The Economics of Postdoctoral Researcher Positions

Donna K. Ginther
University of Kansas & NBER

Joshua L. Rosenbloom
Iowa State University &
NBER

September 17, 2025

Abstract

Between 1979 and 2019 the number of postdoctoral researchers in the U.S. increased approximately four-fold, substantially outpacing growth in the numbers of graduate students and faculty at U.S. universities. This chapter argues that the increased reliance on postdocs within the scientific workforce reflects the uncoordinated nature of science funding. The NIH doubling in the early 2000s increased both demand for and the supply of postdocs resulting in a worsening of employment conditions, but this relationship between biomedical R&D funding and postdoc numbers broke down after 2010. Using evidence drawn from newly available data by discipline at the university level, which allows analysis of differences in reliance on postdocs across different fields of scholarship as well as the relationship between postdocs, faculty, funding and scientific productivity across institutions, we find that increases in the number of postdocs are associated with higher levels of research productivity across a range of different disciplines. In addition, we find, mixed support for the hypothesis that research funding is associated with the demand for postdocs. This conjecture appears to be true in chemistry, chemical engineering and psychology, but not in other fields. As federal research funding is reduced and immigration policies likely limit the number of international postdocs, the U.S. may have reached peak postdoc for the foreseeable future. Based on our estimates, this may result in less future research productivity.

Acknowledgements

We thank Alfred Arthur, Seongyeob Kim, Thomas Becker, Daria Milakhina, and Carlos Zambrana for excellent research assistance. Participants in the NBER conference on early career scientists held in Washington, DC in April 2022 made a number of helpful comments. Rosenbloom acknowledges support from the National Science Foundation Grant SMA-18548491. Ginther acknowledges support from the Alfred P. Sloan, NSF SES-2152437 and SMA-1854849, NIH grants 1P20GM152280 and R01GM148816. The views expressed in this paper are those of the author and not those of the National Science Foundation.

Introduction

For almost thirty years, there have been increasing calls to reimagine the postdoctoral researcher experience (NRC 1998, NRC 2005, NIH 2012, NAS 2014, NASEM 2018, NIH 2018, NIH 2023). Postdoctoral research positions (postdocs), defined as a limited time of training designed to support scientists in launching independent research careers, were intended to provide opportunities to build human capital for aspiring independent researchers. Given their relatively low cost (and flexibility), however, postdocs have become an increasingly important part of laboratory staff and, as labs have relied more heavily on postdocs, policy makers have increasingly raised concerns that these positions are no longer primarily a form of training but rather a source of inexpensive, highly skilled, and highly motivated labor (NRC 1998, NRC 2014 Stephan 2012a, Stephan 2012b). However, questions remain about the value of the postdoc for individual scientists, the principal investigators that hire them, and the research enterprise.

In this chapter, we consider the economics of the postdoc in light of the significant changes in federal research funding. We begin with a review of the historical evolution of the postdoc position through the 1980s and discuss challenges in accurately measuring this important part of the scientific workforce. Having established this background, we turn our attention to the causes and consequences of the rapid growth in postdoc numbers since the early 1990s. In this part of the chapter, we first examine what can be learned from relatively aggregated data and review past studies that have focused on these data. Then we introduce, new, disaggregated data that allow us to examine the relationship between R&D funding, and the number of postdocs, faculty and graduate students by discipline and university. Drawing on these data we document the highly concentrated nature of postdoc training, and show that postdocs make an important contribution to the production of scientific knowledge. We also find evidence that in at least some fields, variation in R&D funding may be an important determinant of postdoc numbers. We concluded by providing a research agenda that will allow researchers and policymakers to gain a better understanding of the role of the postdoc in the research ecosystem.

The Early History of Postdoctoral Researchers in US Science

The term postdoctoral researcher, taken literally, refers to a career stage for an individual, not to a particular activity or set of job requirements. We follow the guidance of the National Institutes of Health and the National Science Foundation who in 2007 defined a postdoc as "…an individual who has received a doctoral degree (or equivalent) and is engaged in a temporary and defined period of mentored, advanced training to enhance the professional skills and research independence needed to pursue his or her chosen career path" (NSF, 2007). As such postdocs are the career stage immediately following the doctoral degree in some but not all fields of science and engineering. While some postdocs are supported on fellowships awarded to the individuals they support or on larger training grants, most postdocs are funded via research grants to a tenure-track faculty researcher. The characteristics of individual postdoc positions vary depending on the supervisor, but it is readily apparent that in many cases postdocs have become relatively low paid laboratory staff, more senior than doctoral students, but dependent on the Principal Investigator (PI) for support.

Postdocs first emerged primarily as a mechanism to enable further training in advanced skills. The history of postdoctoral appointments, at least in the United States, coincides with that of the modern research university. In 1876, the year of its founding, Johns Hopkins University offered 20 fellowships with the purpose of "…attract[ing] and support[ing] young men starting research careers." While the majority of the fellowships supported doctoral students, four were awarded to men already holding Ph.D.'s (NAS 1969, p. 8). In the wake of the First World War, which prompted an awareness of the growing importance of science for national security, the National Research Council, with funding from the Rockefeller Foundation, established fellowships in physics and chemistry. In 1922 the Rockefeller Foundation committed additional funding to support fellowships in medical science (NAS 1969, p. 16). These fellowships contributed to the growth of scientific expertise, but numbers remained relatively small, and their presence attracted little attention. The number of postdocs began to increase more dramatically after World War II, reflecting the growing federal support for science and engineering in the postwar era. The National Institutes of Health, in particular, established funding specifically to support postdoctoral fellows in medical sciences that greatly increased funds directed to this group. While the first systematic efforts to count postdocs were not undertaken until the early 1960s, the Google N-Gram reproduced in Figure 1 suggests that discussion of this group of scientists began in the early 1940s and followed a rising path until the early mid-1960s. After the mid-1960s, references to postdocs slowed for about a decade and then began to accelerate again until the mid-1990s.

Among the earliest efforts to systematically assess the roles and experiences of postdocs was a study by Bernard Berelson (1962) undertaken in the early 1960s at the behest of the American Association of Universities (AAU). Berelson personally visited 10 different campuses and sent a survey to all the members of the AAU. Based on this canvas as well as his examination of data on funding for postdoctoral fellows, Berelson estimated that there were close to 10,000 postdocs in 1960 (of which about 8,000 were employed in higher education), and that the number had clearly been increasing in the years leading up to his study. Summarizing the situation, he observed (p. 128-29): "…postdoctoral work….is substantial, it is established, and it is wanted. It constitutes an invaluable service to the national effort in scientific research. In the arts and sciences, it is an important means to obtaining advanced training in a research specialization. In medicine, it is the major route for research training….In both fields, the universities receive the benefit of a young and well-trained faculty…"

The rapid growth in postdoc numbers noted by Berelson, continued throughout the 1960s. A National Research Council study conducted near the end of the 1960s reported that by 1967 the number of postdocs in higher education had doubled to 16,000, implying a growth rate of 9.9 percent per annum. Postdocs in the life sciences accounted for 55.5% of this total, and another 32.3% were found in the physical sciences, mathematics, and earth sciences. Engineering accounted for only 2.6% of the postdocs counted by the National Research Council, and the remaining 10% were scattered across the social and behavioral sciences and other fields (National Research Council 1969, p. 54).

Like Berelson, the authors of the National Research Council study viewed the rapid growth in the number of postdocs as a positive reflection of the growth of the nation's scientific enterprise (National Research Council 1969). "If a graduate student is pointing toward a career as a faculty member," the preface of the report summarized, "…a postdoctoral appointment will be almost required to acquire new skills and experience in research and to join the pool from which new appointments are almost always made. The period spent in such an apprentice role is for the most part an enjoyable one…" during which predoctoral pressures and near poverty-level stipends are removed (National Research Council 1969, p. xi). The only significant issue that the report identified was that despite the rapid expansion of postdoc numbers the larger academic community remained largely unaware of this segment of the scientific labor force.

Growth in the number of postdocs slowed significantly across the 1970s. When the NSF's National Center for Science and Engineering Statistics (NCSES) began regularly reporting on the number of postdocs in 1979, they found just 18,101, implying an increase of just over 2,000 postdocs in the 12 years between the beginning of the NCSES data collection and the National Research Council Study, or an average annual rate of growth of 1 percent.[1] When the National Research Council returned to the topic of postdocs in 1981, not only had growth slowed but the perception of postdoctoral researchers had shifted considerably, a fact reflected in the title of the report they issued: "Postdoctoral Appointments and Disappointments" (National Research Council 1981). As the National Research Council committee detailed, since 1969, obtaining faculty appointments had become more difficult. Although, most postdocs (84%) reported taking their appointment to gain additional research experience, to work with a particular group or to switch fields, close to 1 in 6 (16%) said they had taken a postdoc because there was no other employment available (National Research Council 1981, p. 84). Whereas the postdoc had been an important but relatively short route to faculty positions in the 1960s, by the early 1980s an increasing number of postdocs were obliged to wait longer before finding more permanent appointments, or to abandon the search for research faculty positions entirely. Almost 40 percent of chemistry and physics doctorate recipients in Fiscal Year 1972 reported extending their postdoc appointments because of a lack of employment opportunities, as did nearly 30 percent of bioscience doctorate recipients (National Research Council 1981, p. 101).

[1] For reasons discussed below, this may have been an undercount of the actual number of postdocs.

In addition to these career related concerns, the committee identified two additional problems, that perhaps loomed larger because of the growing number of postdocs and the longer time spent by many researchers in these appointments. The first of these was the low pay and lack of recognized status for postdocs within the academic community (National Research Council 1981, pp. 226). The second was the absence of women and minority groups among the postdoc population (p. vii).

During the 1990s the National Academies' Committee on Science, Engineering, and Public Policy (COSEPUP) returned to the topic of postdoctoral training as part of a larger agenda investigating the education and training of scientists and engineers in the U.S. (Institute of Medicine 2000, p. vii). In contrast to the 1969 and 1981 studies, which had devoted considerable effort to simply documenting the growth in the number of postdocs and trying to better understand the causes and consequences of this growth, the COSEPUP study shifted attention to the training that postdocs received and the conditions under which they worked.

Their investigation highlighted many areas in which reality fell short of the ideal, noting that: (1) training opportunities varied substantially, (2) mentoring and career development resources were often limited, (3) postdoc employment status remained poorly defined, and (4) postdoc pay was often quite low. The report concluded with a list of actions that advisors, institutions, funding organizations and disciplinary societies should undertake to remedy the situation (Institute of Medicine 2000, p. 99). Chief among these were to regularize the institutional status of postdocs, develop clear policies for this group of employees, increase their compensation and provide access to health insurance and other employee benefits, provide substantive career guidance, facilitate postdoc transitions to regular career positions, and improving the collection of data on the numbers and working conditions of the postdoc population.

Measurement Issues

Despite the NSF's effort to count the number of postdoctoral researchers beginning in 1979, understanding of this segment of the scientific workforce has been hampered by the heterogeneity of postdoc employment relationships, and the limits of data collection by federal agencies (NIH, Biomedical Workforce Group 2012, p. 19; NIH 2023). The National Science Foundation's National Center for Science and Engineering Statistics (NCSES) Survey of Graduate Students and Postdoctorates in Science and Engineering (often referred to as the GSS), first reported counts of the number of postdocs at U.S. universities in 1979. These data exclude postdocs employed outside of academia at government labs or in industry. Moreover, because some postdocs with their own fellowships were not university employees, and because others were hired by departments or individual faculty with grant funds, previous researchers studying postdocs have accepted that, especially in its early years, the survey undercounted the academic postdoc population (Einaudi, Heuer, and Green 2013). In recent years, however, most universities have been encouraged to identify a postdoc coordinator to respond to the survey, and a number of other steps have been taken to improve the accuracy and reliability of data collection (Arbeit, Einaudi, Green, and Kang 2016).

Other researchers have made use of the Survey of Doctorate Recipients (SDR), which is also managed by the NCSES, to estimate the number of postdocs (see, e.g., Kahn and Ginther 2017). The SDR is a panel survey which follows individuals who earned doctorates from U.S. universities over several years and contains relatively rich data on individual characteristics as well as capturing employment transitions. The sampling frame of the SDR ensures that it captures postdocs outside the university sector, but because it is limited to graduates of U.S. universities, it excludes the large number of individuals who earned doctorates outside the country. The effects of this restriction to graduates of U.S. universities are evident in a comparison of aggregate numbers with the GSS. In 2017, for example, the SDR enumerated 18,400 postdocs across all scientific disciplines in academic institutions (SDR, Table S3-7), while the GSS reported a total of 66,733 in Science, Engineering and Health (GSS Table 1-1). With these caveats in mind, we now consider the supply and demand of postdoctoral researchers.

Supply of and Demand for Postdoctoral Researchers since the early 1990s

Figure 2 shows the time series of doctoral degrees awarded by field between 1980 and 2023. The majority of doctoral degrees were awarded in the fields of biomedical sciences and engineering, followed by social sciences, physical sciences and psychology. Health sciences are comparatively small. Figure 3 shows the primary postdoc fields using data from NSF's GSS. The distribution of postdocs across science fields differs considerably from that of doctoral degrees. Postdocs are concentrated in biomedical and health fields, followed by physical sciences and engineering, although the extent of this concentration has been declining over time. In 1994, 69% of postdocs were in biomedical and health fields but by 2023, that share has dropped to 58%.

The growth in overall postdoc numbers up to 2019 is also apparent in Figure 3. Forty-five years ago, in 1979, when the NSF first began to collect data on postdoctoral researchers (or postdocs) there were 18,101. By 2019, the total had reached a peak at

68,500. Postdoc numbers dipped during the COVID-19 pandemic, but have begun to recover, reaching 65,850 by 2023. Over roughly the last four decades the number of postdocs has grown at an average annual rate of 3.24%, resulting in a nearly 4-fold increase in their numbers. Over the same period, the number of graduate students at U.S. Universities approximately doubled.[2] Comparable data on faculty numbers are more difficult to obtain, but it seems likely that growth in the number of postdocs greatly outpaced increases in faculty numbers as well.[3] Part of this increase could be driven by the need for additional training. Jones and his coauthors argue that the increased complexity of scientific research has required longer training resulting in more students pursuing postdocs (Jones 2009, 2010, Jones and Weinberg 2011).

Since 2000 the most rapid growth in postdoctoral researchers has occurred in engineering. Figure 4 graphs postdoc numbers by field relative to a base of 100 in 2000. Although biomedical and health sciences still account for the largest share of postdocs, their numbers have increased only about 30 percent since 2000, with almost all of that growth

---

[2] Counts of postdoctoral appointees and graduate students are from National Center for Science and Engineering Statistics (20210, Table 1-1 [downloaded 4 August 2025]. Data collection on postdocs has improved over time so some of the growth is likely an artifact of better measurement in recent years. Postdocs are also employed outside universities, in national labs and in private industry. Reliable statistics on their numbers are more difficult to obtain, but those that exist suggest they are a relatively small part of the total postdoc population. The graduate student figure includes both M.S. and Ph.D. students, Unfortunately, the survey only began collecting data separately for Ph.D. and Master's students in 2017, so it is not possible to disentangle these two groups in earlier years. In 2019 Ph.D. students accounted for about 40% of graduate student enrollment.

[3] The Integrated Postsecondary Education Data System (IPEDS) aggregates data on faculty at all degree-granting postsecondary institutions. According to these data full time faculty in higher education increased 87% (from 450,000 to 832,119) between 1979 and 2018. IPEDS Digest 2019 Table 315.10 <https://nces.ed.gov/programs/digest/d19/tables/dt19_315.10.asp> accessed 9/5/2021. The IPEDS universe is much broader than that covered by the Survey of Graduate students and Postdoctorates. An alternative is provided by data from the Survey of Doctorate Recipients, which is based on longitudinal samples of individuals who earned doctorates from U.S. universities in science and engineering fields. According to this source full time science and engineering faculty numbers grew by 88 percent (from 125,600 to 223,5000) between 1977 and 2017.

concentrated in the first decade of the 2000s. In contrast, the number of postdocs in engineering has increased more than 2.5-fold over the same period, while the number of postdocs in chemistry has actually declined by 15 percent.

Figure 5 compares the growth rate of U.S. citizen and temporary visa holder postdocs. Beginning in 1994, the number of temporary residents and U.S. citizens who were postdocs was the same, but starting in 1999 the shares diverged. The number of U.S. citizen postdocs remained flat through the 2000s but then rapidly increased in the middle of the decade before leveling off at around 30,000 after 2010. The number of temporary resident postdocs fell between 2019 and 2021 only to rebound through 2023. However, the number of U.S. citizen postdocs dropped starting in 2019 and has not recovered. Both the increase in temporary residents and the subsequent growth in U.S. citizen postdocs were likely the result of the doubling of the NIH budget during the early 2000s as we discuss below.

Taken together, the consequences of larger numbers of postdocs within the scientific workforce have been well documented and much complained about. The length of time spent in postdoc positions has increased over time, while the prospects of transitioning to independent research faculty positions have declined. Since the mid-1990s there have been a growing number of reports calling on universities to improve the working conditions of postdocs and on funding agencies to increase minimum salaries for these position (National Research Council 1981; Institute of Medicine 2020; National Institutes of Health 2012; Institute of Medicine 2014; National Academies of Sciences, Engineering and Medicine 2018). Other scholars have suggested that better information about career prospects for science and engineering doctorates might reduce the inflow of new postdocs and thus help to redress the imbalances in the system (Ganguli, Gaulé and Cugalj 2020).

Consistent with the evidence that rising postdoc numbers coincided with worsening employment conditions, a number of recent studies by economists have argued that the growth in biomedical postdocs in this period was attributable to increases in the supply of doctorate recipients (Stephan and Ma 2005, Stephan 2012a, Stephan 2012b, Teitelbaum 2014, Freeman et al 2001, Borjas 2009 and Garrison & Gerber 1998). In the absence of a comparable increase in faculty positions and the elimination of mandatory retirement at universities in 1994, this increased supply of doctorates had the inadvertent effect of expanding the supply of potential postdocs (Blau and Weinberg 2017). Using a simulation model, Ghaffarzadegan and Xu (2018) demonstrate that there was a reduction in the number of younger scientists hired into tenure-track academic positions by roughly 20% after the end of mandatory retirement.

One important potential source of increased supply comes from non-U.S. doctorate recipients seeking additional training in the U.S. To determine whether variation in the share of temporary residents obtaining doctorates is driving this result, in Figure 6 we show the share of temporary visa holders who are doctorates and postdocs from 1994—2023 in the fields of biomedical science, physical science, and engineering. Engineering has a relatively higher number of doctorates who are temporary visa holders, but in 2023, the share of temporary visa holder engineering postdocs was 15 percentage points higher than doctorates. In biomedical sciences, the gap was 35 percentage points. Reasons for the larger share of postdocs being temporary visa holders are multifaceted. First, postdoc pay has historically been very low, and U.S. citizens may have better-paying employment options. Second, temporary resident postdocs may have different incentives to take postdoctoral research positions compared with their US-born counterparts (Borjas 2009, Lan 2012). Third, U.S.

academic institutions do not face caps on the number of visas for foreign talent and are free to hire them. Regardless of the reason, in the fields most likely to hire postdocs, the majority of postdocs are temporary visa holders.

While these results suggest an important role for supply-side forces in the growing number of postdocs, demand-side influences also appear to have been important. The demand for postdocs depends critically on how they are funded. Using data from the GSS, in 2010 18% postdocs were funded on traineeships and fellowships while 65% were funded by research grants and another 17% had other types of funding. By 2023, only 14% of postdocs were funded on traineeships and fellowships, 62% were funded on research grants, and 24% had other forms of support. Clearly, demand for postdocs is driven by principal investigators with funding needing research support on their projects. We now consider the relationship between NIH funding and the demand for postdocs.

Between 1998 and 2004, the NIH ran what is in effect an uncontrolled experiment on the effects of substantially increasing the funds available to support biomedical research. In this period the NIH pursued a five year program to double available funding from $9.8 billion to $19.6 billion. The rapid acceleration in funding is apparent in Figure 7, which plots both current and inflation adjusted NIH research grant figures from 1973 through 2024. Increased funding made available to a slowly growing pool of faculty researchers resulted in increased demand for biomedical research labor. Because of the time lags involved in producing new Ph.D.'s the initial effect of this demand was to cause an influx of foreign temporary residents to fill new postdoc positions (Blume-Kohout 2013, p. 2). But increased funding also resulted in an increase in support for graduate students, and enrollment in Ph.D. programs in the biomedical sciences expanded. Recent research shows that a 10 percent increase in public support of graduate student training increases the number of doctorates by about 8-9 percent (Shvadron et al 2025).

With normal time to degree in these programs of 5-6 years, the bulk of these students completed their studies just as the NIH doubling was coming to an end or in the next few years (Blume-Kohout 2013). The number of doctorate recipients in the life sciences at U.S. universities, which had been nearly stable at around 8,500 from 1998 through 2004, began to increase in 2005, rising to about 12,000 by 2012, (nearly 40% above its 1998 level, Figure 2). The rapid increase in doctorate recipients, which was not accompanied by a comparable increase in permanent faculty positions, resulted in increases in both the number of doctorate recipients without definite employment at the time of graduation, which rose from 27.6 % in 1998 to 37% in 2012; and the share of those with definite commitments who had accepted positions as postdoctoral researchers, which increased from 60.9% in 1998 to a peak of 70% in 2010 (Figure 3 and NCSES 2022, Survey of Earned Doctorates, special tabulations).

To sum up, it seems that the NIH doubling first increased demand for postdocs, but ultimately caused an even larger increase in supply, and further eroded conditions for students completing Ph.D.'s once funding began to fall in real terms (Figure 7). The result was greatly increased attention to the problem of too many postdocs articlulated in a series of National Academies reports from the 2010s. Among the most controversial recommendations was that biomedical PhDs should consider teaching in middle-school and high school (NAS 2011). Even before the NIH doubling, *Trends in the Early Careers of Life Scientists*, raised concerns that "the current level of PhD production now exceeds the current availability of jobs in academe, government, and industry where they can independently use their training." (p. 4 NRC 1998). As we observe in Figure 3, the opposite happened. There was a rapid increase in postdocs in biomedical and health research fields from 1998 to 2010. Between 2000 and 2010, the number of biomedical postdocs increased 134%[4]

Since the late 1990s reports by NIH and the National Academies have raised concerns about the working conditions, long hours, lack of benefits, forced geographic mobility and most importantly, future employment opportunities faced by postdocs, as well as postdocs' effects on families (NIH 2012, NIH 2018, NIH 2023, NRC 1998, NRC 2005, NAS 2014, NASEM 2018). In 2014, the National Academies conducted another study of postdoctoral experience, noting that since its last study in 2000, "…the number of postdoctoral researchers in all disciplines has continued to grow sharply," but "the number of independent and especially academic research positions into which they might transition did not" (Institute of Medicine 2014, p. ix). *The Next Generation of Biomedical and Behavioral Sciences Researchers: Breaking Through,* found that not only were PhDs in the biomedical sciences less likely to secure faculty positions, but the average age at which they obtained these positions and secured their first independent grant funding was creeping ever higher. As the report observed, the obstacles to success "…have created a career path that is increasingly unattractive, in terms of pay, duration, culture, risk-taking, and future job prospects…" (NAS 2018, p. 2). The report went so far as to call for a $1000 tax to be paid by principal investigators who hire postdocs (NASEM 2018).

Since 2012, the NIH has issued three reports related to the biomedical workforce. The 2012 Advisory Committee to the Director of NIH *Biomedical Workforce Report* called for an increase in the salaries of NIH trainees in part to reduce demand for their services

[4] According to Kahn and Ginther (2017) the average length of time it took to obtain a doctorate in biomedical fields was 7.5 years in 1998 which means that those students admitted during the doubling would have finished their degrees starting in 2005 when the acceleration in biomedical doctorates begins.

(NIH 2012). The 2018 NIH *Next Generation Report* recommended a steep increase in the postdoc stipend with years of experience to decrease the demand for postdocs. The most recent study, the 2023 NIH *Re-envisioning NIH Supported Postdoctoral Training*, echoed the concerns of the three previous studies. However, unlike 2012 and 2018, when postdocs were plentiful, the sharp decline in the number of postdocs starting in 2020, raised significant concerns. In response, this study called for increasing the postdoctoral stipend to $70,000. The NIH responded by raising the NRSA stipend for postdoctoral fellows from $56,484 in FY2023 to $62,652 in FY2025, an 11 percent increase. As prices of postdocs increase, the expectation is that the demand for postdocs will fall.

Interestingly, by the 2010s, the relationship between variations in the NIH budget and postdoc numbers appears to have largely broken down. In Figure 8, we compare the number of postdocs in biomedical and health fields, the number of biomedical faculty in U.S. research universities, the number of R01 grants awarded each year, and the constant dollar NRSA stipend for first-year postdocs. The NRSA stipend for first year postdocs has not decreased in real terms since 2013. Beginning in 2017, the number of R01 grants awarded increased by 31% while the number of faculty increased only 2% and the number of postdocs fell by 7%. The number of doctoral degrees in biomedical fields also increased by 7%. If postdocs are desirable workers, then the increase in the number of R01 grants should have increased the number of postdocs demanded and hired, yet the number of postdocs fell.

In Figure 9 we compare the real value of the average R01 award and the real value of the starting NRSA postdoc salary (both adjusted to 1998 dollars). The average real value of an R01 grant peaked initially in 2003, and the real value of the NRSA stipend peaked as well. While the real value of the NRSA stiped trended downward or remained flat, the number of R01 grants (Figure 8) and the average real value of an NIH R01 award (Figure 9) dropped by 14.5% by 2013. From 2013—2024, the real value of the average R01 award reached a new peak in 2020 before falling sharply through 2024. The postdoc stipend increased in 2024 in response to recommendations from the NIH Advisory Committee to the Director to raise postdoc salaries (NIH 2023). Nevertheless, it is puzzling that the reductions in funding and R01 grants did not reduce postdoctoral appointments between 2009—2017, and that the increase grants and the real value of an NIH R01 award since 2017 did not also increase postdoctoral employment.[5] The results are not consistent with the demand for postdocs waning in recent years.

To drill down further, recent data produced by the NIH has shown how postdocs are utilized on research projects. Starting in 2015, the NIH began to enumerate the type of staff on each funded project. Using recently reported data from NIH,[6] we calculated the share of principal investigators, co-investigators, postdocs, graduate students, staff scientists, and technicians in Figure 10. The number of PIs has increased by close to 8,700 and staffing also changed dramatically. In 2017 there were 30,000 postdocs employed on NIH research grants, but by 2022 that number fell by about 1,100. Staff scientists also decreased by 353, while the share of graduate students increased by 5,300. The NIH also reported on how much effort was allocated by staff type. Graduate students spent an average of six calendar months, while postdocs spent seven, and staff scientists spent over five months. Starting in

[5] We also examined whether the increase in postdoc salaries by years of experience may have affected the demand for postdocs. In 2017, a 5th year postdoc's NRSA stipend was 14% higher than a first-year postdoc salary. In 2024, that ratio was 13%. This suggests that changes in the cost of more senior postdocs was not influencing the change in demand for postdocs.
[6] These data were available at https://nexus.od.nih.gov/all/2024/03/02/number-of-postdoctoral-researchers-supported-by-nih-grant-awards-fy-2017-fy-2022/ (accessed in April 2024). This webpage was removed from the NIH website with the following notice: "We plan on refreshing and rereleasing our older, popular content and migrating historical blog posts over the next few months."

2021, there was a significant decline in the number of postdocs supported on NIH grants.

The Impact of Postdocs on Careers

While it is generally accepted that a postdoc provides valuable preparation for researchers who eventually take research faculty positions, a consensus is emerging that the time spent in a postdoctoral position had negative career consequences for the growing number of researchers who are ultimately employed outside of academia. Using data from the SED and SDR to compare the career outcomes of those who started in the postdoc to the counterfactual of those who skipped the postdoc in biomedical fields, Kahn and Ginther (2017) found that the share of U.S. trained doctorate recipients entering postdocs had remained roughly stable between 1980 and 2010, they found that after 2000, a sharp drop in the share of these Ph.D. recipients transitioning to faculty positions within 10 years of graduation (Kahn and Ginther 2017, p. 92). In addition, they found that postdocs had better productivity characteristics (i.e., were "positively selected"), however, there was no economic return to taking the postdoc. Postdocs were paid substantially less in future employment than those who skipped the postdoc. While the postdoc was useful for obtaining an academic tenure-track research position, Kahn and Ginther found that the likelihood of achieving this goal dropped considerably over time.

Using similar data and methods, Main and Wang (2019) and Main, Wang & Tan (2021) examine the impact of postdoctoral training on the careers and salaries of engineers. These authors find that engineering postdocs are positively selected and are more likely to have academic jobs after graduation. Using more-recent waves of the SED and SDR to examine career outcomes, Diethorn and Marschke (forthcoming) and Cheng

(2023) reinforce the previous findings. Using a task-based framework, Diethorn and Marschke (forthcoming) show that postdoc penalties arise when postdoctoral training is not used in subsequent jobs. Categorizing career paths for research doctorates into six job types - postdoctoral researcher, tenure-track academic, non-tenure track academic, for-profit industry, non-profit, and government, Cheng (2023) found that although postdoctoral positions allow scientists to remain engaged in research, that the likelihood of obtaining an academic job fell over time, and they experienced significant earnings penalties from taking a postdoc. Andalib, Ghaffarzadegan and Larson (2018) model the postdoc as a labor force queue. Using data from the SDR they found that only 17% of scientists who enter the postdoc queue eventually are employed in tenure-track academia. Taken together, the literature shows that postdocs positions attract on average the more productive doctorate recipients, but these postdocs pay a significant price in terms of foregone earnings by engaging in postdoctoral research, and a declining fraction are able to secure academic positions that reward their postdoc experience.

However, not all postdoctoral positions are created equal. NIH training programs and fellowships have been shown to improve subsequent career outcomes. Levitt and Levitt (2017) found that NIH's early-stage investigator program increased success rates of younger scientists in receiving NIH R01 funding. However, Levitt (2010) found that women were more likely to leave scientific research careers than men when examining the association between the 1992-94 cohorts of the NRSA F32 postdoctoral fellowship program and their subsequent biomedical careers. Using NIH administrative data and a regression discontinuity design that compared those who were awarded an NIH F32 postdoctoral fellowship and those that had competitive scores but were not funded, Jacob and Lefgren (2011) found that NIH postdoctoral fellows had more publications and received higher dollar amounts in subsequent NIH funding compared to non-awardees. In related work that used similar data and propensity score matching, Heggeness et al (2023) found that receiving an NRSA F32 postdoctoral award increased the probability of receiving subsequent NIH research funding by about 7 percentage points and the probability of receiving NIH R01 funding by about 5 percentage points. Pickett (2019) echoes these findings by showing that first-time R01 awardees were more likely to have had K-series career development funding from the NIH.

Postdocs and the Production of Scientific Knowledge

The argument of the preceding section is that in the absence of mechanisms linking the inflow of aspiring researchers into postdoc position to the likely opportunities to enter independent faculty research positions increases in the availability of federal R&D funding may encourage growth in the supply of postdocs in at least some areas of science well beyond the number needed to fill faculty vacancies. As a result, postdocs have become an increasingly important part of the scientific workforce and play a key role in the organization of labs and the production of new scientific knowledge, but this transition has, in turn, reduced the value of the advanced training these positions provide. As postdocs' role has shifted toward production of new knowledge, opportunities for training have diminished and the value of the training they do receive has declined, since many will ultimately exit the academic sector for industry or government jobs that place less value on these skills.

A convincing test of the conjectures of the preceding paragraph is difficult given the complex feedback between graduate student numbers, postdocs and funding and the lack of truly experimental variation in the data. Nonetheless newly available data disaggregated by university and academic discipline level allow us to make some progress in understanding both how rising postdoc numbers have affected the production of scientific knowledge and how variations in funding affect postdoc numbers.

In what follows we combine data on the numbers of postdocs and graduate students from the NCSES Survey of Graduate Students and Postdoctorates in Science and Engineering with R&D expenditures based on data reported in the Higher Education Research and Development Survey (HERDS) and data on faculty numbers, publications and citations obtained from Academic Analytics (a private company that collects data on university faculty and their research output). Counts of publications are adjusted by the number of coauthors in the Academic Analytics universe.[7] Data from these sources are available from 2009 through 2022. We limit our analysis to the U.S. universities that accounted for 90 percent of cumulative R&D expenditures in this period.[8] In addition, because of the work involved in merging the different data sets, we restrict attention to seven broad fields of scholarship: (1) biomedical science, (2) chemistry, (3) chemical engineering, (4) electrical engineering, (5) computer science, (6) psychology, and (7) economics.[9] These seven fields of study span a wide range of approaches to research and provide insight into differences in the utilization of postdocs in scientific production.

[7] For example, this chapter would assign .5 publications to the University of Kansas and .5 publications to Iowa State University.

[8] Using the NSF HERD, 90 percent of R&D expenditures were concentrated in the top 173 universities or academic medical centers in this period. Because these 173 entities include multiple entries for some universities for which postdoc and graduate student numbers are reported in aggregate form, merging the HERD data with data on graduate students and postdocs reduces the number of institutions to 147. Not every discipline considered here is represented at each university in the sample, so numbers of observations are lower for some fields of study.

[9] Because of the way the Academic Analytics data are collected, assigning individuals to universities and academic disciplines is not always straightforward. In particular, individuals may appear in the database multiple times with affiliations to different universities, as well as appearing multiple times within a university if they are associated with more than one department or field of study.

The Distribution of Postdoctoral Researchers

Before turning to questions of the relationship between postdocs, publications and funding it is helpful to look briefly at the distribution of our key measures of inputs across institutions. A striking result of this analysis is the extent to which research expenditures and postdocs are concentrated at a small number of universities. Figure 11 shows the relationship between the cumulative distribution of funding and postdocs by plotting the Lorenz curves. In this figure, if funding and postdocs were equally distributed, they would lie along the 45-degree line. Both postdocs and research funding curves are well below this line of equal distribution, but the line for postdocs is lower than that for funding, indicating it is more unevenly distributed. According to the GSS, the top 10 institutions that employ postdocs have 30% of all postdocs but only 16% of total research funding.[10] In Figure 10 we compare the distribution of postdocs to that of faculty and publications. Both faculty and publications are closer to the 45-degree line, hence more equitably distributed than postdocs, with the faculty being somewhat more evenly distributed than publications.

In Table 1 we break these aggregate differences down by field of study. For each field of study, we report share of that discipline's postdocs, federal R&D expenditures, faculty and graduate students accounted for by the top 10 percent of universities at five-year intervals. Funding is most concentrated in electrical engineering, computer science, and economics, where 50-60 percent of expenditures are concentrated at the top 10 percent of institutions. Funding is most equitably distributed in chemistry, chemical engineering, and psychology, where the top 10 percent of institutions account for about 30 percent of expenditures. Biomedical sciences fall somewhere in between, though the concentration of

[10] The top five universities for employing postdocs are Harvard, Stanford, Johns Hopkins, the University of Minnesota, and MIT.

funding has been increasing over time (a trend that is apparent in a number of other disciplines as well).

The concentration of postdocs is consistently high across all disciplines, with the top 10 percent of institutions accounting for nearly 40 percent of the postdocs. Consistent with Figure 11 the concentration of postdocs is higher than that of R&D expenditures in every discipline except electrical engineering and psychology. Levels of concentration are similar in the other disciplines. In contrast to the concentration of postdocs and research expenditures at a relatively small number of universities, faculty and graduate training are relatively dispersed. In most fields, the top 10 percent of institutions account for less than 25 percent of the regular tenure-track faculty, and graduate student numbers parallel faculty distribution. Taken together, these results are consistent with those found in Zhang et al (2022). They attribute increased research productivity to greater numbers of funded graduate students and postdocs at prestigious universities.

Postdoc and Scientific production

One implication of the increased reliance of academic science on postdocs is that they are making an important contribution to the production of new scientific knowledge. This topic has so far been largely neglected in the literature. We are aware of only one paper that has examined the association between the number of postdocs and science outcomes. Using a combination of HERDS and GSS data, Rosenbloom and Ginther (2017) found that academic institutions with more postdoctoral researchers in the previous period received higher amounts of federal research funding in chemistry in subsequent periods. Other researchers have used the Early Career Doctorates Survey (ECDS) to examine early career outcomes. Chang, Phou, Basner and Desai

(2022) found that having published as a doctoral student is associated with a subsequent research career. Kahn and MacGarvie (2024) compared postdoctoral experiences of temporary-resident and U.S. citizen postdoctoral researchers and found that temporary resident postdocs were less likely to develop independent research agendas, more closely monitored, and earned less than U.S.-citizen postdocs.

Using our university discipline level data, we can examine this question using a fixed effects panel regression of the correlates of articles per faculty member (p):

(1) $p_{it} = \alpha_i + \tau_t + \beta_1 pd_{it} + \beta_2 r_{it} + \beta_3 gs_{it} + \varepsilon_{it}$

Where *i* indexes universities, *t* indexes time, *pd* is the number of postdocs per faculty, *r* is federal R&D funding per faculty, and *gs* is the number of graduate students per faculty. In addition equation (1) includes a university fixed effect, α, which captures non-time varying differences across universities, and a year fixed effect, τ, that captures common temporal shocks that affect all universities in the same way. In this specification, the impact of variations in postdocs, research funding and graduate students per faculty are identified based on year-to-year changes within each university, while systematic differences across universities are absorbed by the fixed effects.

Table 2 reports the results of this estimation, where the number of publications is a moving sum of publications in years t, t-1, and t-2, to remove some of the short-run variability. Across all disciplines the effect of postdocs per faculty member is consistently positive, though it varies considerably in magnitude. Focusing on the disciplines in which this relationship is statistically significant, in computer science, an additional postdoc per faculty member results in over 2 more publications per year, while in electrical engineering one more postdoc per faculty results in almost 1.6 additional publications per faculty member per year. In chemistry and biomedicine, the effect is around 0.6 additional publications. The effect in economics is large but not precisely estimated, while the effects of additional postdocs in chemical engineering and psychology are small.

Graduate students are the other labor input besides faculty into scientific production, and Table 2 indicates that departments with more graduate students per faculty member also produce more publications per faculty. The lone exception here is computer science, where the effect of graduate students is negative but small and statistically insignificant. The effect of graduate students in biomedicine is positive, but small and, again, statistically insignificant. R&D funding contributes to research output both through funding graduate students and postdocs and through supporting other research related expenditures. Thus, we would expect more funding per faculty to be associated with higher levels of publications per faculty to the extent these other non-personnel costs are important. Table 2 suggests that this is true in most of the disciplines that we consider. In economics the effect is positive but imprecisely estimated. In electrical engineering the association is statistically significantly negative, but it is relatively small.

One other striking feature of the regressions reported in Table 2 is the positive trend in numbers of publications over time reflected in the increase in coefficients on the year effects. Rosenbloom at al (2015) found a similar upward trend in publications in academic chemistry in the years 1990-2009. These results suggest that this result has persisted to the present and is more general.

Funding and the Demand for Postdocs

As we have seen the number of postdoctoral researchers varies considerably across universities. To a first approximation we can interpret this variation within a discipline as reflecting variations in the demand for postdocs at that institution.[11] Factors affecting the demand for postdocs are likely to include the number of faculty researchers at the university and the level of funding available to support their research activity. To the extent that pre-doctoral students act either as substitutes for or complements to postdocs in producing knowledge, the number of graduate students may also affect the demand for postdocs. Demand also depends on variations in the wage rate for postdocs, but we do not have a good measure of this. Consequently, we assume that variations in wages are common across institutions and thus will be absorbed in common time-effects. Formally then we can write the demand for postdocs at institution i, in year t as:

$$(2) \qquad D_{it} = f(F_{it}, R_{it}, G_{it}, \alpha_i, \tau_t, \varepsilon_{it})$$

Where F is the number of tenured or tenure-track faculty, R is a measure of research funding, G is the number of graduate students, α is time-invariant university fixed effect, τ reflects common temporal effects across all universities, and ε is an idiosyncratic error term.

Assuming a linear approximation to equation (2) we can estimate this relationship in a panel fixed-effects regression. Table 3 reports the results of estimating equation (2) separately by discipline. Interestingly the number of postdocs has no relationship with faculty numbers. But it is important to recall that identification here relies on temporal variation within each university, and there may simply not be enough variation in faculty size over time to reliably measure this effect. On the other hand, the regressions reveal a positive and statistically significant relationship between federal R&D expenditures and

[11] Despite the concentration of postdocs noted in Table 1, individual universities are still small relative to the total market, so they can be thought of as facing a more or less perfectly elastic supply.

employment of postdocs in chemistry, chemical engineering and psychology. For chemistry the estimates imply that each additional $1 million results in almost 0.8 additional postdocs, while the effect in psychology is about 0.5, and that is chemical engineering is about 0.3. Across the remaining disciplines variation in funding has little association with numbers of postdocs. Turning to the effect of graduate student numbers, we again see only a limited association with postdoc numbers. There is a small but statistically significant association between the number of postdocs and the number of graduate students in chemistry and psychology, but otherwise estimates are quantitatively small and insignificant. The year effects capture temporal trends. They indicate that, other things equal, postdoc numbers in chemistry and biomedicine were decreasing after 2009. In electrical engineering, on the other hand there is an upward trend over time.

If individual university level variations in funding from year to year are effectively random, then the coefficients on R&D expenditures could be interpreted as causal. But it seems reasonable to suppose that the quality of research proposals (which remains unobserved) affects both funding and the demand for postdocs. An additional complication is the possibility of reverse causality. Since postdoc appointments are typically longer than one year, departments with more postdocs in prior years may have been able to garner more research support through grants written in whole or in part by the postdocs.

Taken together, these results suggest that postdocs increase research productivity at universities in most disciplines. On the other hand, evidence for a relationship between R&D funding and the demand for postdocs is mixed. It is notably absent in biomedicine—the field with the most postdocs—as well as in economics, computer science and electrical engineering. In chemistry, chemical engineering and psychology we do find that R&D

funding is positively associated with increased postdoctoral appointments in chemistry, chemical engineering, and psychology.

Research Agenda

As mentioned previously, the quality of data available on postdocs is limited and measured with error. U.S. statistical agencies do not have reliable counts of postdocs working in the country (Science and Engineering Indicators, 2012). Future research contributions will depend on access to administrative data that links postdocs to their funding as well as the principal investigators that they work for. At the same time surveys that collect data on postdocs are currently under threat. The Early Careers Doctorate Survey has not been fielded since 2017. The SDR was supposed to be collected this year but was suspended. There are some indications that the National Center for Science and Engineering Statistics plans to merge the SDR with the National Survey of College Graduates and the National Training, Education, and Workforce Survey--a group that does not even have bachelors' degrees. Clearly preserving existing surveys while gaining access to administrative data such as the NIH's IMPAC II would go a long way towards supporting research on the effect of postdocs on academic careers.

Assuming that barriers to data on postdocs are removed, there are a number of important and unanswered questions that would shed light on the role of the postdoc. First, given the paucity of data, descriptive studies would be useful. How long are postdocs? How many postdocs are there? How are postdocs supported financially? Second, while many studies have examined the impact of postdocs on individual careers, few papers have studied the role of postdocs in the research production process. While we show that postdocs do contribute to the research enterprise, a more detailed and causal analysis is warranted. Third, how do postdocs compare across research fields? Most research has focused on biomedicine given the predominance of biomedicine and health postdoctoral positions. However, postdocs have increased rapidly in engineering, thus studies of the impact of postdocs in different fields are warranted. Third, the majority of doctorates will end up working in private industry. Is postdoctoral training required to be productive in industry jobs? Fourth, our analysis has demonstrated that the U.S. relies critically on temporary residents to fill postdoc positions. Given the significant changes in U.S. immigration policy as well as restrictions on grants to selected universities that hire a significant share of postdocs, will we observe the impact on scientific productivity of these negative supply shocks in the coming years?

Use of administrative data such as UMETRICS would be useful to examine the roles that postdocs play in research labs. Clearly, there is a trend on projects funded by the NIH to increase the hiring of graduate students while decreasing the hiring of postdocs. More work is needed to understand whether this is a supply phenomenon (e.g. fewer postdocs willing to work for low wages with reduced prospects for academic jobs) a demand phenomenon (e.g. PIs are stretching their grant dollars by substituting towards cheaper labor) or both. A detailed analysis of the substitution between graduate students, postdocs, and staff scientists is warranted.

Given the relationship between research funding and postdoctoral employment (Figure 11), further investigation into the concentration of research funding and postdocs should be examined. Perhaps the changes in federal funding priorities under the current administration will lead to greater equality in the allocation of research funding as well as the number of postdocs. Alternatively, if federal research funding is cut dramatically then opportunities to work as postdocs will necessarily be limited. Institutions with more postdocs have larger research teams (Zhang et al 2022). If so, how does team size affect the quality and quantity of research? Research has found that larger labs produce incremental science while smaller labs are more innovative (Wu, Wang and Evans 2019). It remains an open question as to whether research performed by postdocs is more incremental or innovative. While researchers have found that overall team size in a field has a negative impact on career prospects (Andalon et al 2024), more work remains to understand how the size and composition of an individual's team affect subsequent career outcomes.

While there is significant evidence that NIH F32 fellowships promote subsequent research careers (Jacob and Lefgren 2011, Heggeness et al 2023), the impact of fellowship funding in other fields deserves attention. Training grants and fellowships may provide improved mentoring that launches students on independent research careers. Like postdocs, mentoring by principal investigators is rarely measured or studied

Discussion and Conclusions

This chapter has examined the economics of postdoctoral researchers by considering the supply and demand for postdocs, the impact of postdocs on career outcomes, and the role of postdocs in the research production process. Research inevitably involves continuing investment in human capital as investigators grapple with new questions on the frontiers of human knowledge. Postdoctoral research positions emerged first as a period in which scholars could invest heavily in the development of the human capital necessary for success in their chosen field. The value of these skills acquired by postdocs in biomedical science, chemistry, physics and some related fields made postdoctoral appointments an important step on the path to an independent research career. This situation persisted from the late nineteenth century through the 1960s.

During the 1960s the rapid growth of U.S. higher education spurred by the arrival of the baby boom generation on college campuses, supported by the expansion of federal R&D

funding in the wake of Sputnik, and further encouraged by individuals seeking draft deferments led to considerable growth in numbers of graduate students, postdocs and faculty. Beginning in the early 1970s, slowing undergraduate enrollments and a deceleration of federal funding resulted in a slowdown in the creation of faculty positions. By the 1970s doctorates entering postdoc positions found it harder to exit into the independent faculty research roles. By the late 1970s this imbalance was becoming apparent to those concerned with higher education and the health of the scientific workforce (National Research Council 1981).

Since the 1980s the lack of articulation between the forces affecting the supply of postdocs entering positions and the factors affecting the creation of new faculty positions into which postdocs can exit has resulted in the relatively more rapid growth of postdocs than faculty and shifted the make-up of the U.S. scientific workforce toward larger research teams with more postdocs. As the length of time spent in postdocs has increased, and the proportion successfully exiting into faculty positions has declined, there are feedback loops that may have helped to slow the number of students seeking Ph.D.s and entering the supply of postdocs. However, the long lags between decisions to enter Ph.D. programs and degree completion, combined with the challenges of forecasting and imperfect information have meant these feedback effects have not been terribly effective. Meanwhile, fluctuations in the availability of research funding, such as the well-publicized doubling of NIH expenditures beginning in the late 1990s supported a substantial expansion of funding for graduate student research assistants in the biomedical sciences which produced, with a lag of five or more years, an increase in aspirants for faculty positions, who saw no other route to these positions than to take postdoc positions.

Taking a deeper look at the relationship between postdoctoral employment and NIH funding yields new insights. The real value of the average NIH grant fell between 2003 and 2013 before peaking at a higher level in 2020. Despite the decreased value of the NIH grant, postdoctoral employment remained steady. When the number of and value of NIH grants increased starting in 2017, the number of postdocs employed dropped. This suggests that while demand side factors mattered more in the early 2000s, by the late 2010s, supply side factors were the more important factor affecting postdoctoral employment. In addition, the decline in biomedical postdocs despite increasing numbers of biomedical PhDs belies the conventional wisdom in the previous literature that more doctorates result in more postdocs (Stephan and Ma 2005, Stephan 2012a, Stephan 2012b, Teitelbaum 2014, Freeman et al 2001, Borjas 2009 and Garrison & Gerber 1998). After 2019, biomedical postdoctoral positions became less attractive for both international and U.S. citizen scientists.

These broad outlines of the growing reliance of the U.S. scientific enterprise on postdoctoral researchers are discernable from aggregate data. But to make further progress we need to develop better disaggregated data that provide a higher resolution picture of where postdocs are employed and what their role is in the production of scientific knowledge. The second part of this paper has combined newly available data on individual faculty productivity from Academic Analytics with publicly available data on postdocs graduate, students, and research funding to begin such an exploration.

This investigation demonstrates first that the training and employment of postdocs is much more highly concentrated across universities than are numbers of faculty or graduate students. It also reveals substantial variations across disciplines in the use of postdocs. As reflected in the aggregate data, reliance on postdocs is most prominent in the biomedical sciences, chemistry, and chemical engineering. Postdocs remain relatively rare in psychology and electrical engineering, and quite rare in economics and computer science.

The data make clear that postdocs are associated with higher levels of faculty research output. After controlling for university fixed effects, the correlation between postdocs and publications is positive and significant in biomedicine, chemistry, computer science, and electrical engineering.

Analyzing the factors affecting the distribution of postdocs across universities, we find some additional support for the role of variations in funding on the numbers of postdocs after controlling for numbers of faculty and graduate students. In panel data estimates of the determinants of the number of postdocs the effect of federal R&D expenditures are positive and economically significant in chemical engineering, chemistry, and psychology—suggesting that every additional million dollars in R&D expenditures results in the increased employment of between .3 to .7 additional postdocs. These estimates rely on intertemporal variation in funding within universities to identify this effect, and the short time horizon of the panels along with limited variation in funding mean that the point estimates are not terribly precise.

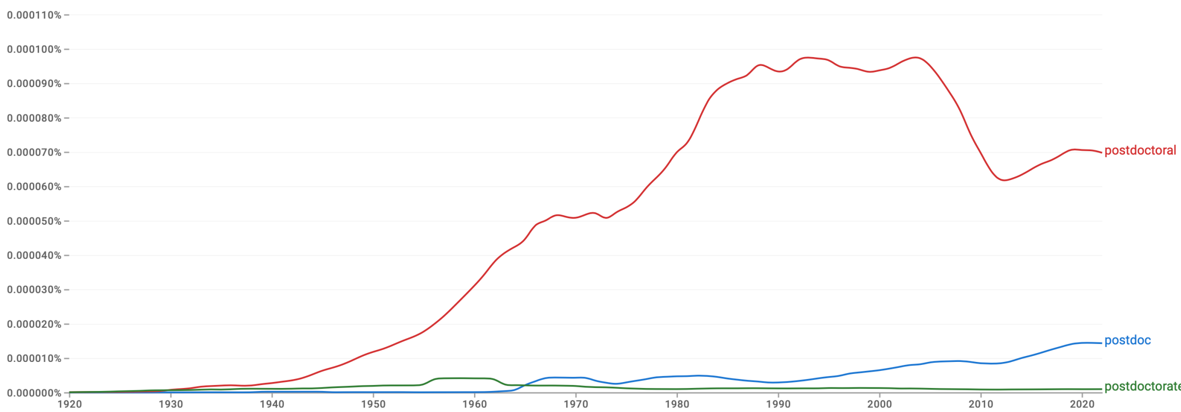
Taken together with the historical narrative of the first part of this paper, these results supported the view that variations in research funding have played an important part in the expansion of postdoc numbers over time and across space. However, this relationship has decoupled for the NIH in the past twenty years. The shift in NIH staffing from postdocs to graduate students may be the result of biomedical doctorates understanding that the postdoc is only valuable for academic jobs that are becoming increasingly scarce.

Given the current changes in the federal research funding landscape, it may be the case that we have reached peak postdoc. The number of postdoctoral researchers in the U.S. peaked in 2019. Given the impact of the COVID-19 pandemic on the labor market, changes in immigration policy brought about in the first and second Trump Administrations, and the recent increases in the postdoc compensation, the number of postdocs in the U.S. is unlikely to increase.

Our analysis showed that the majority of postdocs in this country are temporary residents. Announced executive orders and changes in immigration policy have reduced the number of international students studying in the U.S. NAFSA: The Association of International Educators estimates that there will be 150,000 fewer international students enrolled in the fall of 2025.[12] According to the Center for American Progress, as of July, the Trump Administration has terminated grant award ranging in value of $6.9 to $8.2 billion.[13] These policies will limit the number of postdocs employed in the U.S. For the foreseeable future, there will be fewer postdocs and as a result, less research produced.

[12] https://www.nafsa.org/fall-2025-international-student-enrollment-outlook-and-economic-impact
[13] https://www.americanprogress.org/article/mapping-federal-funding-cuts-to-us-colleges-and-universities/

Figure 1:
Google N-Gram for postdoc, postdoctorate or postdoctoral, 1900-2022



Retrieved August 9, 2025 https://books.google.com/ngrams

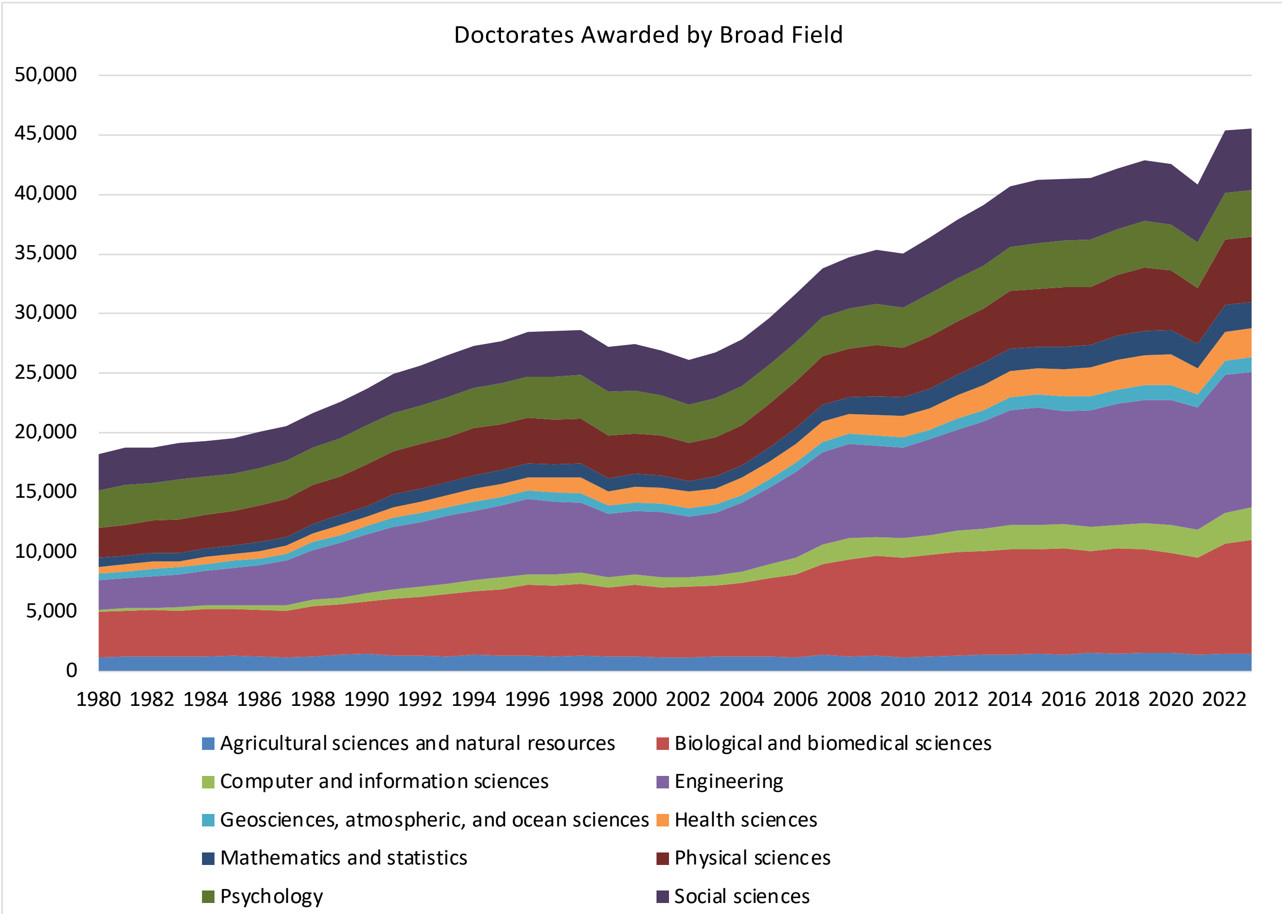


Figure 2: Doctoral Degrees Awarded by Field, 1980—2023. Source: Survey of Earned Doctorates.

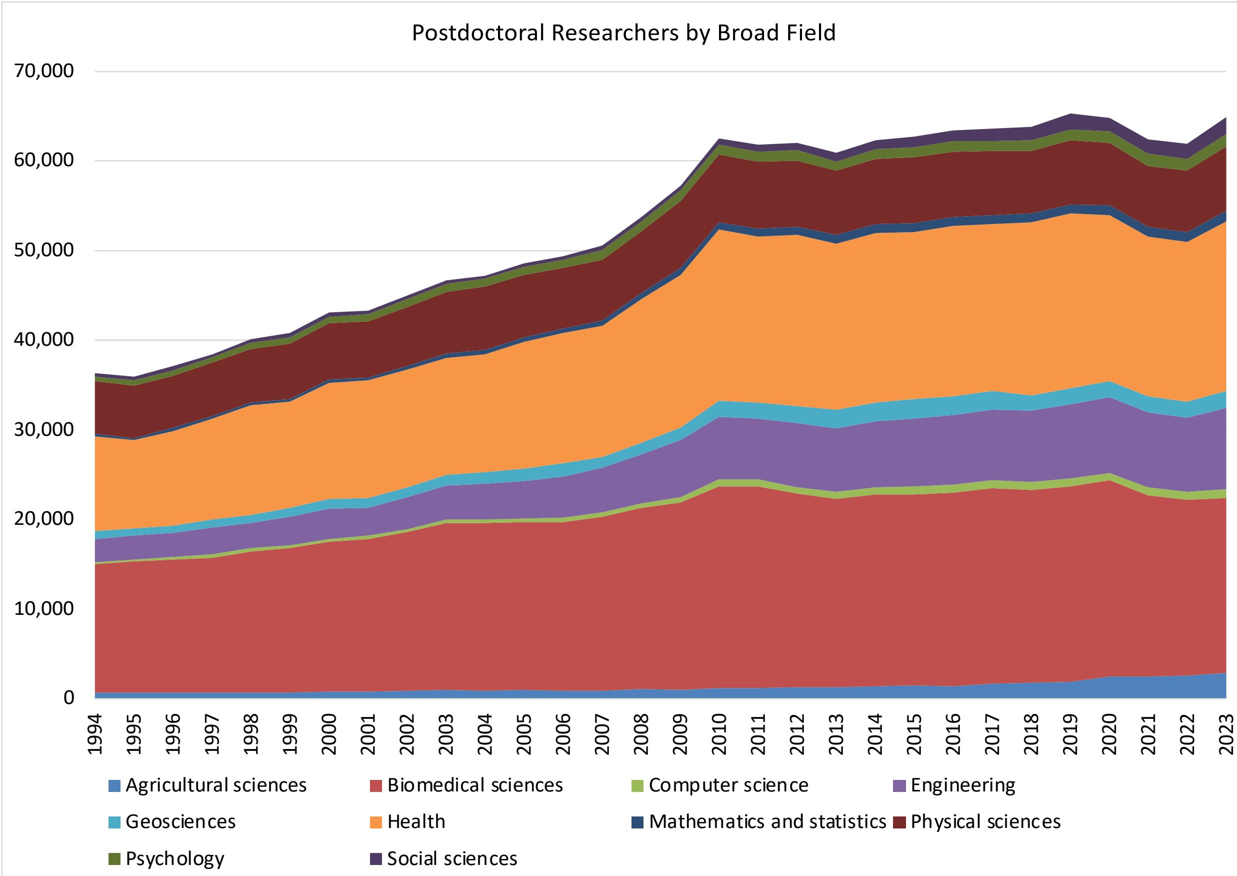


Figure 3: Postdoctoral Researchers by Field, 1994—2023. Source: Survey of Graduate Students and Postdoctorates.

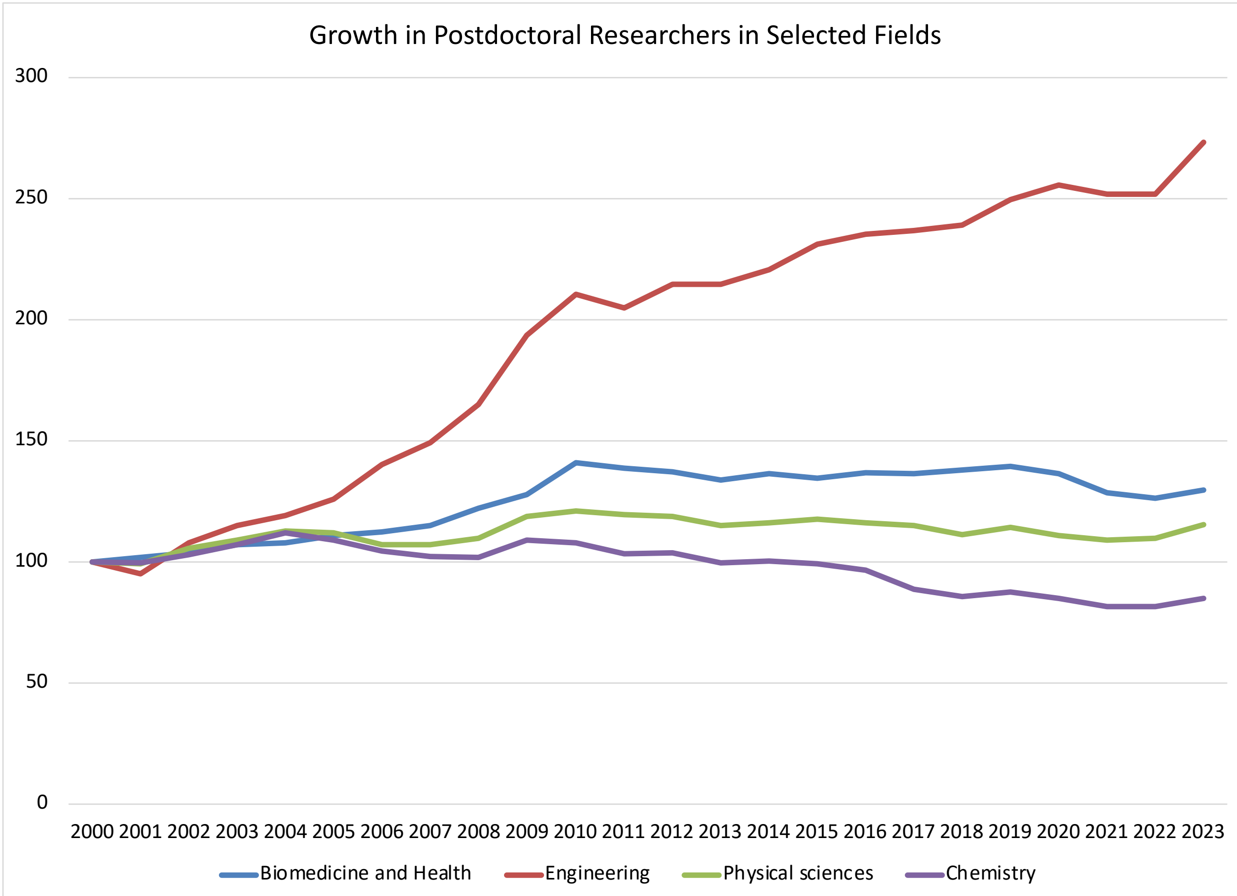


Figure 4: Postdoctoral Researchers by Field, 2000—2023. Source: Survey of Graduate Students and Postdoctorates.

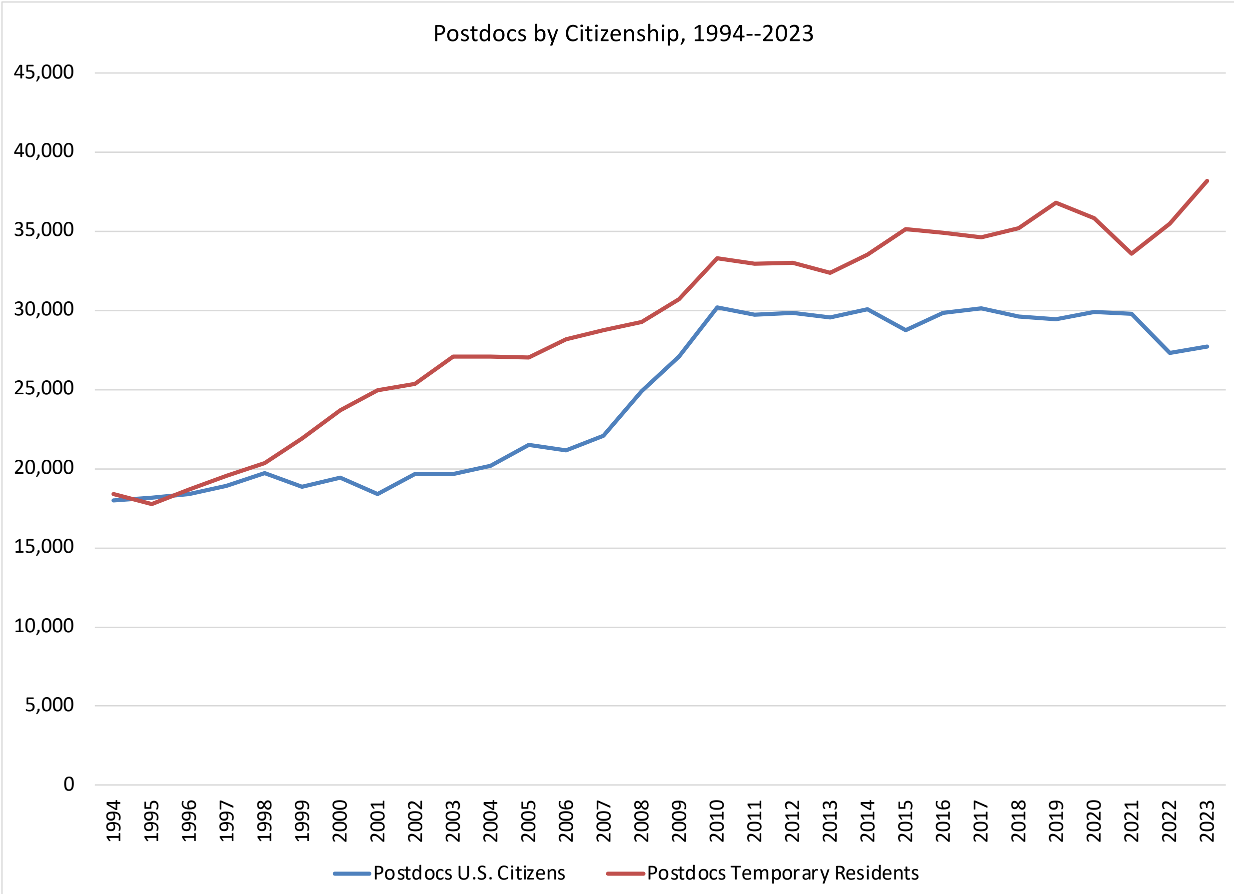


Figure 5: Postdocs by Citizenship Status, 1994—2023. Source: Survey of Graduate Students and Postdoctorates.

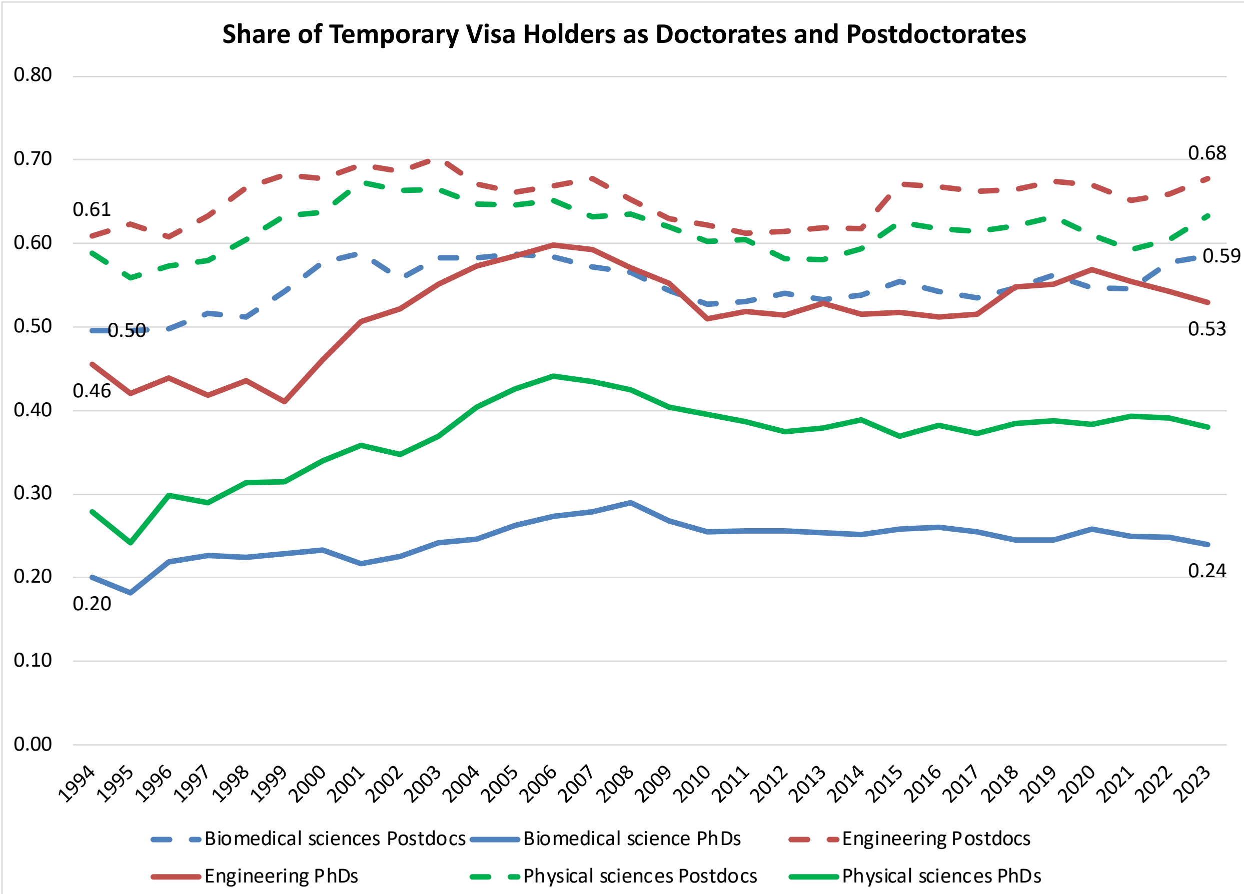


Figure 6: Share of Postdoctoral Researchers and Graduate Students who are Temporary Visa Holders by Field, 1980—2023. Source: Survey of Graduate Students and Postdoctorates.

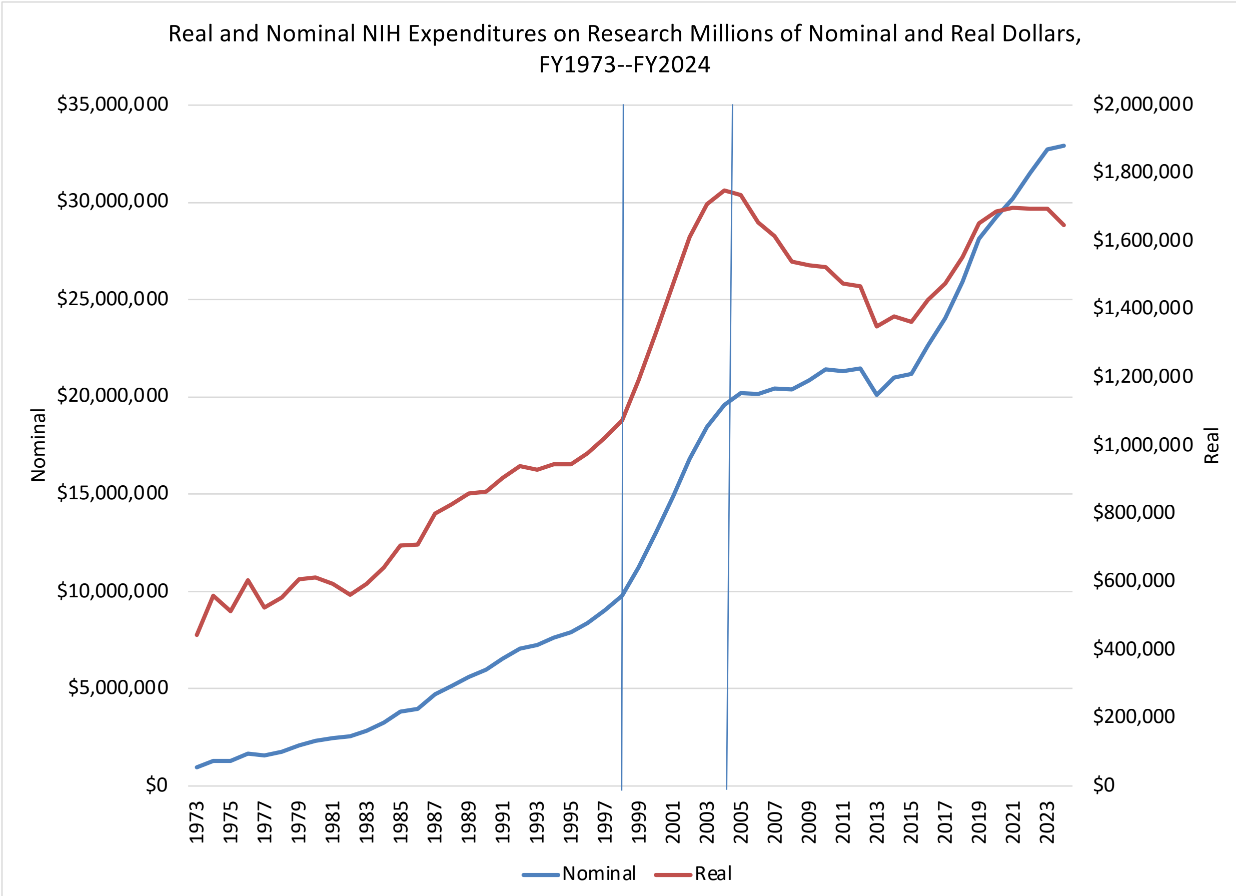


Figure 7: NIH Funding of Research in Real and Nominal Dollars, 1973—2024. Source: National Institutes of Health, Office of External Research Table #304 NIH Research Grants. Constant dollar series deflated using the Biomedical Research and development Price Index (BRDPI), based on 1950 prices.

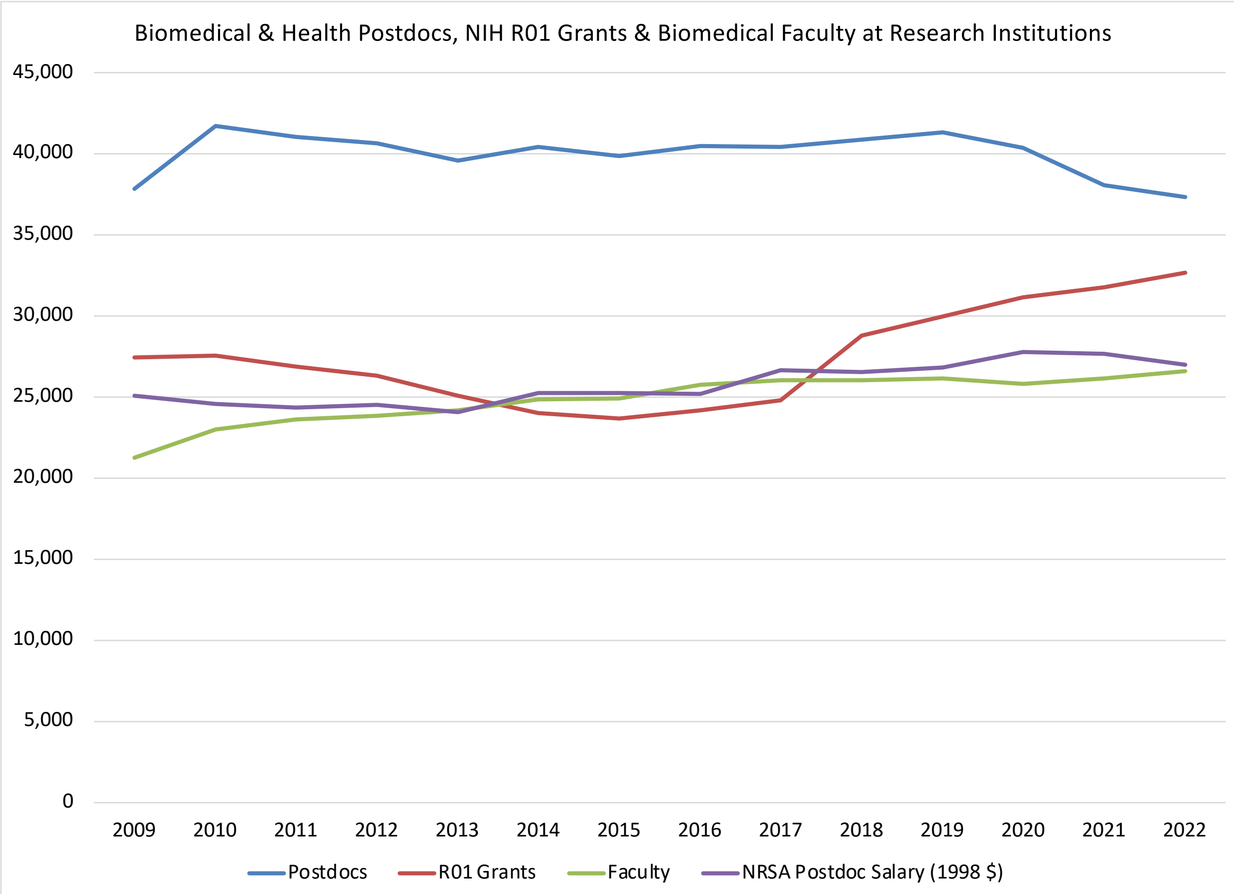


Figure 8: Biomedical & Health Postdocs, NIH R01 Grants, and Biomedical Faculty at Research Institutions FY2009—FY2022. Postdoc Source: NSF Survey of Graduate Students and Postdoctorates.; R01 Grants and NRSA Postdoc Stipends: NIH Data Book; Faculty: Academic Analytics.

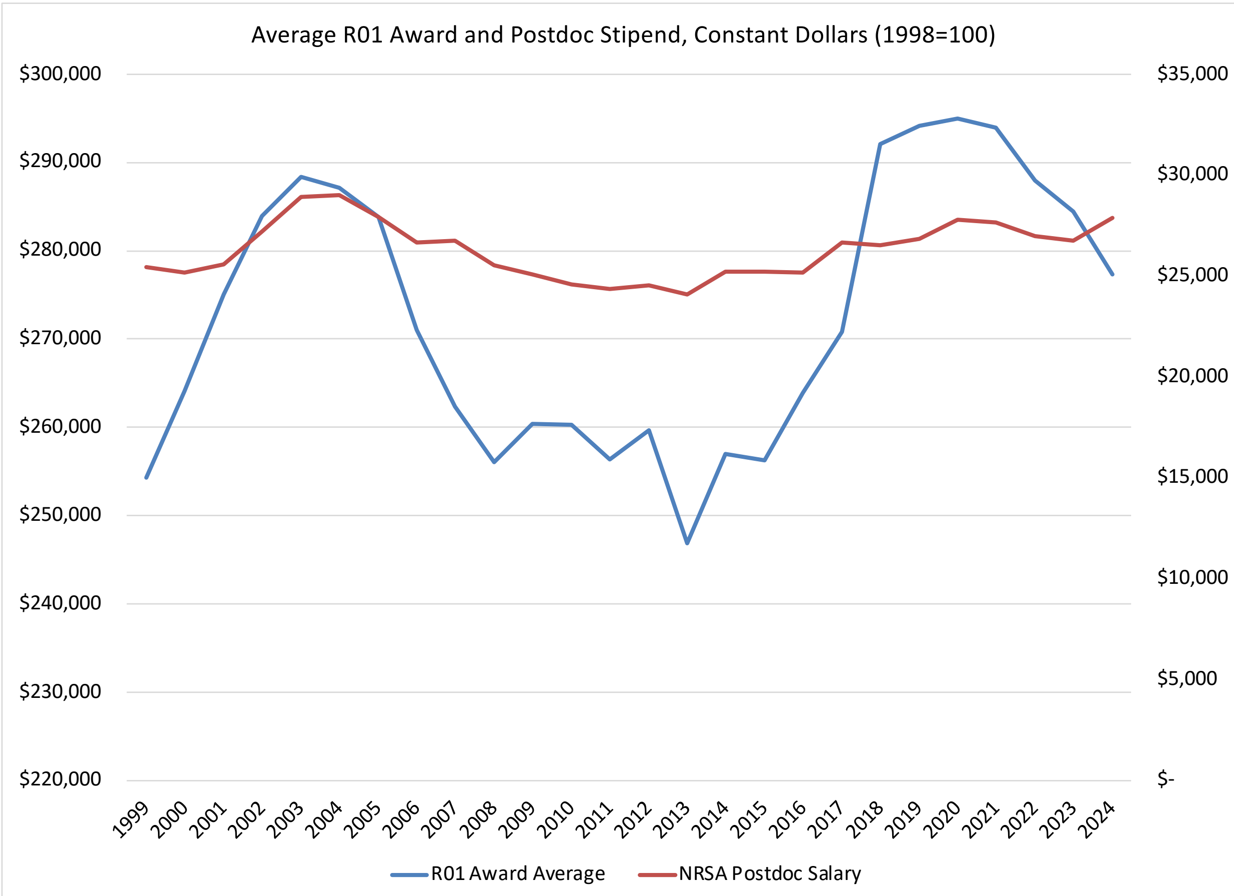


Figure 9: NIH Average R01 Award and NRSA Postdoc Stipend, 1998 Constant Dollars 19199—2024. Source: National Institutes of Health. Constant dollar series deflated using the Biomedical Research and development Price Index (BRDPI), based on 1998 prices.

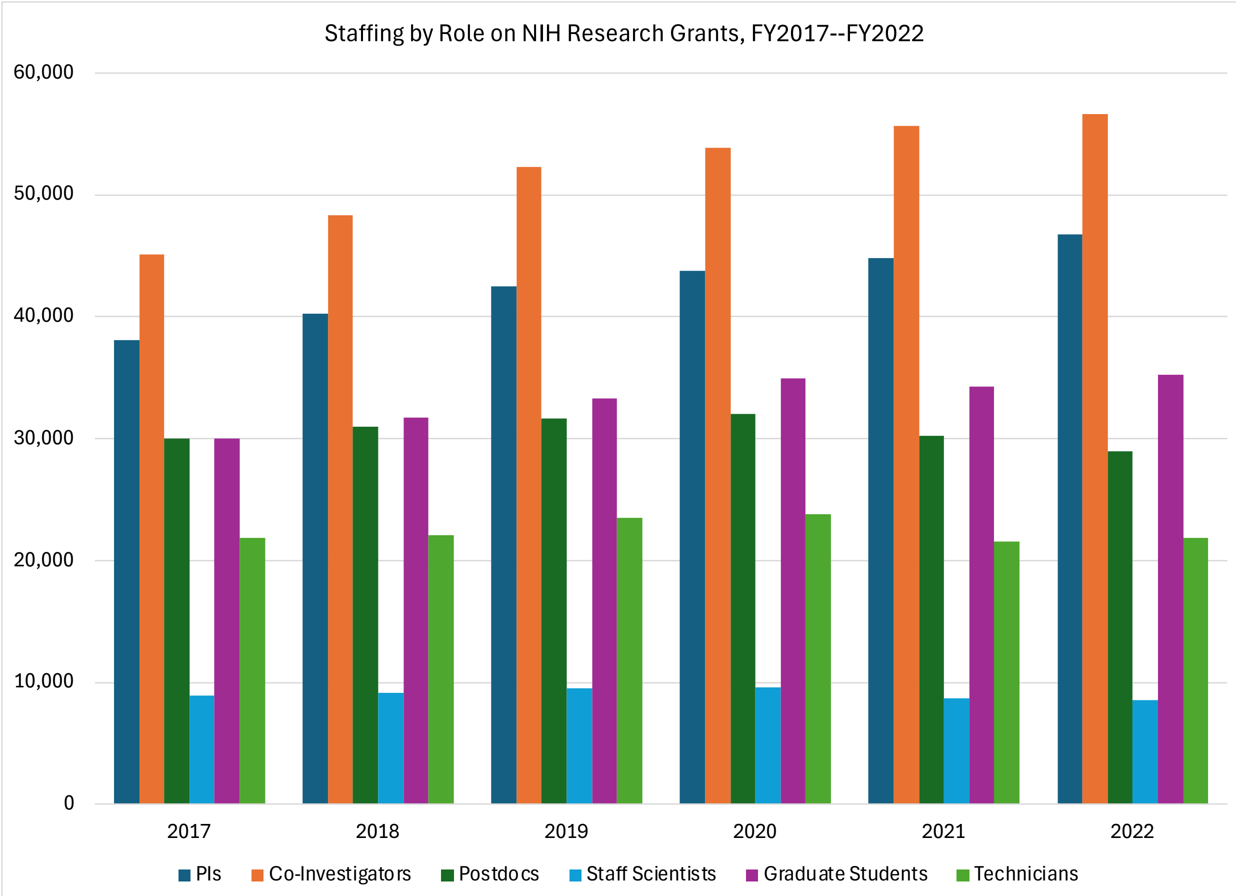


Figure 10: Staffing by Role on NIH Research Grants FY2017—FY2022. Source: NIH Office of Extramural Research.

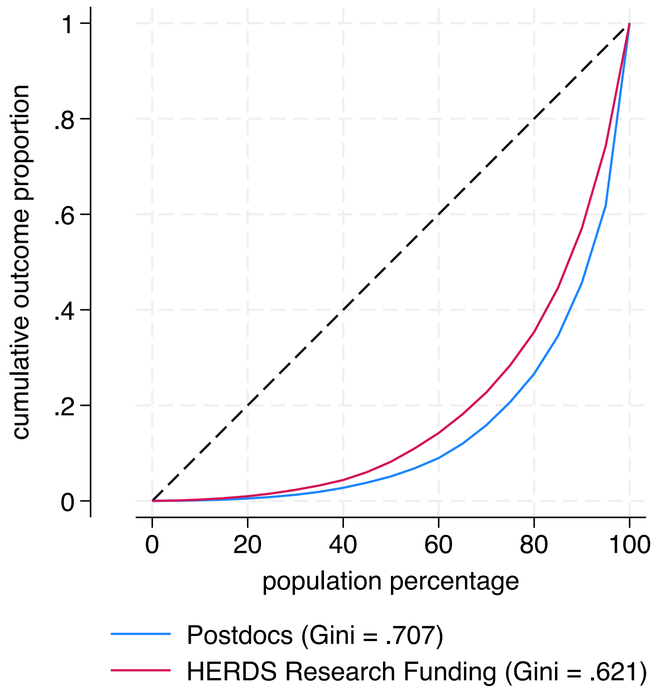


Figure 11: Lorenz curve showing the distribution of postdocs and total research funding in FY2023. Sources: Higher Education Research and Development Survey and Survey of Graduate Students and Postdoctorates.

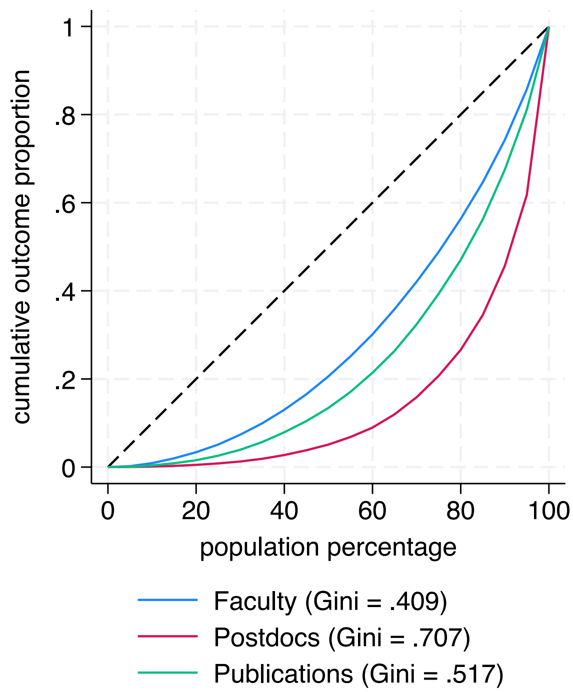


Figure 12: Lorenz curve showing the distribution of postdocs, faculty and research publications. Sources: Higher Education Research and Development Survey, the Survey of Graduate Students and Postdoctorates, and Academic Analytics.

Table 1

Percentage of Students, Postdocs, Faculty and Federal R&D Expenditures at the top 10% of institutions in each category, Selected Years

	2010	2015	2020	2022
Biomedical				
Graduate_Students	26.4	25.1	29.1	30.8
Postdocs	41.4	40.5	41.9	43
Regular_Faculty	22.1	22.5	22.1	24.1
Fed_R&D	34.4	37.5	38.6	38.5
Chemical_Engineering				
Graduate_Students	28.2	28.3	24.7	27.5
Postdocs	42.6	42	39.1	41.7
Regular_Faculty	23	20	19.1	19.2
Fed_R&D	33	33.2	33.1	36.7
Chemistry				
Graduate_Students	22.1	23.3	23.1	23.4
Postdocs	36.1	42.1	37.8	39.1
Regular_Faculty	19.9	21.2	19.5	21.9
Fed_R&D	31	32.5	28.3	28.1
Computer_Science				
Graduate_Students	32.6	41.1	49.2	48.7
Postdocs	49.3	52.5	54.7	56.4
Regular_Faculty	26.8	26.2	25.5	27.1
Fed_R&D	56.5	57.8	60	58.3
Economics				
Graduate_Students	27.2	28.8	30.2	33.4
Postdocs	67	66.2	60.9	66.8
Regular_Faculty	21.9	22.7	22.7	25.1
Fed_R&D	53.4	63.8	56	66
Electiral_Engineering				
Graduate_Students	34.2	32.4	34.1	37.8
Postdocs	46.7	48.1	43.6	42.7
Regular_Faculty	27	25.6	28.5	29.8
Fed_R&D	51.8	61.3	61.7	62.7
Psychology				
Graduate_Students	26.4	25.9	33.7	38.5
Postdocs	43.5	40.7	39.6	44.6
Regular_Faculty	22.7	21.5	22.9	23.3
Fed_R&D	31.9	33	33.2	32.6

Table 2

Fixed Effect Panel Regressions of Publications per Faculty Member

	Biomedical	Chemical_Engineering	Chemistry	Computer_Science	Economics	Electrical_Engineering	Psychology
Postdocs per faculty	0.572 ***	0.118	0.624 **	2.060 *	3.069	1.592 **	0.198
	(0.209)	(0.543)	(0.280)	(1.079)	(2.184)	(0.774)	(0.408)
Federal R&D per faculty ($millions)	0.947 ***	1.263 *	0.190 ***	1.236 *	2.964	-0.171 ***	2.442 **
	(0.343)	(0.703)	(0.022)	(0.628)	(2.557)	(0.048)	(0.973)
Graduate students per faculty	0.093	0.203 **	0.289 *	-0.018	0.082 **	0.105 **	0.063 **
	(0.071)	(0.085)	(0.159)	(0.019)	(0.038)	(0.040)	(0.024)
Year							
2010	1.939 ***	2.931 ***	3.264 ***	3.002 ***	0.942 ***	4.055 ***	1.770 ***
	(0.065)	(0.171)	(0.232)	(0.138)	(0.054)	(0.223)	(0.072)
2011	4.112 ***	6.179 ***	6.520 ***	6.112 ***	2.018 ***	8.699 ***	3.572 ***
	(0.118)	(0.341)	(0.331)	(0.276)	(0.089)	(0.392)	(0.143)
2012	4.394 ***	6.690 ***	6.895 ***	6.488 ***	2.116 ***	9.111 ***	3.803 ***
	(0.145)	(0.369)	(0.321)	(0.270)	(0.095)	(0.375)	(0.143)
2013	4.435 ***	6.538 ***	6.924 ***	6.780 ***	2.141 ***	9.344 ***	4.100 ***
	(0.158)	(0.382)	(0.285)	(0.273)	(0.102)	(0.393)	(0.153)
2014	4.464 ***	6.866 ***	7.117 ***	6.867 ***	2.198 ***	9.571 ***	4.396 ***
	(0.176)	(0.392)	(0.295)	(0.270)	(0.153)	(0.390)	(0.160)
2015	4.480 ***	7.132 ***	7.328 ***	7.085 ***	2.093 ***	9.520 ***	4.527 ***
	(0.157)	(0.410)	(0.308)	(0.299)	(0.101)	(0.358)	(0.139)
2016	4.324 ***	7.105 ***	7.307 ***	7.029 ***	1.977 ***	9.340 ***	4.396 ***
	(0.163)	(0.404)	(0.312)	(0.284)	(0.101)	(0.361)	(0.133)
2017	4.172 ***	7.426 ***	7.254 ***	7.076 ***	2.025 ***	9.708 ***	4.607 ***
	(0.155)	(0.426)	(0.321)	(0.268)	(0.104)	(0.381)	(0.145)
2018	4.139 ***	8.069 ***	7.580 ***	7.070 ***	2.040 ***	10.266 ***	4.844 ***
	(0.139)	(0.435)	(0.344)	(0.263)	(0.097)	(0.389)	(0.159)
2019	4.115 ***	8.029 ***	7.576 ***	5.969 ***	1.936 ***	8.823 ***	5.051 ***
	(0.146)	(0.390)	(0.344)	(0.269)	(0.115)	(0.360)	(0.161)
2020	4.268 ***	8.044 ***	7.626 ***	4.186 ***	1.826 ***	6.647 ***	5.285 ***
	(0.141)	(0.412)	(0.324)	(0.224)	(0.110)	(0.295)	(0.177)
2021	4.200 ***	7.668 ***	7.223 ***	2.452 ***	1.773 ***	4.164 ***	5.537 ***
	(0.136)	(0.393)	(0.336)	(0.198)	(0.140)	(0.274)	(0.195)
2022	4.010 ***	7.708 ***	6.796 ***	1.851 ***	1.615 ***	3.464 ***	5.212 ***
	(0.141)	(0.447)	(0.304)	(0.193)	(0.124)	(0.273)	(0.192)
Intercept	1.152 ***	1.801 ***	1.207	2.703 ***	0.585 ***	2.718 ***	1.042 ***
	(0.279)	(0.553)	(0.798)	(0.273)	(0.214)	(0.366)	(0.197)

Number of observations	1908	1222	1690	1608	1293	1505	1619
R-squared	0.60	0.57	0.54	0.66	0.38	0.67	0.69

*** p<.01, ** p<.05, * p<.1

Note: Regressions include university fixed effects that are not reported here.

Table 3

Fixed Effects Panel Regression Correlates of Postdoc Employment

	Biomedical	Chemical_Engineering	Chemistry	Computer_Science	Economics	Electrical_Engineering	Psychology
Number of faculty	0.114	0.040	0.114	0.012	0.017	-0.015	0.006
	(0.083)	(0.064)	(0.110)	(0.015)	(0.016)	(0.072)	(0.041)
federal R&D expenditure ($ millions)	0.045	0.288 ***	0.781 ***	0.034	-0.024	0.008	0.498 ***
	(0.084)	(0.093)	(0.225)	(0.023)	(0.034)	(0.007)	(0.137)
Number of graduate students	-0.001	0.012	0.056 **	-0.000	0.001	0.001	0.006 *
	(0.020)	(0.012)	(0.023)	(0.000)	(0.002)	(0.007)	(0.003)
year							
2010	8.537 *	-0.599	-0.761	1.154 ***	0.015	0.664	-0.309
	(5.117)	(0.708)	(0.950)	(0.416)	(0.180)	(0.565)	(0.728)
2011	8.141 *	-0.204	-1.814 **	1.285 **	-0.205	0.114	-0.462
	(4.840)	(0.951)	(0.916)	(0.496)	(0.196)	(0.641)	(0.724)
2012	1.841	-0.445	-1.647	1.124 **	-0.128	1.045	-0.166
	(6.237)	(1.167)	(1.019)	(0.439)	(0.187)	(0.938)	(0.814)
2013	-2.058	0.608	-2.450 **	1.031 *	0.200	1.503	-0.936
	(6.157)	(1.181)	(0.946)	(0.604)	(0.251)	(1.055)	(0.857)
2014	-4.712	0.640	-3.160 ***	1.701 ***	0.434 *	1.735	-0.414
	(6.023)	(1.406)	(1.051)	(0.648)	(0.224)	(1.121)	(0.940)
2015	-5.388	0.856	-3.684 ***	2.033 ***	0.338	1.409	0.056
	(6.238)	(1.356)	(1.367)	(0.649)	(0.229)	(1.058)	(0.834)
2016	-3.386	0.641	-4.327 **	2.066 ***	0.492 *	1.280	0.301
	(6.745)	(1.604)	(1.662)	(0.706)	(0.287)	(1.146)	(0.757)
2017	-2.500	-0.051	-6.567 ***	1.639 ***	0.430 *	1.611	-0.336
	(7.480)	(1.600)	(1.632)	(0.576)	(0.252)	(1.199)	(1.213)
2018	-4.736	-0.447	-7.624 ***	1.426 **	0.511 **	1.837 *	0.043
	(7.682)	(1.466)	(1.533)	(0.589)	(0.253)	(1.093)	(0.972)
2019	-0.211	-0.138	-7.134 ***	1.613 ***	0.534 **	2.368 **	-0.316
	(7.749)	(1.468)	(1.519)	(0.610)	(0.259)	(1.071)	(0.999)
2020	-13.710 *	-0.747	-8.134 ***	1.189 *	0.383	2.244 *	-0.102
	(7.440)	(1.530)	(1.534)	(0.611)	(0.244)	(1.225)	(0.973)
2021	-22.238 ***	-0.674	-9.199 ***	1.664 **	0.839 ***	1.794 *	-0.071
	(7.767)	(1.567)	(1.428)	(0.656)	(0.311)	(1.076)	(1.087)
2022	-28.096 ***	-0.084	-9.608 ***	1.489 **	0.841 ***	1.167	-0.685

	(8.182)		(1.645)		(1.458)		(0.659)		(0.315)		(0.919)		(1.004)	
Intercept	114.038	***	8.805	***	13.206	***	3.907	***	0.280		8.315	**	4.896	***
	(16.000)		(1.396)		(3.915)		(0.783)		(0.677)		(3.191)		(1.769)	
Number of observations	1908		1222		1690		1608		1293		1505		1619	
R-squared	0.06		0.03		0.16		0.02		0.05		0.01		0.05	

*** p<.01, ** p<.05, * p<.1

Note: Regressions include university fixed effects that are not reported here.

References

Andalib, Maryam A., Navid Ghaffarzadegan, and Richard C. Larson. 2016. "The Postdoc Queue: A Labour Force in Waiting." *Systems Research and Behavioral Science.* 35: 675-686.

Arbeit, Caren A., Einaudi, Peter, Green, Patricia, Kang Kelly H. 2016. Assessing the Impact of Frame Changes on Trend Data from the Survey of Graduate Students and Postdoctorates in Science and Engineering. Special Report NSF 16-314. Arlington, VA.: National Science Foundation, National Center for Science and Engineering Statistics. http://www.nsf.gov/statistics/gradpostdoc/.

Berelson, Bernard 1962. "Postdoctoral Work in American Universities: A. Recent Survey." Journal of Higher Education 33, no. 3, pp. 119-130. https://doi.org/10.1080/00221546.1962.11772929 .

Blau, David M., & Weinberg, Bruce A. 2017. "Why the US. science and engineering workforce is aging rapidly." Proceedings of the National Academy of Sciences 114(15), 3879–3884.

Borjas George. 2009. "Immigration in high-skill labor markets: the impact of foreign students on the earnings of doctorates," in Science and Engineering Careers in the United States: An Analysis of Markets and Employment, eds Freeman, RB., Goroff, DL. Chicago: University of Chicago Press.

Blume-Kohout, Margaret, E. and John, W. Clack 2013. "Are Graduate Students Rational? Evidence from the Market for Biomedical Scientists." PLoS ONE 8, no. 12: e82759. https://doi:10.1371/journal.pone.0082759 .

Chang, Wan-ying., Phou, Kelly, Basner, Jodi E., Desai, Anand. 2021. "Does Postdoctoral Training Raise the Likelihood of Pursuing a Career in Research and Development?" Presentation at the Investments in Early Career Scientists Workshop, NBER November.

Cheng, Stephanie D. 2023. "What's another year? The lengthening training and career paths of scientists." PLoS ONE 18(5): e0285550.https://doi.org/10.1371/journal.pone.0285550

Diethorn, Holden A., Marschke, Gerald R. 2023. "Task Mismatch and Salary Penalties: Evidence from the Biomedical PhD Labor Market." NBER Working Paper 30919.

Einaudi, Peter, Ruth Heuer and Patricia Green 2013. "Counts of Postdoctoral Appointees in Science, Engineering, and Health Rise with Reporting Improvements." NSCES InfoBrief 13-334 (September). https://www.nsf.gov/statistics/infbrief/nsf13334/nsf13334.pdf .

Ganguli, Ina, Patrick Gaule, and Danijela Vuletic Cugalj 2020. "Biased Beliefs and Entry into Scientific Careers." Upjohn Working Papers 20-334. W.E. Upjohn Insitute for Employment Research.

Garrison, Howard H., Gerbi, and Susan A. 1998. "Education and employment patterns of US. Ph.D.'s in the biomedical sciences." FASEB Journal 12:139–148.

Ghaffarzadegan, Navid, and Xu, Ran. 2018. "Late retirement, early careers, and the aging of U.S. science and engineering professors." PLoS ONE 13(12): e0208411. https://doi.org/10.1371/journal.pone.0208411

Heggeness, Misty L., Ginther, Donna K., Larenas, Maria I., and Carter-Johnson, Frances D. 2023. "Advancing biomedical science through investments in elite training." PLoS ONE 18(2): e0272230.https://doi.org/10.1371/journal.pone.0272230.

Institute of Medicine 2000. Enhancing the Postdoctoral Experience for Scientist and Engineers: A. Guide for Postdoctoral Scholars, Advisers, Institutions, Funding Organizations, and Disciplinary Societies. Washington, DC.: The National Academies Press. https://doi.org/10.17226/9831 .

Institute of Medicine 2014. The Postdoctoral Experience Revisited. Washington, DC.: The National Academies Press. https://doi.org/10.17226/18982 .

Jacob, Brian A., Lefgren, Lars. 2011. "The Impact of NIH Postdoctoral Training Grants on Scientific Productivity." Research Policy 40 (6), 864-874.

Jones, Benjamin. 2009. "The Burden of Knowledge and the Deth of the Renaissance Man: Is Innovation Getting Harder?" Review of Economic Studies 76, 283-317.
Jones, Benjamin. 2010. "Age and Great Invention." Review of Economics and Statistics 99, 1-14.
Jones, Benjamin F., Weinberg, Bruce A. 2011 "Age dynamics in scientific creativity". Proceedings of the National Academy of Sciences 108: 18910–18914.
Kahn, Shulamit and Donna, K. Ginther 2017. "The Impact of Postdoctoral Training on Early Careers in Biomedicine." Nature Biotechnology 35(1): 90-94
Kahn, Shulamit, MacGarvie, Megan 2024. "New evidence on international postdocs in the US.: Less pay, different experiences." Research Policy 53(9), 105077.
Lan, Xiaohuan 2012. "Permanent visas and temporary jobs: Evidence from postdoctoral participation of foreign PhDs in the United States." Journal of Policy Analysis and Management 31:623–640.
Levitt, David G., 2010. "Careers of an Elite Cohort of US. Basic Life Science Postdoctoral Fellows and the Influences of their Mentor's Citation Record." BMC Medical Education 10 (80), 1-7.
Levitt, Michael, Levitt, Jonathan M. 2017. "Future of fundamental discovery in US. biomedical research." Proceedings of the National Academy of Sciences 114(25), 6498–6503.
Main, Joyce B., Wang, Yangbin. 2019. "Is Postdoctoral Training Linked to Faculty Careers and Higher Salaries among Engineering Ph.D.s?" 2019 ASEE Conference and Exposition. https://www.asee.org/public/conferences/140/papers/25629/view
Main, Joyce B., Wang, Yangbin, Tan, Li. 2021. "The career outlook of engineering PhDs: Influence of postdoctoral research positions on early career salaries and the attainment of tenure-track faculty positions." Journal of Engineering Education, 110(4), 977–1002. https://doi.org/10.1002/jee.20416
National Academies of Sciences, Engineering and Medicine 2018. The Next Generation of Biomedical and Behavioral Sciences Researchers Breaking Through. Washington, DC.: National Academies Press. https://doi.org/10.17226/25008.
National Center for Science and Engineering Statistics 2021. Survey of Graduate Students and Postdoctorates in Science and Engineering: Fall 2019. NSF 21-318. Alexandria, VA.: National Science Foundation. Available at https://ncses.nsf.gov/pubs/nsf21318/
National Institute of Health. 2012. Biomedical Research Workforce Working Group Report. Bethesda: NIH.
National Institutes of Health. 2018. Report of the Next Generation Researchers Initiative Working Group of the Advisory Committee to the NIH Director https://www.acd.od.nih.gov/documents/presentations/12132018NextGen_report.pdf
National Institutes of Health. 2023. Report of the Working Group on Re-envisioning NIH-Supported Postdoctoral Training of the Advisory Committee to the NIH Directorhttps://acd.od.nih.gov/documents/presentations/12152023_Postdoc_Working_Group_Report.pdf
National Research Council 1969. The Invisible University: Postdoctoral Education in the United States. Report of a Study Conducted Under the Auspices of the National Research Council. [Richard, B. Curtis, Study Director]. Washington, DC.: The National Academies Press. https://doi.org/10.17226/18693 .
National Research Council 1981. Postdoctoral Appointments and Disappointments.
Washington, DC.: The National Academies Press. https://doi.org/10.17226/19643 .
National Research Council. National Academies of Science, Engineering, and Medicine. 1998. Trends in the Early Careers of Life Scientists. Washington: National Academies Press.
National Research Council. 2005. Bridges to Independence: Fostering the Independence of New Investigators in Biomedical Research. National Academies Press, Washington, DC.

National Research Council. National Academies of Science, Engineering, and Medicine. 2011. Research Training in the Biomedical, Behavioral, and Clinical Research Sciences. National Academies Press, Washington, DC.

National Research Council. National Academies of Science, Engineering, and Medicine. 2014. The Postdoctoral Experience Revisited. Washington: National Academies Press.

National Science Board. 2008. Science and Engineering Indicators 2008. National Science Foundation: Arlington, VA. (NSB 08-01).

National Science Board, National Science Foundation. 2020. Science and Engineering Indicators 2020: The State of U.S. Science and Engineering. NSB-2020-1. Alexandria, VA. Available at https://ncses.nsf.gov/pubs/nsb20201/.

Pickett, CL. 2019. "The increasing importance of fellowships and career development awards in the careers of early-stage biomedical academic researchers." PLoS ONE 14(10): e0223876. https://doi.org/10.1371/journal.pone.0223876

Rosenbloom, Joshua, L., Donna, K. Ginther, Ted Juhl, and Joseph, A. Heppert 2015. "The Effects of Research & Development Funding on Scientific Productivity: Academic Chemistry, 1990-2009." PLOS One 10(9). https:// doi:10.1371/journal.pone.0138176

Shvadron, Dror, Hansen Zhang, Lee Flemming and Daniel, P. Gross. 2025. "Funding the U.S. Scientific Training Ecosystem: New Data, Methods, and Evidence." NBER Working Paper 33944.

Stephan, Paula and Jennifer Ma. 2005. "The Increased Frequency and Duration of the Postdoctorate Career Stage." American Economic Review 95 (2), 71-75.

Stephan, Paula. 2012a. "Research efficiency: Perverse incentives." Nature 4847392.:29–31.

Stephan, Paula. 2012b. How Economics Shapes Science. Cambridge" Harvard University Press.

Su, X. 2013. "The Impacts of Postdoctoral Training on Scientists' Academic Employment." Journal of Higher Education 84 (2), 239-265.

Teitelbaum, M. 2014. Falling Behind? Boom, Bust, and the Global Race for Scientific Talent. Princeton: Princeton University Press.

Wu, Lingfei, Dashun Wang, and James A. Evans. 2019. "Large teams develop and small teams disrupt science and technology." *Nature* 566, 378-382.

Zhang, Sam, K. Hunter Wapman, Daniel, B. Larremore, Aaron Clauset. 2022. Labor advantages drive the greater productivity of faculty at elite universities. Science Advances. 8,eabq70562022.DOI:10.1126/sciadv.abq7056