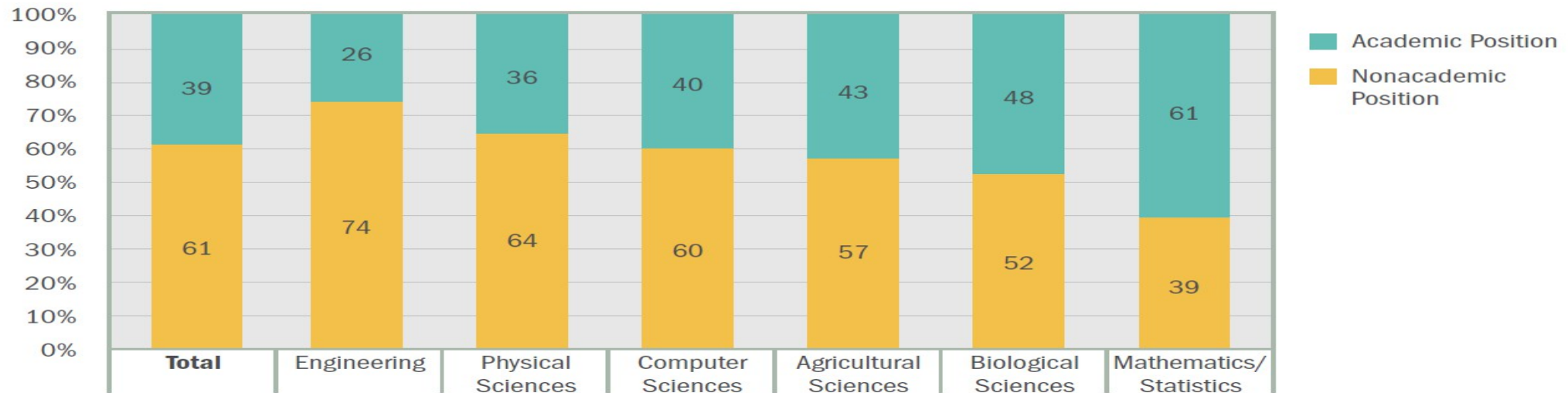


Workers Pathway to the Social Return from Federal R&D

Claim: Much of the social return to R&D grants/PhD support comes via students/workers transferring knowledge to industry rather than through university patents/tech transfer: “it's the people”

Figure 1. Percentage Distribution of Employed STEM PhD Holders, by Career Type and by STEM Field



- 1- Federal R&D in Knowledge Creation-Innovation
- 2- Flows Through Training and Mobility
- 3- Market Dynamics: Historic Cobweb Cycle of Boom and Bust
- 4- Comparative Advantage in Global R&D and Innovation

1. Federal R&D and Innovation

Fed R&D largest share is basic, mostly non-defense, and smallest share is development, with little non-defense. So viewing development as closest to innovation, Fed R&D supports early stage of research so question is how new knowledge gets to innovation

Table1: R&D Spending, 2014 by type; and Shares, by funding group

	All R&D	Basic	Applied	Development
Total (in billions)	\$456	\$80	\$91	\$285
Share of Spending	100.0%	100.0%	100.0%	100.0%
Fed All	26.5%	47.5%	36.3%	17.9%
Non-defense*	12.8%	44.3%	30.8%	2.4%
Business	65.1%	26.3%	50.5%	80.8%
All other	8.4%	26.2%	13.2%	2.3%

Source: National Science Board, Science and Engineering Indicators 2016; *Estimated division of basic, applied, and development between defense and non-defense based on spending by Defense Department vs other departments. From table 5, NSF <https://ncesdata.nsf.gov/fedfunds/2014/>

Some Exceptions

Transforming Translational Research

The National Center for Advancing Translational Sciences (NCATS) is one of 27 Institutes and Centers (ICs) at the National Institutes of Health (NIH). Established to transform and accelerate the translational research process, NCATS is all about getting more treatments to more patients more quickly. The Center complements other NIH ICs, the private sector and the nonprofit community; rather than concentrating on specific diseases, NCATS focuses on what is common among them.

Translation is the process of turning observations in the laboratory, clinic and community into interventions that improve the health of individuals and the public – from diagnostics and therapeutics to medical procedures and behavioral changes.

Translational science is the field of investigation focused on understanding the scientific and operational principles underlying each step of the translational process.

Bridging the Gap

Several thousand genetic diseases affect humans, of which only about 500 have any treatment. A novel drug, device or other intervention can take about 14 years and cost \$2 billion or more to develop, and about 95 percent never make it past clinical trials. Even when a new drug or other intervention is developed and shown to be effective in clinical trials, many years may pass before all patients who could benefit from it are identified and treated.

Numerous scientific and organizational roadblocks can limit the speed of progress. Obstacles along the path to translation include:

- Lack of understanding about the science of translation, leading to unpredictability and frequent failure of possible interventions
- A shortage of qualified investigators
- Organizational structures and incentives that do not encourage the teamwork essential to translational science
- Inflexible, inefficient clinical trial designs and low participation in studies
- Regulatory science issues

NCATS aims to bridge these gaps by **developing** new approaches, technologies, resources and models; **demonstrating** their usefulness; and **disseminating** the resulting data, analyses and methodologies to the broad scientific community.

DARPA: Creating Breakthrough Technologies for National Security

For more than 50 years DARPA has had a singular mission: to make pivotal investments in breakthrough technologies for national security. Through its investments, DARPA catalyzes the development of new capabilities that give the Nation technology-based options for preventing—and creating—strategic surprise.

Established in 1958 as part of the U.S. Department of Defense, DARPA is designed to pursue opportunities for transformational change rather than incremental advances. It does so collaboratively as part of a robust innovation ecosystem that includes academic, corporate, and governmental partners. And while its focus is always on the Nation's military Services, which count on DARPA to create new strategic and tactical options, DARPA's work has historically catalyzed fundamental breakthroughs that have benefited broader society as well.

DARPA has demonstrated time and again how thinking beyond the borders of what is widely considered possible can yield extraordinary results. In the military domain, DARPA made early and timely investments in ballistic missile defense, stealth aircraft technology, unmanned aerial vehicles, and precision guidance. It also played a significant role in developing the Internet; designing the electronics that undergird the information revolution, and making the global positioning system (GPS) as mobile and ubiquitous as it is today. From the enormous rocket engines that powered the first manned space flight to the smallest microelectronics in smartphones at home and on the battlefield, DARPA has been at the forefront of technological innovation.

By focusing its efforts at the boundaries of knowledge and at the edges and intersections of disciplines, DARPA has also helped create new communities of scientists and engineers, both inside and beyond the traditional defense community. Along the way, companies and sometimes entire industries have sprung from

DARPA-funded research—reflecting the agency's commitment to pursue its ideas all the way from initial concept to demonstration of practical feasibility through prototype development.

DARPA programs are led by program managers who come from academia, industry, national laboratories and other parts of government for stints that typically last just a few years—a time limit that helps drive the agency's signature sense of urgency. They are supported by technical and administrative teams motivated by the DARPA tenet that a program is not successful until it has made a difference for national security. Toward that end, and recognizing that some revolutionary goals inevitably prove unachievable, programs are heavily milestone-driven and redirected or discontinued when barriers prove intractable.

DARPA's programs are conducted under the oversight of six technical offices: the Defense Sciences Office, the Information Innovation Office, the Microsystems Technology Office, the Strategic Technology Office, the Tactical Technology Office, and the agency's most recent addition, the Biological Technologies Office.

DARPA's FY 2015 budget is \$2.92 billion. The agency supports approximately 210 government employees, about half of whom are program managers. Its research is conducted by a wide array of public- and private-sector performers via 2,000 contracts, grants and other agreements.

DARPA's mission is to make the pivotal early technology investments that create or prevent strategic surprise for U.S. national security

But D in R&D is not Innovation.

Innovation is: *implementation* of a new or significantly improved product (good or service), or process, new marketing method, or a new organizational method in business practices, workplace organization or external relations. (The *Oslo Manual* (OECD-Eurostat, 2005, p. 46).

It can be new to the firm, market, country. Unlike inventions, patents, input indicators such as R&D, Innovations are commercialized.

Until BRDIS asked about sales of new product, productivity was only quant measure. Key finding on BRDIS innovation is that R&D firms do more innovate while most innovations are from non-R&D firms.

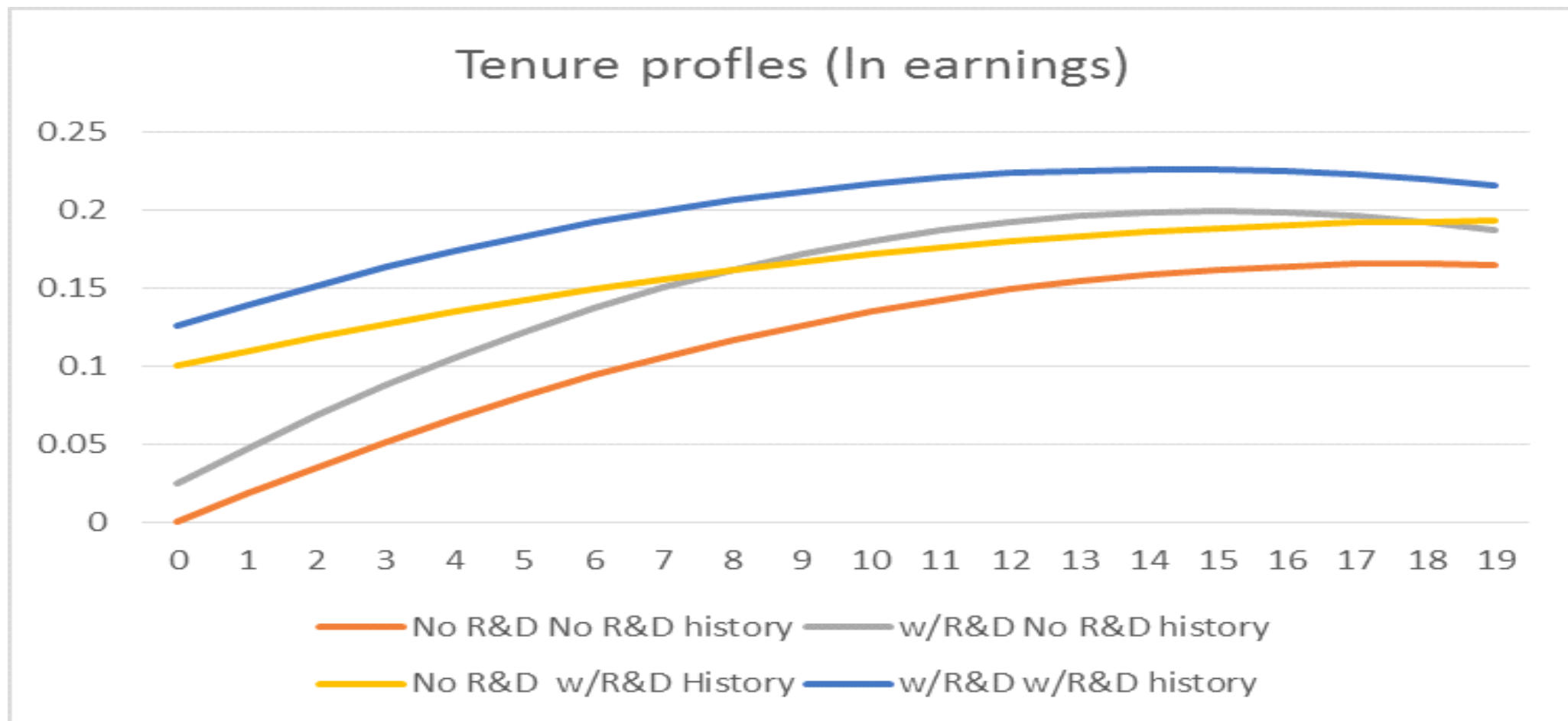
Likely that many non-R&D/non-patent-based innovations use intermediate goods/service innovations from R&D firms but need I-O type analysis of innovation in intermediate sales/purchases to measure.

We have been working with product attributes sold/listed on Internet to create an index of innovation, measured by value of change in attributes weighted by coefficients from hedonic price regressions.

2. What is role of labor mobility in moving knowledge from basic/applied (sci papers) to innovation?

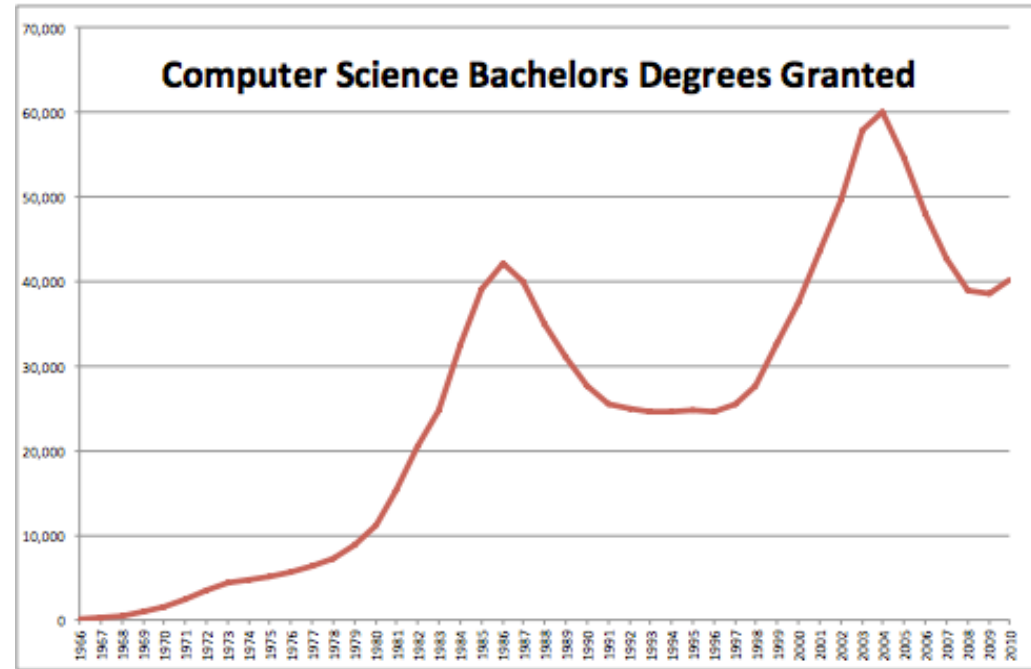
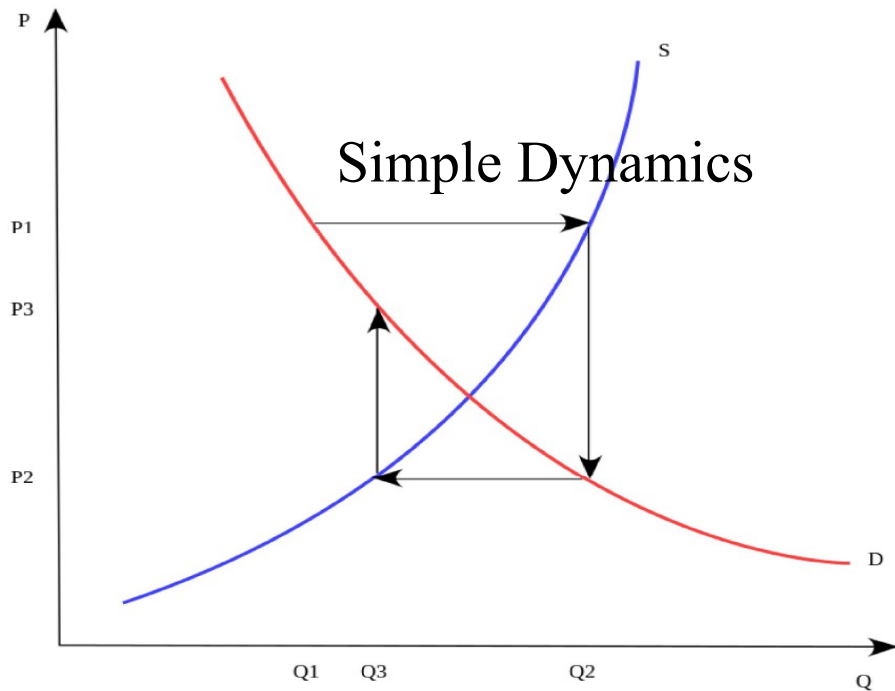
- Paper methodology follows knowledge in papers/patents to patents/other indicators of use in products/processes or effect on productivity.
- People methodology follows workers on R&D project to firms to measure effects on products/processes/productivity. Best will be u-metrics data on fed supported R&D on firms to which project personnel moved, and economic changes in destination firms.
- BDFMW (AEA, 2017) examines how mobility of workers from firms with different R&D intensity to establishments in new firm affects productivity and wages of workers at new establishment.
- BDFW (NBER, forthcoming, 2017) finds establishments with higher S&E share of workers have higher productivity and that effect is larger for firms with greater R&D intensity --> that non-research S&E workers create more value when firm does R&D, (translating or implementing new knowledge?), and adds value to S&E training.

BDFMW combines LEHD Mfg data with NSF SIRD, and Census education and occupation to assess worker transfer of knowledge hypothesis. Finds recent hiring of workers (tenure less than 5 years) from an R&D firm raises establishment productivity; that movers from a high R&D firm earn a wage premium at new workplace; and that having co-workers with experience in high R&D firm raises wages of worker, with some evidence of inverse U shape to productivity and wage gains.



3. The Market for New S&E graduates

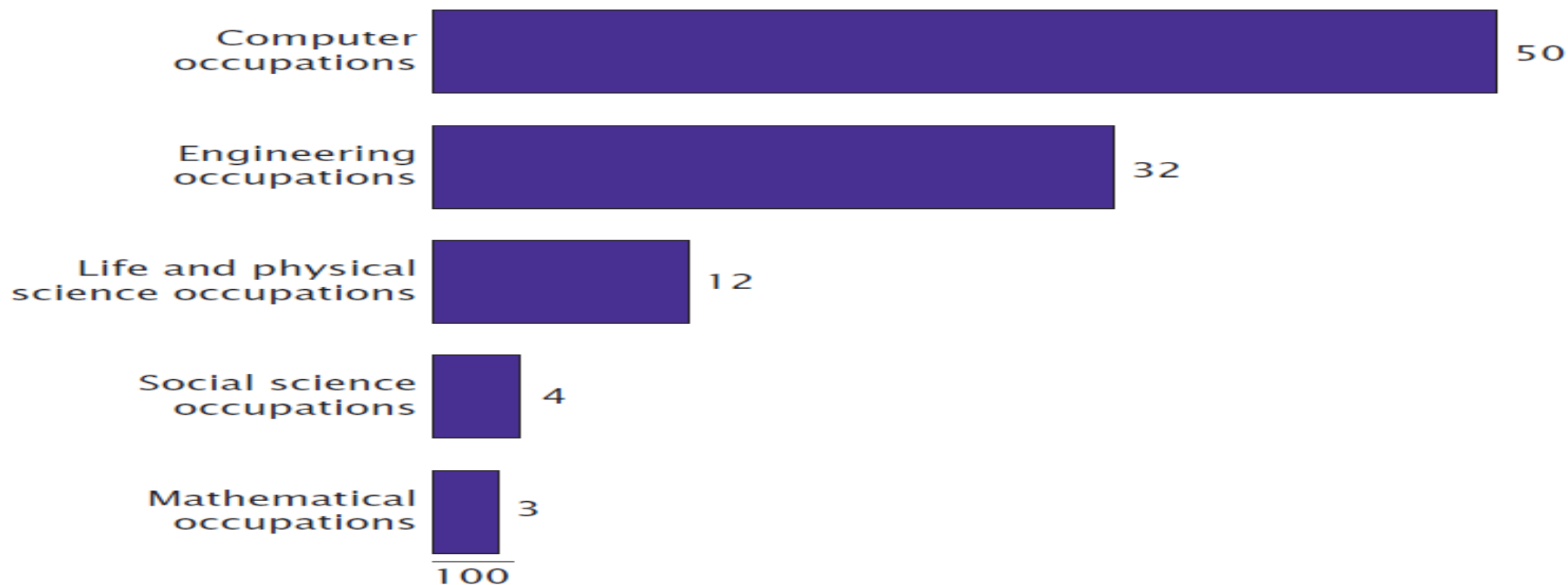
Cobweb Dynamics and Long-term “Oversupply”



Questions: How much overshooting in global economy where non-US supplies should dampen cycles. Overshooting hurts new grads if grads do poorly outside relevant occupations; hurts academe if fall in majors reduces slots/pay. Key questions for this/other cobweb dynamics fields: How do grads do in the surplus phase/what substitutes for grads in shortage phase? How dependent are field enrollments on majors?

Occupational Distribution of STEM Workers

(In percent. Data based on sample. For information on confidentiality protection, sampling error, nonsampling error, and definitions, see www.census.gov/acs/www/)



Source: U.S. Census Bureau, 2011 American Community Survey.

Computer Science and information, 2013

Employed 2,412,000

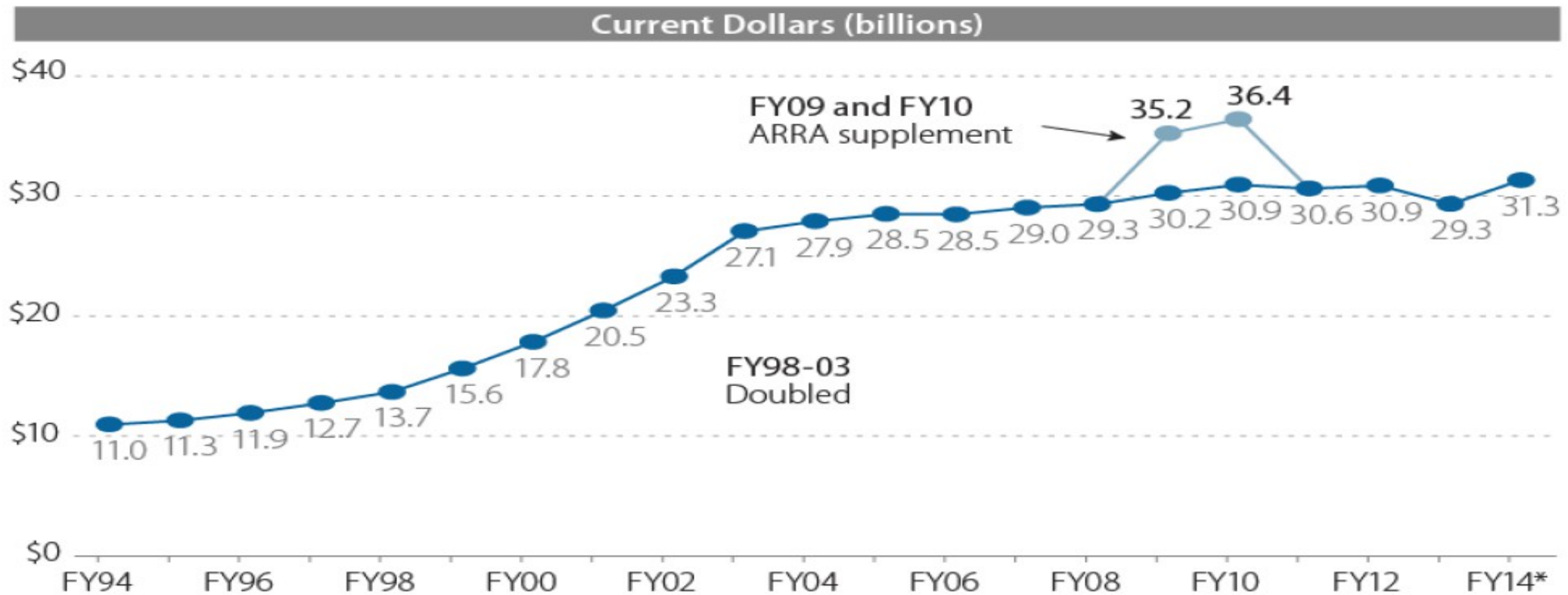
With Degrees 1,623,000

More employed than with degrees

Higher % with degrees working in field

Big R&D Budget Shocks → “Oversupply” of PhDs/post-docs?

Figure 1. National Institutes of Health (NIH) Appropriations, FY1994-FY2014 request



So Many Research Scientists, So Few
Openings as Professors

The Ph.D Bust: America's Awful Market for Young
Scientists—in 7 Charts

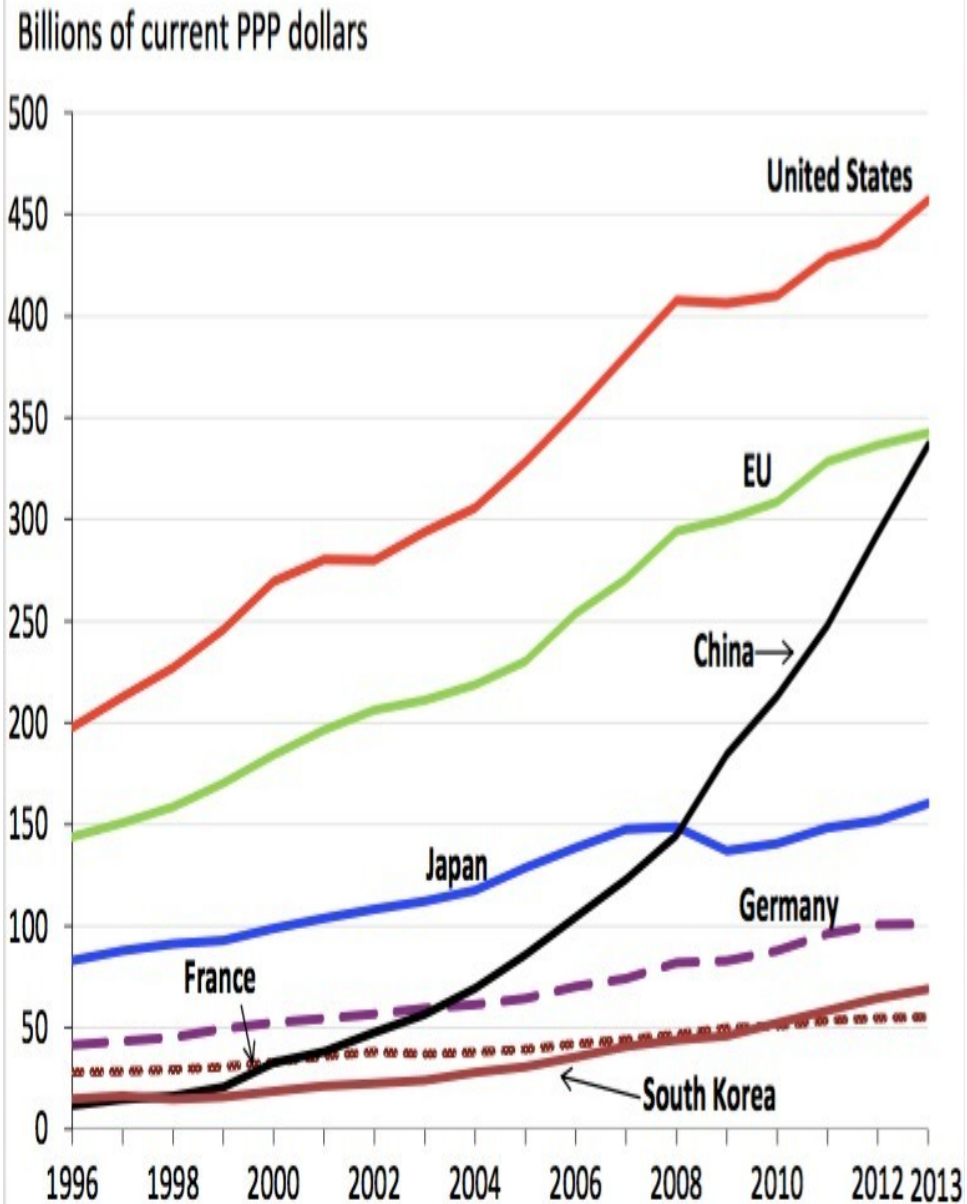
Key Questions to assessing ratio of PhDs/Post-Docs to Independent Researcher Jobs

- Do student decision-makers understand the low odds of getting “ideal job”? If they do, it is a matter of choice. (Think athletes with small chance of getting professional job)
- What do graduates/post-docs who do not obtain professorship or related jobs do outside research at what pay and with what job satisfaction?
- Is there good economics/moral case for increasing their earnings in risky investment in scientific research?

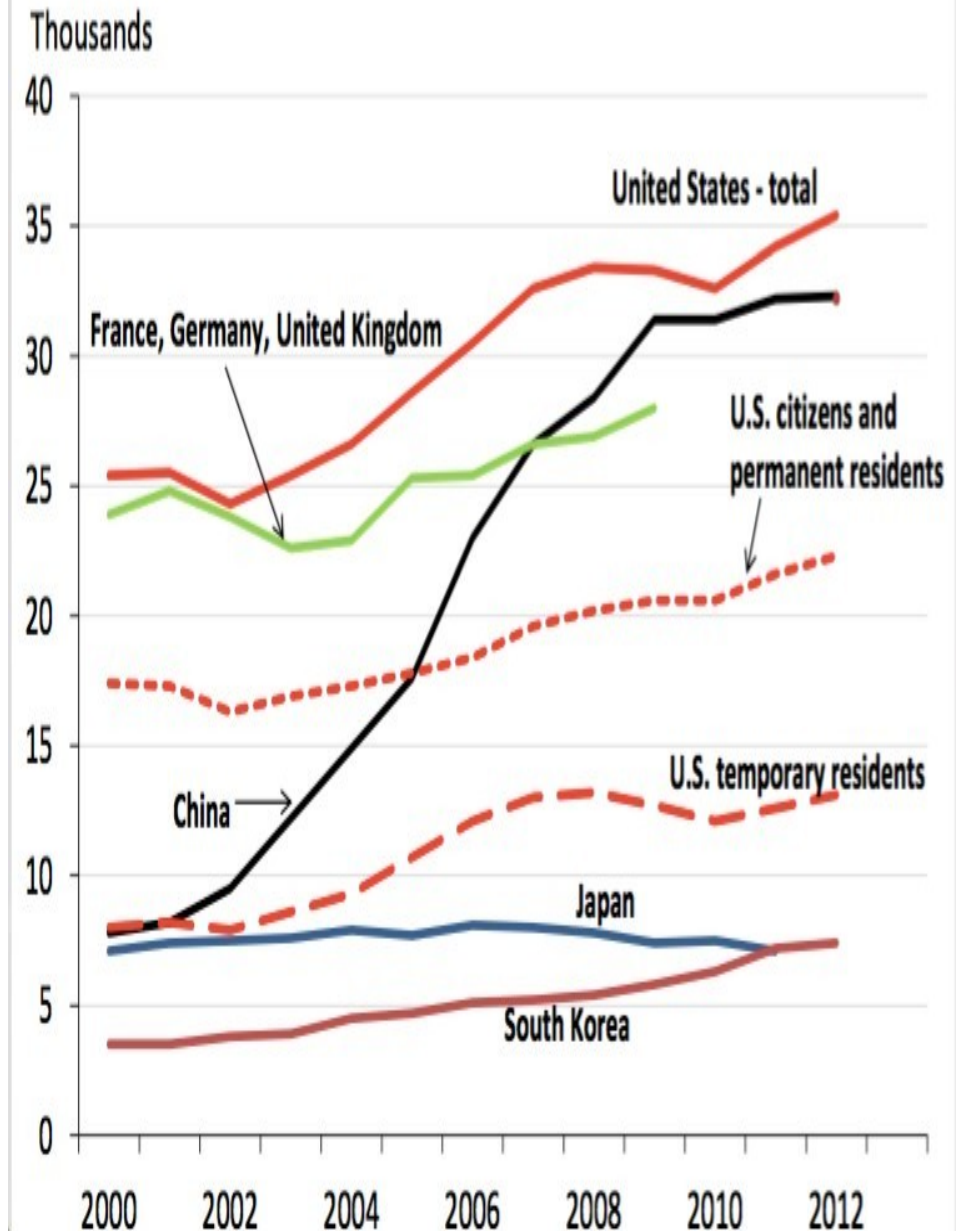
4-US in Global R&D Innovation World

- US no longer dominates world in S&E PhD graduates, R&D spending, scientific papers, patents, and possibly innovation (measures!). Multinationals shift R&D to other successful R&D/S&E countries.
- In S&E graduates, China is number one at bachelor's level and about same as US in PhDs (with many US PhDs to Chinese int'l students).
- In papers, China will surpass US when newest data come out (OECD says 2019), and while US has maintained high quality (indicated by citations) China showing big improvement.
- In R&D spending, China is 2nd at ppp but increasing both GDP and RD/GDP ratio.
- In patents, China has most applications and 2nd to US in patents granted, but China patents make 1/2 claims of US patents and less cited, so quality difference.
- But from US-centric view, it is not China's rise but worldwide rise of others that offers opportunity and challenge.

R&D: Gross domestic expenditures, 1996–2013



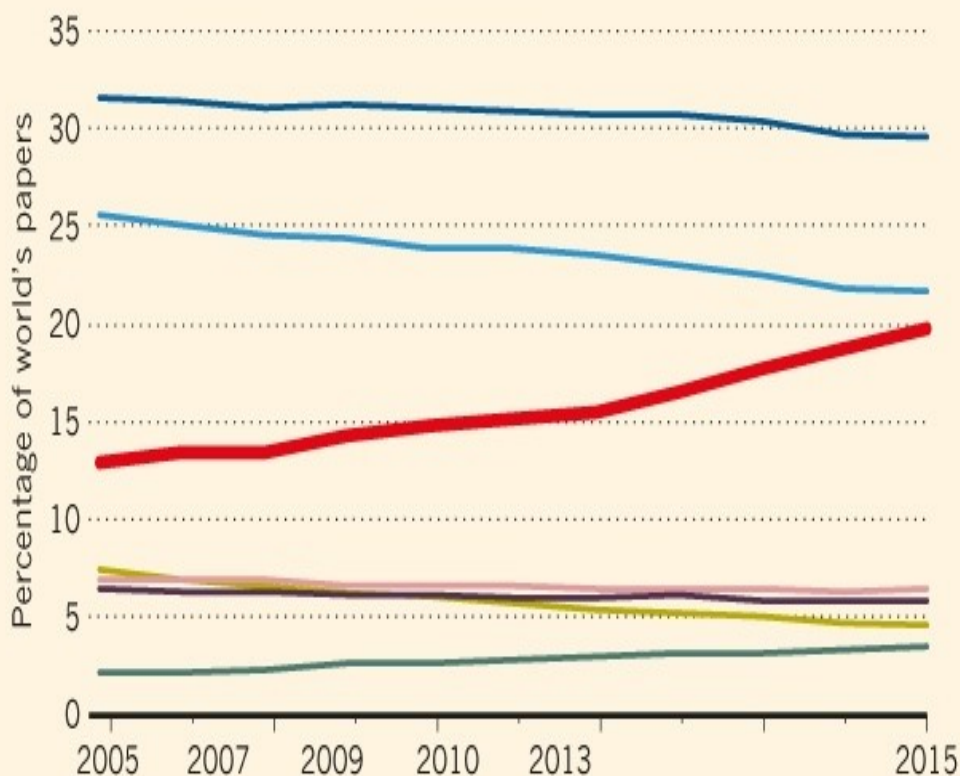
Education: S&E Doctoral Degrees, 2000-12



OUTPUT

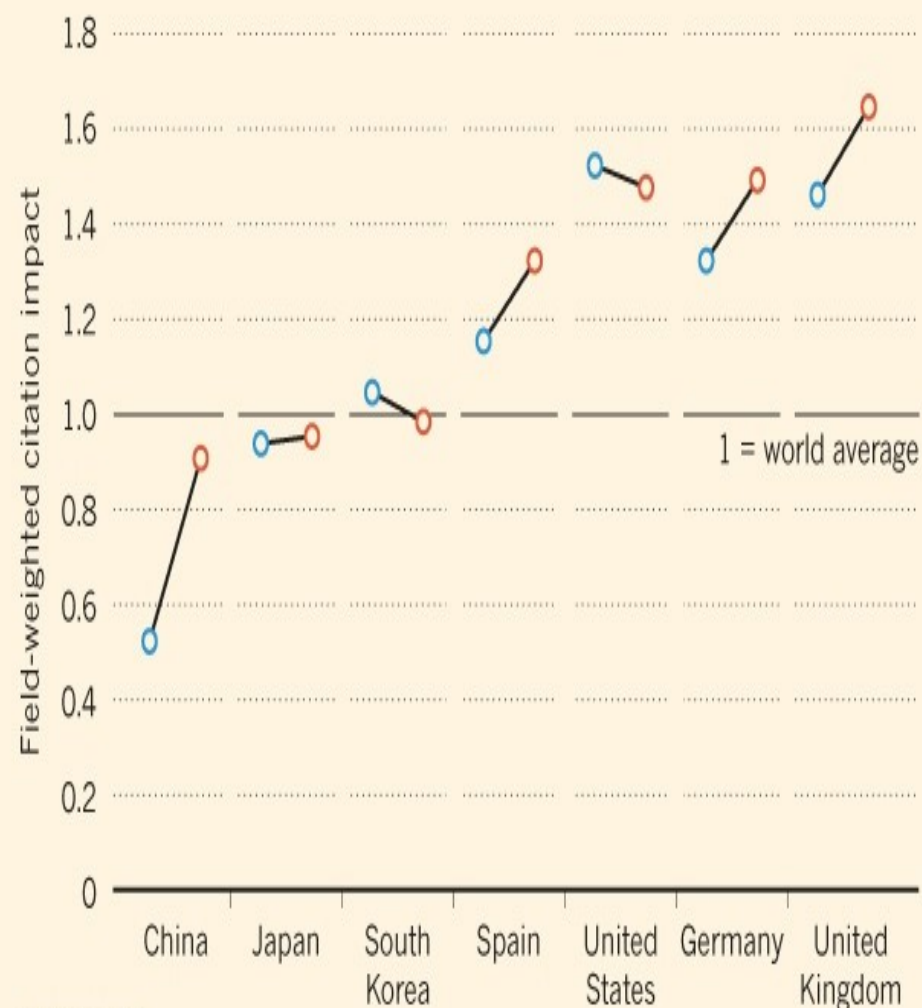
In the past decade, China's share of the world's research articles has surged from 13% to 20% — and its share of the world's top-cited articles has shown similar growth.

EU-28 United States China United Kingdom
Germany Japan South Korea



The scholarly impact of the country's output overall remains below the world's average — but it is rapidly improving. The country has its highest impact in the chemical sciences.

2005 2015



©nature

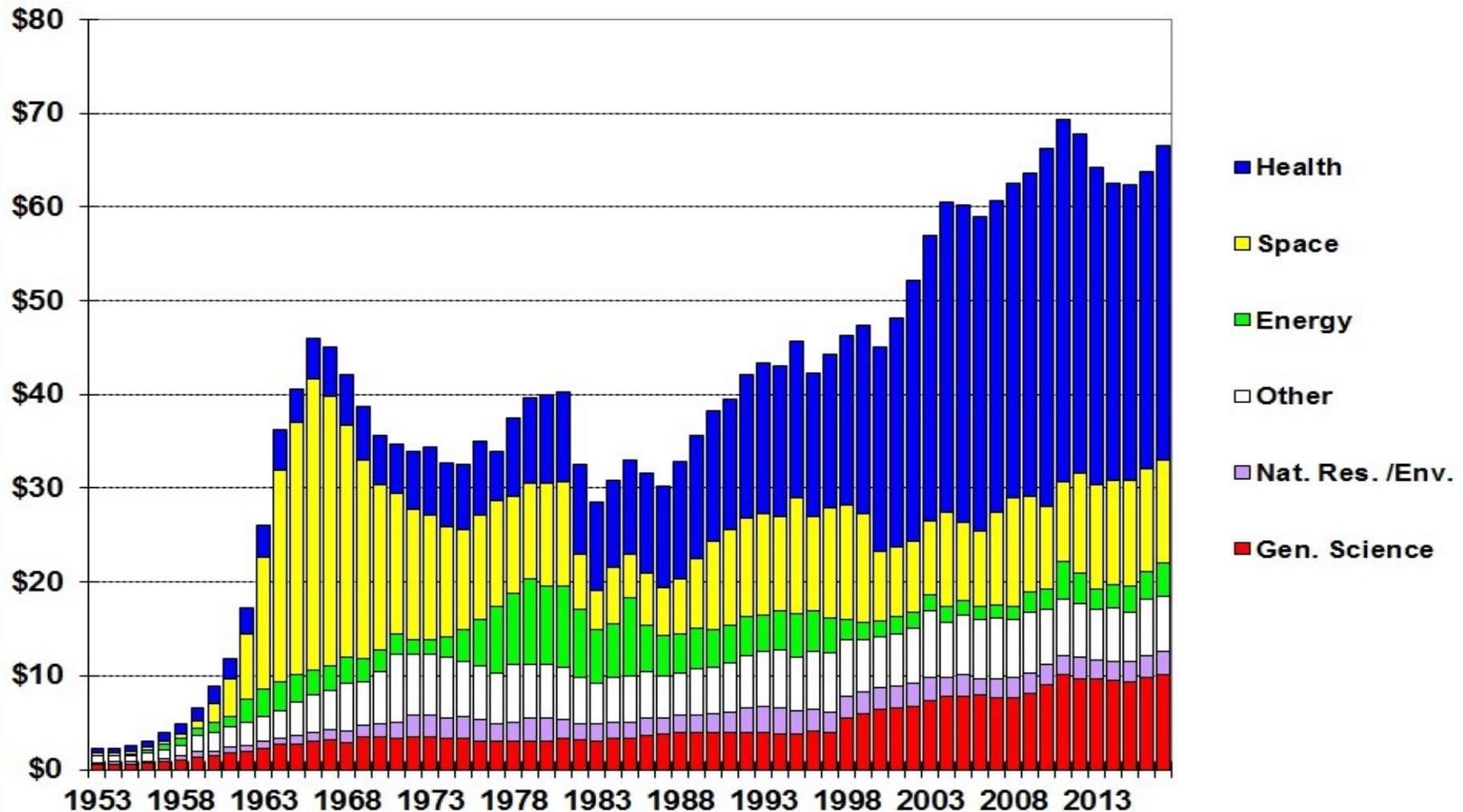
Key Questions to assessing US Federal R&D as one of top countries in Global Basic Research

- How can US innovation process make better use of global research outputs since more comes outside US? Can fed assist in this – basic R&D on the process?
- US should rethink our comparative advantage in research fields – do we do too much basic R&D in bio-medical and not enough in physical sciences, or should we seek ways to use the commons of advances in physical sciences?
- How can we benefit more from being top international collaborator in research and our special relation with China?
- Need to think of balancing national portfolio of R&D topics, with due consideration to uncertainty in where some big breakthrough may benefit us all.

Our Current Non-defense R&D Portfolio

Trends in Nondefense R&D by Function

outlays for the conduct of R&D, billions of constant FY 2016 dollars



Source: AAAS, based on OMB Historical Tables in *Budget of the United States Government FY 2017*. Some Energy programs shifted to General Science beginning in FY 1998. © 2016 AAAS