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THE RISE OF TEAMWORK AND CAREER PROSPECTS IN ACADEMIC SCIENCE

Mabel Andalón
Catherine de Fontenay
Donna K. Ginther
Kwanghui Lim

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ABSTRACT

Teamwork has become more important in recent decades. We show that larger teams generate an unintended side effect: individuals who finish their PhD when the average team in their field is larger have worse career prospects. Our analysis combines data on career outcomes from the Survey of Doctorate Recipients with publication data that measures team size from ISI Web of Science. As average team size in a field increased over time, junior academic scientists became less likely to secure research funding or obtain tenure and were more likely to leave academia relative to their older counterparts. The team size effect can fully account for the observed decline in tenure prospects in academic science. The rise in team size was not associated with the end of mandatory retirement. However, the doubling of the NIH budget was associated with a significant increase in team size. Our results demonstrate that academic science has not adjusted its reward structure, which is largely individual, in response to team science. Failing to address these concerns means a significant loss as junior scientists exit after a costly and specialized education in science.

Mabel Andalón
Melbourne Business School
University of Melbourne
200 Leicester Street
Carlton, VIC 3053
Australia
and IZA
andalon.mabel@gmail.com

Catherine de Fontenay
Melbourne Business School
University of Melbourne
200 Leicester Street
Carlton, VIC 3053
Australia
c.de.fontenay@unimelb.edu.au

Donna K. Ginther
Department of Economics
University of Kansas
333 Snow Hall
1460 Jayhawk Boulevard
Lawrence, KS 66045
and NBER
dginther@ku.edu

Kwanghui Lim
Melbourne Business School
200 Leicester Street
Carlton, VIC 3053
Australia
k@kwanghui.com

Introduction

Career prospects for young people pursuing a career in academic science are increasingly grim (1-5). Tenure-track positions have stagnated relative to non-tenure-track positions (6, 7). The probability of obtaining a tenured position and enough funding for a laboratory of one's own has declined sharply (8). In 1998 a commission of the National Research Council described a "growing crisis in expectation that grips young life scientists who face difficulty achieving their career objectives" (9), and the crisis has worsened and spread to other fields since then (5, 6).

It has proved difficult to identify the causes of such a broad-based and long-term trend. Some point to policy changes such as the elimination of mandatory retirement, which cause senior academics to remain in their roles for longer, leaving fewer openings for young academics to be promoted (10, 11, 12).

At the same time that career prospects have worsened, science has become more specialized and also more collaborative (13). Research teams have grown larger (14, 13); as an indicator, the average number of authors per paper has increased from 2.12 in 1970 to 4.06 in 2004 (15).

While the prevalence and impact of teams on science contributions and productivity have been investigated in the literature, no studies have examined the impact of increasing team sizes on careers. Interestingly, theoretical work by de Fontenay et al. (16) suggests that if team sizes increase in a field, young scientists' careers may suffer. When scientists work in larger teams, the contribution of each team member becomes more difficult to assess, and it becomes more difficult for universities and funding agencies to identify promising junior scientists (17). Consequently, more of the available funding may shift toward senior scientists. Furthermore, the

‘Matthew effect’ (18) could imply that young scientists’ achievements are attributed to senior members of their team, leading to more rewards flowing to senior scientists.

We pose the empirical question: how much of the decline in young academics’ career prospects is due to increasing team size in their field, and how much is due to other factors? We run a regression on career outcomes at the individual level to control for any changes in the characteristics of young scientists (such as whether the scientist obtained their PhD from a top-ranked school). The team size regressor is average team size in one’s field at time of graduation.

It is natural to ask why we are not using individual team size (the size of the teams that the individual has been part of) in that regression. Doing so would give the wrong answer. When rewards are for relative performance rather than absolute, measuring individual-level variables can be misleading. For example, consider a national exam that is graded on a Bell curve, or that ranks students relative to each other. Any regression of individual-level hours studied on individual performance in the exam will show a strong positive effect; but it would be obviously incorrect to infer that if all students studied more, their performance would improve relative to one another. A multi-year regression of individual performance on the average hours that students studied in their exam year would show no effect.

The analogy to Bell curves is an apt one in this case. A regression of an individual’s career success on the size of teams she published with would be likely to show a strong positive effect. Having more co-authors significantly raises citations and the likelihood of receiving funding (19). Teamwork leads to higher academic productivity in science (20), medicine (21), and social science (22-24), with obvious benefits for one’s career. The literature has shown that smaller teams tend to disrupt science and larger teams are associated with the development of existing ideas (25). Probing this result further, the organization of teams also matters; flat teams innovate whereas hierarchical teams develop (26). Multi-university teams are growing in prevalence and produce higher impact papers (27). But rewards in science are largely about relative performance within one's field, not absolute. Therefore, the impact of an individual's team size on productivity will not be included in a regression of career success on average team size in the field (28). But the regression will still pick up the "noisy signals" effect that young scientists' abilities are harder to determine relative to established senior scientists in their field. Thus, we test the theoretical prediction that an increase in average team sizes in a field has a negative impact on young scientists in that field (16).

Results

Our analysis examines academic career outcomes of US-trained Ph.D. graduates in Science, Engineering and Health (SEH) fields working in the US (29). We use nationally representative, longitudinal, biennial data from the Survey of Doctorate Recipients (SDR) from the National Science Foundation (NSF), which tracks Ph.D. graduates from Ph.D. completion until age 76 (30). Our focus will be on understanding the association between the average team size at the time of graduation on subsequent career outcomes. Using the SDR has the advantage of understanding career outcomes for all scientists. Studies that identify individual teams based on the subset of scientists who continue to write research papers will, by definition, miss most of those who leave academic careers. Thus, using publication data to study the "noisy signal" effect would produce biased results.

Sample

Our sample consists of 10 cohorts of SDR respondents who earned a Ph.D. in 217 SEH fields that are part of the seven broad fields of life science, physical science, social science, health, psychology, math and computer science, and engineering. Our survival analysis follows these individuals from their graduation (specifically, from the survey date within three years of their graduation) through to 2013, using 18 waves of SDR data collected between 1973 and 2013 (31). Hence, the first cohort in our data, which consists of individuals who graduated in 1969, is followed for up to 44 years from 1973 to 2013 and the last graduating cohort is followed for up to 9 years from 2004 to 2013. In our main analysis, we further restrict the sample to Ph.D. graduates who started in academia, (those who responded that they were in academia at any time in the first six years after their doctorate) (32).

Our measure of team size is based on publication data from the core collection of Web of Science (WoS). We used the data from the Science Index covering over 8,850 journals across 179 subject categories and the Social Sciences Index covering over 3,200 journals across 56 categories. We have 11 years of team size data from 1970 to 2004. To combine the SDR individual-level data with the WoS team size data we created a cross-walk between Ph.D. fields in the SDR data using the Survey of Earned Doctorates (SED) classification and subject categories in the Web of Science data (33).

Following Wuchty et al. (15), we measure team size as the weighted average number of authors in all papers published in the individual's Ph.D. field f circa the graduation year y (between 1969 and 2004) (34). We use weights because some Ph.D. fields were matched to more than one WoS subject category. The weights are the proportion of papers in each subject category that the Ph.D. field was matched with (35). On average, team size was 1.8 in 1970 and increased to 3.6 in 2004. Supplementary Table S.1 reports the changes in team size by Ph.D. field, ordered by broad science field, and Figure 1 shows the evolution in selected broad fields.

Importantly for the predictive power of our estimation, team size did not evolve smoothly across fields.

Data on career outcomes from the SDR confirm that outcomes are deteriorating over the same period that team size is increasing.

Tenure-track positions

Junior scientists hope to secure a tenure-track position to run their own lab (1-5). Figure 2, which reports on outcomes 10-12 years after the doctorate, compares those who graduated at the beginning of our sample, 1969-74 (who we refer to as the 70s), with those graduating at the end of our sample, in 1995-2004 (who we refer to as the 90s). The figure shows a decline in the share of scientists employed as academic tenure stream in every science field with the exception of Health. The decline was most evident in the Life Sciences, with a 15 percentage point decrease.

Many of the tenure-track positions have been replaced by academic non-tenure track jobs (e.g. postdocs, lecturers and research scientists). For all science fields, the share of all academics who are employed in tenure-track roles 10-12 years after graduation fell from 39.6% to 27.1%, but the share employed in academic non-tenure-track roles increased from 7.4% in the 70s to 14.4% in the 90s.

Tenure

Achieving tenure is a milestone in an academic career as it is a near guarantee of professional stability (4). Supplementary Table S.2 shows that the share of all academics with tenure declined from 53% in 1997 to 47% in 2013 and the percentage of early career researchers with tenure decreased from 37% in 1997 to 27% in 2013. The only exception is computer sciences, where the share of academics with tenure increased from 45.5% in 1997 to 57.1% in 2013.

Research funding

There is a close connection between the decline in tenure-track and tenured positions and the decline in funding success. The SDR does not have data on whether a scientist receives any grants as principal investigator (PI), but asks respondents whether any of their work during the previous year was supported by contracts or grants from the U.S. government. We use this information to construct a proxy for receiving a grant as PI by interacting "receiving government support" with having a tenure-track job.

In Supplementary Figure S.1 the average age of funded scientists has increased over time, from people in their 30s in the 1970s to over 50 in most science fields. This increase of more than a decade cannot be driven by longer completion times for PhDs, which have not increased by more than 1 year in the SDR. This is similar to the trend for NIH-funded scientists reported in Blau and Weinberg (10); Levitt and Levitt (36) (Figure S.2).

Exiting academia

The lack of career prospects in academia may induce young researchers to leave academia. We estimated the share and counts of those who exited from academia by field 10-12 years after the completion of the doctorate in Supplementary Figure S.3 for doctorates who graduated in 1973 and 2003. Exit rates have increased strongly in Life Sciences but have decreased slightly in some fields.

Using SDR data at the individual level, we estimate whether the team size in a student's field at the time of graduation affects the probability that: 1) the individual was employed in a tenure-track or tenured academic position; 2) the individual was employed in a tenured academic position; 3) the individual exited academia; 4) the individual worked in a field outside of their science degree (as a proxy for exiting science); and 5) the individual was a PI and supported by contracts or grants from the U.S. government (as a proxy for whether the individual receives research funding as a PI). We estimate both probit models and Cox proportional hazard models for these outcomes.

Our models include controls for demographic characteristics such as gender, race, marital status, number of children and foreign-born. We interact field team size with females and foreign-born, allowing for the possibility that junior scientists from those demographic groups are more likely to be impacted by field team size. We control for the quality of the university from which the scientist graduated by matching the university's rank in terms of NSF funding within that Ph.D. field and year (37). We also control for graduation year fixed effects to allow for the possibility that both team size and tenure rates have increased over time for exogenous reasons. Finally, we include measures of broad field of study within each cohort, to control for potential differences in the demand for scientific fields over time.

The Impact of Team Size on Careers

Figure 3 graphs the hazard ratio (HR) of the association between field team size and outcomes of interest, with pointwise 95% confidence intervals. Estimation results appear in Table S.4-S.8. One can interpret (1-HR)*100 as the percentage change in the outcome that is associated with a one-author increase in team size. The estimates in Figure 3 suggest that having one more author per paper in an individual's Ph.D. field is associated with a (1-.75)*100 = 25% lower probability of obtaining a tenure track appointment ($p<.05$); a 28% reduction in the likelihood of obtaining tenure ($p<.05$), and 11% reduction in obtaining federal research funding ($p<.05$). Given the importance of tenure as a career milestone and the stiff competition among academics for funding, these are important effects. Given that field team size has increased by 1.8 authors from

1970 to 2004, the implication is that the increase in field team size more than explains the average decline in tenure prospects that graduates have experienced over this period.

There is no statistically significant effect of field team size on the probability of exiting academia, at least for men. This indicates that people are either taking longer postdoctoral appointments or ending up in non-tenure track positions. However, team size is associated with a 6% increase in the probability of exiting science entirely ($p<.05$), measured by taking a job outside of one's scientific field.

We repeat this analysis using the entire sample of science and social science doctorates, meaning that we do not restrict the sample to having started their careers in the academic sector. We do not estimate the probability of exiting academia because this sample does not necessarily start their career in academia. As shown in Table S.9, one more author per team in a scientist's field implies that individuals are 24.3% less likely to hold a tenure-track (or tenured) job, 29.1% less likely to receive tenure, 11.4% less likely to receive federal funding and 10.7% more likely to leave science (all estimates $p<.01$). As with the academics-only sample, increasing average team size can more than account for the observed average decline in tenure prospects.

The impact of team size on women and the foreign-born.

If output is published by larger teams, the publication record contains less information on the individual's ability, particularly for younger unproven individuals. It is rational for funding agencies to channel more funding toward established scientists, in response (16).

Poor information also raises the likelihood of bias, as the inferences drawn about an individual scientist's quality may be affected by the decision-maker's priors. There is the bias in favor of established scientists, known as the Matthew effect (18), which tends to attribute a high-quality paper to the best-known scientist on the project. There are also traditional biases that can be detrimental to women and to foreign-born scientists. The evidence as to how important such biases are in funding and promotion processes is mixed (38, 39).

Our hypothesis would suggest that increasing team sizes would be particularly harmful to women scientists and to foreign-born scientists as there is more risk of bias toward those demographic groups, in the absence of reliable information. The data confirm that increasing team sizes have been more harmful on women and foreign-born. Supplementary Tables S.4 to S.8 provide the full set of results for the Cox hazard model. They indicate that one more author per paper lowers the likelihood that a woman holds a tenure-track or tenured job by 5.6% ($p<.05$); this is in addition to the 24.8% lower likelihood for all scientists. We do not find a significantly lower probability of women getting tenure, however. Women are also 5.5% ($p<.05$) less likely to receive federal funding, and 6.4% ($p<.05$) more likely to leave academia. Foreign-born scientists are 5.1% less likely to hold a tenure-track or tenured appointment, 8% less likely to obtain tenure, and 6.7% less likely to receive funding (all at the $p<.05$) if there is one more author per paper in their field; again, this is in addition to the effects for all scientists described above. We do not find a significantly larger likelihood that foreign-born will exit academia, however.

Alternative Explanations for the Effect of Team Size

It is important to account for major changes in policy, to see if they are driving our results, with the most notable policy being the end of mandatory retirement for academics in 1994. We also consider the impact of the doubling of the NIH budget (40).

It is possible that our team size effects are simply the manifestation of mandatory retirement; however, our evidence indicates that this is unlikely. Figure 1 shows no change in the trend in team size post 1994. We analyze this further in Supplementary Table S.10, which shows the percentage change in team size from 1970 to 1992, and from 1992 to 2004 by broad science field. Overall, team size grew by over 46% from the 1970s to the early 1990s, whereas it grew by 24% after the end of mandatory retirement. In the computer science, social science, and health fields, team size grew more rapidly after mandatory retirement. However, in all remaining fields much of the growth in team size occurred before mandatory retirement.

We estimated the hazard model separately for the sub-samples who graduated before and after mandatory retirement in Supplementary Table S.11. For all outcomes, the magnitude of the team size estimate is larger before mandatory retirement than afterwards. Figure 4 visually demonstrates that the slope of the relationship between team size and exit rates is flatter after mandatory retirement. These results suggest that mandatory retirement might exacerbate the career crisis (by increasing the likelihood that graduates leave academia and reducing the likelihood that they obtain a tenure track job), but it does not explain the team size effect that we find.

Next, we examine the impact of the NIH doubling on overall team size. Between 1998 and 2003, the NIH budget doubled in real terms (40). However, funding for other science fields remained constant. Much of the NIH budget funds basic biomedical sciences. The NIH doubling could have reduced team size if more researchers were funded during that time. We test whether team size is smaller in cohorts graduating in basic biomedical fields during the years of the NIH doubling (1998-2003) and with a three-year lag (2000-2006). We graph the team size coefficients from these difference-in-difference regressions comparing biomedical fields to all science fields and to life science and chemistry fields in Figure S.4. In our preferred specification, where the effect of the NIH doubling was lagged three years, team size in basic biomedical fields increased by 0.55 ($p<.001$) people relative to all other science fields. When we compare to only life science fields and chemistry, team size increased in basic biomedical fields by nearly 0.42 people ($p<.012$). These results show that the doubling of the NIH budget was associated with an increase in team size in biomedical fields.

Discussion

Our evidence suggests that increases in average team size worsen the career prospects of scientists. Following 10 cohorts of science and social science graduates over time, we found that as team size at the time of graduation increased across fields and time, individuals were less likely to take tenure track jobs, receive tenure and receive federal research funding. In addition, these individuals were more likely to leave academia and their scientific field. Surprisingly, the estimated impact of team size is able to account for the entire decline in tenure prospects for young scientists over this period.

We examined whether mandatory retirement explains this effect of team size and found that team size had a strong effect on career outcomes well before mandatory retirement. Mandatory retirement did increase the likelihood of exiting academia as well as reducing the likelihood of having a tenure track job. However, mandatory retirement did not change the effect of team size on receiving federal funding, receiving tenure and leaving one's science field.

We also examined the association between the doubling of the NIH budget and team size. While the likelihood of obtaining funding increased in biomedical fields, so did team size. Indeed, in Figure 2 we observed that the largest decline in academic positions occurred in Life

Science fields. The NIH has raised concerns about the effect of funding being concentrated in the hands of few (likely older) scientists (41). However, the focus was on the number of grants received by individual PIs and not on the size of labs.

There are theoretical explanations for why the careers of junior scientists might suffer when larger teams become the norm: it becomes more difficult for funding agencies and universities to be confident in the abilities of young scientists working in teams (16). As a result, less funding goes to junior scientists and more funding and rewards end up being allocated to well-established scientists. The shift in funding away from junior scientists has led to concern that funding agencies may suffer from bias (for example the Matthew effect, which attributes young scientists' achievements to senior scientists on their team Merton (18)), and we do find some that female and foreign-born scientists have worse career outcomes. It has also led to policies that allocate some funding exclusively for young scientists. But it is possible that funding agencies are not highly biased and are mostly responding to the reduced information now available on younger scientists.

Some may argue that this is the result of an excess supply of graduate students relative to the demand for tenure-stream faculty. However, recent work demonstrates that 80% of faculty were trained at less than 28% of research universities (42). Given this high concentration of hiring, if anything, the supply of doctorates from these elite institutions may outstrip the demand.

Future research should consider how NIH policies such as those designed to fund early-stage investigators or the K99/R00 awards have impacted science careers and the total output of science. While some prizes and awards exist to encourage junior researchers, these are often ex-post and awarded only to the few, and schemes to identify and support junior researchers are unevenly spread across universities and research institutions. That said, understanding how team size affects information about individual research contributions is a topic for future research. Likewise, young scientists may want to diversify their research projects or work on smaller teams in order to highlight their research contributions. More generally, academic science has not adjusted its reward structure, which is largely individual, in response to a production technology which has become team-based (43). Failing to address these concerns means a significant loss as junior scientists exit after a costly and specialized education in science, and/or fail to achieve their full potential by facing funding and promotion constraints

Data Sharing

The Survey of Doctorate Recipients restricted use data are available by submitting an application to the National Center for Science and Engineering Statistics. Information on how to submit the application is available here: https://ncses.nsf.gov/about/licensing. All code used to create the data and perform the analysis will be archived and made available to researchers who have obtained a license to the SDR data. Researchers interested in the code should contact Donna Ginther (dginther@ku.edu).

Author Contributions:

Conceptualization: MA CdF DG KL

Methodology: MA DG

Investigation: MA DG

Visualization: MA DG

Funding acquisition: CdF KL

Project administration: CdF KL DG

Supervision: CdF DG

Writing – original draft: MA CdF DG KL

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28. The current literature on team size examines individual research teams measured by collaborations on research papers (25,26). This approach is not possible using the Survey of Doctorate Recipients because we do not observe individual publications or the number of authors on those publications.

29. SEH fields include life sciences, computer and information sciences, mathematics and statistics, physical sciences, psychology, social sciences, engineering and health.

30. We use the restricted SDR. The sampling frame is drawn from the Survey of Earned

Doctorates (SED), which is a census of all individuals in the United States at or near the time of receipt of the doctoral degree.

31. The SDR eliminated two-thirds of its longitudinal sample after 2013, so the analysis ends with that survey year.

32. In the SDR academics are U.S. doctorate holders employed at 4-year colleges or universities, medical schools, or university research institutes

33. Data sources and methods are described more fully in the supporting material appendix.

34. So, for example, individuals who graduated between 1969 and 1972 are assigned the team size in their field of PhD in 1970.

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Figures and Tables

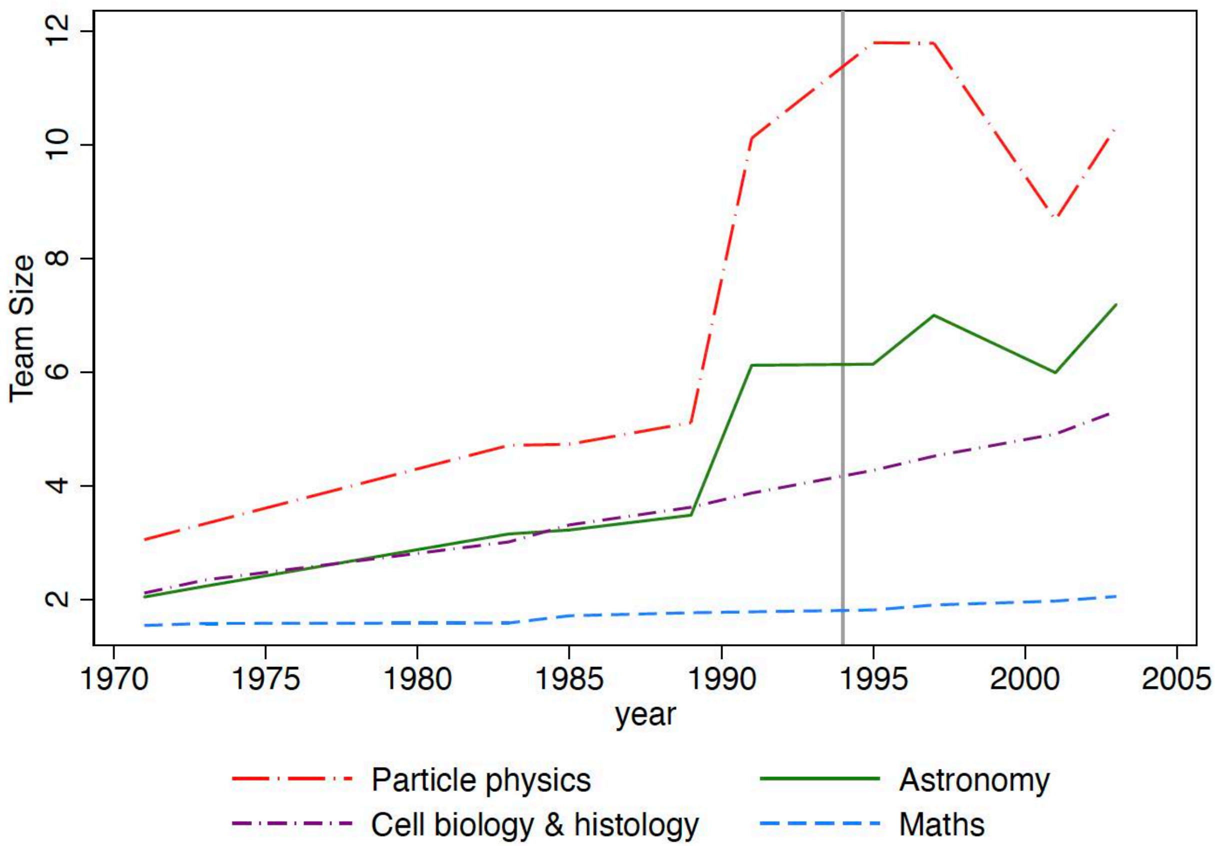

Figure 1: Evolution of team size in selected Ph.D. fields.

Note: Source Web or Science 1970—2004.

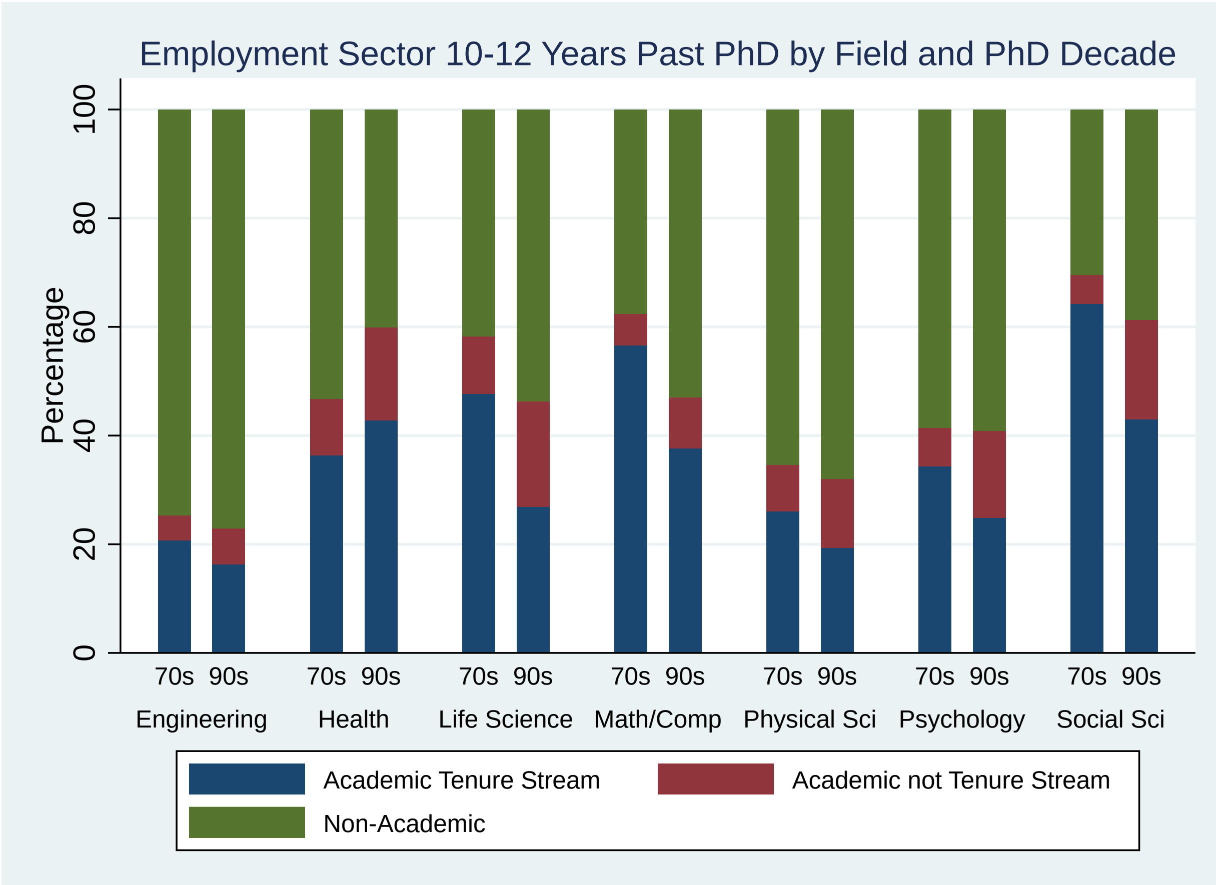

Figure 2: Percent of Doctorates by Employment Sector, 1969-74 (70s) and 1995-2004 (90s).

Note: Academic Tenure Stream include tenure track and tenured faculty. Academic Non- Tenure Track includes postdocs and lecturers. Government/Other includes employment in the non-profit sector.

Source: Authors' calculations, Survey of Doctorate Recipients.

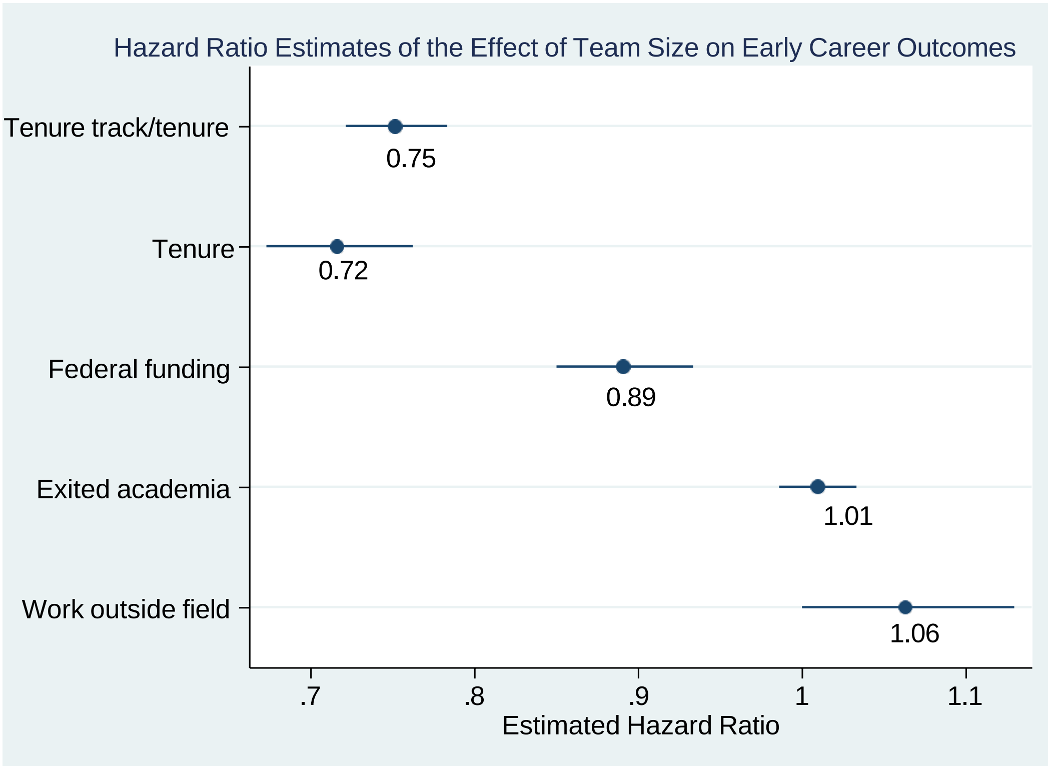

Figure 3: Hazard Ratio Estimates of the Effect of Team Size on Career Outcomes.

Note: Estimates using 1973—2004 Survey of Doctorate Recipients. Each hazard ratio is estimated by a separate model for each outcome and shown with 95% confidence intervals.

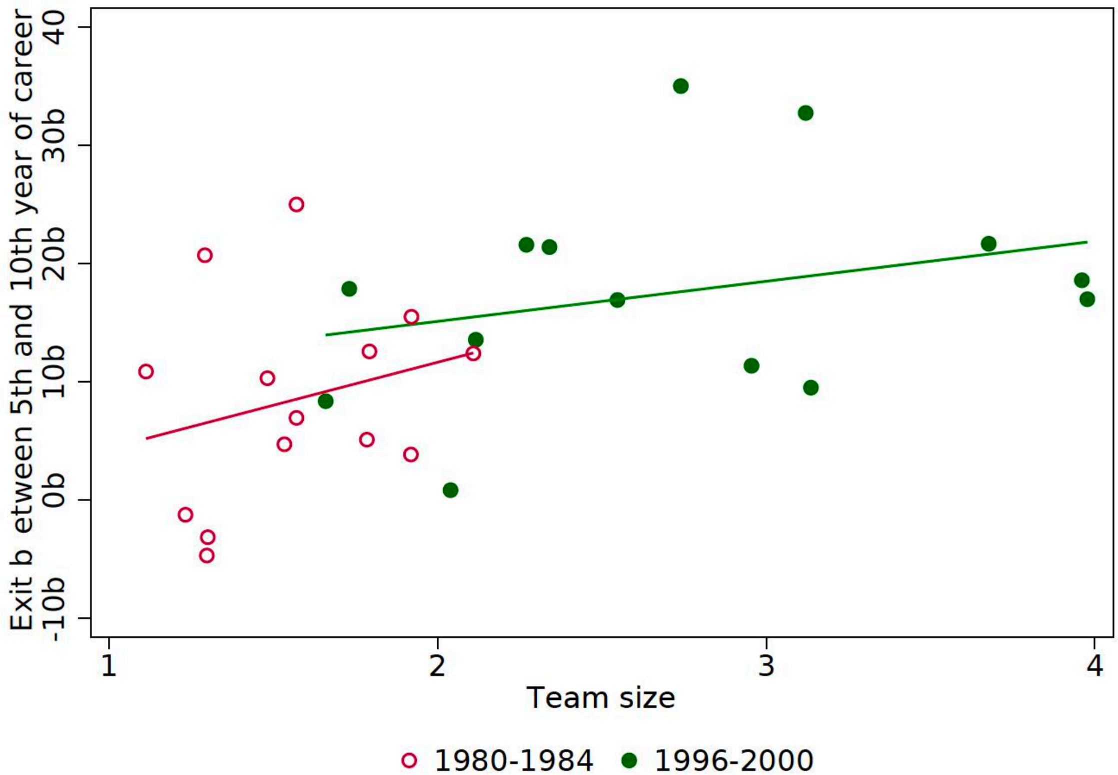

Figure 4: Exits from Academia between 5th and 10th year of Career by Team Size, Before and After Mandatory Retirement.

Note: Sources--Survey of Doctorate Recipients and Web of Science.

Supplementary Materials for

The Rise of Teamwork and Career Prospects in Academic Science

Authors: Mabel Andalón[1]*, Catherine de Fontenay[2], Donna K. Ginther[3], Kwanghui Lim[4]

This file includes:

Supplementary Materials

Materials and Methods

In this supplemental appendix we provide a description of how the data were developed, describe the methods used in the analysis, and provide additional estimation results.

A.1 Data Sources

Our analysis links the Survey of Doctorate Recipients (SDR) individual-level data on academic career outcomes with team size data from Web of Science (WoS). We linked the two datasets, creating a cross-walk between 217 Ph.D. fields in the SDR data and 235 subject categories in the WoS data.[1] For a match to occur, the Ph.D. fields and the WoS subject areas had either (nearly) identical names or very similar descriptions. For example, the PhD field of "Agricultural Engineering" was matched with the WoS category "Agricultural Engineering" based on the name and, additionally with the WoS category "Applied Microbiology", based on their descriptions.

The total number of Ph.D field and WoS subject category matches was 458: each Ph.D. field was matched with one or more WoS subject categories. Also, all 235 subject categories were matched with at least one of the 217 Ph.D. fields. 150 Ph.D. fields (61%) were matched to one WoS subject category only and 94 Ph.D. fields were matched to two or more. Less than 4% of fields were matched to four or more WoS categories.

As some Ph.D. fields were matched to more than one WoS subject category, following Wuchty et al. (15), we measure team size as the weighted average number of authors in all papers published in the individual's Ph.D. field circa the graduation year. The weights are the proportion of papers in each subject category that the Ph.D. field was matched with.

Table S.1 shows the Survey of Earned Doctorates (SED) PhD fields and associated change in team size between 1970-2004.

A. 2 Methods

We estimate the effect of team size on academic career outcomes using the Cox proportional hazard model with time varying-covariates. The model estimates the likelihood each year of a career outcome such as obtaining tenure, given that the individual has survived untenured until that point. We also estimated probit models for the likelihood of experiencing these outcomes 10-12 years after the Ph.D., as a robustness check for the hazard analysis.

$$h(t)_{icfb} = \lambda_0 exp(\delta + \beta TS_{cf} + \alpha_c + \gamma_b + \lambda Xi' + \varepsilon_{icfb}) \qquad (1)$$

[1] In the SDR, Ph.D. fields that are part of the broad fields of Life and Physical Sciences, Engineering and Social Sciences, are based on the Survey of Earned Doctorates (SED) classification.

There are five different regressions, and thus $h(t)_{icfb}$ represents the five different outcomes of interest for individual i in Ph.D. graduation cohort c from field f and broad field b.[2] The outcomes are indicator variables for whether: 1) the individual was employed in a 'tenure stream' position, meaning a tenure-track or tenured academic position; 2) the individual was employed in a tenured academic position; 3) the individual exited academia; 4) the individual worked in a field outside of their science degree (a proxy for exiting science); and 5) the tenure-track or tenured individual was supported by contracts or grants from the U.S. government in the year before the date of the interview (this is a proxy for whether the individual receives research funding as a PI).

The main explanatory variable in equation (1) is average team size in the scientist's chosen field, TS_{cf}, which is measured by the number of authors per paper in the individual's Ph.D. field f, in the year the individual in cohort c graduated.[3] The specification is unbiased if average team size in a field is uncorrelated with other unobserved factors that affect the scientist's career outcomes. One possible threat to this assumption is field-specific changes in outside options. For example, an increase in team size in a given field might also worsen employment options for junior scientists outside academia, if their academic standing affected their outside job options for some reason. If this was the case, we would expect a downward bias in the estimated effect of field-specific team size on the four career outcome variables.

All specifications also include cohort fixed-effects α_c, which allow for the possibility that both team size and exit rates have increased over time, exogenously. For example, cohort fixed-effects capture demand side shocks in the academic labor market affecting all fields at the same time. There are also field fixed effects: γb are seven indicators for broad field of Ph.D. (the omitted category is life sciences). The inclusion of these broad field indicators is intended to control for omitted variable biases that might arise due to the potential correlation between field of Ph.D. and both team size and the scientist's career outcomes, if some fields have innately different team sizes and career outcomes.

In Model 2, X_i is a vector of individual characteristics that includes indicators for gender, age, race, foreign-born, marital status, and whether they have children. Model 3 adds the rank (in terms of federal research funding) of the university from which the scientist graduated. We expect that adding individual characteristics to the specification will not statistically affect estimates, as they should not be correlated with team size, but they will improve precision. We also interact average team size with female and foreign-born, allowing for the possibility that the effect of field team size is stronger (or weaker) for those demographic groups.

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[2] Our sample spans 10 cohorts of individuals who graduated in 217 Ph.D. fields that are part of the seven broad fields of life science, physical science, social science, health, psychology, math and computer science, and engineering.

[3] It is the year the doctoral student graduated, or the year before or after.

Model 4 includes indicators for the type of job the Ph.D. scientists held in their first academic position: postdoc or tenure-track appointment. We view these as mediator variables. In particular, team size at the time of graduation is likely to influence the scientist's first job and that in turn would affect mid-career outcomes, such as the likelihood of obtaining tenure. We thus expect that the coefficient on team size will be reduced when the 'first job' variables are added to the regression as the 'first job' variables will capture the indirect effect of team size on career outcomes. Finally, Model 5 includes interactions between broad field of Ph.D. and cohort years to control for potential differences in the demand for scientific fields over time. In our empirical analysis, we focus on the results in model 3.

Supplementary Text

A. 3 Empirical Results of the Impact of Team Size on Academic Careers, Descriptive statistics and Estimates of First Job.

Table S.2 shows the tenure status of U.S. trained doctorates employed in academia 1997 and 2013. The share tenured dropped in every field except for computer science.

First, we analyzed the impact of average team size on the first job an SDR respondent reports.[4] Table S.3 reports on probit estimation with three different outcomes: the probability of the first observed job being in the academic sector, the probability that job is a tenure track position, and finally the probability that job is a postdoc. In addition to controlling for team size, we include measures of demographic characteristics, broad science field, funding rank of the institution, and cohort dummies. All coefficients are marginal effects evaluated at the means. We find that increasing team size is associated with a slight 0.7 percentage point (ppt) increase in the likelihood of being employed in the academic sector. (However, as team size increases, females are 1.9 ppt less likely to be employed in the academic sector whereas the foreign-born are 1.2 ppt more likely.) Although the effect of team size on academic employment is slightly positive, the type of academic employment significantly shifts. As team size increases in a field, the likelihood of the first job being in a tenure track position falls by 7.8 ppt. There is no significant additional effect of team size on females, but increasing team size decreases the likelihood that a foreign-born scientist is employed on the tenure track by an additional 1.3 ppt. Many of those starting in academia end up as postdocs. As team size increases, the likelihood of the first job being a postdoc increases by 3 ppt. There is no additional effect of team size for females, however increasing average team size reduces the likelihood that a foreign-born scientist takes a postdoc by 1.1 ppt.

Hazard Model of the Effect of Team Size on Academic Career Outcomes. Supplementary Tables S.4 to S.8 contain the full set of results for the Cox proportional hazard model. As a robustness check, the final column in these tables includes the marginal effect of team size on outcomes after 10-12 years in a probit model. The hazard ratio for team size is less than one and statistically significant in the hazard model for obtaining a tenure-track (or tenured) appointment, and for obtaining tenure. This suggests that larger average team

[4] This probit was estimated for respondents whose first job was observed within six years of receiving the Ph.D.

size in a field is associated with a lower probability of getting a tenure-track or tenured appointment, and a lower probability of obtaining tenure. The hazard ratio for exiting academia is not statistically significant for men, but women in larger teams are significantly more likely to exit academia, as indicated in table S.7. The hazard for exiting science is significantly greater than one: a larger field team size at the time of graduation is associated with a higher probability of taking a job outside of one's scientific field – our measure of exiting science altogether. These estimates from Model 3 suggest that one more author per paper in the individual's field of Ph.D. lowered the probability of getting a tenure-track/tenured position by 24.8% ((0.752-1)*100) and the probability of obtaining tenure by 28.4%. A one-author increase in team size decreased the probability of receiving federal funding by 10.9% and increased the probability of taking a job outside the Ph.D. field by 6.3%.

The results in tables S.4 to S.8 also indicate that certain individuals face worse career prospects, independently of the effect of team size. In particular, female academics are less likely to receive federal funding, less likely to be employed in a tenure-track or tenured position, and more likely to exit academia. Asian and Pacific Islander individuals were less likely to hold a tenure-track or tenured appointment and more likely to exit academia than whites. But outcomes are more favorable for black academics than for whites.

<u>*Direct and Indirect Effects of Team Size on Academic Career Outcomes.*</u> The effect we are trying to capture — that scientific fields with larger changes in team size reduce the chances of scientists to secure funding and tenure and encourages them to exit academia and their field of Ph.D. — is likely to partially operate through the type of job the graduate is able to obtain. Controlling for first job variables would allow us to isolate the indirect effect that team size has through its effect on the type of first job from the direct effect that team size has on subsequent career outcomes. When adding the first job variables in column (4) of tables S.4 to S.8, the coefficient on team size at the time of graduation on career outcomes measures the direct effect on outcomes, which is smaller than the total effect, as expected. For example, while the total effect of team size on getting tenure is a 27.7% lower hazard (column (1)), the direct effect is 12.2% lower hazard for men and an additional 5.4% lower hazard for women (column (4)).

Surprisingly, holding a postdoc as one's first academic job leads to worse outcomes than a non-tenure track appointment. Relative to a non-tenure-track appointment, holding a postdoc as the first academic job increases the probability of exiting academia and reduces the probability of obtaining funding, and of obtaining a tenure-track or tenured position.[5]

Column (5) of tables S.4 to S.8 includes broad field by cohort interactions. The results do not appreciably change from column (4).

[5] This is an underestimate of the individuals who take postdocs after completing the Ph.D. because it usually takes 1 or 2 years after graduation for a person to be included in the SDR sample. Many respondents may have completed a postdoc before being included in the SDR. Kahn and Ginther (2017) discuss the challenges of measuring postdocs.

Next, in tables S.4 to S.8, column (6), we estimate the impact of team size on each outcome after 10-12 years, using a probit that includes cohort and field fixed effects, with the same explanatory variables as the hazard model reported in column (1). Thus, for example, in Table S.4 we report marginal effects of team size evaluated at the mean on the probability that an individual has a tenured or tenure-track job after 10-12 years. As with the Cox hazard model, larger team size negatively affects the likelihood of obtaining a tenure-track role, obtaining tenure, and receiving federal funding; and larger team size positively affects the likelihood of exiting academia. Its effect on exiting science is positive but not statistically significant.[6]

Specification checks: Full sample of scientists. We repeat this analysis using the entire sample of science and social science doctorates, meaning that we do not restrict the sample to those having started their careers in the academic sector. This is our second approach to allowing for broad changes in the PhD market. We do not estimate the hazard of exiting academia, given that this sample does not necessarily start in academia. In our preferred specification, of Table S.9, individuals are 24.3% less likely to start in a tenure track job, 29.1% less likely to receive tenure, 11.4% less likely to receive federal funding and 10.7% more likely to leave science.

Robustness checks: Mandatory Retirement and the NIH doubling

Table S.10 shows the percentage change in team size from 1970 to 1992, and from 1992 to 2004 by broad science field. Overall, team size grew by over 46% from the 1970s to the early 1990s, whereas it grew by 24% after the end of mandatory retirement. The only fields where team size grew more rapidly after mandatory retirement were computer science, social science, and health fields. We also estimated the hazard models for the sub-samples who graduated before and after mandatory retirement in Table S.11. For all outcomes, the magnitude of the team size estimate is larger before mandatory retirement than afterwards.

To examine the impact of the NIH doubling on team size, we estimated a difference-in-difference (DID) model where team size is regressed on basic biomedical fields and all other science fields are the control group. We estimated two different time periods in this model. First, contemporaneous team size was measured for the years of the NIH doubling (1998-2003). Second, we measured the effect with a three-year lag (2000-2006). This model estimates the change in team size during the NIH doubling in biomedical fields, relative to science fields less likely to be funded by NIH. In basic biomedical fields, team size increased by 0.42 ($p<.001$) people relative to the control group of all other science fields during the NIH doubling using the contemporaneous measure. When we lag the impact of NIH funding for three years, team size increased by .55 ($p<.001$). When we limit the control group to other life sciences and chemistry, team

[6] Additional model specifications, which are not reported in tables S.4 to S.8 but are available on request, explore probit models that account for individual characteristics, the quality of the PhD and first job variables. As in the case of hazard models, the inclusion of these variables hardly changes the estimated coefficient on team size.

size increased in basic biomedical fields by nearly 0.35 people ($p<.012$) after lagging NIH funding by three years.

Fig. S1.

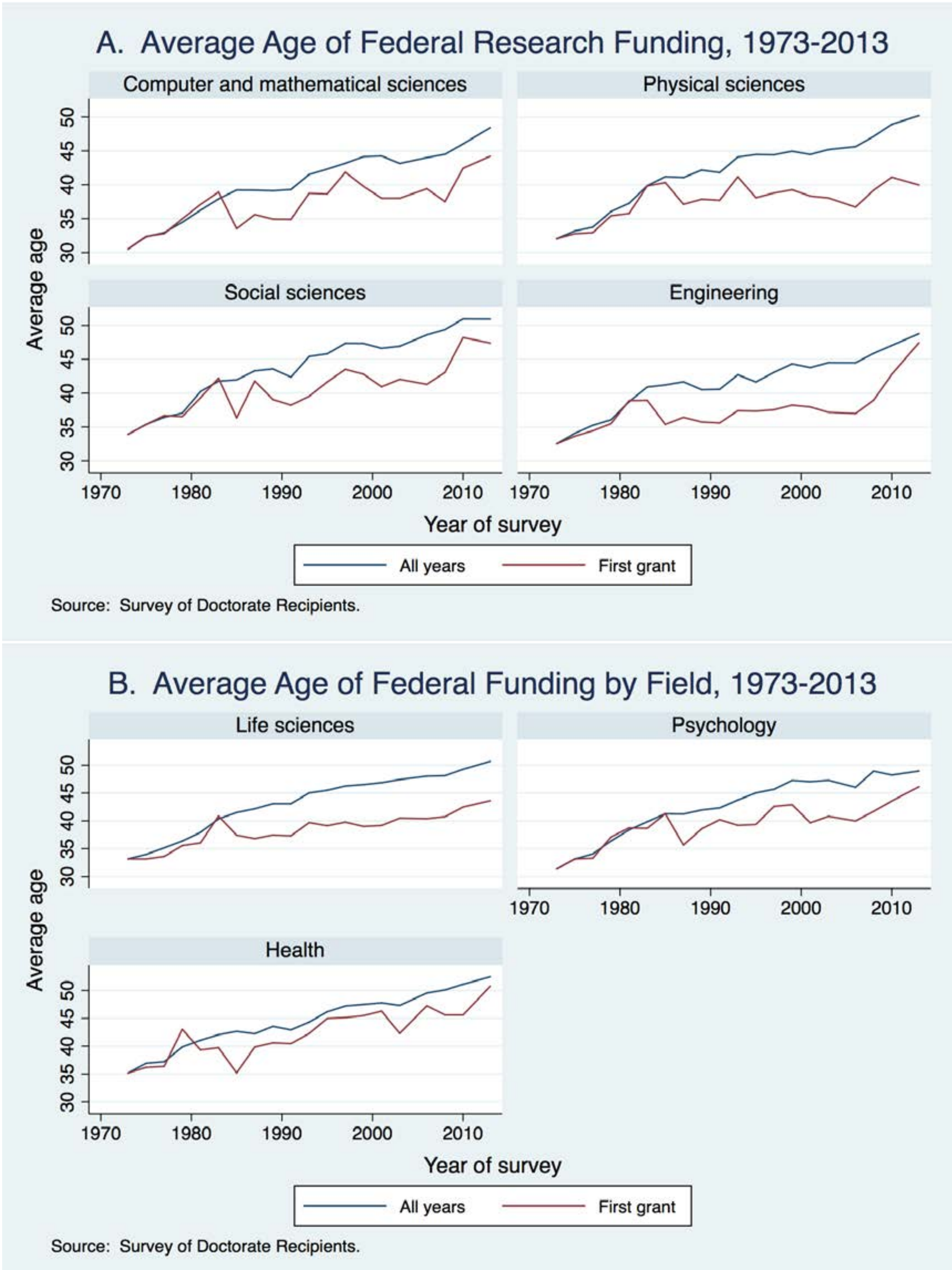

Fig. S.1: Average age of full-time faculty with federal funding.

Note: Source: Survey of Doctorate Recipients 1973-2013. The blue line reports the average age of tenured or tenure-track faculty reporting government support (our proxy for research funding). The red line reports the average age the first time a faculty member reported government support.

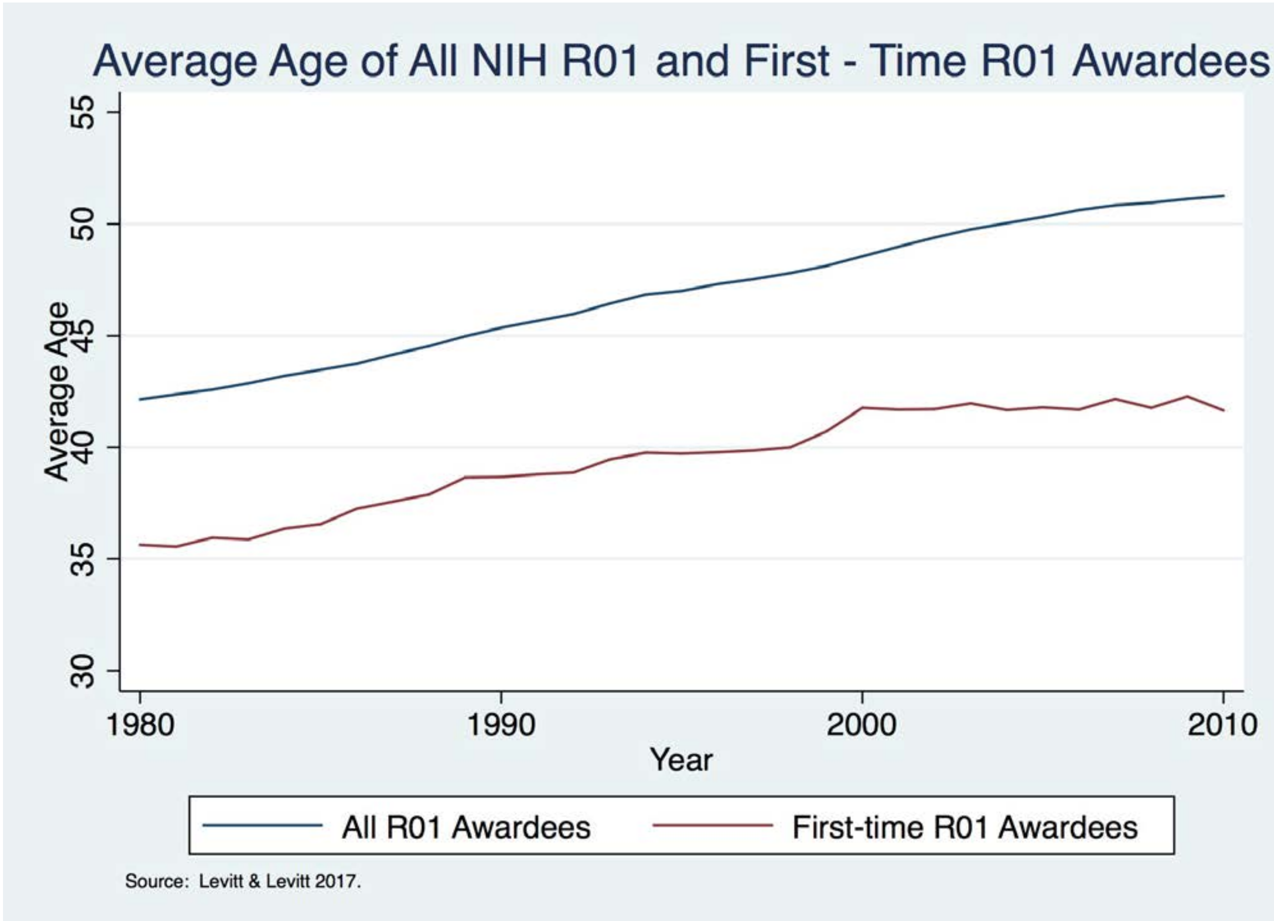

Fig. S.2: Average Age of NIH R01 Awardees and First-time R01 Awardees

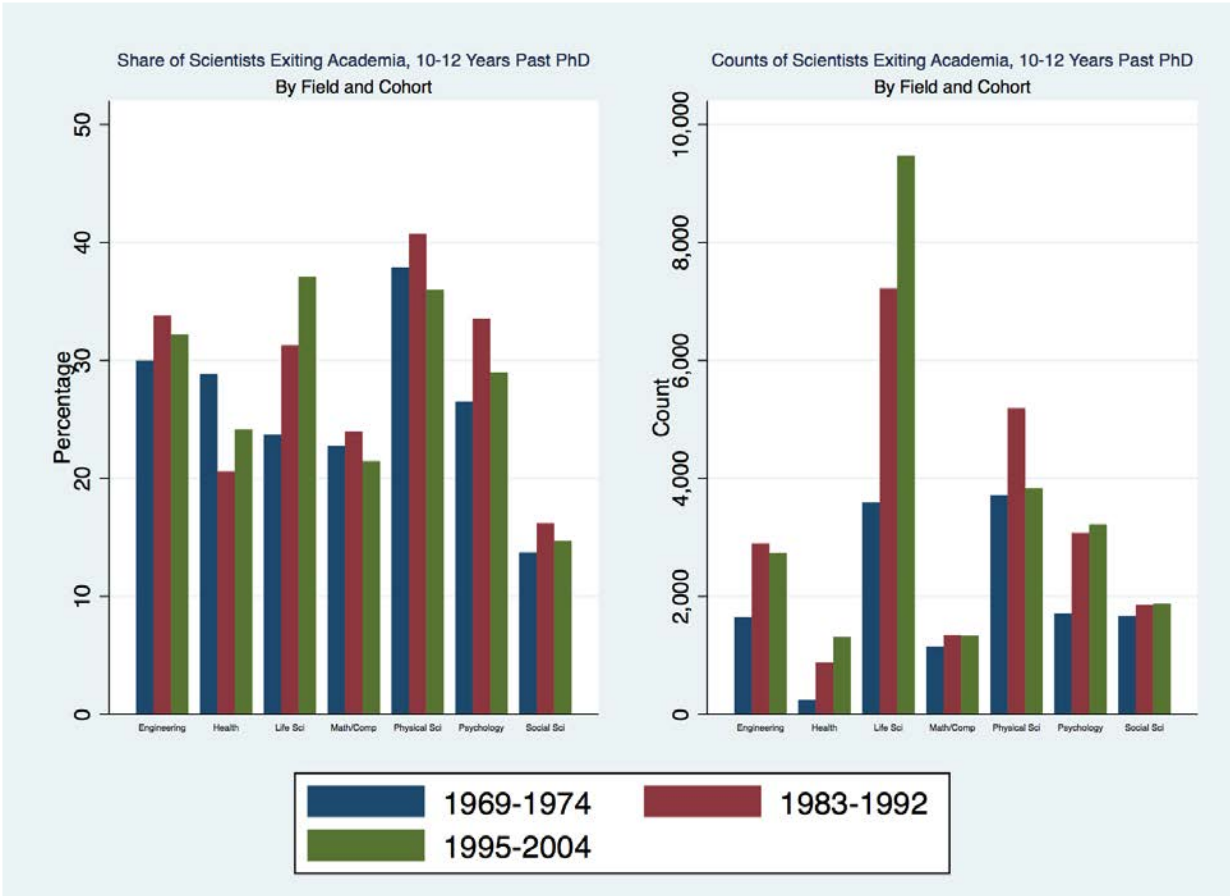

Fig. S.3: Percent and Count of Doctorates who exited academia by broad field and cohort years.

Note: All individuals were observed starting in academic employment. The employment sector was measured 10-12 years past Ph.D. Source: Authors' calculations, Survey of Doctorate Recipients.

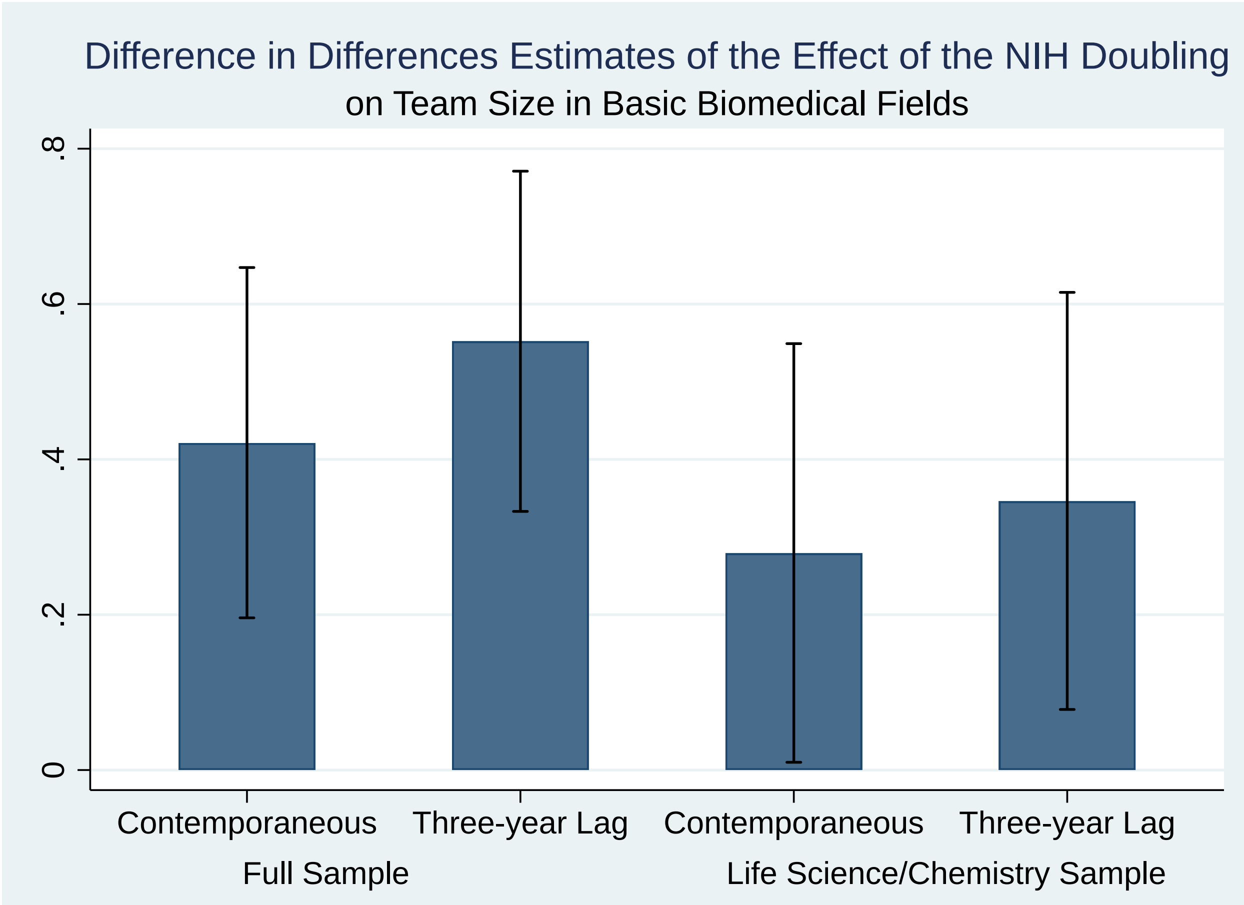

Fig. S.4: Difference-in-Differences Estimates of the Effect of NIH Doubling on Team Size in Basic Biomedical Sciences with 95% confidence intervals.

Note: In the full sample all other science fields are the control group. In the second estimates Life Science/Chemistry fields are the control group.

Table S.1: Increase in field team size (average number of authors per paper) between 1970 and 2004, by PhD field and broad field

SDR Field	PhD field	SED Code	TS Change
Biological, agricultural, and environmental life sciences	Biomedical Sciences	103	0.82
	Forest Engineering	68	1.22
	Wood Science & Pulp/Paper Technology	72	1.38
	Zoology	189	1.43
	Entomology	148	1.43
	Evolutionary Biology	137	1.58
	Biometrics & Biostatistics	133	1.59
	Computational Biology	104	1.59
	Bioinformatics	102	1.59
	Biology/Biomedical Sciences, General	198	1.60
	Forestry Science	65	1.61
	Wildlife/Range Management	80	1.61
	Forest/Resources Management	70	1.61
	Forestry & Related Science, Other	79	1.61
	Wildlife Management	60	1.61
	Forest Sciences and Biology	66	1.61
	Ecology	139	1.65
	Soil Sciences	45	1.66
	Soil Chemistry/Microbiology	46	1.66
	Soil Sciences, Other	49	1.66
	Hydrobiology	140	1.72
	Fish & Wildlife	54	1.74
	Natural Resources/Conservation	74	1.75
	Physiology, Human & Animal	185	1.82
	Agriculture, General	98	1.83
	Animal Science, Poultry (or Avian)	14	1.85
	Food Sciences and Technology, Other	44	1.91
	Food Sciences	40	1.91
	Food Distribution	42	1.91
	Dairy Science	12	1.92
	Environmental Science	580	1.94

Continued on next page

Table S.1 – continued from previous page

SDR Field	PhD field	SED Code	TS Change
	Environmental Science	81	1.94
	Animal & Plant Physiology	186	1.96
	Animal Science, Other	19	1.99
	Botany/Plant Biology	129	2.01
	Animal Husbandry	7	2.02
	Food Science	43	2.05
	Fishing and Fisheries Sciences/Management	55	2.06
	Environmental Toxicology	167	2.06
	Agricultural Science, Other	99	2.07
	Biotechnology	107	2.09
	Plant Pathology/Phytopathology	120	2.17
	Plant Sciences, Other	39	2.17
	Plant Physiology	125	2.17
	Nutrition Sciences	163	2.19
	Plant Protect/Pest Management	32	2.21
	Agronomy & Crop Science	20	2.25
	Anatomy	130	2.27
	Biology/Biomedical Sciences, Other	199	2.29
	Animal Nutrition	10	2.34
	Horticulture Science	50	2.35
	Agricultural Animal Breeding	5	2.39
	Toxicology	169	2.39
	Neurosciences	160	2.49
	Microbiology	157	2.54
	Pharmacology, Human & Animal	180	2.54
	Agricultural & Horticultural Plant Breeding	25	2.55
	Biophysics	105	2.61
	Biochemistry	100	2.66
	Structural Biology	155	2.76
	Plant Genetics	115	2.76
	Molecular Biology	154	2.79
	Parasitology	166	2.87
	Endocrinology	145	2.88

Table S.1 – continued from previous page

SDR Field	PhD field	SED Code	TS Change
	Microbiology & Bacteriology	156	2.92
	Developmental Biology/Embryology	142	3.04
	Pathology, Human & Animal	175	3.15
	Plant Pathology/Phytopathology	30	3.15
	Cell/Cellular Biology and Histology	136	3.20
	Bacteriology	110	3.25
	Genetics/genomics, Human & Animal	170	3.26
	Genetics	171	3.46
	Virology	168	3.61
	Immunology	151	3.65
	Cancer Biology	158	4.17
Computer and mathematical sciences	Mathematics/Statistics, General	498	0.51
	Topology/Foundations	455	0.51
	Algebra	425	0.51
	Geometry/Geometric Analysis	435	0.51
	Number Theory	445	0.51
	Analysis & Functional Analysis	430	0.51
	Logic	440	0.58
	Applied Mathematics	420	0.65
	Computing Theory & Practice	460	0.80
	Mathematics/Statistics, Other	499	0.95
	Operations Research	930	0.96
	Statistics	450	1.01
	Statistics	690	1.01
	Operations Research	363	1.21
	Operations Research	465	1.21
	Computer Science	400	1.42
	Information Science & Systems	410	1.45
	Computer & Information Science, Other	419	1.54
	Robotics	415	1.96
Engineering	Naval Architecture & Marine Engineering	354	-0.49
	Ocean Engineering	360	0.55
	Petroleum Engineering	366	0.67

Table S.1 – continued from previous page

SDR Field	PhD field	SED Code	TS Change
	Textile Engineering	375	0.68
	Engineering Management & Administration	376	0.81
	Engineering, General	398	0.98
	Systems engineering	372	0.99
	Computer engineering	321	1.07
	Engineering Science	333	1.13
	Communications Engineering	318	1.21
	Mechanical engineering	345	1.31
	Chemical engineering	312	1.33
	Structural Engineering	316	1.34
	Civil Engineering	315	1.34
	Polymer & Plastics Engineering	369	1.42
	Aerospace, Aeronautical & Astronautical Eng.	300	1.44
	Industrial & Manufacturing Engineering	339	1.48
	Metallurgical Engineering	348	1.66
	Bioengineering & Biomedical Engineering	306	1.84
	Mining & Mineral Engineering	351	1.88
	Electrical Engineering	322	1.90
	Electronics Engineering	323	1.90
	Electrical, Electronics & Communications Eng.	324	1.90
	Ceramic Sciences Engineering	309	2.00
	Environmental Health Engineering	336	2.09
	Agricultural engineering	303	2.21
	Materials Science Engineering	342	2.32
	Engineering Mechanics	327	2.35
	Engineering, Other	399	2.37
	Engineering Physics	330	2.40
	Nuclear Engineering	357	3.77
Health	Kinesiology/Exercise Science	222	1.22
	Nursing Science	230	1.26
	Speech-Language Pathology & Audiology	200	1.47
	Environmental Toxicology	211	1.65
	Rehabilitation/Therapeutic Services	245	1.82

Table S.1 – continued from previous page

SDR Field	PhD field	SED Code	TS Change
	Veterinary Sciences	250	1.91
	Environmental Health	210	2.03
	Hospital Administration	224	2.07
	Health Systems/Services Administration	212	2.07
	Health Sciences, General	298	2.08
	Oral Biology/Oral Pathology	207	2.09
	Dentistry	205	2.09
	Medicinal/Pharmaceutical Sciences	240	2.34
	Public Health	215	2.39
	Epidemiology	220	2.52
	Medicine & Surgery	225	2.67
	Optometry & Ophthalmology	235	2.68
	Gerontology	227	2.80
	Health Sciences, Other	299	2.88
	Public Health & Epidemiology	219	2.90
Physical sciences	Mechanics	567	1.05
	Fuel Technology & Petroleum Engineering	547	1.13
	Applied Geology / Geological Engineering	555	1.30
	Paleontology	546	1.39
	Polymer Physics	572	1.44
	Thermal Physics	573	1.47
	Mineralogy/Petrology/Geological Chemistry	549	1.48
	Acoustics	560	1.53
	Hydrology & Water Resources	585	1.55
	Theoretical Chemistry	534	1.56
	Geological and Earth Sciences, General	558	1.56
	Atomic/Molecular/Chemical Physics	561	1.59
	Physical Chemistry	530	1.64
	Chemistry, General	538	1.64
	Mineralogy & Petrology	548	1.65
	Geophysics (solid earth)	545	1.74
	Geochemistry	542	1.74
	Geophysics & Seismology	544	1.74

Table S.1 – continued from previous page

SDR Field	PhD field	SED Code	TS Change
	Physics, Other	579	1.75
	Geological and Earth Sciences, Other	559	1.75
	Analytical Chemistry	520	1.75
	Organic Chemistry	526	1.75
	Marine Sciences	595	1.75
	Oceanography, Chemical and Physical	590	1.76
	Polymer Chemistry	532	1.77
	Geology	540	1.79
	Stratigraphy & Sedimentation	550	1.79
	Geomorphology & Glacial Geology	552	1.79
	Optics/Phototonics	569	1.81
	Atmospheric Science/Meteorology, General	518	1.84
	Electromagnetism	563	1.85
	Ocean/Marine, Other	599	1.86
	Nuclear Chemistry	524	1.90
	Inorganic Chemistry	522	1.90
	Agriculture & Food Chemistry	521	1.94
	Applied Geology	554	1.97
	Fluids Physics	566	2.02
	Plasma/Fusion Physics	570	2.02
	Condensed Matter/Low Temperature Physics	574	2.19
	Atmospheric Science/Meteorology, Other	519	2.24
	Chemistry, Other	539	2.27
	Electron Physics	562	2.30
	Atmospheric Physics and Dynamics	512	2.35
	Meteorology	514	2.35
	Atmospheric Chemistry and Climatology	510	2.35
	Applied Physics	576	2.40
	Medicinal/Pharmaceutical Chemistry	528	2.41
	Physics, General	578	2.42
	Medical Physics/Radiological Science	577	2.56
	Biophysics	565	2.61
	Theoretical Physics	575	3.39

Table S.1 – continued from previous page

SDR Field	PhD field	SED Code	TS Change
	Astronomy & Astrophysics	506	5.15
	Astronomy, Other	509	5.15
	Astrophysics	505	5.15
	Astronomy	500	5.15
	Nuclear Physics	568	6.15
	Particle (Elementary) Physics	564	7.27
Psychology	Psychometrics and Quantitative Psychology	633	0.75
	School Psychology	636	0.98
	Educational Psychology	822	0.98
	Educational Psychology	618	0.98
	Psychometrics	630	0.99
	Personality Psychology	624	1.04
	Social Psychology	639	1.04
	Experimental/Comparative & Physiological Psy.	616	1.12
	Industrial & Organizational Psy.	621	1.22
	Counseling	609	1.22
	Psychology, General	648	1.28
	Human Engineering	619	1.34
	Physiological/Psychobiology	627	1.37
	Comparative Psychology	606	1.37
	Experimental Psychology	615	1.39
	Cognitive Psychology & Psycholinguistics	603	1.58
	Developmental & Child Psychology	612	1.64
	Family Psychology	620	1.87
	Clinical Psychology	600	1.87
	Human Development. & Family Studies	613	1.87
	Psychology, Other	649	1.90
Social sciences	History, Science and Technology and Society	710	0.19
	American/U.S. Studies	770	0.24
	International Relations/Affairs	674	0.27
	Political Science & Government	678	0.32
	Sociology	686	0.35
	Political Science / Public Administration	679	0.38

Table S.1 – continued from previous page

SDR Field	PhD field	SED Code	TS Change
	Social Sciences, General	698	0.55
	Urban Affairs/Studies	694	0.63
	Area/Ethnic/Cultural/Gender Studies	652	0.64
	Demography/Population Studies	662	0.69
	Economics	667	0.74
	Econometrics	668	0.78
	Linguistics	676	0.88
	Public Policy Analysis	682	0.91
	Criminology	658	0.92
	Agricultural Economics	0	1.08
	Geography	670	1.35
	Social Sciences, Other	699	1.37
	Anthropology	650	1.55
	Archaeology	773	1.55
	Gerontology	684	2.25

Table S1.
Source: Own calculations based on Web of Science data.

Table S2.
Tenure status of US-trained doctorate holders employed in academia

Field	1997	2013
All fields	52.6	46.8
Engineering	58.6	49.0
Life	43.6	38.3
Physical	50.7	47.0
Psychology	50.4	42.1
Social	63.0	58.1
Computer	45.5	57.1
Mathematical	70.3	61.6
Early career researchers (7 to 10 years since doctorate)	37.0	27.0

Table S.3. Probit Estimates of First Job Outcomes

	(1) Academic job	(2) Tenure track job	(3) Academic postdoc job
Team size			
	0.007*	-0.078***	0.030***
	(0.004)	(0.005)	(0.002)
Black	0.044***	0.084***	-0.042***
	(0.011)	(0.010)	(0.006)
Hispanic	0.037***	0.066***	-0.019***
	(0.011)	(0.010)	(0.006)
Native American	-0.004	0.068***	-0.039***
	(0.028)	(0.026)	(0.014)
Asian or Pacific Islander	-0.049***	-0.063***	0.021***
	(0.008)	(0.006)	(0.005)
Multiple race or other	0.045	0.019	-0.000
	(0.030)	(0.026)	0.018)
Married	-0.022***	0.016**	-0.030***
	(0.007)	(0.006)	(0.004)
Has children	-0.029***	0.006	-0.033***
	(0.007)	(0.006)	(0.004)
Female	0.065***	-0.012	-0.003
	(0.014)	(0.013)	(0.009)
foreign-born	-0.005	-0.006	0.086***
	(0.016)	(0.015)	(0.012)
Female * team size	-0.019***	-0.000	0.000
	(0.005)	(0.005)	(0.003)
Foreign-born * team size	0.012**	-0.013**	-0.011***
	(0.005)	(0.006)	(0.003)
PhD Inst. Top 50	0.043***	0.038***	0.024***
	(0.008)	(0.006)	(0.005)
PhD Inst. Ranked 51-100	0.027***	0.044***	0.016***
	(0.009)	(0.008)	(0.006)
PhD Inst. Ranked 101-150	0.026**	0.043***	0.005
	(0.010)	(0.009)	(0.007)
PhD. Inst. Ranked 151-200	-0.005	0.050***	-0.010
	(0.013)	(0.012)	(0.008)
PhD Inst. Ranked above 200	-0.046***	0.021	-0.029***
	(0.016)	(0.015)	(0.009)
Observations	45,847	45,847	45,847

Table S.4: Impact of Field Team Size on Getting Tenure Track/Tenure Appointment for Sample that Started in Academia

	Hazard ratios					Probit Coefficients
	(1)	(2)	(3)	(4)	(5)	(6)
Team Size	0.723***	0.723***	0.752***	0.878***	0.871***	-0.180**
	(0.014)	(0.014)	(0.016)	(0.016)	(0.016)	(0.014)
Black		1.296***	1.291***	1.073**	1.071**	
		(0.041)	(0.041)	(0.035)	(0.036)	
Hispanic		1.177***	1.177***	1.085***	1.097***	
		(0.039)	(0.039)	(0.034)	(0.034)	
Native American		1.289***	1.286***	1.173*	1.176*	
		(0.120)	(0.119)	(0.105)	(0.105)	
Asian or Pacific Islander		0.814***	0.817***	0.854***	0.859***	
		(0.023)	(0.023)	(0.023)	(0.024)	
Multiple race or other		0.843*	0.839*	0.913	0.911	
		(0.080)	(0.079)	(0.077)	(0.078)	
Married		1.032	1.031	0.991	0.991	
		(0.026)	(0.026)	(0.021)	(0.021)	
Has Children		0.924***	0.925***	0.917***	0.916***	
		(0.021)	(0.021)	(0.018)	(0.019)	
Female		0.863***	0.983	1.016	1.000	
		(0.014)	(0.046)	(0.049)	(0.049)	
Foreign-born		0.885***	0.997	0.883**	0.908*	
		(0.020)	(0.057)	(0.051)	(0.052)	
Team size * female			0.944***	0.946***	0.952**	
			(0.019)	(0.018)	(0.018)	
Team size * foreign-born			0.949**	1.017	1.001	
			(0.022)	(0.022)	(0.021)	
PhD Inst. Top 50			0.954*	0.938**	0.908***	
			(0.023)	(0.024)	(0.024)	
PhD Inst. Rank 51-100			0.963	0.921***	0.893***	
			(0.026)	(0.026)	(0.026)	
PhD Inst. Rank 101-150			0.985	0.904***	0.875***	
			(0.030)	(0.029)	(0.030)	
PhD Inst. Rank 151-200			1.021	0.951	0.922*	
			(0.040)	(0.039	(0.038)	
PhD Inst. Rank above 200			0.999	0.869***	0.853***	
			(0.051)	(0.046)	(0.046)	
First job postdoc				0.528***	0.535***	
				(0.013)	(0.013)	
First job tenure-track				4.888***	4.923***	
				(0.101)	(0.104)	
Observations	66,357	65,841	65,841	65,841	65,841	25,612

Table S.5: Impact of Field Team Size on Getting Tenure for Sample that Started in Academia

	Hazard ratios					Probit Coefficients
	(1)	(2)	(3)	(4)	(5)	(6)
Team Size	0.700***	0.693***	0.716***	0.909***	0.859***	-0.122**
	(0.021)	(0.021)	(0.023)	(0.027)	(0.027)	(0.022)
Black		1.158***	1.151***	0.936	0.934	
		(0.057)	(0.056)	(0.051)	(0.051)	
Hispanic		1.218***	1.216***	1.072	1.081	
		(0.058)	(0.057)	(0.055)	(0.056)	
Native American		1.241*	1.238*	1.069	1.075	
		(0.152)	(0.151)	(0.147)	(0.146)	
Asian or Pacific Islander		0.821***	0.825***	0.818***	0.822***	
		(0.035)	(0.035)	(0.037)	(0.037)	
Multiple race or other		0.667***	0.663***	0.617***	0.635***	
		(0.094)	(0.094)	(0.103)	(0.105)	
Married		1.024	1.026	1.024	1.018	
		(0.035)	(0.035)	(0.036)	(0.036)	
Has Children		1.239***	1.242***	1.201***	1.202***	
		(0.036)	(0.036)	(0.036)	(0.036)	
Female		0.802***	0.816***	0.808***	0.787***	
		(0.019)	(0.058)	(0.057)	(0.057)	
Foreign-born		0.869***	1.044	0.831**	0.872	
		(0.029)	(0.095)	(0.071)	(0.075)	
Team size * female			0.990	1.020	1.031	
			(0.030)	(0.031)	(0.032)	
Team size * foreign-born			0.920**	1.050	1.030	
			(0.036)	(0.037)	(0.037)	
PhD Inst. Top 50			0.882***	0.847***	0.841***	
			(0.031)	(0.031)	(0.033)	
PhD Inst. Rank 51-100			0.884***	0.828***	0.833***	
			(0.035)	(0.034)	(0.036)	
PhD Inst. Rank 101-150			1.005	0.924*	0.930	
			(0.045)	(0.042)	(0.044)	
PhD Inst. Rank 151-200			0.938	0.894*	0.905	
			(0.054)	(0.055)	(0.056)	
PhD Inst. Rank above 200			0.939	0.846**	0.856**	
			(0.070)	(0.062)	(0.064)	
First job postdoc				0.783***	0.796***	
				(0.028)	(0.029)	
First job tenure-track				6.809***	7.161***	
				(0.235)	(0.252)	
Observations	101,331	100,636	100,636	100,636	100,636	25,612

Table S.6: Impact of Field Team Size on Receiving Federal Research Funding for Sample that Started in Academia

	Hazard ratios					Probit Coefficients
	(1)	(2)	(3)	(4)	(5)	(6)
Team Size	0.859***	0.868***	0.891***	1.005	0.996*	-0.050**
	(0.019)	(0.019)	(0.021)	(0.021)	(0.021)	(0.014)
Black		1.188***	1.212***	1.083*	1.101**	
		(0.054)	(0.055)	(0.050)	(0.051)	
Hispanic		1.119**	1.122**	1.042	1.074	
		(0.051)	(0.052)	(0.049)	(0.050)	
Native American		1.233*	1.252*	1.202	1.203	
		(0.155)	(0.158)	(0.157)	(0.161)	
Asian or Pacific Islander		0.745***	0.746***	0.764***	0.767***	
		(0.030	(0.030)	(0.031)	(0.031)	
Multiple race or other		0.914	0.921	0.930	0.933	
		(0.116)	(0.116)	(0.124)	(0.125)	
Married		1.066*	1.067**	1.049	1.043	
		(0.035)	(0.035)	(0.034)	(0.034)	
Has Children		0.963	0.963	0.955	0.963	
		(0.028)	(0.028)	(0.027)	(0.028)	
Female		0.809***	0.927	0.916	0.893*	
		(0.019)	(0.059)	(0.057)	(0.056)	
Foreign-born		0.939**	1.127	1.091	1.088	
		(0.030)	(0.087)	(0.078)	(0.079)	
Team size * female			0.945**	0.955*	0.971	
			(0.023)	(0.022)	(0.023)	
Team size * foreign-born			0.933**	0.965	0.958*	
			(0.027)	(0.025)	(0.025)	
PhD Inst. Top 50			1.108***	1.109***	1.051	
			(0.037)	(0.038)	(0.038)	
PhD Inst. Rank 51-100			0.914**	0.886***	0.848***	
			(0.035)	(0.035)	(0.035)	
PhD Inst. Rank 101-150			0.865***	0.815***	0.780***	
			(0.039)	(0.037)	(0.037)	
PhD Inst. Rank 151-200			0.809***	0.769***	0.736***	
			(0.050)	(0.048)	(0.046)	
PhD Inst. Rank above 200			0.715***	0.654***	0.631***	
			(0.058)	(0.054)	(0.053)	
First job postdoc				0.773***	0.780***	
				(0.023)	(0.023)	
First job tenure-track				2.544***	2.551***	
				(0.067)	(0.069)	
Observations	99,258	98,615	98,615	98,615	98,615	25,612

Table S.7: Impact of Field Team Size on Exiting Academia for Sample that Started in Academia

	Hazard ratios					Probit Coefficients
	(1)	(2)	(3)	(4)	(5)	(6)
Team Size	1.032***	1.029***	1.010	0.982	0.979*	0.055***
	(0.010)	(0.010)	(0.012)	(0.012)	(0.012)	(0.012)
Black		1.031	1.028	1.069**	1.075**	
		(0.031)	(0.031)	(0.033)	(0.033)	
Hispanic		0.938**	0.935**	0.956	0.961	
		(0.030)	(0.030)	(0.030)	(0.031)	
Native American		1.270***	1.267***	1.295***	1.309***	
		(0.093)	(0.093)	(0.095)	(0.097)	
Asian or Pacific Islander		1.184***	1.182***	1.157***	1.157***	
		(0.025)	(0.025)	(0.025)	(0.025)	
Multiple race or other		0.647***	0.645***	0.636***	0.636***	
		(0.065)	(0.065)	(0.065)	(0.065)	
Married		0.924***	0.923***	0.938***	0.939***	
		(0.018)	(0.018)	(0.018)	(0.018)	
Has Children		0.866***	0.867***	0.879***	0.874***	
		(0.017)	(0.017)	(0.017)	(0.017)	
Female		1.044***	0.886***	0.890***	0.914**	
		(0.016)	(0.035)	(0.035)	(0.036)	
Foreign-born		1.137***	1.140***	1.127***	1.115***	
		(0.022)	(0.046)	(0.046)	(0.046)	
Team size * female			1.064***	1.063***	1.050***	
			(0.014)	(0.014)	(0.014)	
Team size * foreign-born			0.999	0.993	0.996	
			(0.013)	(0.013)	(0.013)	
PhD Inst. Top 50			0.973	0.970	1.012	
			(0.022)	(0.022)	(0.026)	
PhD Inst. Rank 51-100			1.020	1.024	1.068**	
			(0.026)	(0.026)	(0.029)	
PhD Inst. Rank 101-150			1.023	1.032	1.079**	
			(0.029)	(0.029)	(0.033)	
PhD Inst. Rank 151-200			1.006	1.018	1.054	
			(0.037)	(0.037)	(0.040)	
PhD Inst. Rank above 200			1.012	1.038	1.073	
			(0.047)	(0.048)	(0.051)	
First job postdoc				1.223***	1.218***	
				(0.022)	(0.022)	
First job tenure-track				0.780***	0.784***	
				(0.015)	(0.016)	
Observations	95,072	94,526	94,526	94,526	94,526	25,612

Table S.8: Impact of Field Team Size on Exiting Ph.D. Field for Sample that Started in Academia

	Hazard ratios					Probit Coefficients
	(1)	(2)	(3)	(4)	(5)	(6)
Team Size	1.100***	1.096***	1.063**	1.028	1.032	0.022
	(0.027)	(0.026)	(0.033)	(0.033)	(0.035)	(0.022)
Black		1.208*	1.201*	1.274**	1.288**	
		(0.122)	(0.121)	(0.130)	(0.133)	
Hispanic		0.977	0.978	1.030	1.023	
		(0.100)	(0.100)	(0.105)	(0.106)	
Native American		1.524*	1.506*	1.526*	1.535*	
		(0.378)	(0.375)	(0.384)	(0.391)	
Asian or Pacific Islander		1.219**	1.219**	1.211**	1.205**	
		(0.098)	(0.099)	(0.098)	(0.098)	
Multiple race or other		1.219	1.222	1.192	1.160	
		(0.262)	(0.263)	(0.258)	(0.258)	
Married		0.704***	0.703***	0.709***	0.706***	
		(0.041)	(0.041)	(0.042)	(0.042)	
Has Children		0.976	0.978	0.983	0.978	
		(0.054)	(0.054)	(0.054)	(0.054)	
Female		0.907*	0.786**	0.772**	0.789*	
		(0.048)	(0.094)	(0.096)	(0.100)	
Foreign-born		0.862**	0.704***	0.694***	0.701**	
		(0.060)	(0.093)	(0.096)	(0.099)	
Team size * female			1.053	1.053	1.049	
			(0.040)	(0.042)	(0.042)	
Team size * foreign-born			1.069*	1.062	1.056	
			(0.042)	(0.044)	(0.044)	
PhD Inst. Top 50			0.967	0.972	0.968	
			(0.087)	(0.087)	(0.088)	
PhD Inst. Rank 51-100			1.097	1.117	1.112	
			(0.106)	(0.107)	(0.108)	
PhD Inst. Rank 101-150			1.146	1.163	1.147	
			(0.124)	(0.126)	(0.125)	
PhD Inst. Rank 151-200			0.968	0.976	0.968	
			(0.134)	(0.135)	(0.135)	
PhD Inst. Rank above 200			1.115	1.125	1.122	
			(0.170)	(0.172)	(0.173)	
First job postdoc				0.845***	0.845***	
				(0.051)	(0.051)	
First job tenure-track				0.349***	0.343***	
				(0.027)	(0.028)	
Observations	136,138	135,366	135,366	135,366	135,366	17,843

Table S.9: **Hazard Ratios of the Impact of Field Team Size on Academic Career Outcomes for Full Sample**

	(1)	(2)	(3)	(4)	(5)
a. Tenure Track Position					
Team size	0.757***	0.766***	0.800***	0.898***	0.885***
	(0.015)	(0.015)	(0.017)	(0.017)	(0.017)
Team size * female			0.917***	0.919***	0.927***
			(0.018)	(0.018)	(0.018)
Team size * foreign-born			0.948**	1.007	0.983
			(0.022)	(0.022)	(0.022)
First job postdoc				1.380***	1.406***
				(0.033)	(0.034)
First job tenure-track appointment				11.810***	11.768***
				(0.247)	(0.251)
b. Tenure					
Team size	0.709***	0.712***	0.738***	0.926**	0.858***
	(0.022)	(0.022)	(0.025)	(0.028)	(0.028)
Team size * female			0.971	0.990	1.011
			(0.029)	(0.030)	(0.031)
Team size * foreign-born			0.908**	1.036	0.996
			(0.036)	(0.037)	(0.037)
First job postdoc				1.562***	1.610***
				(0.056)	(0.059)
First job tenure-track				13.982***	14.685***
				(0.441)	(0.477)
c. Federal Research Funding					
Team size	0.886***	0.902***	0.937***	1.029	1.006
	(0.020)	(0.020)	(0.023)	(0.022)	(0.022)
Team size * female			0.910***	0.925***	0.942**
			(0.022)	(0.022)	(0.023)
Team size * foreign-born			0.938**	0.976	0.959
			(0.027)	(0.025)	(0.026)
First job postdoc				1.896***	1.931***
				(0.023)	(0.023)
First job tenure-track				2.544***	2.551***
				(0.056)	(0.058)
d. Exited science					
Team size	1.107***	1.104***	1.091***	1.086***	1.092***
	(0.020)	(0.019)	(0.023)	(0.023)	(0.024)
Team size * female			1.010	1.006	1.007
			(0.028)	(0.028)	(0.028)
Team size * foreign-born First job postdoc			1.036	1.030	1.038
			(0.029)	(0.030)	(0.030)
First job postdoc				0.647***	0.641***
				(0.031)	(0.031)
First job tenure-track				0.263***	0.257***
				(0.019)	(0.018)

Table S.10: Percentage Change in Team Size Before and After Mandatory Retirement

Field	1970-1992	1992-2004
All fields	46.4	23.9
Life Science	51.4	27.8
Computer Science and Mathematics	27.1	28.1
Engineering	50.5	20.4
Health	16.3	24.2
Physical Science	39.8	28.7
Psychology	29.4	26.2
Social Science	20.8	22.5

Table S.11: Effect of Pre- and Post- Mandatory Retirement on Team Size Estimates

	Tenure Track		Tenured		Research Funding	
	Pre	Post	Pre	Post	Pre	Post
Team size	0.722*** (0.022)	0.868*** (0.026)	0.706*** (0.030)	0.809*** (0.046)	0.901*** (0.033)	0.975 (0.030)
Team size * Female	0.956 (0.027)	0.846*** (0.027)	0.999 (0.040)	0.876** (0.048)	0.954 (0.034)	0.844*** (0.036)
Team size * Foreign-born	0.960 (0.033)	0.969 (0.035)	0.923 (0.049)	0.938 (0.066)	0.972 (0.043)	0.957 (0.040)
Observations	121,729	40,965	151,824	47,517	152,192	46,142
	Left Academia		Left Science			
	Pre	Post	Pre	Post		
Team size	1.019 (0.024)	1.017 (0.017)	1.111*** (0.041)	1.097*** (0.028)		
Team size * Female	1.090*** (0.027)	0.925*** (0.020)	1.054 (0.050)	0.965 (0.038)		
Team size * Foreign-born	1.096*** (0.027)	1.037* (0.021)	1.051 (0.051)	1.023 (0.039)		
Observations	154,887	41,339	182,106	47,075		