# Guns & Growth:
# The Economic Consequences of Defense Buildups

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# Main Conclusions

Short term fiscal multipliers in the 0.6 - 1 range.

- But can be even larger under “ideal” circumstances.

Military buildups should be mostly debt financed

- Withing credible medium-run fiscal frameworks

Long run effects can be large:

- Learning by doing: TFP $\uparrow \frac{1}{3}\%$ per 1% increase in spending.
- Public R&D: similar gains

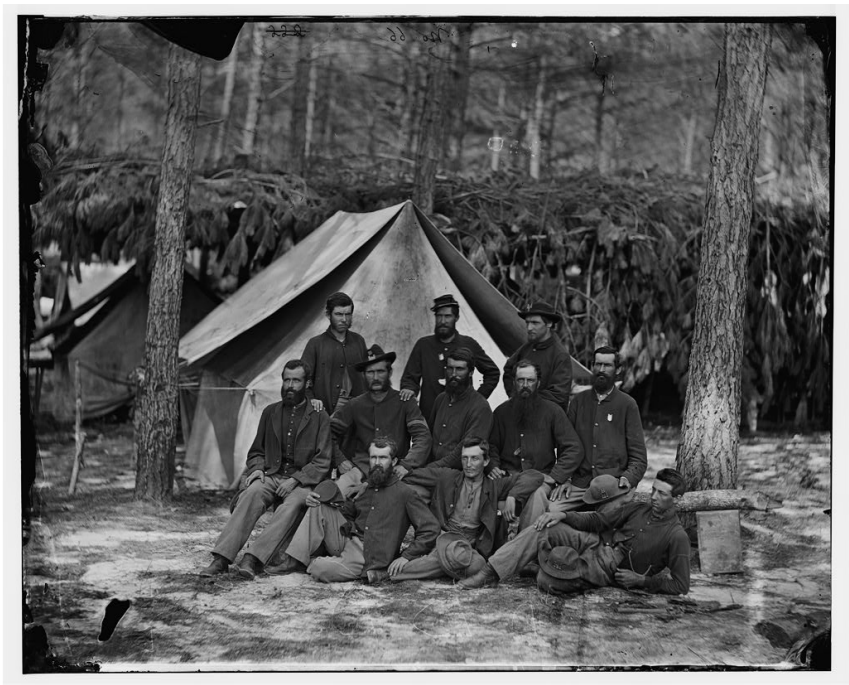
Devil in the details of procurement

- EU: Less imports; better European coordination

% of GDP targets are counter-productive

# Historical Perspectives

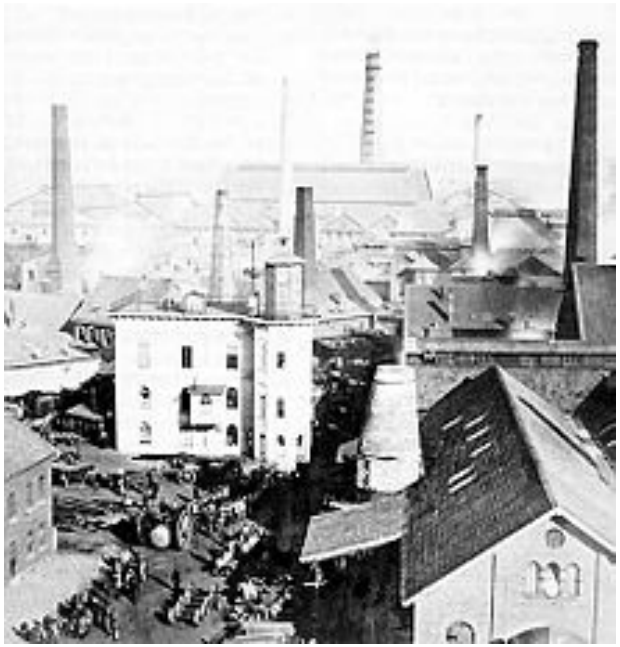
# US Civil War



- Infrastructure: telegraph, railroads.
- Industry: ships, weapons, mass production, scientific management
- Currency reform, income tax.

Photo: NARA College Park. Readings: Beard & Beard (1927), Howard (1978), Wilson (2006)

# Bismark and Kaiserreich



- Industrial policy: railroad expansion, state support for heavy industry, tariffs on industrial imports.
- State support helps create Krupp (Steel) BASF (chemicals) and Siemens (electrical engineering)
- Banking: Reformed to aid industry.

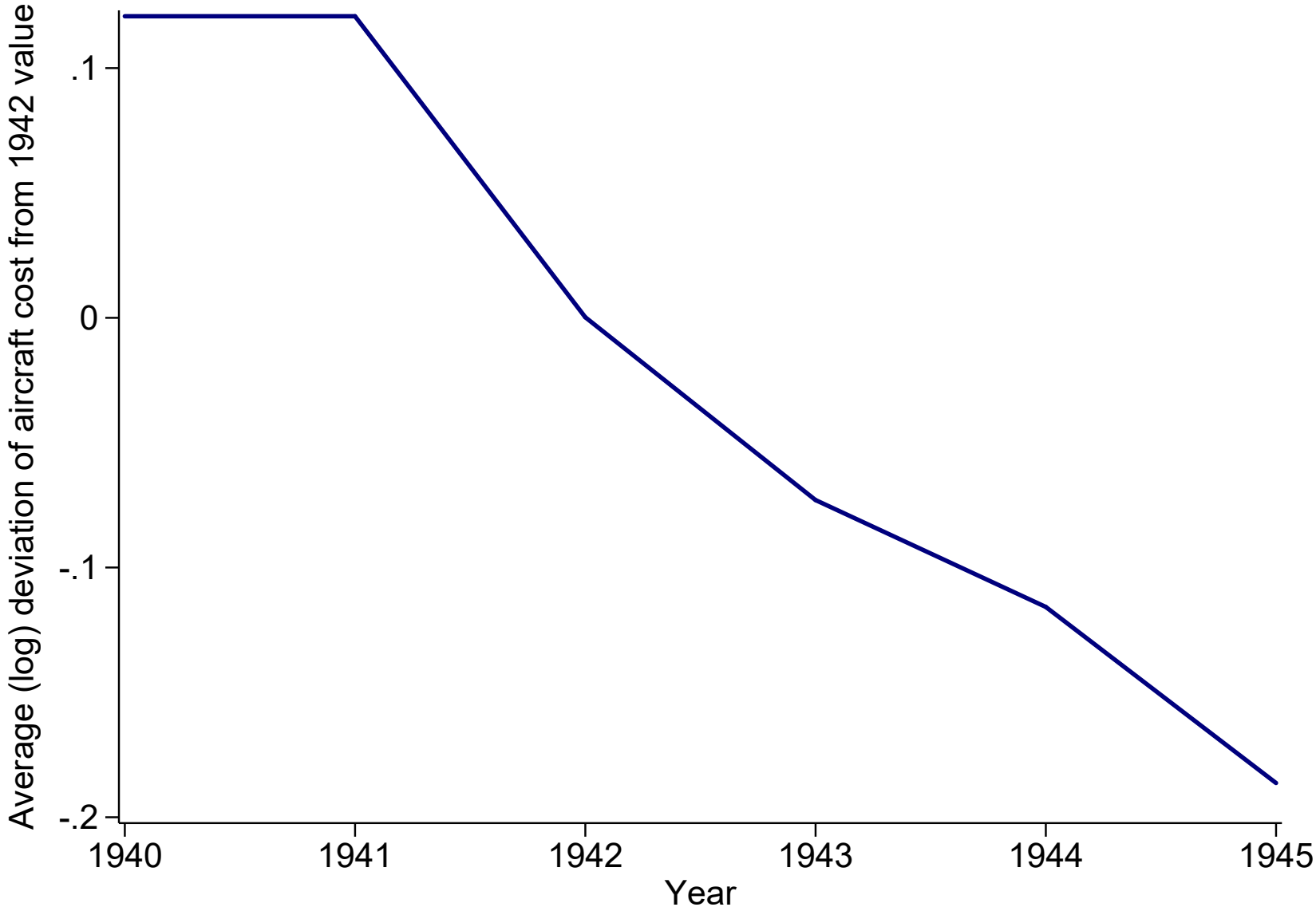
Photo: Krupp, 1964. http://www.preussen-chronik.de. Readings: Kennedy (1987), Berghahn (2005)

# World War II

- Massive productivity gains.
- Atomic energy, synthetic rubber, radar

Photo: https://www.thehenryford.org/. Readings: Herman (2012), Klein (2013), Field (2002), references in Ilzetzki (2024)

# Cost Reductions in Aircraft Production




Decline in price of average model. Source: Ilzetzki (2024)

# Massive Quality Improvements

**B-17 Bomber**

Speed: 462 km/h
Range: 3,219 km
Bomb load: 3600 kg

**B-29 Bomber**

Speed: 575 km/h
Range: 5,230 km
Bomb load: 9000 kg

Source: US Air Force

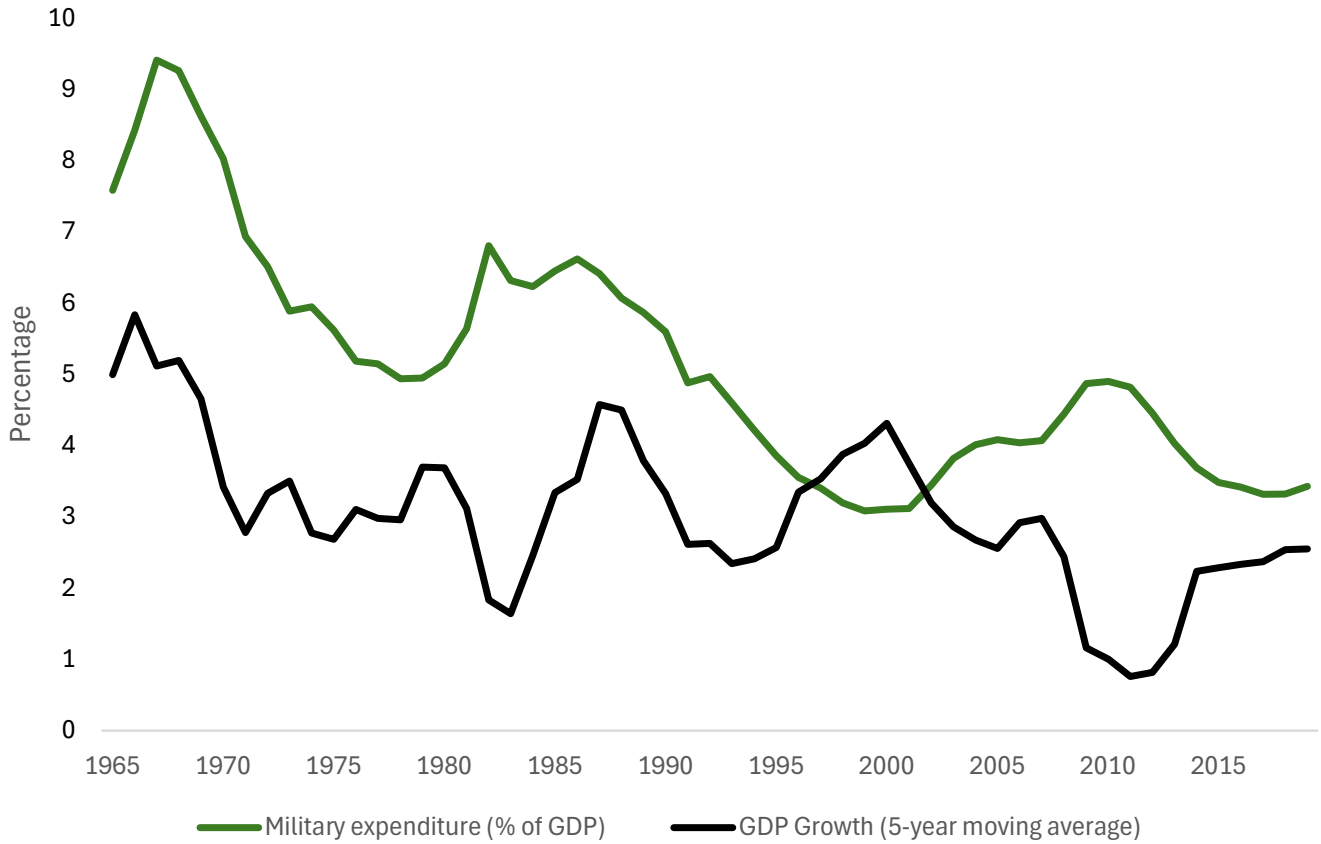
# Cold War Era Evidence

Focus on “guns vs. butter” (Payne & Sahu 1993 for a review)

Benoit (1973, 1978): positive correlation defense spending & growth; Subsequent literature: estimates all over the place (Ram, 1995; Alptekin & Levine, 2012; Yesilyurt & Yesilyurt, 2019; Dunne & Smith, 2020)

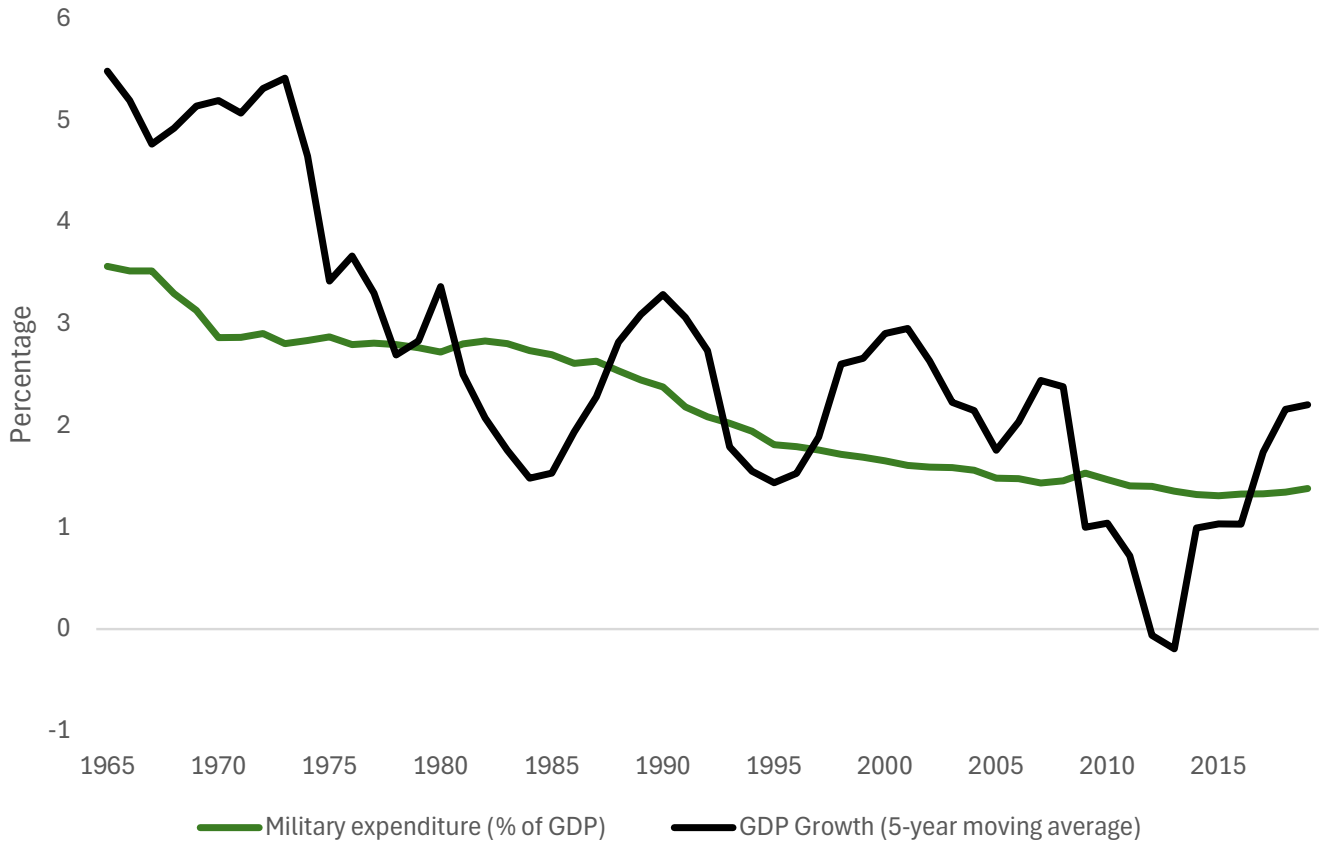
Barro & Sala-i Martin (2003): positive but not stat. sig.

# The Elusive Peace Dividend: US




US Military Expenditure and GDP Growth

# The Elusive Peace Dividend: EU



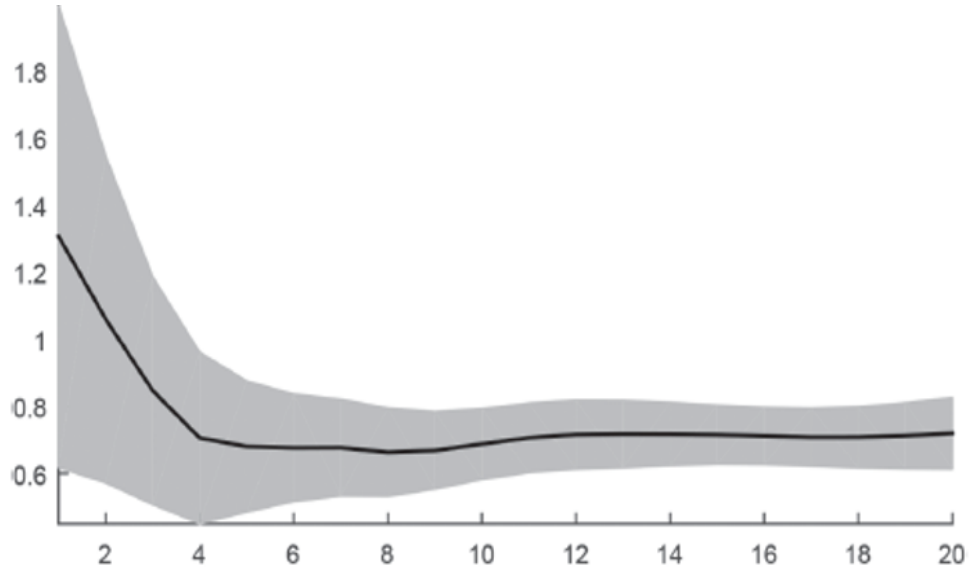

EU Military Expenditure and GDP Growth

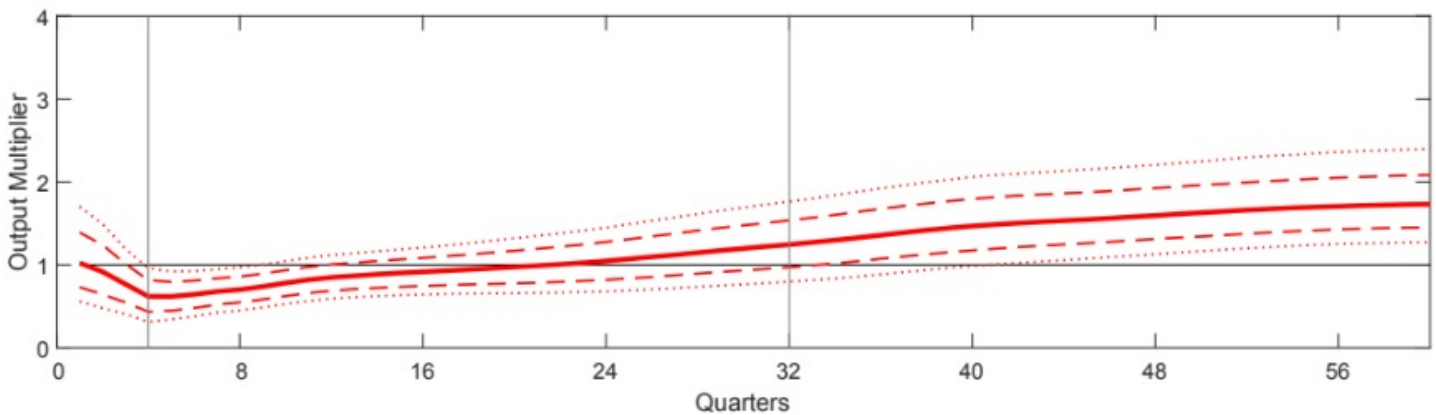
# The Elusive Peace Dividend: US & EU


US and EU Military Expenditure and GDP Growth

# Fiscal Multiplier

# Fiscal Multipliers: Time Series




Source: Ramey & Zubairy (2018), Antolin-Diaz & Surico (2025); see also Perotti (2014).

# Factors determining size of fiscal multiplier

| Factor | Source |
|---|---|
| Degree of slack | Ramey & Zubairy (2018) vs. Auerbach & Gorodnichenko (2012, 2013), Nakamura & Steinsson (2014), Born *et al.* (2024) |
| Monetary stance | Christiano *et al.* (2011), Ilzetzki *et al.* (2013), Nakamura & Steinsson (2014) |
| Trade openness | Ilzetzki *et al.* (2013) |
| Debt financing? | Debt: Baxter & King (1993), Nakamura & Steinsson (2014), Chodorow-Reich (2019), Angeletos *et al.* (2024)<br><br>Tax: Angeletos *et al.* (2023), Bianchi *et al.* (2023b), Bianchi *et al.* (2023a) |

## EU Case: ECB response is key

- Inflation targeting central bank
- + Phillips curve logic
- + not at the ZLB =
- Zero multiplier

# Debate I: Time Series vs. Cross-Sectional

Time series multipliers typically $\leq 1$: guns vs. butter.

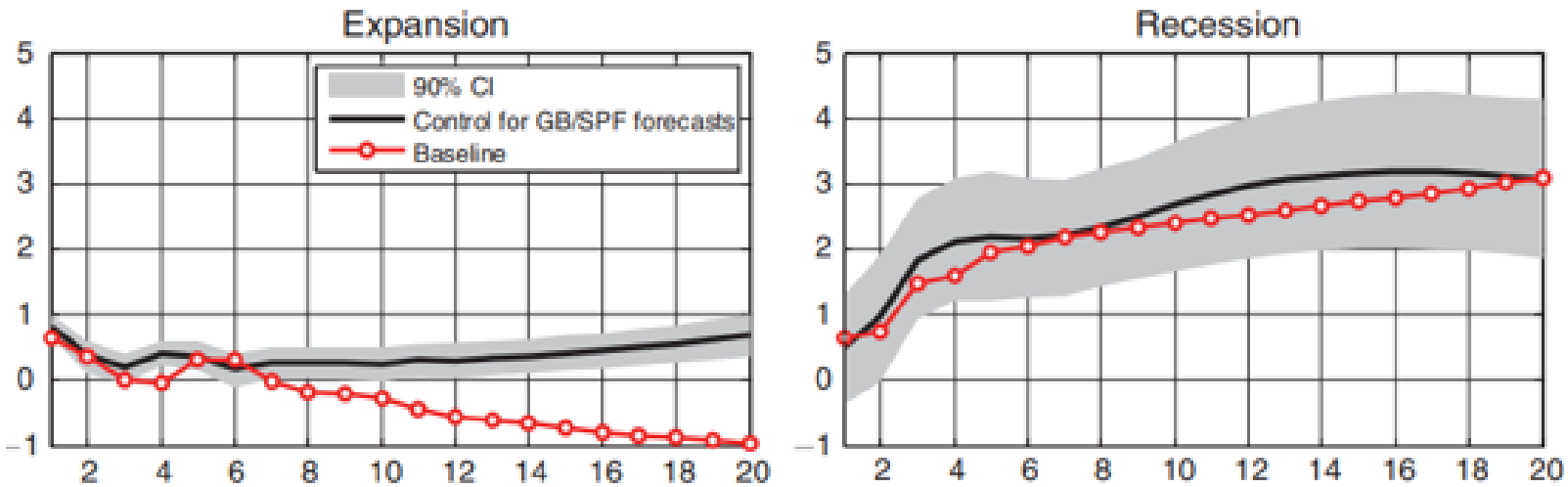
Cross sectional multipliers typically $\geq 1$: guns **and** butter.

Chodorow-Reich (2019); Wilson (2012); Nakamura & Steinsson (2014); Auerbach *et al.* (2020); **?**

Ramey (2019): Time series gives us general equilibrium response.

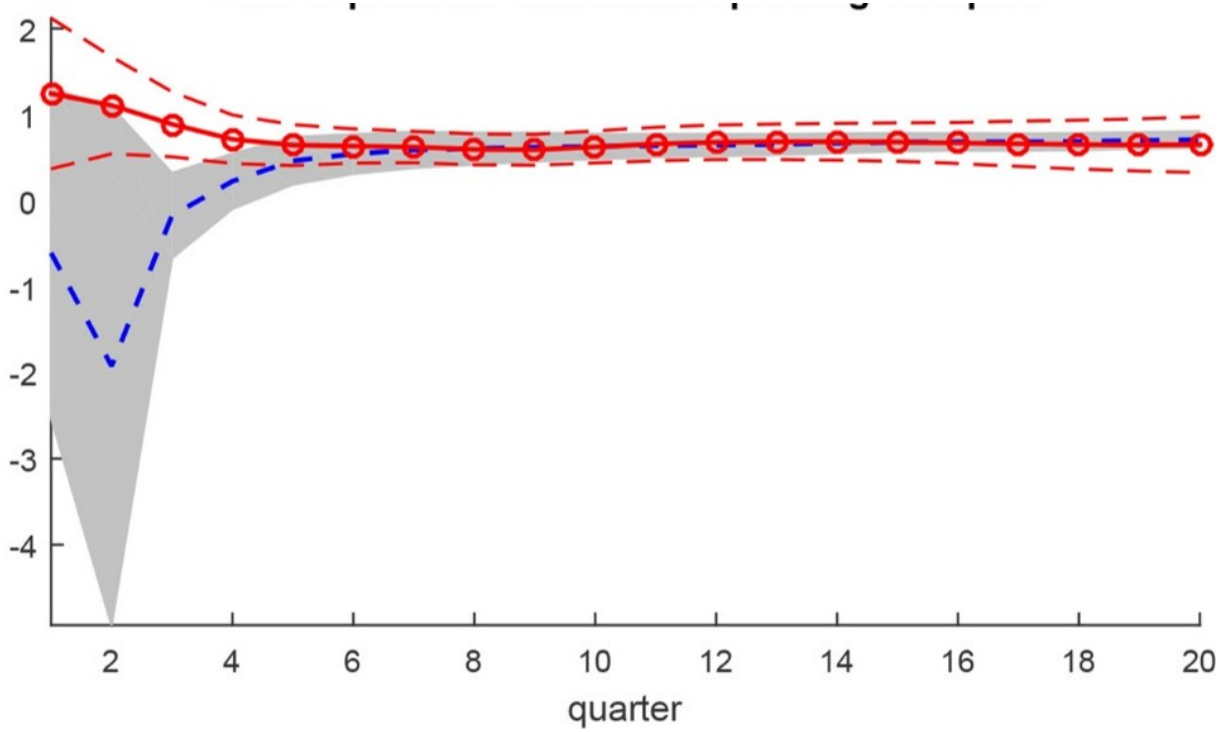
Chodorow-Reich (2019): Cross sectional gives us "pure"/"controlled" response.

# Debate II: Are multipliers higher with slack?




Auerbach & Gorodnichenko (2012, 2013): Yes (VAR)

# Debate II: Are multipliers higher with slack?




Owyang *et al.* (2013); Ramey & Zubairy (2018): No (using military spending); Blue: High unemployment; Red: low

# Defense Finance

# Military spending and optimal taxation

Optimal taxation models call for:

- Borrowing to finance temporary wars
- Increase taxes for permanent buildups
- Typical duration of a buildup: 5 years (Marzian & Trebesch, 2025)
- And defense buildups tend to be front-loaded
  - Durable procurement at first and maintenance costs later

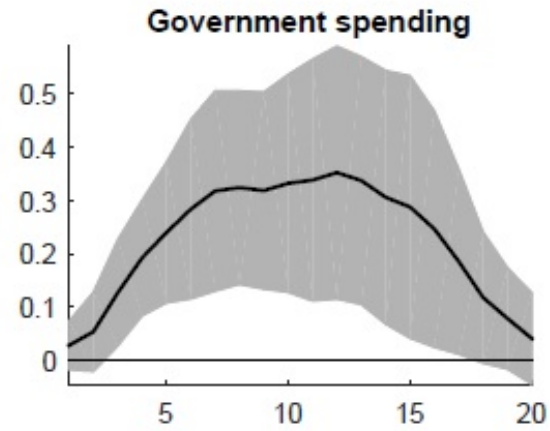
Optimal policy (Vietnam war sized shock):

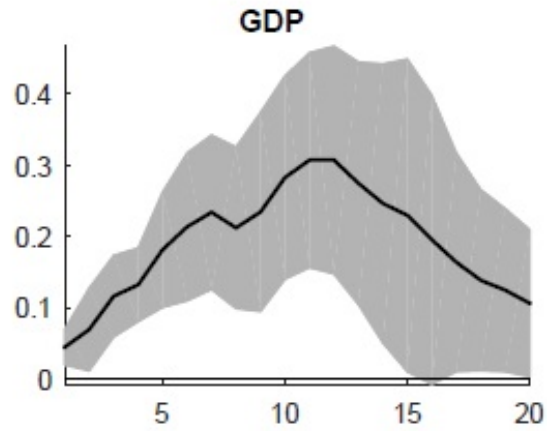
- Increase taxes by 0.2% of GDP if $r - g = 3\%$

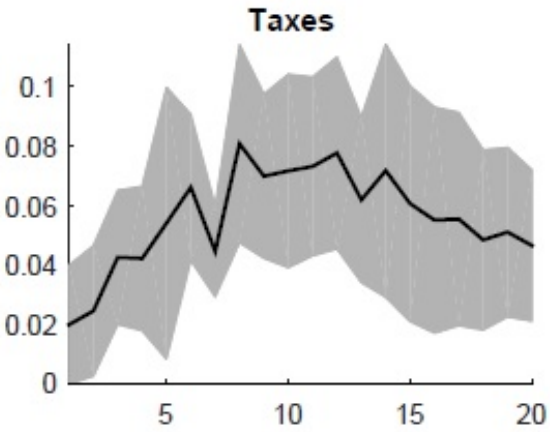
Ramey & Zubairy (2018): Past US buildups financed by

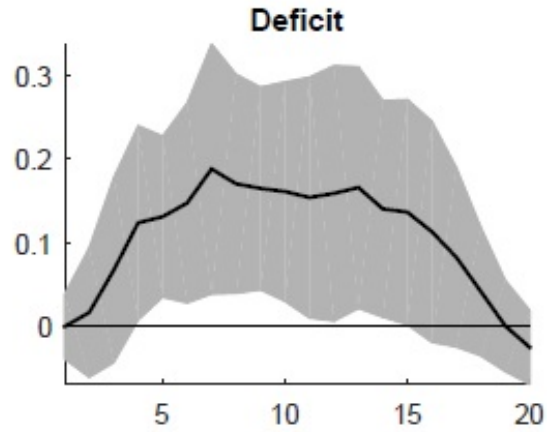
- 50% borrowing
- 30% endogenous revenue growth
- 20% tax increases

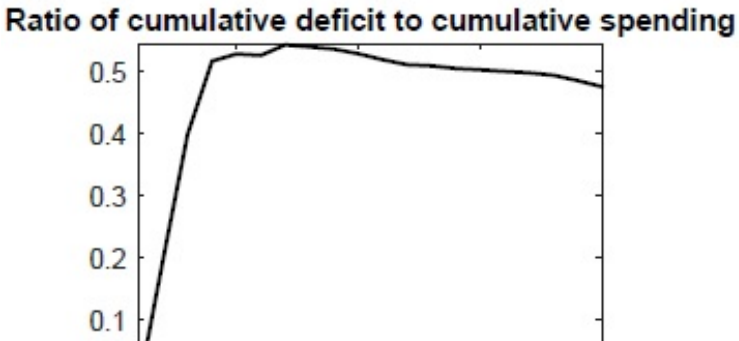
# Financing in the Average US Military Buildup



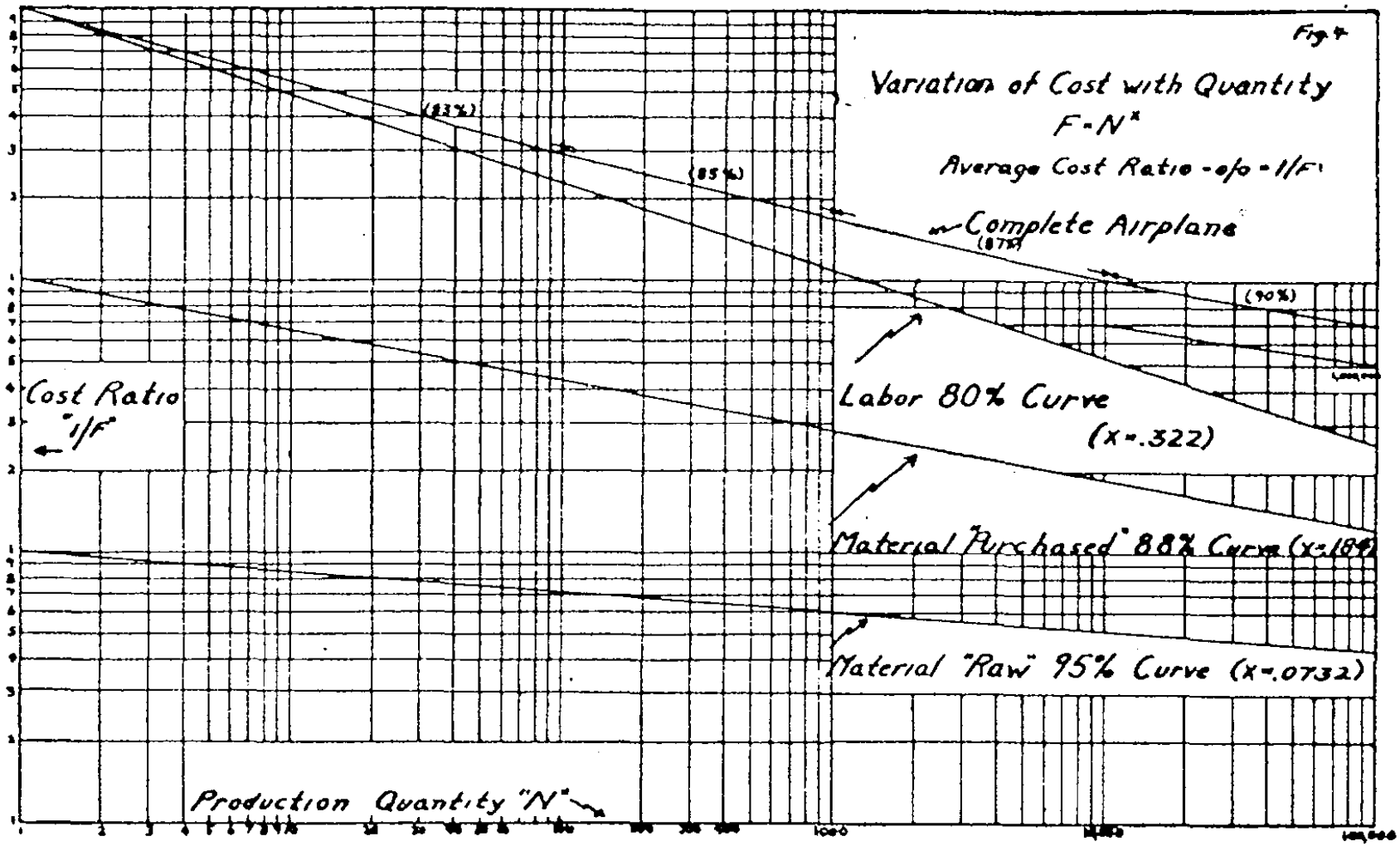



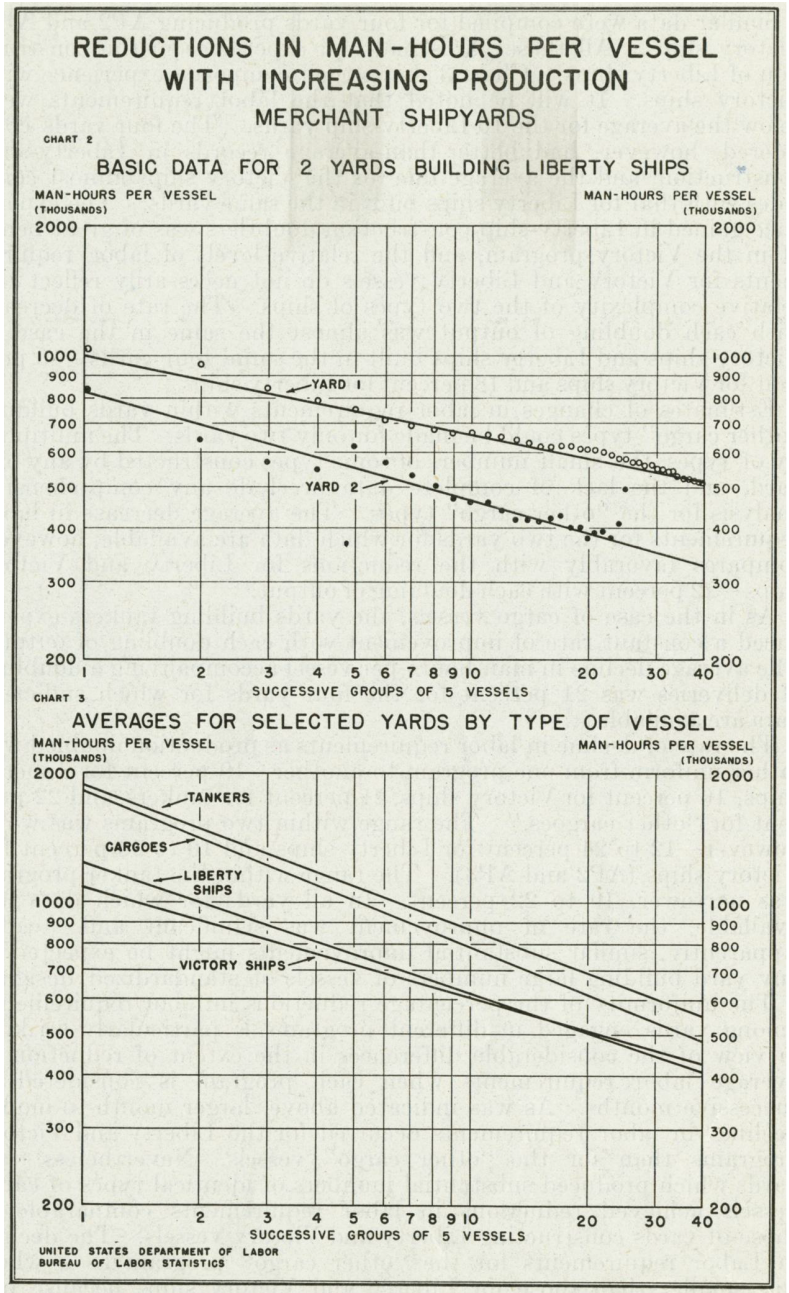
# Defense Buildups & Productivity

# Learning by Doing

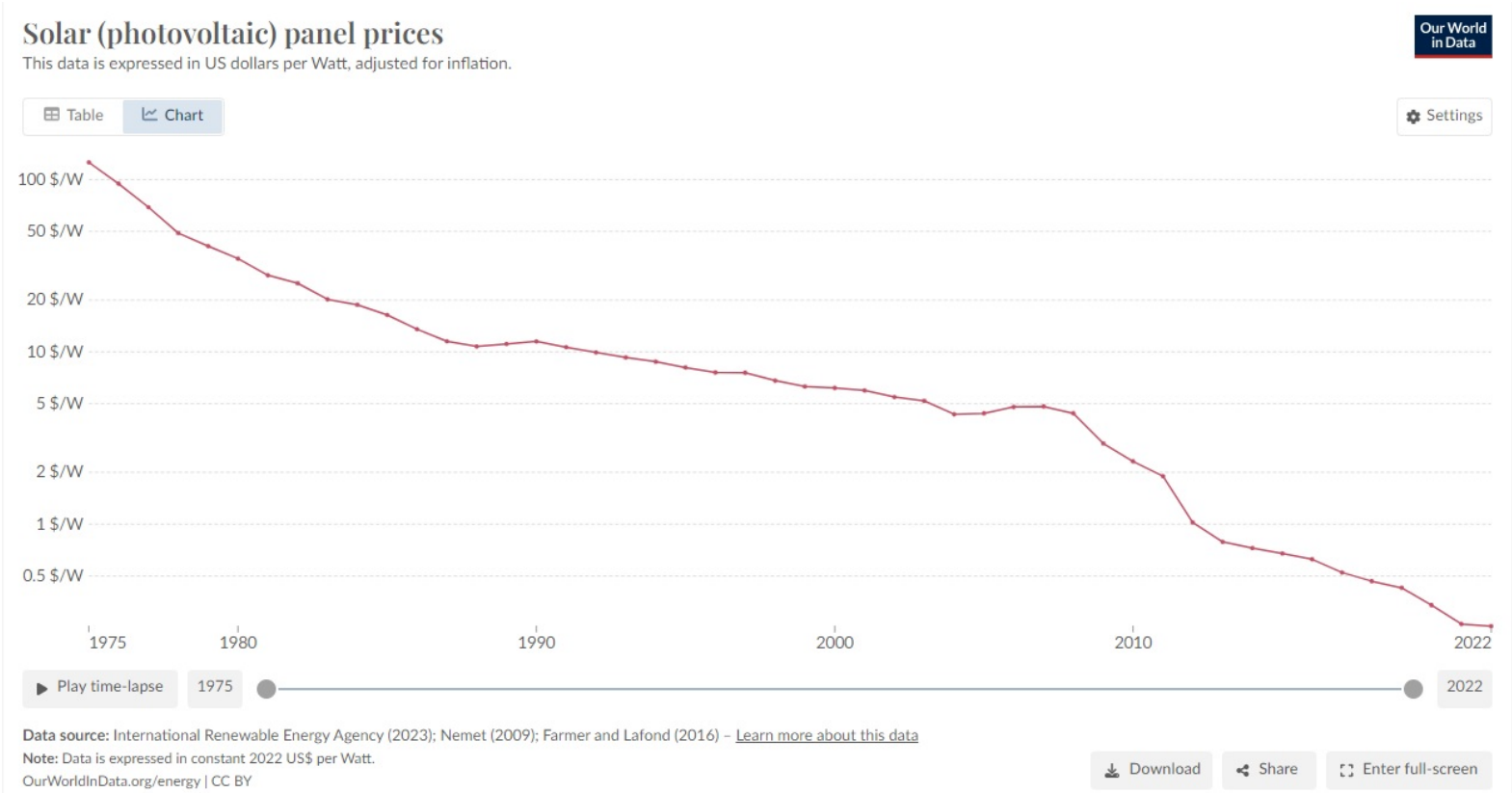
# Wright (1936): Inter-war aircraft



# Searle (1945): WWII ships



# Declining prices of solar panels



# Induced innovation

**Directed technological change**: Direction of technological change affected by relative factor prices. Rothbarth (1946), Habakkuk (1962), Wright (1978), Jones (2003), Allen (2009), Acemoglu & Restrepo (2018, 2019)

**Induced Innovation**: Innovation spurred because of key input price Hickman (1957), Fellner (1961, 1971), Romer (1987), Popp (2002), Newell *et al.* (1999)

**Medium term cycles and scarring effects**: Benigno & Fornaro (2018), Anzoategui *et al.* (2019)

# Ilzetzki (2024), Learning by Necessity: A synthesis

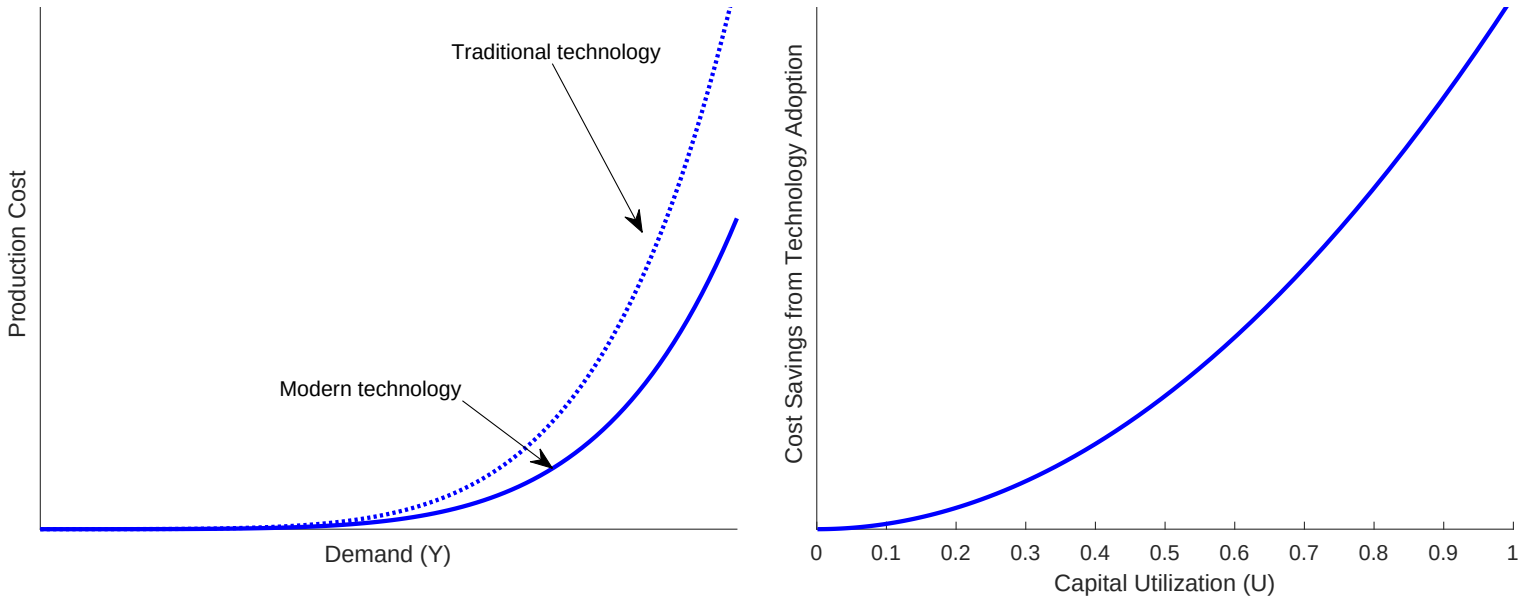
I present a theory of induced innovation where costly **high utilization** leads to **technology adoption**

**Theory**: With convex costs to utilization, high demand will induce innovation and more so when utilization is high

**Empirical**: Evidence from WWII aircraft production that demand induces TFP growth, and more so when utilization is high.

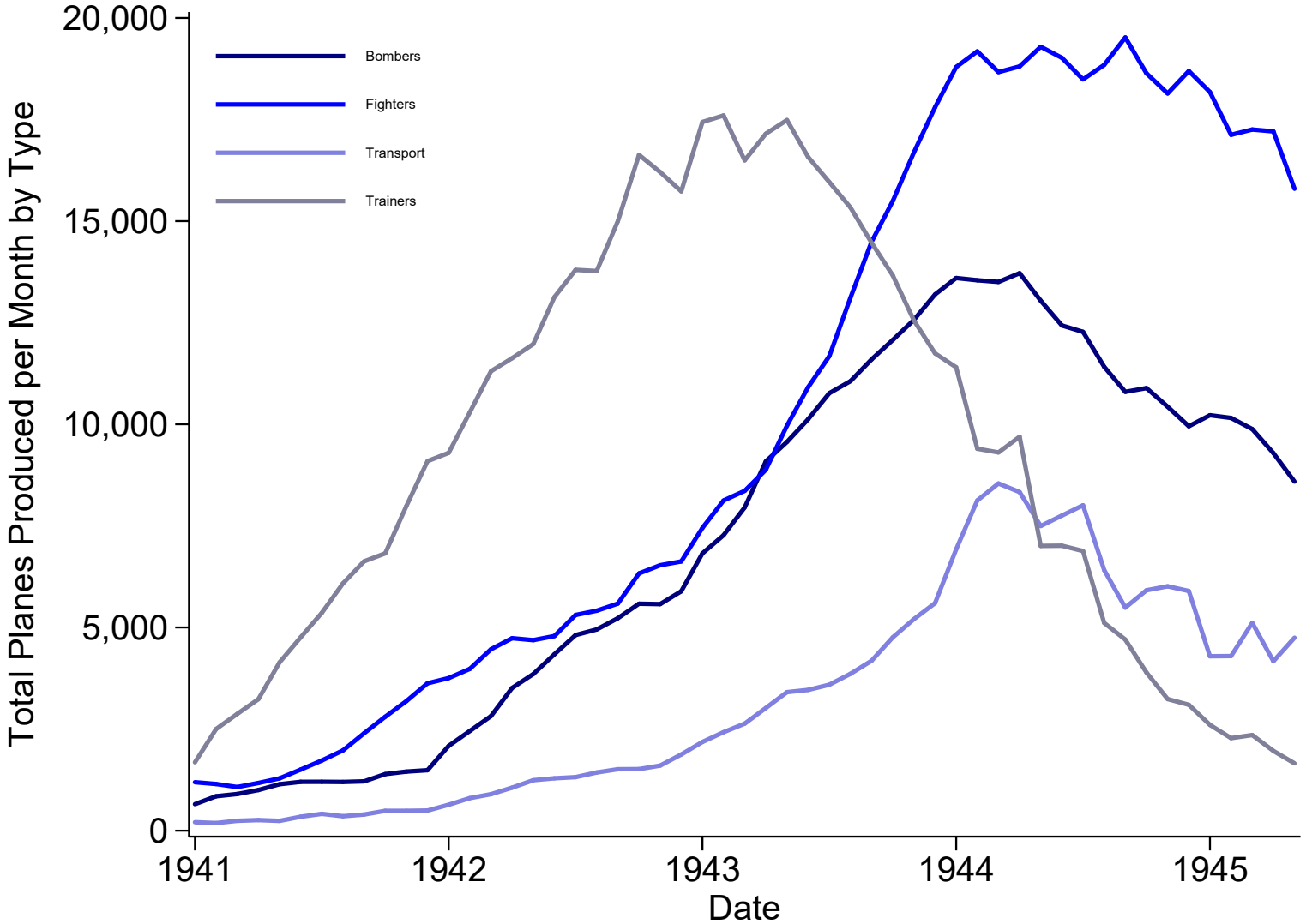
- Causal evidence
- Distinct from economies of scale.
- Suggests active learning.
- Still can't separate "demand" from "learning".

# Learning by Necessity Theory in a Nutshell



# Production by Broad Aircraft Type

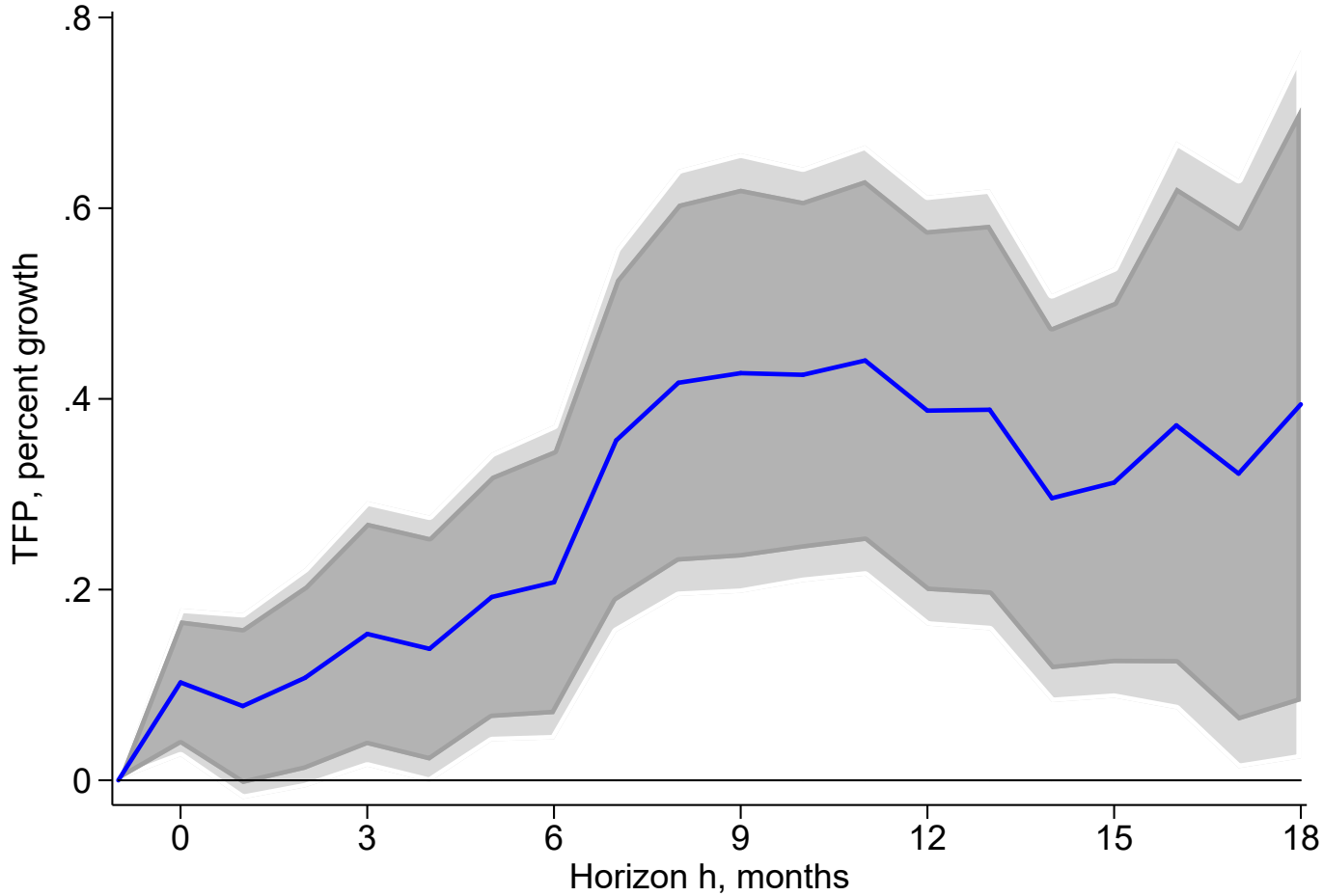
## Monthly Number of Planes per Production Line




Historical Narrative

# TFP Response

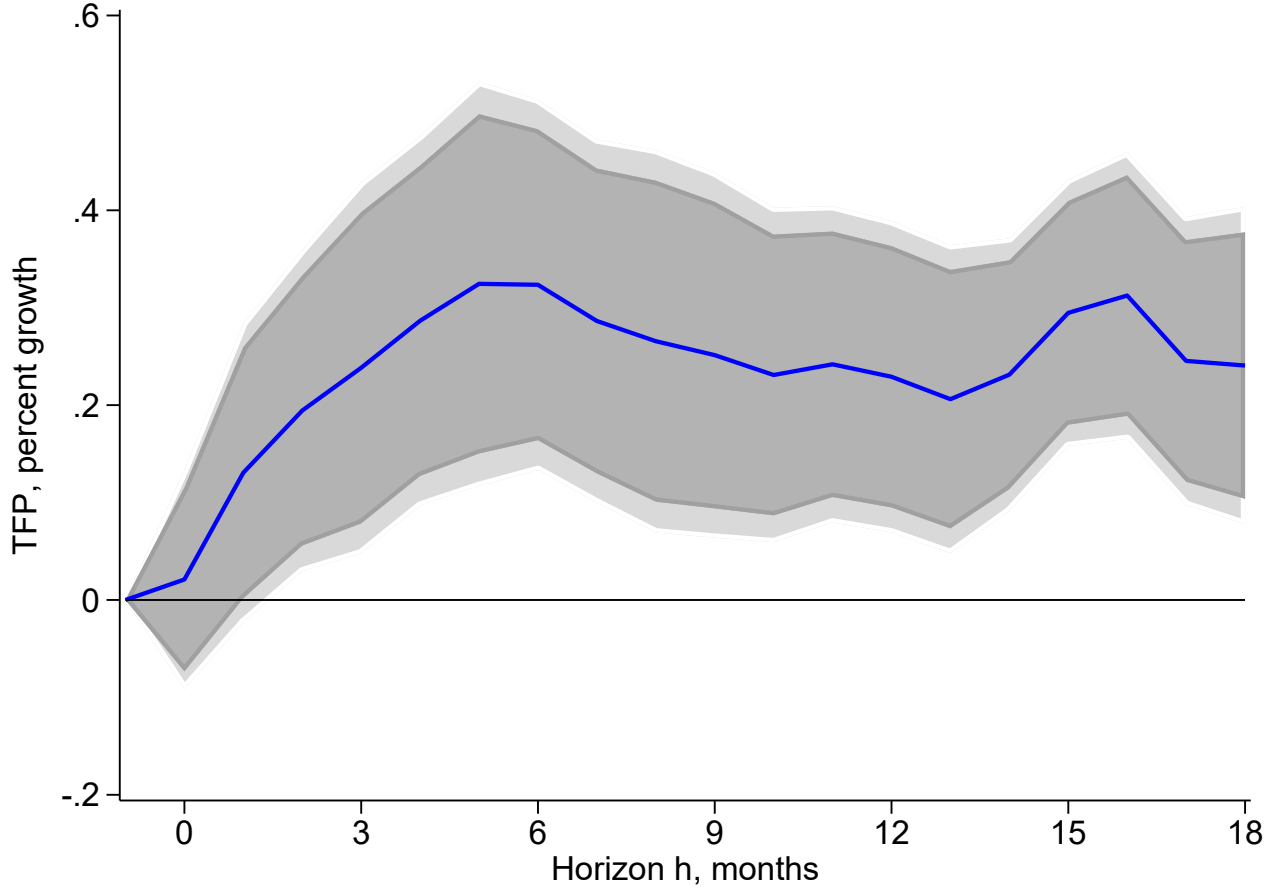
## TFP Controlled for Capital Utilization




Local projections response of log output per hour worked to 1% shock to aircraft demand, instrumented with the ("leave one out") production of broad aircraft of the same broad type. Includes month and plant $\times$ model (production line) fixed effects, 6 monthly lags of output. 90% and 95% Newey-West standard errors shaded. First stage F-stat at 12-month horizon = 30.

# TFP Response to Demand

## High vs. Low Capital Utilization Plants




Local projections response of TFP to 1% shock to aircraft demand interacted with a dummy =1 if plant had above-median initial capacity utilization. These are instrumented with the ("leave one out") production of broad aircraft of the same broad type and its interaction with the capital utilization dummy. Includes month and plant $\times$ model (production line) fixed effects, 6 monthly lags of output. 90% and 95% standard errors shaded. F-stat at 12-month horizon = 15.

# Mechanisms

The historical narrative points to several channels through which TFP may have increased.

1. Improved production methods: Most notably move from job-shop to production line methods
2. Greater reliance on production outsourcing
3. Labor relations reduced absenteeism and turnover

# Public R&D

# Public R&D Support: An intellectual history

Arrow (1962) gave an early, comprehensive, analysis of the multitude market failures causing insufficient R&D.

Bush (1945) drew lessons from WWII R&D for the design of peacetime public infrastructure to support R&D

Endogenous growth literature previously reviewed

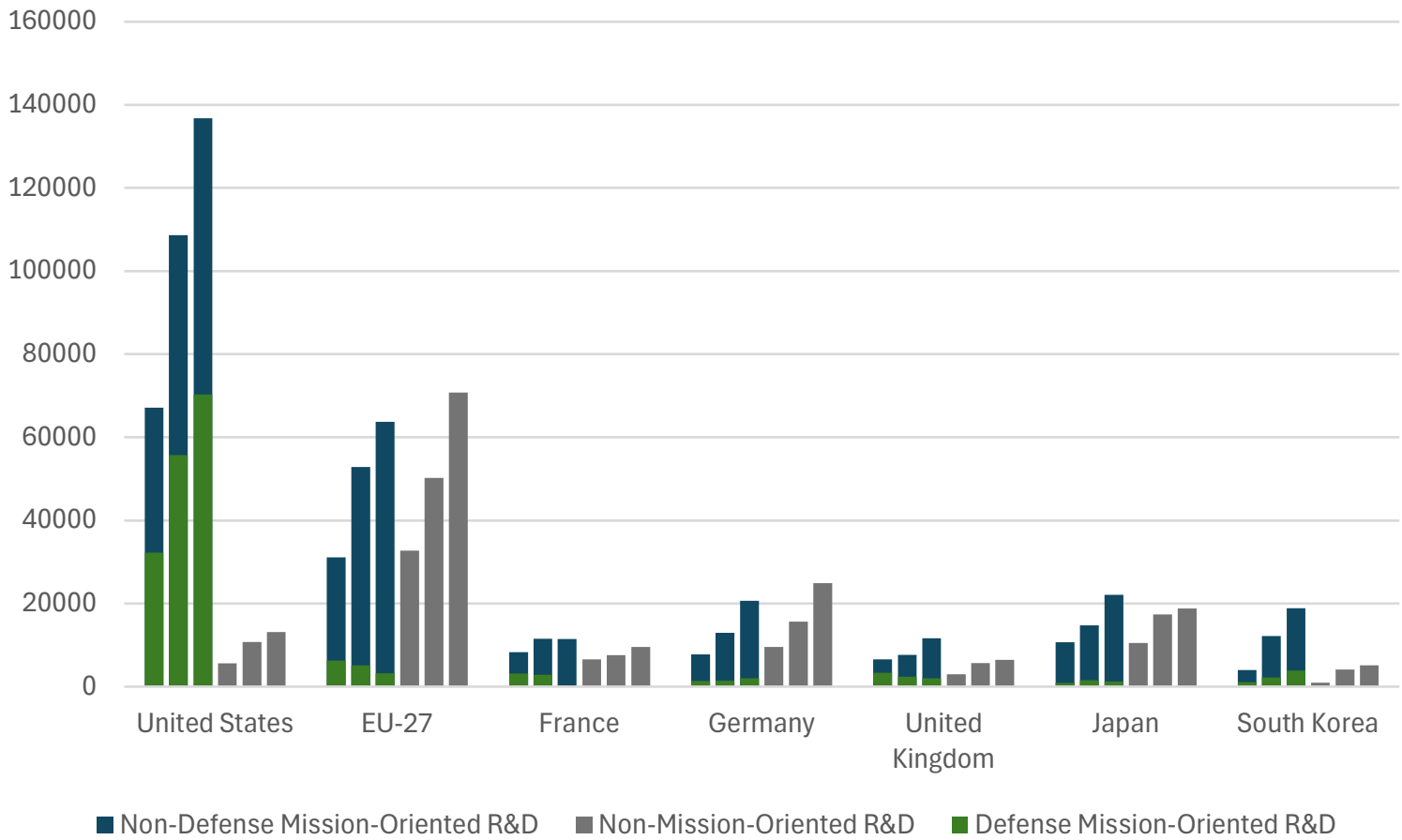
Modern view that R&D support should be **undirected** and supported through **tax policy.**

# Why public support for R&D?

Arrow (1962), Mowery (2010) give a list of market failures:

- Knowledge is non-rival and can be disseminated at near zero-cost (public good)
  - Property rights could be created, but many forms of knowledge are non-patent-able.
- Production of knowledge is risky and is under-provided absent complete insurance markets.
- human capital is fungible
- fixed costs to knowledge production

# The prominence of mission-oriented public R&D



# Is Defense Special?

The Arms-race nature of military R&D may make it uniquely suited to invest in frontier & general purpose technologies.

Being 20$^{th}$ country in green technology makes contribution to climate goals.

Being 20$^{th}$ country in military technology isn't even in the race.

# Procuring Innovation

European defense procurement more concentrated than US, which reaches far smaller firms.

- Spillovers to civilian use technologies more likely in small firms (Mowery, 2010).

US practice of “dual sourcing” increases knowledge sharing.

Howell *et al.* (2021) open competitions for procurement are more successful and reach firms that are smaller, younger, and more technology-oriented.

# Recent Evidence

**Large multipliers on public R&D spending**: Antolin-Diaz & Surico (2025), Fieldhouse & Mertens (2023)

**The economic spillovers and benefits to R&D**:

Moretti *et al.* (2019): government funded military R&D crowds in in private R&D. Myers & Lanahan (2022): DoE funded patents lead to 3$\times$ private-sector patents. Gross & Sampat (2023): long-lasting effects. Kantor & Whalley (2023): NASA spurred employment in high-tech sectors. Dyevre (2023).

**Spin-offs or spin ons?**: Feiglin (2020) warns that the cold war was unique in the extent of "spinoffs" and the 21$^{st}$ century is more suitable for "spin-ons"

**ROI on Public R&D**: Jones & Summers (2022) 67%; Fieldhouse & Mertens (2023) 300% (!)

# Gross & Sampat (2023)

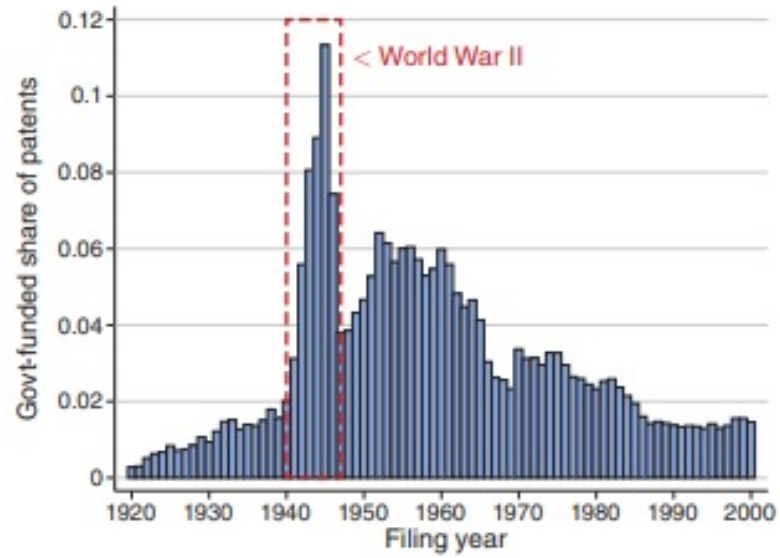
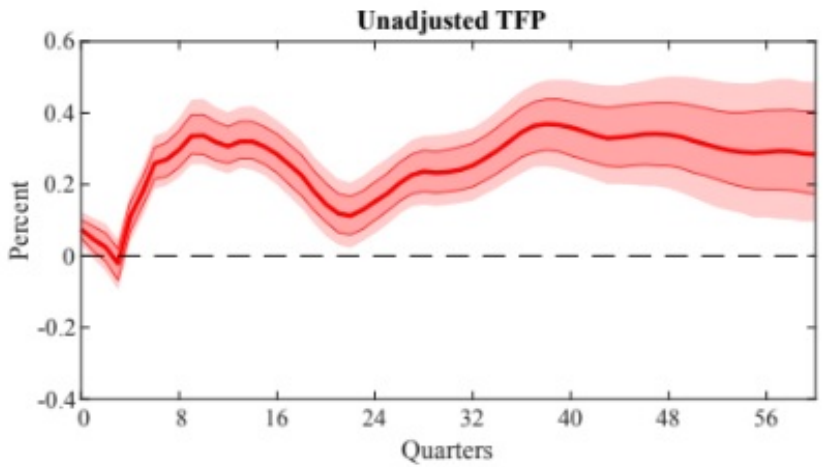
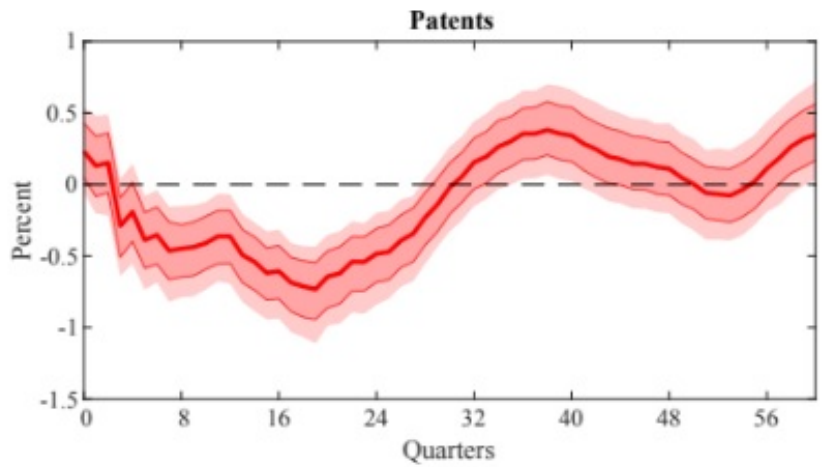



FIGURE 1. GOVERNMENT-FUNDED SHARE OF US PATENTS, 1920 TO 2000

FIGURE 2. GEOGRAPHY OF OSRD-FUNDED INVENTION IN WORLD WAR II

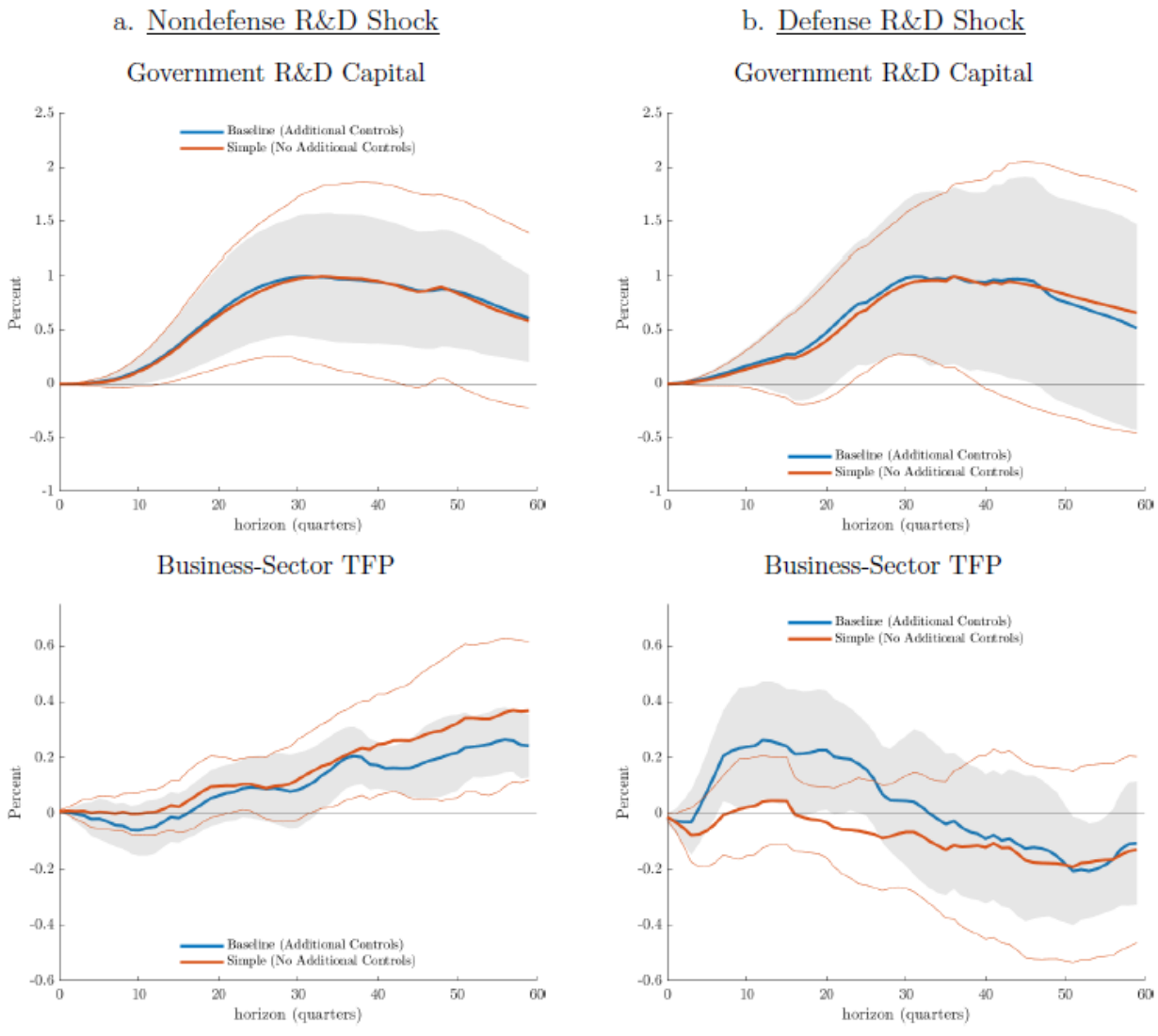
# Antolin-Diaz & Surico (2025)



# Fieldhouse & Mertens (2023)

Figure 6: Government R&D Capital And TFP Following an Increase in R&D Appropriations



# Industrial Policy

# Industrial Policy: An intellectual history

Long history of the use of industrial policy for mercantilist and military purposes

**Post-war "big push" literature**: Rosenstein-Rodan (1943), Hirschman (1958)

Lost credibility in the late 20$^{th}$ century

**Revived literature**: Liu (2019), Lane (2022). Juhász *et al.* (2024) for a review.

# Industrial Policy: Criticism

Potential political capture

- Particularly acute in the case of military spending?
- Military-industrial complex
- More research needed

Government picking "winners"

- Juhász *et al.* (2024): Bigger problem is "letting go of losers".
- So depends on procurement process
- Liu (2019) gives new methodology to allocate spending based on **distortion centrality**.

# Procurement considerations

# How to Spend It?

Dual-use firms maximize private sector spin offs

- and “spin ons” (Feiglin, 2020)
- Antithetical to German post-War model

Dual-sourcing

- Across borders?

Support for SMEs

- US procures from far smaller firms than EU on average

“Open” procurement competitions (Howell *et al.*, 2021)

**EU procurement far too fragmented**

# Learning by Importing

70% of EU defense procurement imported

Far too high for advanced economy

But imports can be used strategically. Case in point: **Poland**

- Military spending ↑ to 4.8% of GDP in 2025
- Most material imported from US and S. Korea, but
- Technology import from servicing the equipment
- Poland plans to produce 820/1000 S. Korean Black Panther tanks in the Military Automotive Works in Poznań.
- Contract for joint Korean-Polish joint venture to design next generation of tanks

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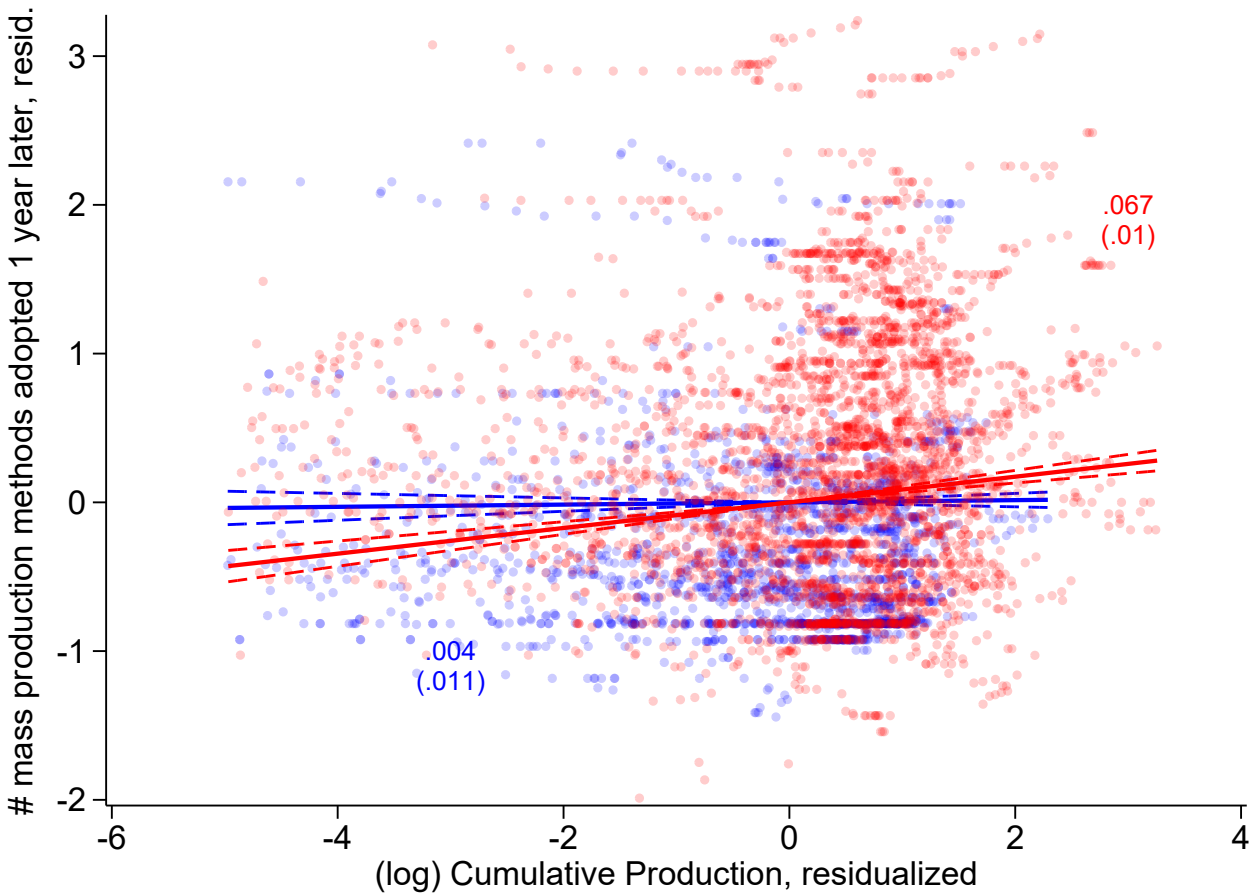
# Additional Figures

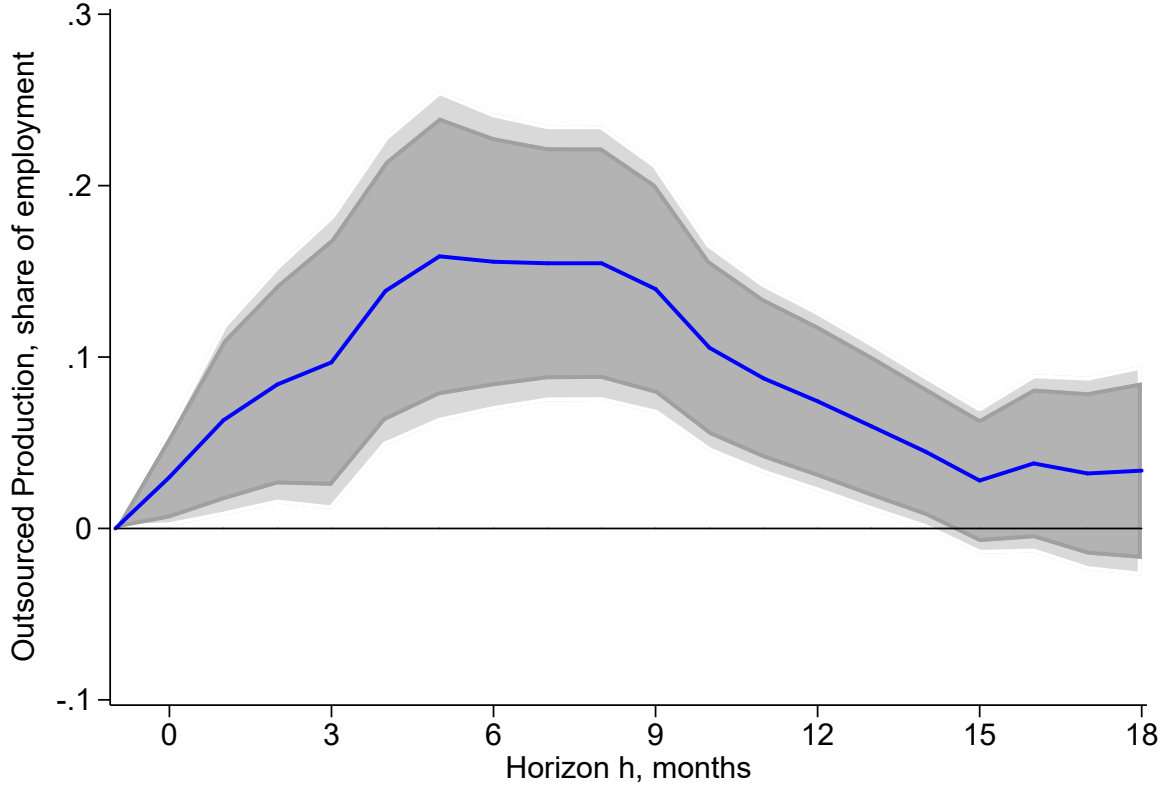
# Mass Production Technique Adoption




Number of mass-production methods adopted plotted against log cumulative production 12 months earlier. Both series are residualized from time, plant, and aircraft model fixed effects. Red dots and regression lines are for plants with above median capital utilization at the beginning of the war. Blue dots and lines are for plants and below median utilization. Regression coefficients and standard errors for each subsample reported.

# Outsourcing

## Relative Response in High vs. Low Capital Utilization Plants

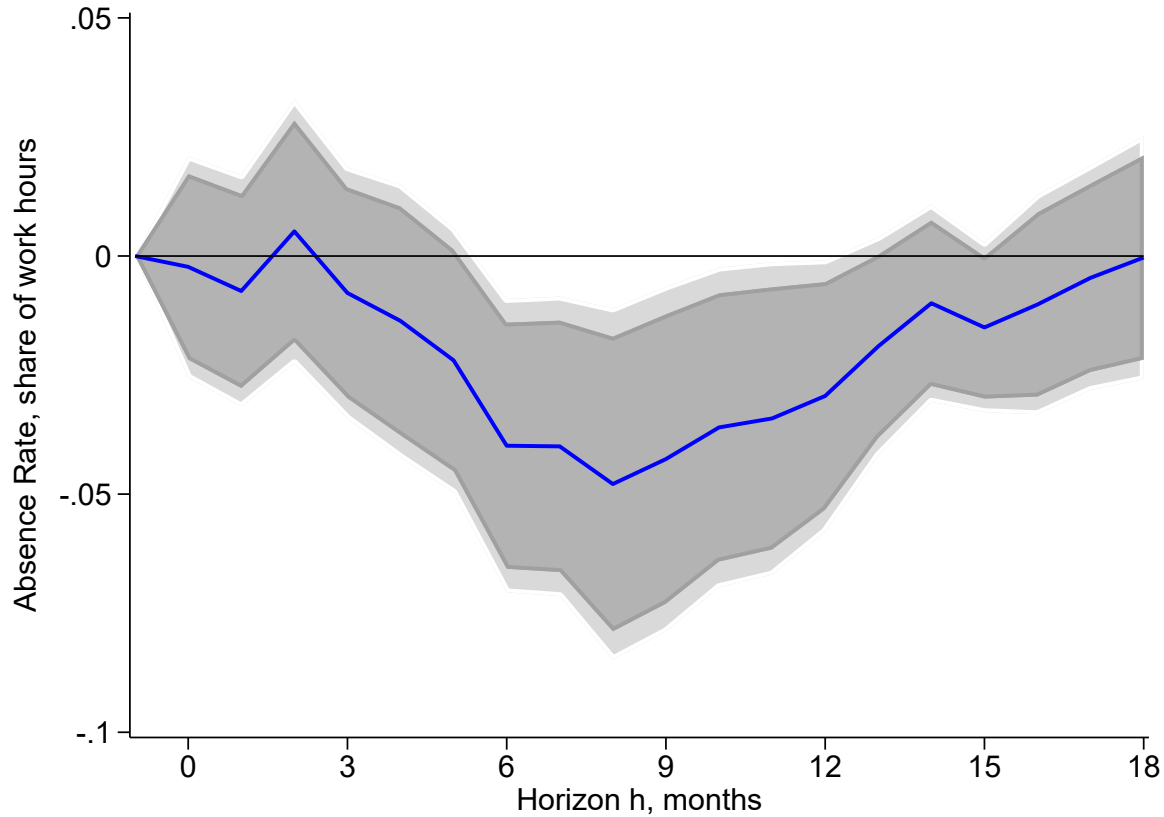



F-statistic at 12-month horizon = 13

Local projections response of percent outside production to 1% shock to aircraft demand interacted with a dummy = 1 if plant had above-median initial capacity utilization. These are instrumented with the ("leave one out") production of broad aircraft of the same broad type and its interaction with the capital utilization dummy. Includes month and plant $\times$ model (production line) fixed effects, 6 monthly lags of output. 90% and 95% standard errors shaded. F-stat at 12-month horizon = 13

# Absenteeism

## Relative Response in High vs. Low Labor Utilization Plants




Local projections response of monthly hours lost due to worker absence to 1% shock to aircraft demand interacted with a dummy = 1 if plant had above-median initial capacity utilization. These are instrumented with the ("leave one out") production of broad aircraft of the same broad type and its interaction with the capital utilization dummy. Includes month and plant × model (production line) fixed effects, 6 monthly lags of output. 90% and 95% standard errors shaded. F-stat at 12-month horizon = 6.