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AN EXAMPLE OF POSITIVE FEEDBACKS**

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The Biomedical Workforce in the US: An Example of Positive Feedbacks

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ABSTRACT

This paper makes the case that the biomedical workforce in the United States is characterized by positive feedbacks. The paper begins by setting out background information on (1) the way in which research is structured in the biomedical sciences; (2) the reward structure among biomedical researchers; and (3) the funding enterprise for biomedical sciences. After addressing these three key components, the paper examines what these mean in terms of the market for graduate students, postdocs and faculty. It then explores ways in which the positive-feedback mechanisms could be dampened. It concludes that the presence of positive feedbacks in the biomedical workforce is a result of system-wide problems. Any fix requires changing incentives. This is unlikely to occur as long as the U.S. Congress and faculty have their way.

¹ The author wishes to thank Erin Coffman for research assistance and Bill Amis for helpful suggestions on an earlier draft of this chapter. Portions of this chapter are drawn from Stephan (2009b)

1. Introduction

The standard neoclassical model of the labor market assumes that negative feedbacks occur, causing the market to self-correct if it is out of equilibrium. Thus, for example, an oversupply of workers in a specific sector leads wages to decline relative to those in other sectors. This in turn leads to a decrease in supply, resulting in an eventual increase in wages. The contraction in supply is accomplished through the outward mobility of workers to higher wage sectors as well as the choice by potential entrants of alternative sectors in which to work.

In the 1970s radical political economists proposed that not all labor markets were characterized by negative feedback. Instead, they argued that, because of segmentation, labor markets existed in the secondary sector that were characterized by positive feedbacks. As a result, low relative wages persisted, coupled with signs of oversupply. Moreover, they argued that the welfare system was an “integral part of this vicious circle” acting on the one hand to provide “a payroll subsidy to secondary employers” and on the other hand, to maintain “living levels low enough to force a steady flow of labor supply into the secondary labor market.” (Victorisz and Harrison 1973, Page 366).

While dual labor market economists focused on the low-wage-low-skill sector, in recent years several scholars have suggested that positive feedback is not limited to the low-skill sector. Indeed, a market which has many positive feedback characteristics is thriving among those who have ten-plus years of post-baccalaureate training. Furthermore, the government, by providing much of the funding for the market, plays an integral part in perpetuating the positive feedback in this market. The market in question is that for biomedical workers; the government agency that plays a leading role is the National Institutes of Health (NIH).

In a 2008 article, Michael Teitelbaum, a demographer by training, characterized the disequilibria in biomedical research in the United States (discussion to follow) as caused by “structural problems” and pointed out in an article in *Science* that research funding in the biomedical sciences is subject to “positive-feedback loops” that “drive the system ineluctably toward damaging instability.” (Page 644). He went on to point out that while in theory the poor job market outcomes experienced by individuals in the biomedical workforce should result in negative feedback “that would tend toward more stable equilibria,” because of structural problems this has not occurred (Page 644). Seven years earlier, Richard Freeman et. al. asked in another article in *Science* “why in the face of poor career prospects has the field [of biomedical science] increased its supply of students relative to other Ph.D. fields?” (2001, Page 2294)

In this chapter we extend the argument of Freeman et. al and Teitelbaum, making the case as to why the biomedical workforce is characterized by positive feedback. To do so requires background information on (1) the way in which research is structured in the biomedical sciences; (2) the reward structure among biomedical researchers; and (3) the funding enterprise

for biomedical sciences. After addressing these three key components, we set out to examine what these mean in terms of the market for graduate students, postdocs and faculty. We then explore ways in which the positive-feedback mechanisms could be dampened.

1. How research is structured in the biomedical sciences

The majority of biomedical research in the U.S. is performed at universities and medical schools. For example, 75.5 % of all papers authored by U.S. scientists in the field of biological sciences are produced in the university sector (National Science Board, 2010, Appendix Table 5-42).² The vast majority of this research is conducted in a lab setting, led by a faculty member, known as the principal investigator (PI).

How labs are staffed varies across countries. For example, in Europe research labs are often staffed by permanent staff scientists, although increasingly these positions are held by temporary employees (Stephan 2008). In the United States, while positions such as staff scientists and research associates exist, the majority of scientists working in the university lab are doctoral students and postdocs. Stephan, Grant Black and Tanwin Chang's study (2007) of 415 labs affiliated with a nanotechnology center, while not specific to the biomedical sciences, makes the point, finding that the average lab has 12 technical staff, excluding the PI. Fifty percent of these are graduate students; 16% are postdocs and 10% are undergrads.³ Some labs are quite large. A case in point is the Susan Lindquist lab at MIT which has 36 members (excluding Lindquist herself)—20 postdocs, 7 graduate students, 1 visiting scientist, 1 staff scientist, 3 technicians, and 4 administrators.⁴

This way of staffing labs has been embraced in the U.S. for a variety of reasons. Pedagogically, it is an efficient training model. It is also an inexpensive way to staff laboratories. Moreover, and as faculty are not abashed to note, it provides a source of “new” ideas, especially given the relative young age of doctoral students and postdocs. To quote Trevor Penning, while serving as the Associate Dean for Postdoctoral Research Training at the University of Pennsylvania School of Medicine, “A faculty member is only as good as his or her best postdoc” (Penning 1998). In addition, funding is often more readily available for predoctoral and postdoctoral students than for staff scientists. The typical NIH grant, for example, supports both types of training, as do many other forms of grants. There is also the added advantage that postdocs and graduate students, with their short tenure, provide for more flexibility in the staffing of laboratories than do permanent technicians.

Labs at U.S. universities “belong” to the faculty PI, at least in name if not in fact, as is readily seen by the common practice of naming the lab for the faculty member. A mere click of the

² Computed on the basis of fractional counts.

³ Approximately a third of the PIs were affiliated with departments of engineering, a third with departments of chemistry and the remainder with departments of physics.

⁴ The Lindquist lab is large compared to the labs of her colleagues at MIT in biochemistry and biophysics, which have an average of 6.3 graduate students (median of 7) and average of 5.25 postdocs (median of 5).

mouse, for example, reveals that all of the 26 faculty at MIT in biochemistry and biophysics use their name in referring to their lab.⁵ Sometimes, as in the case of the Nobel laureate Philip Sharp, lab members and former members are referred to using a play on the PI's name—in this case “Sharpies.”⁶

Research is expensive. Personnel costs alone for a small-to-medium lab, composed of three GRAs, one postdoc, one technician and the PI are approximately \$210,000 including salaries and benefits but excluding the cost of buying out the PI's time for research. Each additional graduate student adds approximately \$37,000; each additional postdoc adds approximately \$52,000⁷. Additional expenses include the cost of supplies and equipment. For research in the life sciences, supplies can easily average \$18,000 per year per lab member, or add another \$108,000 to the costs for a lab of six including the PI (Pelekanos 2008). This excludes the cost of animals, which can be quite expensive. An off-the-shelf mouse cost between \$17 and \$60 (US) in 2009; mutant strains begin at around \$40 and can go to more than \$500. The cost to recover a mouse from a strain that is only available from cryopreserved material is \$1,900 (Stephan 2010). With the large number of mice in use (over 13,000 are already published), the cost of mouse upkeep becomes a significant factor in doing research. U.S. universities, for example, charged from \$.05 to \$.10 per day per mouse (mouse per diem) in 2000 (Malakoff 2000).⁸ Equipping a lab adds considerably more to expenses. Pelekanos (2008) estimates that start-up equipment for a lab in the life sciences costs about \$60,000. But equipment can cost much more than this. The next generation sequencing machines, such as Illumina's Genome Analyzer System, cost approximately \$470,000 (Stephan 2009b).

In order to get started on an independent research career, faculty usually receive resources from the dean at the time they are hired. Included in these start-up packages are funds for equipment and stipends to hire graduate students, staff scientists and postdocs. Also, and of crucial importance in the lab sciences, they are assigned lab space. Ehrenberg, Rizzo and Jakubson (2003) surveyed U.S. universities regarding start-up packages in the early 2000s. They found that the average package for an assistant professor in biology was \$403,071. At the high end it

⁵ Details regarding research and staffing are available for 17 of the 26 via lab web pages. Three other faculty have web pages for their labs that are not fully developed. For the other six one can find reference to the name of their lab when searching the internet.

⁶ In a similar manner, graduate students and postdocs working in Alexander Pines' lab at Berkeley, are referred to as “pinenuts” and alumni are referred to as “old pinenuts” (<http://waugh.cchem.berkeley.edu/people/>).

⁷ The graduate student amount includes stipend, fringe benefits and tuition and is based on the amount allowed by NIH for the Ruth Kirstein NRSA fellowship for FY 2007. Many institutions pattern their support for other students on the Kerstein fellowship. The postdoc figure includes stipend and fringe benefits; it is the average paid under NIH guidelines for postdocs with varying experience. The fringe estimate comes from Pelekanos (2008), as does the cost estimate for the technician.

⁸ The cost of mouse up-keep can rapidly add up. Irving Weissman of Stanford University reports that before Stanford changed its cage rates he was paying between \$800,000 and \$1 million a year to keep the 10,000 to 15,000 mice in his lab. Costs for keeping immune-deficient mice are far greater (on the order of \$.65 per day), given their susceptibility to disease.

was \$437,000. For senior faculty they report start-up packages of \$957,143 in biology (high end is \$1,575,000).

Start-up packages are exactly that. After several years, the faculty member becomes responsible for procuring the resources for the lab. Faculty do this primarily through the grants system, writing proposals and, if successful, receiving funds from Federal agencies and private foundations.⁹ Faculty also receive support for their labs from industry. One exception to the rule is that faculty sometime host postdocs who have received funding through a fellowship or graduate students supported on training grants (awarded to the department) who work (on a rotation basis) in a faculty lab.¹⁰ Increasingly, faculty are expected not only to cover the research expenses of the lab through grants and contracts, but also to cover a portion of their own salary. Indeed, it is becoming increasingly common for faculty in tenured positions at U.S. medical institutions to be required to procure a portion of their salary from grants.¹¹

Organizationally, PI labs in the United States are structured as pyramids. At the pinnacle is the faculty principal investigator. Below the PI are the postdocs; below the postdocs are graduate students and undergraduates. Some labs also have scientists who have completed postdoctoral training in this or another lab and are hired in such non-tenure-track positions as staff scientists and research faculty. The pyramid analogy does not stop here, however. In certain ways the research enterprise itself resembles a pyramid scheme. In order to staff their labs, faculty recruit PhD students into their graduate program with funding and the promise of interesting research careers (Stephan and Levin 2002). Upon receiving their degree it is mandatory for students who aspire to a faculty position to first take an appointment as a postdoc. Postdocs then seek to move on to tenure-track positions in academe. The Sigma Xi study of postdocs, for example, found that 72.7% of the postdocs who were looking for a job were “very interested” in a job at a research university and 23.0% were “somewhat interested” (Davis 2005). In recent years, however, the transition from postdoc to tenure track has been slowed as the number of tenure-track positions has failed to keep pace with the increase in supply (discussion to follow).

Faculty actively recruit and select the students who work in their lab. Unlike admission decisions to PhD programs, however, which generally occur at the department level, decisions regarding staffing are usually made by the faculty member who, in effect, is paying for the student. Recruitment is even more direct in the case of postdocs, since the department plays no intermediate role in terms of admission. All decisions are the domain of the faculty member.

⁹ The primary sources of federal funds are The National Institutes of Health (NIH), the Department of Energy (DOE), the Department of Defense (DOD) and, to a lesser extent, the National Science Foundation (NSF).

¹⁰ MIT, for example, distinguishes between postdoctoral associates and postdoctoral fellows. The former are supported through grants that faculty have procured at MIT; the latter have received fellowships or stipends to work with a faculty member at MIT.

¹¹ A survey of medical schools found that tenure is accompanied with no financial guarantee for 35% of basic science faculty and 38% of clinical faculty (Bunton and Mallon 2007).

Not surprisingly, given the role faculty play in staffing decisions, networks or what may more accurately be described as “affinity effects” appear to play a role in staffing. Tanyildiz (2008) has studied paired labs in 82 departments of engineering, chemistry, physics and biology. In each case she matches a lab directed by a “native” PI (as established by name and undergraduate institution) to a lab directed by a foreign PI, either of Chinese, Korean, Indian or Turkish background. She then studies the graduate student composition of the labs, assigning nationalities to the students based on the common-name methodology used by Kerr (2008). She finds significant differences in the role that ethnicity plays in staffing. The mean paired difference in the percent of Chinese students in a lab directed by a Chinese PI versus a lab in the same department directed by a “native” U.S. faculty is 37.8%; that for Koreans is 29.0%; that for Indians is 27.1%; that for Turkish is 36.3% (very small sample). When she compares labs directed by natives to non-natives from one of these four groups the mean paired difference is 28.9%. Clearly clustering by ethnicity occurs in labs. Tanyildiz also finds that affinity effects are more common in “bottom”-ranked departments; less common in “top” departments.¹² In related work, Gaulé and Piacenti (2010) find that around 40% of the dissertation students of Chinese advisors in the U.S. are themselves Chinese.

2. The Incentive System in Biomedical Sciences

Scientists are motivated to do research because of their interest in solving puzzles; they also do research because of desire for being recognized as being first, or as Robert Merton articulated, establishing priority of discovery. Moreover, they are not immune to the reward of money. Stephan and Sharon Levin (1992) describe these three components as “puzzle, ribbon and gold.”

By far the most important of these motives, at least from the point of view of this chapter, is the interest in recognition, which comes by being the first to solve a particular problem. The recognition that the scientific community bestows on priority has varied forms, depending on the importance the scientific community attaches to the discovery. Heading the list is eponymy, the practice of attaching the name of the scientist to the discovery. The hunt for the Higgs particle, for example, is in the news these days with the completion of the new accelerator at CERN (the LHC) and its associated four colliders. The particle is named for the Scottish physicist Peter Higgs, who was first to postulate a theory (in 1964) to explain why fundamental particles have mass, and predict a new particle that subsequently bore his name. Many other examples of eponymy exist: Haley’s comet, Planck’s constant, Hodgkin’s disease, the Copernican system, Boyle’s law, RSA, to name but a few.¹³

¹² Using National Research Council rankings, she finds that the mean difference is 25.9% in “top” departments; 35.9% in “middle” departments and 53.2% in “bottom” departments. These calculations do not include mean differences between native students in native labs vs. native students in non-native labs.

¹³ RSA, an algorithm for a public-key cryptosystem and the algorithm of choice for encrypting Internet credit-card transactions, was published in 1977 by Ron Rivest, Adi Shamir, and Leonard Adleman (hence the name

Recognition also comes in the form of prizes; sometimes for a particular discovery, in other instances in recognition of a scientist's life work. Among prizes, the Nobel is the best known, carrying the most prestige and a large--although not the largest--purse of approximately \$1.3 million. But hundreds of other prizes exist, a handful of which have purses of \$500,000 or more such as the Lemelson-MIT prize with an award of \$500,000, the Crafoord Prize (\$500,000), the Albany Medical Center Prize (\$500,000), the Shaw prize (\$ 1 million), the Spinoza Prize (1.5 million euros), the Kyoto Prize (\$460,000) and the Louis-Jeantet Prize (700,000 CHF) to name but a sampling.

Other forms of recognition exist. For example, many countries have societies to which the luminaries are elected: The National Academies of Science, Engineering, and Medicine in the United States, the Royal Society in England, the Académie des Sciences in France.

The importance scientists attribute to priority and reputation can be inferred by a variety of social conventions and practices in science. It is not unknown for scientists to argue about the order in which they appear on a program. Two issues are at stake: not wanting to be scooped and enjoying the prestige associated with being listed first. Scientists have been known to collect class notes from students in an effort to stave off the competition or, in the case of mathematicians, to leave out a key point of a proof. Disputes regarding author order can also occur.

The research enterprise in the biomedical sciences has characteristics of what economists call a tournament model (Lazear and Rosen 1981; Freeman et al 2001). Such contests are characterized by offering contestants the chance to win a large prize such as becoming a principal investigator, receiving tenure, holding an endowed chair, winning a prestigious prize, being elected to the National Academy. Because small differences in productivity can be amplified into large differences in rewards, tournament models are characterized by intense competition. A researcher can be scooped by another, merely because her article arrived several days later; a principal investigator can fail to get his grant renewed, missing out by a tenth of a percent.

The tournament nature of the research enterprise puts enormous pressure on faculty members: since "the slightest edge can make the difference between success and failure." (Freeman et. al 2001, Page 2993). Given the pressure to publish and publish quickly, PIs work long hours. Moreover, they look for ways to increase speed and output. One way to accomplish this is to increase the size of one's lab: the easiest (and cheapest way) to do so is to recruit more graduate students and postdocs. Graduate students and postdocs are, as noted above, full of fresh ideas and are relatively inexpensive. Moreover, they are dispensable if one's financial fortunes decline. The tournament nature of research also creates students and postdocs with narrow specialties.

RSA). Recognition is also awarded by attaching a scientist's name to a building, professorship, or lecture series, although this form of recognition usually comes after the death of the scientist while eponymy can occur during the scientist's life.

Faculty, after all, have narrow foci (essential for establishing a reputation); they recruit graduate students to work with them and they “keep” them in their lab for four or five years.

3. The Funding Enterprise for Biomedical Sciences in the United States

U.S. universities in 2008 spent almost \$52 billion on research (in 2008 dollars). The largest contributor to research by far was the federal government (60.2%), followed by universities themselves (20.1%). Considerably less came from state and local governments (6.6%), industry (5.5%) and other sources (7.6%) such as private foundations. (Britt 2009 Table 1).

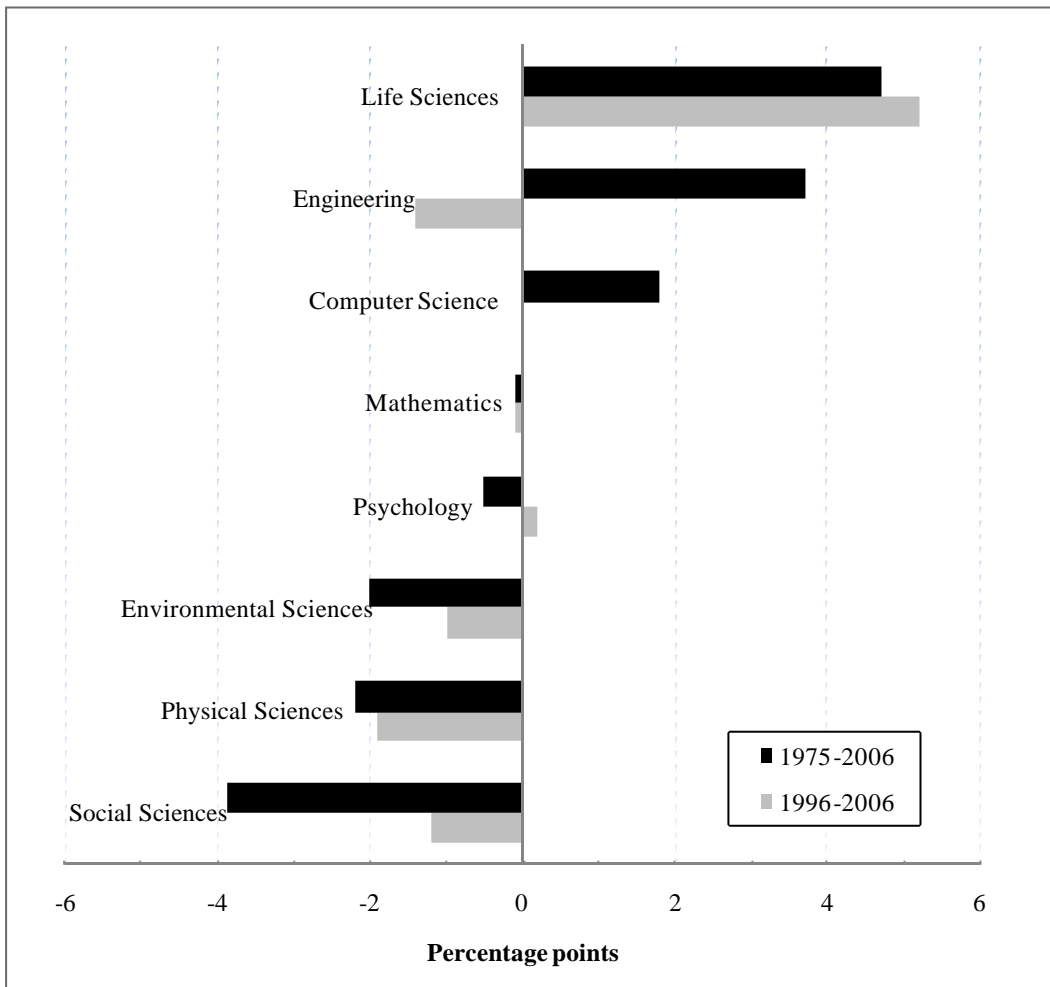
Funding data for U.S. university research by field is given in Figure 1 for the entire period 1975-2006 and for the later period, 1995-2006. The decline of the physical and engineering sciences and the growth of the biomedical sciences are abundantly clear. Over the entire period, only three areas of research have experienced an increase in share: computer science, engineering, and the life sciences. The share of funds going to the physical, environmental and social sciences, psychology and math has declined. In the most recent period, the share going to the life sciences has increased at the expense of the share going to all other fields of research.

Federal funding for biomedical research comes primarily from NIH. Figure 2 shows the NIH budget in current and real terms over the period 1997 to 2009. Although growth has been far from steady, especially when the budget doubled between the years 1998 and 2002, the upward trend is impressive and the envy of the physical and engineering sciences as well as of biomedical researchers in other countries.

The U.S. love affair with funding for the life sciences, especially the biomedical sciences is not difficult to understand. It is far easier for Congress to support research that the public sees as benefiting their well-being. Moreover, a large number of interest groups constantly remind Congress of the importance of medical research for “their” disease. The age distribution of Congress does not hurt. The average member of the House of Representatives in 2009 was 56.0; the average senator was 61.7.¹⁴ Both houses are considerably older than they were at their “youngest” in 1981 when the average member of the House of Representatives was 48.4 and the average Senator was 52.5 (Congressional Quarterly 2008). Certain senators are particularly focused on biomedical research. Senator Arlen Specter (born in 1930), for example, has long been a champion of NIH funding and almost single-handedly increased the amount that NIH got out of the 2009 stimulus funds (officially referred to as the American Recovery and Reinvestment Act—or ARRA) from \$3.9 billion to \$10.4 billion. He is also a three-time survivor of cancer.

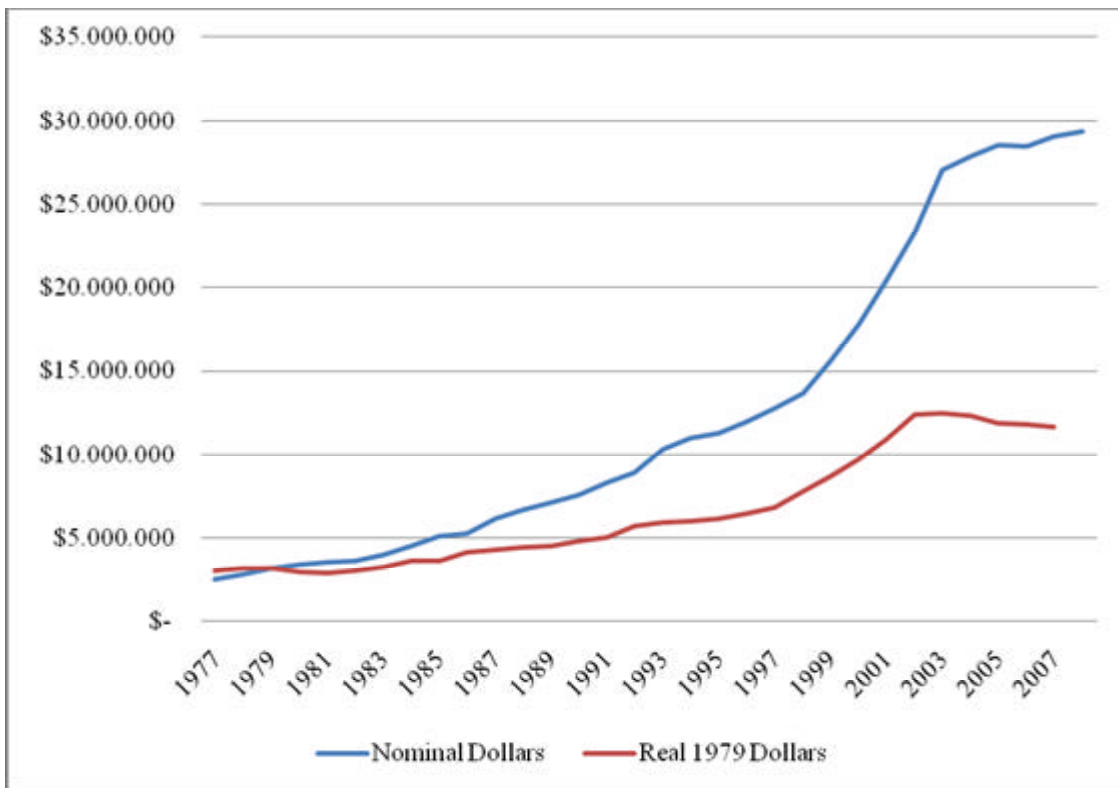
¹⁴ http://www.centeroncongress.org/learn_about/feature/qa_members.html#age

FIGURE 1: CHANGES IN SHARE OF ACADEMIC R&D IN SELECTED S&E FIELDS: 1975-2006 AND 1996-2006



SOURCE: National Science Board 2008, Figure 5-7.

FIGURE 2: NIH BUDGET, 1977-2008



SOURCE: The NIH Almanac – Appropriations, National Institutes of Health, 2010.

The ARRA package, as noted above, included a substantial amount of funds for NIH to be spent over a two-year period.¹⁵ By the end of the first year of the stimulus awards, fully a third of these funds had been committed to administrative supplements to existing awards, provided to “accelerate the tempo of research” by hiring more people or buying more equipment. The supplements are reviewed by NIH staff, not peer reviewed. Although it is too early to know exact numbers, many of the new hires are postdoctoral scholars and graduate students.

NIH spent an additional 33% of the first year funding on projects that had been reviewed prior to the stimulus package, but had missed the payline. Many of these projects will involve graduate students and postdocs, as well. In addition, it spent approximately a quarter of the first-year funds on projects submitted in response to the stimulus announcement; some of these will also involve graduate students and postdocs.¹⁶

¹⁵ At the time of this writing, it is unclear what the fate of the NIH budget will be after the stimulus funds expire. To be more precise, it is unclear whether NIH will receive funds to offset the loss of stimulus moneys.

¹⁶ NIH spent the rest of the first-year stimulus funds on competing revisions (supplements to existing awards) and on summer supplements. “Preliminary NIH ARRA FY2009 Funding.”

See http://report.nih.gov/PDF/Preliminary_NIH_ARRA_FY2009_Funding.pdf

Support for research in the biomedical sciences also comes from private foundations. The most prominent among these is the Howard Hughes Medical Institute (HHMI). Established in 1953 by Howard Hughes, the Institute acquired a stronger footing when it sold the Hughes Aircraft Company to General Motors in 1985, thus establishing the Institute's endowment at \$5 billion.¹⁷ In 2008 its endowment was valued at close to \$18 billion. By law HHMI is required to distribute 3.5% of its assets each year. It has done so by supporting between 300 and 350 HHMI investigators at research universities, funding a number of training programs, and establishing the Janelia Farm Research Campus, in Ashburn, Virginia, that opened in 2006 with the goal of bringing 25 interdisciplinary teams together to study neural circuits and imaging (Kaiser, 2008a).

The decision as to whether or not NIH will support a particular research project is determined through a process of peer review. It begins when the Principal Investigator submits a proposal to NIH; the proposal is then assigned to a "study section." Study section members review proposals in advance of the meeting. When the study section meets, a process of triage occurs which results in approximately half of the proposals not being formally discussed and not scored. Investigators whose proposals are not scored receive no written comments. Proposals that survive the triage process are discussed in some detail and scored to one decimal point by members of the study section on a 1 to 5 scale, 1 representing the most favorable review and 5 representing the least favorable. An average of the reviewers' scores (rounded to two decimal points) is then computed and multiplied by 100.¹⁸ Scores are standardized by pooling them with those given in other recent meetings. The resulting priority score and accompanying written review is forwarded to the specific institute (there are 27 institutes and centers at NIH) and reviewed by the institute's national advisory committee. Percentile cutoffs are important in determining who gets funded, although NIH does fund PIs whose proposals fall outside the cutoff. Investigators whose proposals are turned down have the right to resubmit two additional times. Most do. It is particularly challenging to resubmit if one's proposal is not scored, for then there are no written comments to address. This is a particularly serious problem for new, not established investigators.¹⁹

The review process puts considerable weight on past accomplishments, which are enumerated on a standardized NIH biosketch form. Results from the previous grant (if there was one) also play an important role in the evaluation. The presence of demonstrated expertise and strong preliminary data also play an especially key role in the review process. A major reason that universities provide start up funds is to permit the newly hired faculty member time to continue

¹⁷ <http://www.hhmi.org/about/growth.html>

¹⁸ <http://www.niaid.nih.gov/ncn/newsletters/2008/1217.htm#n01>

¹⁹ NIH recently made major modifications in its peer review system in an effort to address various concerns. To wit, it has restricted the length of the proposal (cutting it from 25 to 12 pages beginning in January of 2010), and streamlined the quantity and format of written comments expected from reviewers. NIH also modified the scoring system, resulting in a two-digit score rather than a three-digit score, and instituted a policy to score and rank all proposals, thereby effectively abolishing triage.

the process of collecting preliminary data for an NIH proposal. Researchers must also demonstrate that they have adequate space at their university in which to conduct the research.

Historically anywhere between 10 and 40% of applications have been funded. Success obviously depends on the number of applications, the cost of the proposals being considered and the availability of funding. It is also institute specific. For example, in 2008, the highest success rate was for applications reviewed by the National Eye Institute (29.5%); the lowest was for proposals reviewed at National Institutes of Child Health and Human Development (16.8).²⁰ In 2001, during the doubling, several institutes had success rates above 35%; many more had success rates above 30%.²¹

The R01 grant, the “bread and butter” for university investigators, typically lasts for three to five years. Researchers can apply to renew their grant. This is the norm, not the exception. It is greatly encouraged by the fact that renewals do much better in the review process than new proposals. It is not unknown for researchers to be supported on the same grant for forty-plus years. Or even fifty-plus. Harold Scheraga (Cornell University) has had the same NIH grant to study protein folding for 52 years.²²

The NIH grants system has not been friendly to the young. In recent years, for example, the number of new investigators funded by NIH has remained almost constant while the number of experienced investigators increased (more to follow). And success, when it comes, increasingly comes to older scientists. The average age at which one receives first independent funding increased from 37.2 to 42.4 between 1985 and 2006. (American Academy of Arts and Sciences, 2008, Page 11). At least three factors contribute to this outcome: First, the need for preliminary results biases funding decisions towards more established researchers and delays the submission of grants by investigators just starting out. Second, more than 70% of new investigators must resubmit their proposals before receiving funding; thirty years ago over 85% of all new investigators received funding on their first submission. Resubmission can easily add an additional year to the process. Third, people increasingly are older at the time that they get a tenure-track position. (American Academy of Arts and Sciences, 2008, Page 12).

It’s tempting to assume that more money will translate into higher success rates and better outcomes for the young. But this did not occur when the NIH budget doubled between 1998 and 2002. By the time the doubling was over, success rates were no higher than they had been before the doubling. By 2009, and partly because of the real decreases that NIH experienced in the intervening years, success rates were considerably lower than they had been before the doubling. Faculty were spending more time submitting and reviewing grants. The percent of

²⁰ See http://report.nih.gov/award/success/Success_ByIC.cfm. Excluded from the discussion are institutes that received fewer than 500 proposals and the NCCAM National Center for Complementary and Alternative Medicine.

²¹ http://report.nih.gov/award/success/Success_ByIC.cfm

²² Scheraga, who was born in 1921, may be the oldest NIH investigator. In March of 2009 he wound down another NIH grant for experimental work and in the process freed up lab space for a new faculty member. See Kaiser 2008b).

proposals funded on the first submission fell from over 60% in the early 2000s to 30%.²³ Over one-third of all funded R01 proposals were not approved until their last and final review. This not only took time and delayed careers; the perception was that these “last chance” proposals were favored over others, creating a system that, according to Elias Zerhouni, the former director of NIH, awarded “persistence over brilliance sometimes.” (Kaiser, 2008c, Page 1169). Moreover, and jumping ahead to the discussion in Section 5, there is little evidence that the increase translated into permanent jobs for new PhDs, as had been the case in the 1950s and 1960s when government support for research expanded.

A major cause of this seeming paradox was the response of universities to the doubling. Some universities saw the doubling as an opportunity to move into a new “league” and establish a program of “excellence.” Others saw it as an opportunity to augment the strength they already had. For others, expansion of their existing programs was simply necessary if they were to remain competitive in biomedical research. Regardless, the end result was that the majority of research universities went on an unprecedented building binge.²⁴ Universities used philanthropic, local, and state resources, as well as debt, to finance the expansion. They hired additional faculty and research scientists, many in soft-money positions. Universities also encouraged faculty who had heretofore not applied for grants from NIH, to apply. They also encouraged those who had NIH grants to get additional grants: not one grant or two grants but three became the expectation at many research institutions. New buildings with larger labs required more resources to support them.

Not surprisingly, the number of applications for new and competing research projects grew. In 1998, NIH received slightly over 20,000 applications for R01 awards; by 2003 it received 24,634 and by 2008, long after the doubling had ended, it received 26,648. Success rates, which initially grew, declined from 32% to 23%.²⁵ Some of the new grants went to researchers who had heretofore not received NIH funds. But the vast majority of new grants went to established researchers: the percent of investigators who had more than one R01 grant grew by one-third during the doubling, going from 22% to 29%. (Davis 2007). The number of first time investigators grew by no more than 10%.²⁶

Young researchers were at a disadvantage competing against more seasoned researchers who had better preliminary data and more grantsmanship expertise; at every submission stage the success

²³ PowerPoint “Update on NIH Peer Review,” distributed by National Institutes of General Medicine to Advisory Council.

²⁴ See Heinig et al. (2007) for a discussion of the dramatic increase in building that occurred at American medical schools.

²⁵ See Research Portfolio Online Reporting Tool RePORT.

<http://report.nih.gov/NIHDatabook/Charts/SlideGen.aspx?chartId=126&catId=1>

²⁶ The number of first-time investigators who received R01 (or equivalent funds) from NIH went from 1439 in 1998 to 1559 in 2003. (NIH, Office of Extramural Research.) There was a considerable increase, however, in the number of R03 and R21 awards made to new investigators. Both are small (the R03 is for \$50,000 for two years; the R21 is for two years and cannot exceed \$275,000 in direct costs).

rates of new investigators was lower than for established researchers submitting a proposal for a new line of research.²⁷ The increased number of grants for experienced investigators and minimal growth in grants for first time investigators resulted in a dramatic change in the age distribution of PI's. In 1998 only a third of awardees were over 51: almost 25% were under 40. By 2003 42.3% were over 51 while less than 17% were under 40. Fully a quarter were over 55 (Stephan 2007).

4. The Market for PhD Students, Postdoctoral Scholars and Faculty

In 1996 the National Research Council formed a committee to study trends in early careers of life scientists. The impetus for the study was that the number of PhDs in the life sciences had grown substantially in recent years but the job market opportunities for young life scientists had not kept pace. Increasingly, young life scientists had found themselves in a "holding pattern," waiting for a permanent position. (National Research Council, 1998).

There were a number of disturbing trends: Time to degree had increased, the percent of life scientists holding postdoc positions had grown, and the duration of the postdoc position had also increased. Moreover, the likelihood that a young life scientist would hold a tenure track position, especially at a research university, had declined. Furthermore, young faculty were experiencing increasing difficulty getting their NIH grants funded and were getting funded for the first time at later and later ages.

To be a bit more specific, during the 10 year period 1985-1995, the number of PhDs awarded in the biomedical sciences in the U.S. had increased by almost 40%.²⁸ Median time to degree, which was just over 7 years in 1995, had increased to 8 years. Sixty percent of all new PhDs took a postdoc position, up from around 55% a decade earlier. Over 30% of PhDs who had been out of graduate school for three to four years held a postdoc position, up from 25 percent a decade earlier. And the percent who held a postdoc position for five to six years had grown by approximately 50%.²⁹

Obtaining a tenure-track position had become increasingly unlikely. In 1985 the odds were about one in three that someone who had received his PhD five to six years before (1979-1980) held a tenure track position at a PhD-granting institution. By 1995 the odds were approximately one in five that a recent PhD held a tenure-track position. Not only had the odds declined; the actual number of young faculty holding tenure-track positions at PhD-granting institutions had declined. The big growth was in "other" positions, a category that included postdocs, staff scientists and other non-tenure-track positions, as well as those who were working part-time.

²⁷ PowerPoint "Update on NIH Peer Review," distributed to National Institute of General Medicine Advisory Council.

²⁸ Data in the report allow one to differentiate between general life sciences and the biomedical sciences. The data provided here are for the biomedical sciences.

²⁹ All data are taken from the report. National Research Council, 1998.

After documenting and studying these trends, the committee made five recommendations: (1) restraint in the growth of the number of graduate students in the life sciences, (2) dissemination of accurate information on career prospects of young life scientists, (3) improvement of the educational experience of graduate students; 4) enhancement of opportunities for independence of postdoctoral fellows, and (5) alternative careers for individuals in the life sciences. The committee's intent regarding recommendation five was to convey the conviction that "the PhD degree [should] remain a research-intensive degree, with the current primary purpose of training future independent scientists." (National Research Council, 1998, Page 8). In other words, the committee did not endorse the idea of training PhDs in the life sciences who would then pursue alternative careers.

The committee expanded on recommendation three in the text of the report, encouraging federal agencies to place greater emphasis on training grants and individual fellowships for supporting predoctoral training-- as opposed to indirectly supporting training through the funding of graduate research assistantships on research projects. Their rationale was that training grants are pedagogically superior because the quality of the training is peer-reviewed, while the quality of training is not considered in the review of research projects. In addition, training grants minimize potential conflicts of interest that can arise between the trainer and trainee since the graduate student is not "indentured" to a faculty member. Despite the advantages of training grants, the number of students supported on training grants had remained fairly constant for a number of years, while the number supported on research assistantships had grown dramatically.³⁰

The life science community did not embrace the recommendations. Graduate programs continued to grow, little effort was made to disseminate information concerning career outcomes, and there was virtually no reallocation of funds between training grants and research assistantships. Indeed, while training grants used to fund two-thirds of graduate students and post docs, today they fund about 15%.³¹ Primarily at the initiative of the Alfred P. Sloan Foundation, a number of professional masters programs were started in the life sciences in the late 1990s. The hope was that such programs could prepare individuals for non-research positions in industry.³²

Then, in 1998 the NIH budget began its five-year doubling. Many hoped that the doubling would be particularly beneficial to the young. This was not to be the case, although conditions initially marginally improved. The probability that a biomedical PhD age thirty-five or younger held a tenure-track position, which had declined from around 10.3% in 1995 to 6.9% in 2001 "rebounded" to 10.4% by 2003. The percent of individuals remaining in a postdoc position for

³⁰ Training grants were established in 1974 when Congress established the National Research Service Awards (NRSA). In the early years, the program provided over two-thirds of the support for graduate and postdoctoral training. Today it funds about 15 percent of the total number of trainees. See Committee to Study the Changing Needs for Biomedical, Behavioral, and Clinical Research Personnel hand-out distributed at NIGMS.

³¹ Data come from presentation made to members of an ad hoc committee assembled to discuss workforce issues, American Association of Medical Colleges, March 5, 2008.

³² It is still too early to know the degree to which such programs have been successful.

six plus years declined.³³ There was considerable growth in non-tenure track positions, especially at medical schools,³⁴ as well as considerable growth in non-academic jobs. But by 2005 the number of new PhD faculty hires at medical schools began to decline.³⁵

In short, the pickup in academic jobs was relatively modest for the young. There were some other, disquieting trends. For example, there was an increase in the percent of young PhDs working part time, and the age at which new faculty with PhDs were hired at medical schools increased by two years between 1992 and 2004, reaching 39.³⁶ Moreover, the young, as we have seen, had a hard time competing for funding. The number of awards to first-time investigators, which had initially increased, declined.³⁷ The “spread” between the success rate on grant applications from established investigators and that for new investigators grew. In 1996 the difference was about 2.6 percentage points.³⁸ By 2003 it was over 6 percentage points. Career trajectories of young life scientists were sufficiently bleak to prompt the journal *Nature* to run an editorial entitled “Indentured Labour” which argued that “too many graduate schools may be preparing too many students, so that too few young scientists have a real prospect of making a career in academic science.”³⁹

During this entire time the number of PhDs awarded in the biosciences continued to grow. In 1980, for example, the U.S. produced 3733 PhDs in the biosciences. By 1995, just before the NRC committee was constituted, the number had reached 5300. By 2006 it had grown to 6313 and by 2008 it exceeded 7500. (See Figure 3). At least three factors contributed to the increase: first, the success of early biotechnology companies as well as a number of research breakthroughs in the late 1980s and 1990s bestowed “hot field” status on the biosciences. The field was seen as having a future. Second, the heavy emphasis in the U.S. on Federal funding for biomedical research meant that graduate research assistantships were readily available for doctoral study. This attracted students, particularly international students, to study in the field. While only one in ten of the PhDs bestowed in the biosciences in 1980 went to someone on a temporary visa, by 2008, close to one in three went to someone on a temporary visa. Third, while the evidence suggests that U.S. males are somewhat sensitive to market opportunities in choosing a field of study, the evidence is less clear that women make choices regarding field of study based on market signals. And this was a period when increasing numbers of U.S. women headed to graduate school.

³³ This decline, of course, may be in name only since at approximately the same time many institutions, in response to the gentleman’s agreement that a postdoc position not last longer than five years, began to develop new, creative titles, for senior postdocs.

³⁴ 33% of U.S.-trained PhDs working at medical schools were in non-tenure track positions in 1993. By 2003, 45% were in non-tenure track positions..

³⁵ Biomedical Research Workforce, Background Information, September 7, 2007. Prepared by OER, NIH. Slide 29.

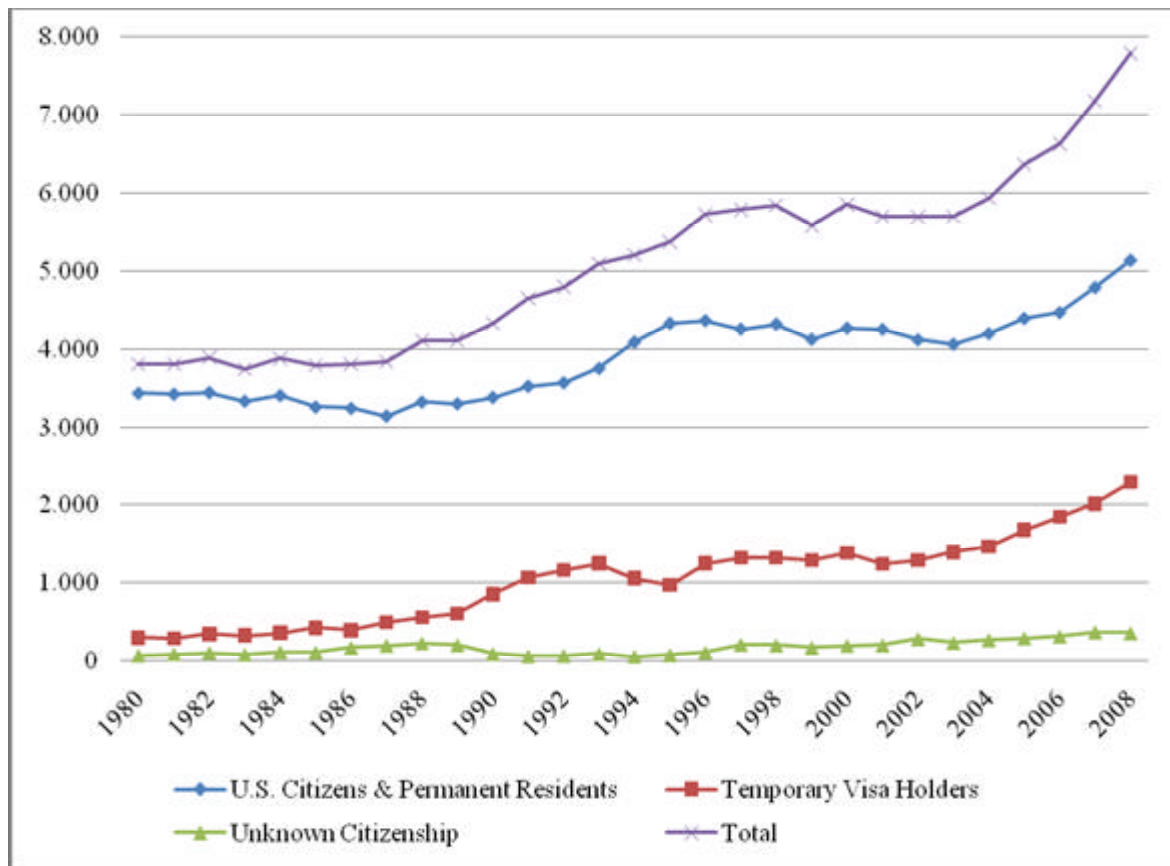
³⁶ Faculty Roster Data, American Association of Medical Colleges.

³⁷ Elias Zurhuni and the NIH leadership put special emphasis on the young; the number awarded to new investigators has grown in very recent years.

³⁸ Data come for OER, NIH, and were prepared for GREAT. See Stephan 2007.

³⁹ Editorial, *Nature*, 448, Pages 839-840, 23 August 2007. The editorial was based on data released by FASEB, summarizing the career trajectories of young life scientists.

FIGURE 3: DOCTORATES AWARDED IN BIOSCIENCES, 1980-2008

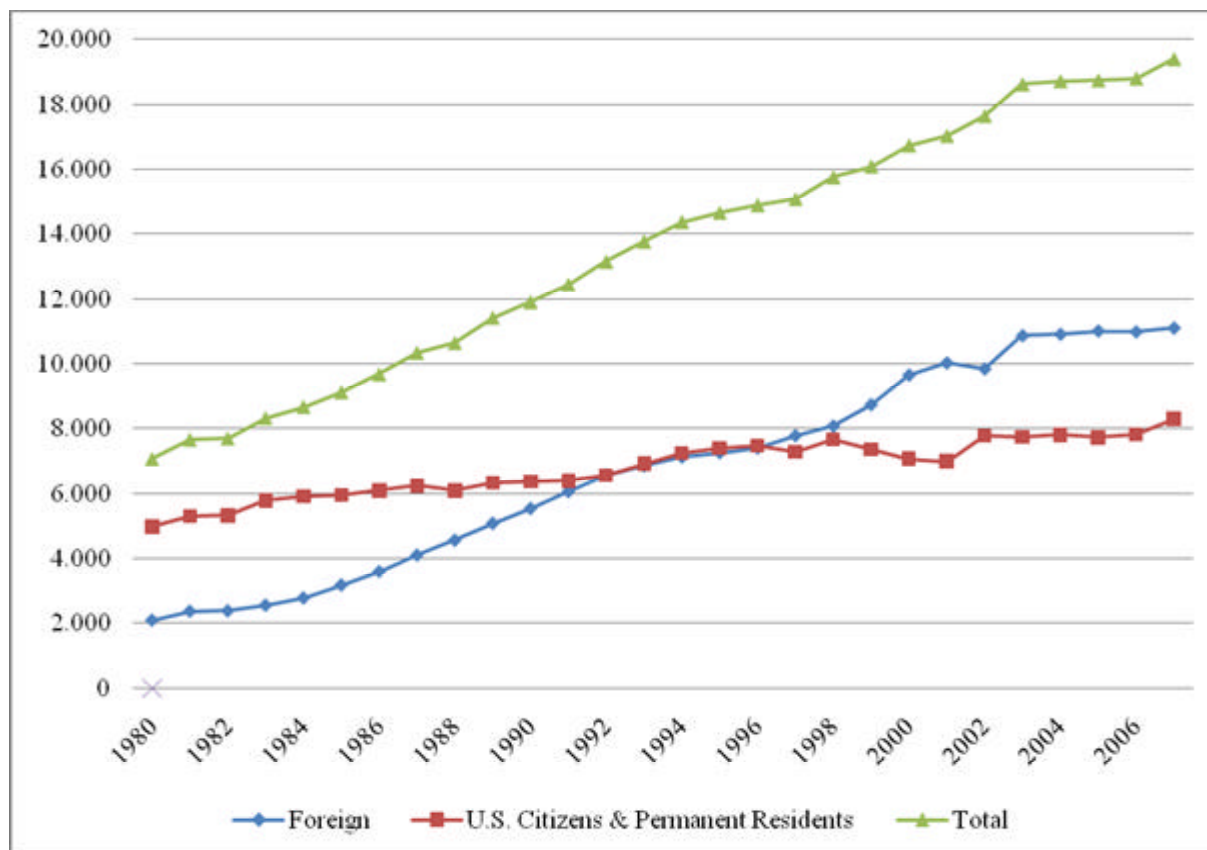


SOURCES: National Science Foundation, Division of Science Resources Statistics, WebCASPAR database, <http://webcaspar.nsf.gov>, and National Science Foundation 2009, table 11.

The number of individuals holding postdoctoral positions also grew dramatically during these years. (See Figure 4). For example, NSF estimates that there were approximately 7000 postdocs working in academe in the biosciences—regardless of where the postdoc received their PhD—in 1980. By 1995, the number stood at 14,500 and by 2006 the number exceeded 19,000. A large percent of these postdocs were in the U.S. on temporary visas. Indeed, while slightly less than 30% were on temporary visas in 1985, by 2006 fully 57% were on temporary visas. The growth is easy to understand: first the NIH budget increase meant that ready funds were available for postdocs. While \$37,000—the initial salary for many postdocs—may not be a princely sum to a U.S. citizen, it is highly attractive to an international scholar, especially scholars coming from Asia. Moreover, once the scientist enters the U.S., the probability increases that the scientist will eventually become a permanent resident and thus be able to stay in the U.S.. Second, being a postdoc is a necessary milestone on the route to becoming an independent researcher at a university—a goal that the majority of doctoral scientists in the biomedical sciences hold, despite

the poor job prospects.⁴⁰ Third, when jobs are tight, people remain in postdoc positions for a longer period of time, increasing the number of postdocs at any one time.

FIGURE 4: POSTDOCTORATES IN BIOSCIENCES, 1980-2007



SOURCES: National Science Foundation, Division of Science Resources Statistics, WebCASPAR database, <http://webcaspar.nsf.gov>, and National Science Foundation 2009, table 37.

The counts of postdoctoral fellows produced by the National Science Foundation are known to be an undercount of the actual number of postdoctoral fellows. The extent of the undercount is difficult to determine, however. Problems in enumerating the total arise in part because postdocs work for individual faculty members and this makes it more difficult to collect data. It is also difficult to determine who exactly is a postdoc because it is not uncommon for individuals who are essentially postdocs to be called by another title, such as research scientist.

To summarize, the supply of life scientists being trained in the U.S. has increased dramatically in the recent past despite considerable evidence that permanent jobs are scarce, especially

⁴⁰ Davis (2005) reports that 1110 of the 2770 respondents in the survey of postdocs that he fielded indicated that they were looking for a job. Among these, 72.7% were “very interested” in a job at a research university and 23.0 were “somewhat interested.”

permanent positions in academe. A back of the envelope estimate suggests that the probability of a U.S. trained PhD being hired into a tenure track position and becoming a PI is less than 5%. And for the lucky few, this only occurs when the PI is in her 40s. Moreover, conventional negative feedback models predict that such a situation cannot persist: bleak job prospects, long periods of postdocing, and the low probability of receiving funding should make the field relatively less attractive. This does not appear to be the case in the biomedical sciences. In section 5 we examine why this has occurred.

5. The Failure of Negative Feedbacks

At least two factors discourage the negative feedback process from occurring. First, and as noted above, there is a severe lack of information regarding job prospects in the biomedical sciences. Second, the supply of foreign-born wishing to study in the U.S., both for a PhD and for a postdoc, is quite elastic. Money speaks and the increase in the NIH budget has meant that funds are readily available for graduate and postdoctoral study. Finally, and integral to the first two points, faculty incentives are incompatible with negative feedback: graduate students and postdocs are key to faculty advancing in the tournament. And when competition is fierce, more research staff is always better. We address each of these below.

Information

The lack of accurate information concerning the placement of graduates contributes to the growth in the number of individuals going to graduate school. In the U.S., information, especially with regard to the job outcomes of recent graduates, has typically not been readily available from graduate programs. By way of example, in the late 1990s, and by way of an experiment, the economist Paul Romer (2000) asked a research assistant to initiate application to the top ten graduate departments of mathematics, physics, chemistry, biology, computer science and electrical engineering in the U.S, as measured by *U.S. News and World Report*. For purposes of comparison, the student also began to apply to the top ten business and law schools. The student's efforts resulted in "not one response giving information about the distribution of salaries for graduates, either in the initial information packet or in response to a follow-up inquiry from him. In contrast, he received salary information for 7 of the 10 business schools in the application packet, and in response to his second request, he was directed to a web page with salary information by one of the three non-respondents... Four out of the 10 law schools gave salary information in the application packet and three more of them directed him to this information in response to a second request." (Romer 2000, Page 3).

The spread of information technology has not improved the amount of information that departments make available concerning the job outcomes of their graduates. An examination of the web pages of fifteen top programs in each of the fields of electrical engineering, chemistry and biomedical sciences in the winter of 2008 found that only two of the forty-five programs listed actual information on placements. Four others provided some information on placements

but did not list specific information regarding the placements. By way of contrast, seven of the fifteen programs in economics provided a list of students and where they were placed, year by year.⁴¹(Stephan 2009a).

It is easy to understand why departments are reluctant to provide placement data given that faculty are in the business of recruiting students to staff their labs. Revealing placement data could discourage potential applicants and thus place their research in jeopardy. The culture of the university also stresses careers in academe, rather than careers in industry. Most graduate students with academic ambitions, especially in the biomedical and physical sciences, take a postdoc position after receiving their PhD. In this sense, they have a job, albeit in a temporary, training position after they graduate. The ready availability of postdoc positions also conveniently lets the department “off the hook” for helping to provide permanent placements. They have, after all, placed the student. The MIT program in biology can thus safely state on its webpage that the “majority [of PhD recipients]...go on to a postdoctoral position in an academic setting.”⁴²

The Presence of International Students and Scholars

The ready supply of international students, extremely responsive to the availability of financial support for graduate study, is another factor that dampens the negative feedback process. To understand just how important international students are to U.S. science education, consider the fact that three of the top five BA-source institutions for those receiving PhDs in science and engineering in the U.S. are located outside the U.S. To be more specific, Tsinghua University heads the list, followed by its neighbor Peiking University. The University of California Berkeley is third and Seoul National University takes fourth place. Cornell follows in fifth (Mervis 2008).⁴³ It is not difficult to understand why students come to the U.S. to pursue graduate study. Admission for full-time students generally comes with a research assistantship which pays between \$20,000 and \$30,000 as well as full tuition.

Some would argue that the supply of international graduate students is likely to diminish because of increasing competition, both outside the primary source countries of Asia as well as within these countries. And this is a factor that must be taken into consideration. As Figure 5 demonstrates, the U.S.’s position as the dominant trainer of PhDs in the world is being challenged by other countries and regions of the world. The EU-15 production, for example, has surpassed U.S. production since 1997. More importantly, China, which produced less than 5%

⁴¹ For each field, the top ten programs, as ranked by the National Research Council in 1995, were surveyed, as well as the five programs rated 21-25.

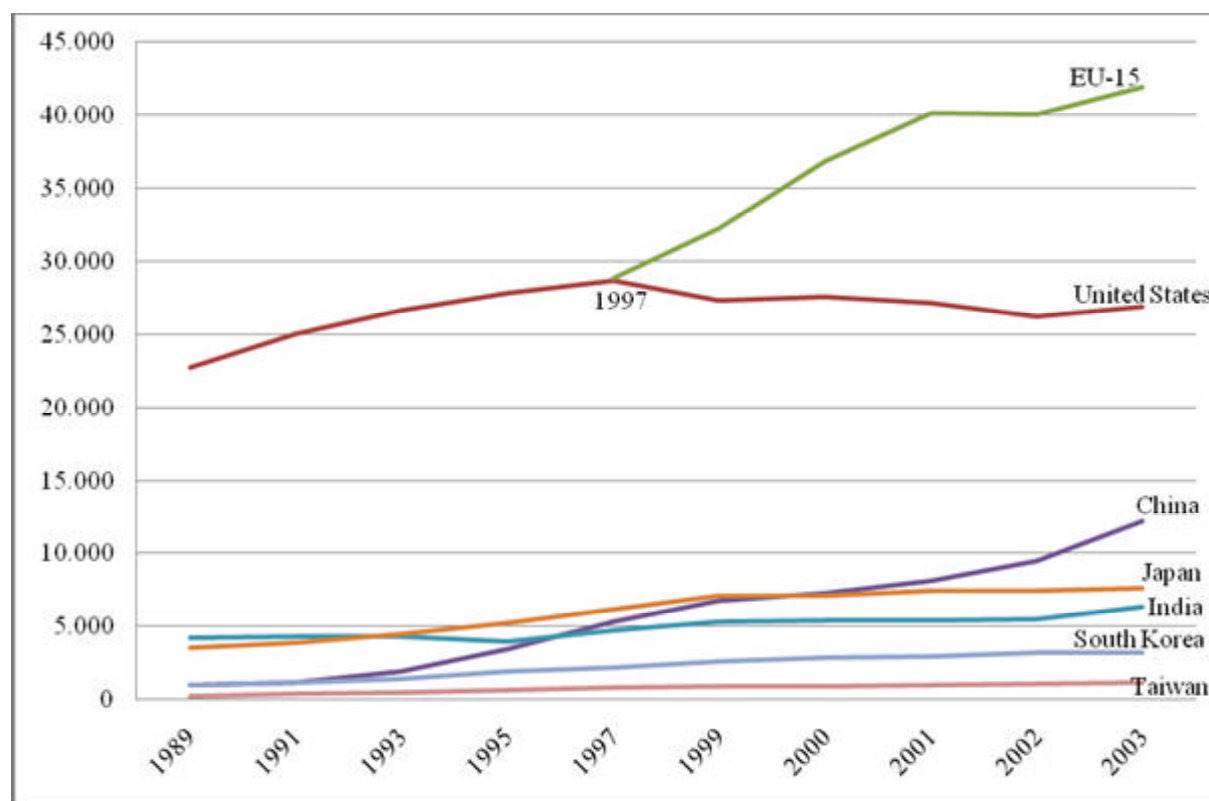
⁴²The web page goes on to say “Other areas ... include medical school, teaching, science publishing, investment banking, patent law and venture capital” but provides no specific placement information.

⁴³ The calculations are for degrees awarded between 2004 and 2006. The University of Michigan, Ann Arbor holds sixth place. Just a few years earlier the University of California Berkeley was the number-one undergraduate institution.

of the number of PhDs produced by the U.S. in 1989 produced approximately 50% of what the U.S. produced in 2003 (the latest date for which data are readily available).

This is only part of the story, however, given that the supply of those eligible to pursue graduate study is growing more rapidly outside the U.S. than within. To wit, the number of Chinese students who have completed a BA in science and engineering has doubled in recent years, going from 268,400 in 1990 to 533,600 in 2002. By way of comparison, the number of BAs in science and engineering awarded in the U.S. increased from 329,100 to 415,600 (an increase of 26%). (National Science Foundation 2007, Table 2).

FIGURE 5: SCIENCE & ENGINEERING DOCTORATE PRODUCTION, SELECTED COUNTRY/ECONOMY: 1989-2003



SOURCE: National Science Foundation, 2007, Page 5.

The dramatic increase in the number of PhDs bestowed outside the U.S. also means that there is a growing supply of individuals to come to the U.S. for postdoctoral training after receiving their PhD. And this is compatible with an incentive system which encourages faculty to substitute postdoctoral fellows for graduate students in their lab, given that graduate students, especially in private institutions, can cost the faculty more than a postdoc, since the PI is responsible not only for the stipend but also for tuition.

The stipends associated with postdoctoral positions make them particularly attractive to those on temporary visas. NIH guidelines, issued March 27, 2009, state a minimum of \$37,368 for those starting out; a minimum of \$51,552 for postdocs with seven or more years of experience. Some institutions pay more than this. Stanford University, for example, starts postdocs at \$40,785 and the Whitehead Institute starts postdocs at \$47,000. It is no wonder that the number of postdocs who are in the U.S. on a temporary visa has grown dramatically. The advent of the 2009 stimulus package will, without a doubt, increase the number further.

Many assumed that visa restrictions associated with the U.S. response to the events of September 11 would curtail the flow of graduate students and postdocs to the U.S. And it did in certain fields. But not in the biomedical sciences. Indeed, and unlike the overall trend, in no year since the data have been collected have first-time enrollments among full-time students in the biological sciences on temporary visas declined at U.S. graduate schools. This is seen in Table 1.

Table 1. FIRST-TIME FULL-TIME ENROLLMENT CITIZENSHIP IN U.S. GRADUATE PROGRAMS IN THE BIOLOGICAL SCIENCES

Field/citizenship	2000	2001	2002	2003	2004	2005	2006	2007
U.S. citizen/permanent resident	8355	8768	9261	9763	9808	9925	9946	10,230
Temporary residents	2600	2840	2866	2956	2988	2993	3109	3255

SOURCE: Data for 2000-2006 come from National Science Board 2009, Appendix table 2-18. Data for 2007 come from Laura Burns, Peter Einaudi and Patricia Green 2009.

6. Discussion

The positive feedback character of the biomedical labor market in the U.S. is not inherent in the way in which research is conducted. Rather, it has evolved from a structure that has placed biomedical research in an institutional setting that has the license to staff labs with temporary workers. These temporary workers eventually leave with credentials that allow them to (try to) compete in the biomedical research tournament. It has been fed by a public, and a receptive Congress, eager to provide research funds to address popular diseases.

There are a variety of ways to attenuate the positive-feedback mechanisms at work in this market. Three are discussed here. First, and most obvious, is a permanent and substantial cut in the research budget of U.S. universities. Without research funds, many universities, especially those with lower-tier graduate programs, would be forced to dramatically cut or eliminate their PhD programs. Fewer students and postdocs would be trained and the pyramid nature of the research enterprise would be attenuated.

Is this likely to occur? Absolutely not. The public is too hungry for cures and Senators and Representatives are too happy to oblige, especially if it means supporting research in their state or district.⁴⁴ Moreover, pharmaceutical companies, who have benefited from much of the research performed in the university sector, represent a formidable lobby. The Congress may temporarily halt increases in funding for research, as it did in the years 2002-2009, but a permanent and dramatic cut appears to be outside the political will. Furthermore, even if the Federal government were to curtail support for biomedical research, other sources of support exist. States have embraced biomedical research as a mechanism for economic growth and development; private foundations provide support; and industry also provides funds for biomedical research at universities.

A second alternative is to decouple the biomedical workforce from the training enterprise. The most straightforward way to do this is to staff university labs with permanent staff scientists, rather than with graduate students and postdocs. To some extent, this is already occurring, but not on a large enough scale to make a sizeable impact. Moreover, the staff scientist positions that have evolved often pay little more than a senior-postdoc position and offer little job security. For this alternative to have teeth, the position of staff scientist would need to be upgraded in three respects: (1) salary; (2) job security and (3) research independence. If PIs were increasingly to staff their labs with such staff scientists, research would be less coupled to training. NIH could encourage this by providing funds to support career-path staff scientist positions in the NIH budget.

University faculty, however, are likely to resist such a plan. PI's like the status quo: not only does it provide flexibility, allowing them to downsize their labs in lean times and grow them when resources are plentiful. But graduate students and postdocs provide fresh, new ideas, which are absolutely key for faculty to do well in the biomedical tournament. Moreover, more permanent positions could provide competition for research space, always a concern at a university.

A third approach is to shift control of training funds away from PIs and towards the trainee or the department in which training occurs. The former could be done by awarding more fellowships for study directly to students. This accomplishes two things. First, it encourages selection on the basis of quality rather than on the basis of availability to staff a lab and meet a research objective of the PI. Second, it allows trainees to "vote with their feet." If students and postdocs are free agents they will arguably select programs that focus on addressing student needs. Moreover, they are more likely to inquire about job prospects if they are in a position to select where they

⁴⁴ Congressional representation affects NIH allocations and (indirectly) the distribution of grants. Powerful congressmen, for example, can provide guidance on the allocation and disbursement of appropriated funds, and can direct reallocations among various NIH institutes and support funds for specific diseases. In recent years, having an additional member on the appropriate subcommittee of the House Appropriations Committee that deals with the NIH budget increased NIH funding to public universities in the member's state by 8.8%. (Hedge and Mowery 2008).

train. A related way of addressing this goal is to place greater emphasis on training grants, providing resources to the department for training rather than to the PI. Such grants are peer-reviewed, while the quality of training, as we noted above, is not considered in the review of a research project. Moreover, training grants generally require students to rotate across labs, thereby decreasing the possibility that a student “belongs” to a faculty member.

Again, this is unlikely to occur. For almost fifteen years, committees have been making such a recommendation. But the biomedical community is extremely resistant to such suggestions; the incentives are far too strong to cause them to shift course. And it is the senior investigators, not the trainees, who influence how funds are allocated.

In short, the presence of positive feedbacks in the biomedical workforce is a result of system-wide problems. Any fix requires changing incentives. This is unlikely to occur as long as the U.S. Congress and faculty have their way.

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