Cutting the Innovation Engine: How Federal Funding Shocks Affect University Patenting, Entrepreneurship, and Publications

Tania Babina
Columbia

Alex Xi He
Maryland

Sabrina Howell
NYU & NBER

Elisabeth Perlman
US Census Bureau

Joseph Staudt
US Census Bureau

July 27, 2022

DISCLOSURE

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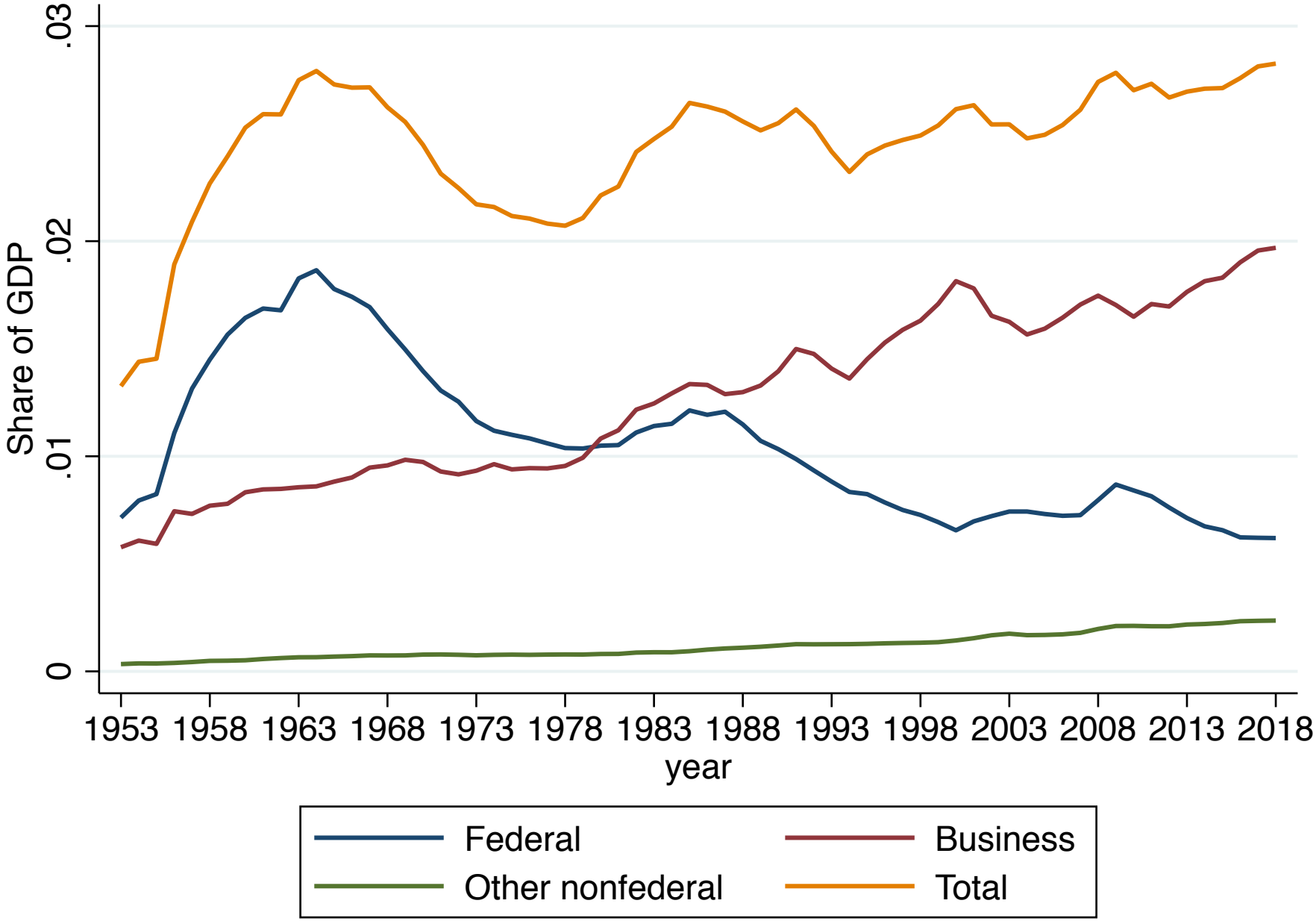
(DRB Approval Numbers CBDRB-FY20-152, CBDRB-FY20-CES009-004, CBDRB-FY20-CES009-006, CBDRB-FY21-CES009-007, CBDRB-FY21-CES007-008, and CBDRB-FY22-CES17-002.)

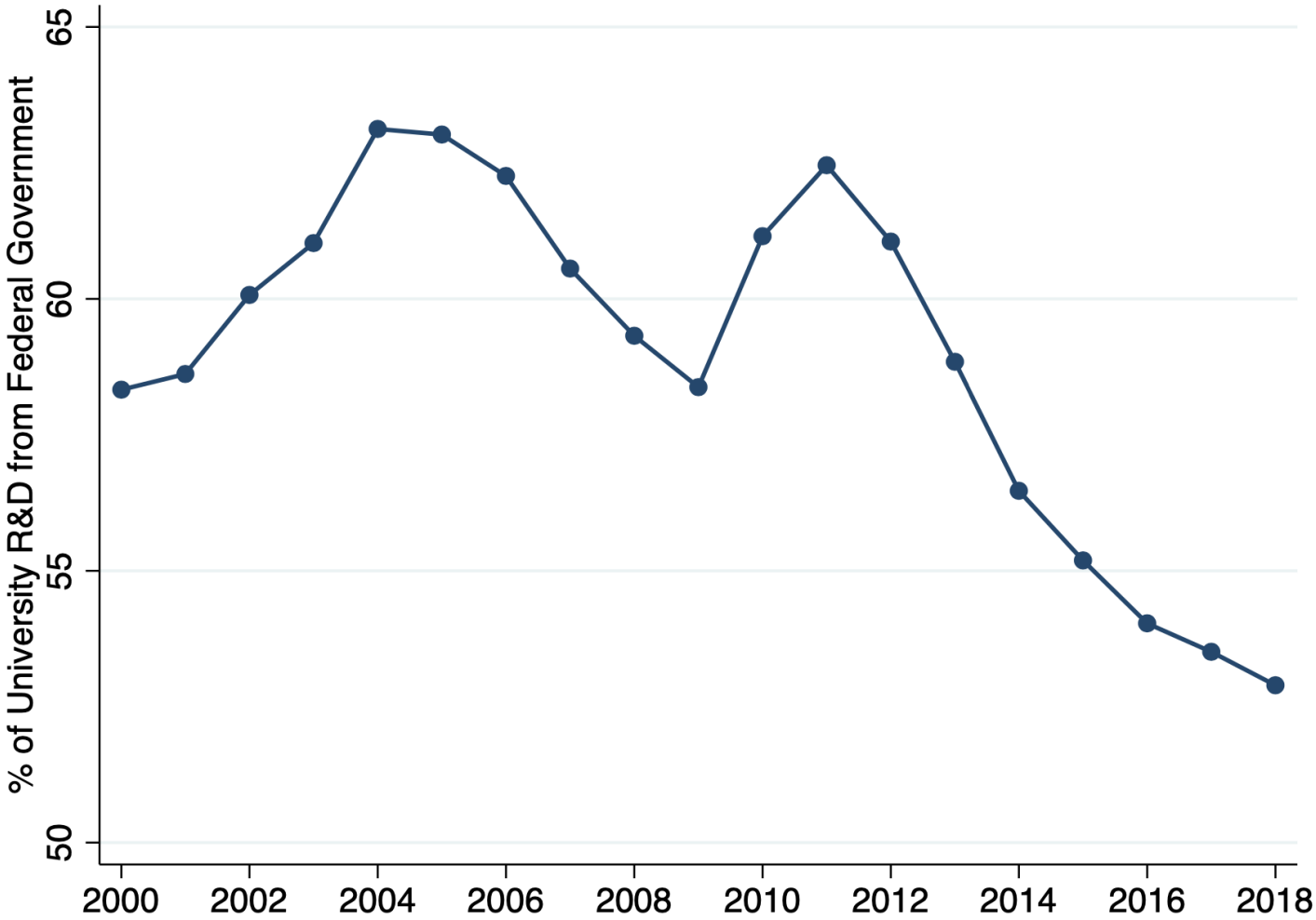
Outline

1. Introduction
2. Data and Empirical strategy
3. Main Results
4. Quality Heterogeneity
5. Mechanisms
6. Conclusion

Sources of U.S. R&D Funding



University R&D Funding from Federal Sources



Research Question

- **How does a decline in federal funding affect the innovation outputs of university researchers?**

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- Why universities:
  - Engines of innovation, crucial for economic growth
    Jaffe 1989, Audretsch and Feldman 1996, Tartari and Stern 2021
  - Pivotal to human capital production and to training next generation of researchers
  - Federal and private funding both play important roles

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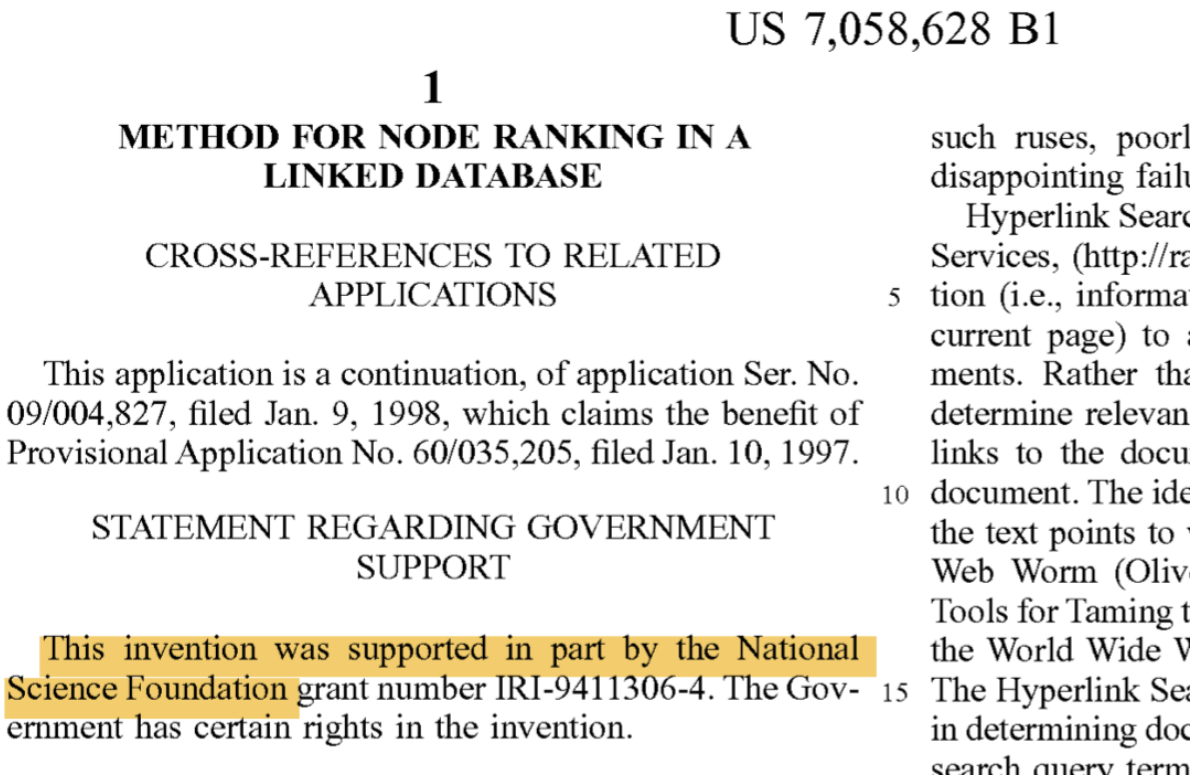
- Examine research outputs representing key paths for spillovers and the openness of innovation:
  - High-tech entrepreneurship
  - Patents
  - Publications

Federal Funding Leading to Patents and High Tech Startups

- Page and Brin's work in 1994 on PageRank algorithm funded by NSF/NASA/DARPA $4.5mill Digital Library grant to Stanford



US 7,058,628 B1

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METHOD FOR NODE RANKING IN A LINKED DATABASE

CROSS-REFERENCES TO RELATED APPLICATIONS

This application is a continuation, of application Ser. No. 09/004,827, filed Jan. 9, 1998, which claims the benefit of Provisional Application No. 60/035,205, filed Jan. 10, 1997.

STATEMENT REGARDING GOVERNMENT SUPPORT

This invention was supported in part by the National Science Foundation grant number IRI-9411306-4. The Government has certain rights in the invention.

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Overview of Findings

- Focus on the effects of large, idiosyncratic, and temporary cuts to federal funding in a researcher's pre-existing narrow field of study

- Main finding: **Cuts to federal funding reduce high-tech entrepreneurship and publications, but increase patenting**
  - Lost publications tend to be more basic and gather more citations
  - Additional patents tend to be less general, less cited, and more often privately assigned

- Takeaway: Federal funding plays an important role in generating impactful, open research outputs
  - Published by researchers to disseminate findings
  - Can be taken by researchers to startups
  - While private funders appear to more often appropriate outputs

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Data Sources

- Grants:
  - IRIS/UMETRICS data:
    - ★ Comprehensive research grant/award data for 22 research universities
    - ★ Individual-level monthly payments for all employees on grant
    - ★ Funding source: federal (links to CFDA code), private, other
  - Federal funding data from Single Audit
    - ★ Annual data on funding by all federal programs on narrow fields of study (CFDA codes)
- Outcomes:
  - High-Tech Entrepreneurship: Census
    - ★ IRS W-2 forms (includes grad stipends that are not in LEHD)
    - ★ Complete LEHD
    - ★ LBD BR/SSEL
  - Patents: IRIS/UMETRICS link to inventors and assignees in USPTO
  - Publications: IRIS/UMETRICS link to PubMed publications

Summary Statistics Funding Histogram

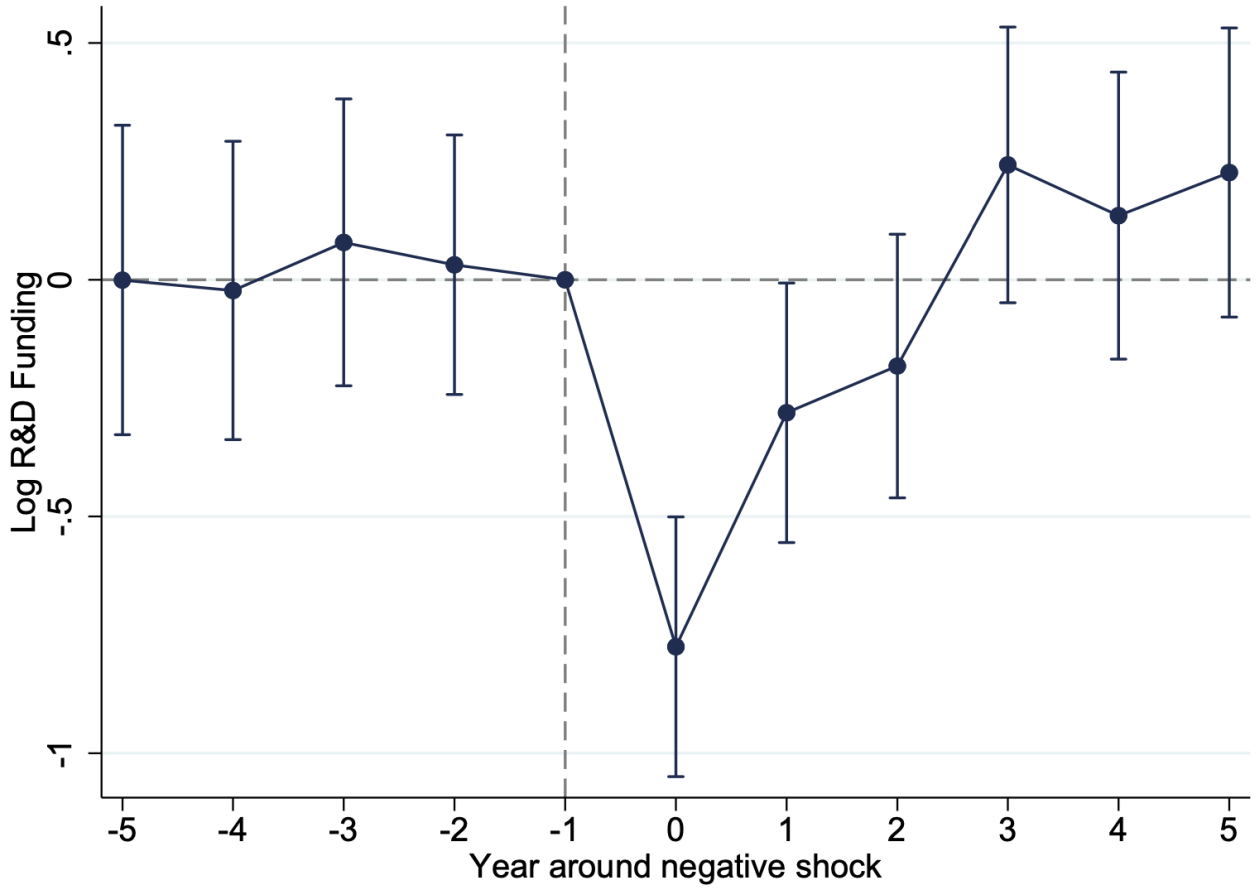
Empirical Strategy

- Challenge: Researcher's funding is endogenous

- Focus on large and temporary negative shocks to aggregate federal research funding in a researcher's narrow pre-existing field of study
  - Shocks address endogeneity in the relationship between funding and research outcomes:
    - ★ Uncorrelated with observed researcher characteristics
    - ★ Idiosyncratic vis-à-vis technology opportunities
  - Defined as a decrease of >40% that reverts back to the pre-shock level later, and there are no changes >20% or <-20% in the two preceding years.
    - ★ In final sample, 61 shocked CFDA codes, 210 control CFDA codes (1,300 treated and 16,700 control individuals)

- Informative about relevant policy counterfactuals given overall declines federal funding

Aggregate Funding Expenditure from Federal Grants around Shocks



Balance Tests NIH Budget Pictures

Empirical Strategy

Average Effect

$$y_i = \beta \text{Post}_{i,t} + \delta_p[+\gamma_i] + \eta_{u,d,t} + \epsilon_{i,u,d,t}$$

Event Study

$$y_i = \sum_{\tau=-5}^{5} \beta_\tau D_{i,\tau} + \delta_p[+\gamma_i] + \eta_{u,d,t} + \epsilon_{i,u,d,t}$$

- i individual, p principal investigator (PI), d department, u university, t year
- PI fixed effects (δ_p) control for quality of lead researcher and topic
- Individual fixed effects (γ_i)
  - Not for high-tech entrepreneurship or patents, because rare to have multiple for individual
- University-department-time fixed effects ($\eta_{u,d,t}$)

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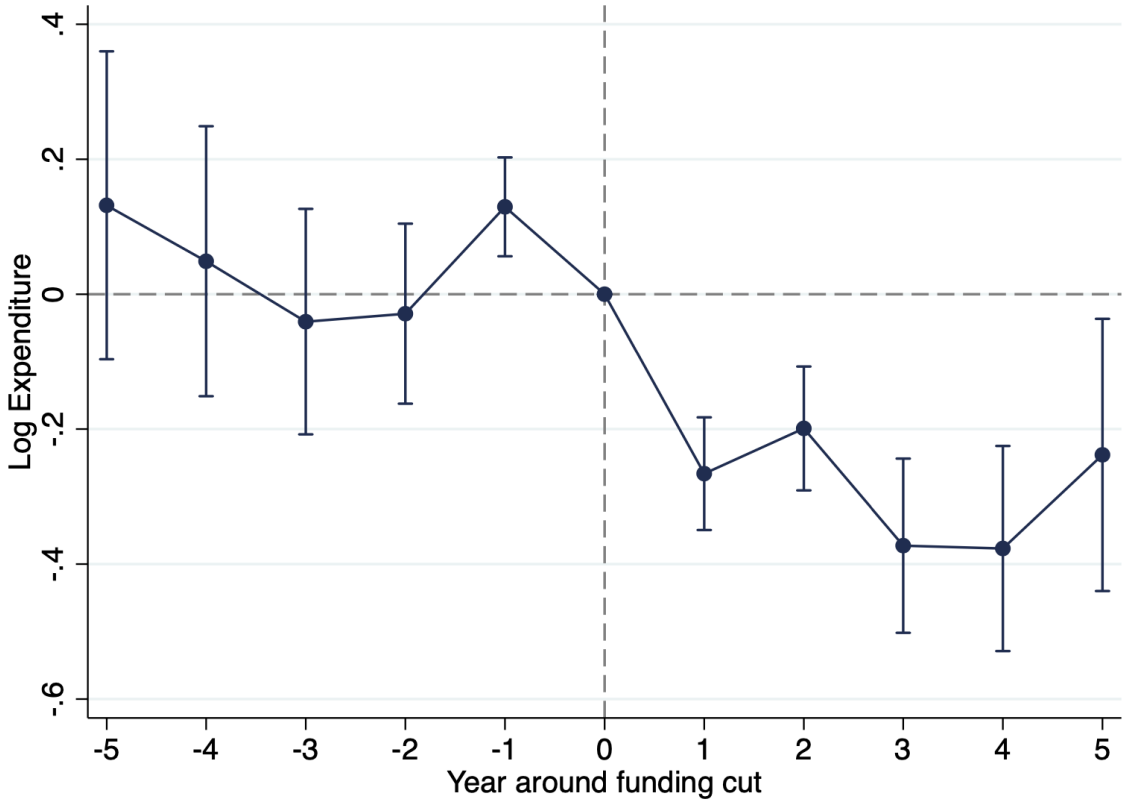
The Effects of Federal Funding Cuts: Expenditure Associated with Individuals from Federal Grants



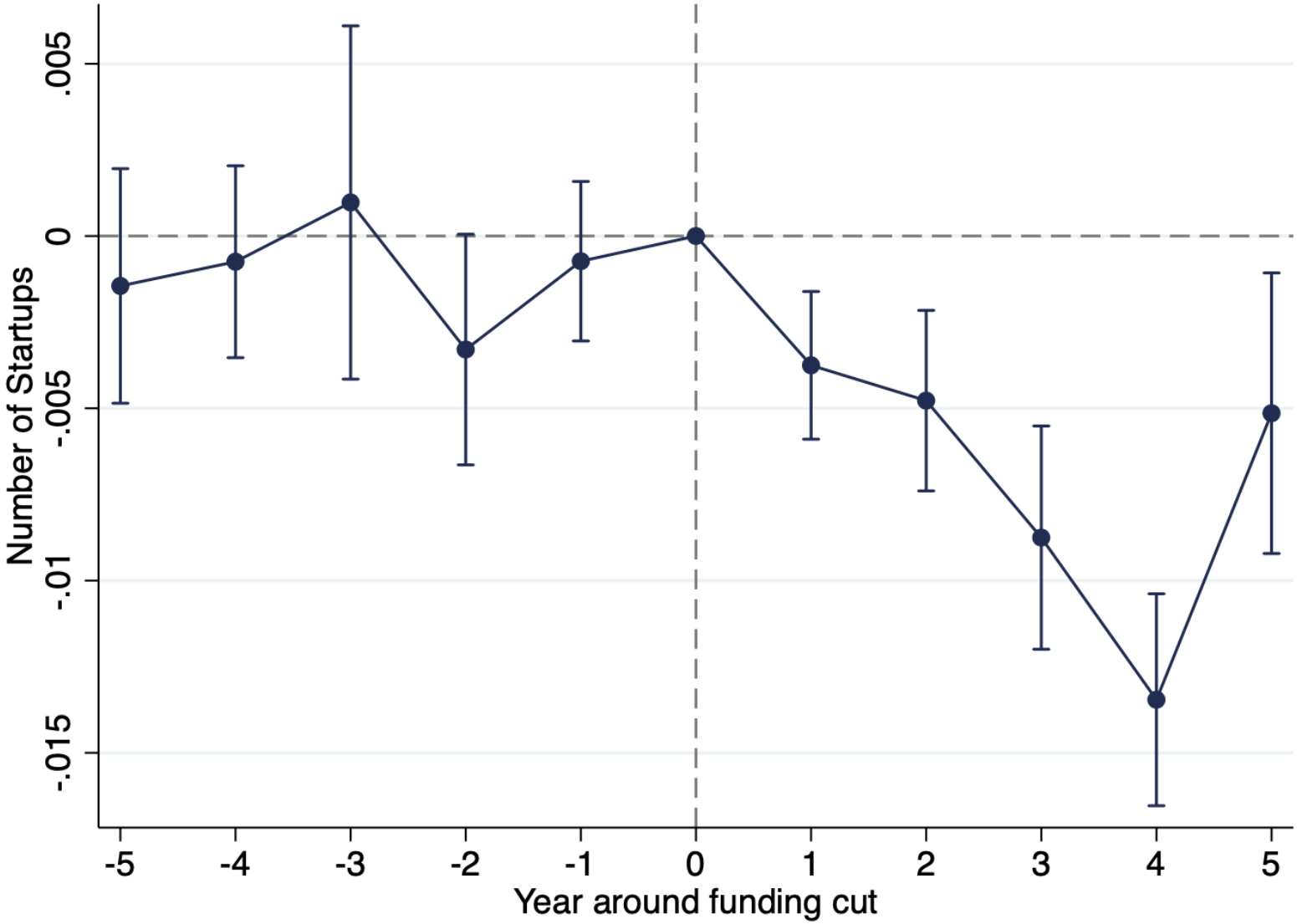
- **"First stage" effect:** Individual-level federal grant expenditure declines persistently after a shock, reflecting researchers who needed new grant funding during time of shock
- Small interruptions have large impact on individual researchers
  Cheng, Perlman, Staudt, and Tham (2022)

The Effects of Federal Funding Cuts: Expenditure Associated with Individuals from Federal Grants

Dependent Variable:	log Federal Funding$_{i,t}$
	(1)
Post$_{i,t}$	-0.3275***
	(0.0586)
University×Year×Department FE	Yes
PI FE	Yes
Person FE	Yes
Number of Observations	316,602
Adjusted R-squared	0.726
Mean of Dependent Variable	9.2

- Col 1: Decrease in federal expenditure of 28%

Effect of Federal Funding Shocks on High-Tech Entrepreneurship

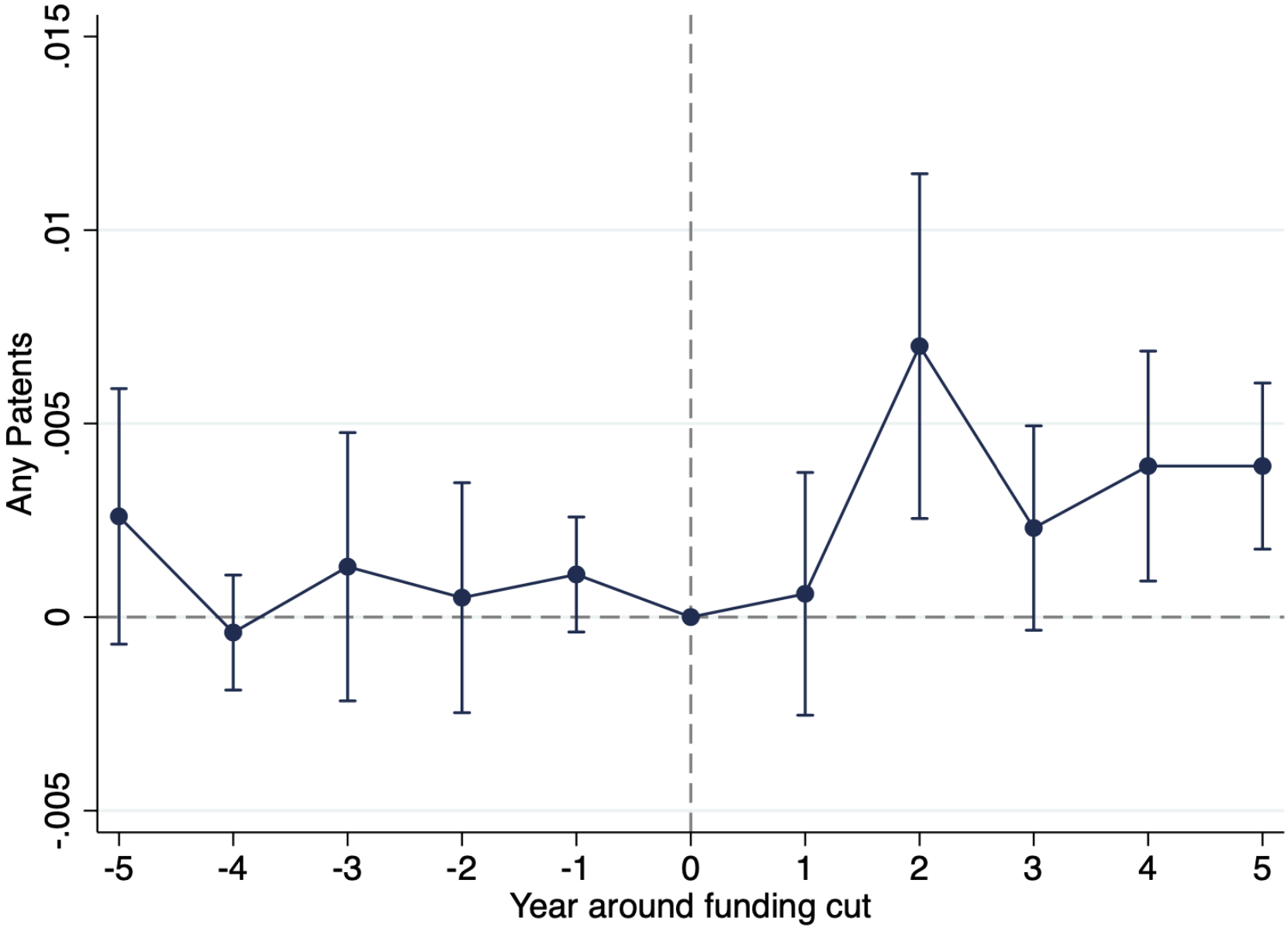


The Effects of Federal Funding Cuts

Dependent Variable:	High-tech Entrepreneurship$_{i,t}$
	(2)
Post$_{i,t}$	-0.0018**
	(0.00077)
University×Year×Department FE	Yes
PI FE	Yes
Person FE	No
Number of Observations	197,000
Adjusted R-squared	0.011
Mean of Dependent Variable	0.00225

- High-tech entrepreneurship important for job creation, has spillovers
- Col 2: Large, negative federal funding shock reduces chance of high-tech entrepreneurship by 0.18 percentage points, 80% of mean
- Back-of-the-envelope calculation: average shock in our data → 1,000 fewer high-tech startups (2.3% annual US new high-tech startups)

Effect of Federal Funding Shocks on Any Patents



The Effects of Federal Funding Cuts

Dependent Variable:	Any Patents$_{i,t}$	Number of Patents$_{i,t}$
	(3)	(4)
Post$_{i,t}$	0.0026**	0.0039***
	(0.0010)	(0.0013)
University×Year×Department FE	Yes	Yes
PI FE	Yes	Yes
Person FE	No	No
Number of Observations	316,602	316,602
Adjusted R-squared	0.053	0.044
Mean of Dependent Variable	0.0023	0.0028

- Granted patents proxy for innovation with commercial application
  - More productive research will likely be associated with more patents
  - Reflects creation of contractible intellectual property
- Col 3: Negative shock doubles chances of having a patent
- Back-of-the-envelope calculation: average shock in our data→ 2,200 more patents (1% of the U.S. mean)

The Effects of Federal Funding Cuts

Dependent Variable:	Any Publications$_{i,t}$	Number of Publications$_{i,t}$
	(5)	(6)
Post$_{i,t}$	-0.0120**	-0.0466***
	(0.0055)	(0.0172)
University×Year×Department FE	Yes	Yes
PI FE	Yes	Yes
Person FE	Yes	Yes
Number of Observations	316,602	316,602
Adjusted R-squared	0.554	0.647
Mean of Dependent Variable	0.097	0.302

- Publications most common way academic research is disseminated
  - Information can be freely used
- Col 6: Negative shock reduces a researcher's overall number of publications by about 16%
- Back-of-the-envelope calculation: average shock in our data → 27,000 fewer publications (4% of the U.S. mean in PubMed)

Effects by Occupation

Occupational Group:	Faculty	Graduate Students and Postdocs	Undergraduate Students	Staff
	(1)	(2)	(3)	(4)
Panel A. Dependent Variable:		High-tech Entrepreneurship$_{i,t}$		
Post$_{i,t}$	-0.000078	-0.0023*	-0.0085	-0.00052
	(0.00103)	(0.0013)	(0.0066)	(0.0017)
University×Year×Department FE	Yes	Yes	Yes	Yes
PI FE	Yes	Yes	Yes	Yes
Number of Observations	35,500	91,000	19,000	53,000
Adjusted R-squared	0.029	0.007	0.26	0.026
Mean of Dependent Variable	0.0016	0.0025	0.0019	0.0023
Panel B. Dependent Variable:		Number of Patents$_{i,t}$		
Post$_{i,t}$	0.0072	0.0038**	-0.0037	0.0006
	(0.0052)	(0.0017)	(0.0047)	(0.0008)
University×Year×Department FE	Yes	Yes	Yes	Yes
PI FE	Yes	Yes	Yes	Yes
Number of Observations	52,172	134,949	25,785	103,696
Adjusted R-squared	0.174	0.067	0.040	0.122
Mean of Dependent Variable	0.008	0.0028	0.0007	0.0006
Panel C. Dependent Variable:		Number of Publications$_{i,t}$		
Post$_{i,t}$	-0.2201***	0.0118	0.0095	-0.0131
	(0.0607)	(0.0281)	(0.0257)	(0.0111)
University×Year×Department FE	Yes	Yes	Yes	Yes
Person FE	Yes	Yes	Yes	Yes
Number of Observations	52,172	134,949	25,785	103,696
Adjusted R-squared	0.651	0.520	0.244	0.537
Mean of Dependent Variable	1.21	0.18	0.02	0.08

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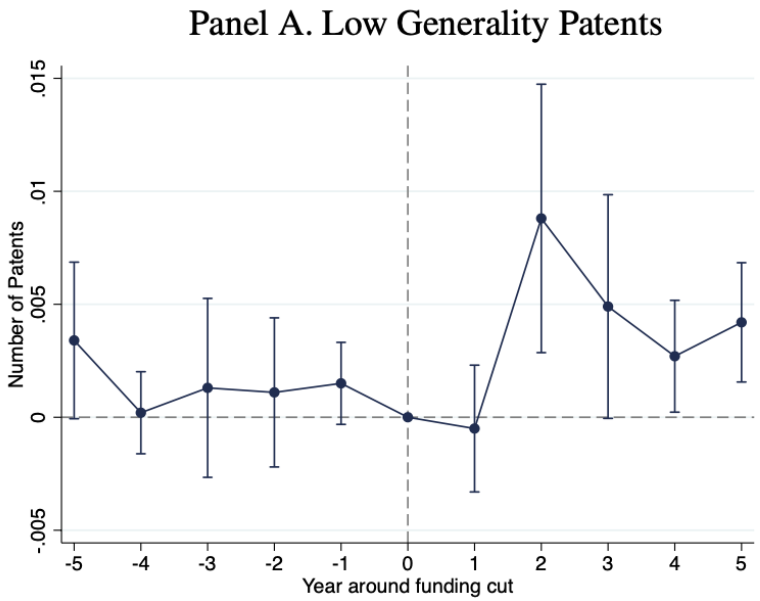
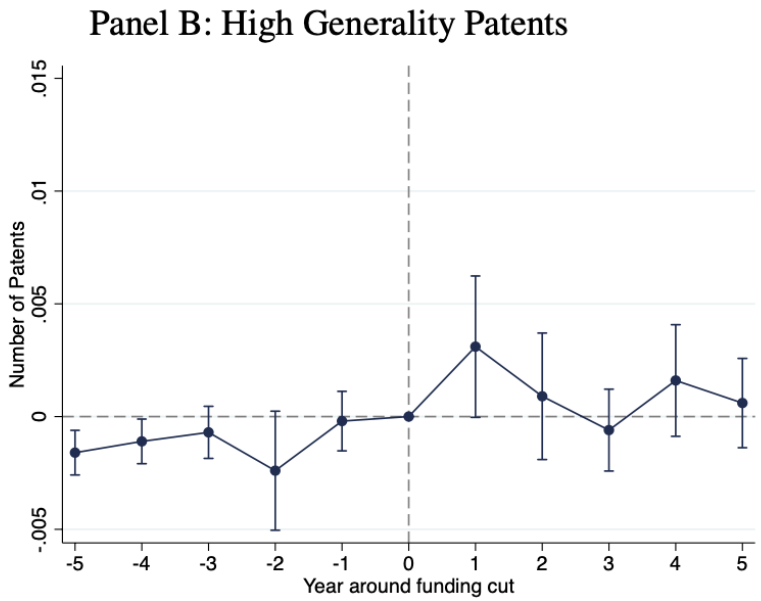
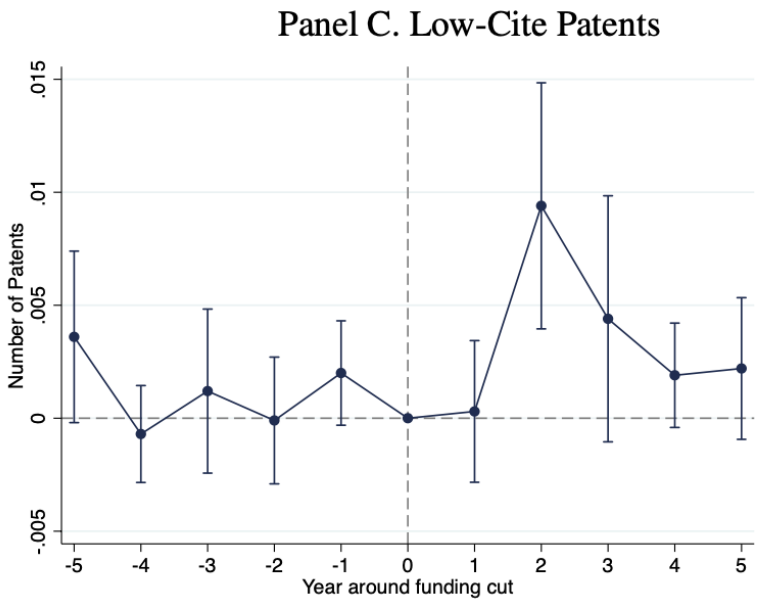
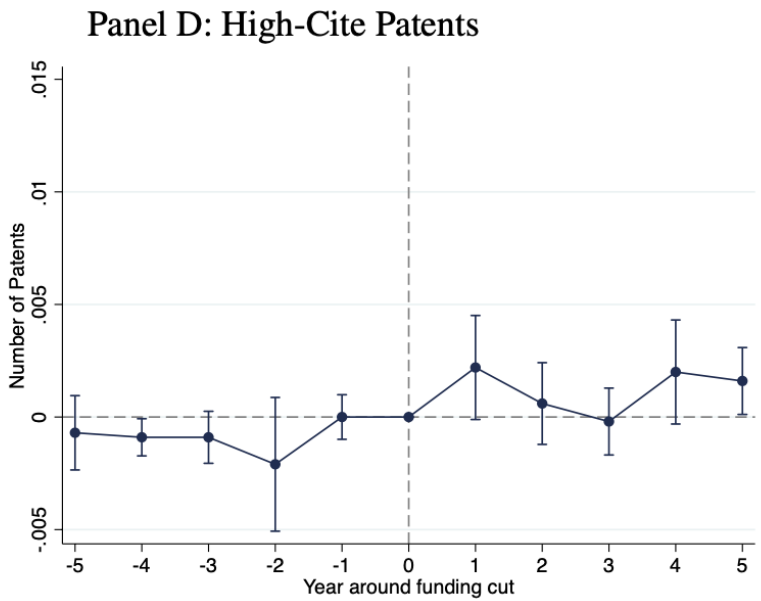
Effects of Federal Funding Cuts on Patents by Type



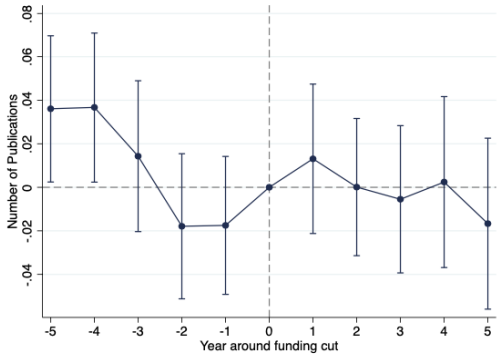




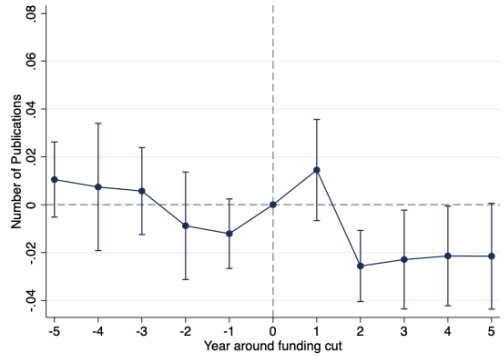


Effects of Federal Funding Cuts on Publications by Type

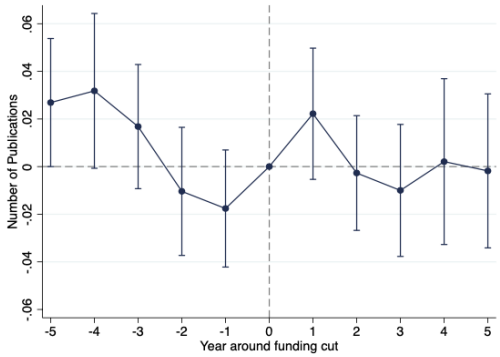
Panel A. Publications in Low-impact Journals



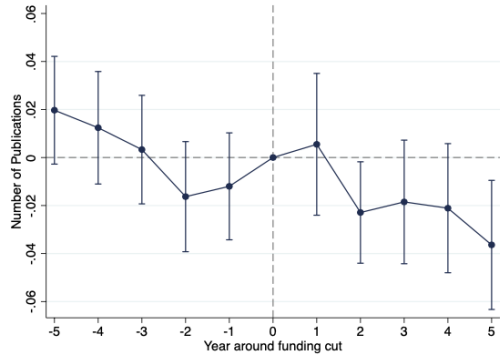
Panel B: Publications in High-impact Journals



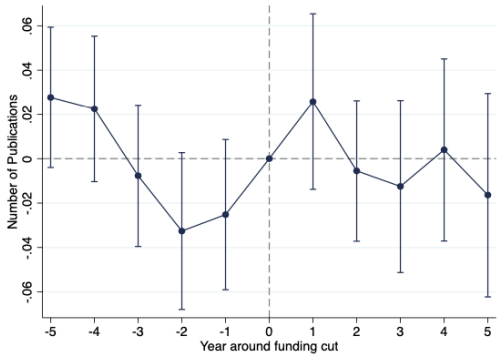
Panel C. Low-Cite Publications



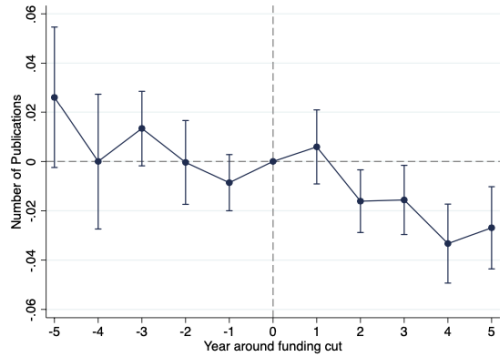
Panel D: High-Cite Publications



Panel E. Applied Publications



Panel F: Basic Publications



Robustness

- Exposure by Grant Timing: Grants that are >=2 years old driving the result Split Grants
- Balance Test: Shocks uncorrelated with observed researcher characteristics Balance Tests
- Technological Opportunities: See no effect in industries/technology classes assorted with shocks Placebo Test
- Positive Funding Shocks: Many fewer shocks but find consistent results Positive Shocks
- Lab-Level Analysis: Labs also see impacts Lab Size
- Standard Error Clustering: Robust to alternative clustering Other Standard Errors

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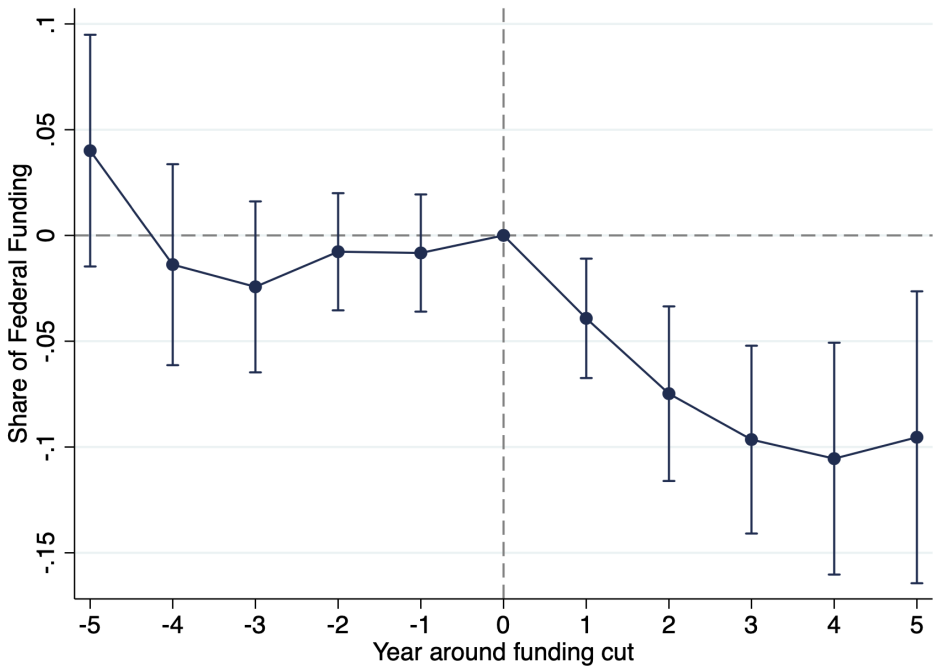
Overall Effect on Funding

Dependent Variable:	log All Funding$_{i,t}$	log Private Funding$_{i,t}$		Share Federal$_{i,t}$	Share Private$_{i,t}$
	(1)	(2)	(3)	(4)	(5)
Post$_{i,t}$	-0.1556**	0.1401	0.2536*	-0.0411***	0.0302***
	(0.0725)	(0.1515)	(0.1566)	(0.0115)	(0.0089)
University×Year×Department FE	Yes	Yes	Yes	Yes	Yes
PI FE	Yes	Yes	Yes	Yes	Yes
Number of Observations	316,602	316,602	157,763	316,602	316,602
Adjusted R-squared	0.404	0.435	0.455	0.316	0.285

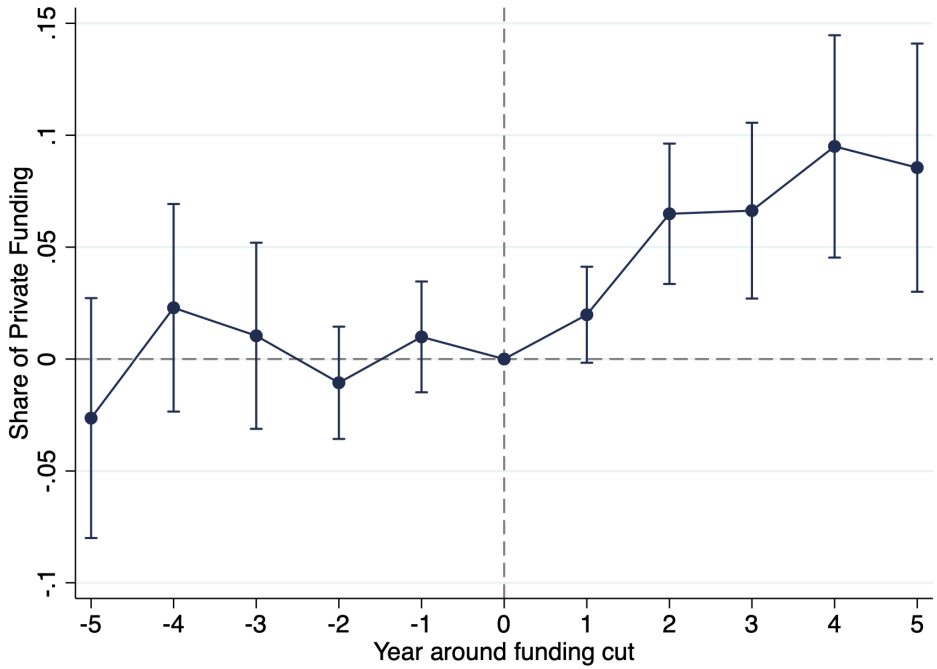
- Total funding decreases by 14.4% after the 28% decrease in federal funding, but there is a 15% increase private in funding
- Different types of funders have different goals and structure their research funding programs accordingly
  Azoulay and Li (2020)

Share Event Studies

Share of Federal Funding



Share of Private Funding



Summary Statistics by Funding Source

Funding Type:	Federal	Private	T-test p-value
UMETRICS Outcomes:			
Mean Total Expenditure (thousands)	367.2	216.4	0.000
Median Total Expenditure (thousands)	123.4	50.0	
Mean Team Size	7.42	4.75	0.000
Median Team Size	4	2	
Patent Outcomes:			
Number of Patents	6,083	1,303	
Mean Patent Generality	0.185	0.143	0.000
Mean Adjusted Citation (by filing year and field)	1.19	0.895	0.016
Percent of Assignees That Are Private Firms	3.3	5.7	0.000
Publications Outcomes:			
Number of Publications	448,714	61,293	
Mean Journal Impact Factor	2.63	2.48	0.000
Mean Citation (with 3 year of publishing)	21.2	20.8	0.183
Mean Citation (all years)	42.4	39.8	0.000
Mean Appliedness Score	0.102	0.184	0.000
Mean Citations by Patents	0.125	0.127	0.802

Effect of Federal Cuts

- **Research Productivity** due to decline in funding level
  - High-tech entrepreneurship ↓ [✓]
  - Patents ↓ [✘]
  - Publications ↓ [✓]

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- **Basic vs. Applied**: federal funders willing to fund basic research, private funders will seek projects with clear commercial applicability
  - High-tech entrepreneurship ↑ [✘]
  - Patents ↑ [✓]
  - Publications ↓ [✓]

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  - Publications ↓ [✓]

- **Appropriation**: Expect private firms seeking to maximize shareholder value will demand research outputs that they can appropriate
  - High-tech entrepreneurship ↓ [✓]
  - Patents ↑ [✓]
  - Publications ↓ [✓]

Appropriation

- High-tech entrepreneurship ↓ [✓]
  - Also find evidence that human capital created by a private grant often appropriated by the sponsor: Among individuals with private funding who subsequently work at any funder firm (~500 firms), 20% go to the firm that funded their own research
- Patents ↑ [✓]
  - Cuts also increase the probability that a patent has a private assignee
  - Manually matching private funders to patent assignee firms: 40% of the privately assigned patents assigned to the firm that funded the researcher's grant (>> 1.6% that random chance would predict)
- Publications ↓ [✓]
  - More open form of sharing knowledge

Contractual Evidence

- Private industry grants are accompanied by detailed contracts, which may follow long negotiations, while federal grants come with no contract at all

- Common for industry funders to have rights of first refusal to research findings, complex non-disclosure agreements, and some control over the direction of research
  NAP (1993), McCluskey (2017)

Contractual Evidence Examples

NYU: *"Results.* ***Company shall have and retain all right, title and interest in and to the Results****, and Institution hereby assigns to Company all of its right, title and interest in and to the Results. Company hereby grants to the Institution a limited, non-exclusive, and fully-paid license to* ***use the Results for its internal academic, research and educational purposes****."*

Harvard: *"With respect to each Invention, Harvard hereby grants to Company an option to negotiate in good faith with Harvard (an "Option") for a non-exclusive or an exclusive (at Company's discretion), royalty-bearing, worldwide license..."*

University of Maryland: *Sponsor will be notified of any research results within 60 days and may choose "to negotiate an exclusive or nonexclusive commercial use license in the UMD Research Results."*

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Conclusion

- Causal analysis of effect of federal funding on university research outcomes
- Cuts to federal funding
  - Increase patenting
    - ★ Additional patents are relatively low-quality
  - Reduce high-tech entrepreneurship
  - Reduce publications
    - ★ Lost publications are relatively basic as opposed to applied and lower citation
- $\rightarrow$ **Federal funding plays an important role in generating impactful, open research outputs**
  - Cuts to Federal funding lead to more appropriation of research outputs

Thank You

Tania Babina	tania.babina@gsb.columbia.edu	@TaniaBabina
Alex Xi He	axhe@umd.edu	@AlexXiHe
Sabrina Howell	sabrina.howell@nyu.edu	
Elisabeth Perlman	elisabeth.perlman@census.gov	@BitsyPerlman
Joseph Staudt	joseph.staudt@census.gov	@JosephStaudt

Appendix

Balance Tests

Dependent Variable:	Share of Federal Funding	Share of Private Funding	log Total Funding	Faculty	Graduate Students and Postdocs	Undergraduate Students	Any Patents	Number of Patents	Any Publications	Number of Publications
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Treated	0.0052	-0.0059	-0.0496	0.0088	-0.0081	-0.0054	-0.0007	-0.0012	-0.0026	-0.0282
	(0.0061)	(0.0071)	(0.0515)	(0.0055)	(0.0063)	(0.0036)	(0.0007)	(0.0009)	(0.0037)	(0.0184)
University×Year×Department FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of Observations	291,092	291,092	291,092	291,092	291,092	291,092	291,092	291,092	291,092	291,092
Adjusted R-squared	0.094	0.076	0.178	0.066	0.129	0.137	0.008	0.005	0.123	0.065

Back Event Study

Back Robustness

Case Histories of Shocks

"Congress may tell us to spend more money on Alzheimer's disease, and that means we'll spend less money on, say, hip fractures. Or they might tell us to spend more money on Down's syndrome, perhaps we'll spend less money on cerebral palsy. This does not mean someone made a deliberate decision to spend less on cerebral palsy. The particular area of science is being favored for funding; the opportunity cost is that something else must go down. ... there may have been a push to fund some other area of science, either from congress or strategic planning; because that area got funded more, it would be more difficult for a grant in another CFDA within the broader area to get funded unless it got an unbelievable score."

- Deputy Director for Extramural Research at the National Institutes of Health

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Case Histories of Shocks

- "Animal Health and Disease Research" at the U.S. Department of Agriculture. The "Food, Conservation, and Energy Act of 2008" reauthorized funding for this area until 2012, suggesting that policymakers did not see meaningful changes in opportunities in this area in the medium term. However, the 2009 budget cut this item to zero
  - The budget explains that there are increases in some research programs "totaling more than $43 million. These increases are offset by the reduction of $88 million in lower priority programs." "Animal Health and Disease Research" was reduced from $5 million to zero, the following year, the "Animal Health and Disease Research" program was funded at $3 million
- "Water Desalination Research and Development" program at the U.S. Department of the Interior (DOI). Despite increased funding requests from DOI, Congress enacted a significant decline for 2010, which may have reflected increasing funds for a particular desalination project, the "Long Beach Area Water Reclamation Project." We do not observe any rationale in public documents for the Congressional appropriations

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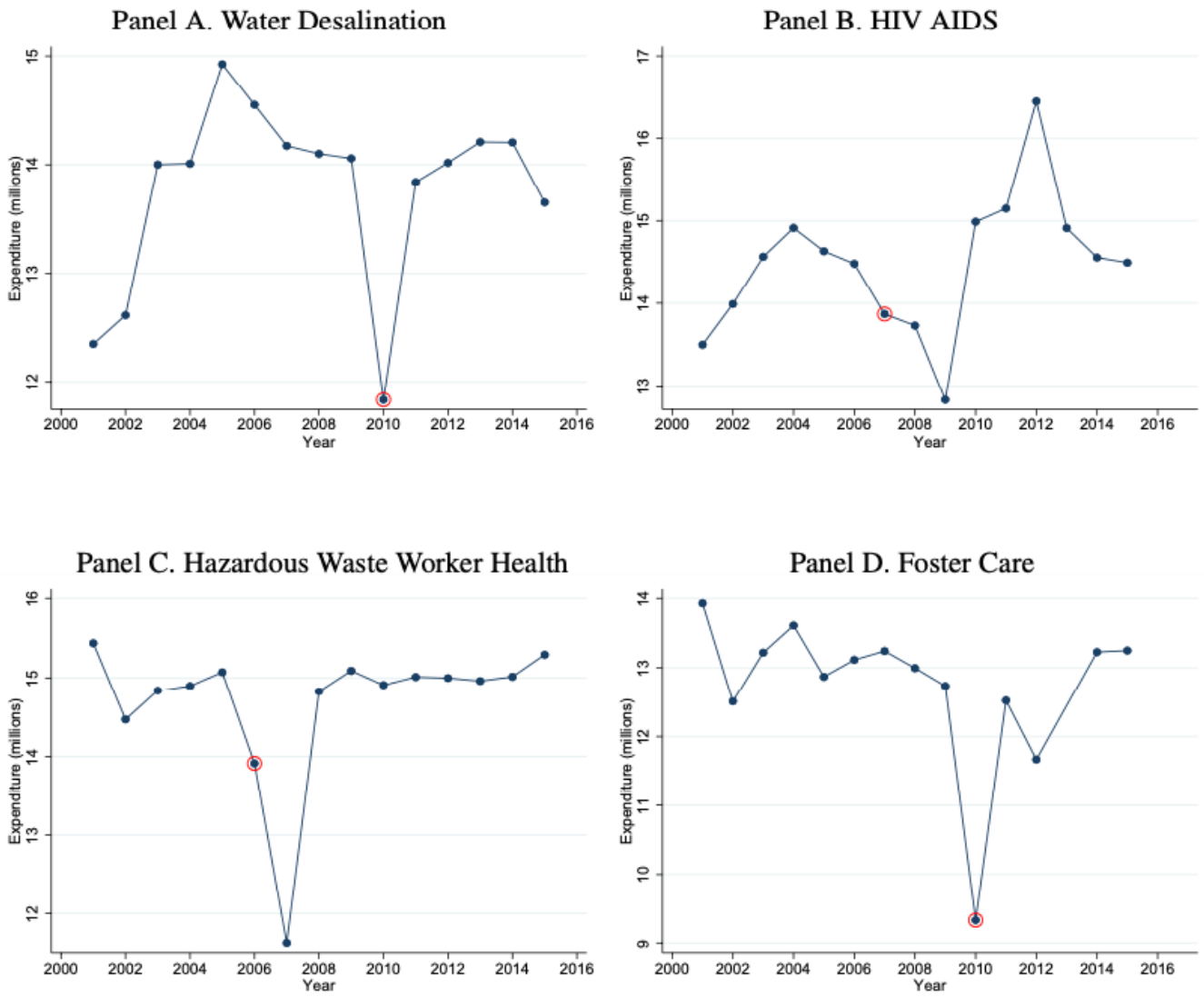
Examples of CFDA-level Funding Histories



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Summary Statistics: UMETRICS and Patents

	Number of Observations	Mean	Standard Deviation
Panel A. Umetrics			
Faculty	316,602	0.164	
Graduate Students and Postdocs	316,602	0.432	
Undergraduate Students	316,602	0.081	
Staff	316,602	0.323	
Total Direct Expense$_{i,t}$	316,602	13,309	96,072
Overhead Charged$_{i,t}$	316,602	3,404	13.227
Share Federal$_{i,t}$	316,602	0.801	0.365
Share Private$_{i,t}$	316,602	0.128	0.293
Share Other$_{i,t}$	316,602	0.105	0.276
Number of CFDA Codes	316,602	1.76	1.27
Δ Log(Amount R&D$_{i,t}$)	316,602	0.041	1.06
Panel B. Patents			
Any Patents$_{i,t}$	316,602	0.0023	0.048
Number of Patents$_{i,t}$	316,602	0.0028	0.067
Number of Patents with low citations$_{i,t}$	316,602	0.0019	0.048
Number of Patents with high citations$_{i,t}$	316,602	0.0009	0.041
Number of Patents with low generality$_{i,t}$	316,602	0.0021	0.053
Number of Patents with high generality$_{i,t}$	316,602	0.0007	0.036
Number of Patents with Private Assignee$_{t}$	316,604	0.0002	0.020
Number of Patents$_{i,t}$ (Faculty)	51,923	0.0080	0.118
Number of Patents$_{i,t}$ (Graduate Students)	136,772	0.0028	0.065
Number of Patents$_{i,t}$ (Undergraduate Students)	25,645	0.0007	0.027
Number of Patents$_{i,t}$ (Staff)	102,262	0.0006	0.028

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Summary Statistics: Publications and Career Outcomes

	Number of Observations	Mean	Standard Deviation
Panel C. Publications			
Any Publications$_{i,t}$	316,602	0.097	0.296
Number of Publications$_{i,t}$	316,602	0.302	1.45
Number of High-citation Publications$_{i,t}$	316,602	0.134	0.786
Number of Low-citation Publications$_{i,t}$	316,602	0.168	0.824
Number of High-impact Publications$_{i,t}$	316,602	0.125	0.742
Number of Low-impact Publications$_{i,t}$	316,602	0.177	0.936
Number of Basic Publications$_{i,t}$	316,602	0.085	0.568
Number of Applied Publications$_{i,t}$	316,602	0.165	1.07
Number of Publications cited by patents$_{i,t}$	316,603	0.043	0.340
Number of Publications$_{i,t}$ (Faculty)	51,923	1.21	2.82
Number of Publications$_{i,t}$ (Graduate Students)	136,772	0.18	1.09
Number of Publications$_{i,t}$ (Undergraduate Students)	25,645	0.02	0.219
Number of Publications$_{i,t}$ (Staff)	102,262	0.08	0.567
Panel D. Career Outcomes			
High-tech Entrepreneurship$_{i,t}$	197,000	0.00225	0.0483
Entrepreneurship$_{i,t}$	197,000	0.016	0.1299
Work for Young Firm$_{i,t}$	197,000	0.0519	
Work for Young High-tech Firm$_{i,t}$	197,000	0.0091	0.0963
Work for University$_{i,t}$	197,000	0.4996	
Real Wage$_{i,t}$	197,000	69,540	93,180
High-tech Entrepreneurship$_{i,t}$ (Faculty)	35,000	0.192	
High-tech Entrepreneurship$_{i,t}$ (Graduate Students)	91,000	0.462	
High-tech Entrepreneurship$_{i,t}$ (Undergraduate Students)	19,000	0.153	
High-tech Entrepreneurship$_{i,t}$ (Staff)	53,000	0.202	

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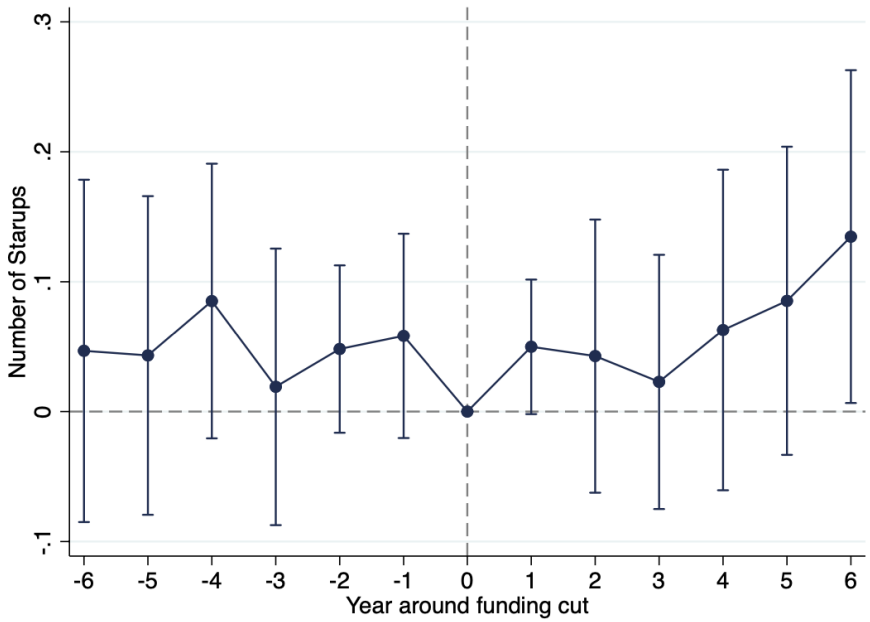
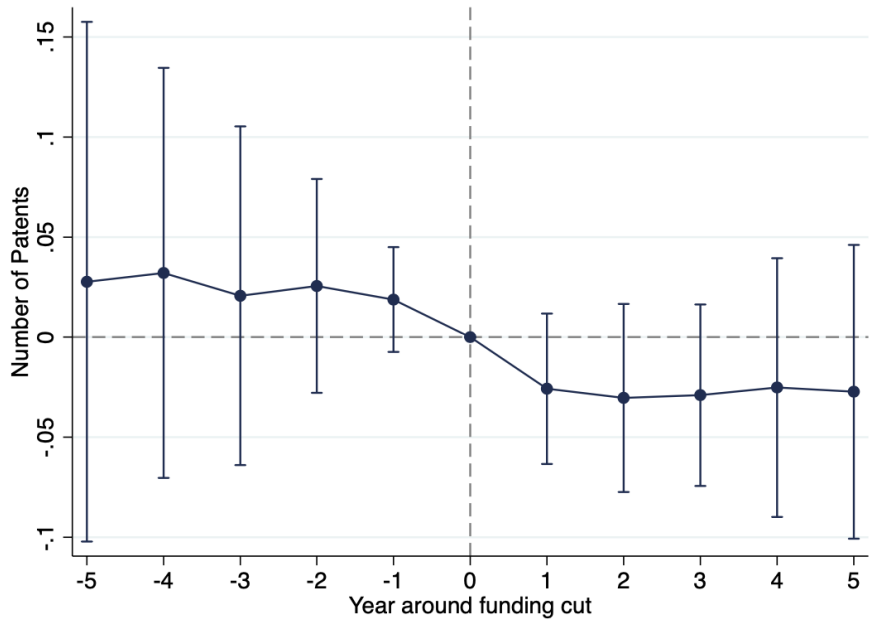
Robustness: Placebo Test for Technological Opportunities

Panel A. High-Tech Entrepreneurship



Panel B. Placebo Test for Number of Patents



- No pre-trend and no change post-shock, supporting the assumption that the shock is idiosyncratic & doesn't reflect technological changes or opportunities associated with a CFDA program's field

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Describe Details

Robustness: Exposure by Grant Timing

Dependent Variable:	log Federal Funding$_{i,t}$	Any Patents$_{i,t}$	Number of Patents$_{i,t}$	Any Publications$_{i,t}$	Number of Publications$_{i,t}$
	(1)	(2)	(3)	(4)	(5)
Post$_{i,t}$ * (Award $<$ 2 years)	-0.2290***	0.0007	0.0012	-0.0054	-0.0382*
	(0.0808)	(0.0010)	(0.0010)	(0.0082)	(0.0204)
Post$_{i,t}$ * (Award $>=$ 2 years)	-0.4940***	0.0029**	0.0048***	-0.0160**	-0.0580**
	(0.0642)	(0.0012)	(0.0015)	(0.0063)	(0.0228)
University×Year×Department FE	Yes	Yes	Yes	Yes	Yes
PI FE	Yes	Yes	Yes	Yes	Yes
Person FE	Yes	No	No	Yes	Yes
Number of Observations	316,602	316,602	316,602	316,602	316,602
Adjusted R-squared	0.727	0.053	0.044	0.554	0.647
Mean of Dependent Variable	9.2	0.0023	0.0028	0.097	0.302
p-value for the Difference	0.020	0.091	0.024	0.365	0.477

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Robustness: Positive Funding Shocks

Dependent Variable:	log Federal Funding$_{i,t}$	Any Patents$_{i,t}$	Number of Patents$_{i,t}$	Any Publications$_{i,t}$	Number of Publications$_{i,t}$
	(1)	(2)	(3)	(4)	(5)
Post$_{i,t}$	0.2504*	-0.0027	-0.0028	0.0136*	0.0376*
	(0.1498)	(0.0020)	(0.0023)	(0.0076)	(0.0223)
University×Year×Department FE	Yes	Yes	Yes	Yes	Yes
PI FE	Yes	Yes	Yes	Yes	Yes
Person FE	Yes	No	No	Yes	Yes
Number of Observations	230,175	230,175	230,175	230,175	230,175
Adjusted R-squared	0.753	0.054	0.045	0.553	0.637
Mean of Dependent Variable	9.3	0.0028	0.0035	0.104	0.322

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Robustness: Lab-Level Analysis

Dependent Variable:	Lab Size$_{i,t}$	Any Patents$_{i,t}$	Number of Patents$_{i,t}$	Any Publications$_{i,t}$	Number of Publications$_{i,t}$
	(1)	(2)	(3)	(4)	(5)
Post$_{i,t}$	-0.3706**	0.0085*	0.0159*	-0.0119	-0.0721*
	(0.1747)	(0.0048)	(0.0093)	(0.0184)	(0.0371)
University×Year×Department FE	Yes	Yes	Yes	Yes	Yes
PI FE	Yes	Yes	Yes	Yes	Yes
Person FE	Yes	No	No	Yes	Yes
Number of Observations	38,277	38,277	38,277	38,277	38,277
Adjusted R-squared	0.566	0.039	0.021	0.479	0.489
Mean of Dependent Variable	2.62	0.013	0.018	0.23	1.12

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Robustness: Standard Error Assumptions

Cluster Standard Errors at University-By-Department Level

Dependent Variable:	log Expenditure Federal$_{i,t}$	High-tech Entrepreneurship$_{i,t}$	Any Patents$_{i,t}$	Number of Patents$_{i,t}$	Any Publications$_{i,t}$	Number of Publications$_{i,t}$
	(1)	(2)	(3)	(4)	(5)	(6)
Post$_{i,t}$	-0.3275***	-0.00181***	0.0026***	0.0039***	-0.0120	-0.0466
	(0.1160)	(0.000601)	(0.0009)	(0.0014)	(0.0139)	(0.0413)
University×Year×Department FE	Yes	Yes	Yes	Yes	Yes	Yes
PI FE	Yes	Yes	Yes	Yes	Yes	Yes
Person FE	Yes	No	No	No	Yes	Yes
Number of Observations	316,602	197,000	316,602	316,602	316,602	316,602
Adjusted R-squared	0.726	0.011	0.053	0.044	0.554	0.647
Mean of Dependent Variable	9.2	0.00225	0.0023	0.0028	0.097	0.302

Cluster Standard Errors at CFDA Level

Dependent Variable:	log Expenditure Federal$_{i,t}$	High-tech Entrepreneurship$_{i,t}$	Any Patents$_{i,t}$	Number of Patents$_{i,t}$	Any Publications$_{i,t}$	Number of Publications$_{i,t}$
	(1)	(2)	(3)	(4)	(5)	(6)
Post$_{i,t}$	-0.3275***	-0.00181**	0.0026***	0.0039***	-0.0120	-0.0466
	(0.1160)	(0.000846)	(0.0009)	(0.0014)	(0.0139)	(0.0413)
University×Year×Department FE	Yes	Yes	Yes	Yes	Yes	Yes
PI FE	Yes	Yes	Yes	Yes	Yes	Yes
Person FE	Yes	No	No	No	Yes	Yes
Number of Observations	316,602	197,000	316,602	316,602	316,602	316,602
Adjusted R-squared	0.726	0.011	0.053	0.044	0.554	0.647
Mean of Dependent Variable	9.2	0.00225	0.0023	0.0028	0.097	0.302

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Robustness: Placebo Test

- Identification assumption: Large shocks do not reflect fundamental changes in tech opportunities in affected field
- Test: Does broader field respond to our one-time funding cuts?
- High-tech entrepreneurship (event study at NAICS-year level)
  - Industry shocked in a given year if an individual in our sample is shocked in that year and then goes on to found a high-tech startup
- Patents (event study at patent class-year level)
  - Patent class is shocked if its corresponding CFDA code is shocked

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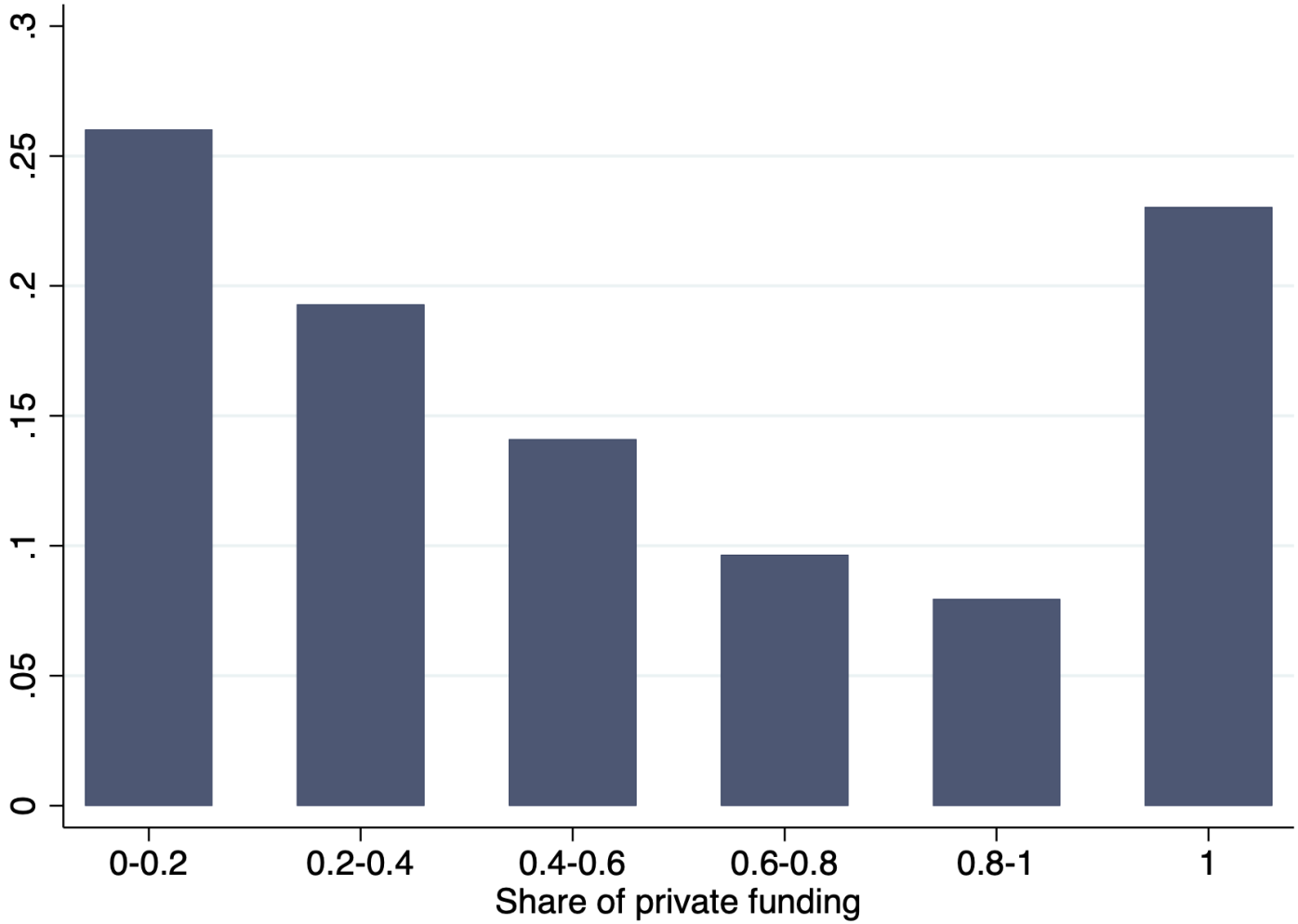
Distribution Funding Shares of Funding Among People With Some Private Funding: Share of Private Funding



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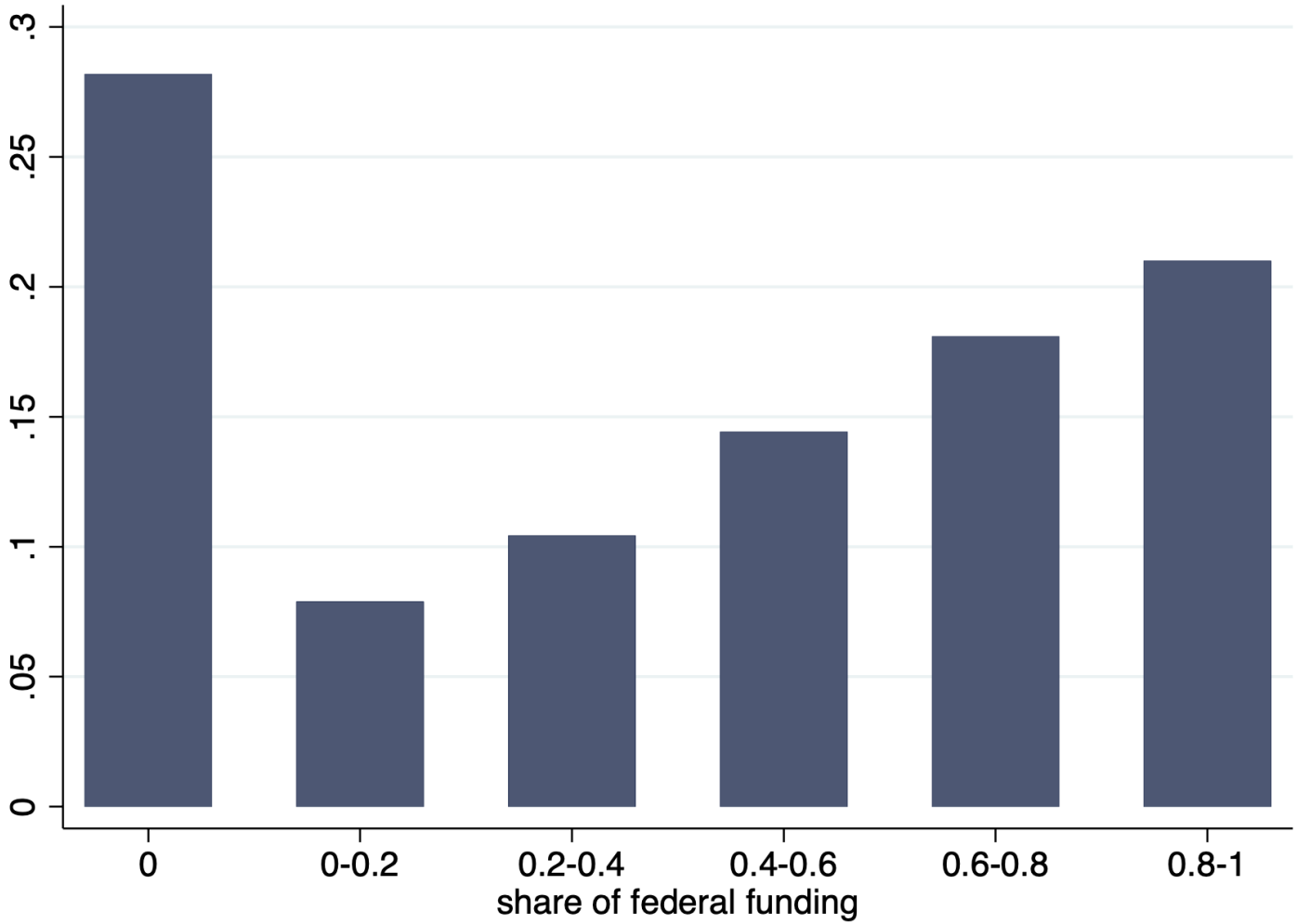
Distribution Funding Shares of Funding Among People With Some Private Funding: Share of Federal Funding



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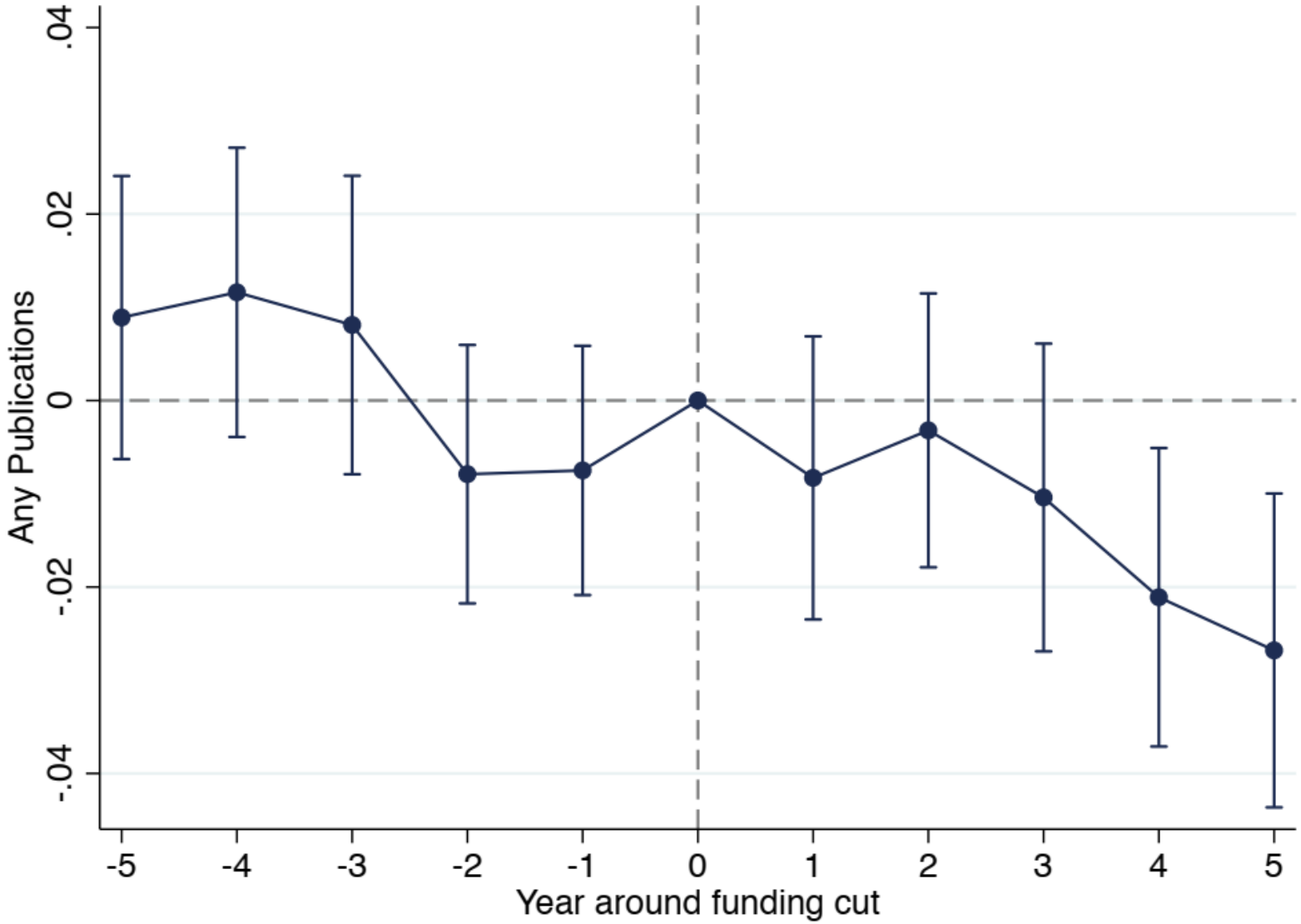
Main Results: The Effects of Federal Funding Cuts

Dependent Variable:	log Expenditure Federal$_{i,t}$	High-tech Entrepreneurship$_{i,t}$	Any Patents$_{i,t}$	Number of Patents$_{i,t}$	Any Publications$_{i,t}$	Number of Publications$_{i,t}$
	(1)	(2)	(3)	(4)	(5)	(6)
Post$_{i,t}$	-0.3275***	-0.0018**	0.0026**	0.0039***	-0.0120**	-0.0466***
	(0.0586)	(0.00077)	(0.0010)	(0.0013)	(0.0055)	(0.0172)
University×Year×Department FE	Yes	Yes	Yes	Yes	Yes	Yes
PI FE	Yes	Yes	Yes	Yes	Yes	Yes
Person FE	Yes	No	No	No	Yes	Yes
Number of Observations	316,602	197,000	316,602	316,602	316,602	316,602
Mean of Dependent Variable	9.2	0.00225	0.0023	0.0028	0.097	0.302

Effect of Federal Funding Shocks on Any Publications



Controlling for Total Expenditure

Dependent Variable:	High-tech Entrepreneurship$_{i,t}$	Any Patents$_{i,t}$	Number of Patents$_{i,t}$	Any Publications$_{i,t}$	Number of Publications$_{i,t}$
	(1)	(2)	(3)	(4)	(5)
Post$_{i,t}$	-0.00204***	0.0025**	0.0036***	0.0037	0.0027
	(0.00079)	(0.0010)	(0.0012)	(0.0083)	(0.0290)
Log(1+Total Funding$_{i,t}$)	-0.00021***	0.0002***	0.0002**	0.0047***	0.0209***
	(0.000044)	(0.0001)	(0.0001)	(0.0003)	(0.0014)
Log(1+Total Funding$_{i,t-1}$)	0.00014***	0.0002***	0.0003***	0.0034***	0.0112***
	(0.000054)	(0.0000)	(0.0001)	(0.0002)	(0.0007)
Log(1+Total Funding$_{i,t-2}$)	-0.0000049	0.0002***	0.0002***	0.0053***	0.0205***
	(0.000045)	(0.0000)	(0.0001)	(0.0002)	(0.0011)
University×Year×Department FE	Yes	Yes	Yes	Yes	Yes
PI FE	Yes	Yes	Yes	Yes	Yes
Person FE	No	No	No	Yes	Yes
Number of Observations	197,000	316,602	316,602	316,602	316,602
Adjusted R-squared	0.011	0.054	0.050	0.265	0.246
Mean of Dependent Variable	0.00225	0.0023	0.0028	0.097	0.302

- Effect on publications seems to reflect level → suggests amount of funding is a central constraint on basic research

Heterogeneous Effects of Federal Funding Cuts on Patents by Their Type

Dependent Variable:	Number of Patents$_{i,t}$				
	Low Generality	High Generality	Low Citations	High Citations	Private Assignee
	(1)	(2)	(3)	(4)	(5)
Post$_{i,t}$	0.0027***	0.0013**	0.0026***	0.0014**	0.0005**
	(0.0010)	(0.0006)	(0.0010)	(0.0006)	(0.0002)
University×Year×Department FE	Yes	Yes	Yes	Yes	Yes
PI FE	Yes	Yes	Yes	Yes	Yes
Number of Observations	316,602	316,602	316,602	316,602	316,602
Adjusted R-squared	0.047	0.024	0.041	0.033	0.068
Mean of Dependent Variable	0.0021	0.0007	0.0019	0.0009	0.0002

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Heterogeneous Effects of Federal Funding Cuts on Publications by Their Type

Dependent Variable:	Number of Publications$_{i,t}$						
	Low Impact Journal	High Impact Journal	Low Citations	High Citations	Applied	Basic	Cited by Patents
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Post$_{i,t}$	-0.0188	-0.0277***	-0.0184*	-0.0282***	-0.0054	-0.0218***	0.0124***
	(0.0119)	(0.0090)	(0.0105)	(0.0096)	(0.0134)	(0.0075)	(0.0041)
University×Year×Department FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Person FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of Observations	316,602	316,602	316,602	316,602	316,602	316,602	316,602
Adjusted R-squared	0.574	0.598	0.519	0.573	0.610	0.549	0.486
Mean of Dependent Variable	0.125	0.177	0.134	0.168	0.165	0.085	0.043

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The Effects of Federal Funding Cuts on Additional Career Outcomes

Dependent Variable:	Entrepreneurship$_{i,[t,t+2]}$	Work for Young Firm$_{i,[t,t+2]}$	Work for Young High-tech Firm$_{i,[t,t+2]}$	Work for Any University$_{i,[t,t+2]}$	Work for Research University$_{i,[t,t+2]}$	Log(Wage$_{i,t}$)
	(1)	(2)	(3)	(4)	(5)	(6)
Post$_{i,t}$	0.0055**	0.0256***	-0.0051**	-0.164***	-0.125***	-0.013
	(0.0027)	(0.0064)	(0.00205)	(0.0169)	(0.0141)	(0.148)
University×Year×Department FE	Yes	Yes	Yes	Yes	Yes	Yes
PI FE	Yes	Yes	Yes	Yes	Yes	Yes
Number of Observations	197,000	197,000	197,000	197,000	197,000	197,000
Adjusted R-squared	0.003	0.033	0.058	0.289	0.329	0.322
Mean of Dependent Variable	0.016	0.052	0.0091	0.50	0.41	$69,540