How Economics Shapes Science

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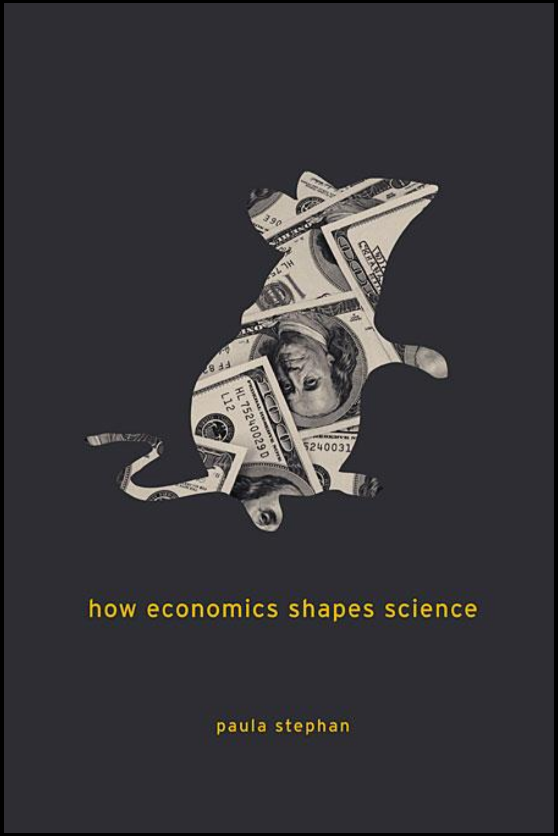
Overview

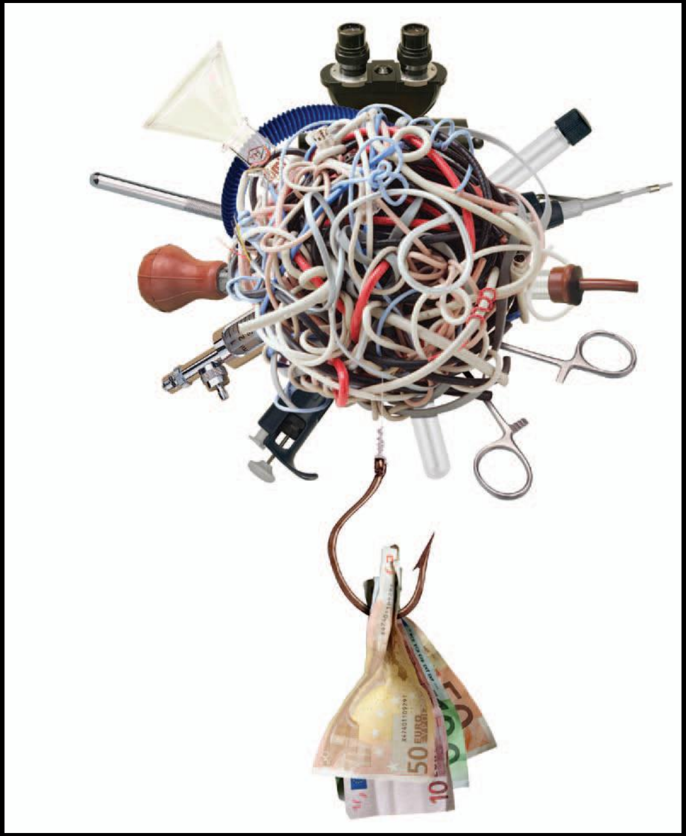
- Economics is about incentives and costs
- Talk about how incentives and costs shape practice of science at research universities and medical schools—especially in the area of biomedical sciences and chemistry
- Do so by providing
  - background concerning how we got to where we are today
  - perspective on unintended consequences of the system
  - thoughts regarding possible reforms of system

Drawn from

Recent book



Comment in *Nature*



How We Got to Where We Are

Science Emerged Triumphant from WWII

- Radar
- Manhattan project
- Penicillin
  - Death rate for all diseases in Army reduced from 14.1 per thousand in WWI to 0.6 per thousand in WWII
- Beyond penicillin, breakthroughs in gamma globulin, adrenal steroids, cortisone and blood plasma
- Public officials and the public were impressed
- From the end of the War on "science was spelled with a capital 'S' and research with a capital 'R.' (Dr. Frederick Stone)

Vannevar Bush's Proposal

- FDR's Science Advisor
- Understood time was ripe for federal funding of scientific research
- Authored *Science, the Endless Frontier*
- Set out role for Federal government in science

Bush's Proposal

- Government had important role to play in fostering creation of new knowledge and in training individuals to create that knowledge
- Important to have federal science agencies
  - Substantially increase funding for NIH
  - Develop a national foundation—genesis of NSF

Considerable Change

- Approximately $31 million was spent on research at universities and medical schools in 1940 ($513 million in 2013 $'s) -- less than 1% of what is spent on university research today
- Sources
  - Endowments
  - Private foundations
  - Donations

Objectives of *Endless Frontier*

Promote Basic Research

- At universities and at institutes by providing funds for research
- Bush thought universities were right place because they were “least under pressure for immediate, tangible results.”
- Related goal—build up less strong departments—especially at medical schools
  - At time Bush wrote only 5 to 10 medical schools doing research
  - 10 to 15 top research universities

Address Deficit in Number of Trained Researchers

- Train graduate and medical students by supporting them through fellowships
- Scholarships for undergraduate students
- Note: concept of research assistantships were not part of the proposal

Early Days: NIH

Building Capacity

- Missionary mode— “it wasn’t anything to travel 200,000 miles a year” (*Fred Stone, later director of NIGMS, said circa 1950)*
- NIH wanted not only to support top but to build programs

Grants

- Grants of small size ($9000--$90,000 in today’s dollars) and for one year
- Success rates high—65%
- Indirect low at NIH: 8%
- Top five institutions receiving funding: Columbia, Hopkins, NYU, Harvard, Minnesota
- Grants viewed as “additive”
  - Some funding for facilities
  - Funding for equipment, including computers, some for faculty salary

Training

- Shortage of talent was seen as bottleneck to getting research done— "from the beginning of the extramural research grants programs, the lack of a sufficient number of qualified research investigators was a continuing bottleneck." (*Mary G. Munger reflecting in 1960 on first 12 years of NIH*)
- NIH initially awarded fellowships; quickly turned to training grants—resulted in institution, not NIH making the choices

Situation by late 1960s

Universities’ Response to Opportunities

- Increasingly wrote-off salary on grants—by late 1960s almost half medical school faculty received some salary support from federal government
- Press Federal government to
  - provide funds to support faculty directly
  - increase funding for research
  - increase indirect rates
- Train more and more students
  - PhD production almost tripled in the biological sciences in 1960s; number of PhD programs doubled
  - Support came increasingly from research assistantship positions, not training grants

Tables Turned

- Before 1960s, Federal government was pushing universities to develop research and training capacity and perform research;
- After late 1960s, roles were reversed: universities began to push Federal government for funds
- Positive feedbacks of system had begun to emerge—with increased funding accompanied by increased training, accompanied by increased demand for funding; unstable system

Ultimate Outcome of University Efforts

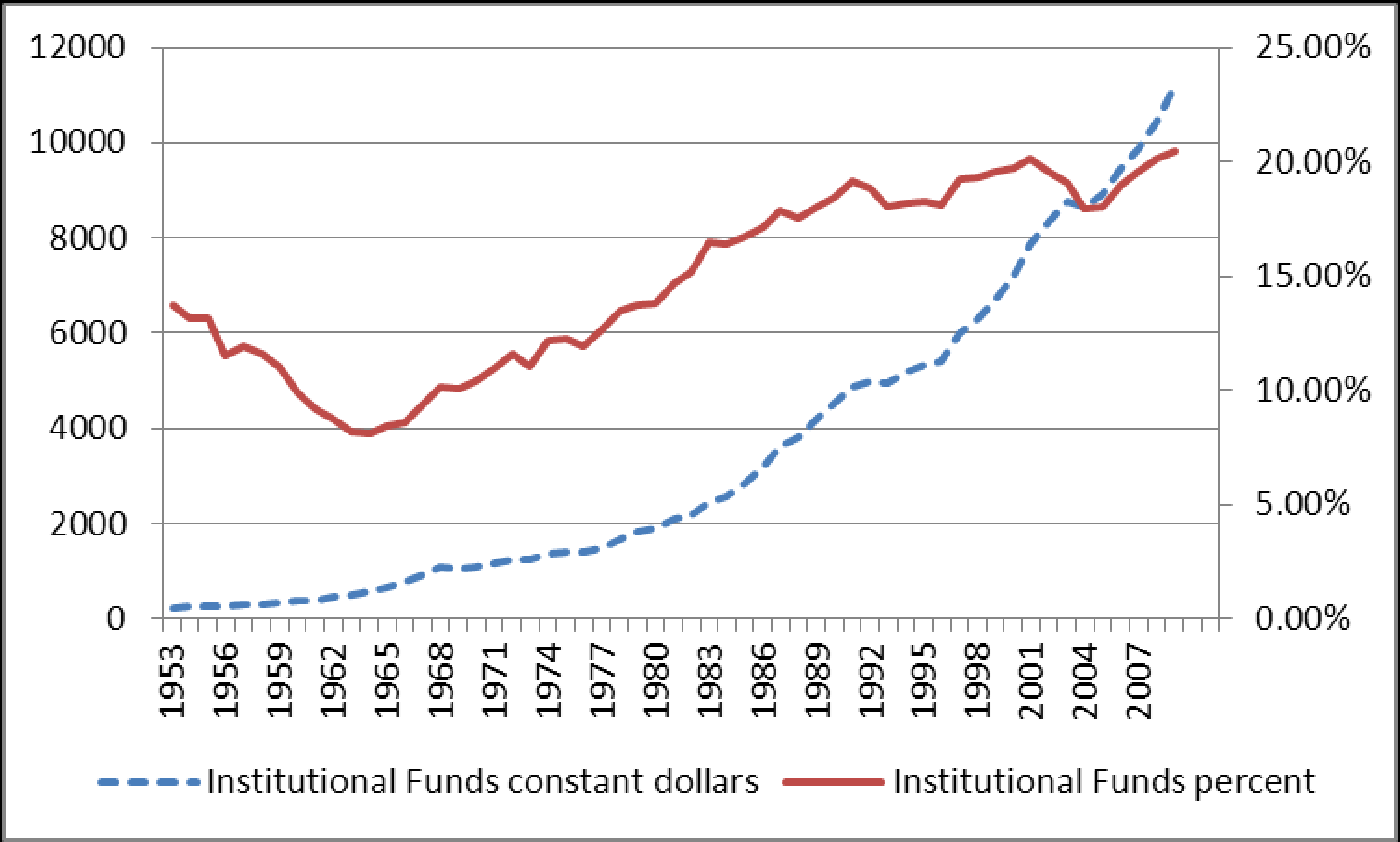
- Doubling of NIH between 1998-2003
- Funding went from approximately $14 billion to $28 billion in nominal terms; from $19 billion to $28.4 billion in 2009 constant dollars

Situation today

Funding All Important to Universities

- Prestige and rank of universities depends critically upon amount of funding – as does AAU membership
- Universities invest growing amount of own resources to make faculty grant ready
- Target federal opportunities
- Compete for star scientists
- “Encourage” faculty to write-off salary on grants
- Hire people in “soft-money” positions

Institutional Support for R&D



High-end Shopping Malls

- Business of building state-of-the art facilities and reputation that attracts good students, good faculty and resources
- Lease facilities to faculty in form of indirect costs on grants and buyout of salary
- Faculty receive start-up-funds when hired
- Many faculty “pay” for the opportunity of working at university, receiving no guarantee of income if they fail to bring in a grant
- Staff labs with graduate students and postdocs

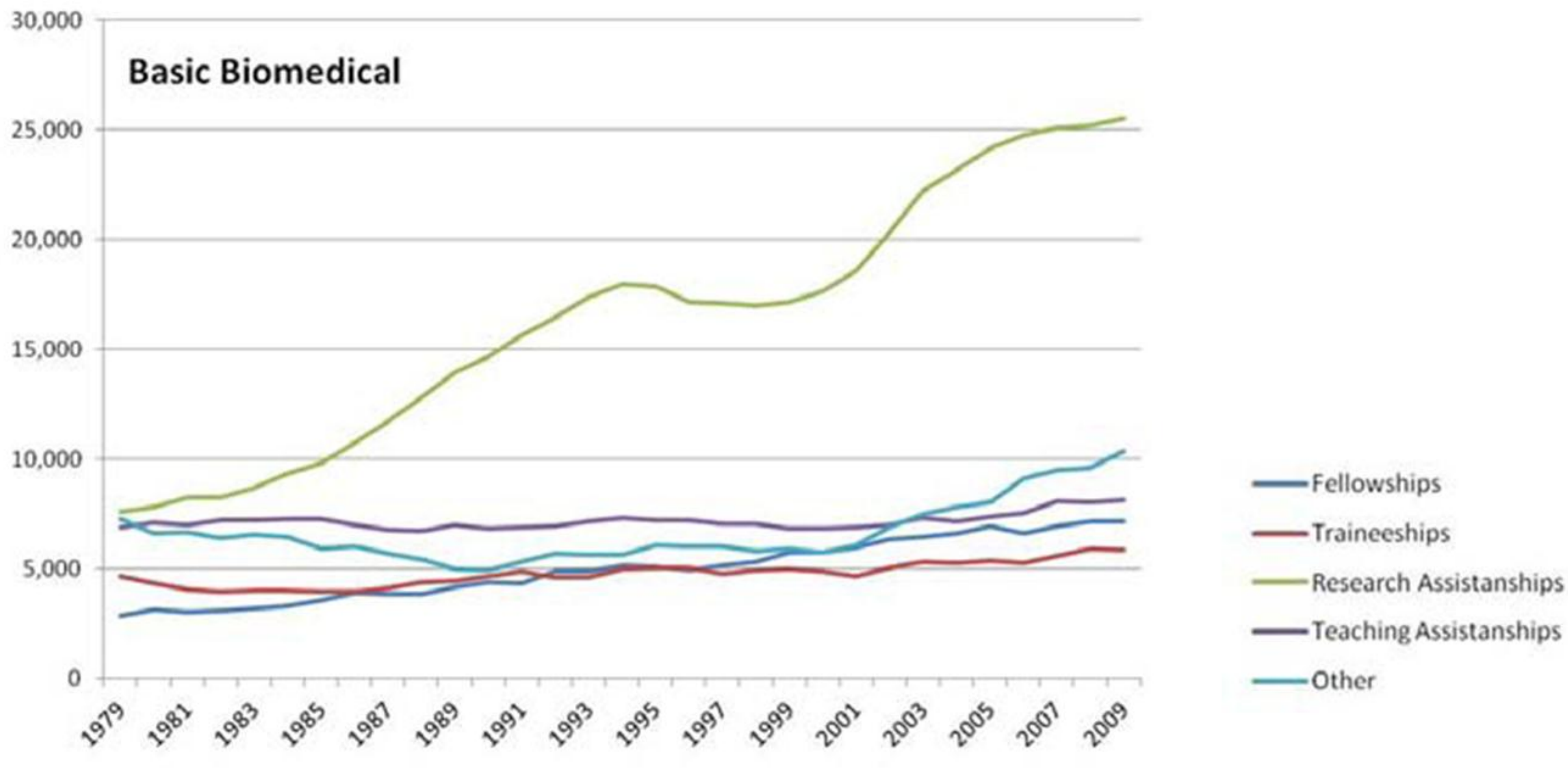
Funding and Salary

- 70 percent of direct grant costs of NIH cover compensation for labor services
- Faculty salaries at medical schools often almost entirely covered by grants—even for those on tenure track
- Universities increasingly hiring other faculty on soft money positions

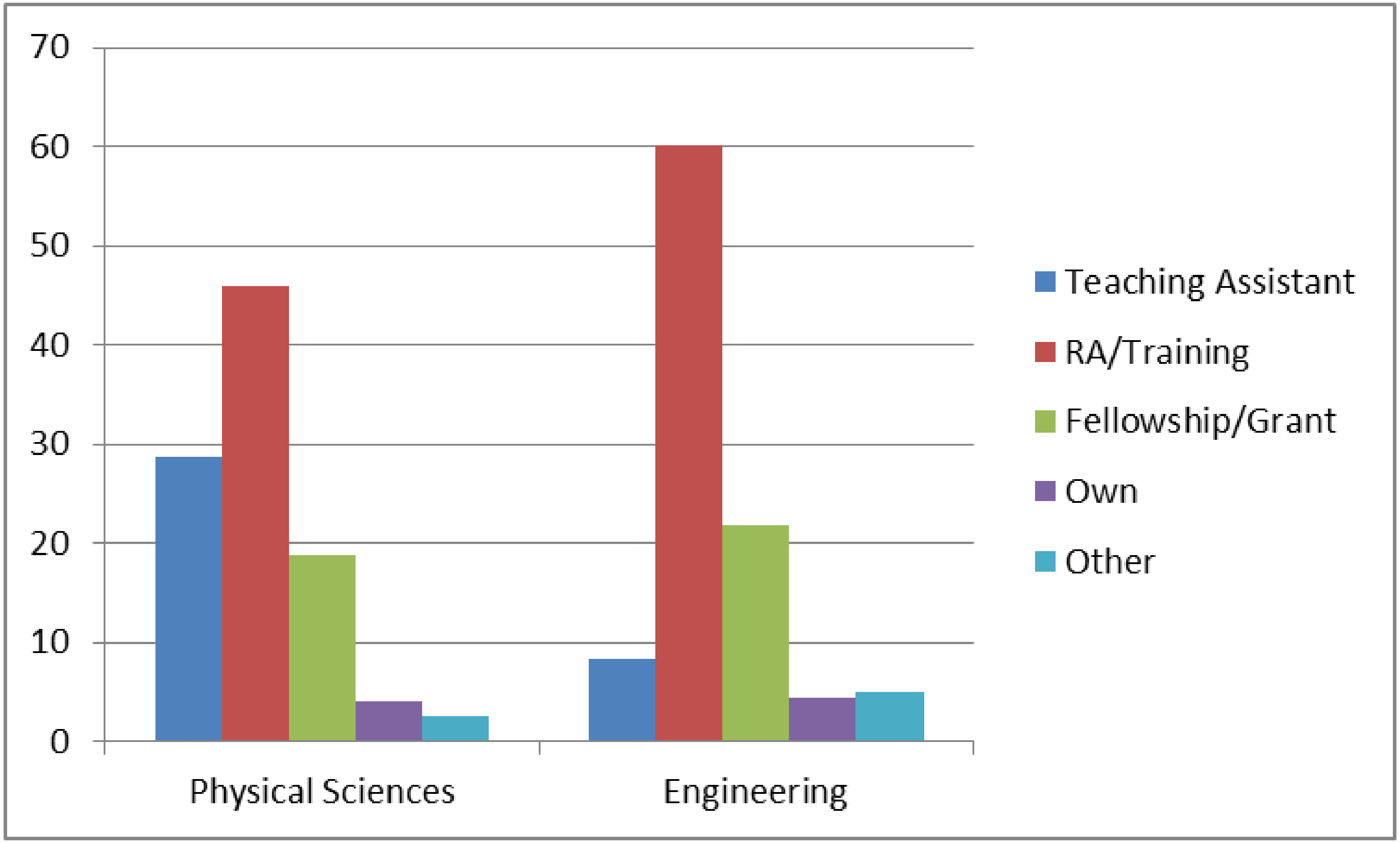
Response of PI’s

- Staff labs with postdocs and graduate students
  - Young
  - Full of ideas
  - Temporary
  - Cheap: postdoc costs about $15.00 an hour; graduate students about $20.00 (before fringes and indirect); staff scientist costs about $32.00 per hour.
  - Funds have been available for these positions on grants
- Costs and need to produce research discourage supporting graduate students on training grants rather than in GRA positions

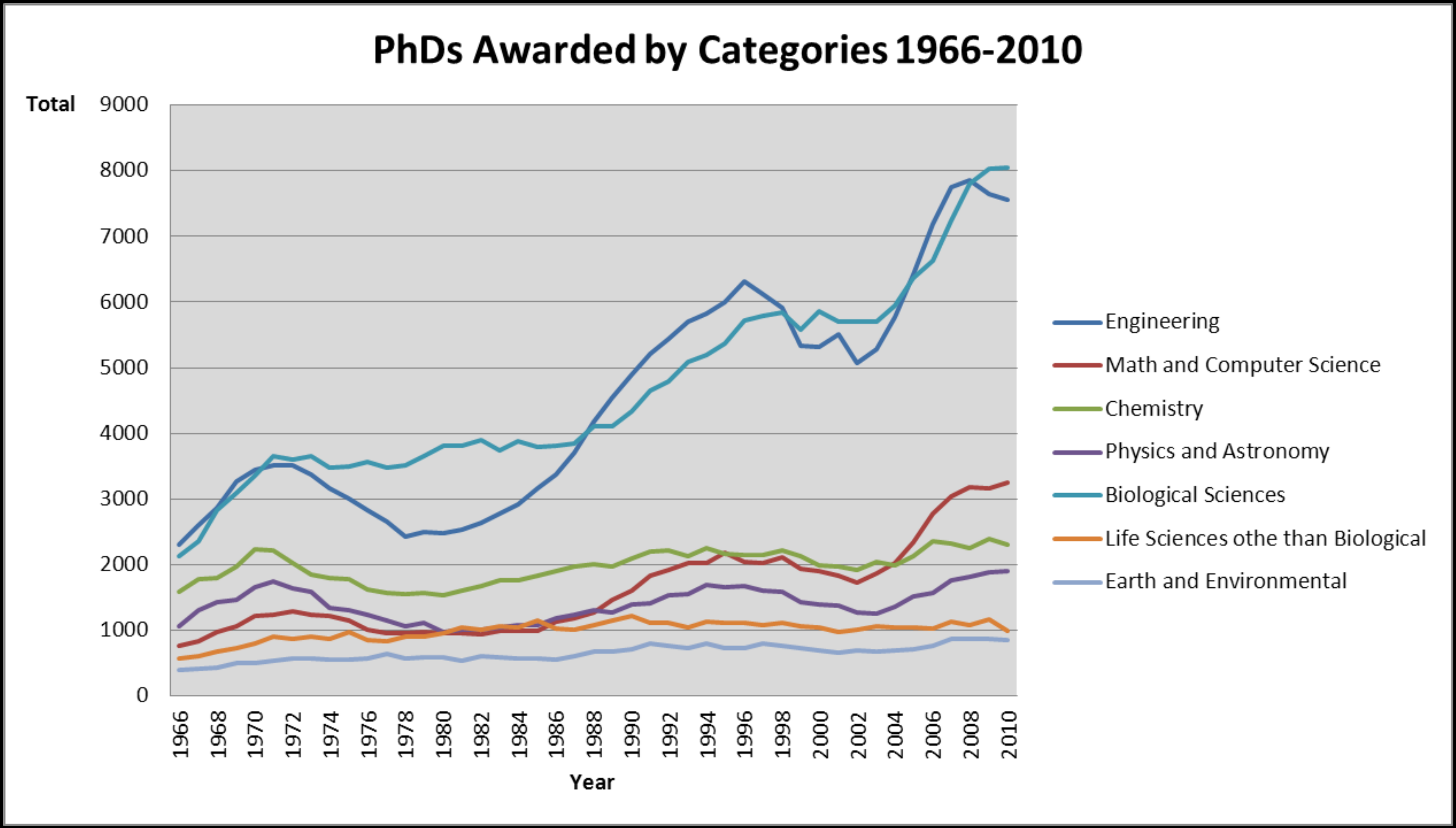
Doctoral Students by Type of Support



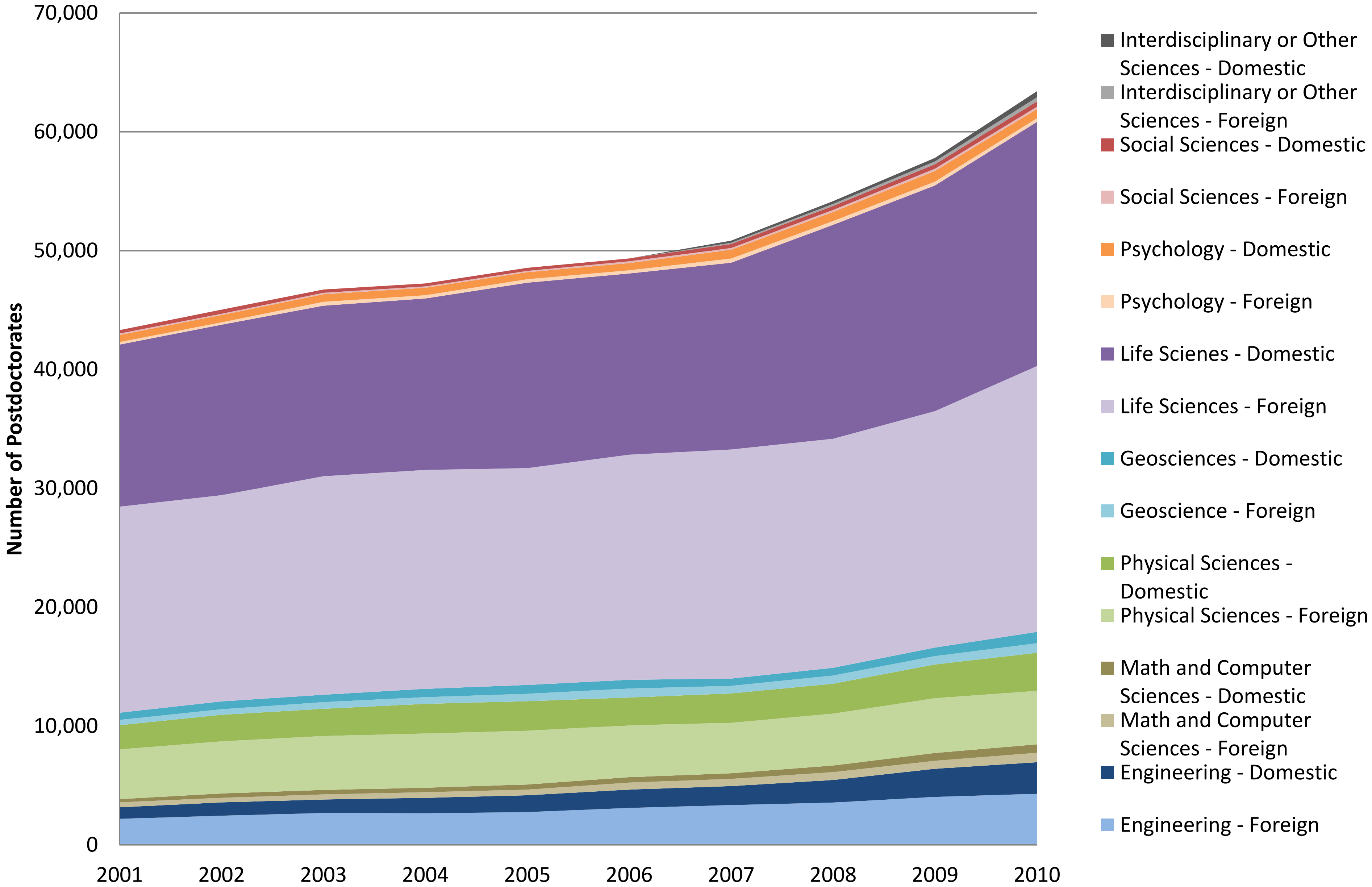
Primary Method of Support: 2011



Production of PhDs



Number of Foreign and Domestic Postdoctorates by Broad Field



The Life sciences are the largest contributor to the number of postdocs, foreign or domestic

In Short

Training has become less about future supply and more about getting research done now

Research System Comes with Unintended Consequences

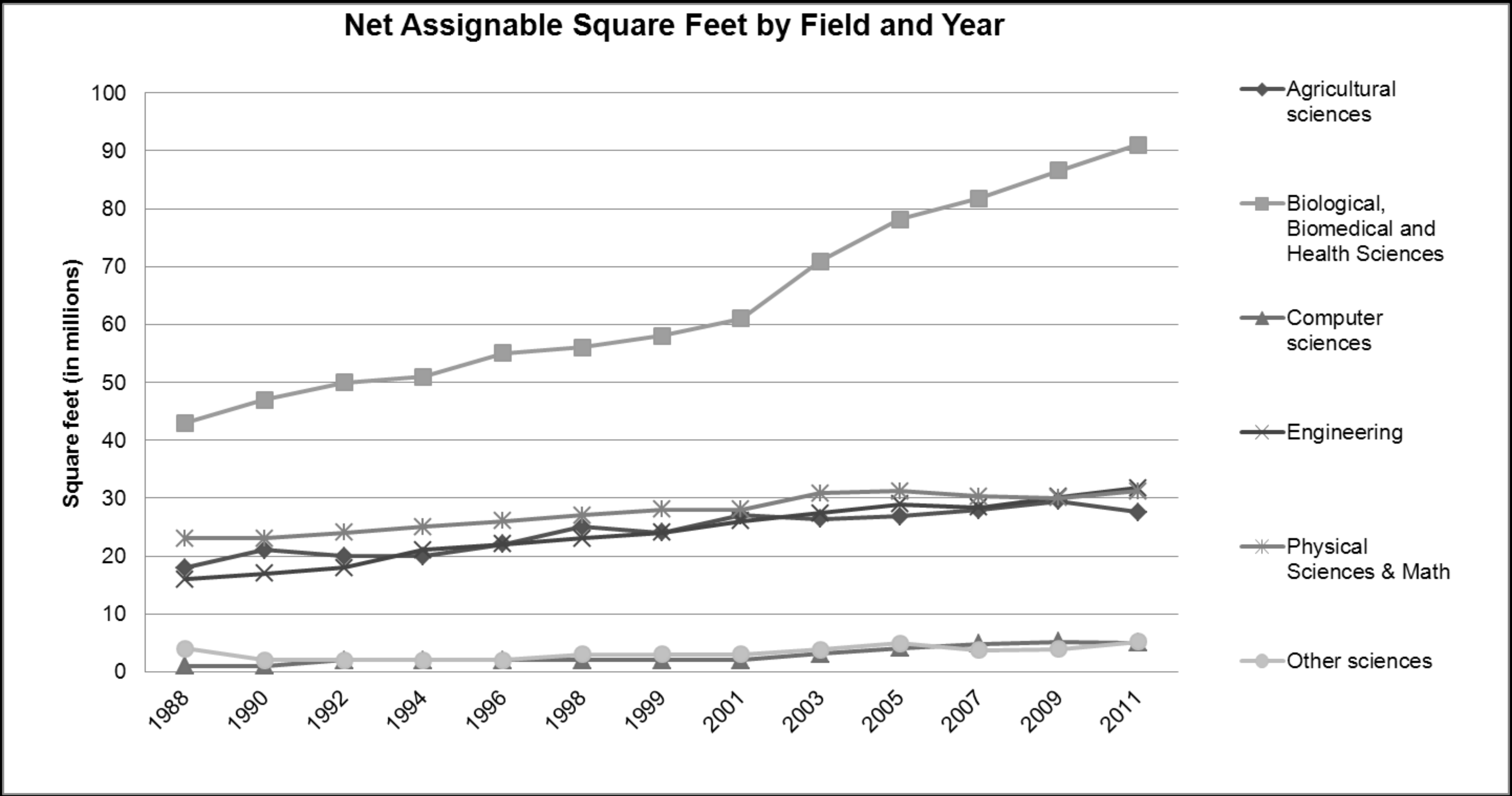
Unintended Consequences

- Overbuilding
  - Universities are at risk of defaulting on debt
- Overtraining has led to problems finding jobs
  - Discourages best and brightest from entering science
  - Inefficient use of resources
- Over emphasis on safe projects on part of investigators as opposed to risky agendas—
  - Detracts from ability to make fundamental breakthroughs—if most scientists are risk averse little chance that transformative research will occur, leading to significant returns from investments in research and development

Overbuilding

- Doubling encouraged universities to build new biomedical research facilities—assumed NIH funding would continue to grow
- Many universities borrowed to do so
  - Encouraged by government accounting rules which make debt an accounting asset
  - Interest university pays for debt service can be included in calculating indirect
- Building binge further fuelled by competition among universities to recruit senior, high-performing faculty

University Response



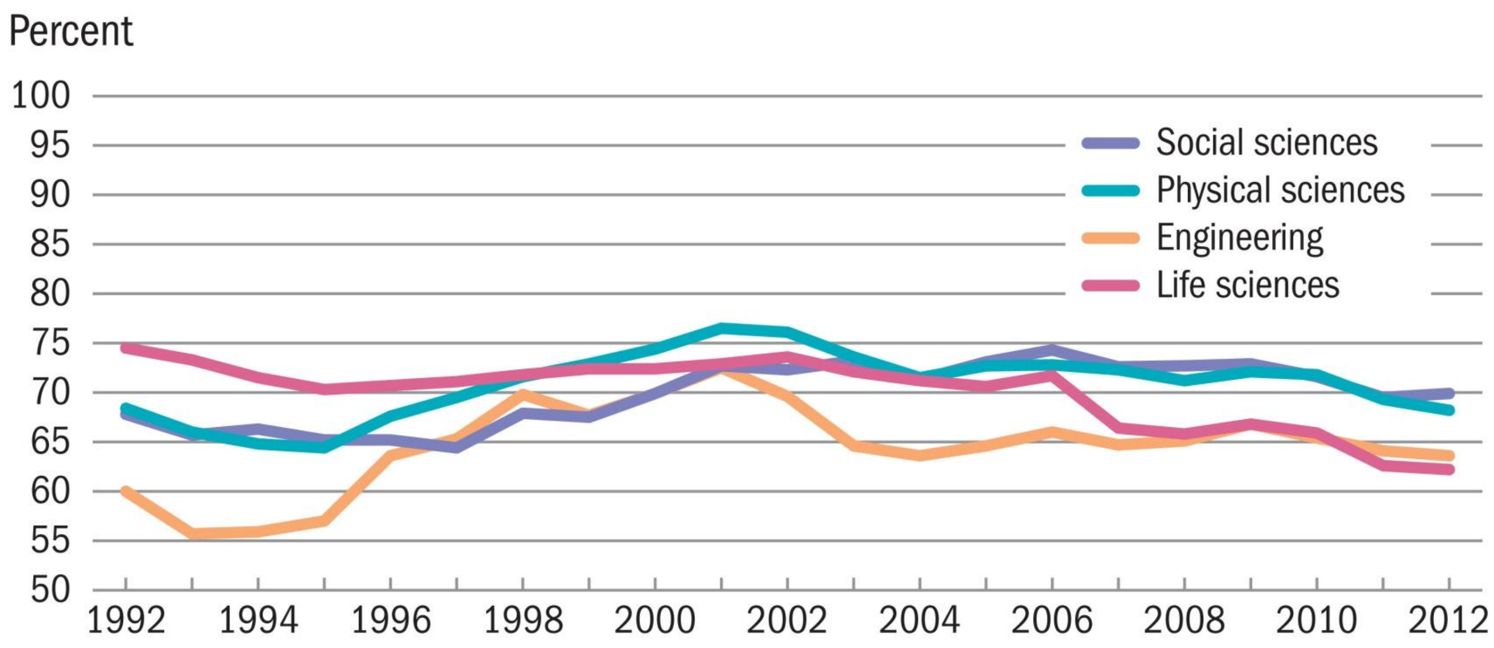
Debt

- Buildings often built with debt
- AAMC survey found
  - average annual debt service for buildings in 2003 was $3.5 million per medical school
  - grew to $6.9 million in 2008
- Where will the money come from?

Overtraining

- Overtraining relative to demand
- Evidence: from SED and NIH Workforce Committee
  - definite commitments down
  - postdoc taking rate up
  - growth in non-research jobs
  - growth in working in an area outside one’s field
  - decline in non-tenure track positions

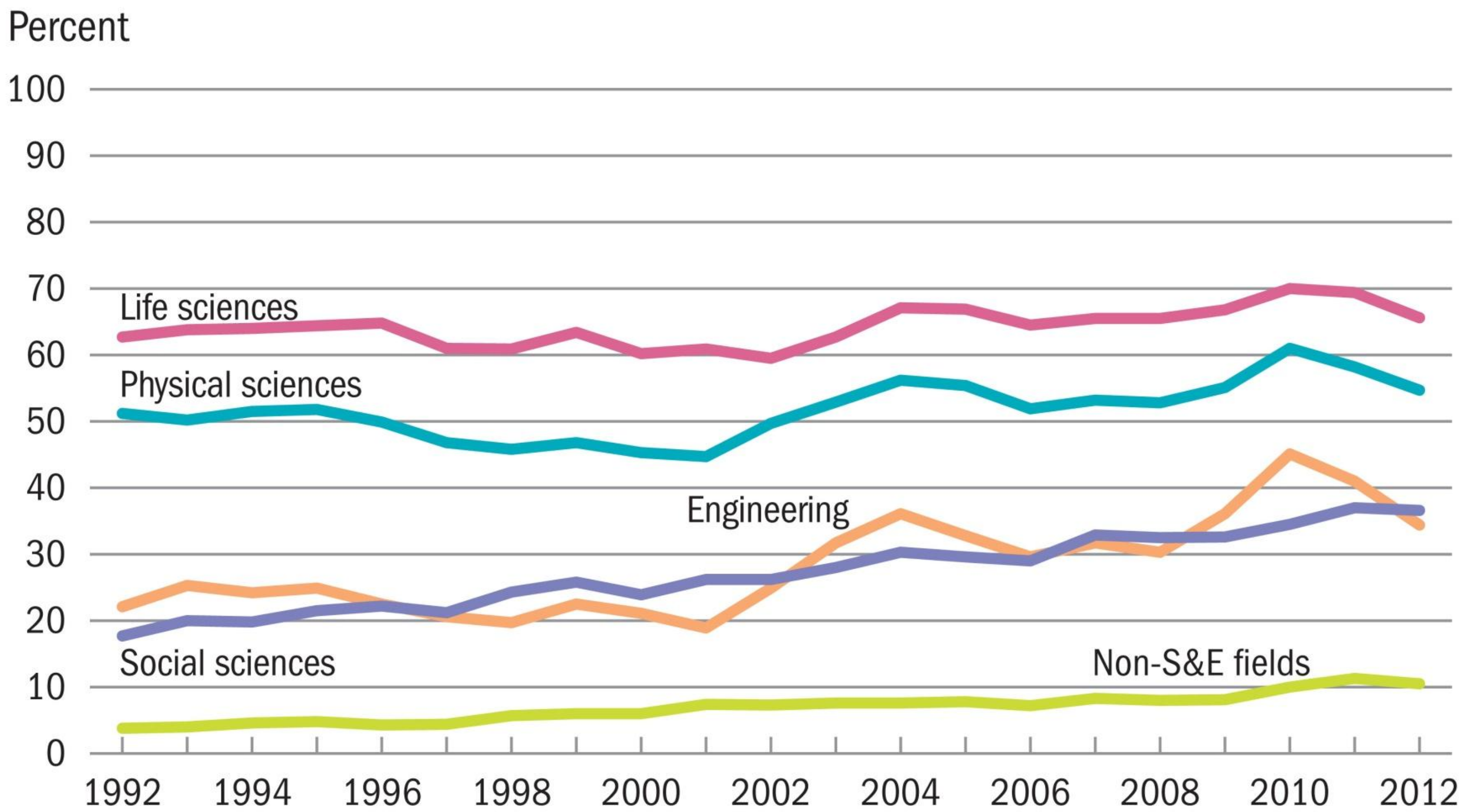
Definite commitments at doctorate award, by science and engineering fields of study: 1992–2012



NOTE: Definite commitment refers to a doctorate recipient who is either returning to pre-doctoral employment or has signed a contract (or otherwise made a definite commitment) for employment or a postdoc position in the coming year.

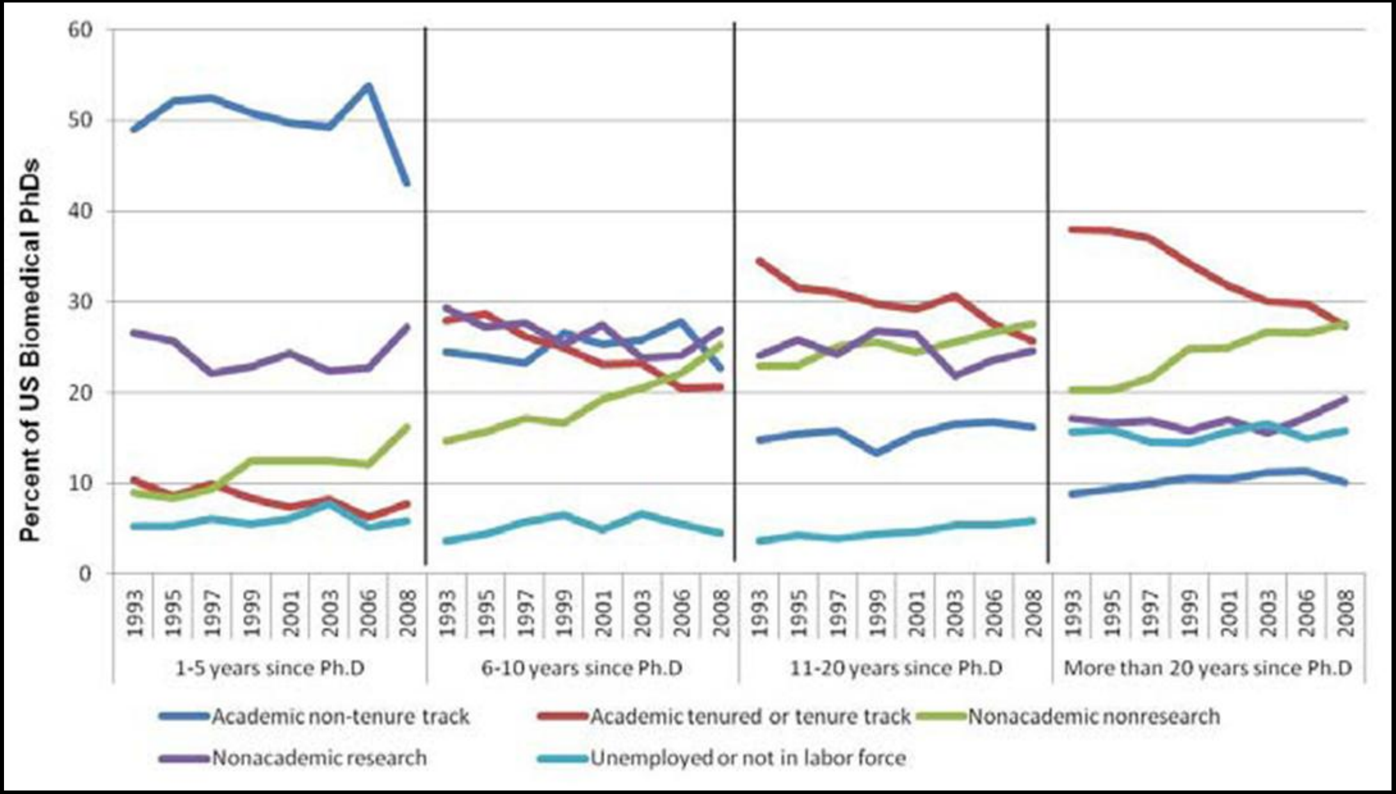
Related detailed data: tables 42, 43.

Postdoc rate, by field of study: 1992–2012

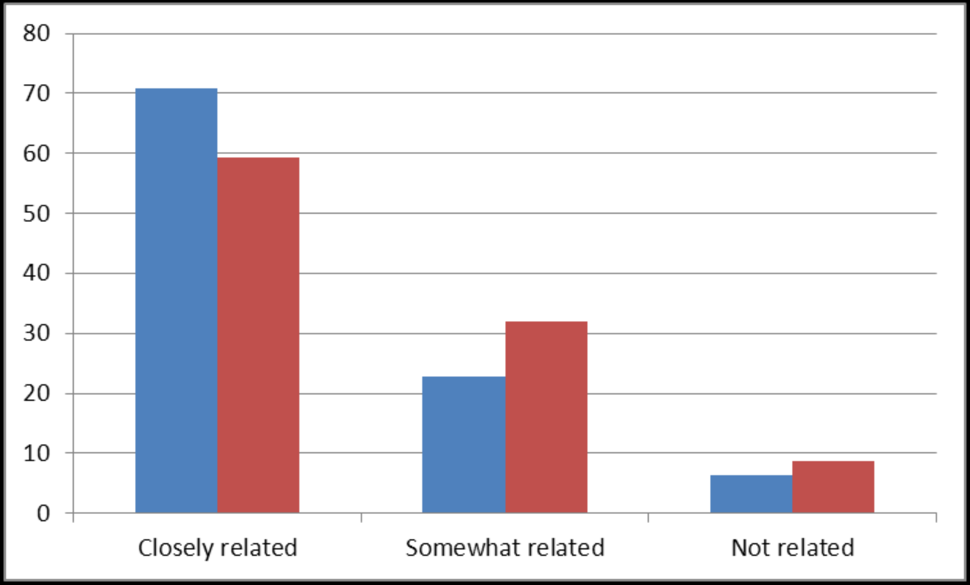


Related detailed data: tables 44, 51, 52.

Employment Outcomes by Cohort
Biomedical Sciences



Employment Related to Training (%) Biomedical Sciences

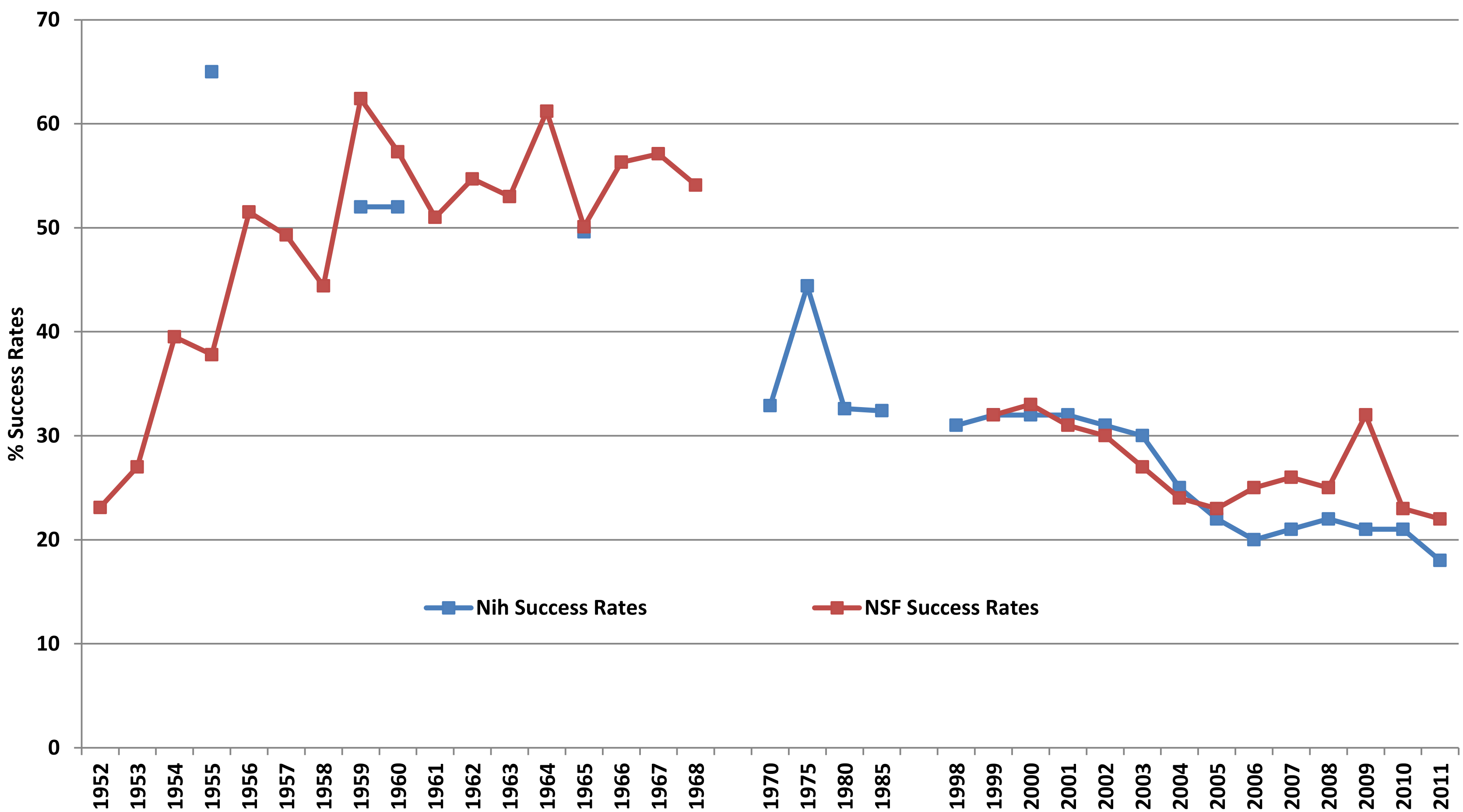


Blue: 1997; Red 2008

Over Emphasis on "Safe" Projects

- Evidence that scientists avoid risk by submitting proposals they see as "sure bets"
- Why?
  - One must have external support to keep lab going; university only supports lab for 3 to 4 years
  - Need for faculty to obtain grants to support their salary—especially important for faculty on soft money and for tenure-track faculty at medical schools
  - Low probability of success – currently 12 to 24 percent at NIH depending on institute; pay lines considerably lower
  - Reviewers prefer proposals with convincing preliminary data: "no crystal, no grant."
  - To quote Nobel laureate Roger Kornberg, "If the work that you propose to do isn't virtually certain of success, then it won't be funded."

NIH and NSF Success Rates Available Years



NSF rates for 1952-1968 are for the Division of Biological and Medical Sciences

Other Factors that Contribute to Risk Aversion

- Short term nature of grant—3 to 5 years (3.5 is average length
  - Hard to recover in this short period of time from a "failure"
- Focus on projects, not people
- Ability to continue a line of research—some continue a line for over 40 years
  - Continuations have higher success rates than new proposals

Way Forward

Increased Funding

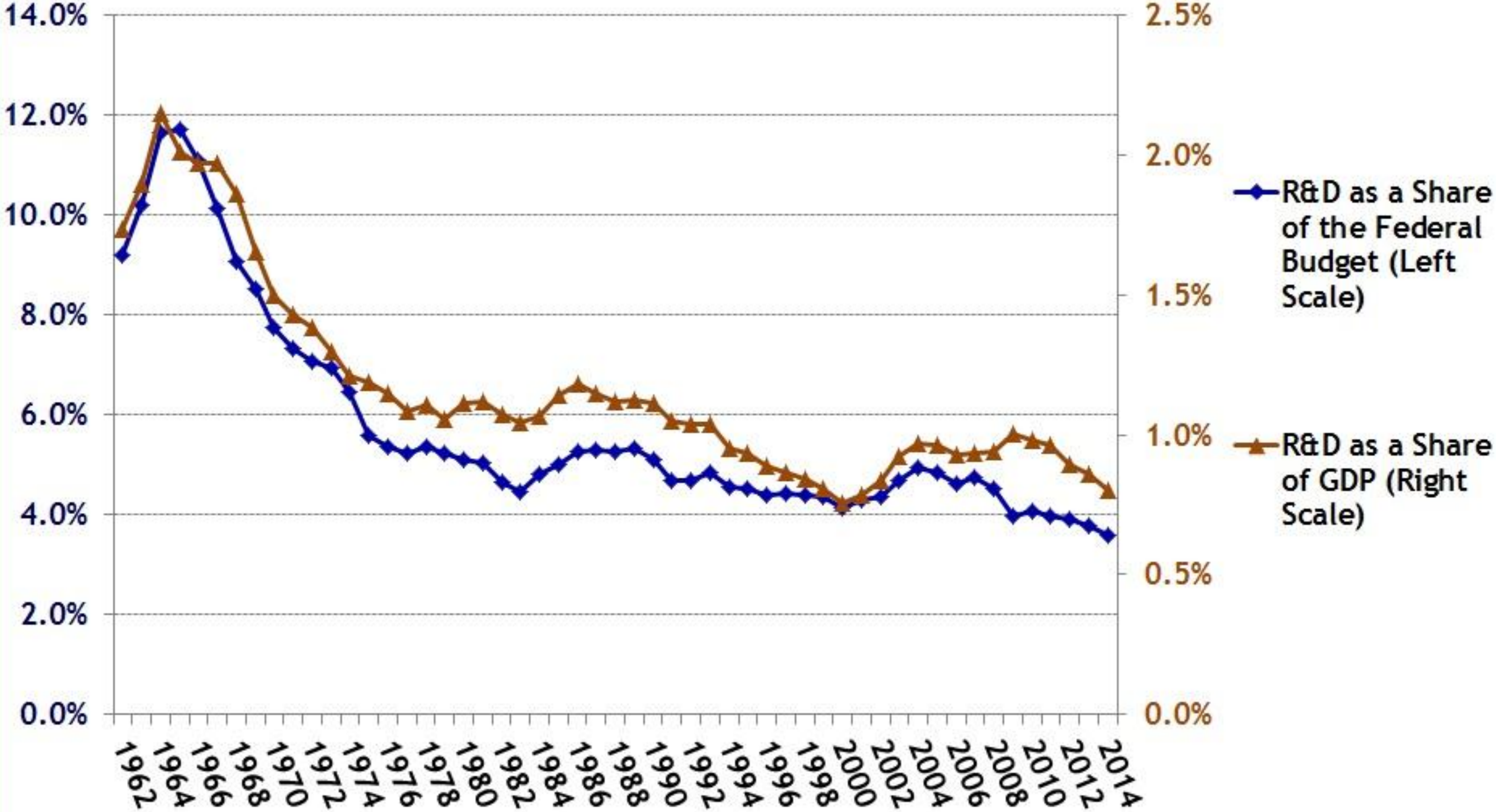
- Increased funding would provide relief but is not answer to solving inherent problems that have led system, with its positive feedbacks, to be unstable
  - To address these, incentives and costs must change
- Where would funds come from, if they were to increase?

Federal Funding

- Significant increase in Federal funding not likely to occur given current mood in Congress

Federal R&D in the Budget and the Economy

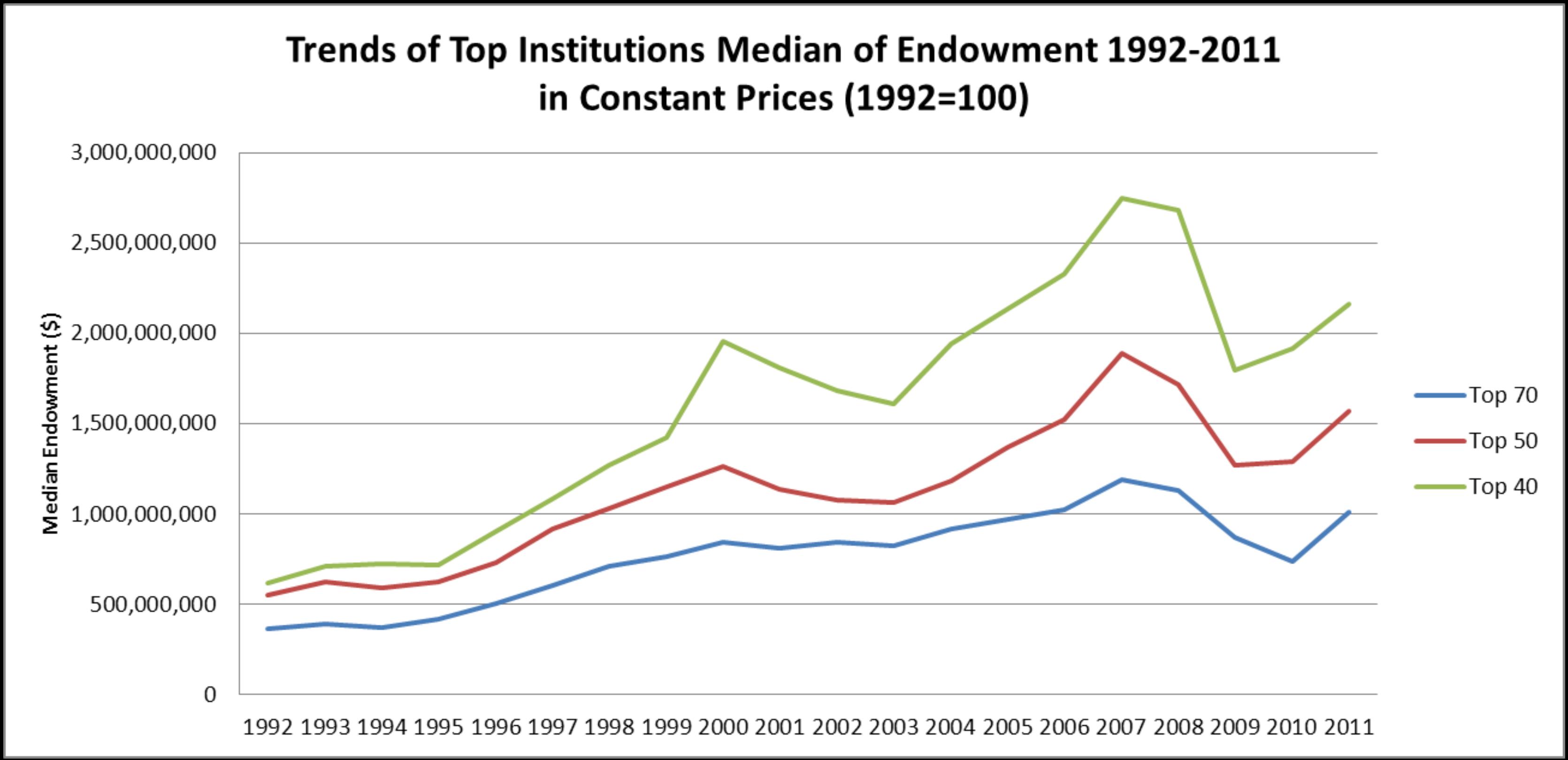
Outlays as share of total, 1962 - 2014



Source: *Budget of the United States Government, FY 2014.* FY 2013 data do not reflect sequestration. FY 2014 is the President's request.

Other Sources?

- Industry may step up funding, but unlikely to provide a significant increase—hovers around 5%
- States and local governments: picture is not rosy—now contribute less than 6%
- Endowments: highly cyclical, generally “dedicated,” low spending rules


Trends of Top Institutions Median of Endowment 1992-2011
in Constant Prices (1992=100)
Median Endowment ($)
3,000,000,000
2,500,000,000
2,000,000,000
1,500,000,000
1,000,000,000
500,000,000
0
1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011
Top 70
Top 50
Top 40

The New York Times

"Billionaires With Big Ideas Are Privatizing American Science"
New York Times, March 15, 2014

Funding from Nonprofits

- Now contributes more than industry—6% vs. 5%
- Has grown in recent years
- Likely to continue to grow as more wealthy individuals make bequests to universities and foundations in support of research
- Impressive—but a small amount (at most $2 billion a year)—compared to federal funding

A Panacea?

- Concerns:
  - Much is targeted, often translational support in biomedical sciences; who will fund basic research?
  - Incentives for universities to focus skills and research on rich and diseases that interest them, hoping to convince grateful patients to support research
  - Augments imbalance in US research portfolio that deemphasizes physical sciences and engineering
  - Philanthropy “answer” to research funding less readily available to some publicly funded and non-elite institutions

Funding from Securitization

- The Andrew Lo model, first presented in *Nature Biotechnology* 2012
- Idea: Use securitization techniques to raise funds from private sector to support biomedical research in firms
- Possibility of eventually extending concept to university research and to other fields
  - Combine many risky projects into one financial entity—provides “de-risking”
  - Allows a single entity to raise capital for projects by selling bonds and securities (200 times bigger)
  - Bonds and securities can have different risk

levels and thus appeal to broader range of investors.

But Concerns

- Securitization could provide funds for research with tangible goals such as cure for specific type of cancer
- But far more challenging to use such a financial instrument to fund basic research—if not goal oriented and no intellectual property is likely to emerge in foreseeable future
- Yet such research contributes greatly to our understanding and is most at risk of being cut by funding agencies

Moving Forward
Changing incentives and costs

Changing Incentives and Costs to Dampen Positive Feedbacks in Research System

- How we staff labs
- How salary is written off grants
- How funding is awarded

How Labs Are Staffed

- Diminish demand for graduate students & postdocs
  - Raise salaries of postdoctoral scholars to reflect cost, thereby discouraging their use
  - Support more graduate students on training grants; fewer as GRAs
  - Create incentives for hiring staff scientists
- Diminish supply of graduate students and postdocs
  - Require departments to post placement information on line—no placement data, no funding
  - Provide information on career outcomes to students at time they apply
  - Provide information regarding different career paths early in graduate training experience; don’t wait for career counseling until the postdoc!
  - Encourage internships during college and first year of graduate school

How Salary is Handled on Grants

- Place limits on amount and percent of salary that can be written off grants
  - Discourages soft money hiring
  - Makes system less volatile
  - Encourages risk taking

How Funding Is Awarded

- Fund according to portfolio theory: agencies must assume more risk in their portfolio
- Place more emphasis on funding people, rather than projects
- Make grants of longer duration

Suggestions Not New

- 1976 NRC report evaluating training grants concluded that a slower rate of growth in labor force in biomedical fields was advisable
- 1998 Biomedical Workforce Committee *Trends in the Early Careers of Life Scientists* made some of these recommendations
- Bruce Alberts made some of these suggestions in 2009 in an editorial in *Science*
- NIH Workforce Committee made several recommendations in keeping with these

The Challenge

- To date they have been largely ignored -- in large part because they had no “teeth” to them
- It is time to move forward and make changes in the way biomedical research is conducted
- Goal today has been to convince you that the biomedical community faces a challenge—and not just one of funding
- But of changing incentives and costs that have created a system that over trains, overbuilds and underinvests in risky research

Questions/comments

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