The Returns to Government R&D: Evidence from U.S. Appropriation Shocks

Andrew J. Fieldhouse
Mays Business School
Texas A&M University

Karel Mertens
Federal Reserve Bank of Dallas
CEPR

American University

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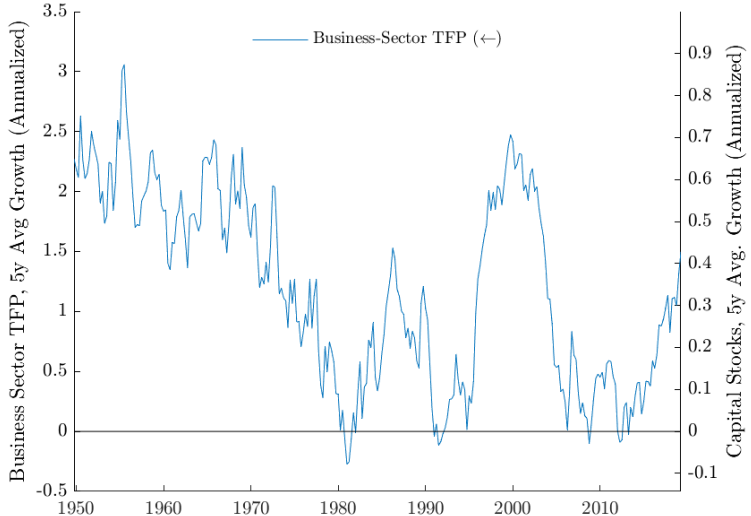
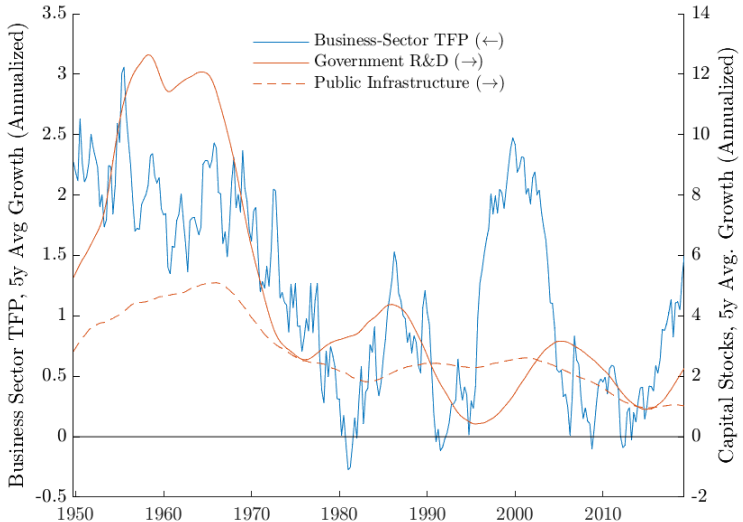
Slowdown in U.S. Productivity Growth



Note: Business-sector total factor productivity (TFP) is utilization-adjusted (Fernald 2012)

Slowdown in U.S. Productivity: Contribution of Public Investment?



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Influence of Government R&D on U.S. Productivity Growth?

Contribution:

- We estimate the causal effects of government-funded R&D on business-sector TFP, exploiting a new source of exogenous variation in federal R&D appropriations
- Medium-run local projections and structural estimation of elasticities, rates of return

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Context for magnitude of results:

- Dyèvre (2024): Public R&D ↓ accounts for ∼33% of TFP slowdown over 1950-2017
- Jones and Summers (2022): Social returns to total U.S. R&D expenditure of ∼67%

Is Government-funded R&D Special?

Theory: private sector under-invests in basic research because of knowledge externalities, limited returns

▸ R&D Types

- Nelson (1959), Akcigit, Hanley, and Serrano-Velarde (2021)

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Micro evidence: lots on specific government R&D programs boosting patents etc

- Defense: Moretti, Steinwender, and Van Reenen (2021); Energy: Myers and Lanahan (2022); NIH: Li, Azoulay, and Sampat (2017); Azoulay, Graff Zivin, Li, and Sampat (2019); NASA: Kantor and Whalley (2024); Total: Akcigit, Hanley, Serrano-Velarde (2021); Dyèvre (2024)

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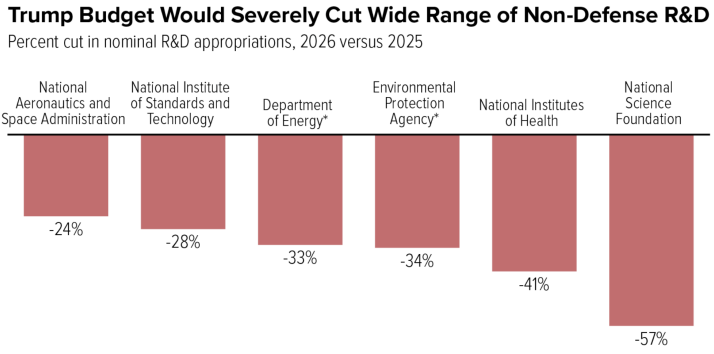
Macro evidence: little on aggregate social returns to government-funded R&D

- Bloom, Schankerman, and Van Reenen (2013); Jones and Summers (2020)
- De Lipsis, Deleidi, Mazzucato, and Agnolucci (2023), Antolin-Diaz and Surico (2025)

Policy Context and Policy Analysis



Source: Center on Budget and Policy Priorities (2025)

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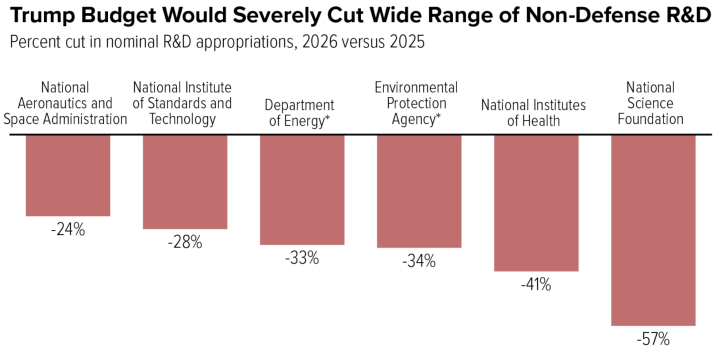

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We hope our estimates are useful, timely inputs for policy analysis:

- Gonzalez Garcia, Montecino, and Ramaswamy (2025)
- Congressional Budget Office (2025)

"A Narrative Analysis of Federal Appropriations for Research and Development"

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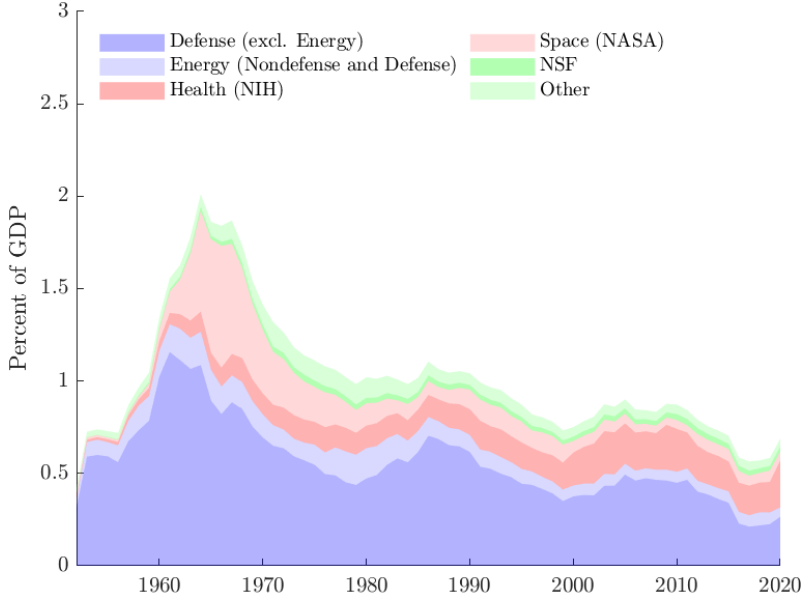
We analyze R&D appropriations for 5 major agencies (∼87-93% of total):

- Department of Defense (DOD): FY1947-2019
- Department of Energy* (DOE): FY1947-2019
- National Institutes of Health (NIH): FY1947-2019
- National Science Foundation (NSF): FY1952-2019
- National Aeronautics and Space Administration (NASA): FY1957-2019

*Also the Atomic Energy Commission, Energy Research and Development Administration

Federal R&D Outlays by Agency



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We analyze 257 appropriations changes by agency, fiscal year

▸ Data Sources

"All the News That's Fit to Print"

The New York Times.

LATE CITY EDITION
U. S. Weather Bureau Report (Page 25) Forecast: Cloudy and cool today and tonight. Mostly fair tomorrow. Temp. range: 65—55. Yesterday: 62.4—49.2.

VOL. CVII..No. 36,414. © 1957, by The New York Times Company. NEW YORK, SATURDAY, OCTOBER 5, 1957. 10c beyond 150-mile zone FIVE CENTS

SOVIET FIRES EARTH SATELLITE INTO SPACE; IT IS CIRCLING THE GLOBE AT 18,000 M. P. H.; SPHERE TRACKED IN 4 CROSSINGS OVER U. S.

HOFFA IS ELECTED TEAMSTERS HEAD; WARNS OF BATTLE

Defeats Two Foes 3 to 1 —Says Union Will Fight 'With Every Ounce'

Text of the Hoffa address is printed on Page 6.

By A. H. RASKIN
Special to The New York Times.

MIAMI BEACH, Oct. 4—The scandal-scarred International Brotherhood of Teamsters elected James R. Hoffa in His president today.

He won by a margin of nearly 3 to 1 over the combined vote of two rivals who campaigned on pledges to clean up the nation's biggest union.

Senate rackets investigators and Hoffa critics in the union rank-and-file immediately opened actions to stop the 44-year-old former warehouseman from Detroit of his election victory.

A jubilant Hoffa exhibited,

Associated Press Wirephoto

IN TOKEN OF VICTORY: Dave Beck, retiring head of the Teamsters Union, raises hand of James R. Hoffa upon his election as union's president. At right is Mrs. Hoffa.

COURSE RECORDED

Navy Picks Up Radio Signals—4 Report Sighting Device

By WALTER SULLIVAN
Special to The New York Times.

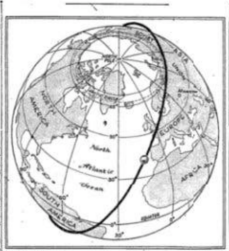
WASHINGTON, Saturday, Oct. 5—The Naval Research Laboratory announced early today that it had recorded four crossings of the Soviet earth satellite over the United States.

It said that one had passed near Washington. Two crossings were farther to the west. The location of the burth was not made available immediately.

It added that tracing would be continued in an attempt to pin down the orbit sufficiently to obtain scientific information of the type sought in the International Geophysical Year.

[Four visual sightings, one of which was in conjunction with a radio contact, were reported by early Saturday morning. Two sightings were made at Columbus, Ohio, and one each from Terre Haute, Ind., and Whittier, Calif.]

Press Reports Voted



The New York Times Oct. 5, 1957

The approximate orbit of the Russian earth satellite is shown by black line. The rotation of the earth will bring the United States under the orbit of Soviet-made moon.

Device Is 8 Times Heavier Than One Planned by U.S.

Special to The New York Times.

560 MILES HIGH

Visible With Simple Binoculars, Moscow Statement Says

Text of Tass announcement appears on Page 3.

By WILLIAM J. JORDEN
Special to The New York Times.

MOSCOW, Saturday, Oct. 5—The Soviet Union announced this morning that it successfully launched a man-made earth satellite into space yesterday.

The Russians calculated the satellite's orbit at a maximum of 560 miles above the earth and its speed at 18,000 miles an hour.

The official Soviet news agency Tass said the artificial moon, with a diameter of twenty-two inches and a weight of 184 pounds, was circling the earth once every hour and thirty-five minutes. This means more than fifteen times a day.

Two radio transmitters, Tass said, are sending signals continuously on frequencies of 20.005 and 40.002 megacycles

Identifying Variation in Federal R&D Appropriations

Wars and other national security concerns

- Korean War, Sputnik 1, ICBM race, Vietnam War, Soviet invasion of Afghanistan, Cold War "peace dividend," 9/11, Global War on Terror, nuclear arms proliferation

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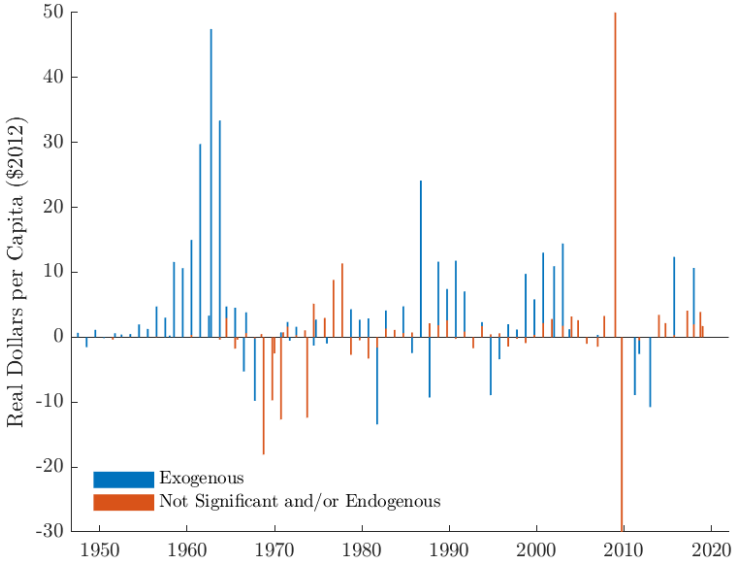
Recessions, supply shocks

- Energy Reorganization Act of 1974, Department of Energy Organization Act of 1977, ARRA of 2009

Changes in Nondefense R&D Appropriations



▸ NASA ▸ NIH ▸ NSF ▸ DoE: Nondefense ▸ Defense

Benchmark Regression Framework and Impulse Responses

Jordà (2005) Local Projections Regression Framework

Direct forecasting regression for each horizon $h = 0, 1, ..., 59$ over 1948Q1-2021Q4:

$$y_{t+h} = c_h + \gamma_h z_t^i + \sum_{j=1}^{p} \beta_h^j \ln a_{t-j}^i + \sum_{j=1}^{p} \delta_h^j y_{t-j} + \sum_{j=1}^{p} \zeta_h^{j\prime} \boldsymbol{x}_{t-j} + v_{t+h}$$

- y_{t+h}: (4Q-MA) outcome variable of interest at horizon h, e.g., TFP
- z_t^i: exogenous R&D appropriations shocks for budget category $i = D, ND$
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Scale factor: Responses scaled to induce a 1% increase in government R&D capital

Benchmark Controls in Regression Framework

The vector of lagged macroeconomic controls, $\mathbf{x}_{t-j}$, includes:

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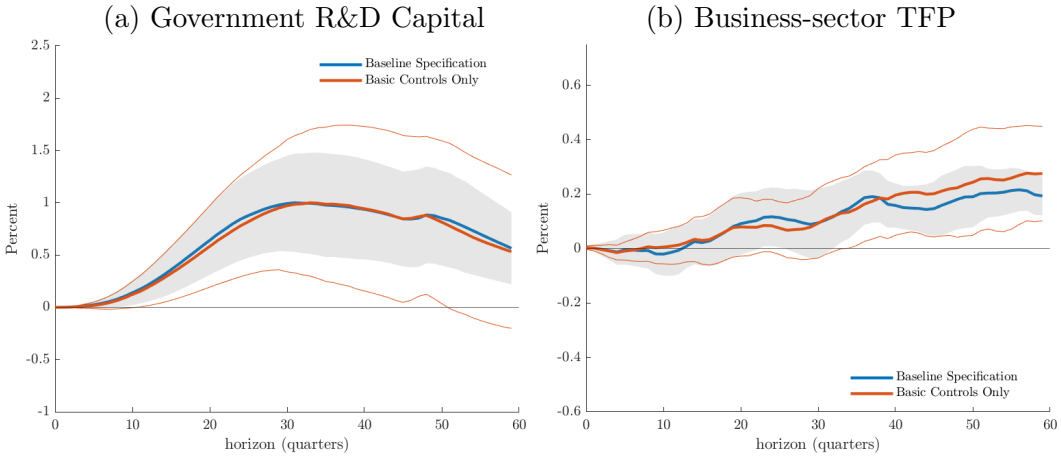
Benchmark specification: 4 quarterly lags of controls ($p = 4$)

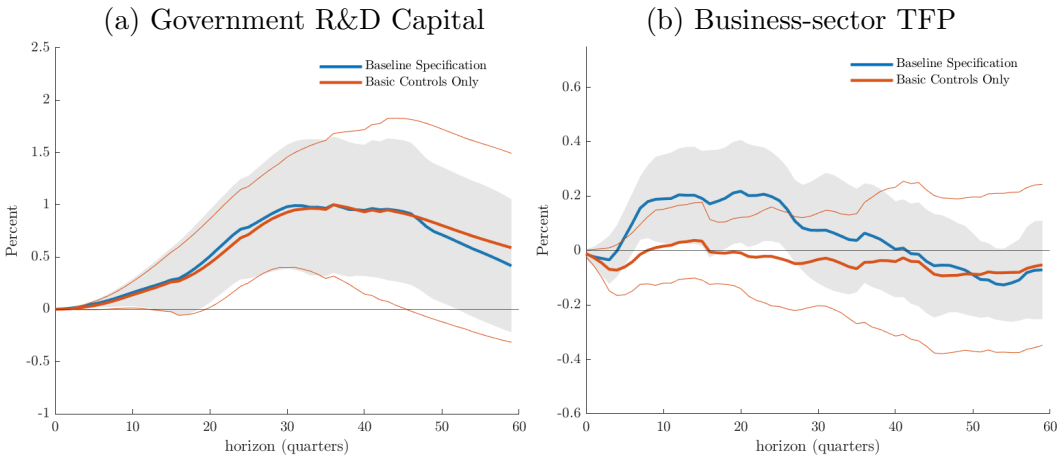
Responses to Nondefense R&D Appropriations Shocks



Notes: Shaded areas and finer lines are 95% confidence bands.

▸ Role of Narrative Classification

Responses to Defense R&D Appropriations Shocks



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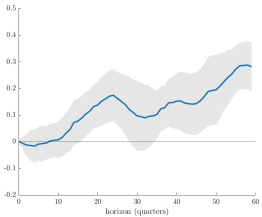
Other Productivity/Innovation Responses to Nondefense R&D Shocks

(a) Labor Productivity



Notes: Shaded areas are 95% confidence bands. Source: BEA

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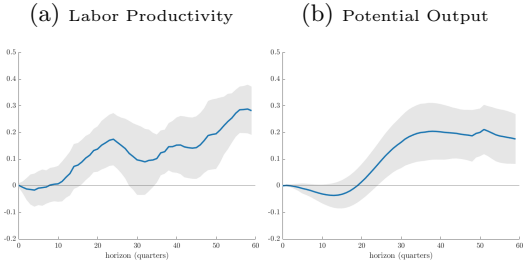

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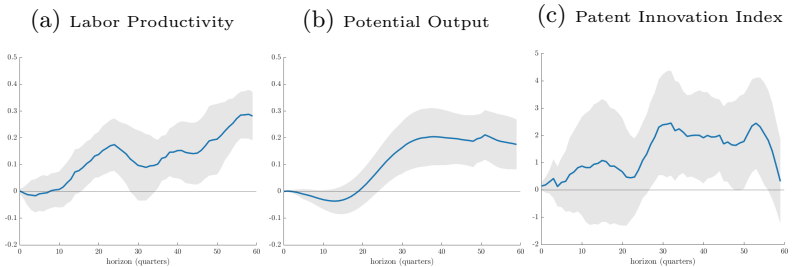

Notes: Shaded areas are 95% confidence bands. Source: Kogan et al. (2017), Gascaldi-Garcia and Vukotic (2022)

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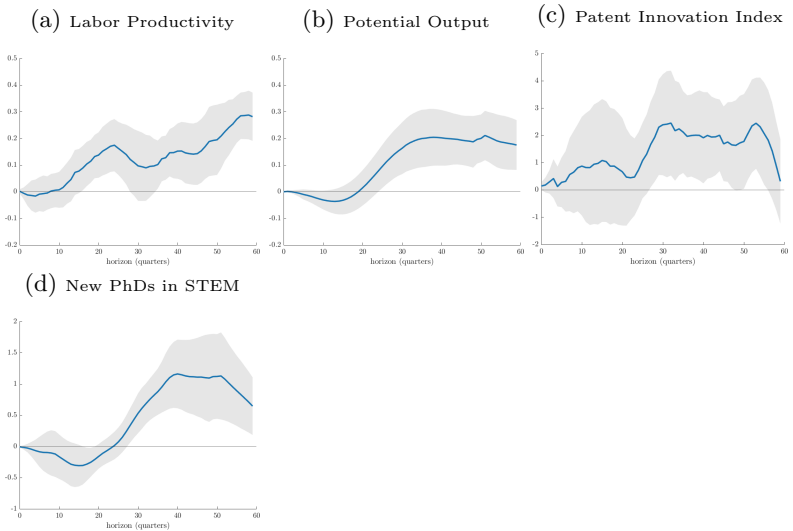
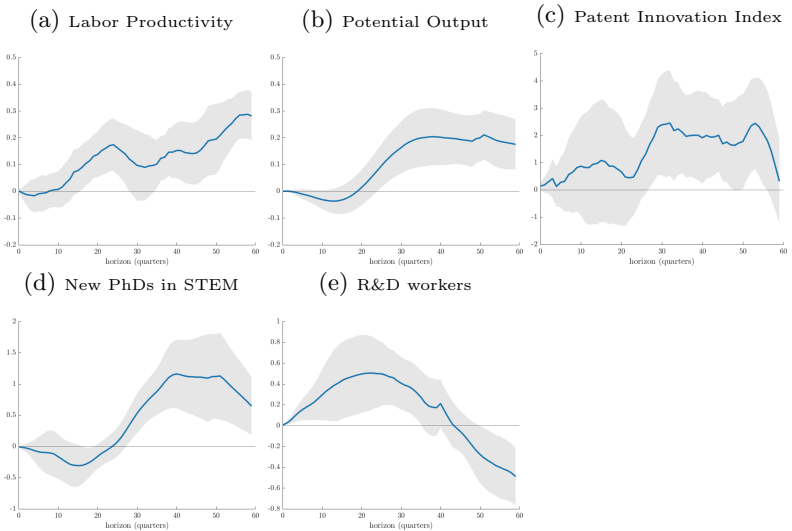


Notes: Shaded areas are 95% confidence bands. Source: NCSES, Survey of Earned Doctorates

Other Productivity/Innovation Responses to Nondefense R&D Shocks



Notes: Shaded areas are 95% confidence bands. Source: OECD, Bloom et al. (2020)

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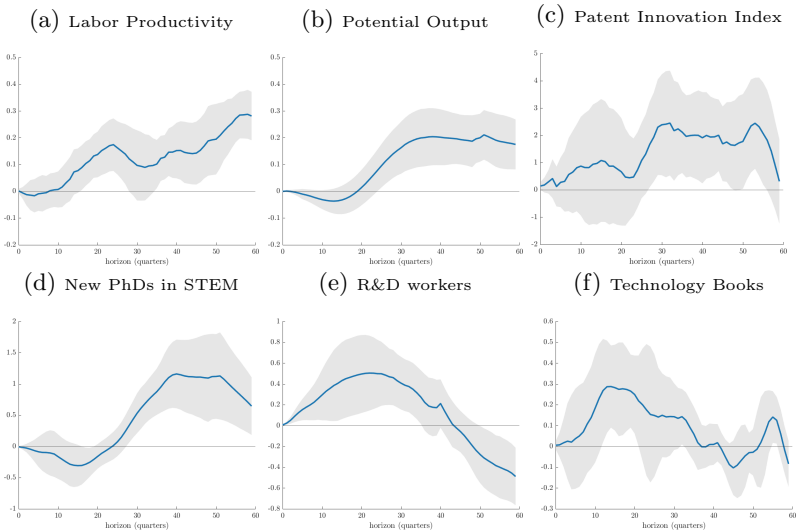

Notes: Shaded areas are 95% confidence bands. Source: Alexopoulos (2011)

Interpreting Macroeconomic Effects of Federal R&D Appropriations Shocks

Interpreting TFP Responses to Federal R&D Appropriations Shocks

The interpretation of the TFP response to the federal R&D appropriations shocks hinges on how these shocks affect other determinants of TFP

- e.g., private R&D, public infrastructure...

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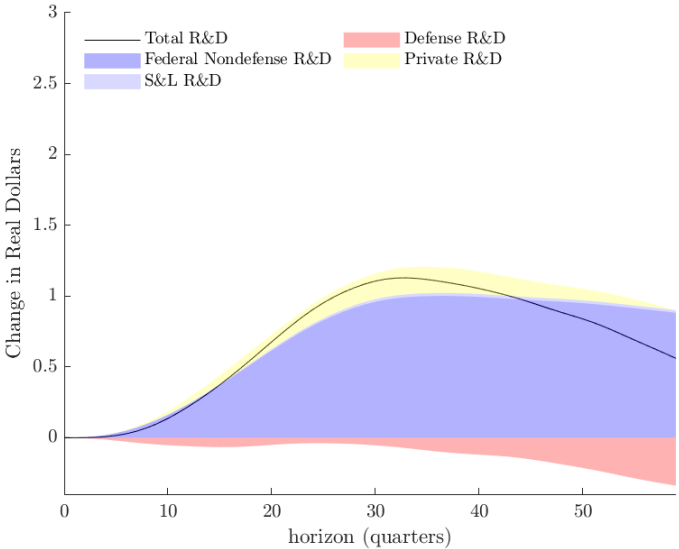
We estimate decompositions of impulse responses to the total real R&D capital stock, K_t^{tot}, using of the following Tornqvist index approximation of log changes:

$$\Delta \ln K_t^{tot} \approx \sum_j \frac{s_t^j + s_{t-1}^j}{2} \Delta \ln K_t^j$$

where

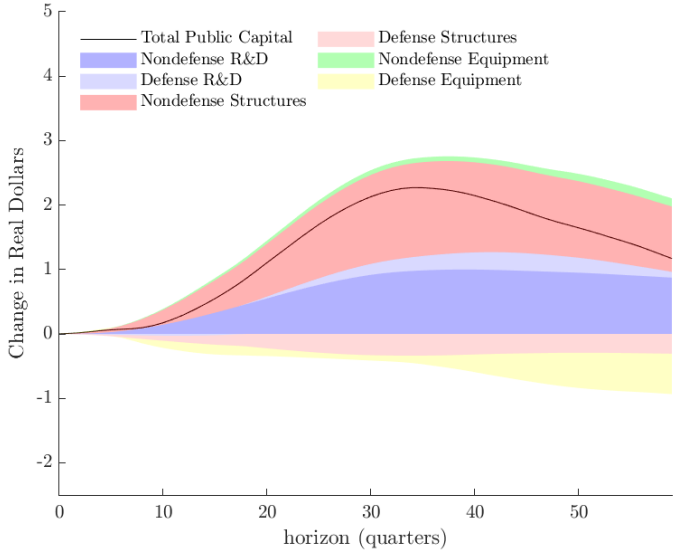
- K_t^j is capital in category j in constant dollars (e.g., private R&D)
- s_t^j denotes the nominal share of category j ($K^{n,j}/K^{n,tot}$)

Response of R&D by Performer to Nondefense R&D Shocks



▸ Response to Defense R&D

Response of Public Capital Stocks to Nondefense R&D



▸ Response to Defense R&D

Estimating Elasticities and Returns to Government R&D Capital

Structural Estimation of Government R&D Elasticities

From a Cobb-Douglas production function augmented w/ public capital, we define:

$$\Delta tfp_t = \eta \Delta q_t + \phi \Delta k_t + \Delta w_t$$

where

- Δtfp_t is utilization-adjusted TFP in the business sector
- q_t is the log of the public infrastructure capital stock
- k_t is the log of the government R&D capital stock
- $\Delta w_t = \Delta \nu_t + \epsilon_t$ is the TFP residual + measurement error

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Taking values of η as known (Ramey 2021, CBO 2021), define:

$$\Delta \widetilde{tfp}_t \equiv \Delta tfp_t - \hat{\eta} \Delta q_t$$

This yields our structural estimation equation for ϕ:

$$\Delta \widetilde{tfp}_t = \phi \Delta k_t + \Delta w_t$$

SP-IV Estimation of Government R&D Elasticities

We use the System Projections on Instrumental Variables (SP-IV) framework of Lewis and Mertens (2023) to estimate ϕ, the elasticity of government R&D:

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- We also use our exogenous R&D shocks as IV for $\widetilde{tfp}_t$ growth (2)

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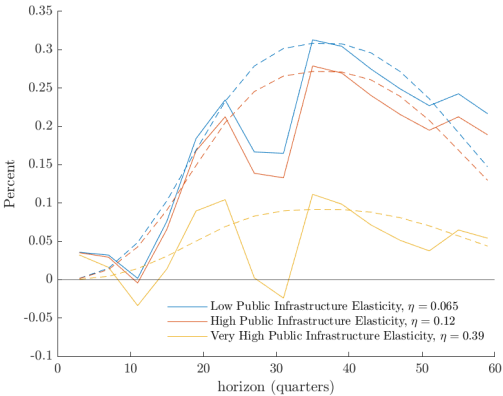
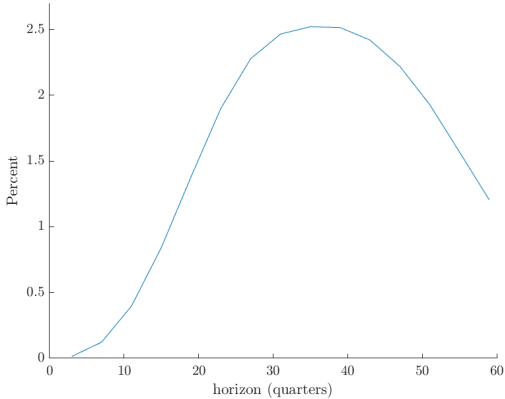
- We use our exogenous R&D shocks as IV for k_t, government R&D capital (1)
- We also use our exogenous R&D shocks as IV for $\widetilde{tfp}_t$ growth (2)
- The SP-IV estimator—a GMM estimator in the impulse response space—essentially regresses the impulse response of $\widetilde{tfp}_t$ (2) on the response of k_t (1)
- The SP-IV estimator captures an average effect, significance over our 15-year impulse response horizon (estimation collapsed to one-year horizons)

Simple Illustration of the SP-IV Estimator



Impulse response of $\widetilde{tfp}_t$



Impulse response of k_t

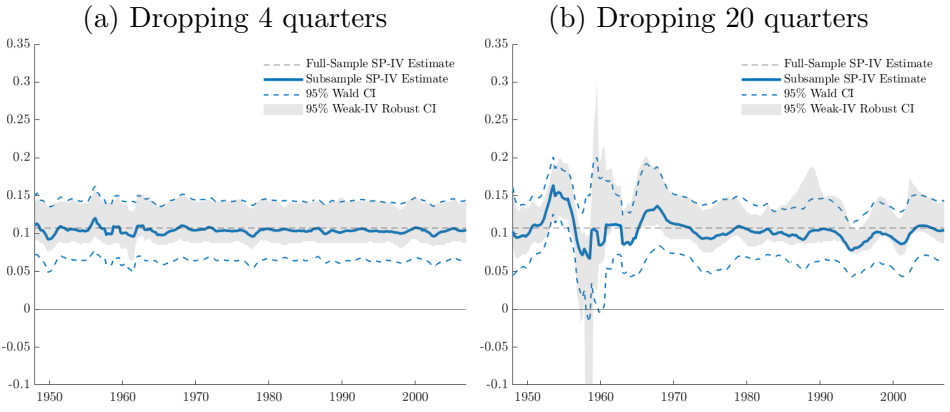
Table 1: Estimates of Production Function Elasticities of Government R&D Capital

	Public R&D Measure	Instruments	Intermediate $\eta = 0.08$ $\hat{\phi}/\hat{\phi}_{ND}$	Intermediate $\eta = 0.08$ $\hat{\phi}/\hat{\phi}_{D}$	Low $\eta = 0.065$ $\hat{\phi}/\hat{\phi}_{ND}$	High $\eta = 0.12$ $\hat{\phi}/\hat{\phi}_{ND}$
[1]	Total	Exo ND	0.11^{***} (0.09,0.15)		0.11^{***} (0.09,0.15)	0.10^{***} (0.08,0.13)
[2]	Total	Exo ND, No NASA	0.11^{***} (0.08,0.20)		0.12^{***} (0.08,0.21)	0.10^{***} (0.07,0.19)
[3]	Total	All ND	0.10^{***} (0.09,0.14)		0.11^{***} (0.09,0.15)	0.09^{***} (0.07,0.13)
[4]	Total	Exo D		-0.13 $(-1.20,0.04)$		
[5]	Total	All D		-0.11 $(-1.11,0.05)$		
[6]	ND/D	Exo ND	0.10^{***} (0.06,0.19)	-0.01 $(-0.22,0.39)$	0.11^{***} (0.06,0.20)	0.09^{***} (0.05,0.18)
[7]	ND/D	Exo ND/D	0.10^{***} (0.04,0.19)	-0.07 $(-0.27,0.40)$	0.10^{***} (0.04,0.19)	0.09^{***} (0.03,0.18)
[8]	ND/D	Exo ND, No NASA	0.11 $(-2.00^{\dagger},0.58)$	0.20 $(-2.00^{\dagger},0.69)$	0.11 $(-2.00^{\dagger},0.60)$	0.10 $(-2.00^{\dagger},0.54)$
[9]	ND/D	All ND	0.10^{***} (0.06,0.18)	-0.03 $(-0.23,0.35)$	0.10^{***} (0.06,0.18)	0.09^{***} (0.05,0.17)

Notes: Stars *, **, and *** denote statistical significance at 10, 5, and 1 percent levels, respectively.

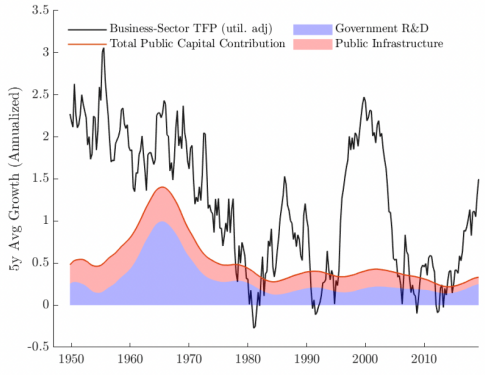
▸ Alternative Depreciation Rates

Subsample Stability of Production Function Elasticities



Historical Contributions of Public Investment to TFP Growth

Assumption: $\phi_D = 0, \phi_{ND} = 0.11$



	'47-'69	'70-'89	'90-'09	'10-'21
TFP growth	1.98	0.98	1.15	0.87
		a. Intermediate η		
Infrastructure	0.33	0.19	0.19	0.09
R&D	0.48	0.25	0.19	0.19
		b. Low η		
Infrastructure	0.27	0.16	0.15	0.07
R&D	0.50	0.25	0.20	0.20
		c. High η		
Infrastructure	0.50	0.29	0.28	0.14
R&D	0.44	0.22	0.18	0.18

→ Government R&D explains ∼20-25% of TFP growth, TFP slowdown since late 1960s

→ Government R&D contributes roughly as much (or more) than public infrastructure

Composition of Public Capital Stock

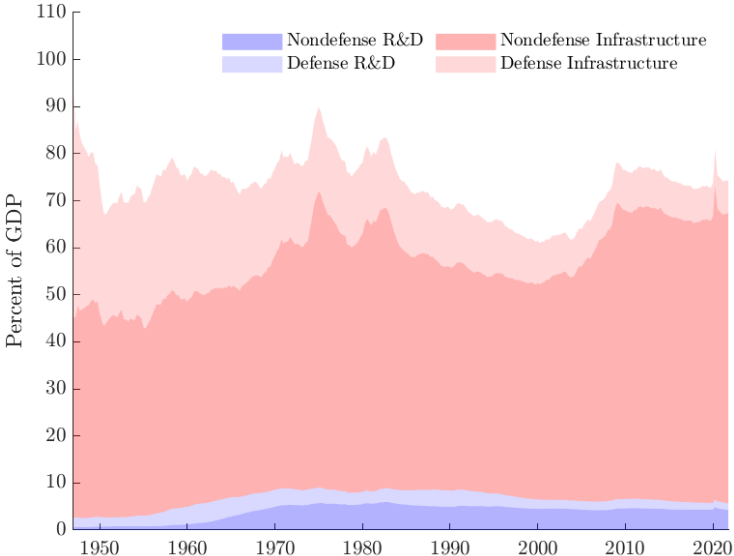


Table 2: Estimates of the Return to Government R&D Capital

	Government R&D Measure	Instruments	Intermediate $\eta = 0.08$ $\hat{\phi}_{ND} \times \frac{Y}{K}$	Intermediate $\eta = 0.08$ $\hat{\rho}_{ND}$	Low $\eta = 0.065$ $\hat{\phi}_{ND} \times \frac{Y}{K}$	Low $\eta = 0.065$ $\hat{\rho}_{ND}$	High $\eta = 0.12$ $\hat{\phi}_{ND} \times \frac{Y}{K}$	High $\eta = 0.12$ $\hat{\rho}_{ND}$
[1]	Total	Exo ND	1.85	1.71^{***} (1.07,2.22)	1.91	1.77^{***} (1.13,2.26)	1.67	1.57^{***} (0.91,2.11)
[2]	Total	Exo ND, No NASA	1.94	1.60^{**} (0.62,4.01)	2.00	1.62^{**} (0.69,4.03)	1.77	1.53^{**} (0.42,3.97)
[3]	Total	All ND	1.79	1.58^{***} (1.04,2.08)	1.86	1.63^{***} (1.10,2.12)	1.62	1.44^{***} (0.88,1.98)
[4]	ND/D	Exo ND	1.75	1.68^{**} (0.23,3.20)	1.81	1.74^{**} (0.30,3.24)	1.58	1.52^{**} (0.08,3.11)
[5]	ND/D	Exo ND/D	1.67	2.04^{**} (0.12,3.79)	1.73	2.10^{**} (0.16,3.81)	1.50	1.88^{**} (0.01,3.70)
[6]	ND/D	Exo ND, No NASA	1.92	6.84 ($-2.00^{\dagger}$,$5.00^{\dagger}$)	1.98	6.91 ($-2.00^{\dagger}$,$5.00^{\dagger}$)	1.75	6.65 ($-2.00^{\dagger}$,$5.00^{\dagger}$)
[7]	ND/D	All ND	1.72	1.58^{**} (0.27,2.90)	1.78	1.64^{**} (0.32,2.95)	1.55	1.42^{**} (0.11,2.81)

Notes: Stars *, **, and *** denote statistical significance at 10, 5, and 1 percent levels, respectively.

▸ Regression Framework ▸ Alternative Depreciation Rates

Concluding Thoughts

Summary: Big Kick from Nondefense R&D

Our exogenous nondefense R&D appropriations shocks yield a significant, often persistent increase in measures of productivity and innovation

Scaled to a 1% shock to government R&D capital:

- Utilization-adjusted TFP rises ∼0.2% after 8 years
- Potential output rises ∼0.2% after 8 years
- Increases in employment of scientific researchers, new STEM PhDs, new patents...

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Nondefense government R&D capital has a high rate of return:

- Estimated production function elasticity: $\hat{\phi}_{ND} = 0.11$
- Accounts for ∼20-25% of U.S. business-sector TFP growth since WWII
- Estimated macroeconomic (social) returns: ∼140-210%

Summary: No Kick from Defense R&D?

We find no evidence of an economically or statistically significant increase in TFP or measures of innovation in response to U.S. defense R&D spending*

*At least not over the 15-year horizons we consider

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▸ Responses by R&D Type

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Defense R&D surely contributes to national security, but does not appear to drive post-war economic growth the same way as nondefense R&D...

Appendix Slides

Glossary: Standard Definitions of Types of R&D

Basic research: "In basic research the objective of the sponsoring agency is to gain more complete knowledge or understanding of the fundamental aspects of phenomena and of observable facts, without specific applications toward processes or products in mind"

Applied research: "In applied research the objective of the sponsoring agency is to gain knowledge or understanding necessary for determining the means by which a recognized need may be met"

Development: "Development is systematic use of the knowledge or understanding gained from research, directed toward the production of useful materials, devices, systems, or methods, including design and development of prototypes, and processes..."

Source: NSF (2022) and OECD (2015)

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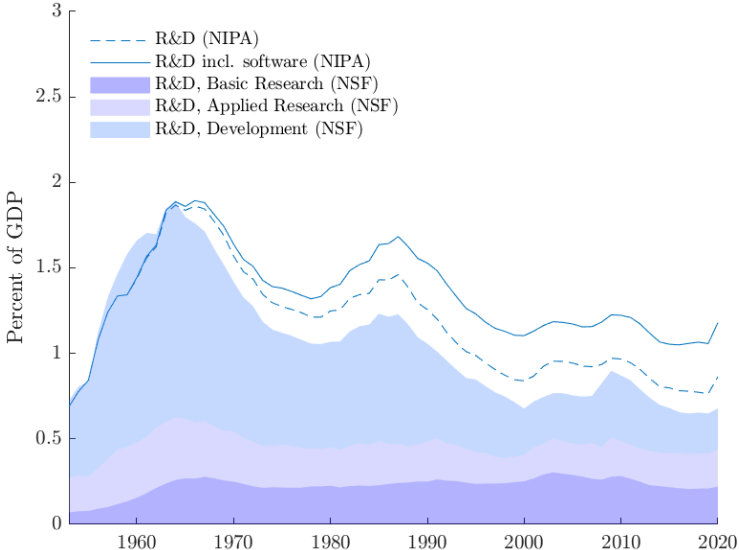
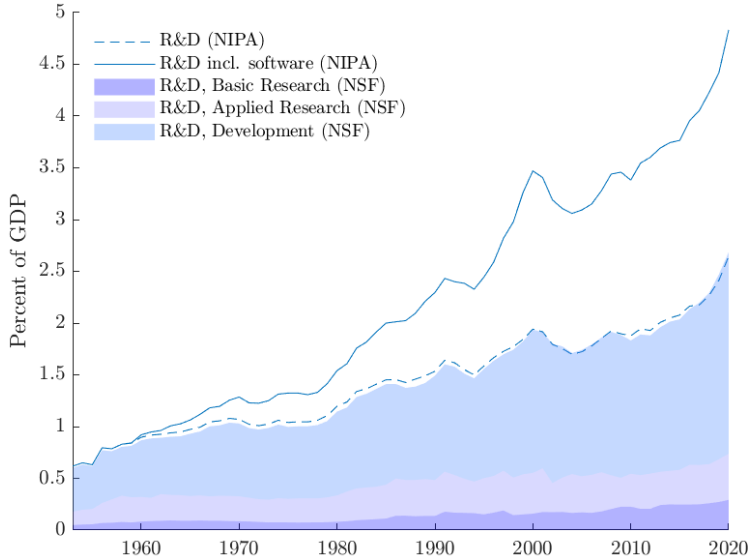
Government R&D Spending by Type of Research



Private R&D Spending Back

Private R&D Spending by Type of Research



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Narrative Approach to Identification

Monetary policy shocks

- Friedman and Schwartz ('63), Romer and Romer ('89, '04, '23), Cloyne and Hürtgen ('16)

Oil supply shocks

- Hamilton ('83)

Military spending shocks

- Ramey and Shapiro ('98), Ramey ('11), Ramey and Zubairy ('18)

Tax policy shocks

- Romer and Romer ('10), Mertens and Ravn ('13), Cloyne ('13)

Government mortgage purchase shocks

- Fieldhouse and Mertens ('17)

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Narrative Analysis Data Sources

Analyze primary, secondary sources for each agency, fiscal year:

- Congressional committee reports, hearings (ProQuest)
- Budget of the U.S. Government
- Budget Message of the President
- State of the Union Addresses
- Presidential signing statements, vetos, speeches
- *CQ Almanac*, *NYT*, *WaPo*, *WSJ*, *Politico*, *CRS*,...

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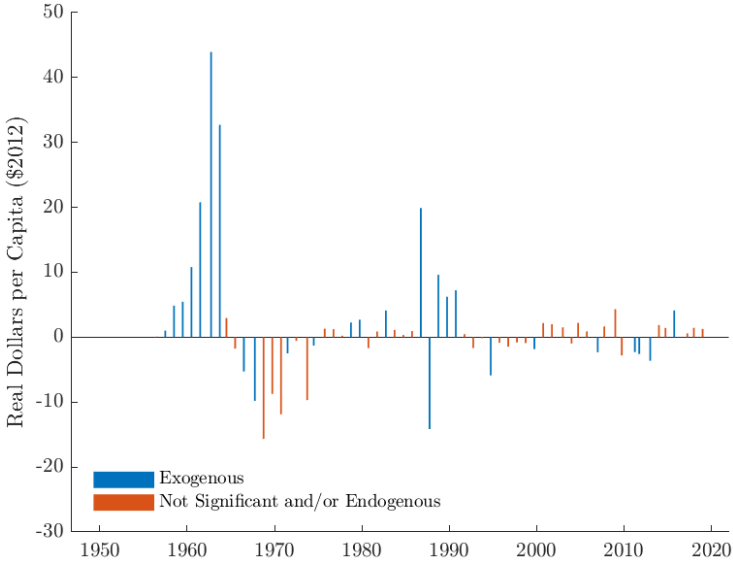
Changes in NASA R&D Appropriations



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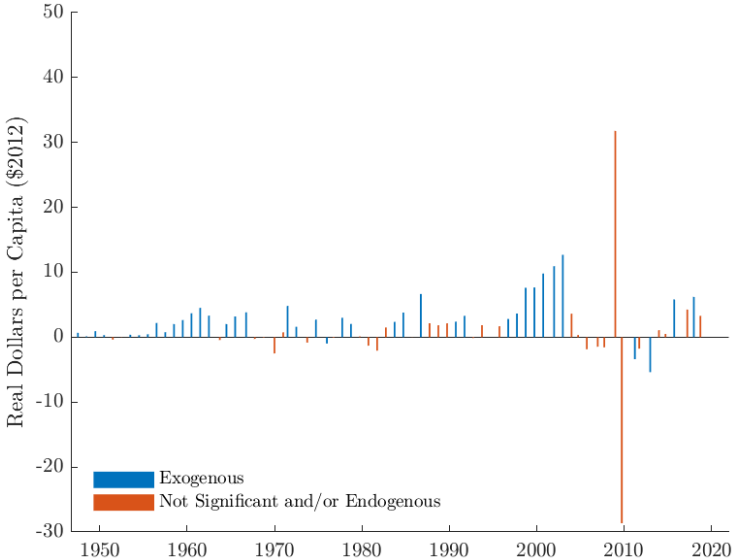
Changes in NIH R&D Appropriations



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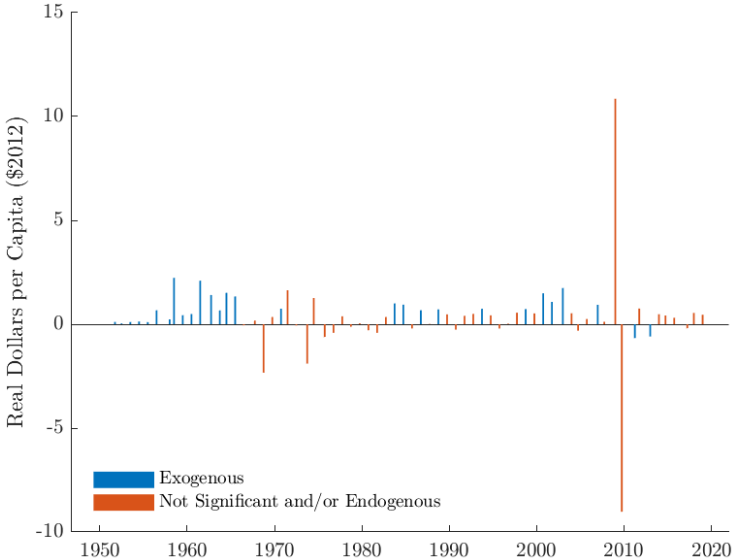
Changes in NSF R&D Appropriations



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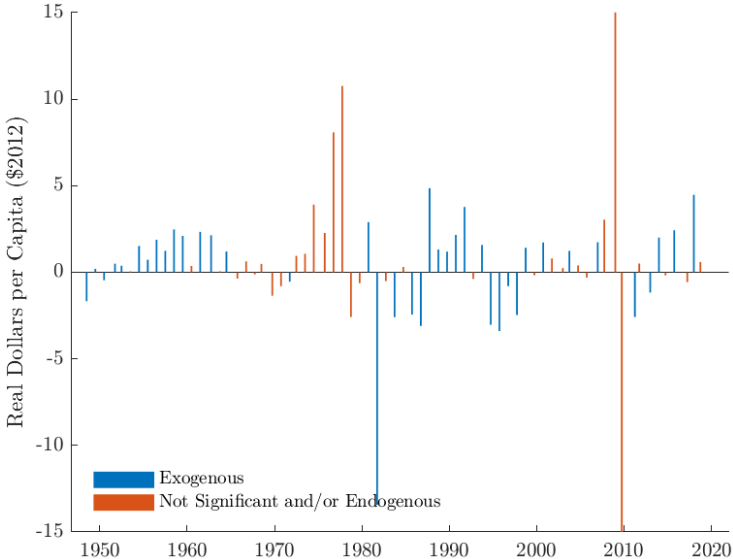
Changes in Nondefense Energy Appropriations



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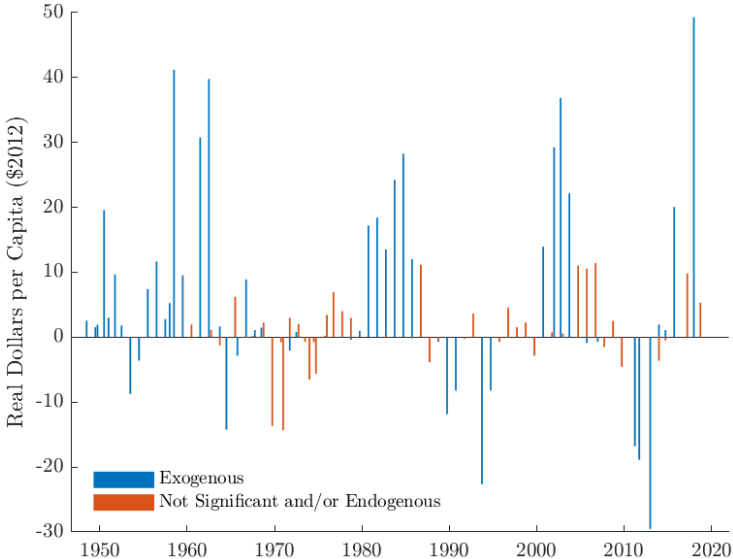
Changes in Defense R&D Appropriations



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Fernald (2012) TFP-U from Cobb-Douglas Production

$$Y_t = F(Z_t \times K(K_{1,t-1}, K_{2,t-1}, ..., K_{J,t-1}), E_t \times L(H_{1,t-1}, H_{2,t-1}, ..., H_{N,t-1}), A_t)$$

where

- Y_t is business-sector output
- K_t is capital input, aggregated from aggregated from J types
- L_t is labor input, aggregated from H hours worked by N types
- Z_t is capital utilization (e.g., average workweek of machinery)
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Assuming perfect competition and taking log first differences:

$$\Delta \ln Y = \alpha \Delta \ln K + (1-\alpha)\Delta \ln L + \Delta \ln U + \Delta \ln A$$
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TFP and utilization-adjusted TFP (*TFP-U*) are defined as:

$$\Delta \ln TFP \equiv \Delta \ln Y - \alpha \Delta \ln K - (1-\alpha)\Delta \ln L$$
$$\Delta \ln \textit{TFP-U} \equiv \Delta \ln TFP - \Delta \ln U = \Delta \ln A$$

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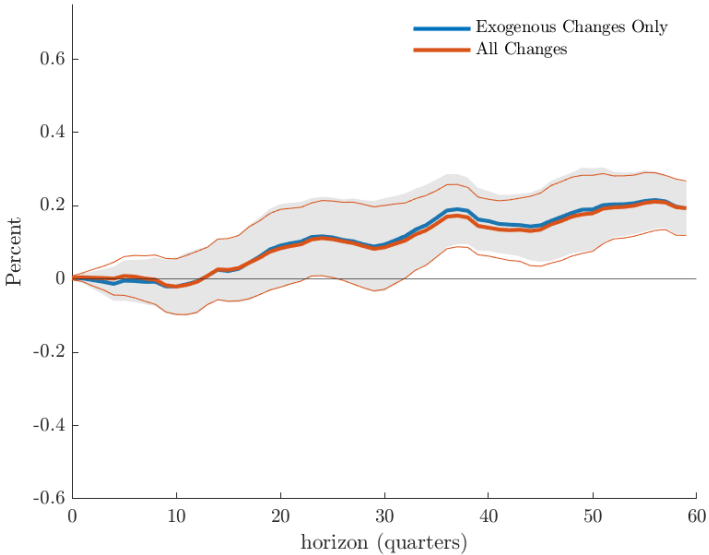
Role of Narrative Classification for Nondefense R&D Appropriations



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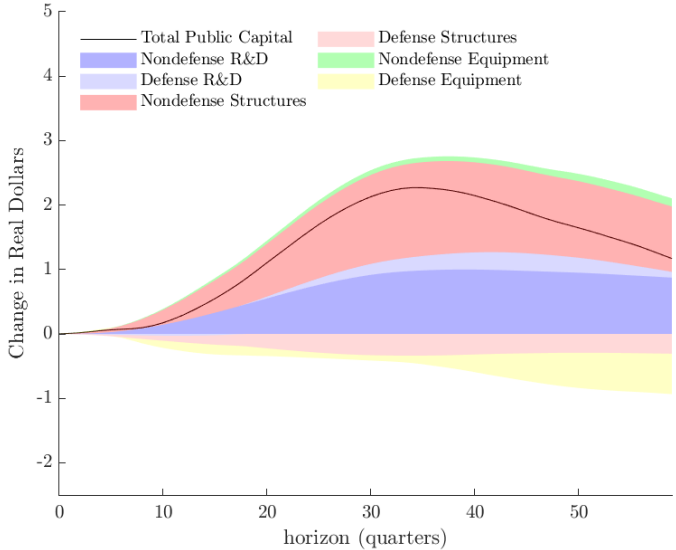
Response of Public Capital Stocks to Nondefense R&D



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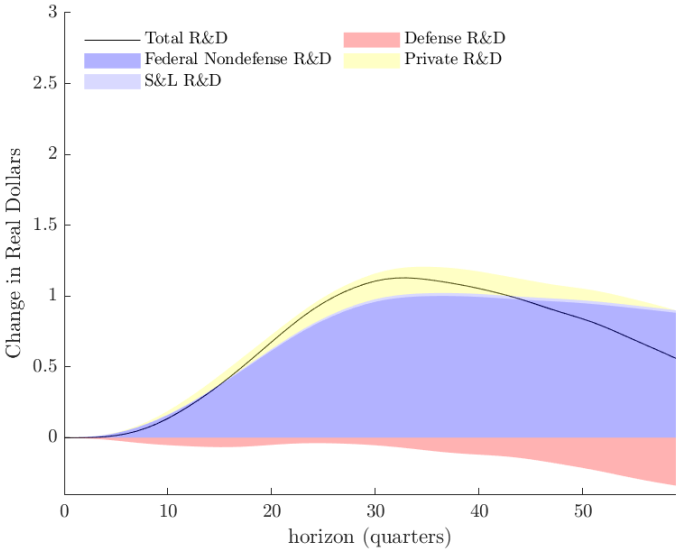
Response of R&D by Performer to Nondefense R&D Shocks



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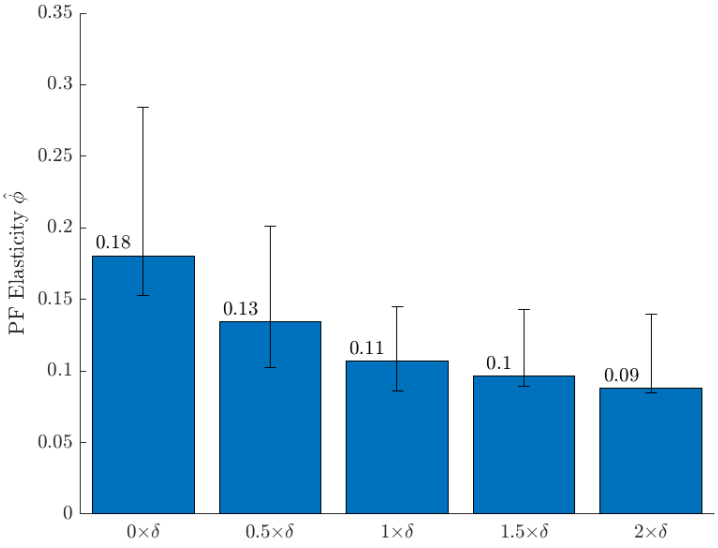
Government R&D Elasticities Under Alternative Depreciation Rates



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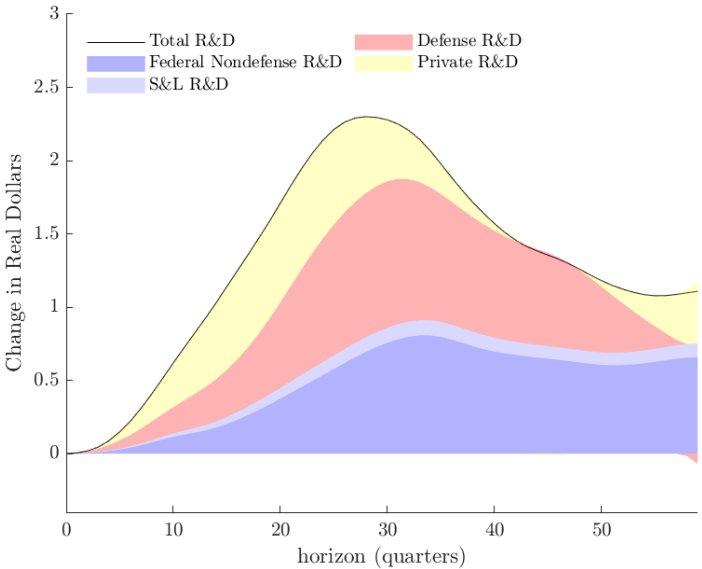
Response of R&D by Performer to Defense R&D Shocks



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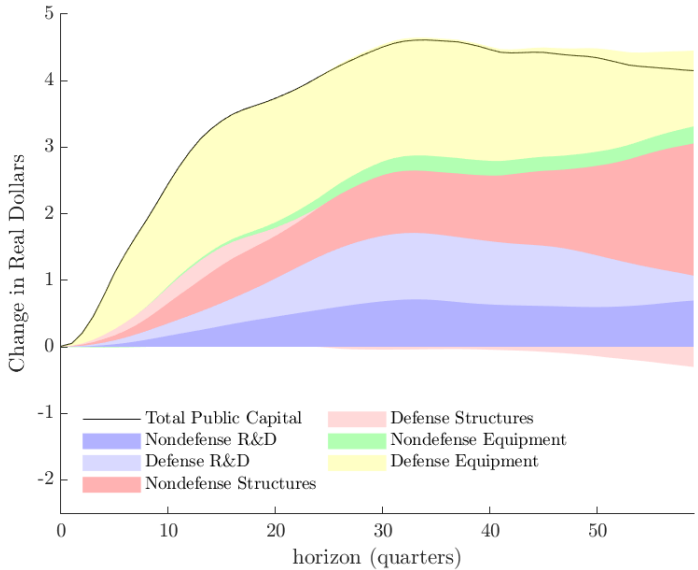

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Regression for Direct Estimates of Returns to Government R&D

Define the net rate of return on government R&D as

$$\rho_t^n = \rho_t - \delta_t$$

where

- $\rho_t = \phi_t K_t / Y_t$ is the gross return
- K_t/Y_t is the government R&D capital stock/output ratio
- δ_t is the depreciation rate of government R&D capital

Using $\Delta k_t \approx (K_t - K_{t-1})/K_{t-1}$ and substituting yields

$$\Delta \widetilde{tfp}_t = \rho \frac{\Delta K_t}{Y_t} + \Delta w_t$$

Which we estimate via SP-IV, now instrumenting $\frac{\Delta K_t}{Y_t}$ with z_t^i

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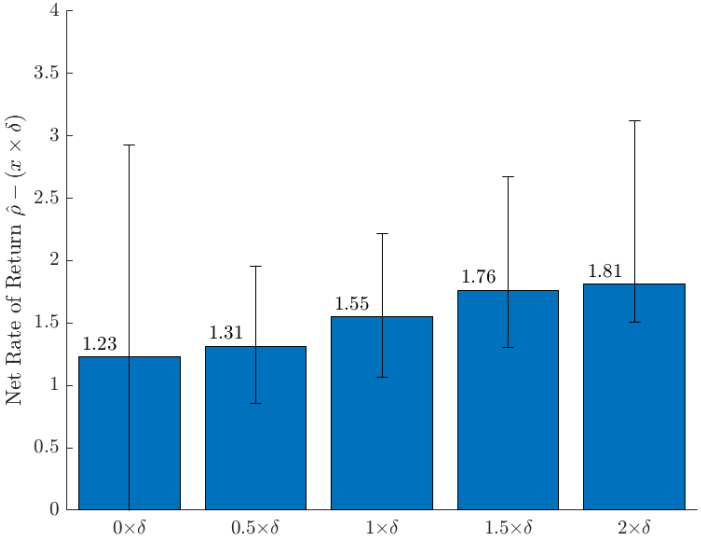
Returns to Government R&D Under Alternative Depreciation Rates



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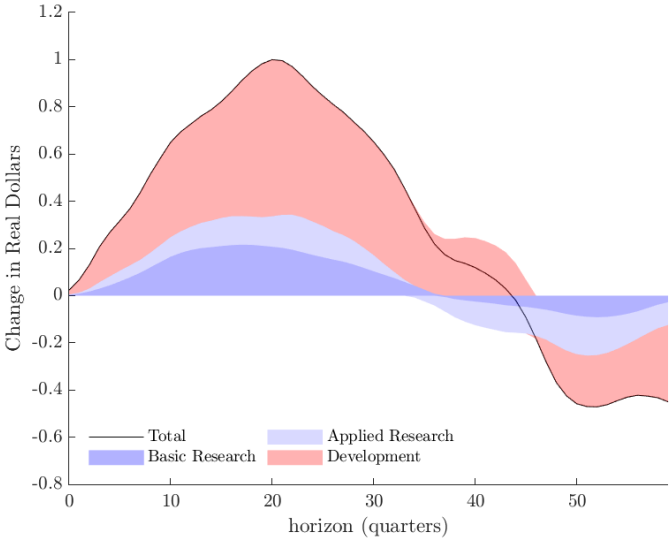
Changes in R&D by Type to Defense R&D Shock



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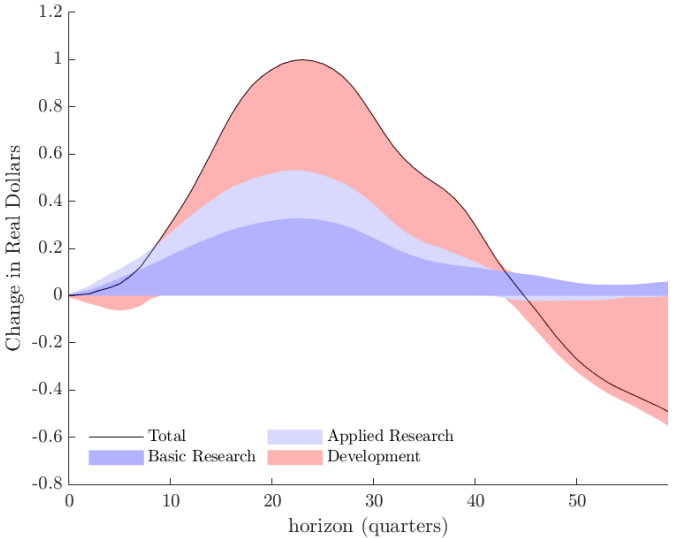
Changes in R&D by Type to Nondefense R&D Shock



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