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

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New Thinking in Industrial Policy:
Perspectives from Developed and Developing Countries
Columbia University
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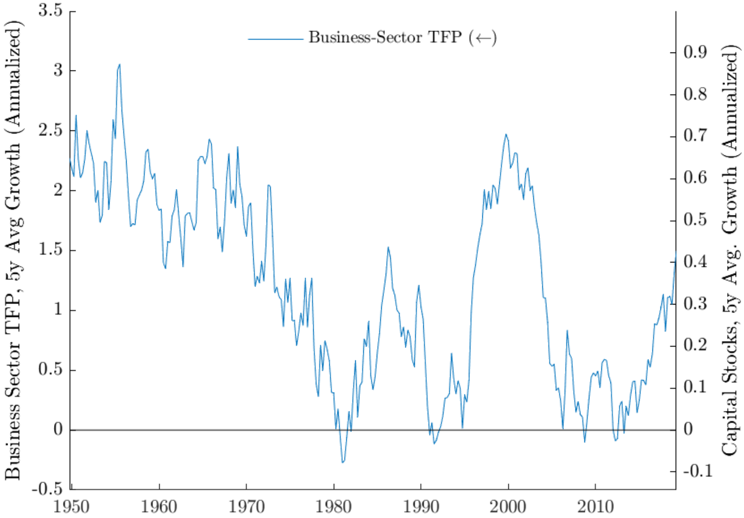
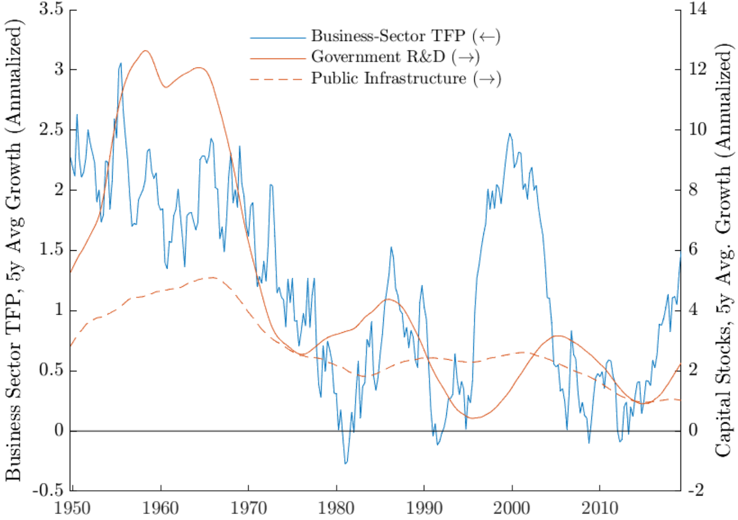
Slowdown in U.S. Productivity Growth



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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Government R&D/GDP

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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

- Griliches (1979), Bloom, Schankerman, and Van Reenen (2013); Jones and Summers (2020)

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

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New companion paper develops instrumental variables for federal R&D funding

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Narrative Analysis of Federal Appropriations for R&D

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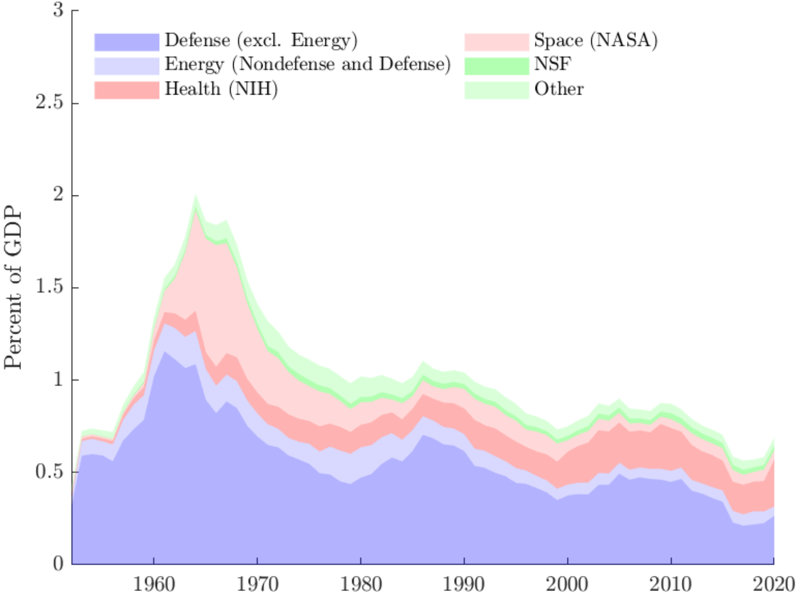
We analyze R&D appropriations for 5 major agencies (∼87-93% of total):

- 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



Identifying "Exogenous" R&D Appropriations Shocks

We proceed as follows:

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We analyze 257 appropriations changes by agency, fiscal year

▸ Data Sources ▸ Example Events

"All the News That's Fit to Print"

The New York Times.

LATE CITY EDITION
U. S. Weather Bureau Report (Page 33) forecast: Cloudy and cool today and tonight. Mostly fair tomorrow.
Temp. range: 65—53. Yesterday: 62.4—49.2.

VOL. CVII..No. 36,414. | © 1957, by The New York Times Company. Times Square, New York 36, N. Y. | NEW YORK, SATURDAY, OCTOBER 5, 1957. | 10c beyond 100-mile zone from New York City | 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 as its 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 strip the 44-year-old former washouseman 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 fourth was not made available immediately.

It added that tracking 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 Noted

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.

WASHINGTON, Oct. 4—Leaders of the United States

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.

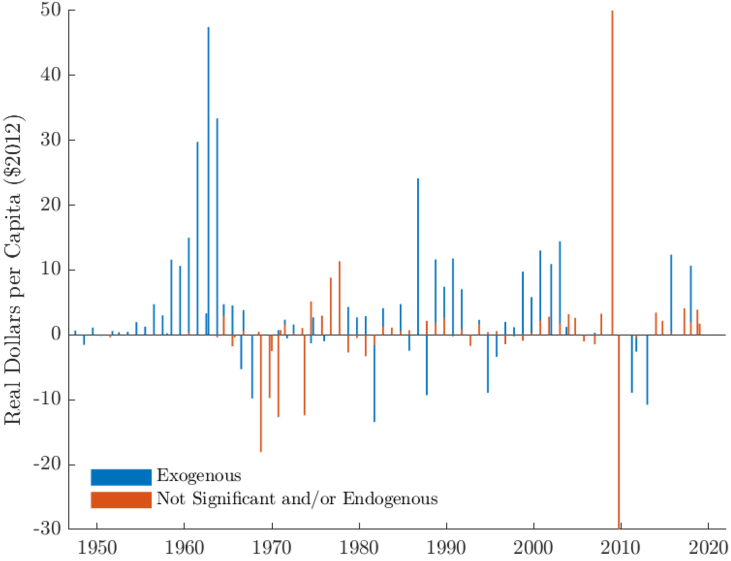
MOSCOW, Saturday, Oct. 5—The Soviet Union announce[d] this morning that it success[-]fully launched a man-mad[e] earth satellite into space yester[-]day.

The Russians calculated th[e] satellite's orbit at a maximu[m] of 560 miles above the eart[h] and its speed at 18,000 miles a[n] hour.

The official Soviet new[s] agency Tass said the artifici[al] moon, with a diameter o[f] twenty-two inches and a weigh[t] of 184 pounds, was circling th[e] earth once every hour an[d] thirty-five minutes. This mean[s] more than fifteen times a day.

Two radio transmitters, Tas[s] said, are sending signals con[-]tinuously on frequencies o[f] 20.005 and 40.002 megacycles.

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}: 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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- $\boldsymbol{x}_{t-j}$: lagged controls to address longer-run endogeneity concerns: TFP, R&D capital stocks, relevant stock returns, capacity utilization, Ramey (2016) defense news shocks

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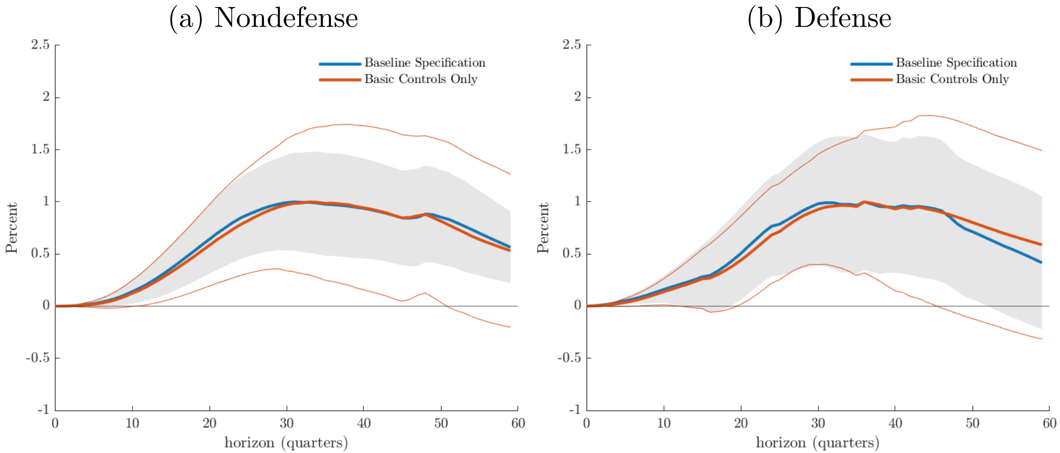
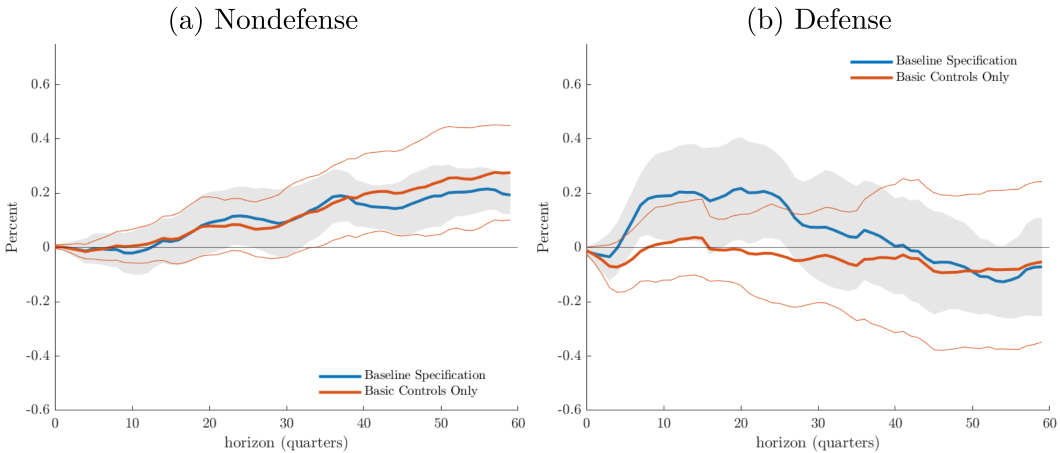
Scale factor: Responses scaled to induce a 1% increase in government R&D capital

Response of Government R&D Capital to R&D Appropriations Shocks



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

Response of TFP Growth to R&D Appropriations Shocks

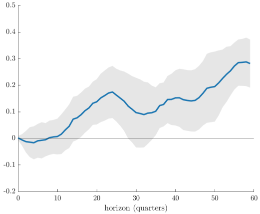


▸ Role of Narrative Classification

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

Other Productivity/Innovation Responses to Nondefense Shocks

(a) Labor Productivity



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

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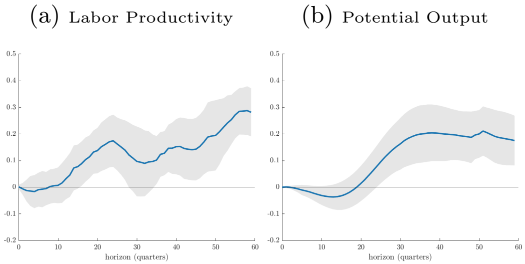
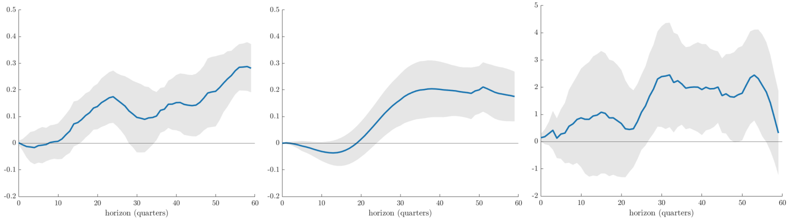


Notes: Shaded areas are 95% confidence bands. Source: CBO

Other Productivity/Innovation Responses to Nondefense Shocks

(a) Labor Productivity (b) Potential Output (c) Patent Innovation Index



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

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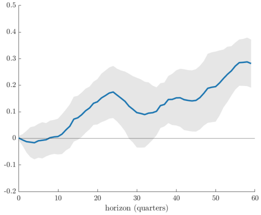
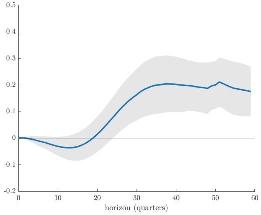
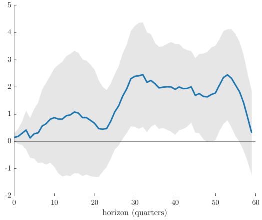


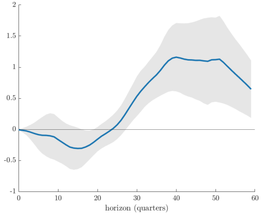
(b) Potential Output



(c) Patent Innovation Index



(d) New PhDs in STEM



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

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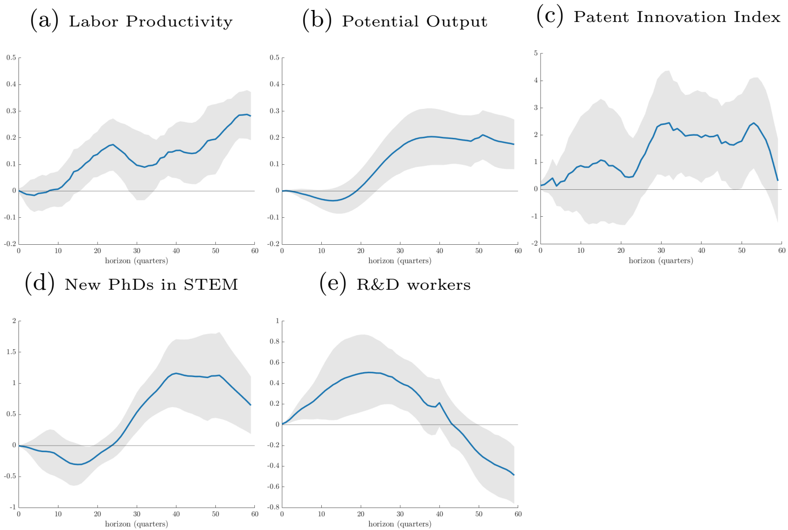

Notes: Shaded areas are 95% confidence bands. Source: OECD, Bloom et al. (2020)

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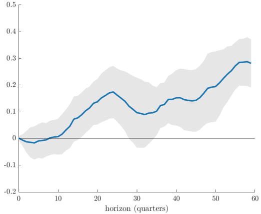

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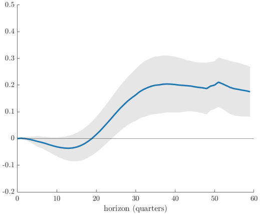

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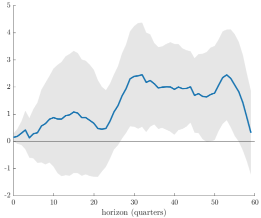

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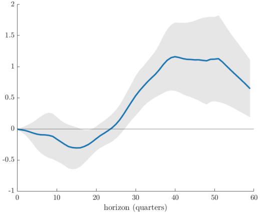
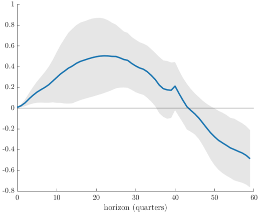
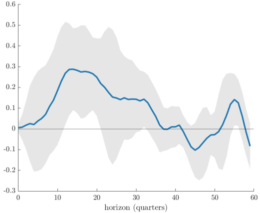


(e) R&D workers



(f) Technology Books



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

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

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

▸ Response of Public Capital Stocks

This yields our structural estimation equation:

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

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)

SP-IV Illustration

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

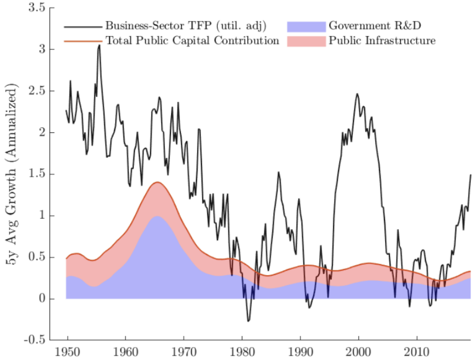
	Public R&D Measure	Instruments	Intermediate $\eta = 0.08$ $\hat{\phi}/\hat{\phi}_{ND}$	Intermediate $\eta = 0.08$ $\hat{\phi}/\hat{\phi}_{D}$	Low $\eta = 0.065$ $\hat{\phi}/\hat{\phi}_{ND}$	High $\eta = 0.12$ $\hat{\phi}/\hat{\phi}_{ND}$
[1]	Total	Exo ND	0.11*** (0.09,0.15)		0.11*** (0.09,0.15)	0.10*** (0.08,0.13)
[2]	Total	Exo ND, No Space	0.13*** (0.10,0.17)		0.13*** (0.10,0.18)	0.12*** (0.09,0.16)
[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*** (0.06,0.19)	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*** (0.04,0.20)	0.09*** (0.03,0.18)
[8]	ND/D	Exo ND, No Space	0.13** (0.08,0.23)	0.20 (−0.16,0.53)	0.14** (0.09,0.23)	0.13** (0.07,0.22)
[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.

▸ Subsample Stability ▸ Alternative Depreciation Rates

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

TABLE 2: ESTIMATES OF THE RETURN TO GOVERNMENT R&D CAPITAL

	Government R&D Measure	Instruments	Intermediate $\eta = 0.08$		Low $\eta = 0.065$		High $\eta = 0.12$	
			$\hat{\phi}_{ND} \times \frac{Y}{K}$	$\hat{\rho}_{ND}$	$\hat{\phi}_{ND} \times \frac{Y}{K}$	$\hat{\rho}_{ND}$	$\hat{\phi}_{ND} \times \frac{Y}{K}$	$\hat{\rho}_{ND}$
[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 Sp.	2.22	1.72*** (1.20,2.72)	2.28	1.75*** (1.26,2.76)	2.05	1.62*** (1.03,2.61)
[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 Sp.	2.33	3.54 (−1.01,3.60)	2.39	3.61 (−0.92,3.64)	2.17	3.37 (−1.22,3.49)
[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: 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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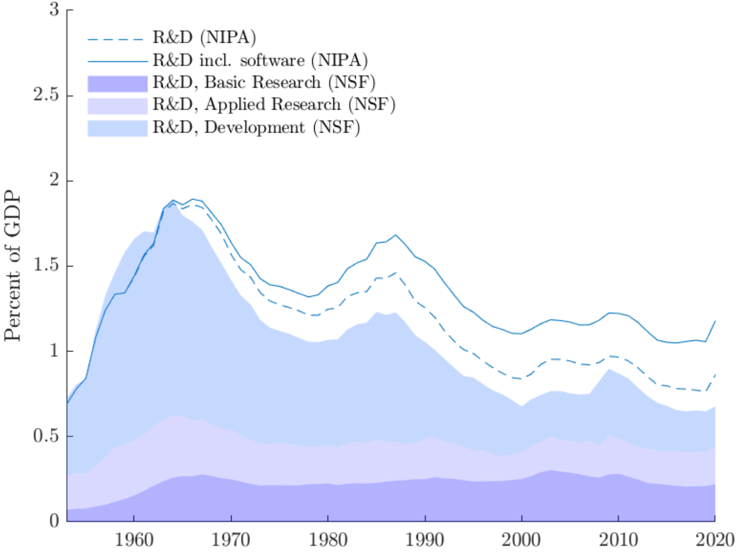
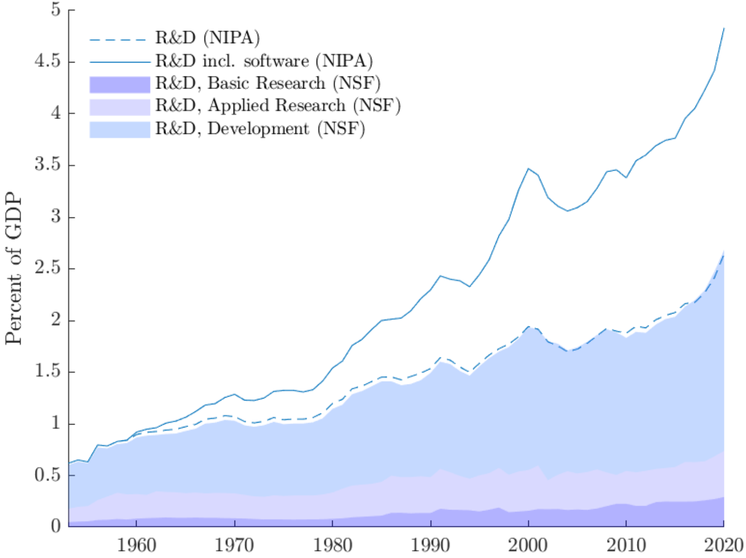
Government R&D Spending by Type of Research



▸ 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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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

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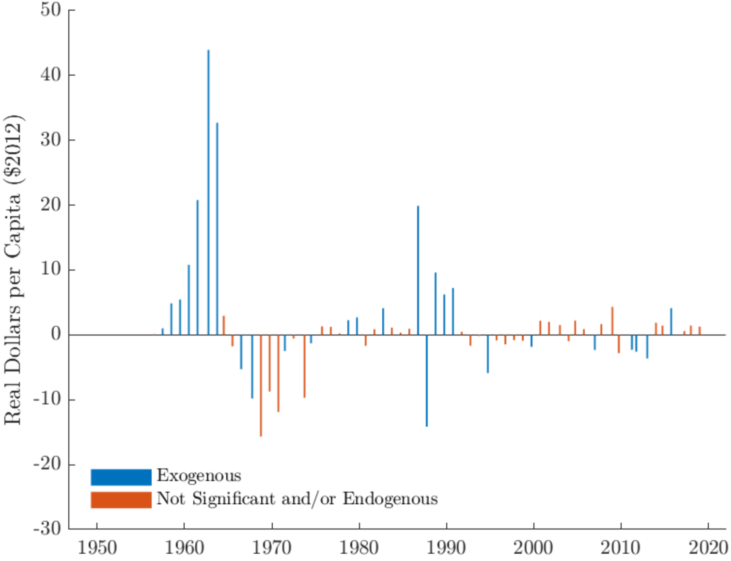
Changes in NASA R&D Appropriations



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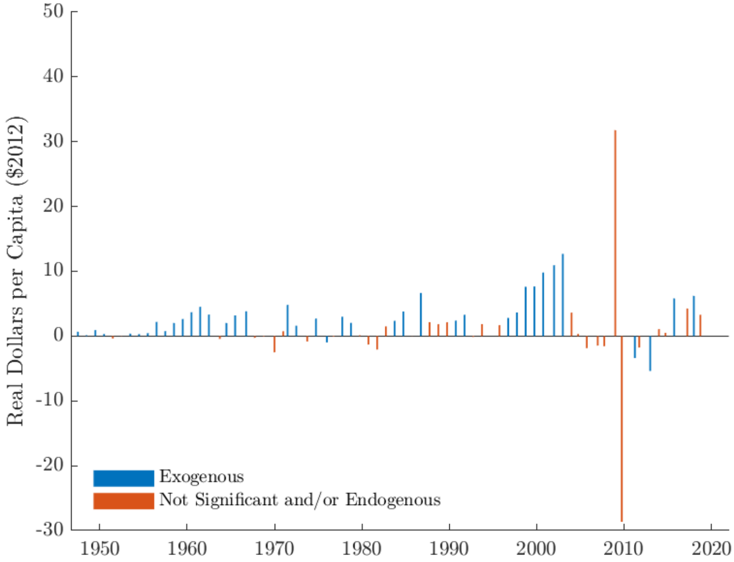
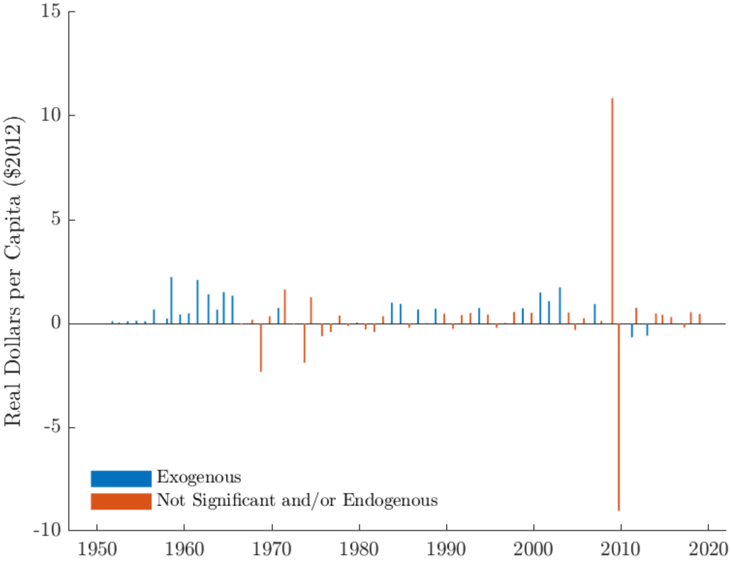
Changes in NIH R&D Appropriations



Changes in NSF R&D Appropriations



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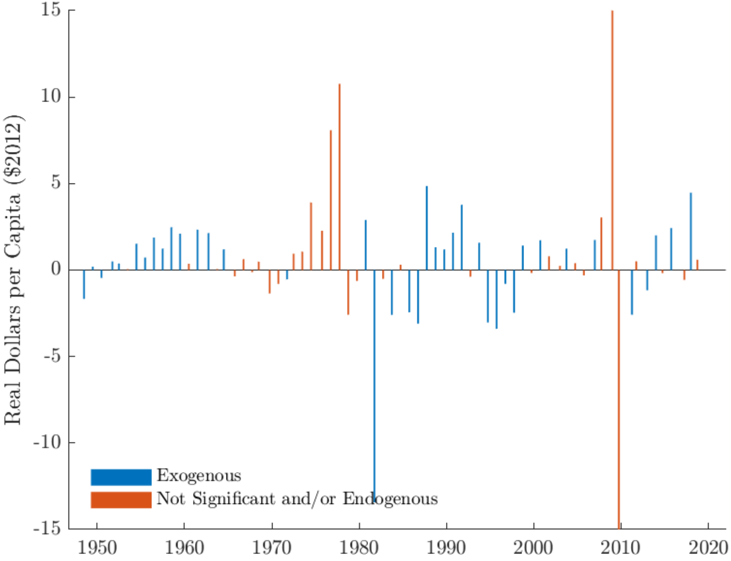
Changes in Nondefense Energy Appropriations



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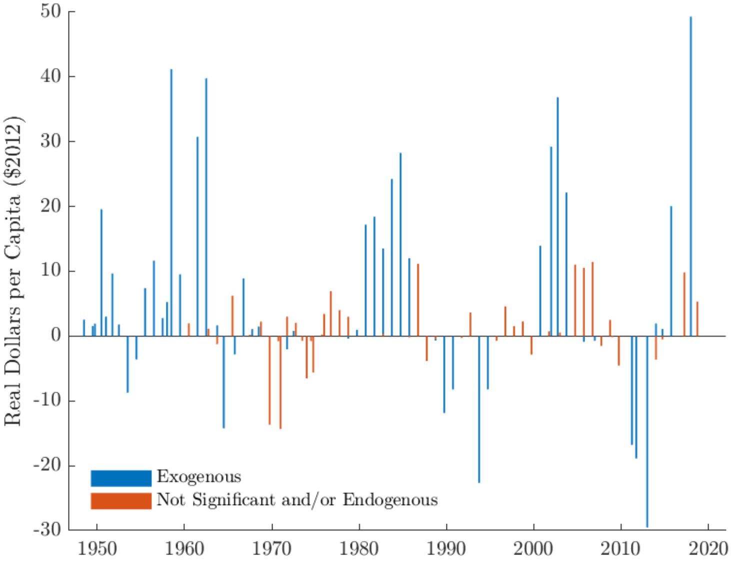
Changes in Defense R&D Appropriations



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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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- A_t is technological change

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Assuming perfect competition and taking log first differences:

$$\Delta \ln Y = \alpha \Delta \ln K + (1 - \alpha) \Delta \ln L + \Delta \ln U + \Delta \ln A$$

$$\text{where } \Delta \ln U = \alpha \Delta \ln Z + (1 - \alpha) \Delta \ln E$$

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TFP and utilization-adjusted TFP (*TFP-U*) are defined as:

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

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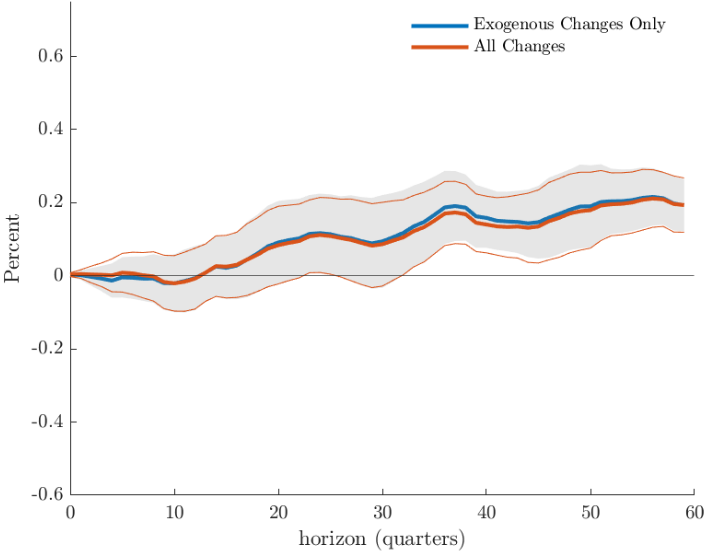
Role of Narrative Classification for Nondefense R&D Appropriations



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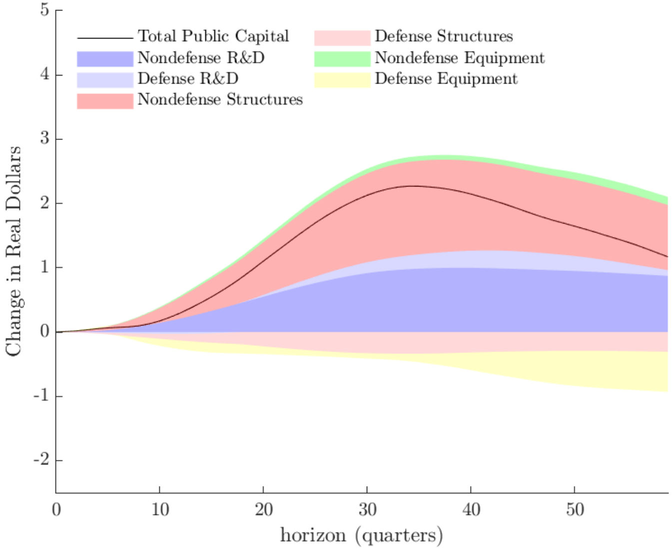
Response of Public Capital Stocks to Nondefense R&D



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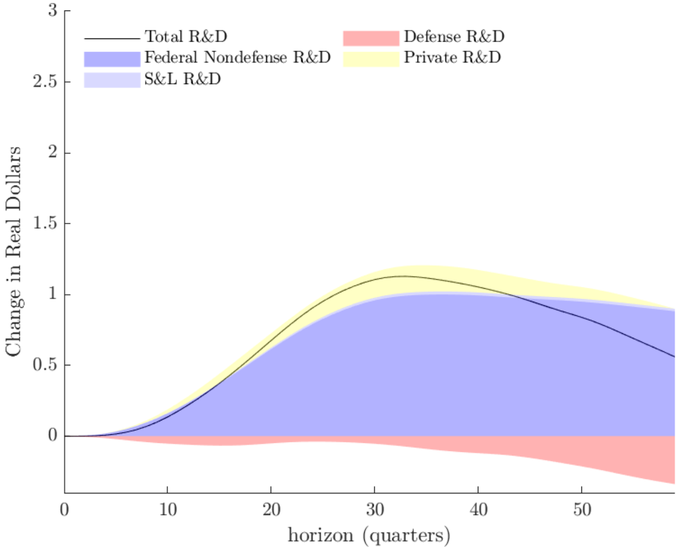
Response of R&D by Performer to Nondefense R&D Shocks



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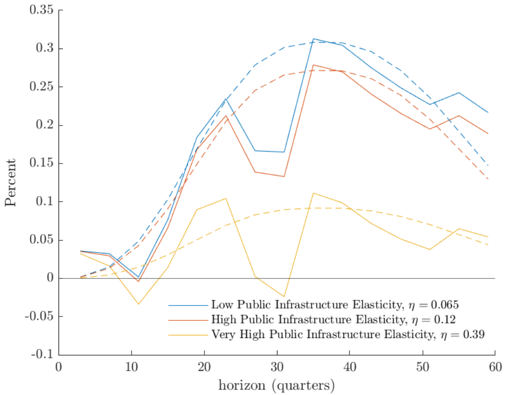
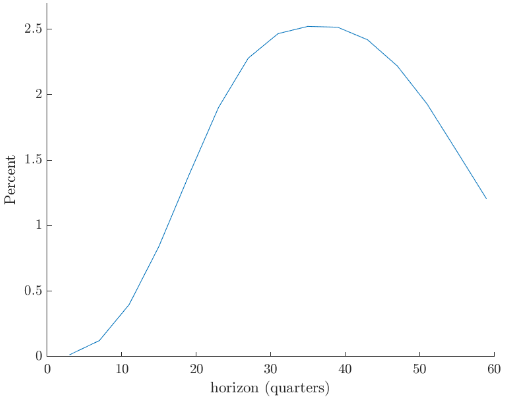
Simple Illustration of the SP-IV Estimator



Impulse response of $\widetilde{tfp}_t$



Impulse response of k_t

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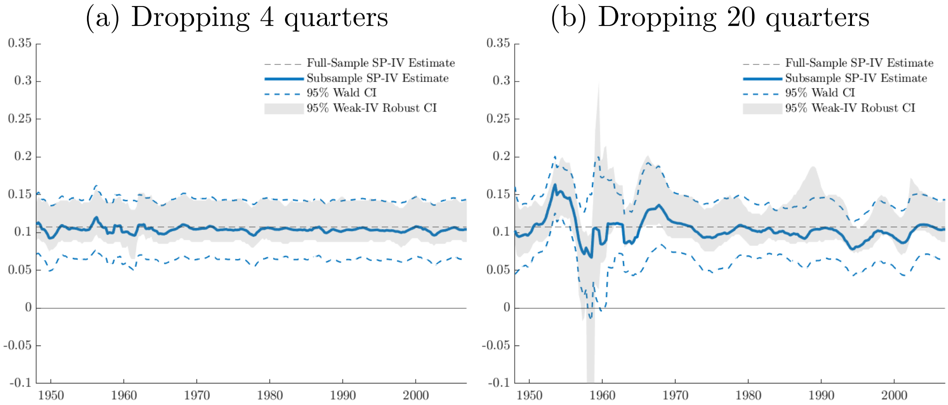
SP-IV Subsample Stability of Production Function Elasticities



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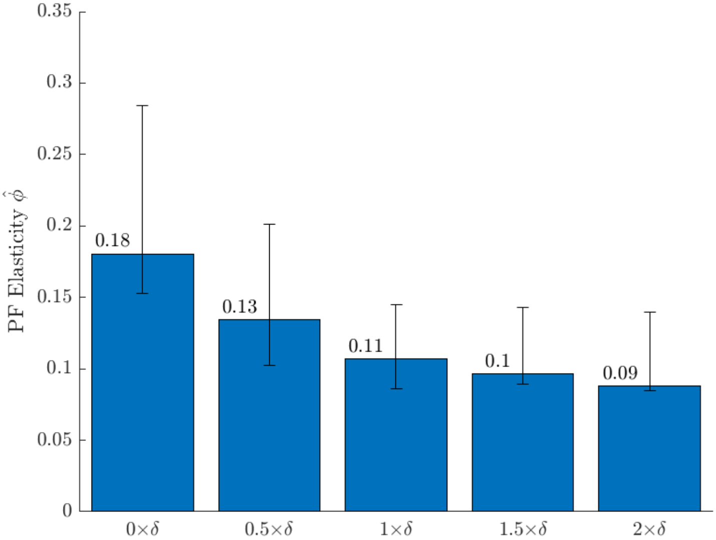
Government R&D Elasticities Under Alternative Depreciation Rates



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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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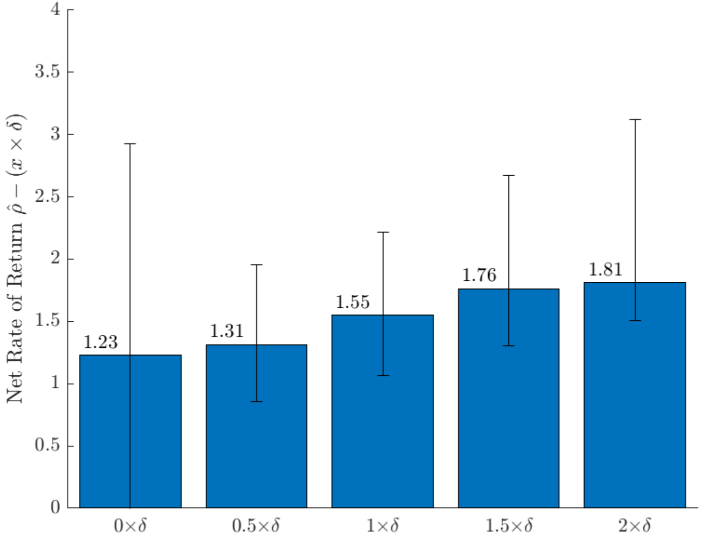
Returns to Government R&D Under Alternative Depreciation Rates



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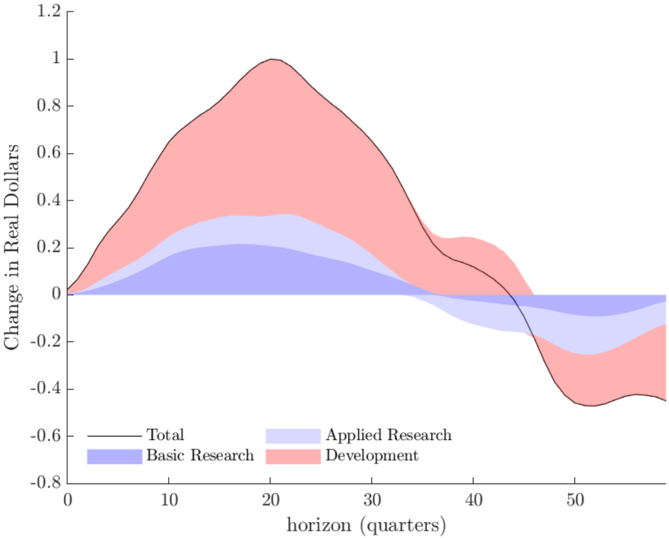
Changes in R&D by Type to Defense R&D Shock



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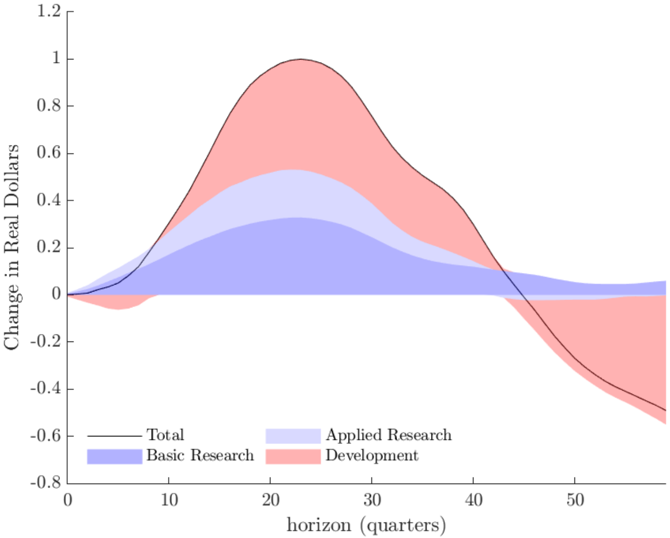

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