Where Do Technology Shocks Come From? Public Funding and Private Ownership

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This presentation does not necessarily reflect the view of the Bank of Italy or Eurosystem

Where Do Technology Shocks Originate?

Technology shocks are central to macroeconomics

- A large literature identifies technology shocks and traces their dynamic effects
  Blanchard & Quah (1989); Galí (1999); Ramey (2005); Fernald (2012); Ramey (2020)

But their economic origins remain largely unexplored

- Shocks arrive as *primitive disturbances*
  - Aggregate effects are identified
  - The institutional source of innovation is not observed

This paper

- Do funding and ownership shape shock propagation?
- Which dimensions of heterogeneity matter?
  - Basicness, funding agency, innovator type and research field

Technology-Shock Proxies by Funding Source and Ownership

(1) Build aggregate patent series by funding source × ownership (Gross & Sampat, 2025)

- private-private: privately funded and owned
- public-private ("license"): government-funded, privately owned
- public-public ("title"): government-funded and government-owned

(2) Use unanticipated filings as source-specific technology-shock proxies

- Local projections with rich macro controls: residual filings = shock proxy
- IRFs of TFP, GDP, R&D and investment

(3) Discipline the shock interpretation

- Information-sufficiency tests; orthogonality to identified macro shocks & SPF forecasts
- Instrumental variable approach
  - Private patents: patent-news IV (Miranda-Agrippino et al., 2025)
  - Public patents: agency-level R&D shocks (Fieldhouse & Mertens, forthcoming)

▸ Patent series

Main Findings

Government-funded but privately owned innovation is a large source of fluctuations

- 2% of patent filings, yet $\sim$20% of medium-run fluctuations in TFP and GDP
- larger and more persistent responses than privately funded patents

Propagation through the private sector

- sustained crowding-in of private R&D and capital investment
- model-implied social returns to public R&D $\approx 2\times$ those to private R&D

Where the effects come from

- science-based patents; NIH & NSF; universities, research institutes, start-ups

Government-owned patents

- weak average effects, but a consequential upper tail (high-risk, high-reward)

A Simple Framework: Basic Research and Private Innovation

$s \in \mathcal{S}$: technology source; X_{st}: technology stock; R_{st}: R&D spending

$$Y_t = A_t L_{yt} \qquad \text{Final output} \qquad (1)$$

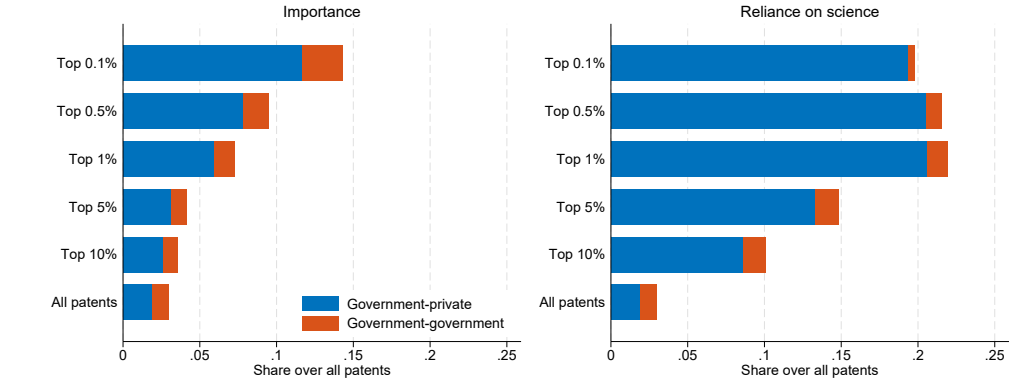
$$\frac{\dot{A}_t}{A_t} = \sum_{s \in \mathcal{S}} \lambda_s \frac{X_{st}}{A_t} \qquad \text{TFP growth} \qquad (2)$$

$$\dot{X}_{st} \propto R_{s,t}^{\eta} \prod_{s' \in \mathcal{S}} X_{s't}^{\theta_{s'}} \qquad \text{New technologies} \qquad (3)$$

- λ_s: direct productivity effect; θ_s: spillovers to subsequent R&D
- Public funding supports basic, upstream research
- Its effects propagate by stimulating private R&D

Government-Funded Patents Are Likelier to Be Basic

- Publicly funded patents: 3% overall, ∼20% of the most science-reliant



Importance: Kelly et al. (2021); reliance on science: Marx & Fuegi (2020, 2022). See also Dyèvre (2024).

Time-series Approach

Local Projections: $y_{t+h} = \alpha_h + \beta_h x_t + \boldsymbol{\gamma}_h \mathbf{w}_t + \upsilon_{h,t}, \ h = \{0...T\}$

- y_{t+h}: GDP, TFP, investment, R&D... (log, per capita, quarterly)
- x_t: Patent *filings* by category (pub-priv, priv-priv, pub-pub), agency, innovator...
- $\mathbf{w}_t$: four lags of outcomes, filings and macro controls
  - GDP, TFP, investment, stock prices, T-bill rate and R&D
  - Patents filed in other groups
- Shock size normalized to 1% impact on total patents

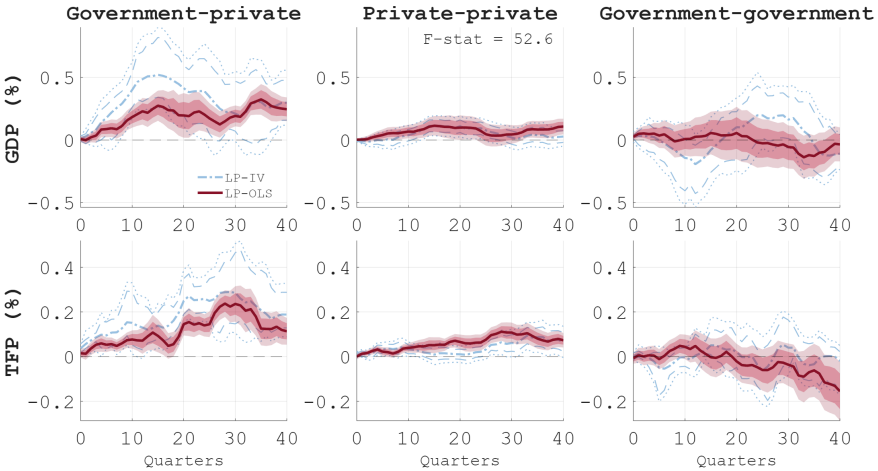
Residual source-specific filings = patent-based technology-shock proxies

Corroborated by external instruments

▸ IV details ▸ Orthogonality

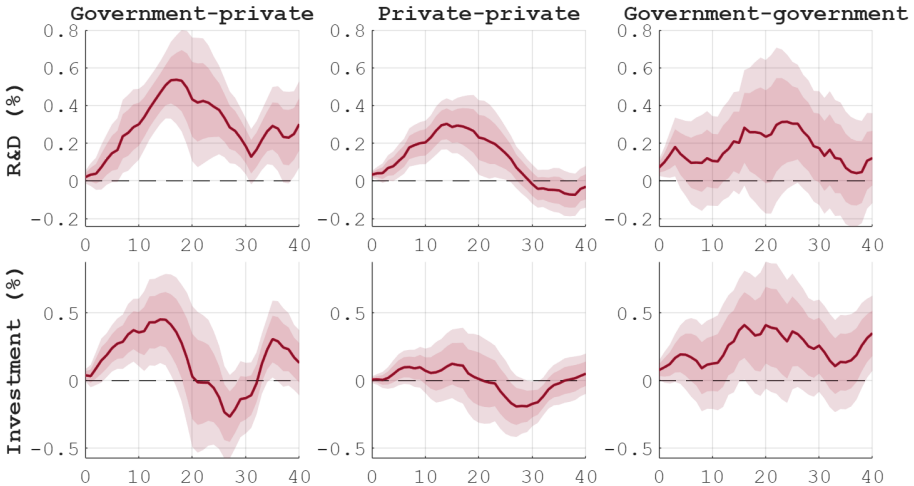
Miranda-Agrippino et al. (2025); Fieldhouse and Mertens (forthcoming)

GDP and TFP Responses by Funding Source and Ownership



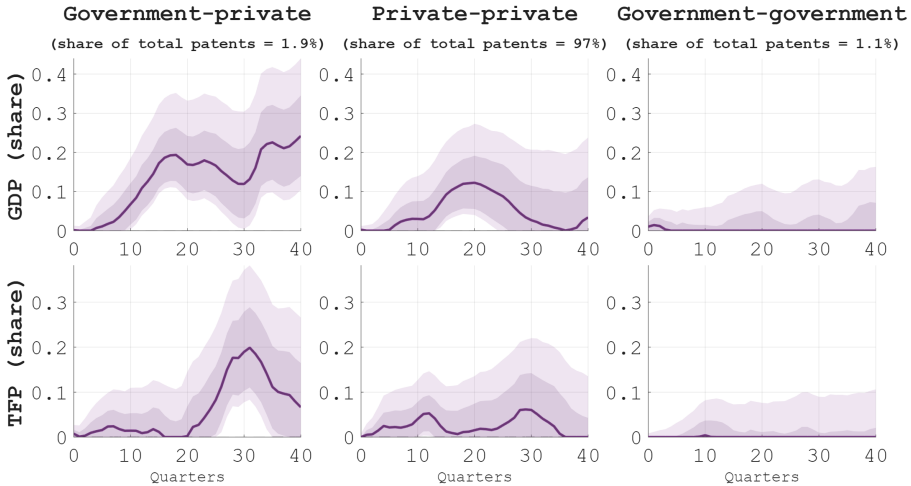
▸ Pre-trends ▸ Pool ▸ Robustness

Propagation: Effects on Business-Sector R&D and Investment



▸ Pre-trends ▸ Wages & consumption

Contribution to Aggregate Fluctuations



▸ Historical decomposition

Model-Implied Social Returns to R&D

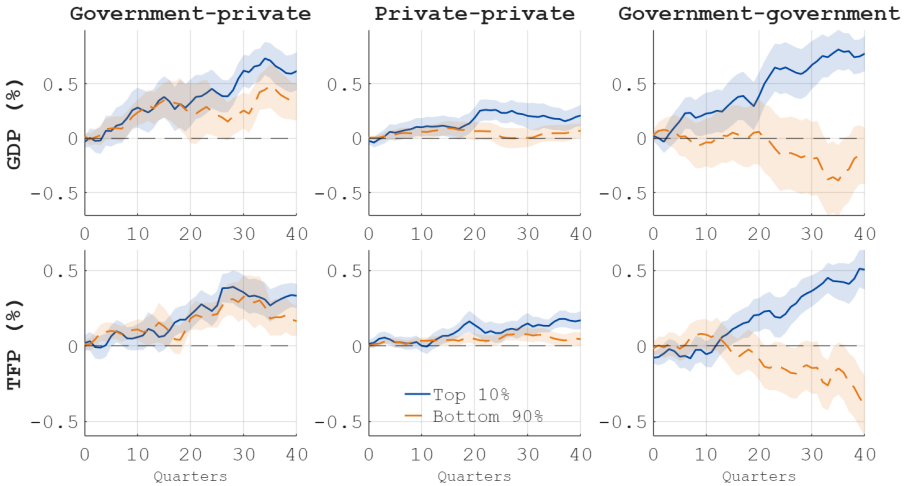
funding source	*cost per patent*	**Estimated return**	**Output multiplier**	**R&D multiplier**
private	1.22M$	0.88 [0.55, 1.17]	4.01 [2.50, 5.30]	0.16 [0.01, 0.27]
public	25.90M$	1.91 [1.16, 2.93]	8.67 [5.28, 13.30]	0.52 [0.29, 0.82]

- Our patent-based IRFs imply a source-s social return to R&D

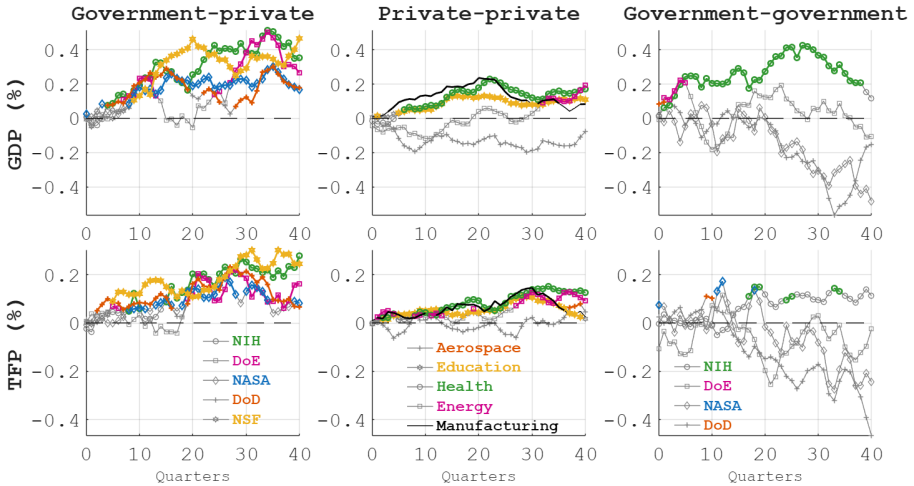
$$r_s = (r+\delta)\frac{\eta}{C_s}\sum_{h=0}^{T}\left(\frac{1}{1+r}\right)^h \hat{Y}_{h,s}, \tag{4}$$

- $\hat{Y}_{h,s}$: GDP response in real \$, scaled by the discounted source-s patent sequence over 40 quarters
- Public pools public-private and public-public patents
- C_s: average R&D cost per patent; s: public or private funding
- With $\eta = 0.4$ (Danguy et al., 2014; Hall et al., 1986), multipliers and returns align with existing estimates Public: Fieldhouse & Mertens forthcoming, Bergeaud et al. 2025; Private: Bloom et al. (2013), Jones & Summers (2021)

Mechanism: "Basic" Patents

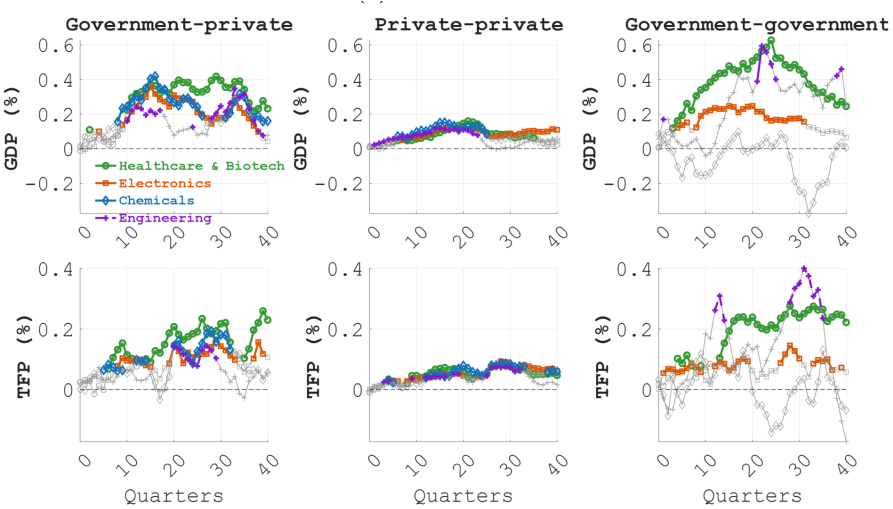


Mechanism: Federal Agencies and Industries

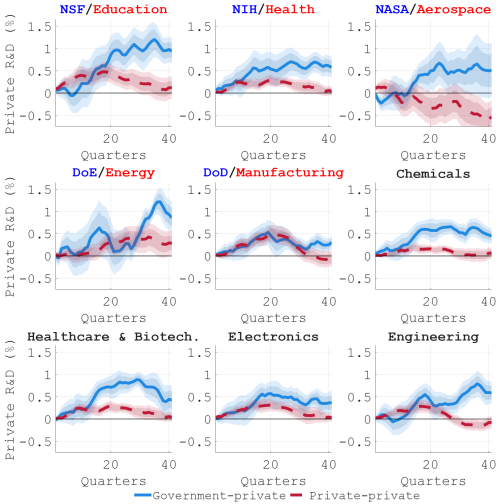


▸ Research fields ▸ R&D spillovers by agency

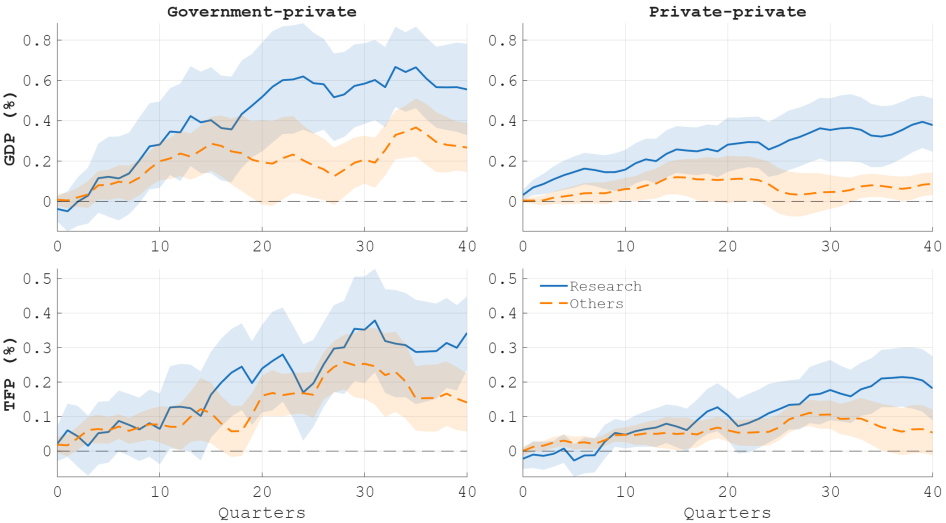
Mechanism: Research Fields



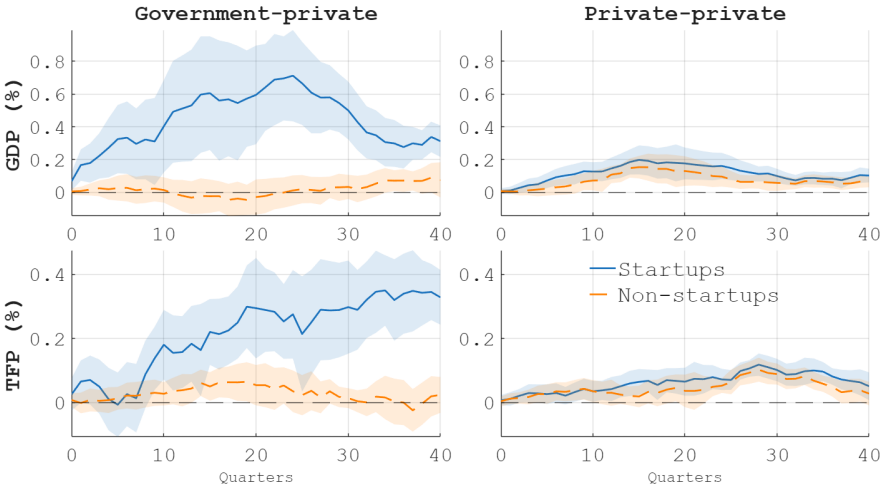
Business R&D Spillovers by Agency and Research Field



Universities and Research Institutes vs. All Others



Mechanism: Start-ups vs. Established Firms



Conclusions

Technology shocks are not institutionally homogeneous

- the **funding and ownership** structure of innovation matters for propagation
- Public-private patents account for 2% of filings
  - They drive $\sim$20% of medium-run GDP/TFP fluctuations
- Strong **crowding-in** of business-sector R&D and capital investment
- **Social returns** to public R&D $\approx 2\times$ those to private R&D
- Effects concentrate in **science-based patents**
  - NIH and NSF
  - Universities, research institutes and start-ups
- Public-public patents: weak on average, **consequential upper tail**

Public funding and private deployment are **complements**

- Largest effects arise from upstream, science-based technologies
  - They crowd in subsequent private research
  - Bush (1945); Nelson (1959); Arrow (1962)

Appendix

Are These Technology-Shock Proxies? Validation

- Sufficient information test following Forni & Gambetti (2014)
- Control variables predict patent applications (column 1 in table below)
- Residuals are orthogonal to:
  - Military spending news (Ramey-Zubairy)
  - Monetary and tax shocks (Romer; Mertens-Ravn)
  - Survey of Professional Forecasters forecasts

	Controls	Orthogonality Tests			
Variable	LP spec	Mil. shocks	All shocks	SPF	Combined
Total patents	0.001	0.897	0.976	0.154	0.384
Private-private	0.001	0.834	0.976	0.164	0.402
Public-private	0.008	0.507	0.996	0.580	0.909
Public-public	0.038	0.787	0.564	0.766	0.614

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Data: Sources and Coverage

Government Patent Register (Gross & Sampat, 2025)

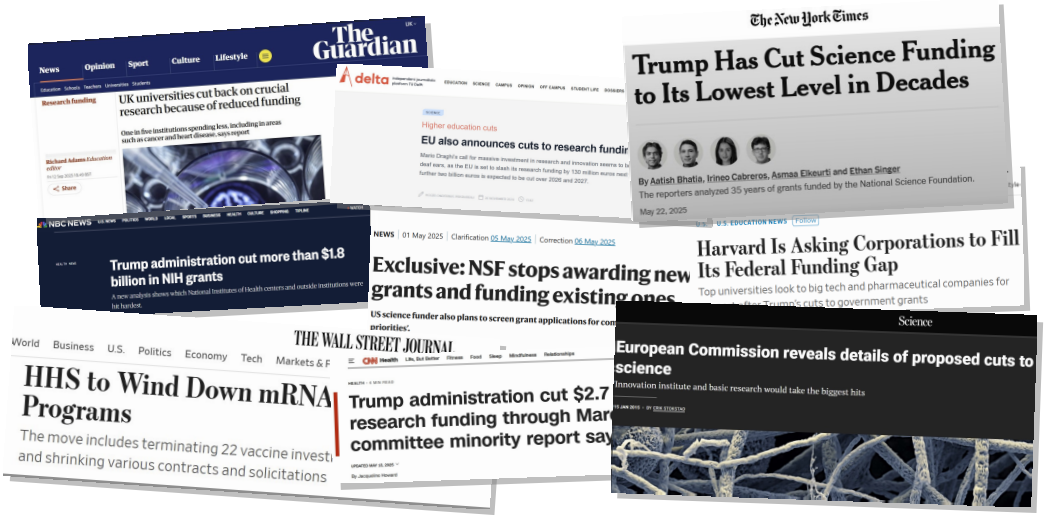
- Universe of U.S. patents since 1890
- Analysis covers 1950–2015 due to data limitations
- Combines multiple databases to reduce measurement errors

Additional data

- Reliance on science: Marx & Fuegi (2020, 2022)
- Startups and VC: Ewens & Marx (2024)
- Patent importance: Kelly et al. (2021)

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Why It Matters for Policy



Public Funding, Private Ownership: Examples of Success

RNA interference (2003, funded by NIH)

- Andrew Fire and Craig Mello (Nobel Prize, 2006)
- Revolutionary gene-silencing technology

PageRank algorithm (1998, funded by NSF)

- Foundation of Google
- Transformed digital economy

CDMA technology (1992, funded by DARPA/NSF)

- Qualcomm
- Backbone of 2G/3G mobile networks

Pluripotent stem cells, CAR-T cell therapy, CRISPR–Cas9 genome editing, etc.

Public Funding: Failures Are Easy to Cherry-Pick

- Aircraft Nuclear Propulsion program (1946–1961)
  - $1 billion effort to develop nuclear-powered airplanes
- Lockheed Martin X-33 (1990s)
  - $1 billion NASA investment in a reusable spaceplane
- DARPA Hybrid Insect Micro-Electro-Mechanical Systems
  - NSF/DARPA-funded effort to create insect cyborgs

Full Two-Source Semi-Endogenous Growth Model

Final output	$Y_t = A_t L_{y,t}$	(M1)
TFP accumulation	$\dot{A}_t / A_t = X_{p,t} / A_t - \delta$	(M2)
Private idea arrival rate	$\mu_{P,t} = R_t^{\eta} A_t^{\phi} X_{g,t}^{\theta}$	(M3)
Private idea stock	$\dot{X}_{p,t} = \mu_{P,t} - \delta X_{p,t}$	(M4)
Private R&D input	$R_t = A_t L_{r,t}$	(M5)
Public idea arrival rate	$\mu_{G,t} = G_t^{\eta} A_t^{\phi}$	(M6)
Public idea stock	$\dot{X}_{g,t} = \mu_{G,t} - \delta X_{g,t}$	(M7)
Public R&D	$G_t = G_0 e^{gt}$	(M8)
Population (constant labor shares)	$L_{r,t} + L_{y,t} = L_0 e^{nt}$	(M9)

- Patents arrive as draws from independent Poisson processes with rates $\mu_{P,t}$, $\mu_{G,t}$

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IRF of TFP and R&D to a new idea

Step 1: log-deviations from BGP. $\hat{z}_t \equiv \log z_t - \log \bar{z}_t^{\text{BGP}}, \;\; z \in \{A, X_p, X_g\}$
Log-linearize the source equations around the BGP $\Rightarrow$ linear ODE system

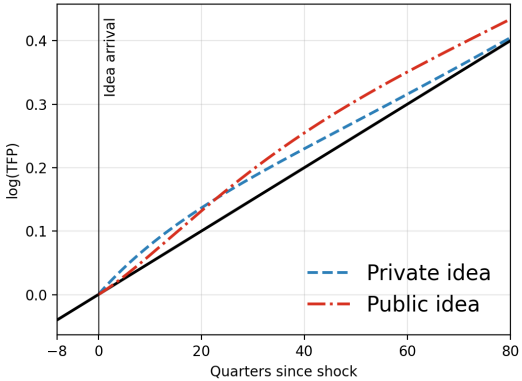
$$\begin{aligned}
\dot{\hat{A}}_t &\propto \hat{X}_{p,t} - \hat{A}_t \\
\dot{\hat{X}}_{p,t} &\propto (\eta + \phi)\hat{A}_t - \hat{X}_{p,t} + \theta\, \hat{X}_{g,t} \\
\dot{\hat{X}}_{g,t} &\propto \phi\, \hat{A}_t - \hat{X}_{g,t}
\end{aligned}$$

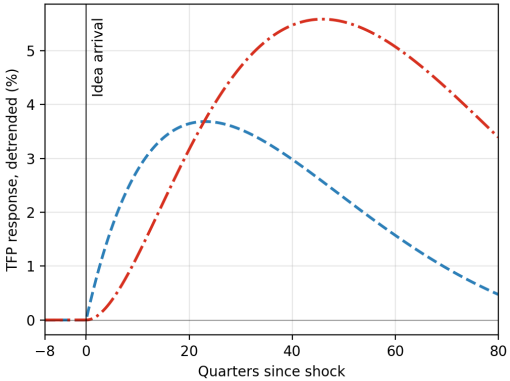
Step 2: the IRF to a source-s patent shock ($s \in \{pub, priv\}$) is a deterministic path

$$\hat{A}^{(s)}_{t+h} \;=\; f_h\big(\, h;\, \eta, \phi, \theta, \delta\big)$$

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IRF of TFP and R&D to new ideas





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Identification: External Instruments by Funding Source

Different instruments by funding source:

- Private-private
  - Orthogonalized patent series (Miranda-Agrippino et al., 2025)
  - Removes past patents, macro shocks and SPF forecasts
  - Single instrument; Newey–West inference; $F = 52.6$
- Publicly funded (pub-priv, pub-pub)
  - Agency-level R&D shocks (Fieldhouse & Mertens, forthcoming)
  - Six agencies $\times$ 0–80 quarter distributed lags
  - Third-degree Almon polynomial: 24 instruments
  - Weak-IV-robust Anderson–Rubin confidence bands

Role of LP-IV: corroborating evidence from external R&D-funding variation

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Robustness

1. Filing spikes ▸ Figure 5a

Data-defined filing spikes: dummy out jointly or one at a time; zero out the episode-specific shock; pool gov't-funded categories (pub-priv ∪ pub-pub)

2. R&D dynamics ▸ Figure 5b

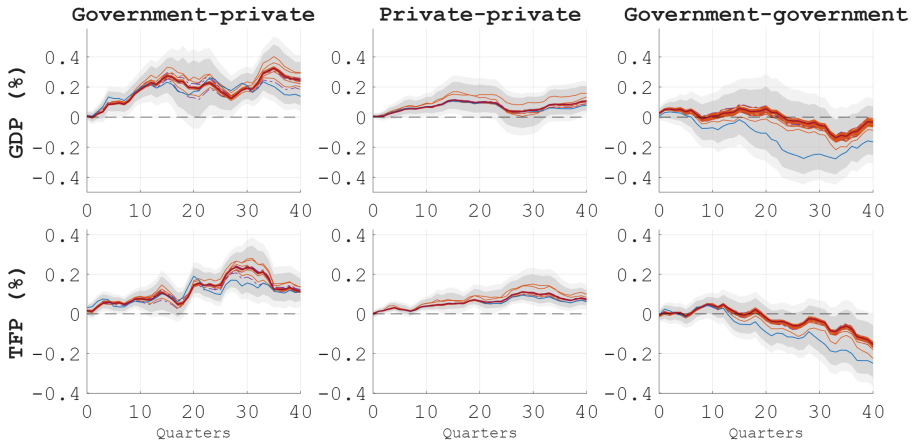
Add aggregate R&D capital stock; extend R&D expenditure to 20 lags; BVAR benchmark with 20 lags of all variables (Antolin-Diaz & Surico 2025)

3. Alternative time-series identification

Max-share VAR — recursive VAR — factor-augmented LP (FRED-QD factors) — VAR via non-Gaussianity (ICA, GMM, PML) and time-varying volatility (TVV)

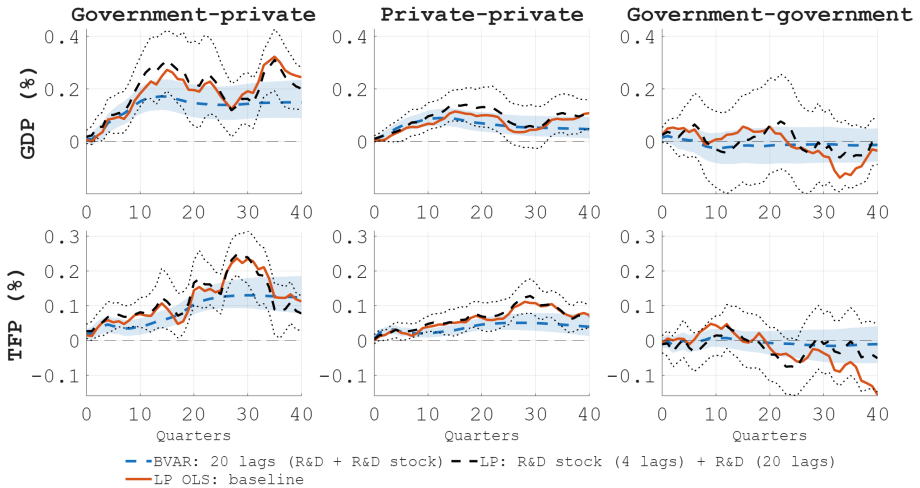
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Robustness: The Role of Outliers



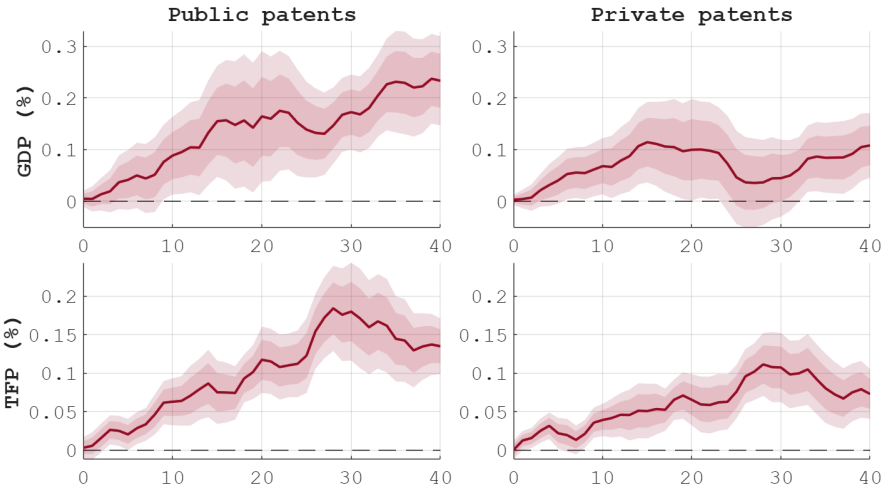
▸ R&D lags ◂ Robustness ◂ Main results

Robustness: The Role of R&D Lag Structure



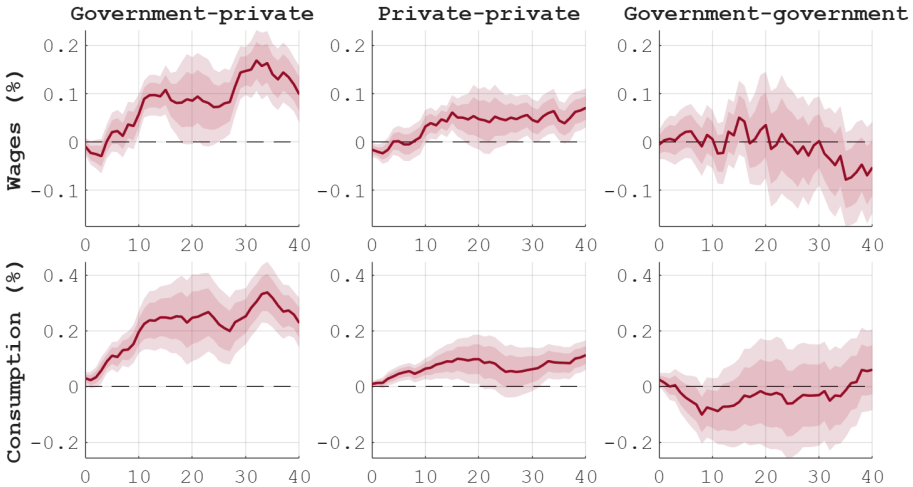
Outliers | Robustness | Main results

Pooling Government-Funded Patents



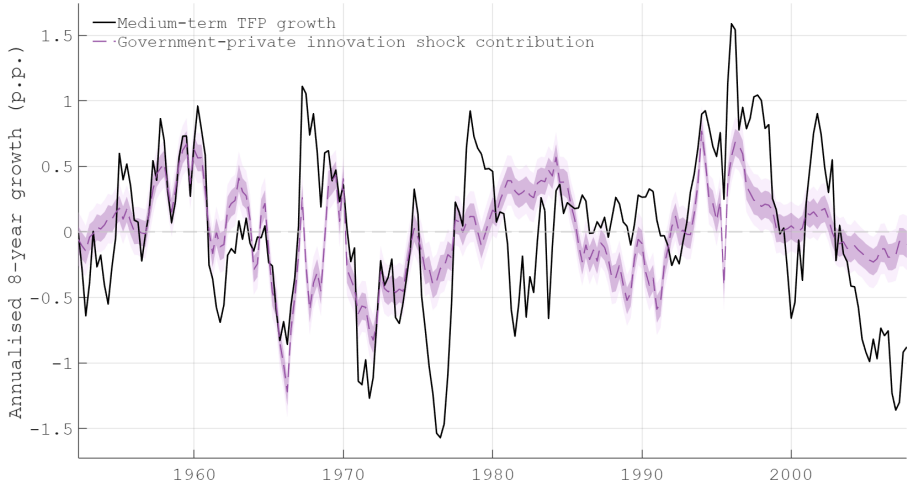
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Effects on Households: Real Wages and Consumption

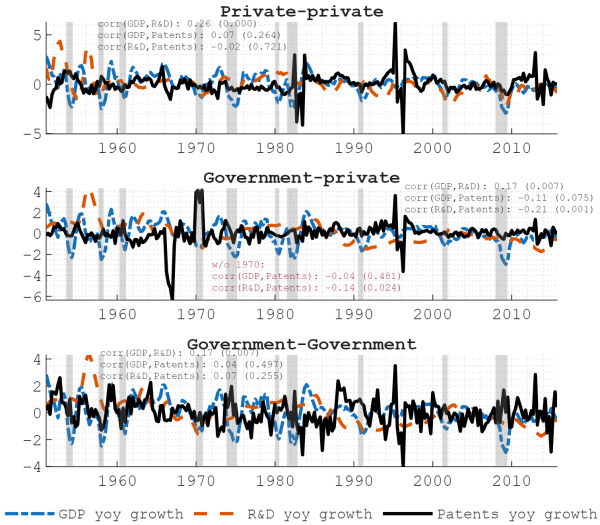


Pre-trends Back

Historical Decomposition of Medium-Term TFP Growth, h=32



Cyclicality of Patents vs. R&D Expenditure



Top Assignees by Patent Category

Public-Private Top 5:

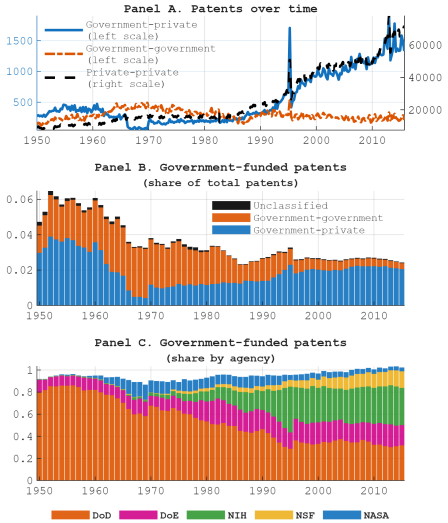
1. University of California (6,537)
2. MIT (3,301)
3. General Electric (2,547)
4. Caltech (2,266)
5. Wisconsin Alumni Research (2,158)

Private-Private Top 5:

1. IBM (113,608)
2. Samsung (87,658)
3. Canon (65,872)
4. Fujitsu (48,771)
5. Sony (41,398)

- Public-private dominated by universities and research institutes
- Private-private dominated by large corporations
- Different innovation models and objectives

Patent Time Series and Distributions by Category



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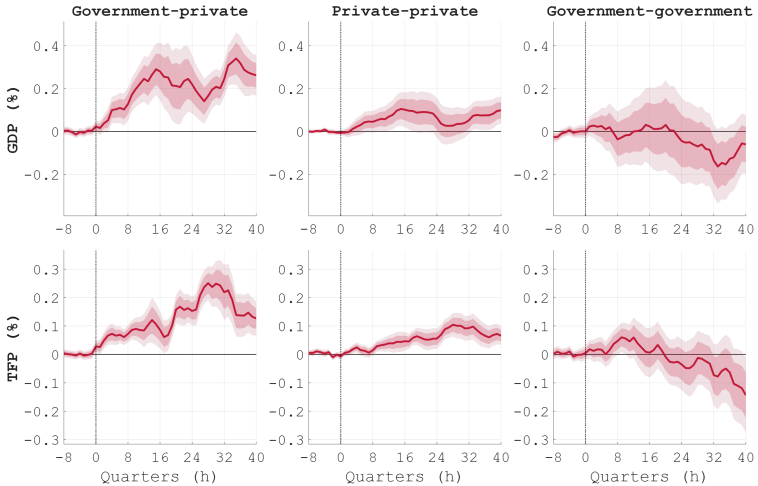
Research Field Definitions

Research field name	CPC codes
Chemicals	B01, C01, C07, C08, C09B, C09D, C09J, C09K
Electronics	H01, H03, H05, H10
Engineering	B03, B04, B05, B06, B07, B21, B22, B23, B24, B25, B26, B29, B30, B31, B32, B33, B41, B65, B66, B67, C03, C04, C21, C22, C23, C25, D21, F04, F15, F16, F26, F27
Healthcare & Biotechnology	A61B, A61C, A61D, A61F, A61G, A61H, A61J, A61K, A61L, A61M, A61N, A61P, C12M, C12N, C12P, C12Q

Agency specializations:

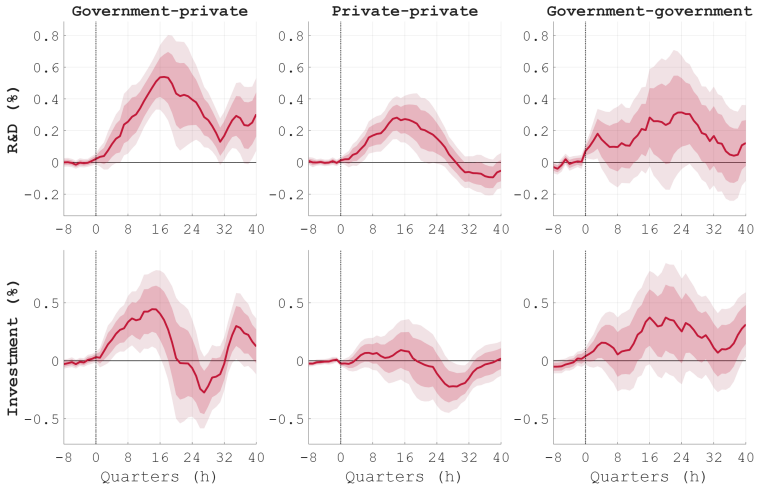
- NIH: 50% healthcare/biotech
- NSF: Balanced across fields
- DoD & NASA: Electronics and engineering
- DoE: Chemicals and energy

Pre-trend Check: GDP and TFP



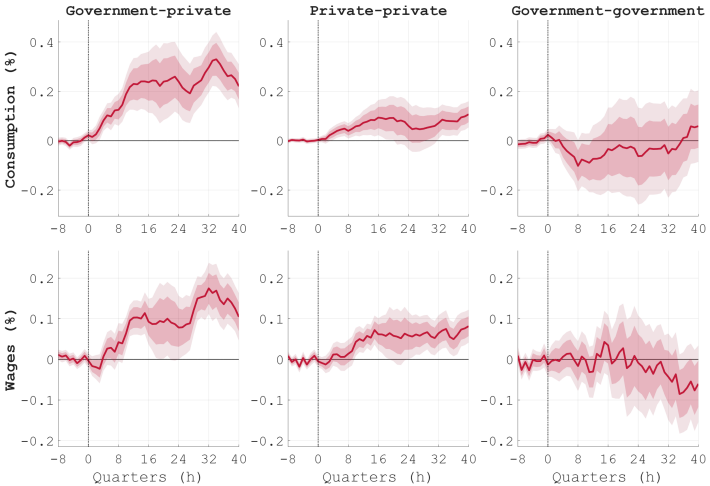
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Pre-trend Check: Business-Sector R&D and Investment



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Pre-trend Check: Real Wages and Consumption



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