 7 shows the big picture; note that data in this section come from surveys administered by NSF's National Center for Science and Engineering Statistics (NCSES), a different source from that shown in earlier figures.

Industry now accounts for the vast majority of national R&D, which has been growing for decades. Interestingly, the character of the national R&D enterprise hasn't changed much even as government and industry funding has flipped. Basic research, applied research, and development have all held steady or grown as a share of the economy, according to NSF surveys (Figure 8).

This is somewhat counterintuitive given industry's focus on short-term development. But if one recalls the trends discussed earlier, federal development has declined more rapidly than federal research, mainly due to defense declines. Thus, an important note is that the federal government still accounts for the greatest share of total research spending (Figure 9).

Who Performs Federal R&D?

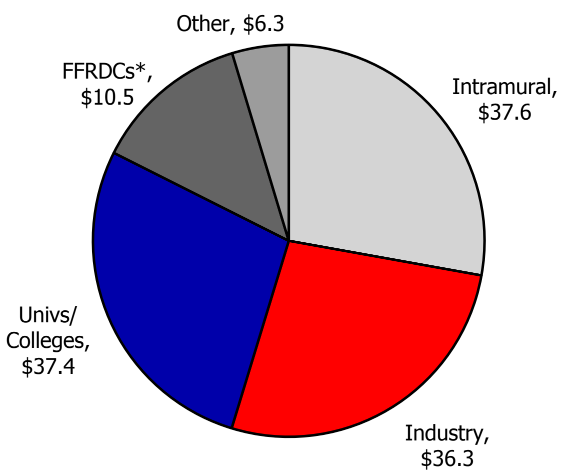
Federally-funded R&D is conducted by a range of performers. Figure 10 shows the distribution of research and development by performer as of 2012, courtesy of the NCSES *National Patterns of R&D Resources* survey[vii]. The figure excludes R&D plant.

As can be seen, intramural researchers, industry, and universities all accounted for similar shares of the federally-funded R&D portfolio, around 29 percent each.

Federally funded R&D centers (FFRDCs), also known as the national labs, accounted for 8.1 percent. The "Other" category is primarily nonprofit research institutes.

While most agencies offer a mixed funding profile, they also have clear emphases and tendencies regarding performers. DOD R&D funding emphasizes industrial contractors who handle its technology development work, though DOD also maintains an extensive intramural research enterprise and, given its size, still has enough dollars left over to remain a major university research funder, behind only NIH and NSF. NIH also maintains significant intramural research capacity. DOE channels the largest portion of its funding through the FFRDCs for both defense and civilian science and technology work, while NASA's largest expenditures are for industry-performed R&D.

Figure 10: Federal R&D by Performer, FY 2012
obligations in billions



* Federally funded R&D centers: government-owned, contractor-operated laboratories. Source: National Science Foundation, *National Patterns of R&D Resources.* Figures are preliminary.

The Changing Global Landscape

While this review is primarily focused on U.S. trends, it is worth bearing the international context in mind. Global spending on R&D is on a rapid upward trend. Per NCSES, global R&D has roughly doubled since 1999, approaching $1.5 trillion today.[viii]

While the United States remains by far the single largest contributor to R&D – funding more than twice as much as the next-largest funder, China – R&D resources are steadily shifting east. Within the OECD data set, the United States accounted for 40.1 percent of R&D in 2000 but only 30.6 percent in 2012. The EU showed a somewhat smaller decline, from 27.4 percent to 23.1 percent. Meanwhile, the five East Asian states included in the set – China, Singapore, Taiwan, Japan, and South Korea – collectively increased their share of R&D from 24.0 percent in 2000 to 36.8 percent in 2012.[ix] China has been the major driver in this growth, but three of the other four, excluding Japan, have also grown rapidly (see box). OECD analysts believe China may surpass the United States in total R&D funding from all sources by 2019.[x]

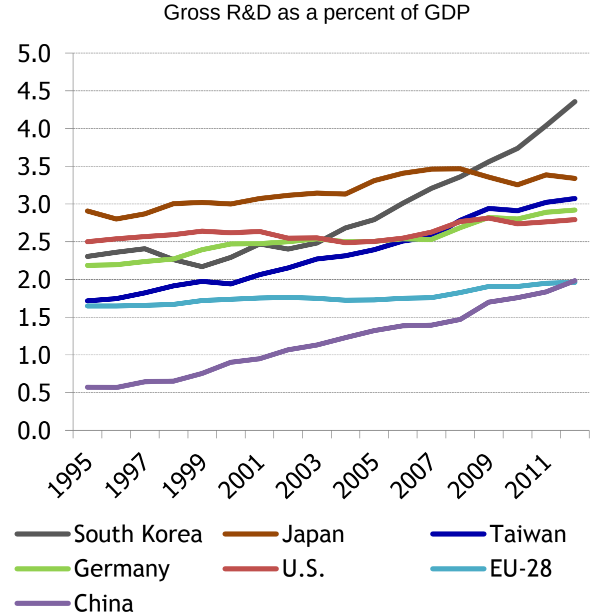
Average Annual R&D Growth in Select Economies, 2000-2012
Constant dollars

United States	2.3%
China	17.6%
Japan	1.5%
Germany	3.5%
France	2.2%
South Korea	8.8%
U.K.	0.7%
Russia	9.0%
Taiwan	7.7%
Italy	2.5%
Canada	1.2%
Singapore	6.5%

Estimates based on OECD Science and Technology Indicators

Examining the trends in research intensity – which, again, refers to R&D as a share of GDP – the gradual shift in R&D resources from west to east is also apparent (Figure 11). Of the major countries shown, since 1995, China,

Figure 11: International Research Intensity
Gross R&D as a percent of GDP



Source: OECD Science & Technology Indicators. © 2014 AAAS

Korea and Taiwan have seen the most rapid increases, while American, Japanese, and European growth has been restrained, albeit starting from a much larger base (with some exceptions, like Germany and certain Scandinavian economies).

Both the European Union and President Obama have established research intensity goals of 3 percent of GDP. Since the vast majority of global R&D is funded by industry, meeting research intensity targets requires both increased and stable public investment and business-oriented policies like tax credits, intellectual property protections, and other measures to incent additional R&D expenditures from industry.

Lastly, it's worth noting that in most countries, the percentage of total R&D funded by government hasn't seen much significant change since 2000. In most major R&D economies, government's share of total R&D tends to hover around one-third, though there can be significant variation country-by-country, a reflection of the diversity of national science and innovation strategies. According to OECD data, the aggregate percentage of R&D funded by governments among the EU-15 countries is virtually unchanged since 2000. Among member states, the British and Swedish governments' relative shares of R&D in their individual economies have increased, while the French government's share is about the same, and the German and Finnish governments' relative shares have declined. The Chinese government funded 21.7 percent of Chinese R&D in 2011, down from 33.4 percent in 2000. The Japanese government only funded 16.4 percent of R&D in Japan in 2011, a slight decrease from earlier years and a reflection of the fact that the Japanese R&D profile has generally been industry-heavy. There are also a few outliers, including Russia, in which government funds a majority of R&D.

[i] Joseph E. Stiglitz, "Leaders and Followers: Perspectives on the Nordic Model and the Economics of Innovation," NBER Working Paper 20493, September 2014.

[ii] National Research Council *Furthering America's Research Enterprise*. R.F. Celeste, A. Griswold, and M.L. Straf (Eds.), National Academies Press, 2014.

[iii] See Wesley M. Cohen, Richard R. Nelson, and John P. Walsh, "Links and Impacts: The Influence of Public Research on Industrial R&D." *Management Science,* Vol 48, no. 1 (1-23), January 2002.

[iv] For case studies, see Vernon W. Ruttan, *Is War Necessary for Economic Growth?* Oxford University Press, 2006; Fred Block and Matthew R. Keller, Eds, *State of Innovation: The U.S. Government's Role in Technology Development*, Paradigm Publishers, 2011; Mariana Mazzucato, *The Entrepreneurial State*, Anthem Press, 2013.

[v] Of course, appropriations for these agencies fell well short of the authorization targets. See "Agency Budgets in the FIRST Act and America COMPETES," AAAS R&D Budget and Policy Program, March 12, 2014, http://www.aaas.org/news/agency-budgets-first-act-and-america-competes.

[vi] For instance, see Venkatesh Narayanamurti, Tolu Odumosu, and Lee Vinsel, "RIP: The Basic/Applied Research Dichotomy," *Issues in Science and Technology,* Winter 2013 (31-36); Ben Shneiderman, "Toward an Ecological Model of Research and Development," *The Atlantic*, April 23, 2013, http://www.theatlantic.com/technology/archive/2013/04/toward-an-ecological-model-of-research-and-development/275187/.

[vii] http://www.nsf.gov/statistics/natlpatterns/

[viii] National Science Board. 2014. *Science and Engineering Indicators 2014*. Arlington VA: National Science Foundation (NSB 14-01), http://www.nsf.gov/statistics/seind14/.

[ix] OECD *Main Science and Technology Indicators*, 2014, http://www.oecd.org/sti/msti.htm

[x] OECD *Science, Technology and Industry Outlook 2014*, http://www.oecd.org/sti/oecd-science-technology-and-industry-outlook-19991428.htm