Federal R&D Budget Trends: A Short Summary

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

Why Does Government Fund R&D?

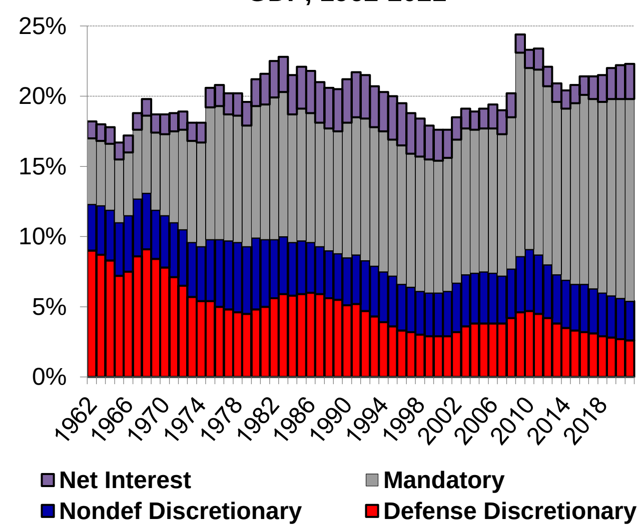
Government has historically had a major hand in science and technology. There are a few simple rationales for this. The most immediate is the need for agencies to fulfill their public missions on national security, agriculture, environment, health, or infrastructure. To successfully fulfill these missions requires robust interaction with science and technology. But there is a broader rationale as well. Generally, the societal benefits of knowledge produced by R&D are greater than the private benefits, and spillovers make it difficult for the creators of new knowledge to reap all of its benefits. 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, and may require long-term commitments of resources and infrastructure. These qualities of the research enterprise can lead to underinvestment by private industry, which *in general* is more focused on lower-risk research and product development for shorter-term results. This is why industry spends about 80 cents of every R&D dollar on development, and only about 20 cents on basic and applied research. For federal nondefense agencies, the ratio is reversed.

As a result, wrote a 2014 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 and technology enterprise lays a foundation of knowledge, tools, and a skilled workforce. At its best, it forms an ecosystem with universities and industry, contributing to progress in pharmaceuticals, semiconductors, food, aerospace, and other sectors through research output, human capital, 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 in East Asia, such public-private interaction will likely become more important over time from a competitiveness perspective.

Declining Discretionary Spending is Important Context for R&D

Virtually all federal R&D funding is part of what's known as the *discretionary budget.* Discretionary spending is the part of the federal budget determined annually through the appropriations process. As seen in Figure 1 below, discretionary spending – especially that for defense –

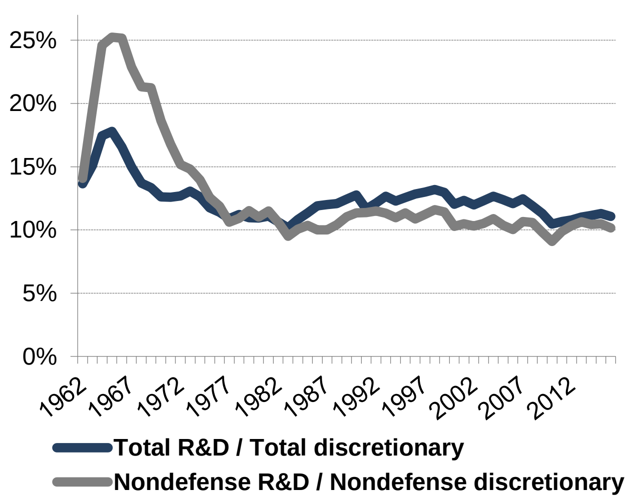
Figure 1: Federal Spending as a Percent of GDP, 1962-2021



Source: Budget of the U.S. Government FY 2017. © 2016 AAAS once occupied a more prominent place in the budget. Over time, however, the federal budget has come to be dominated by *mandatory* spending, which is made up mostly of the major entitlement programs – Social Security, Medicare, and Medicaid – as well as numerous other transfer payment programs. Mandatory spending is known as such because it is written directly into authorizing legislation, is not subject to annual changes by appropriators, and is mostly – but not entirely – on "autopilot." Due to an aging population, rising healthcare costs, and other factors, mandatory spending has come to dominate the federal budget, **accounting for nearly two-thirds of all outlays**. At the same time, the discretionary portion of the budget has declined, especially on the defense side, as can be seen.

This matters for science spending because R&D doesn't tend to change much as a share of the discretionary budget. At the height of the Space Race, R&D comprised 17.4 percent of discretionary spending, as seen in Figure 2. But since the late 1980s, R&D has tended to fluctuate between 11 and 13 percent of discretionary spending. It can be said that as the discretionary budget overall goes, so goes the R&D budget.

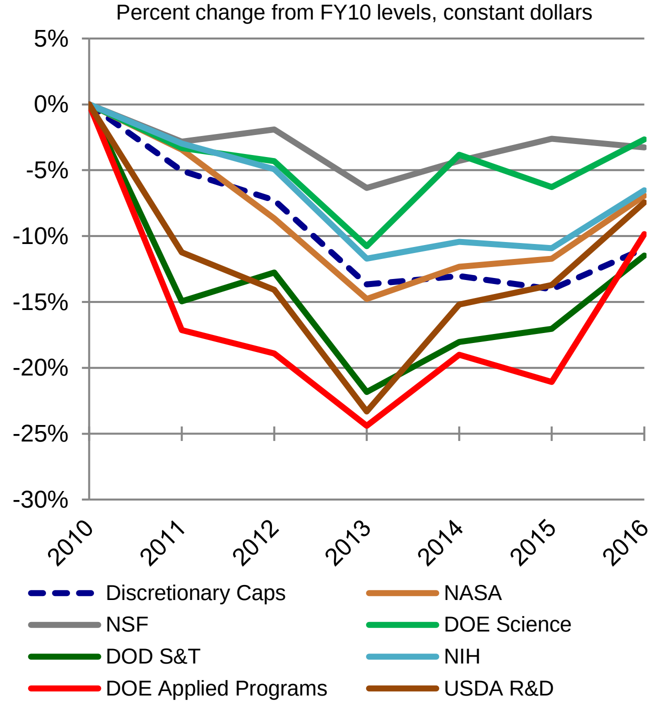
Figure 2: R&D in the Discretionary Budget
percentage of outlays, 1962 - 2016



Source: Budget of the U.S. Government FY 2017 © 2016 AAAS

The centrality of the discretionary budget for science spending can be seen in recent agency-level trends, shown in Figure 3. Beginning in the 2011 fiscal year (FY), the base discretionary budget began coming down. The spending caps established by the Budget Control Act of 2011, including sequestration in FY 2013, further intensified the strain on the discretionary budget, though Congress has also regularly acted to partially undo the effects of these caps.[v] The impact of the caps on science agency discretionary budgets is plain in Figure 3, with major agencies tending to decline and recover somewhat in unison. As of FY 2016, the discretionary budgets for most major science agencies were actually above or near their pre-sequestration funding levels, corresponding with Congressional increases to the overall caps.[vi] This suggests that the discretionary budget is the "center of gravity" around which R&D budgets tend to cluster.

Figure 3: Recent Federal S&T Spending
Percent change from FY10 levels, constant dollars



Based on AAAS analyses of historical OMB, agency, and appropriations data and the President's FY 2017 request. © 2016 AAAS

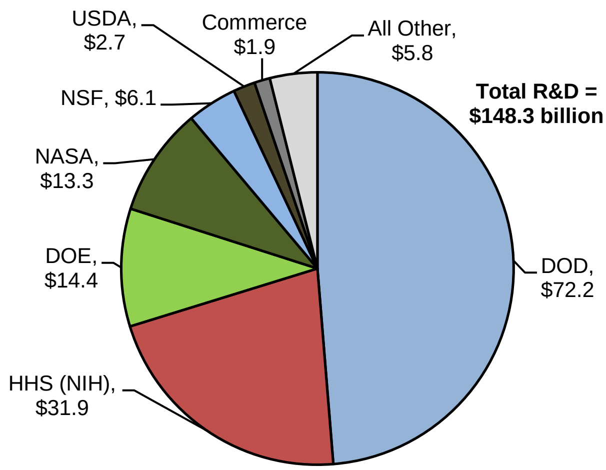
In the long run, the Congressional Budget Office (CBO) predicts discretionary spending will continue to decline relative to the federal budget and the economy overall as mandatory spending continues its growth.[vii] This suggests federal R&D activities may also continue to decline relative to other economic activity, even as federal R&D dollars grow in absolute terms.

Major Recent Trends

The estimated distribution of R&D by agency in FY 2016 is shown in Figure 4. The relative distribution doesn't tend to change radically from one year to the next.

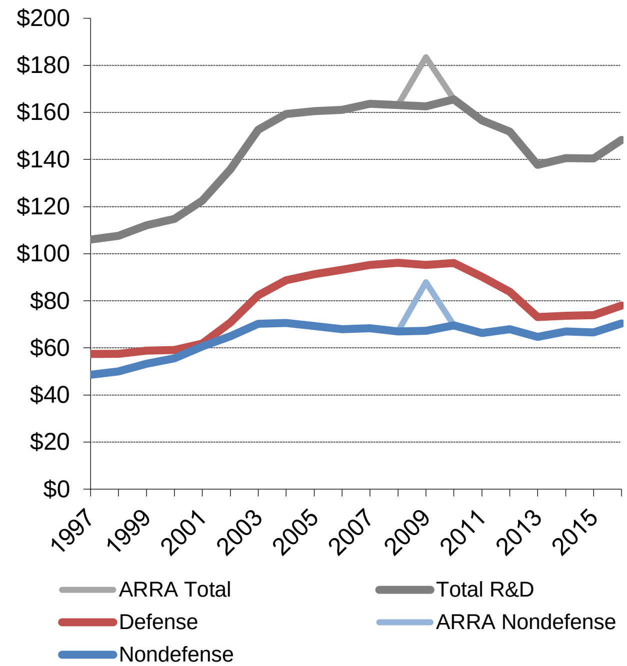
The past 20 years of federal R&D appropriations can be divided into three approximate phases (see Figure 5). In the "first phase," from FY 1997 to FY 2004, federal R&D

Figure 4: Estimated R&D in FY 2016
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. © 2016 AAAS

Figure 5: Federal R&D Since 1997
billions of constant 2016 dollars



Source: AAAS analysis of agency budget data. © 2016 AAAS

funding increased rapidly, by 44.0 percent. This rise was driven partly by increased defense R&D following the September 11 attacks, and partly by the Congressional plan to double the National Institutes of Health (NIH) budget. Other agencies like the National Science Foundation (NSF) and the Office of Science within the Department of Energy (DOE) also experienced funding growth at this time.

The "second phase" ran from FY 2004 to FY 2010 and represents something of a plateau. Defense R&D remained elevated, while the picture was more complicated for nondefense agencies. Funding did increase for some like NSF, DOE Science, and the National Institute of Standards and Technology (NIST), all of which were prioritized for funding by the America COMPETES Act. But this was offset by erosion of the NIH budget following the doubling. The end of the second phase was marked by the one-time funding boost in the American Recovery and Reinvestment Act (ARRA), which added over $18 billion in nominal dollars in FY 2009.

Since FY 2010, funding has entered a jagged "third phase" of decline and recovery, beginning with the aforementioned reduction in discretionary spending in FY 2011. Between FY 2010 and FY 2016 the defense R&D budget dropped sharply, by nearly 20 percent, coinciding with the drawdown of war funding in those years.

Nondefense R&D appeared to continue on a steadier path, as seen in Figure 5. In fact, according to the official agency-reported figures, nondefense R&D in FY 2016 sat 1.2 percent above by 2010 levels. Note that this data contradicts the decline and recovery across science discretionary budgets seen in Figure 3. How can nondefense **R&D** budgets have recovered as described, when overall **discretionary** budgets, which are a better indicator of agency fiscal resources, still lag well below FY 2010 levels? The answer appears to be changes in R&D accounting adopted by NASA and DOE: both agencies have expanded what they count as research and development in recent years, which may mean a more accurate tally, but has had the effect of adding an "extra" $2 billion or so in reported R&D for each agency. This discontinuity means R&D funding comparisons over the past decade are, unfortunately, less meaningful. While the official figures show an increase of 1.2 percent in nondefense R&D between FY 2010 and FY 2016, adjusting for these NASA and DOE discrepancies suggests a *decline* of, perhaps, three to five percent.

Differences in R&D by Character

R&D budget data is recorded by federal agencies 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 below).[viii] Agencies do their best to accurately and consistently apply these definitions, but there will always be a level of subjectivity, especially between basic

OMB's 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."

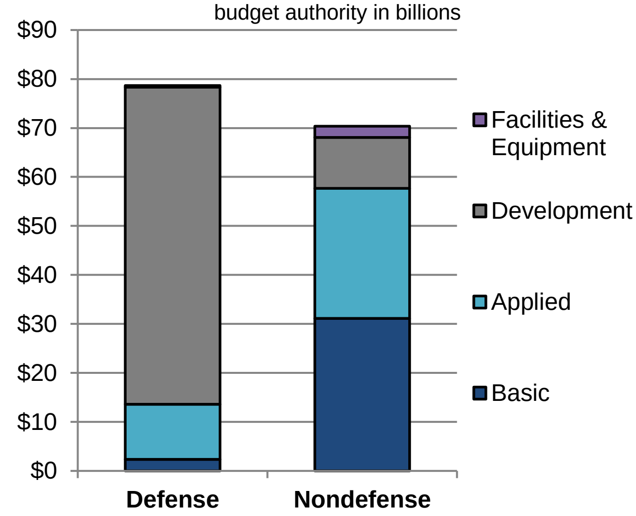
Lastly, **R&D equipment** spending "includes acquisition or design and production of movable equipment, such as spectrometers, research satellites, detectors, and other instruments."

Source: OMB Circular A-11, Section 84

and applied research. Indeed, the idea of jettisoning the entire basic/applied dichotomy has its proponents.[ix] And as mentioned above, what a given agency chooses to officially count (or not count) as basic research, applied research, development, or facilities can change over time.

Different parts of the federal R&D enterprise focus on different classes of R&D. Generally, basic and applied research is a more prominent pursuit for nondefense science agencies like NIH or NSF. Development is mostly funded by the Department of Defense (DOD) as part of its efforts to acquire advanced weaponry, vehicles, and communications technologies (see Figure 6). But this grouping of defense with development, and nondefense

Figure 6: R&D by Character, FY 2016



Source: OMB and agency R&D data. © 2016 AAAS

with research, has some exceptions. For instance, NASA, a nondefense agency, has a substantial development budget as part of its exploration mission. DOD also maintains a sizable research enterprise through the military branches and through agencies like DARPA. And DOE is actually split between the National Nuclear Security Administration (NNSA), a defense agency managing the national nuclear stockpile, and its nondefense programs in discovery science and energy technology. DOE's defense and nondefense sides both expend significant funding on research *and* development.

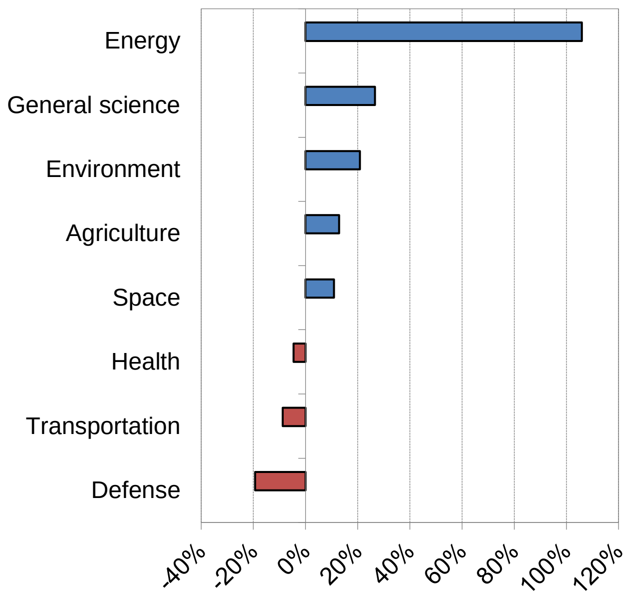
Because of the association of nondefense R&D with research, federal research funding tends to track nondefense R&D (as seen in Figure 5) fairly closely. The same is true for development and defense R&D.

Federal R&D by Functional Category

Yet another way to evaluate changes in R&D is by "budget function." Budget functions are the 20 or so official spending categories used to classify all government outlays. While most functions have some R&D spending, R&D is mostly concentrated in four: defense, health, general science, and space (the latter two are technically part of the same function, but are split for our purposes here). The energy, environment, and agriculture functions also typically contain around $2 billion in R&D spending each. R&D spending in the transportation, commerce, and justice functions has also surpassed $1 billion in recent years.

Figure 7: R&D Outlays by Budget Function, Past Ten Years

Percent change from FY 2007 in constant dollars



Source: Historical OMB data on R&D outlays. © 2016 AAAS

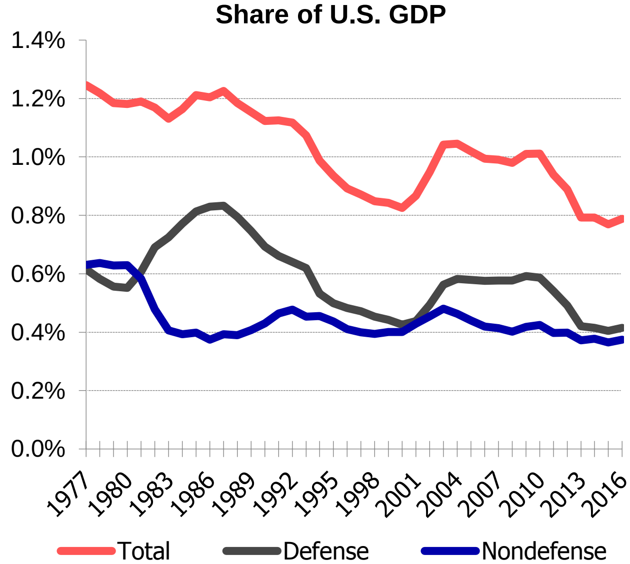
Since budget functions group spending by category, comparing across functions can indicate recent priorities for Congress and the executive branch. Figure 7 above, drawn from historical data provided by the White House Office of Management and Budget, shows changes in R&D spending by budget function over the most recent ten-year window, from FY 2007 to FY 2016. Note that these ten years include the decline and recovery described earlier and visible in Figure 3, and much of the growth shown came early in the ten-year window. Note also that the space, general science, energy, and transportation functions may all have been affected by the DOE and NASA accounting changes cited above.

A brief explanation of each function is warranted. The **energy** function only covers applied technology programs at DOE. Of these, nuclear, efficiency, and renewables have all seen the greatest growth since FY 2007. **General science** includes NSF and DOE Science, the two largest of the three agencies prioritized by America COMPETES. These, as well as NIST, have fiscally fared somewhat better than many other agencies over this time. 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 **health** function is dominated by NIH, but also includes other agencies like the Centers for Disease Control and Prevention. The decline there is primarily a function of NIH budget erosion, albeit from an elevated position following the budget doubling mentioned previously. NASA's aeronautics research activities are housed in the **transportation** function above, which also includes the Department of Transportation, while the rest of NASA is included in the **space** function. The **defense** function includes both NNSA and DOD.[x]

As Share of U.S. GDP: Development Declining, Research Sustained

R&D as a share of gross domestic product (GDP), a metric known as "R&D intensity," is a commonly-used descriptor of a nation's competitive health. It is far from definitive, 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 economic activities.

Figure 8: Federal R&D as a Share of U.S. GDP

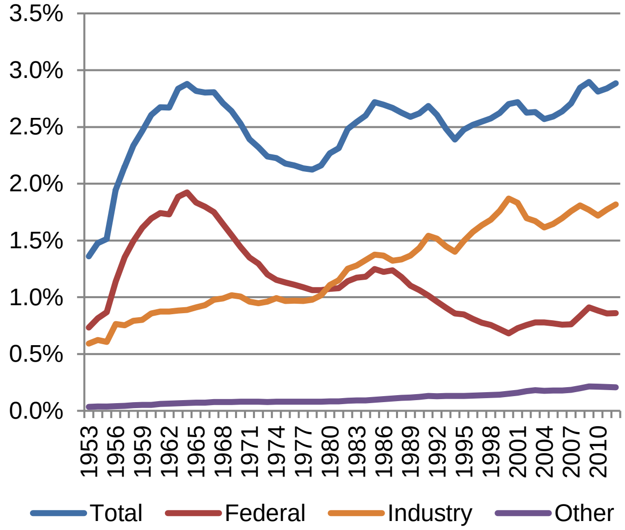


Based on historical R&D and GDP data. © 2016 AAAS

Figure 8 uses R&D budget authority data compiled by AAAS since the 1970s and GDP data from OMB. Clearly, the overall trend has been downward. As of FY 2016, the federal R&D budget had declined to an estimated 0.79 percent of GDP, well below earlier levels. This decline is likely to continue as discretionary spending continues to shrink.

As can be seen, however, nondefense R&D has remained somewhat steadier as a share of GDP since steep cuts in

Figure 9: R&D as a Share of GDP by Funder

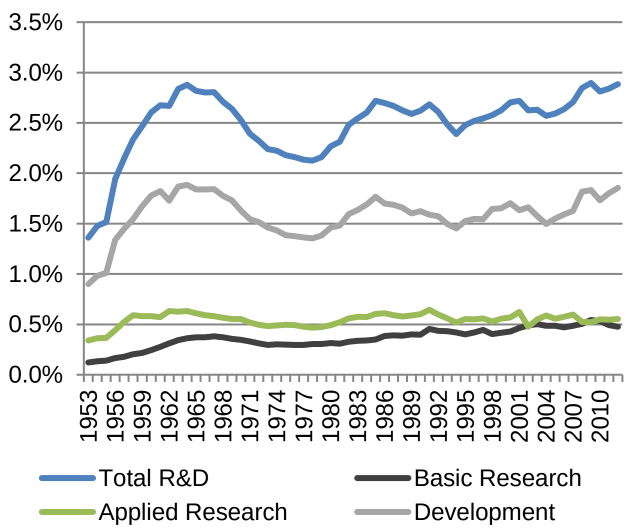


Source: National Science Foundation, *National Patterns of R&D Resources* survey series. © 2016 AAAS

the early 1980s, owing to marginally greater stability in the nondefense discretionary budget overall. The trend has been somewhat more negative since the end of the NIH doubling in FY 2003, and pressures on the discretionary budget will likely pose a greater challenge to this spending going forward. Defense R&D has seen greater decline and fluctuation.

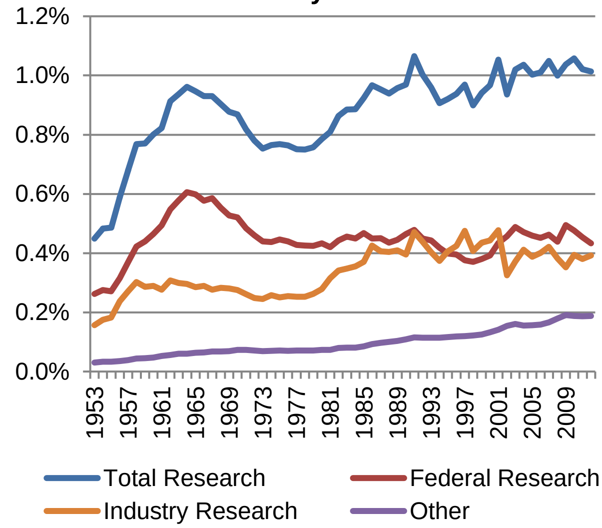
While federal R&D intensity relative to GDP has come down, it has been more than offset by increasing

Figure 10: R&D as a Share of GDP by Character



Source: National Science Foundation, *National Patterns of R&D Resources* series. © 2016 AAAS

Figure 11: Research as a Share of GDP by Funder



Source: National Science Foundation, *National Patterns of R&D Resources* series. © 2016 AAAS

contributions from industry, and to a lesser extent universities, state governments, and private nonprofit research foundations. Industry now accounts for the vast majority of U.S. R&D. Figure 9 shows the big picture since 1953; note that data in this section come from surveys administered by NSF's National Center for Science and Engineering Statistics (NCSES).

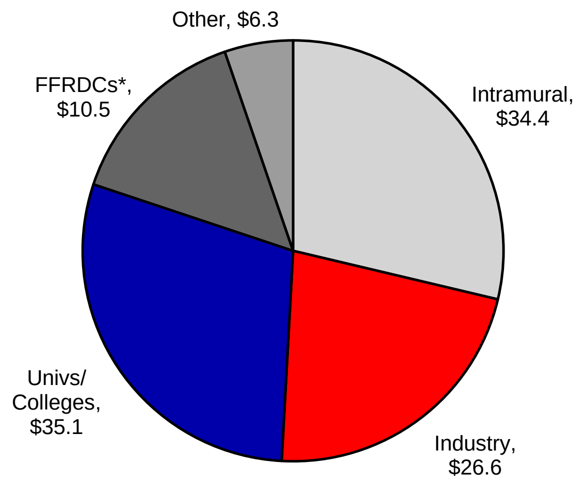
Interestingly, the character of the national R&D enterprise hasn't changed much even as government and industry funding has flipped (Figure 10). Basic research, applied research, and development have all held steady or grown as a share of the economy, according to NSF surveys.

This is somewhat counterintuitive given industry's focus on short-term development and declining federal R&D relative to GDP. But if one recalls the trends discussed earlier, federal development (mostly through defense agency spending) has declined far more than federal research (mostly through nondefense agency spending). Thus, an important note is that the federal government still accounts for the greatest share of total research spending, though industry has caught up (Figure 11).

Performers: Universities Increasing; Declines for Industry, Intramural

Federally-funded R&D is conducted by a range of performers. Figure 12 shows the distribution of research and development by performer as of 2014, the most

Figure 12: Federal R&D by Performer, FY 2014
obligations in billions

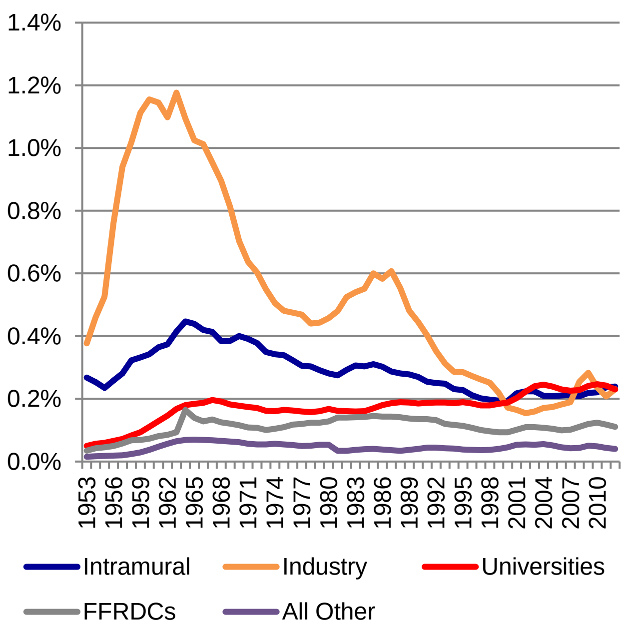


* Federally funded R&D centers: government-owned, contractor-operated laboratories. Source: National Science Foundation, *National Patterns of R&D Resources.* Figures are preliminary. © 2016 AAAS

recent year of data available in the NCSES *National Patterns of R&D Resources* survey.[xi] The figure includes basic research, applied research, and development, but not R&D plant.

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

Figure 13: Federal R&D as a Share of GDP by Performer



Source: National Science Foundation, National Patterns of R&D Resources series. © 2016 AAAS

Industry R&D made up 22 percent, while 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.

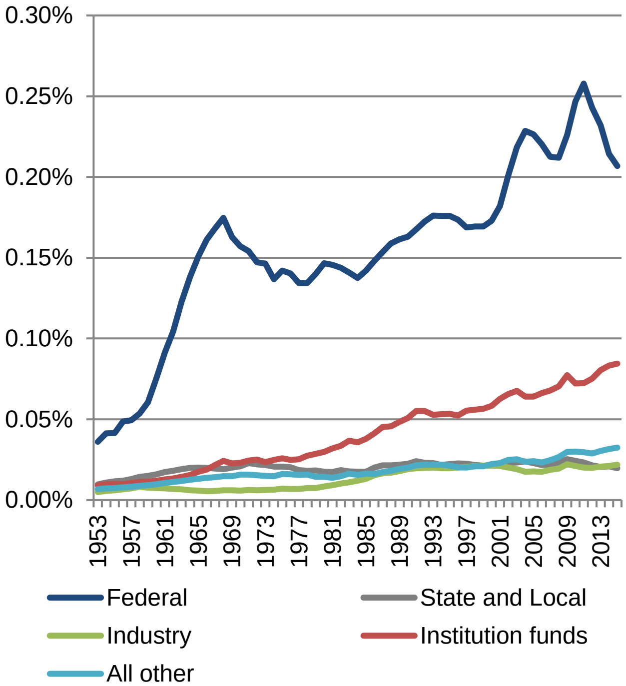
While most agencies offer a mixed funding profile, they also have clear tendencies regarding performers. DOD R&D emphasizes industrial contractors who handle its technology development work, though DOD also maintains an extensive intramural research enterprise and still has enough dollars left over to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

From a historical perspective, federal R&D performed by industry saw significant increases around the time of the Space Race, then experienced a smaller spike during the Reagan defense R&D buildup in the 1980s (see Figure 13, which presents spending data as a share of U.S. GDP). Federal intramural R&D has seen a more gradual decline since the Space Race, while R&D performance by FFRDCs and "other" performers has been fairly steady relative to GDP.

The only performers of federally-funded R&D to have exhibited collective long-run growth relative to GDP are the nation's universities, mostly through basic and applied research expenditures. Figure 14, assembled using data from NSF's Higher Education R&D survey, shows trends in university R&D by funder. Note the rightmost peak in federal funding reflects Recovery Act spending.

While federal funding of university R&D has notably increased, university self-funding of R&D is also an emerging trend. During the Space Race, the federal government regularly accounted for over 70 percent of university R&D expenditures. Today the federal share has dropped somewhat below 60 percent. At the same time, university spending on research has increased from less than nine percent during the Space Race, to over 20 percent and rising today. This means the overall pool of university-performed R&D is rising marginally faster than federal expenditures alone, and suggests the demand for university R&D dollars is outpacing the federal supply. Industry contributions to university research have also increased over this time, though gradually.

Figure 14: University R&D by Funding Source
As a Share of U.S. GDP



Source: NSF, Higher Education R&D survey series. Includes Recovery Act funding. © 2016 AAAS

Global Landscape: R&D Shifting East

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 trajectory. Per NCSES, global R&D has roughly doubled since 2003, approaching $1.7 trillion in 2013.[xii]

While the United States remains the single largest contributor to R&D, investments are steadily shifting east. Within the OECD data set, the United States accounted for 40 percent of global R&D in 2000 but only 29.3 percent in 2013. The EU showed a somewhat smaller decline, from 27.3 percent to 22.7 percent. Meanwhile, the five East Asian economies included in the set – China, Singapore, Taiwan, Japan, and South Korea – collectively increased their share of R&D from 24.1 percent in 2000 to 38.6 percent in 2013.[xiii] China has been the major driver in this growth, but three of the other four, excluding Japan, have also grown rapidly (see box below). OECD analysts believe China may surpass the United States in total R&D funding from all sources by 2019.[xiv]

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 15). Of the major countries shown, since 1995, China, 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 countries). The European Union and President Obama, among others, have cited a preferred research intensity target of 3 percent of GDP.

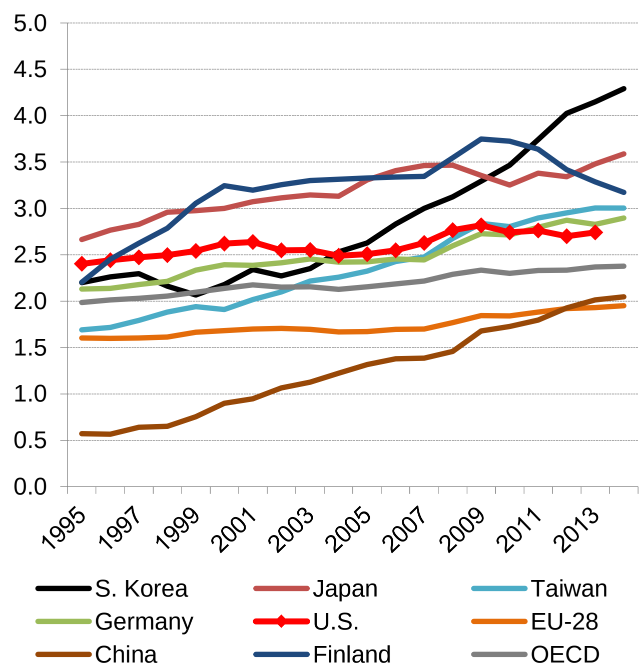
AVERAGE ANNUAL R&D GROWTH IN SELECT ECONOMIES, 2000-2013
Constant dollars

United States	2.0%
China	17.1%
Japan	1.8%
Germany	3.2%
France	2.3%
South Korea	8.3%
U.K.	1.0%
Russia	8.2%
Taiwan	7.5%
Italy	2.7%
Canada	1.5%
Singapore	6.8%

Estimates based on OECD Science and Technology Indicators

While big-picture R&D funding trends offer a starting point for international comparisons, what also matters is the research "mix" comparing basic (longer-term) research versus applied (shorter-term) research and development. According to the latest OECD data, basic research funding among member countries has nearly quadrupled since

Figure 15: International R&D Intensity
Gross R&D as a percent of GDP



Source: OECD Science & Technology Indicators. © 2016 AAAS

1985, reflecting continued efforts to build innovation-driven economies. Manufacturing-oriented countries, such as China, tend to invest less in basic research and more on development and applied research. In fact, basic research accounted for only 4.7 percent of Chinese R&D in 2013, compared to the OECD average of 17.3 percent that year.

Within government research portfolios, US spending on **health R&D** remains the highest among OECD nations in both absolute and relative terms. Additionally, the US devotes the largest share of R&D funding for **defense** purposes, at roughly 50 percent of the federal portfolio in 2014, whereas the European Union set aside only 4.4 percent. However, the fraction of US government research funding for **energy and environment** was a mere 2.2 percent in 2014, compared to the OECD average of 6.2 percent in 2013, the latest year which data is available. Examining international research budgets in this way allows for a better understanding of how countries prioritize R&D by socio-economic objective.[xv]

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 EU-15 countries is virtually unchanged since 2000. The Chinese government funded 20.3 percent of Chinese R&D in 2014, down from 33.4 percent in 2000. The Japanese government only funded 16 percent of R&D in Japan in 2014, a slight decrease from earlier years and a reflection of the fact that the Japanese R&D profile has generally been industry-heavy. 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 private R&D expenditures.[xvi]

[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] For coverage of the Bipartisan Budget Act of 2015, the most recent deal to raise the spending caps at the time of this writing, see: http://www.aaas.org/news/two-year-budget-deal-means-room-rd-growth

[vi] See http://www.aaas.org/news/following-omnibus-most-science-agencies-are-or-near-pre-sequestration-funding

[vii] See CBO's most recent Long-Term Budget Outlook: https://www.cbo.gov/publication/51580

[viii] Available at https://www.whitehouse.gov/omb/circulars_a11_current_year_a11_toc

[ix] 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-anecological-model-of-research-and-development/275187/.

[x] Additional long-term data on federal R&D outlays by function are available on the AAAS website.

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

[xii] National Science Board. 2016. *Science and Engineering Indicators 2016*. Arlington VA: National Science Foundation (NSB 14-01), https://www.nsf.gov/statistics/2016/nsb20161/#/

[xiii] OECD *Main Science and Technology Indicators*, 2016, http://www.oecd.org/sti/msti.htm

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

[xv] For more in-depth analysis, see: http://www.aaas.org/news/look-rd-funding-and-performance-oecd-area-and-beyond

[xvi] A recent IMF report examined ways to boost research through fiscal policies such as technology transfer and R&D tax incentives: http://www.imf.org/external/pubs/ft/fm/2016/01/fmindex.htm