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

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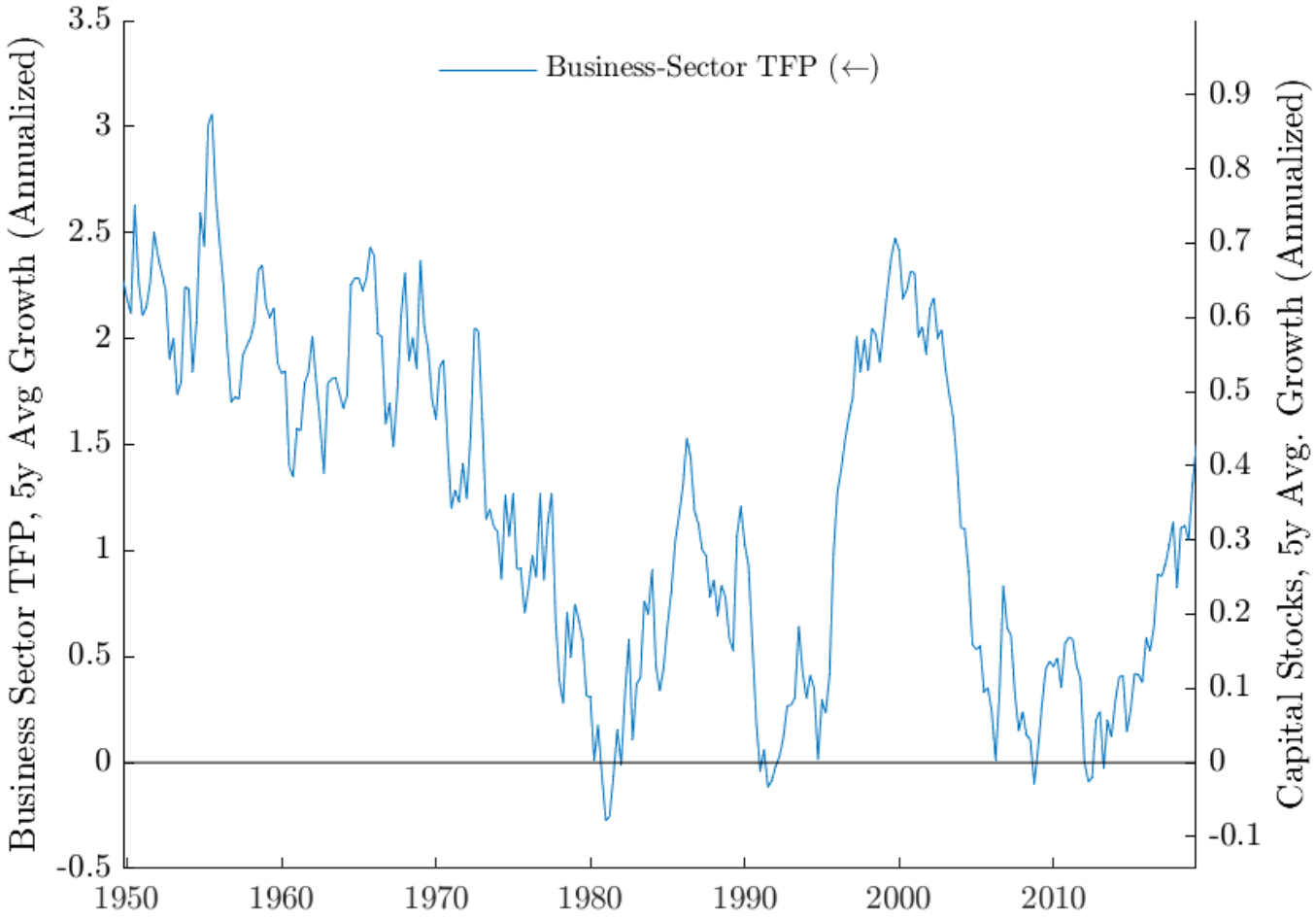
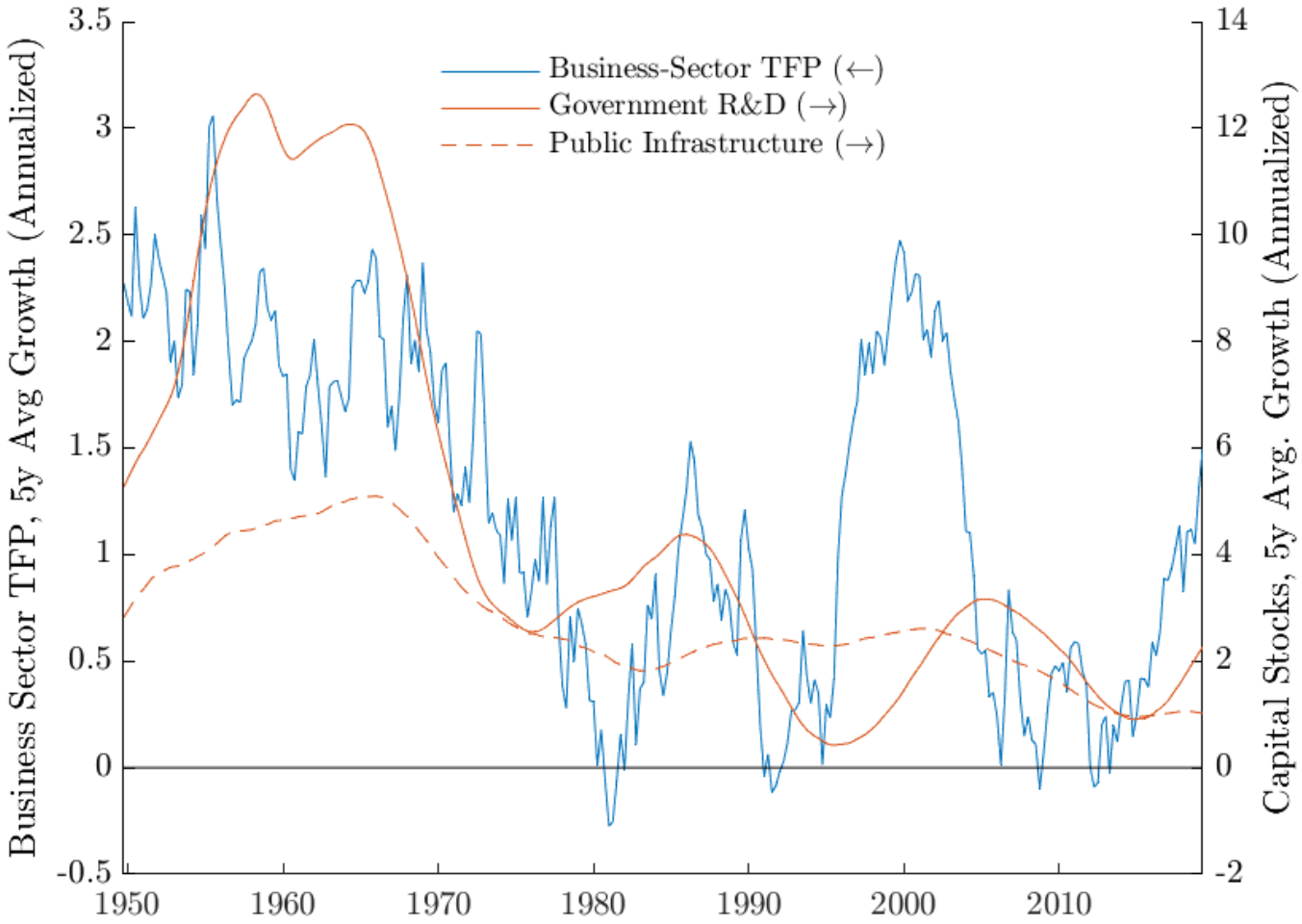
Measured TFP (Business Sector)



Measured TFP is utilization-adjusted (Fernald 2012)

Measured TFP : Role of Public Infrastructure and Government R&D?



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What is the Contribution of Public Investment to Productivity Growth?

$$\Delta \ln TFP = \eta \Delta \ln Q + \phi \Delta \ln K + \Delta w$$

Public infrastructure Q

- Ramey (2021) review: plausible range of η of 0.065 to 0.12
- CBO uses $\eta = 0.08$, implied gross rate of return of $\approx 12\%$

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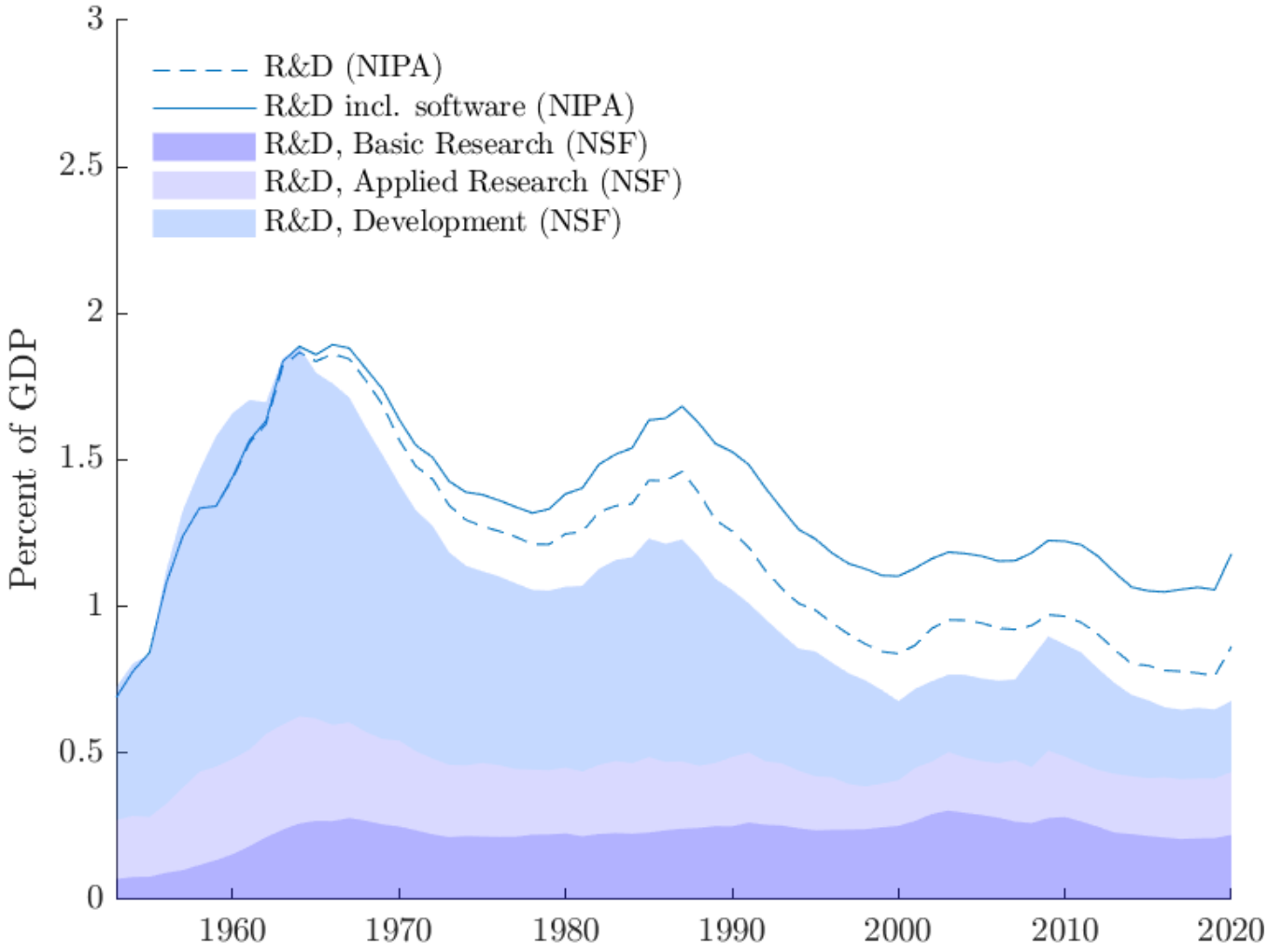
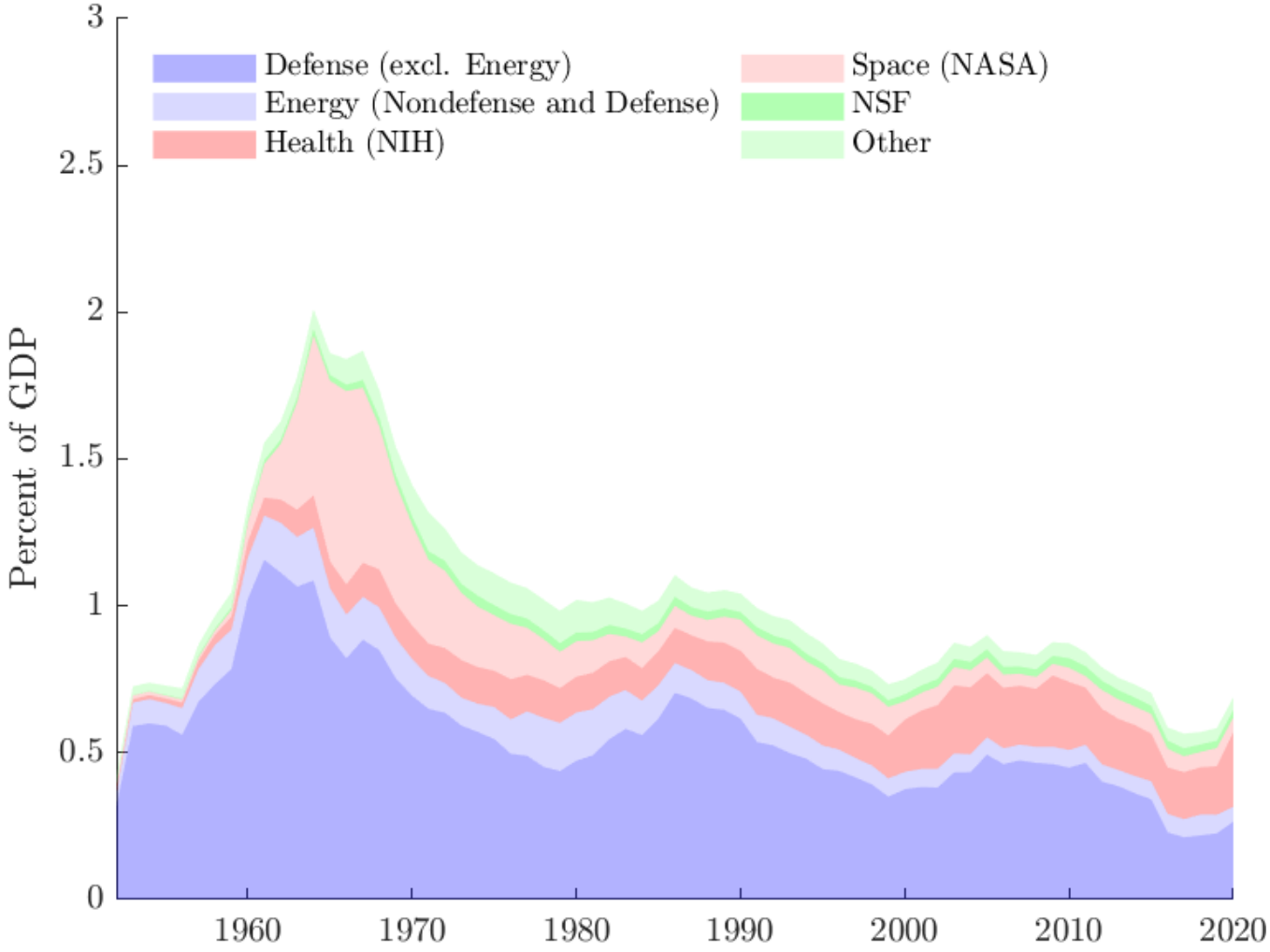
- $\Delta \ln K$ explains at least one fifth of business TFP growth since WWII

Government R&D Expenditures

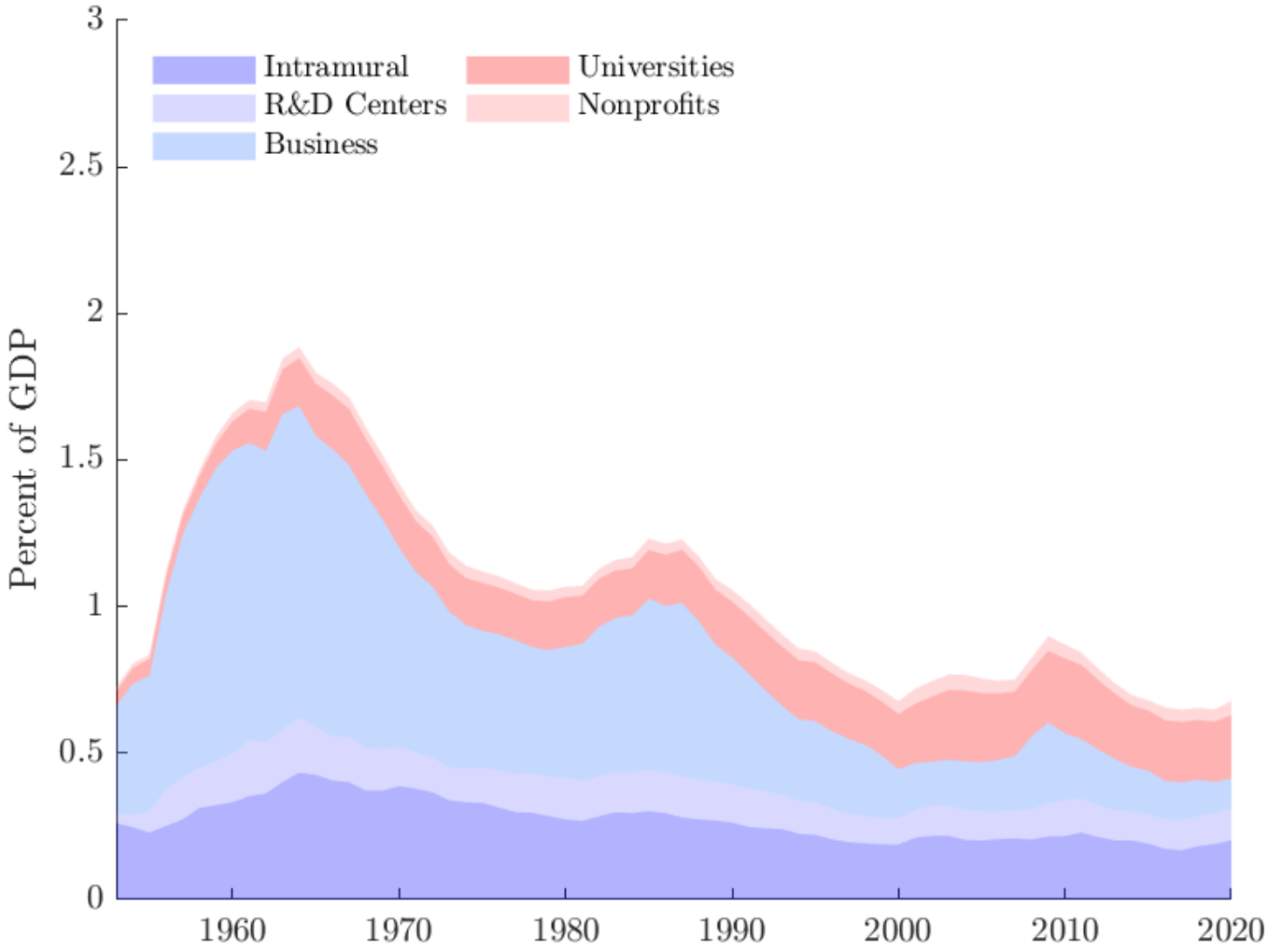


Sources: National Center for Science and Engineering Statistics+older NSF reports, BEA

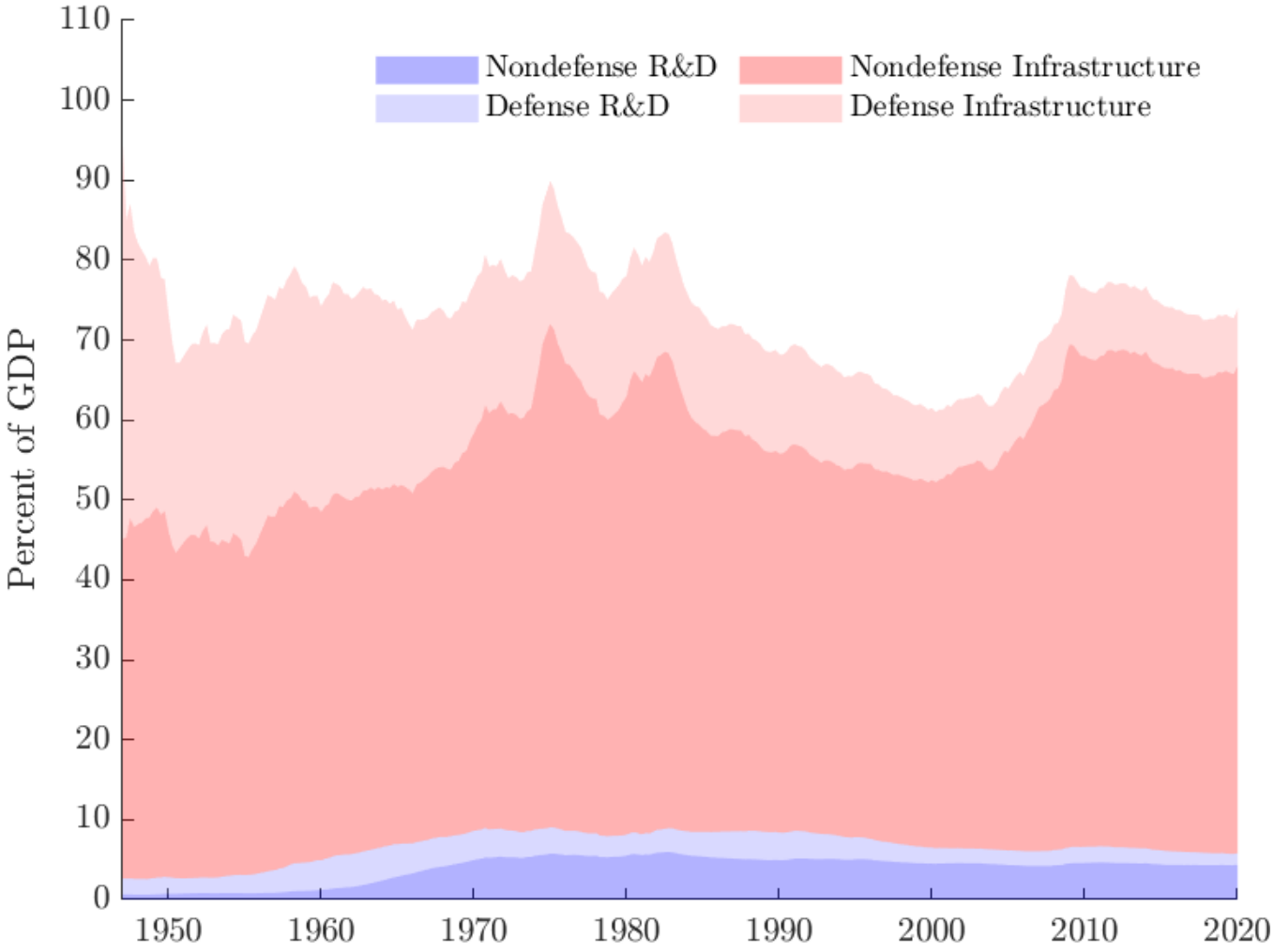
Federal R&D Expenditures by Agency



Government R&D Expenditures by Performer



Composition of Public Capital Stock



Sources: Own calculations, BEA (NIPA and Fixed Asset Accounts)

Structural Estimation Approach ϕ

GMM $\rightarrow$ SP-IV (Lewis and Mertens, 2023)

Step 1 Estimate IRFs of TFP and Govt R&D capital to Govt R&D spending shocks

Step 2 Regress IRF of (adjusted) TFP on the IRF of Govt R&D capital to obtain $\hat{\phi}$

Step 1 (Identifying Govt. R&D Shocks) Empirical Challenges

- Long Variable Lags, Anticipation Effects

  R&D Appropriations, Long-horizon LPs

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  Defense vs Nondefense R&D

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  Narrative Classification, Quarterly Data, Cyclical Controls

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  Unpredicted Variation in TFP

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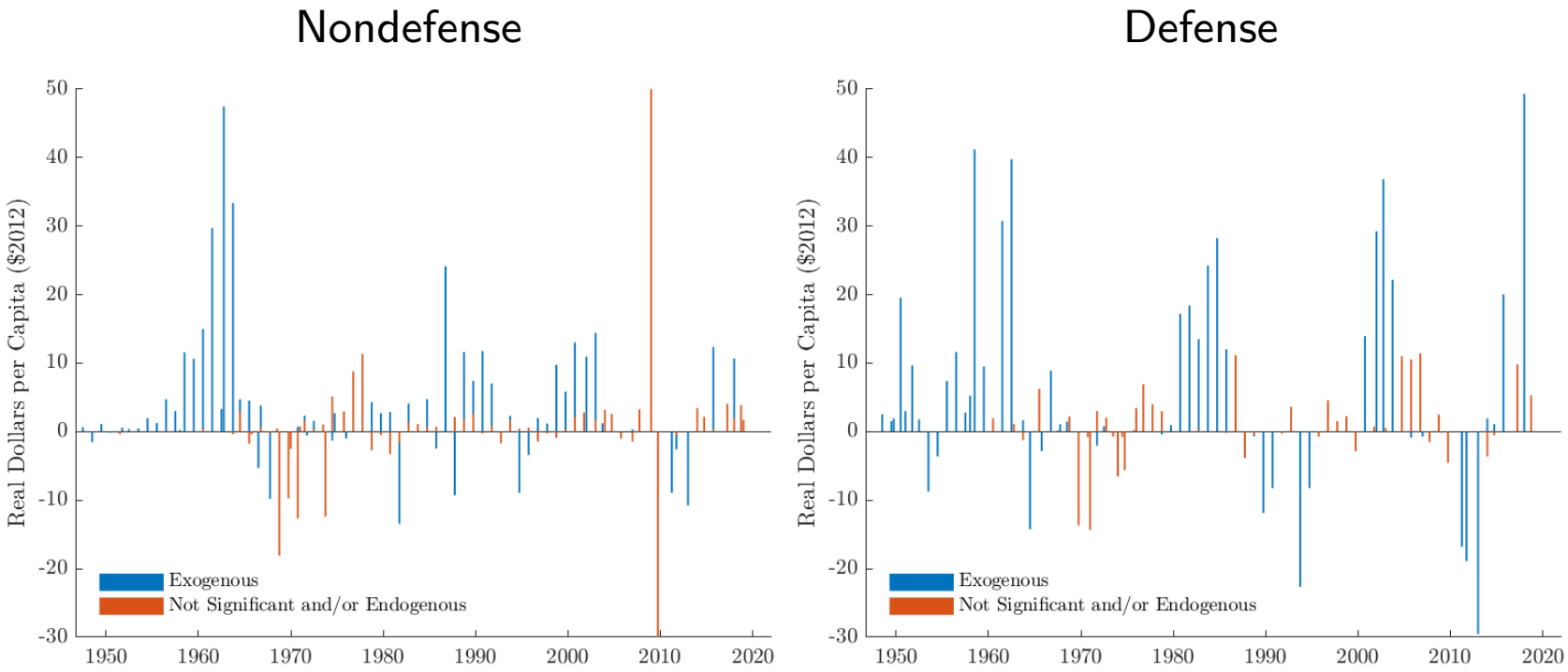
- Small Samples

  WIV-Robust Inference, Sensitivity Analysis

Changes in Appropriations for Federal R&D



In the end, narrative classification not very important for the results

Empirical Specification

Local projections

$$\sum_{j=0}^{3}\left(\frac{1}{4}\times y_{t+h-j}\right) \quad = \quad c_h + \gamma_h z_t + \sum_{j=1}^{4}\beta_h^j \ln a_{t-j} + \sum_{j=1}^{4}\delta_h^j y_{t-j} + \sum_{j=1}^{4}\zeta_h^{j\prime} x_{t-j} + v_{t+h}$$

$h = 0, ..., H-1 \quad H = 60$ quarters

y_t: outcome variable of interest (e.g. measured TFP)

z_t: narrative exogenous appropriations shocks

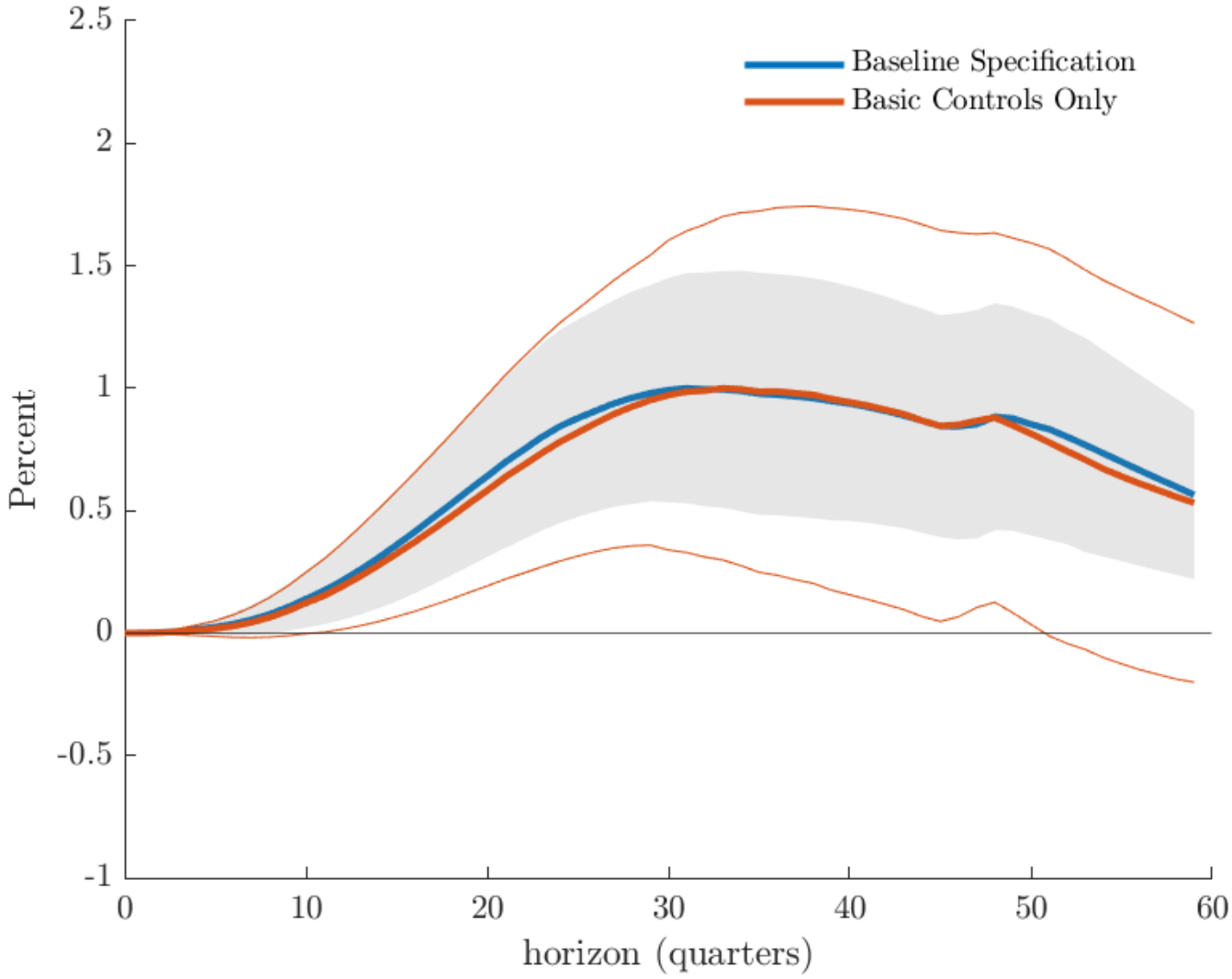
a_t: cumulative appropriations

x_t: other controls

capacity utilization, private R&D capital, government R&D capital, util-adj. TFP, stock returns in tech/manu/health, Ramey and Zubairy (2018) military news

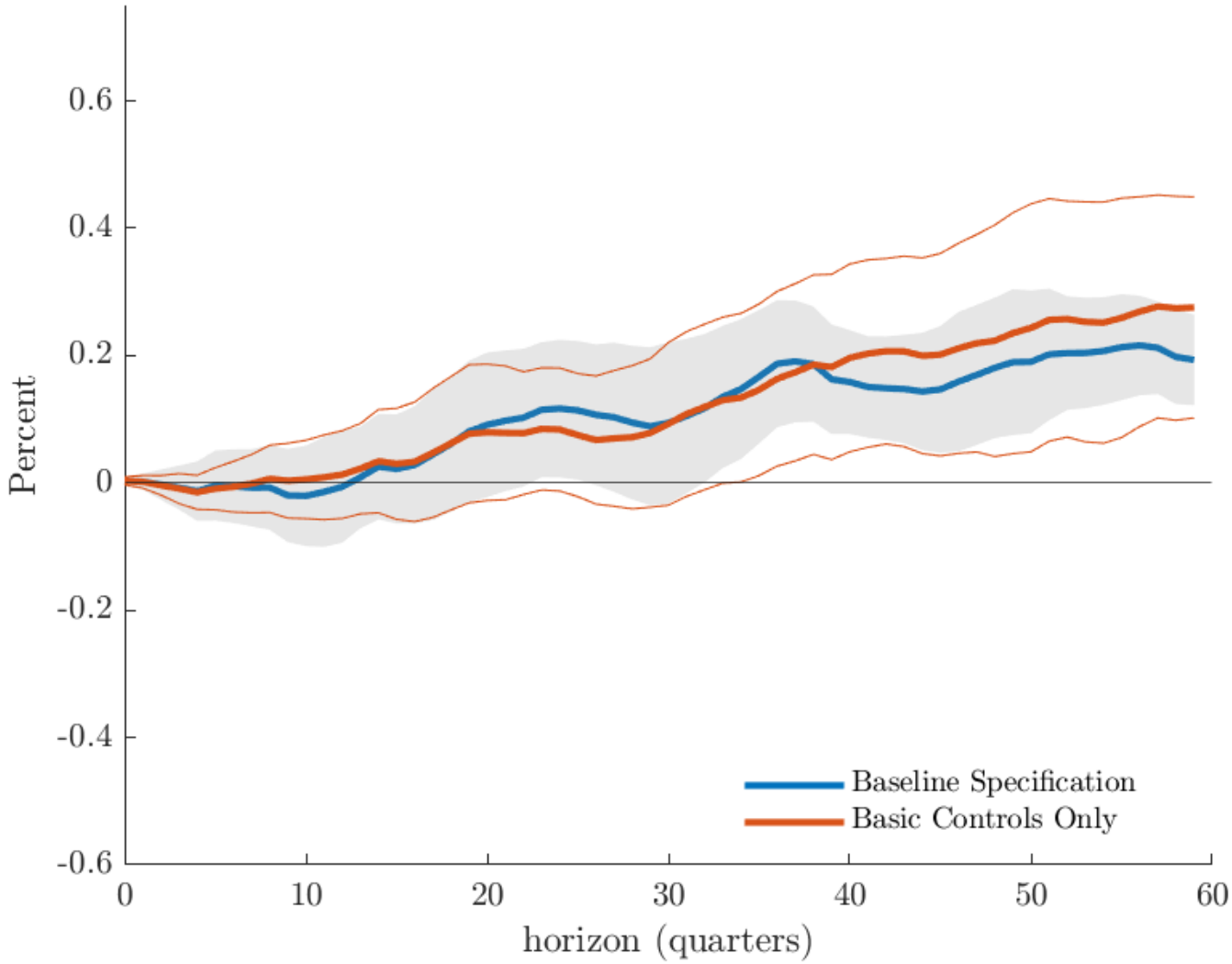
1948Q1 - 2021Q4 unbalanced sample

Response of Government R&D Capital to Nondefense R&D Appropriations Shock



95% HAR CI

Response of Business Sector TFP to Nondefense R&D Appropriations Shock



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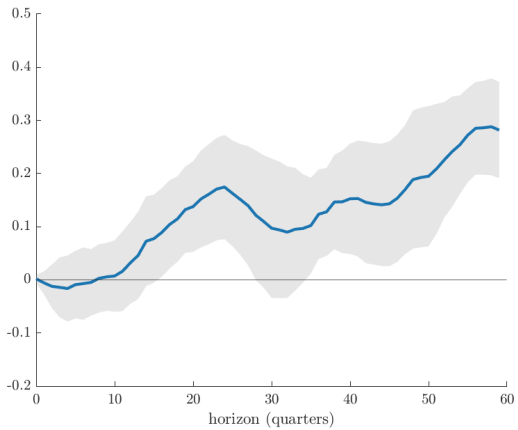
Other Productivity/Innovation Indicators After a Nondefense Shock

(a) Labor Productivity



95% HAR CI Source: BEA

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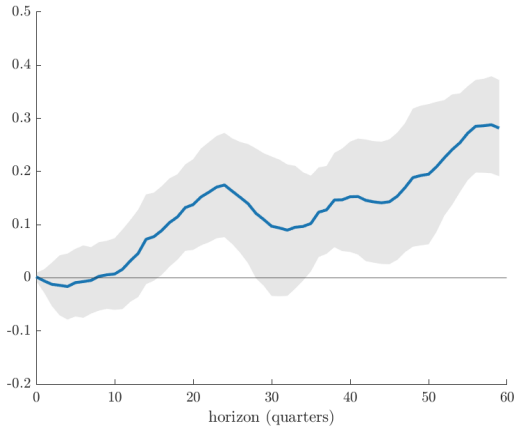
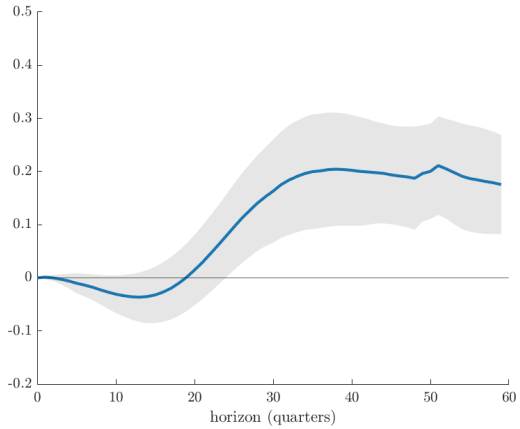


(b) CBO Potential Output



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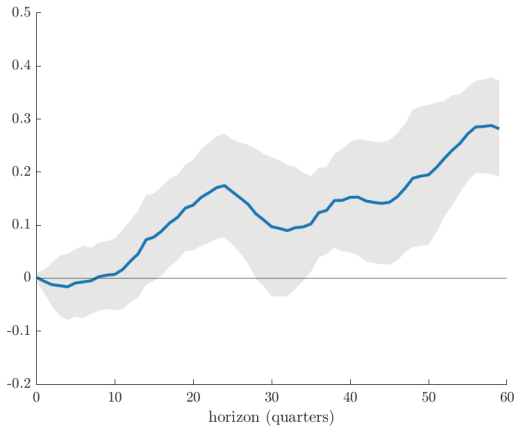

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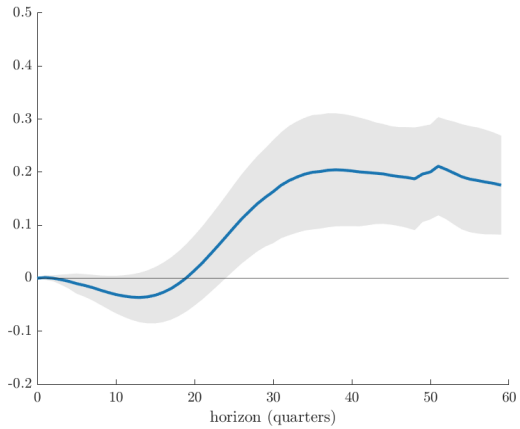
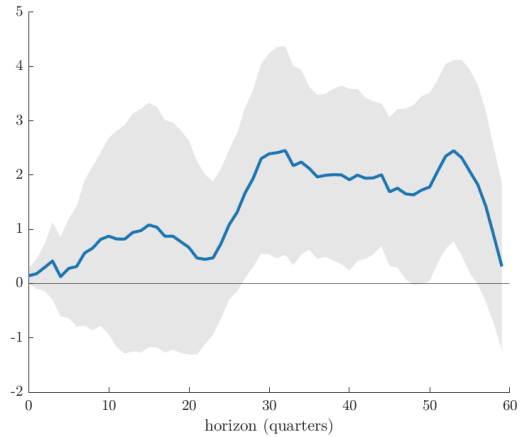


(c) Patent Innovation Index



95% HAR CI Source: Kogan et al. (2017), Gascaldi-Garcia and Vukotic (2022)

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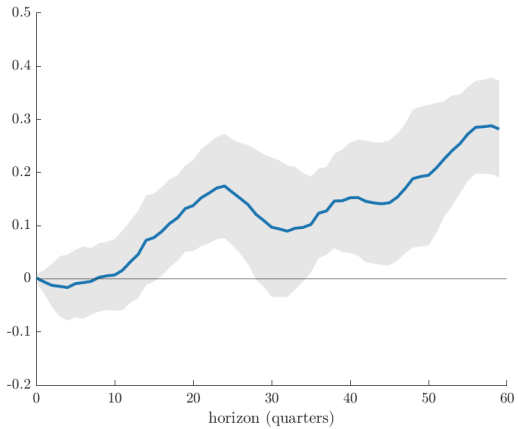

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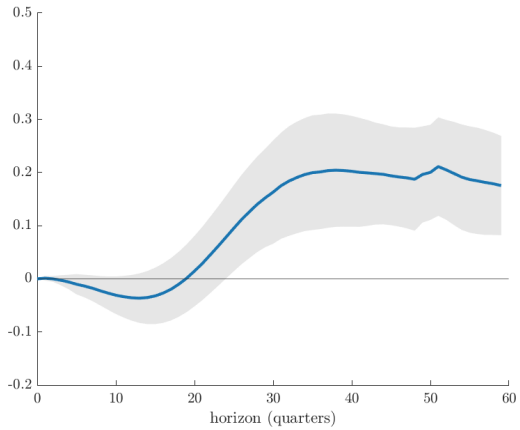

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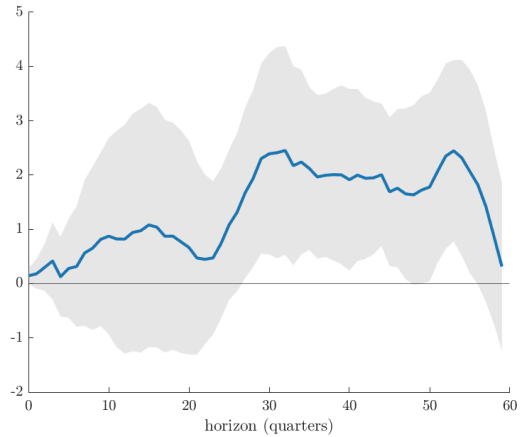
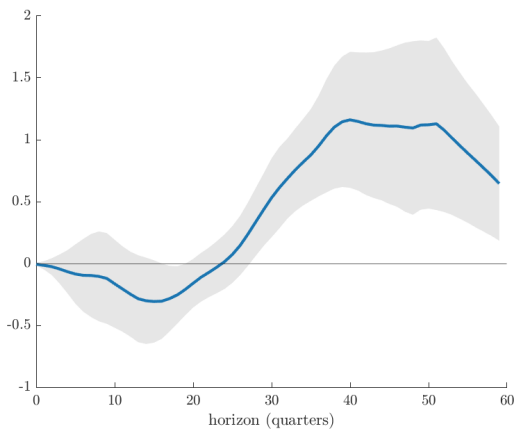


(d) New PhDs in STEM



95% HAR CI Source: NCSES, Survey of Earned Doctorates

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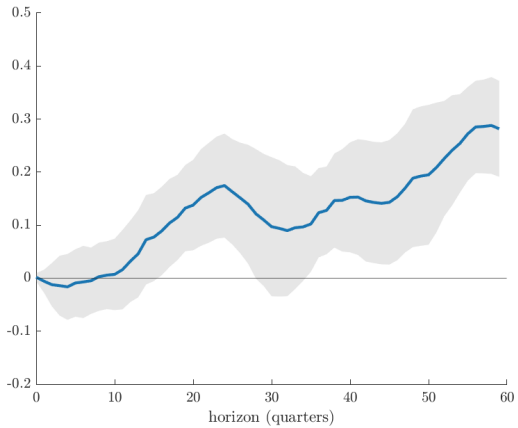

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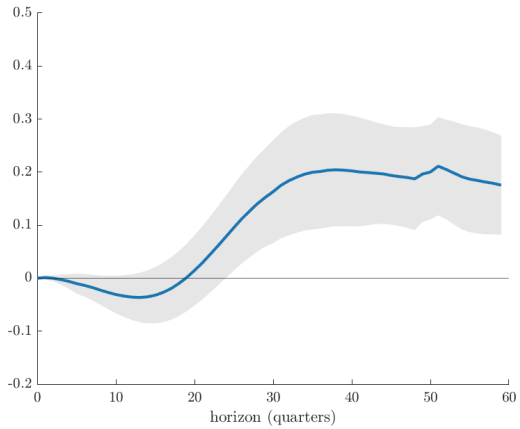

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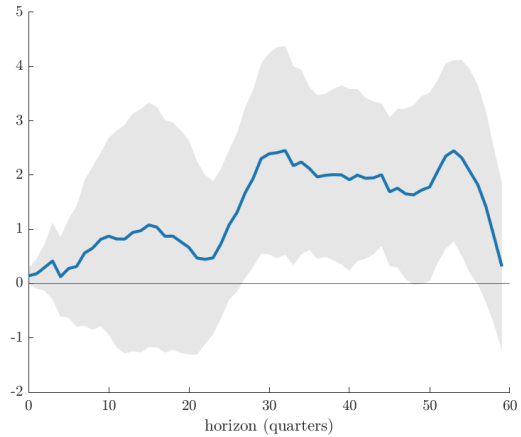

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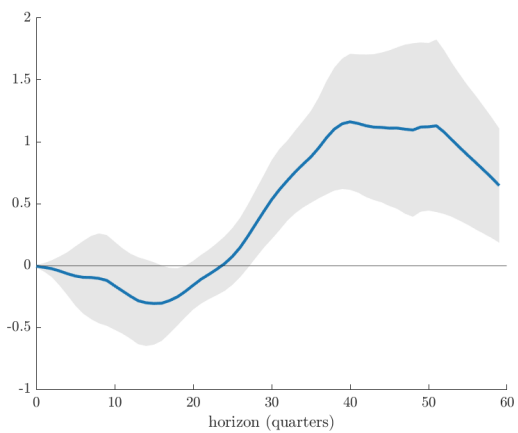
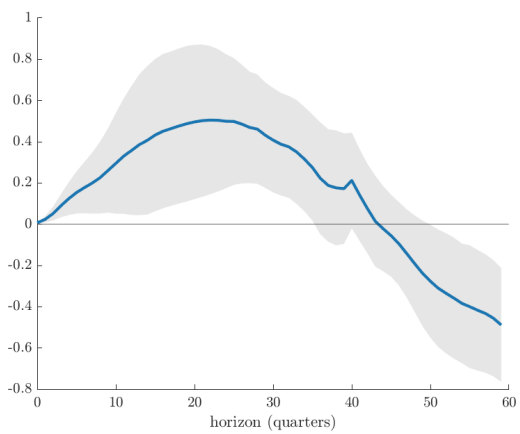


(e) R&D workers



95% HAR CI Source: OECD, Bloom et al. (2020)

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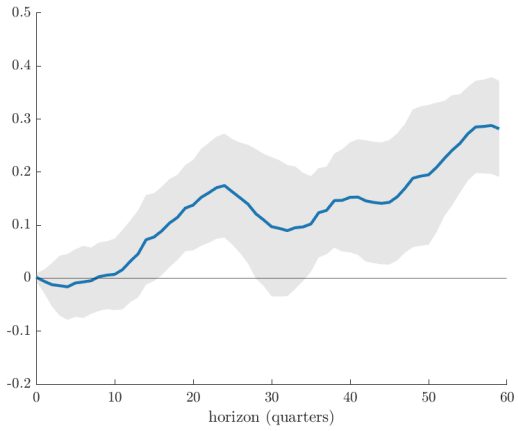

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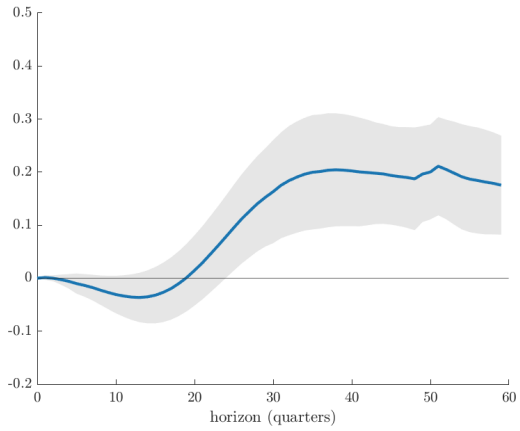

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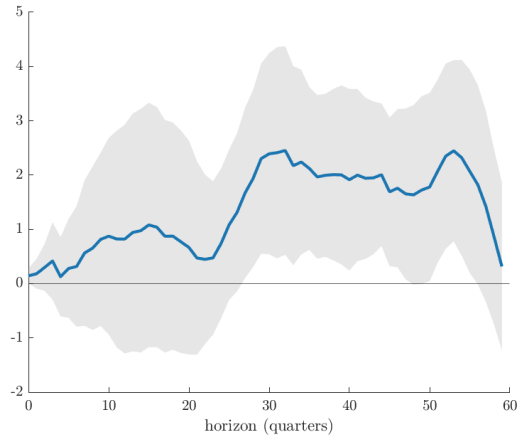

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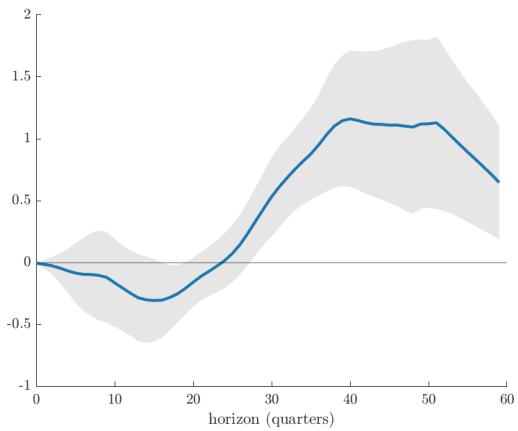

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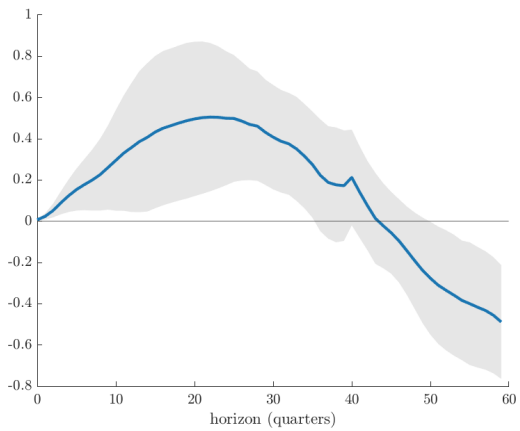
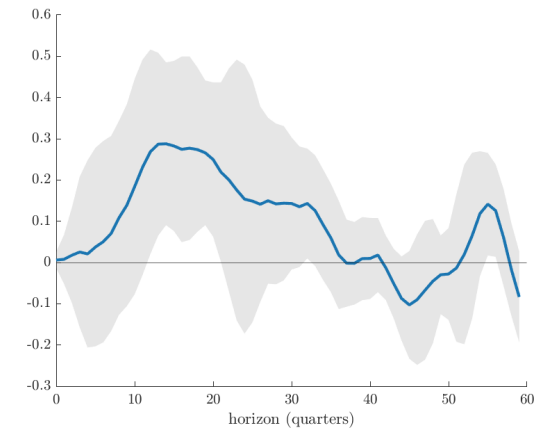
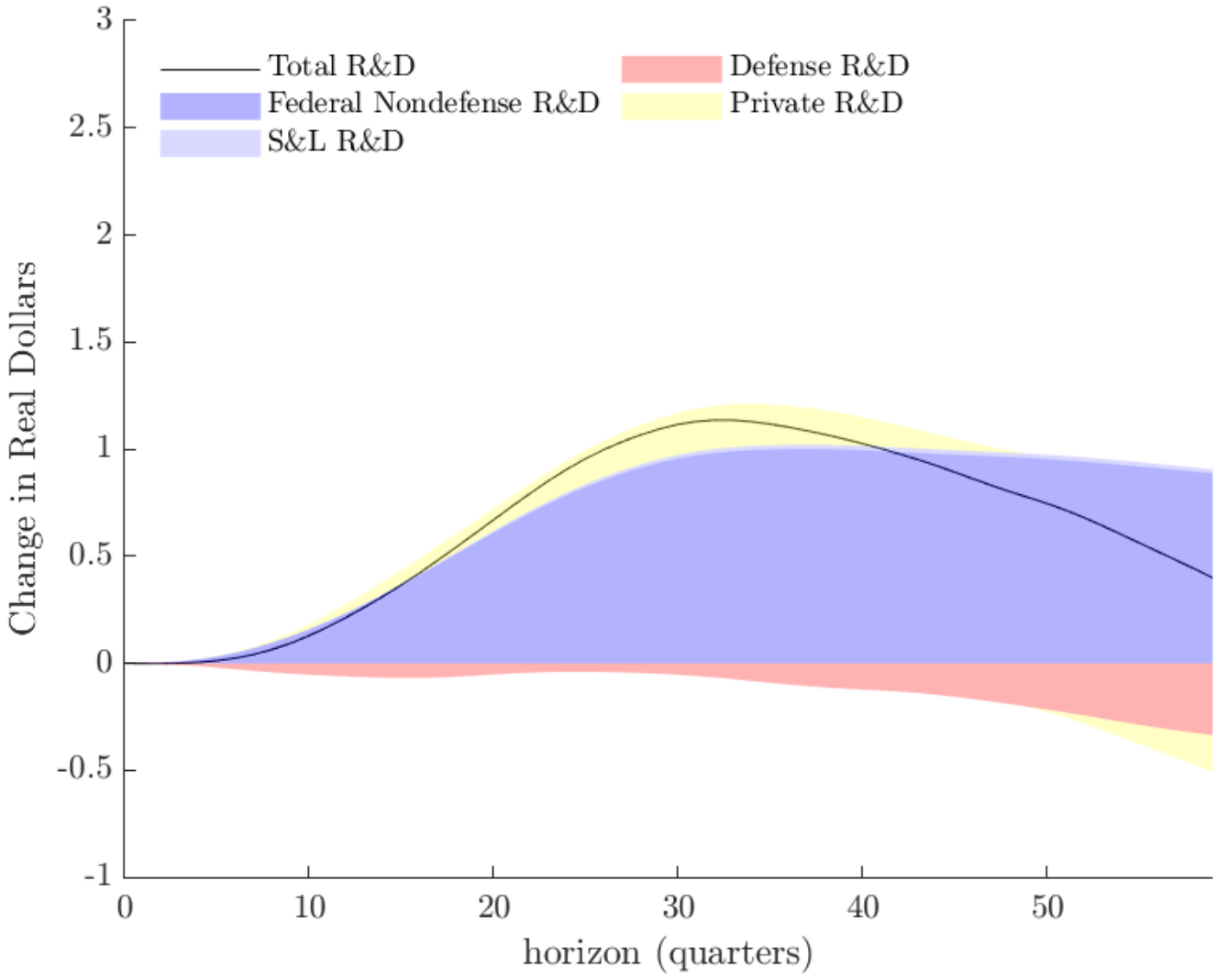


(f) Technology Books



95% HAR CI Source: Alexopoulos (2011)

Decomposition of Effect on Economy-Wide R&D Capital



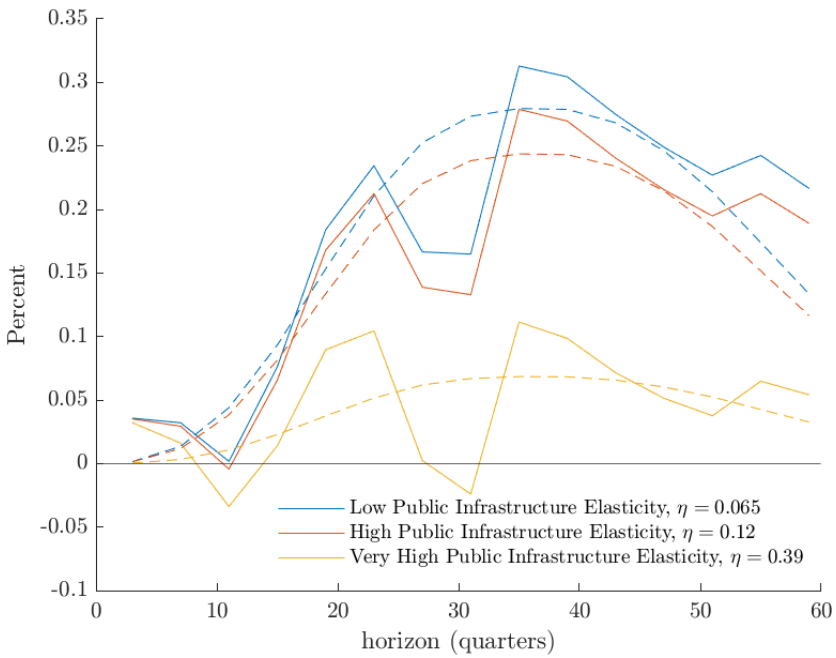
Step 2: Structural Estimation of ϕ

SP-IV Regression in Impulse Response Space

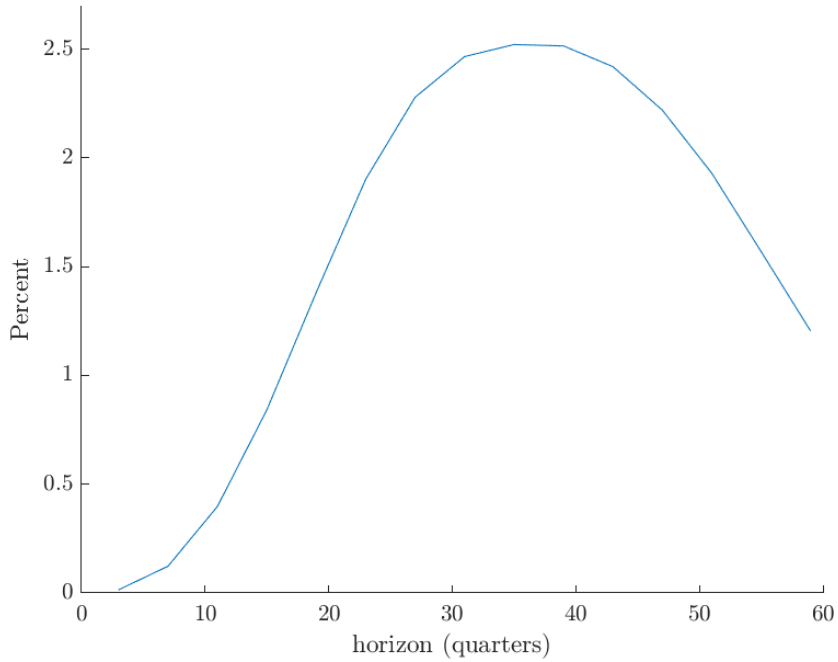
(Lewis and Mertens, 2023; Barnichon and Mesters, 2020; Jorda and Kozicki, 2011)

$\Delta\widetilde{tfp}_t = \Delta tfp_t - \eta_t \Delta q_t$: TFP adjusted for public infrastructure

Response of $\widetilde{tfp}_t$



Response of k_t



Production Function Elasticity Estimates

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)

95% Weak-IV-robust CI based on Kleibergen (2005). Subvector inference based on projection method.

Historical Contributions to TFP Growth

	'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 at least one fifth of TFP growth

Typically at least as important as public infrastructure

Return to Government Investment in R&D

Net rate of return is $\rho_t^n - \delta$ where $\rho_t = \phi_t Y_t / K_t \quad , \quad \delta \approx 0.16$

Calculate $\rho = \hat{\phi} Y / K$ using SP-IV estimates $\hat{\phi}$,

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Net rate of return is $\rho_t^n - \delta$ where $\rho_t = \phi_t Y_t / K_t \quad , \quad \delta \approx 0.16$

Calculate $\rho = \hat{\phi} Y / K$ using SP-IV estimates $\hat{\phi}$,

or, using $\Delta k_t \approx \frac{K_t - K_{t-1}}{K_t}$ and assuming ρ_t rather than ϕ_t is constant

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

estimate ρ using SP-IV

Estimates of Return to Government R&D

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)

95% Weak-IV-robust CI based on Kleibergen (2005). Subvector inference based on projection method.

Conclusion

Large spill-overs of nondefense Govt R&D on business TFP

Social returns larger than best estimates for private R&D

Return to R&D $(140 - 210\%)$ $>>$ return to infrastructure $(\approx 12\%)$

Misallocation of public capital, underinvestment in R&D