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SUPPLEMENTARY INFORMATION

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Unequal effects of the COVID-19 pandemic on scientists

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Supplementary Information for Unequal Effects of the COVID-19 Pandemic on Scientists

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Human research participants

The study protocol has been approved by the Institutional Review Board (IRB) from Harvard University and Northwestern University. Informed consent was obtained from all participants.

Author contributions

KRM, JGT, MCT, KRL, DW conceived the project, KRM, WYT, NC, JGT, MCT, KRL, DW designed the experiments, KRM, WYT, YY, NC collected data, KRM, WYT, YY performed empirical analyses, all authors collaboratively interpreted results, KRM, DW wrote the initial draft of the manuscript, all authors edited and revised the manuscript.

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Supplementary Method 1: Survey Sampling & Recruitment

Web of Science corresponding authors

To compile a large, plausibly random list of active scientists, we leverage the Web of Science (WoS) publication database. The WoS database is useful for two reasons: (1) it is one of the most authoritative citation corpuses available[1] and has been widely used in recent science of science studies[2–4]; (2) among other large-scale publication datasets, WoS is the only one, to our knowledge, with systematic coverage of corresponding author email addresses.

By mid-April 2020, the cumulative number of deaths due to COVID-19 had reached approximately 115,000 with nearly 1,800 deaths per day in the U.S. and 3,000 deaths per day in Europe.[5] Throughout the U.S. and Europe, schools and workplaces were typically required to be closed and restrictions on gatherings of more than 10 people were in place in most countries[6]. For scientists, not only did this drastically change their daily lives, it severely limited the possibilities of using traditional workspaces[7].

Therefore, in this paper we are primarily interested in active scientists residing in the U.S. and Europe. We start from 21 million WoS papers published in the last decade (2010-2019). In an attempt to focus on scientists likely to still be active and in a more stable research position, we link the data to journal impact factor information (WoS Journal Citation Reports), and exclude papers published in journals in the bottom 25% of the impact factor distribution for its WoS-designated category. We use the journal impact factor calculated for the year of publication, and for papers published in 2019, we use the latest version (2018). We then extract all author email addresses associated with papers. For each email address in this list, we consider it as a potential participant if: (1) it is associated with at least two papers in the ten-year period, and (2) the most recent country of residence, defined by the first affiliation of the most recent paper, is in the U.S. or Europe.

We have approximately 2.5 million unique email addresses after filtering, with about 521,000 in the U.S. and 938,000 in Europe. We then randomly shuffled the two lists separately and sampled roughly 280,000 email addresses from the U.S. and 200,000 from Europe. We oversampled the U.S. as a part of a broader outreach strategy underlying this and other research projects.

Participant recruitment

We used Qualtrics © software to design the survey instrument and collect responses. We used the `qualtRics' package in R © to manage the data and download it from the Qualtrics platform.[1]

We recruited participants by sending them email invitations through with the following text:

> *We need your help to shed light on how the coronavirus pandemic is affecting scientists like you. Please take a brief moment to complete this short five-minute survey as part of a research study. Your responses will help scientists and policymakers understand and respond to this rapidly evolving situation.*
>
> ***Follow this link to the Survey****:*
> *[link]*
> ***Or, copy and paste the URL below into your internet browser****:*
> *[link]*
>
> *Upon completion, you can choose charities to receive a donation on your behalf, and you may have the chance of winning a $100 gift card. Please feel free to forward this survey to any other scientists you know (e.g., professors, post-doctoral researchers, graduate students). We need everyone's input to fully understand the breadth of how science is currently changing.*
>
> *Thank you for your time,*
>
> *Kyle Myers, Ph.D. & Karim Lakhani, Ph.D.*
> *Laboratory for Innovation Science at Harvard*
>
> *Dashun Wang, Ph.D.*
> *Northwestern Kellogg Center for Science of Science & Innovation (CSSI)*

[1] Jasper Ginn and Julia Silge (2020). qualtRics: Download 'Qualtrics' Survey Data. R package version 3.1.2. https://CRAN.R-project.org/package=qualtRics.

Supplementary Method 2: Survey Instrument

Survey questions

The survey includes questions on professional information (position type, institution type, fields of study, type of research, tenure status), demographic information (age, gender, cohabitation, dependents, citizenship), time allocation (time spent on different activities before and after the pandemic outbreak) and predicted changes in future publication and funding. Below are the excerpted questions underlying the variables used in our analyses. We did not require respondents to answer any of the demographic questions regarding gender, age, dependents, cohabitation, or citizenship.

Q. Which of the following best describes your current position?

- *Faculty or Principal Investigator | Post-doctoral researcher | Graduate student in a doctoral program | Retired scientist no longer engaged in research | Other*

Q. Which of the following best describes your field of study?

- *General: [list of 20 fields]*

Q. Which of the following best describes the institution you are primarily affiliated with?

- *University or college | Non-profit research organization | Government or public agency | For-profit firm | Other*

Q. Please answer the following:

- *Is your institution physically closed to non-essential personnel?*
  - *Yes | No | Not relevant*
- *Are you exempt from the closure and allowed to travel to your work site(s)?*
  - *Yes | No | Not relevant*
- *Do you have tenure?*
  - *Yes | No | Not relevant*

Q. Gender:

- *Male | Female | Other | Prefer not to say*

Q. Age:

- *Under 20 | 20-24 | 25-29 … 75-79 | 80 or older | Prefer not to say*

Q. Number of dependents of any age you care for:

- *0 | 1 | 2 | 3 or more | Prefer not to say*

Q. In what age group(s) are your dependents? Note. You may select multiple

- *0-2 years old | 3-5 years old | 6-11 years old | 12-18 years old | 18-65 years old | Over 65 years old*

Q. Cohabitation status:

- *I reside with a partner, spouse, or significant other | I reside with friends | I reside by myself | Other | Prefer not to say*

Q. Are you a U.S. Citizen?
- *Yes | No | Prefer not to say*

Q. Before this coronavirus pandemic, about how many hours per week did you work on anything related to your job? (e.g., researching, teaching, writing)

- *14-21 hours per week (avg. 2-3 hours every day) | 21-28 hours per week (avg. 3-4 hours every day) | … | 77-84 hours per week (avg. 11-12 hours every day) | More than 84 hours per week (avg. 12 hours or more every day)*

Q. Currently, about how many hours per week are you working? (e.g., researching, teaching, writing)

- *14-21 hours per week (avg. 2-3 hours every day) | 21-28 hours per week (avg. 3-4 hours every day) | … | 77-84 hours per week (avg. 11-12 hours every day) | More than 84 hours per week (avg. 12 hours or more every day)*

Q. Before this coronavirus pandemic, how did you spend your work hours?
Research: _______
Teaching, advising, or mentoring: _______
Grant writing or other fund-raising: _______
Administration, service, or other (e.g., editorial duties, peer review): _______
Total: ________
Q. Currently, how are you spending the hours you do work?
Research: _______
Teaching, advising, or mentoring: _______
Grant writing or other fund-raising: _______
Administration, service, or other (e.g., editorial duties, peer review): _______
Total: ________

Q. Previously in 2018 and 2019, approximately how much research funding did you oversee or manage per year? Note: Ignore overhead or indirect costs; focusing only on funds used directly for research regardless of source (e.g., home institution, federal grant).
Approximately:
- *<10,000 $/year | 10,000-20,000 $/year | 20,000-50,000 $/year | 50,000-100,000 $/year | 100,000-200,000 $/year | 200,000-500,000 $/year | 500,000-1,000,000 $/year | 1,000,000-2,000,000 $/year | >2,000,000 $/year*

For the following, please consider your "research publications" as all of your publications that focus on a research question. (e.g., journal articles, conference proceedings, patents, books. Ignore commentary, editorials, etc.)

Q. Assuming this pandemic lasts for another [1, 2, 3, 4, 6, 8] *months (until* [May, June, July, August, October, December]*), how do you think the quantity and impact of your research publications will change in 2020 and 2021 compared to 2018 and 2019? (i.e., what will be the percent change?)*

- *Quantity (i.e., number):* [slider scale from -100% to +50% in 10% increments]
- *Impact (i.e., quality influence):* [slider scale from -100% to +50% in 10% increments]

Field definitions

We build on field classifications used in national surveys such as the U.S. Survey of Doctorate Recipients (SDR) to categorize fields in our survey, aggregating to ensure sufficient sample sizes within each field. The notable additions we make to the fields used in these other surveys are to include: Business Management, Education, Communication, and Clinical Sciences. These fields reflect major schools at most universities and/or did not immediately map to some of the default fields used in the SDR (i.e., the "Health Sciences" field in SDR does not include medical specialties).

Supplementary Method 3: Sampling Approach

Distribution and basic statistics

Out of a total of 480,000 emails sent, approximately 64,000 emails were directly bounced either due to incorrect spelling in the WoS data or the termination of the email account. In hopes of soliciting a larger sample, we also undertook snowball sampling by encouraging respondents to share the survey with their colleagues as well.

Overall 9,968 individuals entered the survey and 8,447 continued past the consent stage. Of those that did not, 412 were not an active scientist, post-doc, or graduate student and thus not within our population of interest, 81 did not consent, and 1028 did not make any consent choice. When a respondent continued past the consent stage, we asked them to report the type of role they were in. Out of the 8,447 consenting responses, there 5,728 responses from faculty or principal investigators (PIs), 1,023 responses from post-doctoral researchers, 701 from graduate students in a doctoral program, and 52 from retired scientists. 551 of the remaining respondents were some other type of position and another 392 did not report their position. This yields an estimate of a response rate of approximately 1.6%. First, our low response rate may reflect the disruptive nature of the pandemic, but it also raises concerns for generalizability of our results. However, after we received feedback from the initial distribution that many individuals had received the email in their "junk" folder, we became concerned with our distribution being automatically flagged as spam. Based on spot-checking of five individuals that we ex-post identified as being randomly selected by our sample, and who we had professional relationships with, found that in four of the five cases the recruitment email had been flagged as spam. We know of no systematic way of estimating the true spam-flagging rate (nor how to avoid these spam filters when using email distributions at this scale) without using high-end, commercial-grade products.

Additionally, as with any opt-in survey, there may be correlations between which scientists opt-in and their experiences about which they want to report. For example, scientists who felt strongly about sharing their situation, whether they experienced large positive or negative changes, may be more likely to respond, which would increase the heterogeneity of the sample. Furthermore, there may also be non-negligible gender differences that arise not due to actual differences in outcomes but due to differences in reporting known to occur across genders.[8–12]

For our analyses, we focus entirely on responses from the sample of faculty/PIs. From the full sample of PIs, we retain respondents who reported working for a "University or college", "Non-profit research organization", "Government or public agency", or "Other", and excluding 87 responses from individuals who report to work for a "For-profit firm". We also restrict the sample to respondents whose IP address originated from the United States or Europe (dropping 1,049 responses from elsewhere).

We then drop observations that have missing data for any of the variables used in our analyses: 26 responses do not report their time allocations, 74 do not report their age, 10 do not report the type of institution they work at, and 114 do not report their field of study. Altogether, this amounts to dropping 187 observations. Given the relatively small subset of our sample dropped due to missing data, we do not impute missing variables as this introduces unnecessary noise.[13]

The summary statistics for the final sample used in the analyses are reported in Table S1 and the geographic distribution of respondents is shown in Figure S1.

Comparison to SDR

To estimate the generalizability of our respondent sample, we use the public microdata from The Survey of Doctorate Recipients (SDR) as the best sample estimates of the population of principal investigators in the U.S. The SDR is conducted by the National Center for Science and Engineering Statistics within the National Science Foundation, sampling from individuals who have earned a science, engineering, or health doctorate degree from a U.S. academic institution and are less than 76 years of age. The survey is conducted every two years, and we use the latest data available (2017 cycle). For this comparison, we focus only on university faculty in both our survey and the SDR. We also constrain our sample to only include fields of study with a clear mapping to the SDR categories. The SDR focuses only on researchers with Ph.D.-type degrees, and so it does not capture researchers with other degrees still actively engaged in research (i.e., researchers with only M.D.s). This means we exclude "architecture and design," "business management," "medicine," "education," "humanities," and "law and legal studies." Figure S2 compares respondents between our sample and the SDR sample.

Figure S2a illustrates differences on demographics and career-stage features, including raw differences as well as those adjusted by field. We find only a small difference in age and no difference in partner status. Our survey oversamples on female scientists, those with children, and untenured faculty. These differences persist after conditioning on the scientist's reported field. That we ultimately find female scientists and those with young dependents to report the largest disruptions suggests that these individuals may have been more likely to respond to the survey in order to report their circumstances. The geographic distributions are relatively similar, with slight oversampling of west and undersampling of south. Lastly, we find a significant but small oversampling of U.S. citizens.

We also compare the distribution of research fields (Fig. S2b). Overall the distributions are relatively similar. We appear to oversample most significantly on "atmospheric, earth, and ocean sciences" and "other social sciences." While we undersample most significantly on the biological sciences, "mathematics and statistics," and "electrical and mechanical engineering". There does not seem to be a clear pattern with these field-level differences, as we undersample fields that ultimately report being across the spectrum of disruptions (i.e., mathematics and statistics reports some of the smallest disruptions, and the biological sciences are amongst the most disrupted).

Supplementary Method 4: Covariate Selection and Regression Approach

Lasso selection and post-Lasso regression

The unconditional changes reported by each group of scientists is informative of how the pandemic affected researchers overall. But it does not allow us to infer whether groups reporting larger or smaller disruptions are doing so for reasons inherent to that group (i.e., the nature of work in certain fields, or the demands of home life unique to certain individuals) or because the individuals that select into that group tend to also be disrupted for unrelated reasons. This motivates a multivariate regression analysis to explore whether changes associated with a group of individuals change after conditioning on other observables. However, selecting which of an available set of covariates (or transformations thereof) to include in a regression is notoriously challenging. The Lasso method provides a data-driven approach to this selection problem by excluding covariates from the regression that do not improve the fit of the model.[14,15]

When using the Lasso, our general approach is to include a vector of indicator variables for the fields and demographic and career groups of interest, along with an additional set of controls. The control variables are: pre-pandemic level of time allocations and totals, pre-pandemic share of time allocations, pre-pandemic funding estimate, and indicators for the type of institution (academic, non-profit, government, or other) and the location (state if in U.S., country if in Europe). To make minimal assumptions about the functional form of the control variables, we conduct the following transformations to expand the set of controls: for all continuous variables we use inverse hyperbolic sine (which approximates a logarithmic transformation while allowing zeros), square and cubic transformations, and we interact all indicator variables with the linear versions of the continuous variables.

We perform the Lasso using the lasso linear package in Stata 16 © software. We use the defaults for constructing initial guesses, tuning parameters, number of folds (ten), and stopping criteria. We use the two-step cross-validation "adaptive" Lasso model where an initial instance of the algorithm is used to make a first selection of variables, and then a second instance occurs using only variables selected in the first instance. The variables selected after this second run are then used in a standard post-Lasso OLS regression with heteroskedastic robust standard errors.

Supplementary Result 1: Additional Results

Correlations in time spent on different tasks

Figure S3 plots the reported changes in research time (y-axes) against the reported changes in time allocated to the other three task categories (x-axes). The figures are binned scatterplots, and linear fits of the data suggest that research may be a substitute for the other categories. A 10% increase in fundraising, teaching, or all other tasks is associated with a decline in research by 1.4% (s.e.=0.14), 4.6% (s.e.=0.16), and 3.2% (s.e.=0.13), respectively. We lack exogenous variation in the data that can clearly shift the time allocated to one (or a subset) of tasks, so we cannot identify the extent to which these correlations reflect actual substitution patterns or unobserved factors. Though the magnitudes and precision of these relationships suggests further investigations are certainly warranted to better understand how scientists allocate their time.

University faculty tenure clock policies

Using internet searches, we attempted to identify university-level tenure clock extension policies put in place as a result of the COVID-19 pandemic. While not a comprehensive list, we identified policies for 34 universities, encompassing both public and private, small and large institutions. Of the 34 universities, 17 have automatically applied a tenure clock extension to all faculty, with individuals having the ability to opt out[18–34]; 13 require applications but are automatically approved.[35–47] Four universities have not established unilateral policies.[48–51] Instead, they have either created a separate application process or added COVID-19-related impact to the list of reasons a faculty member may apply for an extension.

Supplementary Tables

	N Obs.	Mean	Median	S.D.	Mean, with pubs.	Mean, miss. pubs.	t-stat
Research HRs. per week, pre-pandemic	4535	23.63	22.40	10.82	23.46	23.86	1.26
Teaching HRs. per week, pre-pandemic	4535	16.39	15.75	9.21	16.51	16.23	-1.03
Fundraising HRs. per week, pre-pandemic	4535	8.58	7.70	5.46	8.65	8.49	-0.97
All other task HRs. per week, pre-pandemic	4535	12.80	10.50	8.29	12.85	12.74	-0.47
Total Work HRs. per week, pre-pandemic	4535	61.41	63.00	11.72	61.47	61.32	-0.44
Research HRs. per week, current	4535	17.85	14.70	12.65	17.65	18.11	1.20
Teaching HRs. per week, current	4535	16.08	13.30	11.93	16.17	15.96	-0.59
Fundraising HRs. per week, current	4535	7.79	4.90	6.92	7.84	7.72	-0.61
All other task HRs. per week, current	4535	12.72	9.80	9.87	12.88	12.52	-1.23
Total Work HRs. per week, current	4535	54.44	56.00	15.87	54.54	54.30	-0.51
Age	4535	47.28	45.00	11.39	47.16	47.43	0.80
Has Tenure	4535	0.60	1.00	0.49	0.60	0.60	-0.05
Female	4535	0.41	0.00	0.49	0.41	0.41	-0.12
Lives with Partner	4535	0.84	1.00	0.37	0.85	0.82	-2.69
U.S. Citizen	4535	0.57	1.00	0.50	0.58	0.55	-2.04
Has Dependent, 0-5yro.	4535	0.19	0.00	0.39	0.20	0.19	-0.72
Has Dependent, 6-11yro.	4535	0.23	0.00	0.42	0.24	0.21	-1.80
Has Dependent, 12-15yro.	4535	0.15	0.00	0.35	0.15	0.14	-0.66
Has Dependent, 16-65yro.	4535	0.29	0.00	0.46	0.29	0.30	0.88
Has Dependent, >65yro.	4535	0.05	0.00	0.22	0.05	0.05	0.13
Has >1 Dependent	4535	0.41	0.00	0.49	0.41	0.40	-0.52
Inst. closed, non-exempt	4535	0.649	1.000	0.477	0.645	0.656	0.765
At University/College	4535	0.85	1.00	0.36	0.86	0.82	-3.51
In U.S. (vs. Europe)	4535	0.64	1.00	0.48	0.65	0.63	-1.42
Approximate Research Funding, pre-pandemic	4535	$ 235,398	$ 35,000	$ 499,425	$ 240,701	$ 228,556	-0.81
Pub. Quantity Forecast (`20-21 vs. `18-19)	4535	-12.43%	0.00%	33.05%	-11.69%	-13.37%	-1.70
Pub. Impact Forecast (`20-21 vs. `18-19)	4535	-7.38%	0.00%	24.84%	-6.98%	-7.90%	-1.23
Pub. Quantity (Number) since 2010, if matched	2555	6.88	4.00	7.92			
Pub. Impact (Eucl. Citations) since 2010, if matched	2555	7.84	3.85	13.40			

Table S1. Summary Statistics. Summary statistics for the main survey sample. “Mean, with pubs.” And “Mean, miss. pubs.” report the averages for the sub-samples that can and cannot be connected to their publication record in WoS, respectively. The “t-stat” column reports the t-statistic from a test of mean differences between these two sub-samples. The two WoS-based variables are “Pub. Quantity (Number) since 2010” (the sum of the author’s number of publications in the WoS record), and “Pub. Impact (Eucl. Citations) since 2010” (the field-demeaned euclidean sum of citations to the author’s publications in the WoS record[14]).

Supplementary Figures

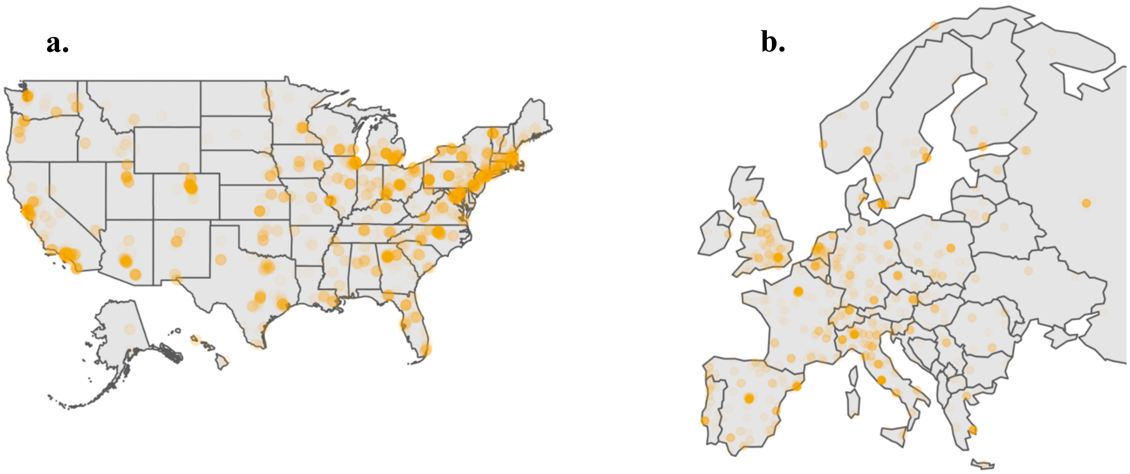
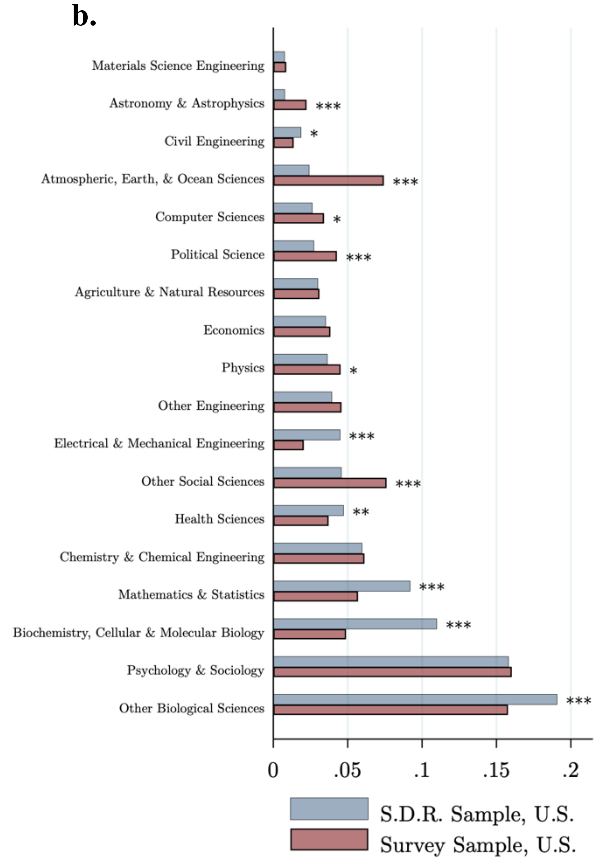


Figure S1. Geographic distribution. Plots respondent locations in U.S. (**a.**) and Europe (**b.**), aggregated to preserve anonymity.

a.

	SDR Sample	Survey Sample	Diff.	Diff., field adjusted
Age	45.67	44.77	-0.900***	-1.054***
Is Female	0.37	0.48	0.111***	0.116***
Has Dependent, 0-5yro.	0.10	0.14	0.045***	.047***
Has Dependent, 6-11yro.	0.06	0.10	0.036***	0.035***
Has Dependent, 12-18yro.	0.10	0.20	0.091***	0.088***
Has Partner	0.84	0.84	-0.003	-0.003
Has Tenure	0.67	0.61	-0.061***	-0.061***
Located in Midwest	0.22	0.23	0.009	0.017
Located in West	0.22	0.28	0.066***	0.054***
Located in South	0.33	0.24	-0.091***	-0.091***
Located in Northeast	0.22	0.24	0.015	0.020*
U.S. Citizen	0.84	0.86	0.018**	0.011

b.



c.

Country	N	Pr(Female)	Country	N	Pr(Female)	Country	N	Pr(Female)
Austria	29	0.21	Hungary	15	0.20	Russia	47	0.23
Belarus	2	0.00	Iceland	4	0.50	Serbia	12	0.50
Belgium	36	0.39	Ireland	8	0.63	Slovakia	7	0.57
Bosnia and Herzegovina	1	0.00	Italy	278	0.36	Slovenia	4	0.75
Bulgaria	4	0.00	Latvia	2	0.00	Spain	216	0.30
Croatia	11	0.73	Lithuania	11	0.18	Sweden	66	0.45
Czech	23	0.22	Luxembourg	2	0.00	Switzerland	47	0.17
Denmark	40	0.33	Netherlands	80	0.38	Ukraine	8	0.00
Estonia	7	0.00	Norway	47	0.47	United Kingdom	204	0.33
Finland	26	0.38	Poland	55	0.40	USA	2890	0.45
France	141	0.39	Portugal	41	0.54			
Germany	111	0.25	Republic of Macedonia	3	0.67			
Greece	39	0.26	Romania	18	0.39			

d.

Field	N	Pr(Female)	Field	N	Pr(Female)
Agriculture & Natural Resources	131	0.39	Economics	191	0.28
Astronomy & Astrophysics	108	0.30	Education	107	0.73
Atmospheric, Earth, & Ocean Sciences	276	0.41	Electrical & Mechanical Engineering	100	0.09
Biochemistry, Cellular & Molecular Biology	187	0.42	Health Sciences	75	0.63
Business Management	140	0.49	Mathematics & Statistics	252	0.28
Chemistry & Chemical Engineering	240	0.32	Other Biological Sciences	489	0.43
Civil Engineering & Urban Planning	85	0.31	Other Engineering	216	0.29
Clinical Sciences	669	0.46	Other Social Sciences & Humanities	334	0.50
Communication	35	0.57	Physics	269	0.17
Computer Sciences	155	0.23	Psychology & Sociology	476	0.64

Figure S2. Comparison to U.S. University-based SDR respondents. Summary statistics for demographic variables and fields common to both our survey and the U.S. Survey of Doctoral Recipients (SDR). All comparisons are based on U.S.-located faculty or PIs at universities or colleges that report affiliation with a field of study present in both surveys (note: all fields present in the SDR are present in our survey, but not vice versa). **a.** Describes the sample averages for both samples and the mean differences in both the raw data ("Diff.") and after adjusting for the different composition of fields in each sample ("Diff., field adjusted") **b.** Plots the share of respondents in each sample that affiliate with each of the fields common to both surveys. (*** $p<0.01$; **$p<0.05$; *$p<0.1$). **c.** Reports the number of respondents and share female by country **d.** Reports the number of respondents and share female by field.

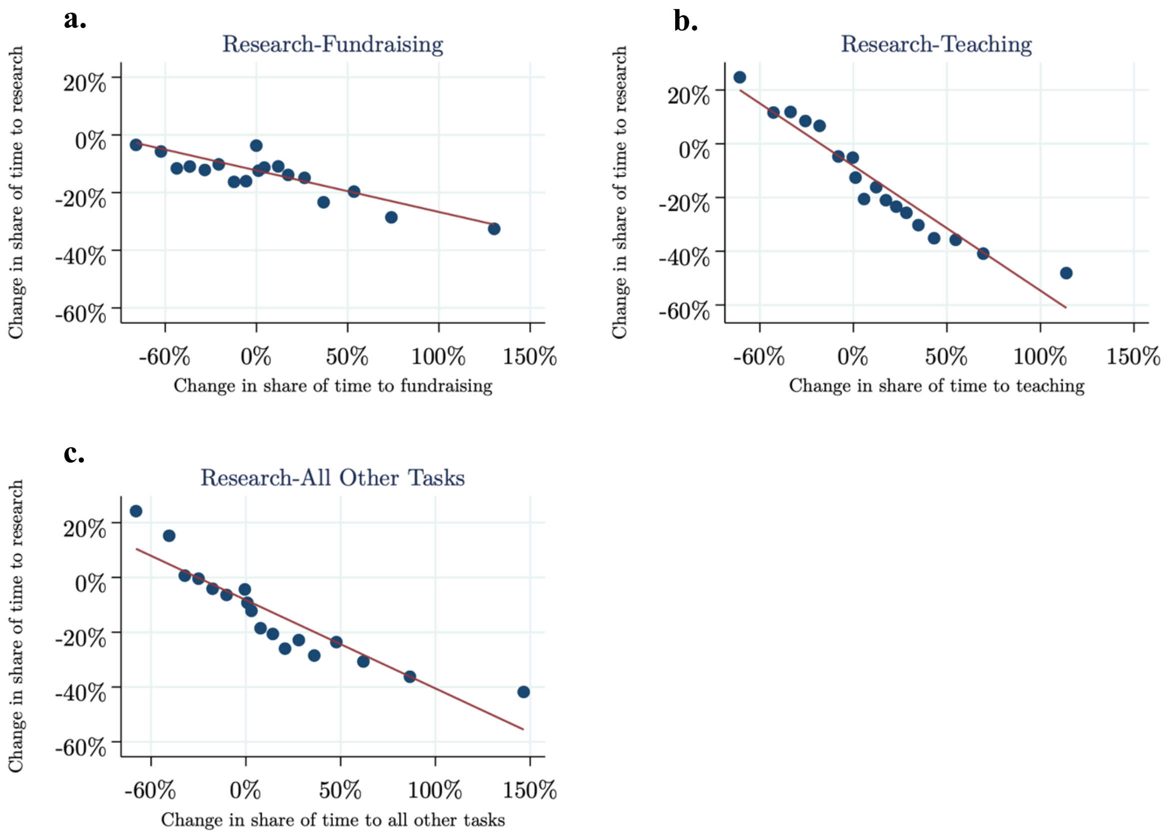


Figure S3. Correlation between changes in task allocations, by category. Binned scatterplots (where each of the 18 dots represent approximately 5.5% of observations) of the relationship between the change in reported time spent on research versus fundraising (**a.**), teaching (**b.**), or the "all other task" residual category (**c.**). Linear fit lines are also plotted.

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