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Title: The Postdoc Rat Race

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Significance Statement:

Conventional wisdom holds that postdoctoral training is a necessary step for a biomedical career. We examined the trends in postdoctoral study and modeled the impact of the postdoc on later careers. Starting in a postdoc improves the probability of working in a tenure-track job. However, the chances of obtaining that job are low and falling over time. Although the postdoc is positively associated with research careers, nearly half of biomedical PhDs who skipped the postdoc are engaged in research. Former postdocs are paid significantly less during their early careers than those who skip the postdoc, regardless of employment sector. Thus, the postdoc has no discernible economic value to individuals besides improving their chance of obtaining increasingly unlikely tenure-track jobs.

ABSTRACT

We examined the association between postdoctoral training ("the postdoc") and subsequent employment and earnings using data from the 1981-2010 waves of the National Science Foundation's Survey of Doctorate Recipients. We showed that a roughly constant 81% of PhDs in biomedical fields entered postdocs over our sample time frame (1980-2007), and a variety of market, funding and individual characteristics influenced this propensity to take a postdoc. While the average postdoc duration rose from 3.4 to 4.7 years for 1981 to 1994 PhDs, it changed very little for later cohorts. Postdocs increased the likelihood that a biomedical PhD obtained a tenure-track job doing research 10 years post-PhD, but only one-quarter of former postdocs obtained these jobs among recent graduates. Moreover, nearly half of those who skipped the postdoc were employed in research jobs. Despite the fact that PhDs who had higher academic ability were more likely to enter postdocs, we find that former postdocs were paid significantly less for a substantial period of their early careers than those who skipped the postdoc. Our results are consistent with postdocs being a "rat race" where PhDs choose to devote years to the postdoc to signal their ability for a chance of obtaining elusive and dwindling academic positions. The high personal costs of postdocs in time, money, and eventual employment sector suggest that most PhDs would be better off skipping the postdoc.

\bodyThe biomedical research enterprise is in crisis. NIH funding rates are low, the age of obtaining an independent research career is high, and there are too few permanent academic positions for the large numbers of PhDs being produced. Exacerbating this crisis is the peculiar institution of postdoctoral training (1-6). The reports, editorials and books that detail the biomedical research enterprise's woes have unanimously called for providing more information to graduate students and postdocs about their limited career prospects. Yet few studies have examined the *value* of postdoctoral training for subsequent careers in biomedical science.

Previous research has determined that increases in supply and demand have fueled the rapid growth in biomedical postdocs (6-9). The number of new PhDs grew faster in biomedical science than in other STEM fields during the past decades – 122% growth from 1980 to 2010 in biomedical PhDs awarded compared with 76% growth in other STEM fields.[*] This increase is largely fueled by the increase in supply of potential postdocs as a result of the rise in foreign students and women obtaining biomedical PhDs (2, 10). Some have argued that postdocs are more and more necessary because of the increasing complexity and difficulty of scientific research (11-13) which would increase the supply—the number of PhDs wanting a postdoc. At the same time, increases in research funding resulting from the NIH doubling likely increased the demand for postdocs to work on research grants (2, 6).

During the past decade, various official bodies have raised concerns about the working conditions, long hours, lack of benefits, and forced geographic mobility faced by postdocs, as well as the postdoc's effects on families (6, 8, 14-20). Such studies have decried the increasing length of PhD plus postdoctoral training and blamed this for the rising age of principal-

[*] Calculated from NSF Science and Engineering Indicators (2012, 1993). SED figures for our biomedical fields provided by Mark Fiegener of the NSF.

investigators between the 1980s and the present. However, while the length of PhD can be easily measured, the total time a person spends in postdocs has been more difficult to measure (as we explain below).

While researchers have surveyed postdocs (21-23), due to data limitations few have examined the impact of the postdoc on later career outcomes. Those studies that *did* examine career outcomes of postdocs have combined many academic fields (23-25), making it difficult to determine how the postdoc influences careers in fields like biomedicine – where the postdoc is commonplace – as opposed to fields where postdocs are positions taken by people who cannot find jobs. These studies found that a postdoc is associated with placement in academic careers. They also found that longer duration postdocs are not associated with improved academic placements (23). One study that examined the association between postdocs and biomedical careers had small sample sizes and focused exclusively on the highly selective NRSA research fellowships (26) and may not generalize to all US-trained biomedical PhDs.

Data and Methods

Our research presents evidence on the facts, correlates and trends related to biomedical postdoc incidence and durations since the 1980s and the associated benefits and costs in terms of early career outcomes of employment placement and earnings, based on National Science Foundation (NSF) data. Measurement of postdoc numbers and careers is difficult and coverage varies across NSF surveys (19, 27); consequently, we use multiple NSF surveys and variables to measure the incidence of US-trained postdocs. Specifically, we use biennial longitudinal data from the 1981 – 2010 waves of the Survey of Doctorate Recipients (SDR) and two special SDR Postdoc Supplements matched to the Survey of Earned Doctorates (SED) administered to all new

STEM PhDs. The SDR and SED exclude postdocs with foreign PhDs, a large but difficult-to-measure proportion of postdocs in the US (Details on data and the methods and construction of the variables, including postdoc incidence and duration, are described in the *SI Appendix*).

In order to identify the postdoc-intensive fields, we used the National Research Council's definition of biomedical fields (18) and limited our sample to those PhD fields where the likelihood of taking a postdoc within 3 years of the doctorate averaged more than 60% (*SI Appendix,* **Table S2**). These fields comprise 82% of biomedical PhDs awarded in 2010. We excluded MD/PhDs from our sample (693 individuals) because their careers develop differently.

Our sample from the 1981-2010 SDR waves included 10,018 US-trained biomedical PhDs who received degrees in the US from 1980-2007 for whom we can identify postdoc status. Our analysis sample is considerably smaller when we consider subsequent career outcomes.[†]

Starting in a postdoc. Scientists are considered as starting their career in a postdoc if we observe them in a postdoc any time within the first three years after their PhD. Conversely, they are considered as *not* starting in a postdoc if they were not observed in a postdoc at *any* time during the first three years after their PhD. We impose the three-year condition because not all PhDs have obtained their postdoc before they respond to the SED and because the biennial SDR takes one to three years to incorporate new PhDs into the sampling frame. In the *SI Appendix* (**Figure S1**) we show that our preferred measure finds rates similar to rates based on the SED alone, but is more inclusive. When we can observe the sector where the postdoc is employed, 77% are in colleges/universities, consistent with published reports *(6)*.

[†] While our analysis of starting in a postdoc includes 10,018 people with 1980-2007 PhDs, our analysis of postdoc duration was limited to the smaller subset of 5,872 1980-2002 PhDs for whom we could measure postdoc duration during the first 8 years post-PhD, and our analysis of later career outcomes was limited to the subset of 4,163 1980-2000 PhDs for whom we could measure 10-year post-PhD outcomes.

Duration of postdoc. We define the duration of the postdoc as the number of years that the person was observed in a postdoc within the first 8 years post-PhD. We limited duration measurement to 8 years because: 1) most individuals had completed their postdoc within this time period (*SI Appendix*, **Figure S2**); 2) postdocs longer than 8 years are likely serving very different purposes than postdocs undertaken to attain a tenure-track job or for training; and 3) calculating postdoc duration for a longer time-period past the PhD would limit us from including more recent PhDs. Postdoc duration can include more than one postdoc, and there can be gaps between these postdocs. In the *SI Appendix* (**Figure S3**), we show that the average duration differs little if postdoc duration is calculated over 10 years, and that both of these averages are close to the median duration.

Employment sector and salary. Employment sector (academia – tenure-track and non-tenure-track; industry; government and nonprofit), research activity (research/non-research) and labor force status (employed, unemployed, out of the labor force) were measured a decade past PhD. Salary was measured biennially and adjusted for inflation.

Results

Incidence and duration of biomedical postdocs 1980-2007. Figure 1A shows that the *number* of biomedical PhDs starting in postdocs grew dramatically between 1986 and 1997, corresponding to the large growth of biomedical PhD recipients. As was found by others (3-4, 9), this increase is associated with the increase in the percentage of temporary residents among new PhDs. Our data indicates that temporary residents exploded from 4.5% of biomedical PhDs in 1980 to 20.0% in 1997 and peaked at 30.3% in 2007. The growth in PhDs and postdocs was also associated with the entrance of women into biomedical fields. In our data, women went from

29.0% of PhDs in 1980 to 45.5% in 1997 and peaked at 52.7% in 2007. However, as **Figure 1A** illustrates, the *percentage* of US biomedical PhDs in these fields varied little for PhD recipients from 1980 and 2007, averaging 81.1% and peaking for PhDs who received their degree in 2005 just after the end of the NIH doubling.

Using our duration measure, postdoc duration averaged 4.1 of the first 8 years post-Ph.D. **Figure 1B** shows the time trend in average time to PhD, average postdoc duration by PhD year (noting that for 2002 PhDs, duration is measured through 2010), and their sum. In contrast to the perception that the average duration of postdocs has increased dramatically over these decades, our data (**Figure 1B** and *SI Appendix* **Figure S3)** indicated this was not the case. The average duration of postdocs increased from 3.37 years for 1980 PhDs to 4.71 years for 1994 PhDs and then flattened out through 2002 PhDs. In a 1994 survey of research institutions, the Association for American Universities (AAU) found that many universities had no time limits on postdoctoral training. Based on this, the AAU in 1998 recommended that postdocs be limited to 6 years. In a 2005 follow-up survey of a sample of AAU institutions, 70% had done so. Response to AAU recommendations may have played a role in keeping postdoc duration roughly constant since the 1990s (28-29). Alternatively, postdocs could have moved into non-tenure track academic research positions with different titles.

Total years of training (graduate school and postdoc) rose for PhDs awarded between 1980 and 1992 (**Figure 1B**), but then showed no clear trend, averaging 12.1 years for people receiving their PhDs between 1992 and 2002. To put this in perspective, average biomedical PhD training is significantly longer than average medical training, which takes 4 years of medical school (compared with 7-8 years of a PhD program) and 3-7 years of residency depending on the specialty (compared with 3-5 years of postdoc) (30).

Factors Associated with Starting in Postdoctoral Positions. We used a probit model to examine the factors associated with starting in a postdoc within the first three years of the PhD for those who received their PhD between 1980 and 2007, with results for key variables reported in **Figure 2** (*SI Appendix* **Table S3**).

Similar to previous research, we find that visa status is associated with the decision to take a postdoc (7, 25). Temporary residents at the time of the PhD are 7.2 percentage points (**ppt.**) more likely to take a postdoc ($p<.001$) than US citizens *ceteris paribus.* This dovetails with research indicating that visa status may be an important incentive for foreign students wishing to remain in the US to take postdocs (3, 31). Even controlling for temporary residency, Asians are more likely to enter a postdoc than whites ($p<.001$), while other under-represented minorities may be less likely to enter than whites ($p=.068$).

Older graduates are less likely to start in a postdoc, even controlling for family-status variables. Each decade lowers the likelihood of starting in a postdoc by 8.2 ppt. ($p<.001$). We allow the impact of family to differ for men and women and find no significant gender difference in starting in a postdoc for *single* females and single males (where single males are the omitted category). However, married women with children and married men with children are each 5-6 ppt. less likely than single men to start in a postdoc (each $p<.001$). Moreover, married women without children behave like married women *with* children, perhaps because they anticipate having children.

Our model also proxies for scientist quality as PhD students. We assume that higher quality PhDs attended more prestigious universities (i.e. with better NRC rankings of the PhD-granting department), took a shorter time to complete the doctorate, and were more likely to receive scholarships or fellowships and to work as research assistants, while being less likely to support their graduate study by outside employment. We found these high-quality characteristics were associated with an increased likelihood of starting in a postdoc: *postdocs were positively selected* compared with those who skip the postdoc. Particularly, being from an above-median NRC-ranked PhD institution increased the likelihood of a postdoc by about 1.7 ppt. relative to being from a below-median institution (p=.09). Each additional year in graduate school decreased the probability of taking a postdoc by 0.8 ppt. (p<.05). Having been a research assistant during graduate school increased the likelihood of starting in a postdoc by 6.2 ppt. (p<.001). Funding one's graduate study primarily by earnings decreased the likelihood of being in a postdoc by 7.2 ppt. (p<.001). Finally, receiving a scholarship or fellowship during graduate study, holding constant these other quality factors, increased the likelihood of a postdoc by 2.1 ppt. (p=.061).

The market demand for PhD scientists at the time of graduation might also affect whether some people choose postdocs or directly enter employment. To examine this, we included variables that measure the field-specific *change* from the year before to the year after PhD receipt, in industry employment, in tenure-track faculty positions and in inflation-adjusted NIH funding, all per PhD awarded. We found that each additional industry job per new PhD in the field lowered the likelihood of a person starting in a postdoc by 1.6 ppt. on average (p=.10). A decreasing number of tenure-track assistant professor jobs might discourage PhDs from starting postdocs or conversely might encourage them to start in a postdoc to gain an advantage. Perhaps due to these countervailing influences, the changes in the number of these jobs per PhD in the field had no significant impact. NIH funding of postdocs may encourage PhDs to enter postdocs. We found that an increase of $1000 in NIH fellowship/traineeship funding per PhD in the field increased the likelihood of taking a postdoc by 6.3 ppt (p<.001); however, increases in R01 grant funding had no significant impact.

Although these market, funding and individual factors affected the probability that an individual PhD started their career in a postdoc, we do not observe any trend in these factors large enough to have radically changed the average likelihood of starting in a postdoc.

Employment Sector and Research Activities of Biomedical PhDs. The longitudinal nature of the SDR data allows us to measure how careers unfold differently for those who did and did not start their careers in a postdoc. Since the postdoc is a temporary position of indeterminate length but is usually completed within six years of the doctorate and almost always completed before ten years post-PhD, we examine career outcomes of 1980-2000 biomedical PhDs approximately ten years after the doctorate.[‡]

Figure 3 shows that the distribution across the five employment sectors ten years post-PhD differed for those who started in a postdoc and for those who did not. Although previous research indicates that many pursue a postdoc in order to obtain tenure-track research jobs (32), just 28.0% of former postdocs are in tenure-track academic, research-related positions. Since those who started in a postdoc differ along many dimensions that are associated with employment sector, we also estimated a multinomial logit model of employment sector, holding constant the same ability, field, PhD year and demographics variables used above (*SI Appendix*, **Table S4, Figure S5**). Comparing **Figure 3** and **Figure S5** indicates that the control variables explained very little of the employment sector differences so that conditional and unconditional probabilities were almost identical.

[‡] In some cases this could be 9, 11, or 12 years post-PhD because of the biennial nature of the SDR. Note that 2000 PhDs' 10-year window ends in 2010, the last year of our data.

Where do the nearly three-fourths of former postdocs without tenure-track academic research positions work instead? **Figure 3** shows that *more former postdocs are employed in industry (34.7%) than in tenure-track jobs*. About 14% of employed PhDs are in non-tenure-track research academia, often soft money jobs. Non-postdocs are more likely to be in industry jobs: 43.0% of those who skip the postdoc proceed directly to industry.

Conventional wisdom holds that a postdoc is necessary for an academic biomedical career, but we found that 11.9% of those employed in academic, research-related, tenure-track jobs skipped the postdoc. However, 80% of them received their degrees before 1995; of the ones with later degrees, about half had post-PhD research experience in other sectors prior to obtaining a tenure-track job. The handful remaining had gone directly from PhD to the lowest quartile of academic institutions.

Dividing jobs by work activity rather than sector, we found that the proportion of former postdocs engaged in research was significantly higher than the proportion of non-postdocs (72.3% compared to 47.8%, $p<.001$). That said, a postdoc is not required for a research career (even though it may be required to be an NIH PI), since nearly half of those who skipped the postdoc worked in (self-reported) basic or applied research-related jobs. Finally, almost one-third (28%) of former postdocs were *not* engaged in research (*SI Appendix* **Figure S6**).

Over time, the probability of obtaining a tenure-track research job has dropped significantly. **Figure 4** graphs the 3-year moving average of the percentage of employed biomedical PhDs in each sector 10 years post-PhD (*SI Appendix* **Figures S7A and S7B**). Despite the NIH funding doubling which might have increased the funding available for new tenure-track positions, **Figure 4** indicates that between 1990 and 2003, the percentage of biomedical scientists in academic tenure-track research jobs 10 years post-PhD held steady near 30% of employed PhDs. Between 2002 and 2005 it declined to only 20% of employed PhDs and remained this low through 2010, a sharp decline experienced both among former postdocs and non-postdocs. Of former postdocs, less than one-quarter (24.2%) were employed in academic tenure-track research in the last years of our sample (**Figure S7A**).

This sharp decline in the percent employed in academic tenure-track research jobs coincided with the end of the NIH doubling in 2003 which decreased demand, and was exacerbated by the increased supply of new biomedical PhDs. While the overall *number* of academic tenure-track research jobs grew by approximately 8,700 people (or 150%) from 1981 to 2010, tenure-track academia simply could not keep up with new biomedical PhDs flooding the labor market who increased the stock by 113,000 people (281%).

We have also examined whether postdoc duration and the prestige of the postdoctoral institution correlate with employment sector 10 years post-PhD (*SI Appendix*, **Figure S8).** Employment in each sector 10 years past PhD does depend on postdoc duration. The probability of obtaining a tenure-track job peaks with 5-6 years of postdoctoral experience, and then drops somewhat for postdocs of longer duration. Postdoc quality also influences employment sector. Thirty-nine percent of postdocs from above-median-ranked institutions hold academic tenure-track research jobs compared with 33% from below-median institutions.

Finally, we measured the relationship between postdoc status and unemployment or being out of the labor force (*SI Appendix* **Figure S9**). There is no significant difference between former postdocs and non-postdocs in the low likelihood of being unemployed. Those who skipped postdocs were twice as likely to be out of the labor force as former postdocs (6.5% v. 3.5%, $p<.001$), mostly mothers who probably opted out of postdocs for that reason.

The impact of starting in a postdoc on early career salaries. Others have noted that during the postdoc, scientists are poorly paid and work long hours, making their hourly wages extremely low (2, 4, 33). Clearly, the longer an individual remains in a postdoc, the larger the financial sacrifice. That said, the postdoc, as defined by the NSF and NIH, is a human capital investment in research skills and research independence. As economists, we expect that these human capital investments will yield a positive return in the labor market once postdocs obtain permanent positions. Our results indicate this was not the case.

Consistent with postdocs' function as training, our data show that scientists were paid much less *during* postdocs than if they had gone directly into the workforce. The median annual salary of people who started in postdocs during their first three years after the PhD – when they would be in the postdoc – was $42,557 in inflation-adjusted 2010 dollars compared with $69,000 among those who entered the workforce directly.

To analyze how postdocs affect later salaries, we regressed inflation-adjusted salary on years from PhD conditional on either starting in a postdoc or skipping the postdoc, including controls for ability, demographic characteristics and field and year dummy variables. (*SI Appendix* **Table S5**). **Figure 5A** graphs the salaries predicted by this regression for the first 15 years of the biomedical career post-PhD receipt, first assuming that everyone skips a postdoc and then assuming that everyone starts in a postdoc, with other variables held constant at their means. Controlling for background characteristics, 10-year post-PhD salaries of those who started in a postdoc averaged $9,627 lower than those who skipped the postdoc. Five-year post-PhD salary differences were even larger at $18,280. Although the earnings difference narrows with years past PhD, the estimated predicted salary of non-postdocs remains significantly higher for the first 14 of 15 years post-PhD. Thus, individuals who skip the postdoc are earning significant returns on work-experience, whereas individuals who spend time in a postdoc forgo that sizeable experience premium.

This salary gap might be explained by employment sector. In the remaining panels of **Figure 5** we look at the predicted average salary profile for those starting in and skipping the postdoc *conditional on sector of employment 10 years past the PhD.* **Figures 5B** through **5E** show the predicted salary profiles in academic tenure-track research, academic non-track research, industry, and government and other sectors conditional on starting in a postdoc. The same overall pattern emerges, where postdocs earned less than non-postdocs throughout the first 15 years post-PhD in each sector, with their earnings *significantly* lower for the first 10 years or longer. (As expected, non-tenure track researchers earn significantly less than tenure-track researchers and industry salaries are higher and increase more quickly than non-industry salaries. The government/other is the only sector where the two wage trajectories cross (at 14 years post-PhD).

Thus in each sector there is a substantial financial penalty for starting the biomedical career in a postdoc, and these differences accumulate. Over the first 15 years of their career (evaluating control variables at their means, using a discount rate of 3% and including lower salaries during the postdoc), those in tenure-track academic research who started in a postdoc earn a cumulative $149,480 (15%) less than those who skipped the postdoc; in non-tenure-track academic research they earn $150,217 (17%) less; in industry they earn $200,009 (16%) less, and in government/nonprofit they earn $149,774 (15%) less. These average cumulative salary gaps account for approximately 2-3 years of earnings in each of these sectors.

Discussion

Over our sample time period, a roughly constant 81% of biomedical PhDs started their careers in a postdoc. Although a variety of market, funding and individual factors have small and significant effects on the probability that any individual biomedical PhD will become a postdoc, the average probability has been stable. However, the number of postdocs has increased because the number of biomedical PhDs has increased significantly. While the average postdoc duration crept up from 3.4 to 4.7 years for PhDs from 1980 to 1994, it has changed very little for later cohorts. These findings challenge some of the published assertions about recent trends in postdocs.

Our paper contributes to the literature by moving beyond the postdoctoral period to compare the later careers of biomedical PhDs who started in a postdoc and those who did not. The likelihood that a postdoc led to an academic tenure-track job engaged in research ten years post-PhD was on average 28.0% for PhDs who graduated between 1980-2000 and fell to less than one-quarter (24.2%) for the most recent cohorts as the number of new tenure-track jobs available per PhD fell. More former-postdocs were engaged in research ten years post-PhD than those who skipped postdocs, but nearly half of those who skipped the postdoc worked in research-related jobs.

We demonstrated that former postdocs continued to earn less than non-postdocs even ten or more years post-PhD. The nearly three-quarters of PhDs who entered a postdoc gave up an estimated 15% or more of their present value of income over the first 15 years of their careers, even controlling for sector. This suggests that postdoctoral education is not an investment in human capital. Instead, our findings indicate that the postdoc is a "rat race" where individuals compete for an increasingly limited number of academic tenure-track research jobs by signaling their ability and commitment via long hours in the lab and years spent as underpaid postdocs.

One potential explanation for lower early career salaries could be that postdocs have lower average *abilities.* However, our previous analysis showed that postdocs have *higher average abilities*. Since higher ability scientists were more likely to pursue postdocs, we may actually be *underestimating* the financial loss from taking a postdoc. Alternatively, ability may be multidimensional: former postdocs might excel in academic research while the skills of those who skip the postdoc may earn higher non-academic returns. This would lead to our findings that non-postdocs have higher industry salaries. But this would also suggest that former postdocs should get higher salaries in research academia than non-postdocs; the opposite is true. In short, there is no obvious effect of unobserved ability consistent with our findings.

Conclusion

When providing prescriptions for what ails biomedical science, many have called for better information on the impact of the postdoc on biomedical careers. Our research answers this call. Starting in a postdoc improves the probability of working in a tenure-track research job. However, the chances of obtaining that job have dropped considerably over time, and given the glut of PhDs and the scarcity of new positions after the NIH doubling, this trend is likely to worsen.

Outside of tenure-track academia, we show that future employers did not (financially) value the training or skills obtained during the postdoc. Instead, former postdocs pay an earnings penalty for more than 10 years of their careers – well past the time of completing the low-paid postdoc. For the nearly three-quarters of former postdocs who ultimately end up without a tenure-track academic job, the time spent in a postdoc not only constitutes a sizeable financial sacrifice but does not yield the desired academic career. Based on these findings, the majority of PhDs would be better off skipping the postdoc entirely.

Our findings have implications for science policy. On the one hand, the current system of postdoctoral training benefits the postdocs' supervisors, mentors, their institutions and funding agencies by providing them with highly-educated labor willing to work long hours to produce cutting-edge science at low cost. On the other hand, no counterfactual exists to show whether our current system – where older PI's dominate the research agenda while young researchers are denied opportunities to be creative or productive independent researchers – creates more and better science than a system where more PhDs go directly into the workforce. Meanwhile, the present system entails significant time and foregone-income costs to individuals while not having demonstrable usefulness outside tenure-track academia. Furthermore, the postdoc rat-race may discourage the best and the brightest from pursuing careers in biomedical science because alternatives such as medicine or finance have shorter training periods and better pay.

Instead of funding postdoctoral positions, we support the development of alternative staffing models. Staff scientist positions should be encouraged because they provide permanent employment, benefits, and higher salaries (2, 6). Universities should consider tenure-track hires of the most highly recommended directly after PhD receipt. Recent moves by the NIH to increase salaries paid to postdocs, thereby making them more expensive as research labor, may in the long-run reduce the demand for postdocs and encourage the development of these alternative staffing models.

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Figure Legends

Figure 1 A) Trends in the numbers of PhDs and Postdocs in selected biomedical fields, by PhD year. Based on data from the NSF SED and SDR 1980 – 2010. **B**) Average years in graduate school, postdoc, and all training by PhD year, 1980 – 2010 SED and SDR (N=5872).

Figure 2. Estimated marginal effects from a probit model of starting in a postdoc within 3 years of PhD for selected covariates with 95% confidence intervals. Full specification in *SI Appendix* **Table S3**. Source: SDR matched to SED for those receiving PhDs between 1980-2007 (N=9922).

Figure 3: Sector of employment 10 years past PhD (with 95% confidence intervals). Proportion in each sector conditional on starting in a postdoc 3 years past PhD or not (N=4,163); Data from the SDR matched to SED for doctorates awarded 1980-2000.

Figure 4: Three Year Moving Average of the percentage of All Biomedical PhDs employed by sector and research activity 10 years past PhD, by PhD year. Source: SDR matched with SED, PhD Years 1980-2000, N for Entire Sample= 4,185.

Figure 5. Effect of starting in a postdoc on inflation-adjusted salary (2010 dollars) 1-15 years past PhD completion (source SDR matched to SED) estimated using regression with clustered robust standard errors. A) Full sample (N=30,433 for 9,010 PhDs 1980-2004; B) Academic tenure-track research (N=6,046 for 1,091 PhDs 1980-2000); C) Non-tenure-track research (N=3,125 for 580 PhDs 1980-2000); D) Industry (N=6,825 for 1,276 PhDs 1980-2000); E) Government/nonprofit (N=3,211 for 592 PhDs 1980-2000). [§]

[§] The full sample has more observations than the sum of the sectors because it is not limited to those who were observed 10 years post-PhD. Also, we do not include the academic non-research sector because it only has 356 people (2,007 observations).