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Assessing the landscape of US postdoctoral salaries

Rodoniki Athanasiadou, Adriana Bankston, McKenzie Carlisle, Caroline A. Niziolek and Gary S. McDowell
Future of Research, Boston, Massachusetts, USA

Received 1 December 2017
Revised 6 April 2018
9 August 2018
Accepted 9 August 2018

Abstract

Purpose – Postdocs make up a significant portion of the biomedical workforce. However, data about the postdoctoral position are generally scarce, and no systematic study of the landscape of individual postdoc salaries in the USA has previously been carried out. The purpose of this study was to assess actual salaries for postdocs using data gathered from US public institutions; determine how these salaries may vary with postdoc title, institutional funding and geographic region; and reflect on which institutional and federal policy measures may have the greatest impact on salaries nationally.

Design/methodology/approach – Freedom of Information Act Requests were submitted to US public universities or university systems containing campuses with at least 300 science, engineering and health postdocs, according to the 2015 National Science Foundation's Survey of Graduate Students and Postdoctorates in Science and Engineering. Salaries and job titles of postdocs as of December 1, 2016, were requested.

Findings – Salaries and job titles for nearly 14,000 postdocs at 52 US institutions around December 1, 2016, were received. Individual postdoc names were also received for approximately 7,000 postdocs, and departmental affiliations were received for 4,000 postdocs. This exploratory study shows evidence of a postdoc gender pay gap, a significant influence of job title on postdoc salary and a complex relationship between salaries and the level of institutional National Institutes of Health/NSF funding.

Originality/value – These results provide insights into the ability of institutions to collate and report out annualized salary data on their postdocs, highlighting difficulties faced in tracking and reporting data on this population by institutional administration. Ultimately, these types of efforts, aimed at increasing transparency regarding the postdoctoral position, may lead to improved support for postdocs at all US institutions and allow greater agency for postdocs making decisions based on financial concerns.

Keywords Universities, Early career researchers, Academia, Policy, Higher education policy, Research funding, Higher education environment, Postdocs, Postdoctoral support, Women academics

Paper type Research paper

Introduction

Postdocs make up a significant proportion of the academic workforce, and yet data on specific aspects of the postdoctoral position are still very sparse. This constitutes a significant barrier to effecting policy changes that are urgently needed to reform the

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Studies in Graduate and Postdoctoral Education
Vol. 9 No. 2, 2018
pp. 213-242
Emerald Publishing Limited
2398-4686
DOI 10.1108/SGPE-D-17-00048

biomedical enterprise (Pickett *et al.*, 2015). It is therefore necessary to increase transparency around multiple aspects of the postdoctoral position.

Postdocs have remained largely invisible at research and teaching institutions since the first comprehensive national study of the postdoctoral position, "The Invisible University" (Curtis, 1969). The most basic piece of information, the number of postdocs nationally, is unknown. A study of the National Institutes of Health (NIH)-funded workforce had to estimate the total number of biomedical postdocs, the largest constituency, within a two-fold range (Biomedical Research Workforce Working Group, 2012). For science and engineering fields, the number of postdocs calculated by the National Science Foundation has been used to make pronouncements on the longitudinal trends of the size of the postdoctoral workforce (Garrison *et al.*, 2016), despite the variation in the ability of institutions to accurately report these data (Pickett *et al.*, 2017).

Other aspects of the postdoctoral position that are largely unknown are the proportion of foreign researchers doing postdocs in the USA and migration patterns of researchers during and after postdoctoral research (Franzoni *et al.*, 2015; Stephan and Levin, 2001). Data on career outcomes for both graduate students and particularly postdocs are very scarce, a concerning fact as up to 90 per cent of US-trained biomedical PhDs go on to pursue postdoctoral research, depending on their specific field of study (Kahn and Ginther, 2017). Postdoctoral career outcomes are therefore particularly important, are becoming an area of more intense scrutiny for data collection efforts (Pickett, 2017) and have led to action taken by the Coalition for Next Generation Life Sciences to begin gathering and disseminating these data from institutions (Blank *et al.*, 2017).

The majority of those undertaking postdoctoral research in the sciences are doing so to compete for independent academic positions. However, in biology, such positions have been the minority destination for 30 years (Weissmann, 2013), with biomedical PhD holders increasingly heading into non-academic, non-research positions (Committee on the Next Generation Initiative, Board on Higher Education and Workforce, Policy and Global Affairs, and National Academies of Sciences, Engineering, and Medicine, 2018). Reforming postdoctoral training to reflect this reality is an area of current discussion (Committee on the Next Generation Initiative, Board on Higher Education and Workforce, Policy and Global Affairs, and National Academies of Sciences, Engineering, and Medicine, 2018; Hitchcock *et al.*, 2017; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, and Institute of Medicine, 2014), but efforts to reform are continuously stymied by the lack of data about this population.

One aspect of the postdoctoral experience that has gotten relatively little attention is the topic of salaries received by US postdoctoral researchers. Recommendations have been made repeatedly to increase postdoctoral salaries at institutions and postdoctoral stipends provided by federal funding agencies such as the NIH (Bankston and McDowell, 2018), which likely funds most biomedical research performed by postdocs in US institutions.

No systematic study of the landscape of individual postdoctoral salaries in the USA had been carried out before this report. In addition, the effect of US federal policy changes related to postdoctoral stipends/salaries on actual salary amounts has not been assessed at the national level. Such analysis is necessary to determine whether institutional policies, or determinations made by federal agencies, are the appropriate focus for future policy efforts to effect change in academia.

The limited literature that exists on the postdoctoral population suggests that postdoctoral salaries have not yet reached recommended levels. The invisible and highly variable nature of the postdoctoral position meant that mechanisms for systemic changes to postdoc salaries were not practically in existence until the creation of the National Research

Service Awards (NRSA) via the National Research Service Award Act of 1974 (USA Congress, 1974), which created the first set of minimum stipends for postdoctoral researchers in biomedical fields. The starting stipends for postdocs with 0 years' experience from 1975 to the present day generally increased over time (from $10,000 in 1975 to $47,484 in 2018, Figure 1(a) (National Institutes of Health, 2016a, 2016b).

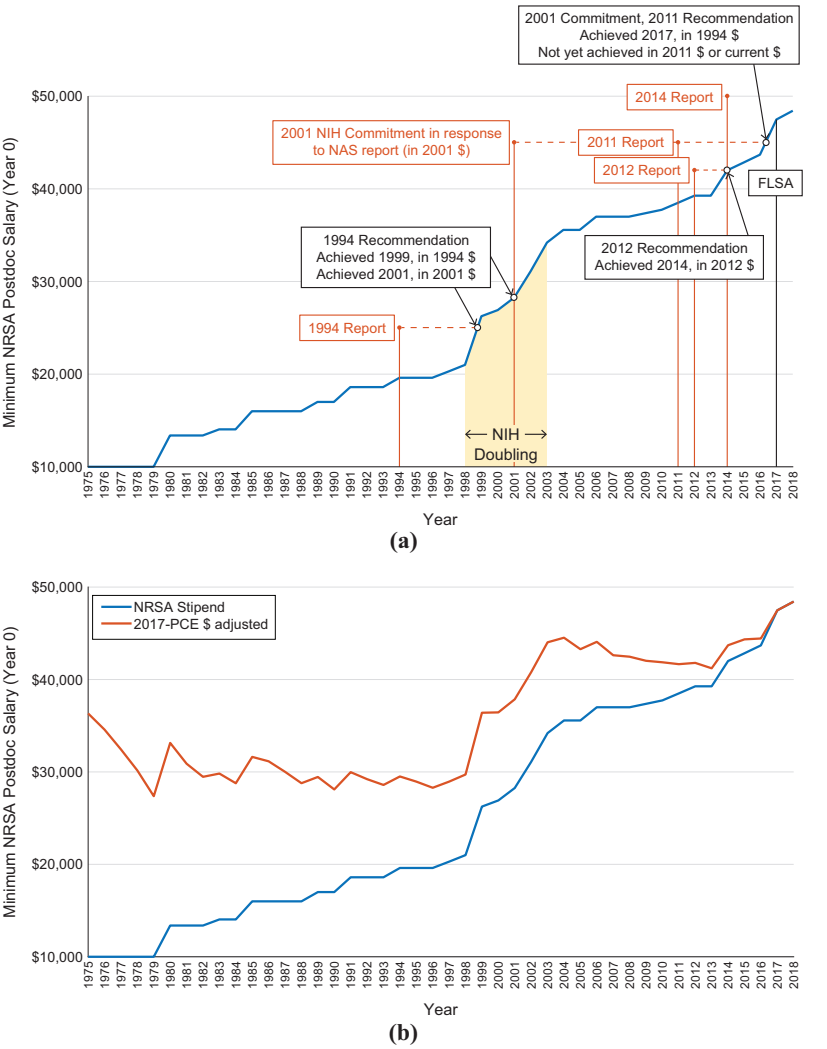
Recommendations for change in postdoctoral salaries were largely synonymous with those for increases in NRSA stipends, perhaps because these stipends were being used as a benchmark for national postdoctoral salaries. Key recommendations and interventions made since 1975 are indicated in Figure 1(a) along with the change in Year 0 NRSA stipends over time. Figure 1(b) shows the same Year 0 stipends adjusted to 2017 inflation-adjusted dollars using the Personal Consumption Expenditure Index, demonstrating how, after an initial high point in 1975, starting stipends oscillate around $30,000 in inflation-adjusted dollars for approximately 20 years.

In 1994, the first recommendation (in "Meeting the Nation's Needs for Biomedical and Behavioral Scientists") was made to raise NRSA stipends to $25,000 in inflation-adjusted dollars by fiscal year 1996 and then annually by 3 per cent (National Research Council, 1994). However, NRSA stipends were not raised to this amount until 2001. This raise was likely due to increased funding during the "NIH Doubling," a period of time between 1998 and 2003 when the NIH budget doubled in size (Berg, 2014) [Figure 1(a)] and not as a direct response to previous recommendations. Since this period, the recommended annual inflationary adjustment has never been implemented, and changes in stipend levels have been sporadic over time. Also during the "NIH Doubling", in 2001, the NIH committed to raising entry-level postdoctoral stipends to $45,000 as part of their response to the 2000 report entitled "Addressing the Nation's Changing Needs for Biomedical and Behavioral Scientists" (National Research Council, 2000), when action on prior recommendations to raise stipends was again urged. The NIH's response stated that:

> Future budget requests will incorporate 10 to 12 per cent stipend increases until these targets are reached. After attainment of these targets, the real value of stipends will be maintained with annual cost-of-living adjustments (National Institutes of Health, 2001).

This commitment has not been realized. A freeze in NIH funding after the "NIH Doubling" has been cited as a reason for the lack of progress in increasing entry-level postdoctoral stipends (National Postdoctoral Association, 2015a, 2015b). In 2011, another National Research Council Report, entitled "Research Training in the Biomedical, Behavioral and Clinical Research Sciences", urged the NIH to honor its 2001 commitment (National Research Council, 2011). In the 2012 Biomedical Workforce Working Group Report to the Advisory Council of the Director at NIH, the starting postdoc stipend was recommended to be adjusted to $42,000 and indexed annually to the Consumer Price Index (Biomedical Research Workforce Working Group, 2012). In 2014, starting salaries for postdocs in all disciplines were recommended to begin at $50,000 (in 2014 dollars), with annual inflationary and cost of living adjustments (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, and Institute of Medicine, 2014). None of these recommendations have been enacted at the time of writing, but a mandate to raise starting postdoc stipends has been included in the Consolidated Appropriations Act of 2018 (USA Congress, 2018a, 2018b):

> The agreement expects NIH to support an increase in the number of Ruth L. Kirschstein National Research Service Awards and to provide a stipend level and inflationary increase to grantees that is at least consistent with the fiscal year 2018 Federal employee pay raise.



Notes: (a) Year 0 NRSA stipends (in dollars at the time of implementation i.e. not adjusted for inflation) plotted by year (1975-2018). Key recommendations made at particular time points are highlighted, and their recommendation and implementation dates are shown. Red vertical lines indicate date of recommendation, along with the recommended dollar amounts (at the time of the recommendation); (b) Year 0 NRSA stipends plotted over time as in Panel (A) (blue line) but also with inflation-adjusted values plotted by year (red line). Values were adjusted to 2017 dollars using the Personal Consumption Expenditure Index

Figure 1.
Changes to the minimum NRSA postdoctoral stipend (i.e. Year 0) over time

In terms of earning potential, recent work by Kahn and Ginther shows that, across all career tracks, individuals who pursue postdoctoral training suffer a financial disadvantage: up to 15 years after PhD completion, they have still not reached the salary levels of peers who opt out of postdoctoral research experiences (Kahn and Ginther, 2017). This phenomenon dates back to the earliest study of postdocs in 1969, where the trend was reversed for humanities postdocs, whose earning potential outstripped that of their peers (Curtis, 1969).

Even with the multitude of reports on postdocs over the past several years, there are still several aspects of the postdoctoral position which are not well understood or have been understudied. Importantly, it is unclear which policies truly determine the actual salaries received by this population, which affect many aspects of postdoc life in academia. One widespread assumption in the academic community is that all NIH-funded postdocs are paid in accordance with the NIH Ruth L. Kirschstein NRSA scale (National Institutes of Health, 2016b). However, NRSA stipend levels only apply to a portion of postdocs supported by specific NIH training and fellowship funding mechanisms, such as training programs (e.g. "T32s") and fellowship awards (e.g. "F32s") (National Institutes of Health, 2015). Out of all NIH-supported postdoctoral researchers in 2015, approximately 84 per cent were funded on their PI's research project grants, whereas only 9 per cent were supported by institutional training grants and 6 per cent through fellowships (National Science Foundation, 2015b), meaning these stipends are only mandatory for less than 16 per cent of NIH-funded postdocs. For the other 84 per cent, the annual legal minimum salary is essentially set by the salary threshold for overtime exemption under the Fair Labor Standards Act (FLSA), currently at $23,660 (Bankston and McDowell, 2016).

Institutional policies exist to recommend salary minima, and in practice, many institutions use the NIH NRSA stipend levels as a guideline, and particularly the Year 0 stipend as a minimum, according to the National Postdoctoral Association Institutional Policy Report (National Postdoctoral Association, 2014). However, open questions remain as to which of these factors determine the actual salaries postdocs receive, as well as whether federal policy changes affect salaries for postdocs across all disciplines. While an institutional policy can recommend or require specific postdoc salary levels, the mere existence of such policies may not accurately reflect the actual annual salaries earned by postdocs at those institutions, unless there is central oversight of postdocs on this specific issue. Likewise, federal salary policies may or may not influence institutional policies, or determine whether every individual postdoc at a particular institution will receive the suggested or mandated salary.

In the current study, we sought to evaluate individual US postdoc salaries in a standardized fashion and compare these data across multiple institutions. Using Freedom of Information Act (FOIA) requests, we compiled annual salaries, and corresponding job titles, for postdocs at 51 public institutions. We were able to analyze postdoc salary data with respect to geographic region, job title and institutional funding level. In addition, for subsets of the data set, we received (unprompted) names and departmental affiliations of postdocs, allowing additional analyses of how gender and discipline affect postdoc salaries.

No previous studies have analyzed the effect of these variables on postdoc salaries at such scale. Although the breadth of our analysis is limited by institutional variability in salary reporting, the large sample size (nearly 14,000 postdocs) allows us to draw meaningful conclusions about salaries for the postdoc population nationally. We find evidence of a postdoc gender pay gap, a significant influence of job title on postdoc salary, and a complex relationship between salaries and the level of institutional NIH awards or NSF R&D expenditures. As a whole, these findings allow us to better understand the

salaries of the USA postdoctoral workforce, which may help inform broader data-driven strategies to enhance the postdoctoral experience in academia.

Methods

Data collection

Postdoc salary data were obtained using FOIA requests made to 51 public universities with full-time postdocs. In addition, we also obtained salary data from one private university (Boston University) for postdocs supported on research project grants/non-fellowship mechanisms. As no FOIA-like mechanism exists for requesting data from private institutions, this is the only data from a private institution in the data set, which was provided voluntarily.

FOIA requests were made for salaries and job titles of all full-time PhD- or MD-holding postdoctoral researchers, regardless of discipline. To estimate the number of postdoc salaries expected to be received from an institution, we used data from the 2015 National Science Foundation's (NSF) Survey of Graduate Students and Postdoctorates in Science and Engineering (GSS) (National Science Foundation, 2015a) reporting the number of postdocs employed at specific institutions in health, science and engineering fields.

While a true comparison is difficult due to variable institutional reporting of postdoc numbers to the GSS from year to year (Pickett *et al.*, 2017), and the fact that this reporting excludes postdocs from disciplines outside of science, health and engineering, GSS numbers served as a guide for the number of postdoc salaries expected from an institution. Given multiple job titles for this population, we used the term "postdoc" to encompass all PhD-holding researchers who are not currently in faculty roles (either tenured, non-tenured or adjunct). These data inevitably include staff scientists, as well as non-research PhD-level administrative staff who are hired in universities and hold titles which are also used to describe postdocs.

Requests for salaries and job titles were made to all public US universities and university systems containing campuses expected to have at least 300 science, engineering and health postdocs according to the GSS (National Science Foundation, 2015a). This number was selected to maximize the yield of responses while minimizing the effort required for data collection. The number of postdocs per institution (Appendix Figure A1) illustrates the fact that the majority of institutions employ a relatively low number of postdocs. Data from institutions containing fewer than 300 postdocs were included in the analysis when they were part of requests made to university systems, e.g. SUNY. For all public institutions, FOIA requests were submitted for:

> The annual salaries, on December 1st 2016, of all full-time PhD or MD-holding postdoctoral employees and fellows, and employees under any other titles that encompass postdoctoral research roles, at [INSTITUTION NAME].

The FOIA request letters asked for a spreadsheet containing all postdoc salaries and job titles. Letters also asked for a written explanation of any denial of all or a portion of the FOIA request. Requests were only denied in two instances. The University of Utah initially denied the request on the grounds of the arduous effort to compile the data. However, upon appeal to the University of Utah's Office of General Counsel, the university was required to provide the data, which are included in this data set. The University of California Public Records Office also rejected the request across all campuses for the same reason, additionally claiming that the data required too much effort to compile and send, but also that the requested data were not currently available. However, the University of California Santa Barbara had already provided us with the requested data when this claim was made by the Public Records Office, and those data are included here. Appeals to the Public Records Office resulted in further refusal to share data, as well as referral to their online

database, which details compensation as reported from Box 5 of W-2 forms, and not annual salaries. These data were thus unsuitable for inclusion in this analysis.

Responses to FOIA requests were supplied in both electronic and paper format, with paper-based records being hand-entered into the database. These data are not a result of postdocs themselves reporting salaries in a survey (i.e. self-reporting). Because of the FOIA mechanism used, universities likely retrieved data from a payroll or HR database in a more automatic fashion, which may or may not be the same method used when departments are reporting data for similar efforts on postdocs such as the NSF's GSS (Pickett *et al.*, 2017).

There was also an individual instance (University of Illinois Chicago) where we can be certain that the data received were incorrect. The University of Illinois Urbana-Champaign informed us that the data for both Illinois institutions were incorrect, but provided us with updated data only from their institution. Therefore, data for the University of Illinois Chicago were subsequently excluded from our analysis. In addition, a small subset of salaries in our data set were extremely low and are therefore presumed to be reporting errors; these cases are most likely due to an institution reporting not annual salaries, but some other amount of compensation that passed through payroll. These low salaries could, for example, indicate postdocs who are paid directly through fellowships and perhaps receive some additional compensation through their institution. Alerted by this discrepancy, we verified through direct communication with individuals, e.g. at the University of Washington, that in some cases, the institutions were providing actual annual postdoc salaries for fellows rather than just compensation. As this demonstrated that institutions had the ability to comply with our request, we continued analyses for institutions unless directly informed of errors, this being the responsibility of institutions rather than a deficiency in our methodology.

Data from 52 institutions were collated and represent postdoc salary information from around the requested date of December 1, 2016, with an estimated range from November 1, 2016, to December 31, 2016. Data were provided for a total of 13,923 postdoctoral researchers in the USA (estimated to be 15-30 per cent of the total US postdoctoral workforce (Biomedical Research Workforce Working Group, 2012; National Science Foundation, 2015a; Pickett *et al.*, 2017; Schaller *et al.*, 2017)).

Data preprocessing and analysis

All analyses were performed using R version 3.4.3 and Python version 3.5.2. The code used for all analyses can be found in our public repository (github.com/futureofresearch/PostdocSalaries).

Preprocessing: Salaries below the $23,660 annual legal minimum as mandated by the FLSA are assumed to be reporting errors and were excluded from the subsequent analysis (401 postdoc entries). In cases where salaries were reported for postdocs working less than 100 per cent effort (82 postdocs across five institutions), the salary for 100 per cent effort was calculated and used in the analyses.

Geographic region: After excluding salaries below the FLSA minimum and updating salaries reported as partial effort to 100 per cent effort, we separated the aggregated data from the 52 institutions into geographic regions based on the USA census (USA Census Bureau, 2015) to show the distribution of postdoc salaries by institution in specific geographic regions. The majority of institutions in this data set were from the South and Midwest (20 and 17 institutions, respectively), with the detailed allocation of the host state of each institution assigned to geographic regions as follows: Northeast (NE): MA, NJ, NY; South (S): FL, MD, NC, TX, VA; Midwest (MW): IA, IL, IN, MI, MN, OH, WI; and West (W): AZ, CA, CO, UT, WA. To evaluate whether salaries varied between the four regions, the

difference of the mean of the salaries between regions was tested using a two-sided *t*-test against the null hypothesis that the true difference is zero with a confidence level of 0.95.

Discipline: Our FOIA request asked only for postdoc salaries and job titles. However, a subset of institutions additionally provided information on postdoc department or school affiliation. For the 4,155 postdocs from 11 institutions where this affiliation was available, we classified each postdoc as being in a science, technology, engineering or mathematics (STEM) or non-STEM field, and compared postdoc salaries between categories. We broadly define STEM as a discipline in engineering, biological sciences, mathematics and physical sciences or in related fields (i.e. fields using research, innovation, or development of new technologies using engineering, mathematics, computer science, or natural science). The Classification of Instructional Programs taxonomic coding scheme, developed by the National Center for Education, was used as a guiding reference for defining the STEM disciplines (National Center for Education Statistics, 2010). Some examples of department affiliations classified as non-STEM were: Business Administration, Criminal Justice, Education, English, History, Law, Philosophy and Religious Studies, and Political Science (a full list of disciplines coded STEM/non-STEM can be found at the Future of Research Github repository Tables folder) (https://github.com/futureofresearch/PostdocSalaries/blob/master/Tables/STEM.csv).

Gender assignment and analysis: A total of 17 out of 52 universities in our data set, accounting for 7,271 of the 13,923 postdoc entries (52 per cent), included individual postdoc names. For these entries, gender was inferred and assigned by first using the Ethnea algorithm (Torvik and Agarwal, 2016), which uses the geographical distributions of institutional affiliations of PubMed authors to assign ethnicity to last names, and then applying an ethnicity-specific gender prediction algorithm (Genni tool, http://abel.lis.illinois.edu/cgi-bin/genni/search.cgi). Based on the algorithm, the gender of 42 per cent of postdocs in our data set was inferred to be male, 30 per cent female and 28 per cent was unassigned, either because the algorithm did not produce a significant result, or due to names of particular national origins allowing "unisex" use (which is therefore considered noise). The salaries of postdocs with assigned gender in institutions with inferred gender information were compared at the national level and within each region (Northeast, Midwest, South and West) using a two-sided *t*-test against the null hypothesis that the true difference in salaries between genders is zero with a confidence level of 0.95.

Job title: Given the different identifying descriptors ("terms") found in the job titles, as well as the multitude of existing postdoc titles nationally (McDowell, 2016; Schaller *et al.*, 2017), we were also interested in whether these titles reflect different salaries. Our data set contained combinations of many of the same identifying terms in specific job titles as follows: Professor, Intern, Teaching, Fellow, Associate, Scholar, Researcher, Trainee, Senior, Clinical, Assistant, Faculty (e.g. Postdoctoral Research Fellow vs Senior Postdoctoral Fellow). These 11 identifying terms were found in all but 392 of the 13,923 job titles.

To examine the distribution of salaries associated with each of the 11 job titles and salaries, we searched for the presence of these terms in each job title. It should be noted that because each identifying term is considered separately, a postdoc could be counted more than once, if the respective job title contained more than one of these terms (e.g. Senior Postdoctoral Fellow).

Additionally, we ran a linear regression using job title terms as predictors of salary, aiming to estimate the dollar impact of each term on the annual salary, in the available data. For the linear model, we transformed the categorical job title description data into a sparse matrix where "1" represents the presence of the word and "0" represents the absence. This data configuration preserves the relationship between an individual's salary and a specific

combination of terms in the job title, and in this manner, each postdoc was counted only once regardless of the number of terms contained in their job title. The model was calculated in R in the simple form:

$$lm(Salary \sim Professor + Intern + Teaching + Fellow + Associate + Scholar + Researcher + Trainee + Senior + Clinical + Assistant + Faculty, data)$$

Or

$$Y_S = \alpha + \beta_P X_P + \beta_I X_I + \beta_{Te} X_{Te} + \beta_F X_F + \beta_{Aso} X_{Aso} + \beta_{Sch} X_{Sch} + \beta_R X_R + \beta_{Tr} X_{Tr} + \beta_{Sr} X_{Sr} + \beta_C X_C + \beta_{Asi} X_{Asi} + \beta_F X_F$$

Institutional funding: To examine potential relationships between total federal NIH awards received by a particular institution and postdoc salaries at that institution in a given year (2017), we utilized a public NIH awards database (National Institutes of Health, 2018) as a federal funding proxy and searched the database for each institution in our data set. Out of the 52 institutions in the data set, 45 received 2017 NIH awards. We assigned an "NIH awards order" value for each institution based on the total 2017 NIH award amount and plotted them in descending order based on this amount. The coefficients of variation for the reported postdoc salaries in each ordered 2017 NIH-funded institution were used to plot the smoothed loess line and 95 per cent confidence intervals. This same methodology was used to order the 40 institutions with available information on the total 2017 NSF R&D expenditures amount for 2017 (National Science Foundation, 2018).

Results

Median postdoc salaries vary by US institution and geographic region

As no such study has previously been attempted, we set out to examine how postdoctoral salaries vary nationally using the available data received through FOIA requests from USA public institutions. We calculated the average, median, minimum and maximum annual salaries for each institution in the data set (Table I). Comparisons between salaries at institutions were made using the median value to account for highly skewed and/or multimodal distributions. The lowest median salary calculated from this data set was University of Texas Health Sciences Center at Tyler at $36,060, and the highest was University of Maryland College Park at $56,000. As discussed in Woolston (Woolston, 2017), median postdoc salaries across US institutions, and a large proportion of individual salaries, cluster around the proposed annual salary levels according to the FLSA threshold for overtime exemption as updated in 2016 ($47,476) (Bankston and McDowell, 2016), and the NIH NRSA Year 0 salary for FY 2017 ($47,484) (National Institutes of Health, 2016b). Approximately 22 per cent of all salaries received from the FOIA requests are within a $25 range of those national benchmarks ($47,475-47,500). Across the entire data set of all postdoc salaries nationally, the median salary was $47,484, suggesting the national median salary may be determined by the NIH NRSA minimum (Year 0) stipend.

One variable that could affect postdoc salaries nationally is geographic region, based on variable cost of living or other factors. We found differences in average postdoc salaries among institutions when comparing between the four different geographical regions, with those in the West appearing to compensate their postdocs the best (Table II). While further studies are necessary to determine the effect of USA regional factors on postdoc salaries,

Table I.
Comparison of postdoc salary information across US institutions

Institution	*No. of postdocs in science, engineering, health (NSF GSS 2015)*	*No. of postdoc salaries received (all disciplines)*	No. of postdoc salaries > $23660 (used for this analysis)	Average	Median	Minimum	Maximum	Max/Min	Total Cost to Bring All to $47,476
Boston University* (Private; fellows not included)	421	297	297	$51,687	$49,200	$47,476	$86,000	1.81	$0
Florida State University	202	140	140	$50,012	$47,659	$47,659	$82,857	1.74	$0
Iowa State University	299	68	68	$49,531	$47,476	$44,100	$91,254	2.07	$19,170
Michigan State University	471	469	469	$48,243	$47,476	$31,000	$99,185	3.20	$1,228,706
North Carolina State University	497	449	*439*	$45,370	$47,476	$27,000	$113,626	4.21	$1,938,136
Purdue University	391	625	*407*	$38,860	$38,896	$23,660	$68,056	2.88	$3,895,515
Rutgers University	362	542	*539*	$47,765	$46,000	$23,780	$85,000	3.57	$1,315,504
State University of New York Albany	86	20	20	$41,949	$39,945	$35,000	$56,863	1.62	$136,569
State University of New York Binghamton	30	1	1	$47,476	$47,476	$47,476	$47,476	1.00	$0
State University of New York Buffalo	256	11	11	$41,948	$42,000	$36,000	$50,000	1.39	$63,328
State University of New York Stony Brook	263	31	31	$47,160	$47,000	$44,450	$52,000	1.17	$40,248
State University of New York Upstate	24	2	2	$45,763	$45,763	$38,495	$53,030	1.38	$8,981
Texas A&M	615	188	*185*	$45,378	$46,350	$24,240	$77,976	3.22	$858,553
The Ohio State University	619	622	*617*	$46,966	$47,484	$27,840	$68,640	2.47	$1,329,710
University of Arizona	471	275	275	$46,620	$47,659	$32,001	$70,500	2.20	$851,548
University of California Santa Barbara	306	284	*283*	$55,262	$53,000	$24,228	$86,143	3.56	$38,268
University of Cincinnati	303	183	*141*	$41,476	$41,647	$23,681	$102,542	4.33	$1,088,126
University of Colorado Boulder	1,199	23	23	$52,867	$49,152	$42,840	$78,000	1.82	$26,236

(*continued*)

Table I.

Institution	*No. of postdocs in science, engineering, health (NSF GSS 2015)*	*No. of postdoc salaries received (all disciplines)*	No. of postdoc salaries > $23660 (used for this analysis)	Average	Median	Minimum	Maximum	Max/Min	Total Cost to Bring All to $47,476
University of Colorado Denver		324	*320*	$49,038	$47,483	$25,000	$77,250	3.09	$38,603
University of Florida	679	610	*606*	$49,273	$47,476	$23,738	$92,400	3.89	$139,455
University of Illinois Urbana-Champaign	542	509	509	$45,809	$45,000	$30,826	$69,565	2.26	$1,917,240
University of Indiana Bloomington		154	154	$49,349	$47,476	$40,000	$72,756	1.82	$8,954
University of Indiana Indianapolis		200	200	$47,842	$47,476	$24,000	$63,000	2.63	$89,089
University of Indiana Northwest	394	1	1	$47,476	$47,476	$47,476	$47,476	1.00	$0
University of Iowa	346	241	241	$47,562	$47,476	$40,698	$75,000	1.84	$357,907
University of Maryland Baltimore	325	278	278	$47,945	$47,268	$23,660	$66,625	2.82	$486,895
University of Maryland Baltimore County	67	24	24	$57,195	$55,688	$40,000	$78,795	1.97	$47,667
University of Maryland College Park	496	448	448	$56,712	$56,000	$34,000	$107,100	3.15	$521,483
University of Massachusetts Medical School	348	360	360	$46,024	$44,556	$41,205	$85,000	2.06	$1,018,877
University of Michigan Ann Arbor		1,165	*1,159*	$48,181	$47,054	$30,000	$94,239	3.14	$2,405,968
University of Michigan Dearborn	1,300	4	4	$42,725	$39,250	$35,000	$57,400	1.64	$28,928
University of Minnesota Duluth	755	3	3	$56,097	$48,661	$46,811	$72,817	1.56	$665

(*continued*)

Table I.

Institution	*No. of postdocs in science, engineering, health (NSF GSS 2015)*	*No. of postdoc salaries received (all disciplines)*	No. of postdoc salaries > $23660 (used for this analysis)	Average	Median	Minimum	Maximum	Max/Min	Total Cost to Bring All to $47,476
University of Minnesota Twin Cities		699	*697*	$44,871	$44,804	$34,618	$61,000	1.76	$2,566,863
University of North Carolina Chapel Hill	803	432	432	$49,588	$47,484	$42,000	$90,000	2.14	$5,476
University of South Florida	282	121	121	$48,346	$47,659	$37,346	$60,000	1.61	$28,725
University of Texas Arlington	60	49	49	$45,782	$45,000	$30,000	$64,260	2.14	$173,944
University of Texas Austin	370	466	*464*	$51,805	$48,000	$45,400	$86,700	1.91	$3,622
University of Texas Dallas	80	53	53	$48,154	$48,000	$30,000	$91,654	3.06	$145,275
University of Texas El Paso	58	45	*43*	$43,540	$42,191	$32,000	$66,134	2.07	$232,133
University of Texas Health Sciences Center at Houston	237	229	229	$48,691	$47,476	$43,000	$60,000	1.40	$4,476
University of Texas Health Sciences Center at San Antonio	167	56	*52*	$48,627	$47,476	$35,543	$61,215	1.72	$29,785
University of Texas Health Sciences Center at Tyler	26	12	12	$35,900	$36,060	$33,000	$40,008	1.21	$138,912
University of Texas MD Anderson Cancer Center	637	151	*150*	$49,336	$47,844	$26,365	$65,000	2.47	$21,319
University of Texas Medical Branch at Galveston	102	137	137	$48,252	$47,484	$47,476	$60,678	1.28	$0
University of Texas San Antonio	39	59	*53*	$44,510	$42,000	$25,000	$77,175	3.09	$362,398

(*continued*)

Table I.

Institution	*No. of postdocs in science, engineering, health (NSF GSS 2015)*	*No. of postdoc salaries received (all disciplines)*	No. of postdoc salaries > $23660 (used for this analysis)	Average	Median	Minimum	Maximum	Max/Min	Total Cost to Bring All to $47,476
University of Texas Southwestern	562	528	*527*	$47,382	$47,268	$42,840	$67,590	1.58	$764,271
University of Utah	487	462	*387*	$46,691	$47,484	$23,660	$91,936	3.89	$1,203,751
University of Virginia	420	316	*302*	$48,596	$47,500	$24,096	$100,000	4.15	$382,799
University of Washington Bothell		6	6	$50,244	$47,994	$41,592	$60,000	1.44	$5,884
University of Washington Seattle	1,205	1,070	1070	$54,904	$50,772	$37,740	$114,600	3.04	$88,586
University of Wisconsin Madison	765	760	760	$49,860	$47,844	$37,000	$84,000	2.27	$150,529
Wayne State University	146	111	*110*	$45,085	$45,000	$35,000	$74,800	2.14	$430,040

Notes: The number of postdocs in the 2015 NSF's GSS was used as a comparison of the number of postdoc salaries expected to be received from an institution (all disciplines), to indicate the amount of postdoc salary data that may be missing. The numbers of postdoc salaries received that are greater than $23,660 are indicated and emboldened where they differ from the number of salaries received. These data were then used to calculate the average, median, minimum and maximum values, as well as the total cost to a particular institution of bringing all salaries up to the FLSA threshold salary proposed for December 1st 2016. *Data from Boston University was not subject to the FOIA mechanism

these differences may serve the purpose of dictating career decisions for current and future postdocs.

Salaries do not significantly differ between postdocs in science, technology, engineering or mathematics and non-science, technology, engineering or mathematics disciplines within specific geographic regions

Given that postdoc salaries may differ by discipline, we compared salaries between STEM vs non-STEM postdocs to test the common hypothesis that salaries are lower for postdocs outside STEM disciplines. We found that salaries for non-STEM postdocs were in the same range as those for STEM postdocs, with 50 per cent ranging between $40,000 and $50,000 per year (Appendix Figure A2(a)). In addition, no consistent differences in salaries between postdocs in STEM and non-STEM disciplines were detected within specific geographic regions (Appendix Figure A2(b)). As only 172 of the total 4,151 (4.14 per cent) salaries with discipline information available were classified as non-STEM, a larger sample size may be needed to determine the effect of discipline on salary. Nevertheless, these results suggest that, at least in this data set, discipline did not significantly affect postdoc salaries. Future studies should seek to incorporate additional disciplines into this analysis.

Gender-related postdoc salary discrepancies exist both nationally and within particular US geographic regions

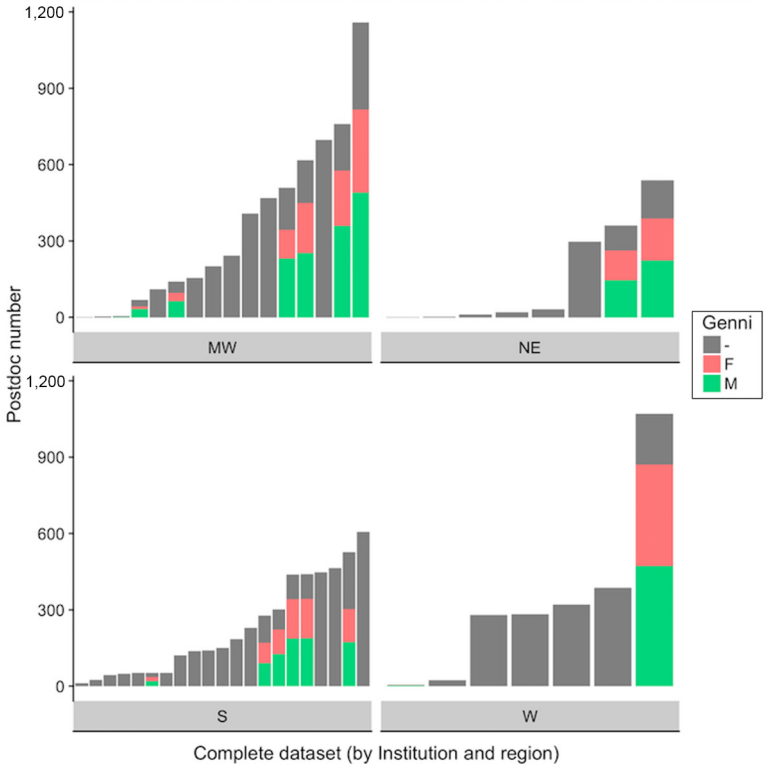
Gender is another factor that may dictate postdoc salaries. While our FOIA requests only asked for salary and job titles, a subset of institutions also provided names, allowing inference of gender for 5,271 of the 7,271 entries where the name was voluntarily provided (17 universities, Figure 2). Our data indicate a male-to-female postdoc ratio of 1.38, equivalent to 42 per cent female postdocs employed at US institutions, which agrees with prior studies (Sheltzer and Smith, 2014). From this data set, we were able to identify 1,428 male postdocs and 900 female postdocs in the Midwest, 369 male postdocs and 281 female postdocs in the Northeast, 784 male postdocs and 634 female postdocs in the South and 475 male postdocs and 400 female postdocs in the West.

To investigate whether gender had an effect on postdoc salaries, we evaluated the difference in salaries between inferred genders at a national level, and within particular USA geographic regions (Figure 3). Salary data from all institutions in this data set ("All" in Figure 3) show an average national salary advantage for male postdocs of $860.47 at the $p < 2 \times 10^{-4}$ confidence level. This is consistent with the gender pay gap in the US workforce in general (Blau, 2012). Breaking up the data by geographic region (Figure 3) indicated that these gender-related salary discrepancies are specific to universities within the Northeast and South (difference in average salary $1,708.77 and $1,943.56, respectively; *t*-test, *p*-values = 2×10^{-3} and 4×10^{-6},

Table II.
Difference in mean postdoc salaries between US census regions

Region comparison	Difference of salary means	*p*-value
MW – NE	$-1,293.819	$4.2\,10^{-9}$
MW – S	$-2,479.156	0
MW – W	$-5,099.463	0
NE – W	$-3,805.644	0
NE – S	$-1,185.337	$1.7\,10^{-7}$
S – W	$-2,620.307	0

Note: The *p*-values are calculated using Student's *t*-test



Notes: MW = Midwest, NE = Northeast, S = South, W = West. Each bar represents an institution within the specified geographic region. Gender was inferred from available names using the "Genni" tool. Lack of gender information ("-", gray bar) signifies absence of name information or the inability of the algorithm to determine a person's gender with confidence. Due to cultural norms in name-giving, names of particular national origins were not assigned a gender using the algorithm, and are therefore depleted from the population used to analyze the effect of gender in this study. In the West, the vast majority of salary data accompanied by gender assignment comes from a single institution

Figure 2.
Number of postdocs at each institution by gender and US Census region

respectively), and not to those in the West and Midwest (difference in average salary $387.38 and $550.82, respectively; *t*-test, *p*-values = 0.567 and 0.057, respectively). Overall, these results suggest that gender has an effect on postdoc salaries, and this effect may be dependent upon the US region where these postdocs are employed.

Postdoc job titles are associated with varying postdoc salaries

Across institutions, postdocs are employed under multiple job titles, which often contain several identifying terms (McDowell, 2016; Schaller *et al.*, 2017), complicating the ability of

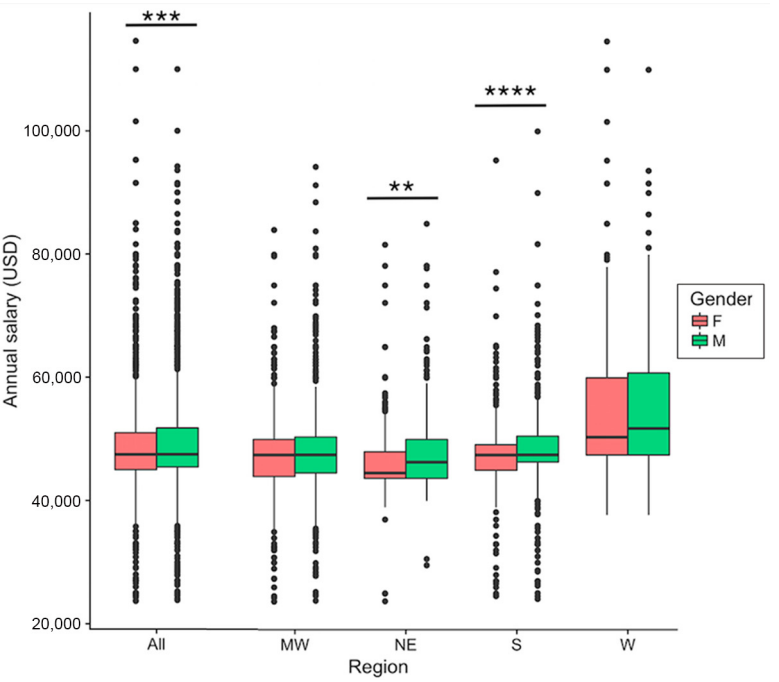


Figure 3.
Postdoc salaries by US Census region and inferred gender

Notes: "All" = salary data from all institutions in this data set. MW = Midwest, NE = Northeast, S = South, W = West. Gender was inferred from available names using the "Genni" tool. Only the entries with available corresponding gender data (from Figure 2) are shown. *t*-test; $^{**}p$-value < 10 − 2, $^{***}p$-value < 10 − 3, $^{****}p$-value < 10 − 5

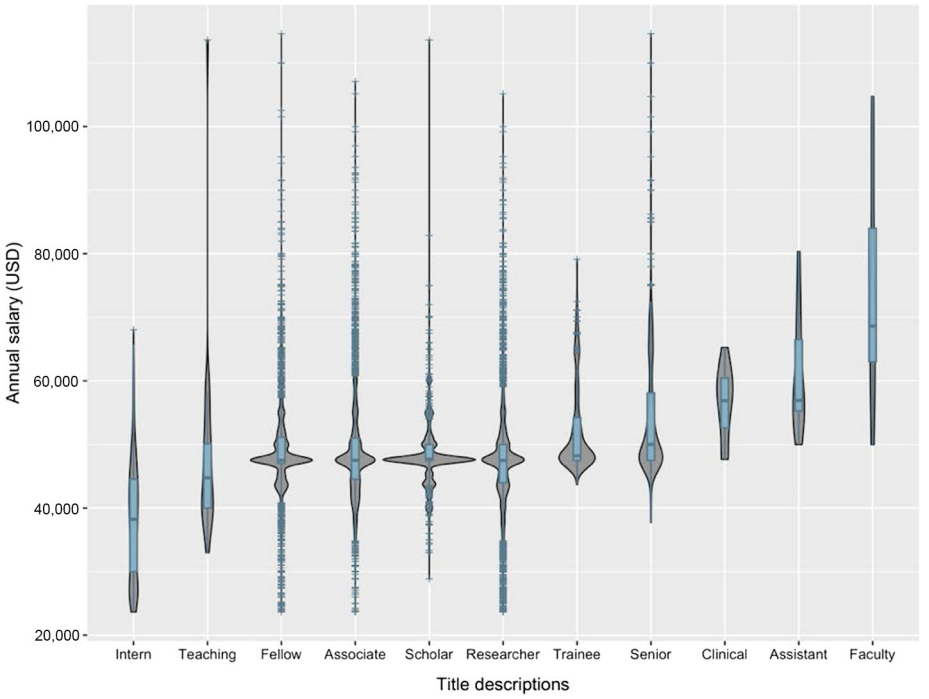
the scientific community to count and classify postdocs. However, the title under which a postdoc is employed could significantly affect multiple aspects of their academic experience, including pay. Our FOIA requests asked for postdoc salaries and titles, as we wanted to examine whether titles reflect different postdoc salaries. To this end, we mapped out the job titles assigned to all postdocs in our data set to the most common 11 descriptive terms (Table III) and analyzed the influence of these terms on the salaries of postdocs with these titles. We observed different salary ranges depending on the specific terms used in each job title (Figure 4). As expected, within our data set, the words "clinical" and "faculty" were associated with higher salaries, and the word "intern" with lower ones (Table IV). Overall, these data exemplify the variability in salaries based on postdoc job titles and particular terms used in those titles.

By modeling salaries as a linear function of the presence of each descriptive term in the job title, we were able to estimate the dollar impact of each term on the annual salary, without assuming a causal relationship (Table IV). The term "intern" appeared in 431 titles from 2 institutions (Table III) and had a negative impact of $9,621.40 on postdoc salaries (Table IV). On the other hand, the terms "associate", "trainee", "senior", "clinical", and "faculty" added $914.00, $1,608.70, $5,468.30, $9,231.20 and $26,767.00 to the salary, respectively (Table IV). Of the terms that did not significantly affect the salary outcome, the

Term	No. of postdocs	No. of institutions
Intern	431	2
Teaching	18	1
Fellow	4,633	31
Associate	6,406	30
Scholar	790	5
Researcher	7,120	29
Trainee	372	4
Senior	740	4
Clinical	17	3
Assistant	14	3
Faculty	8	1

Note: The "term" refers to the 11 most common postdoc job titles in the data set

Table III. Postdoc job title descriptor ("term") by number of postdocs and number of institutions using these terms



Notes: The x-axis contains the descriptive terms used in the various titles assigned to postdocs in our data set. As more than one word can be used in each title, the sum of the entries for each word exceeds the number of postdocs

Figure 4. Postdoc salaries by job title descriptor

Table IV.
The dollar impact of job title descriptor ("term") on salaries

Term	Value ($)	Error	p-value
Intern	−9,621.40	416.30	0.000
Teaching	701.20	1818.20	0.699
Fellow	298.10	232.90	0.200
Associate	*914.00*	*217.20*	2.6×10^{-5}
Scholar	513.20	337.00	0.128
Researcher	−285.70	140.40	0.042
Trainee	*1,608.70*	*435.30*	2.2×10^{-4}
Senior	*5,468.30*	*317.80*	*0.000*
Clinical	*9,231.20*	*2,096.40*	1.07×10^{-5}
Assistant	−2,525.60	2,804.70	0.368
Faculty	*26,767.00*	*3,414.80*	4.89×10^{-15}

Note: Rows of terms with p-values below 0.005 are denoted in italic

term "teaching" and "assistant" are underrepresented and more information is needed to conclude whether they may have an effect on postdoc salary.

The relationship between postdoc salaries and total institutional funding is complex

Given that the NIH funds most biomedical research at US institutions, much of which is undertaken by postdocs, we wanted to examine whether the NIH award amount received by an institution in a given year (2017) would have an impact on postdoc salaries. Institutions in our data set receiving greater NIH award amounts in 2017 tended to have more postdocs (Table V, Pearson correlation: 0.73).

We next hypothesized that higher levels of institutional NIH awards would positively correlate with postdoc salaries. To investigate this question, we examined the relationship between total 2017 NIH award amounts received by individual institutions and postdoc salaries at those same institutions. Plotting the annual postdoc salary distributions per institution, in descending order of the amount of 2017 NIH awards received, demonstrates that regardless of NIH award order, the median postdoc salary is centered around the NRSA minimum of $47,484 at most institutions in this data set [Figure 5(a)]. However, there is more variability in postdoc salaries for institutions receiving less 2017 NIH award amounts where the salary distribution was less homogeneously centered around the mean. To further examine this variability, we looked at the coefficients of variation for postdoc salaries at these same institutions. This reflects both the mean value and variance of postdoc salaries for each institution. Plotted against each institution in Figure 5(a), this metric confirms the increased variability observed in institutional postdoc salaries at institutions with lower funding [Figure 5(b)]. This variability may be due to lower numbers of postdocs at these institutions. The analysis was repeated for NSF R&D expenditures amounts and the results were comparable ((Appendix Figure A3)). These results, to a certain extent, indicate an inverse relationship between institutional NIH or NSF funding and postdoc salaries, which aligns with an NIH assessment that smaller institutions provide better benefits than larger ones. It is possible that those institutions with most funding may have least competition to attract postdocs, leading to a reduced pressure to provide competitive salaries. Future studies are needed to more thoroughly examine this relationship across all US institutions where postdocs are employed on these funding mechanisms.

NIH awards order	% grant $ in set	Postdoc #
1	12.06	1165
2	9.71	440
3	6.89	760
4	5	324
5	4.11	528
6	3.98	297
7	3.95	622
8	3.94	462
9	3.9	278
10	3.72	610
11	3.54	360
12	3.51	243
13	3.41	151
14	3.22	316
15	2.61	121
16	2.22	280
17	2.13	229
18	2.08	466
19	1.87	137
20	1.48	31
21	1.44	183
22	1.42	56
23	1.39	11
24	1.37	111
25	1.37	509
26	1.35	469
27	1.08	448
28	1.03	625
29	0.98	23
30	0.83	140
31	0.82	154
32	0.54	441
33	0.39	53
34	0.36	2
35	0.36	284
36	0.33	68
37	0.31	45
38	0.3	188
39	0.21	24
40	0.2	76
41	0.17	20
42	0.15	1
43	0.12	49
44	0.11	12
45	0.02	3

Note: "% grant $in set" denotes % of the total 2017 NIH institutional awards given to the 45 institutions with this available information

Table V.
Institutions ordered by total 2017 NIH awards, with number of postdocs

Discussion

Our studies show variability of postdoc salaries nationally based on institution, geographic region, gender, job title, and institutional funding. Data also show salaries trending with federal salary policy. While these studies are limited by the amount of data available and

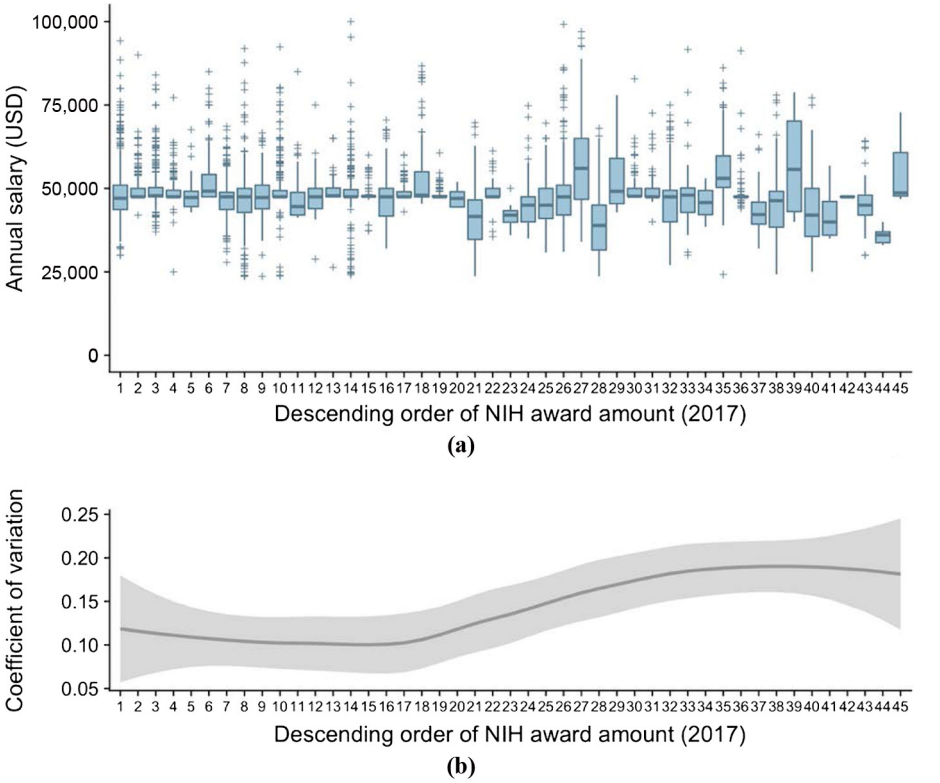


Figure 5.
Postdoc salaries as a function of ordered 2017 NIH institutional awards

Notes: Each institution is depicted numerically in the x-axis, in descending order of the total amount of 2017 NIH awards; (a) Boxplots of annual salary distribution by institution; (b) Smoothed (loess) line of the coefficient of variation (standard deviation/mean) of the salaries in each institution. The gray area denotes the 95% confidence intervals

provided to us from institutions, obtaining postdoc salaries through the FOIA mechanism indicates to an extent the availability and transparency of institutional postdoc data. This type of study could potentially be extended to asking similar questions related to other aspects of the postdoctoral position. More broadly, these studies aim to increase institutional data transparency to promote further comprehensive studies of the biomedical workforce.

We found that median salaries across institutions, as well as in a large proportion of individual salaries, were clustering in the $47,475-47,500 range. While limited in having only a single time point and not previous years' salary data for comparison, one of the major conclusions from these data is that the proposed FLSA salary threshold for overtime exemption as updated in 2016 ($47,476) (Bankston and McDowell, 2016), and the NIH NRSA Year 0 salary for FY 2017 ($47,484) (National Institutes of Health, 2016a, 2016b), had a major impact on determining the standard for postdoctoral salaries represented in our data set. The NIH stipend levels only apply to postdocs paid through specific NIH NRSA funding mechanisms and do not apply to all postdocs employed at US institutions where there is no federal mandate for annual salaries to be above $23,660. The proposed FLSA salary

threshold for overtime exemption was not implemented and yet is an extremely common postdoc salary. Thus, it is striking the potential effect that a now-defunct federal mandate, and benchmarking set by NIH through NRSA stipends, appear to have had on postdoc salary norms.

Delving more deeply into salary variability in our data set, we believe it is possible that some of the lower salaries may be due to means by which postdoc compensation is recorded, tracked and reported by individual institutions, but it is also possible that these amounts could reflect real annual salaries. This uncertainty regarding the small number of the very low reported salaries can only be resolved by institutions accurately collating and internally checking salary data. However, our analyses indicate that these lower salaries may not be attributed to postdocs in non-STEM fields, which may run counter to common assumptions that lower salaries across all fields may be due to disciplines such as the humanities (Appendix Figure A2).

In terms of the relationship between job titles and postdoc salaries, higher salaries in this data set may be due to clinical research fellows, those who have spent prolonged periods in the "postdoc pool" (Bourne, 2013), or simply inappropriate uses of postdoc titles for positions that are not actually postdocs, such as administrative staff and faculty. However, these higher salaries may also reflect pay of a subset of postdocs being compensated differently than the "traditional" postdoc, perhaps due to experience, cost of living or other factors, which may vary by institution, department or PI, or indeed the ability of an individual postdoc to negotiate a higher salary. Therefore, negotiation for higher salary may be an option utilized successfully by a subset of postdocs, and this warrants further study given the likely variation in the temperaments of postdoc and their PIs. It does not seem that higher salaries in general can be entirely due to simply the factors we describe above, although some of the most extreme salaries may well be these cases.

We were also intrigued to find that certain job titles from our data set could be correlated with salary data, which may indicate compliance to a certain policy regulation. With respect to specific titles, the term "trainee" could potentially be associated more closely with postdocs on NRSA fellowships, although this remains to be verified on a larger scale. The term "clinical" suggests higher salaries, whereas the "teaching" group data are slightly surprising given that teaching postdocs are not subject to the FLSA, if teaching is their primary duty, meaning their values may have been expected to be lower than what we find in this data set. However, the teaching postdoc population may also contain postdocs on NIH Institutional Research and Academic Career Development Awards fellowships who perform research 75 per cent of the time and so are subject to both the FLSA and to NRSA stipend requirements. A more thorough analysis of this "teaching" postdoc population is needed. Finally, the "intern" group (observed at only two universities, NC State and Purdue) is interesting, given that postdocs are not typically associated with this term, and this significantly affects their pay level.

Another conclusion is the gender-related discrepancy in postdoc salaries within the Northeast and South regions, but not in the West and Midwest. There is a strong representation of East Coast institutions in the Northeast and South regions, and this warrants further investigation into the systemic biases that affect the postdoc population, not least in light of the fact that elite labs exhibit a gender discrepancy in hiring (Sheltzer and Smith, 2014). This also raises the question of how multiple regional variables within institutions in the USA may affect postdoc salaries, and whether regional differences in salaries may be masked by overall national trends. Overall, more data are needed at both regional and national levels to interrogate this further. A recently published Life Science Salary Survey encompassing more than 2,500 life science professionals from around the

world showed very little difference between the salaries of men and women in US academia, and suggested that salary differences disappeared with more aggregated data (Mika, 2017). Whether aggregate data are however hiding disparities at local levels is a reason for greater investigation at the institutional level.

Given these findings, we call for a universal system by which institutions may better document postdoc salaries across the USA, enabling improved reporting generally on multiple aspects of the postdoctoral position. This includes and repeats our previous calls for better data on career outcomes tracking for both graduate students and postdocs (Polka *et al.*, 2015) and to harmonize postdoc job titles and administration (Schaller *et al.*, 2017). A model for institutional commitment to transparency that could be used in reporting postdoc salaries has been exhibited by the institutions committing to releasing data on graduate and postdoctoral populations as part of the Coalition for Next Generation Life Science (Blank *et al.*, 2017). More broadly, a higher amount of reliable institutional data on the postdoctoral position would allow early career researchers to make informed career decisions. A unified system for tracking and classifying postdocs could also extend to other aspects of the postdoctoral position, such as career-specific achievement metrics. Complete data sets on particular aspects of the postdoctoral experience may also aid in better training and support for postdocs both at the institutional and national levels.

Limitations and future directions

Our findings indicate that several factors contribute to the variability of US postdoc salaries. The largest barrier for our study is the quality and completeness of available institutional data and the ability or willingness of institutions to make their postdoc salary data public. Institutional barriers to maintaining and/or providing these data may also be related to nuances of institution-specific record keeping, the existence of a postdoc office at the time of data collection, or staff turnover in the individuals who have managed these data over time. Other limitations include the fact that not all institutions reported salaries for all postdocs at their institution, and the data were obtained from public institutions (with one exception).

To truly increase transparency on postdoc salaries across US institutions, future work should aim to include data from both public and private institutions in this analysis and to develop standardized data collection methods to enable other comprehensive analyses similar to this study. Due to these limitations, our data collection efforts constitute only a small portion of the total salary data (~14,000 postdocs), estimated at roughly 15-30 per cent of the postdoctoral workforce (Biomedical Research Workforce Working Group, 2012; National Science Foundation, 2015a; Pickett *et al.*, 2017; Schaller *et al.*, 2017) of the potential salary data available nationwide at universities. Also, our FOIA requests did not specifically ask for detailed demographic or other descriptive data, which further limited our ability to characterize the effect of multiple additional variables for postdocs receiving these salaries.

As we plan to repeat this data collection in the future to pursue longitudinal analyses, we may consider expanding data requests to include additional variables. The current data set does, however, offer insights into the capabilities of differing institutions to report data in a FOIA mechanism, presumably requiring staff unfamiliar with postdocs to communicate with other branches of institutional administration to obtain it. It was encouraging to see that some institutions were able to provide the exact data requested, and in the expected quantity. This indicates that some US institutions are able to accurately track and document their postdoc data, likely indicating an institutional commitment to the development of their postdocs. It also indicates that other institutions have the potential to do the same. We hope to see more institutions show this type of dedication in the future, and encourage both public and private institutions to consider making such data publicly available to the community

moving forward. We are also encouraging postdocs to self-report salary data at postdocsalaries.com, to help both current and potential postdocs to set realistic expectations.

The Ethnea/Genni algorithm used to assign gender is a predictive classification algorithm, and the possibility of a small proportion of false positive results cannot be excluded. In addition, it was not possible to assign gender to 28 per cent of the entries in the sample and these entries were discarded from the gender analysis. We found in particular that the algorithm had problems with Mandarin and Korean names, which seems to support general conventions that such names are not as obviously gendered as in other cultures. The 28 per cent of unassigned gender entries may roughly reflect the proportion of researchers from these backgrounds [33 per cent of the whole biomedical workforce are of Asian ethnicity, for example (Heggeness *et al.*, 2017)]. To validate the algorithm's accuracy, a "gold standard" classification would be necessary, e.g. if universities provided absolute gender information of their postdocs, but this information was neither requested by us nor provided to us. We do however posit that the error of the algorithm's predictions was not unacceptably high as:

- our male:female ratios agree with previous estimates; and
- our demographic is the same as that used for training the algorithm (i.e. published scientists).

Another limitation was not looking specifically at salaries of international postdocs working in US laboratories. We strongly encourage others asking such questions in this space to consider whether there are differences between salaries of USA and international researchers, which may shed light on additional barriers this population might face, for example as related to salary negotiation and potential exploitation of a workforce willing to take lower salaries. International researchers comprise approximately two-thirds of the US biomedical postdoc population (Garrison *et al.*, 2005) and more than half of the US biomedical workforce (Heggeness *et al.*, 2017). We also encourage specific consideration of researchers from underrepresented populations, to examine whether differences in postdoc salaries at institutions may arise due to these variables (Heggeness *et al.*, 2016; Heggeness *et al.*, 2017), which will similarly allow for more comprehensive studies of particular postdoc populations. The postdoc-to-faculty transition is a particularly resistant career transition point in efforts to diversify the professoriate (Gibbs *et al.*, 2016; Meyers *et al.*, 2018), and it is important to study how financial factors could be affecting this.

Overall, this work sheds light on the difficulty in reporting actual postdoc counts and salaries across US institutions. It is possible that postdoc pay could be inferred through institutional policies (e.g. general postdoc salary information can be deduced through institutional policies focusing on minimum salary; and general information on postdoc benefits in institutions can be concluded based on the number of postdocs classified into certain benefits-offering job codes). However, many factors likely contribute to determining postdoc salaries beyond institutional policies. Such factors may include: years of experience; the availability of laboratory funding; varying pay of postdocs across disciplines, or even within the same lab or department; postdoc pay based on varying funding mechanisms; and subjective decisions about what a postdoc "should" be paid, which are typically not verified against institutional policies. As postdocs tend to be hired by individual Principal Investigators, and not by institutions, variability in their salaries may exist within an institution in the absence of direct oversight. Differences in the recording and reporting of individual postdoc salaries within individual institutions will likely also contribute to the difficulty in discerning which factors affect the actual salary amounts. This is further complicated by the fact that the total number of postdocs in the USA is currently unknown

(Biomedical Research Workforce Working Group, 2012). In addition, counting postdocs in institutions can be difficult due to the varying means by which they are administered, handled and classified (Schaller *et al.*, 2017; Pickett *et al.*, 2017). Our focus on postdoc salaries illustrates the ability of institutions to provide accurate data on particular aspects of the postdoctoral position. We encourage institutions to increase transparency in relation to postdoc pay, as we have urged for other aspects of the postdoc experience, to give postdocs greater agency when making career decisions.

Author contributions

Gary Steven McDowell conducted the FOIA requests, collected the data and performed preliminary analyses. Rodoniki Athanasiadou analyzed the data, made the figures and wrote relevant paper sections. Rodoniki Athanasiadou, Adriana Bankston, McKenzie Carlisle, Caroline A. Niziolek and Gary Steven McDowell contributed to writing and editing the paper. The final version was approved by all authors.

Acknowledgements

This study was supported by the Open Philanthropy Project and, where needed, these funds were used also to cover the cost for FOIA requests. Open Philanthropy had no role in the design or undertaking of this work. The authors thank Future of Research advisory board member, Dr Sarah Hokanson, for providing postdoc salary data from the only private institution in this data set (Boston University). The authors are also very grateful to those at institutions who have sent data or discussed this data collection effort and clarified issues that were encountered with the data. The authors also thank members of the Future of Research Board of Directors for helpful discussions on this paper. Finally, the authors would particularly like to acknowledge Drew Doering of the University of Wisconsin Madison, who created a plot of postdoc salaries nationwide and shared the code with the scientific community.

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Corresponding author
Gary S. McDowell can be contacted at: garymcdow@gmail.com

Appendix

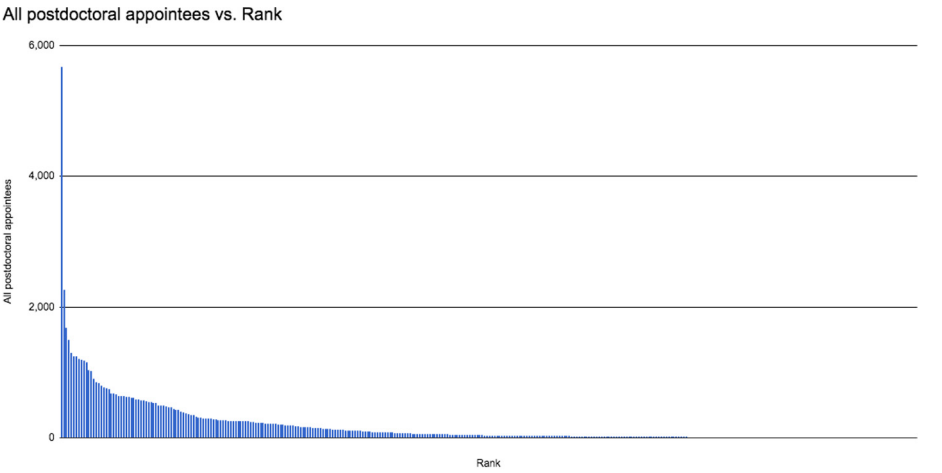
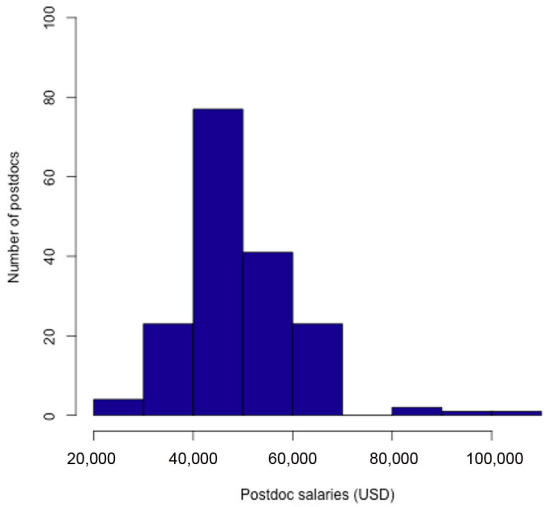
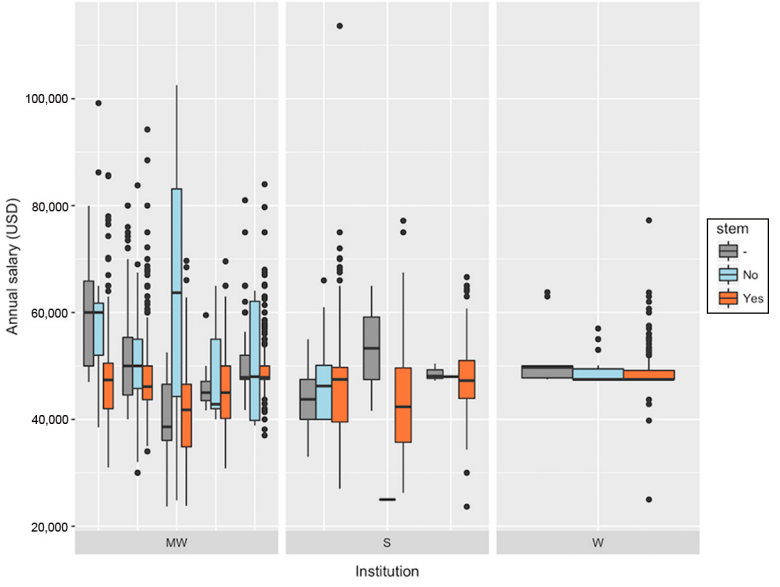


Figure A1.
Number of science, engineering and health postdocs across US institutions, ordered from highest to lowest number of postdocs, in 2015

Notes: The threshold of 300 science, engineering and health postdocs that was included in the FOIA request is shown here. Data are from the NSF GSS. Each bar represents an individual institution



(a)



(b)

Notes: (a) Distribution of salaries for postdocs in non-STEM disciplines; (b) comparison of salary ranges between postdocs in STEM and non-STEM disciplines for ten institutes with the relevant departmental information organized by region. MW = Midwest, S = South, W = West (no relevant data were available from the NE region). Legend: No = non-STEM, Yes = STEM. - = insufficient information to unambiguously classify the department

Figure A2.
Salaries for non-STEM postdocs

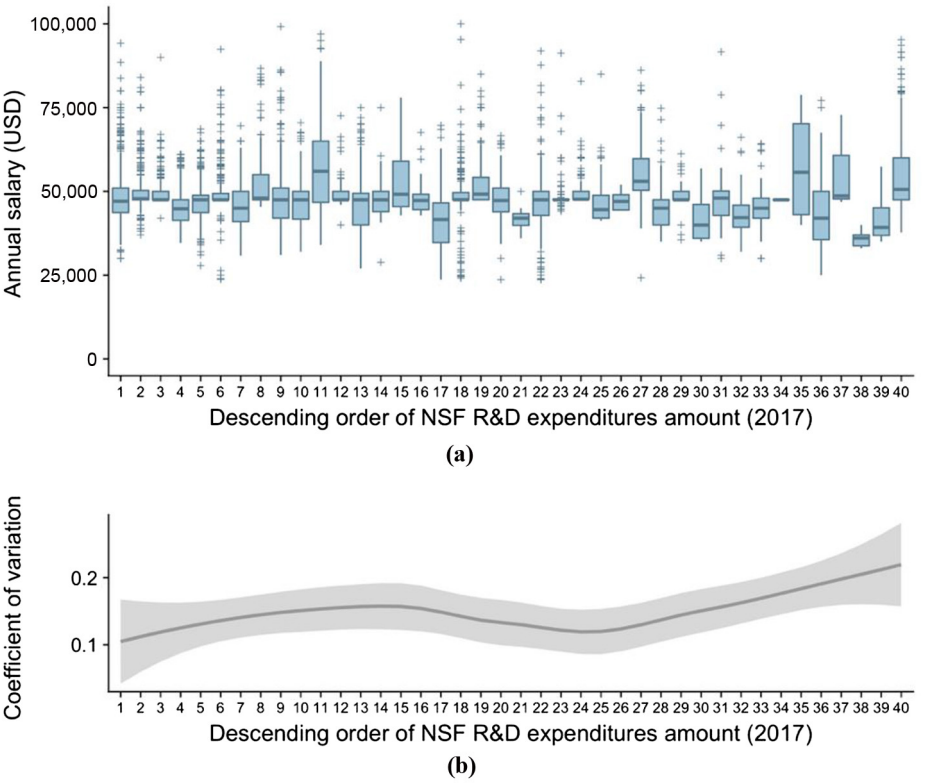


Figure A3.
Postdoc salaries as a function of ordered 2017 NSF institutional R&D expenditures

Notes: (a) Boxplots of annual salary distribution by institution; (b) Smoothed (loess) line of the coefficient of variation (standard deviation/mean) of the salaries in each institution. The gray area denotes the 95 per cent confidence intervals

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