GUNS & GROWTH:

THE ECONOMIC CONSEQUENCES OF DEFENSE BUILDUPS

Ethan Ilzetzki, London School of Economics

Defense Buildups

No Peace Dividend and No Free Lunch

Defense buildups: Potential Long Run Productivity Gains

Finance with Debt–Within Solid Fiscal Frameworks

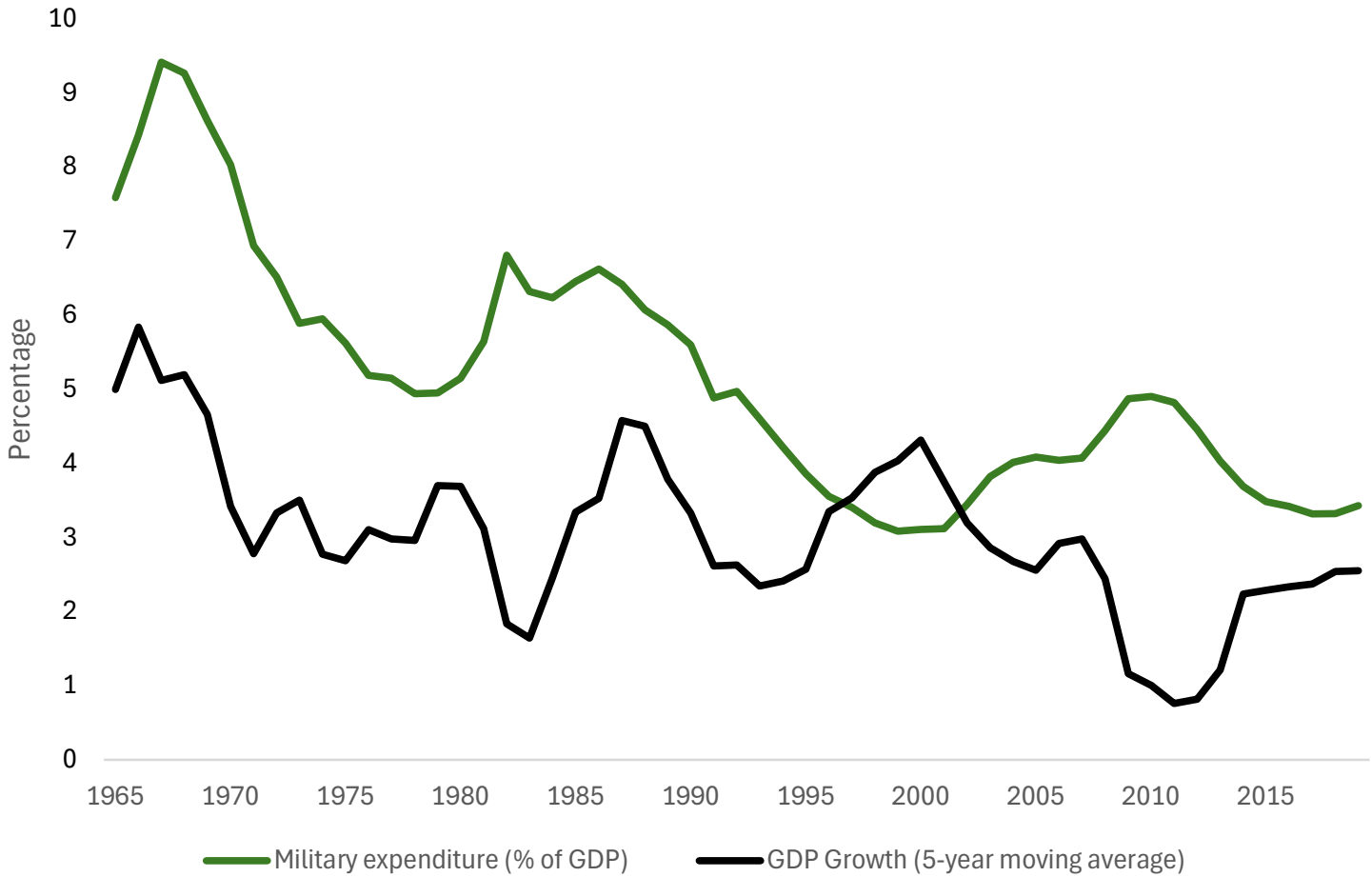
Military jobs = Good jobs

The Devil is in the Procurement Details

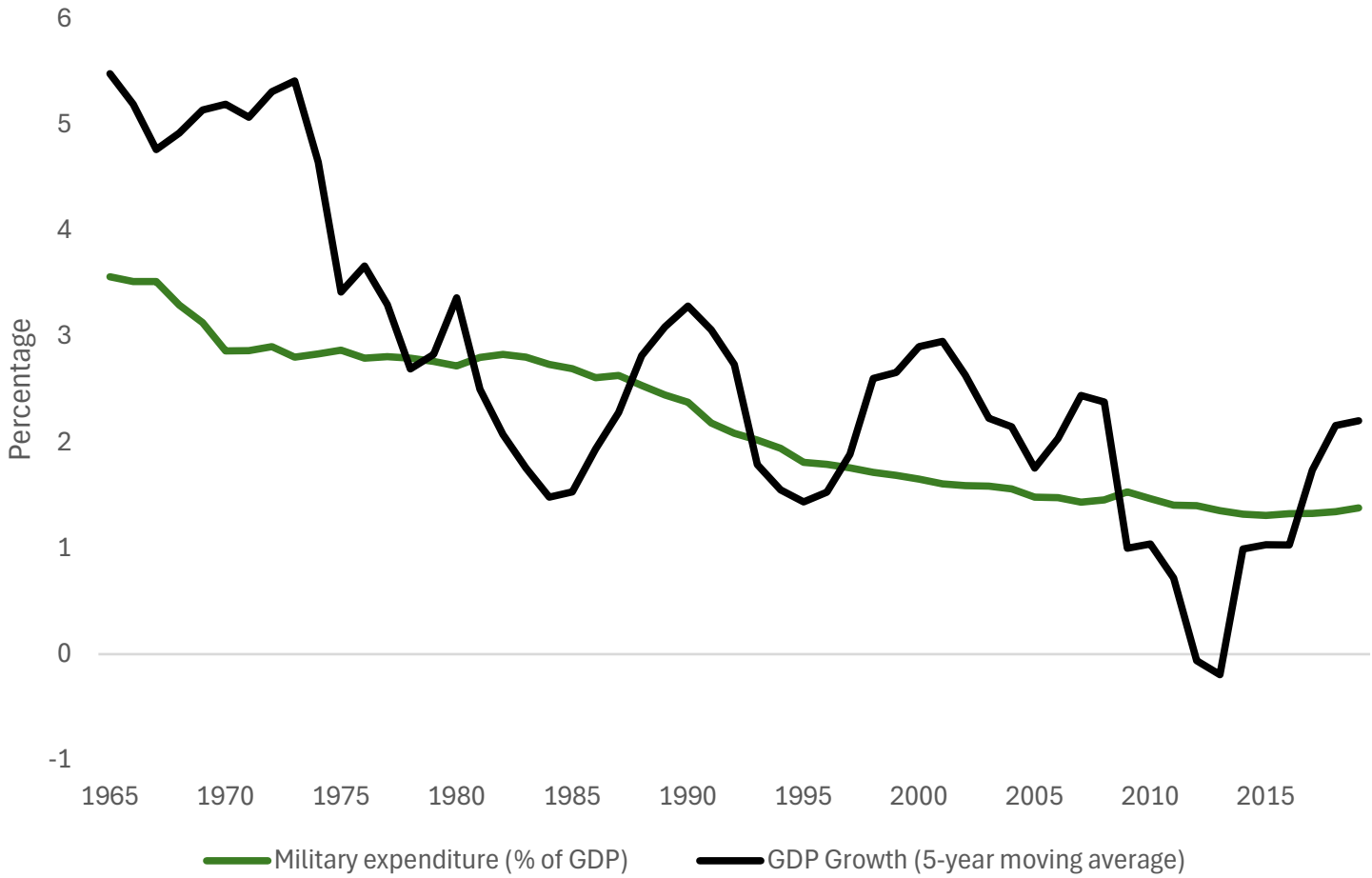
Capacity Targets not % GDP Targets

Peace Dividend or Military Keynesianism?

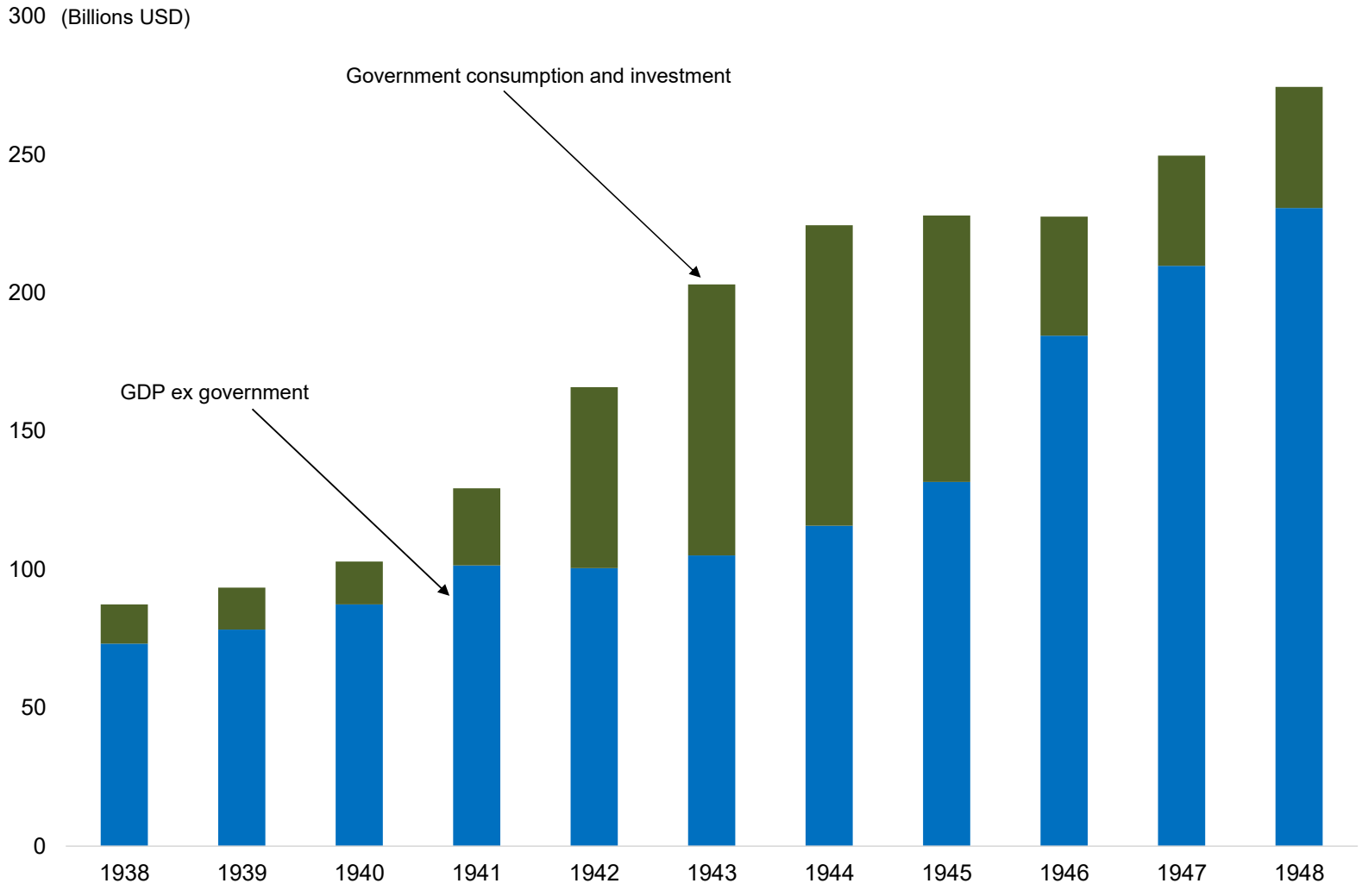
THE ELUSIVE PEACE DIVIDEND: US



THE ELUSIVE PEACE DIVIDEND: EU

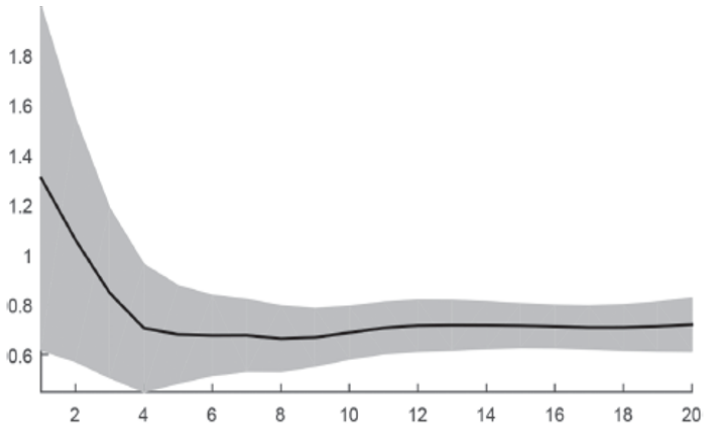


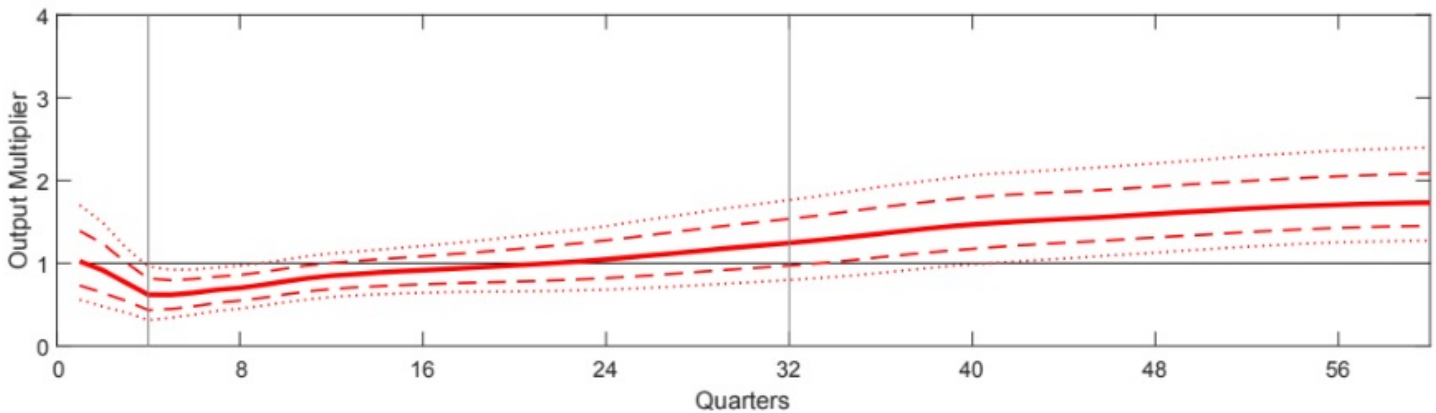
US Economy in WWII



FISCAL MULTIPLIERS

Medium-term **military spending multipliers**: 0.6 to 1.





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

FACTORS DETERMINING SIZE OF FISCAL MULTIPLIER

Tax vs. debt Financing

Baxter & King (1993), Nakamura & Steinsson (2014), Chodorow-Reich (2019), Angeletos *et al.* (2024) (debt) Angeletos *et al.* (2023), Bianchi *et al.* (2023b), Bianchi *et al.* (2023a) (tax)

Monetary response

Christiano *et al.* (2011), Ilzetzki *et al.* (2013), Nakamura & Steinsson (2014)

Slack

Auerbach & Gorodnichenko (2012, 2013), Nakamura & Steinsson (2014), Born *et al.* (2024) (yes)

Ramey & Zubairy 2018 (no)

Trade openness

Ilzetzki *et al.* (2013)

Time Series vs. Cross-Sectional Multipliers

Time series multipliers typically ≤ 1: guns vs. butter.

Cross sectional multipliers typically ≥ 1: guns **and** butter.

Chodorow-Reich (2019); Wilson (2012); Nakamura & Steinsson (2014); Auerbach & Gorodnichenko (2013); Auerbach *et al.* (2020)

Ramey (2019): Time series gives us general equilibrium response in the average historical episode.

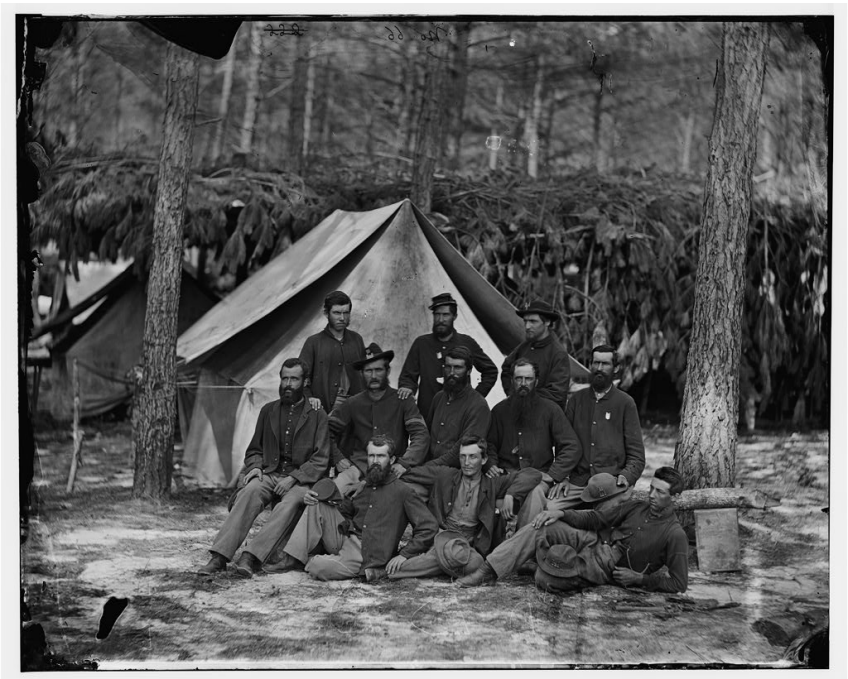
Chodorow-Reich (2019): Cross sectional gives us "pure"/"controlled" response.

Equivalent to 100% debt finance and full monetary accommodation.

Defense Buildups, Productivity & Long-Run Growth

HISTORICAL ANTECEDENTS

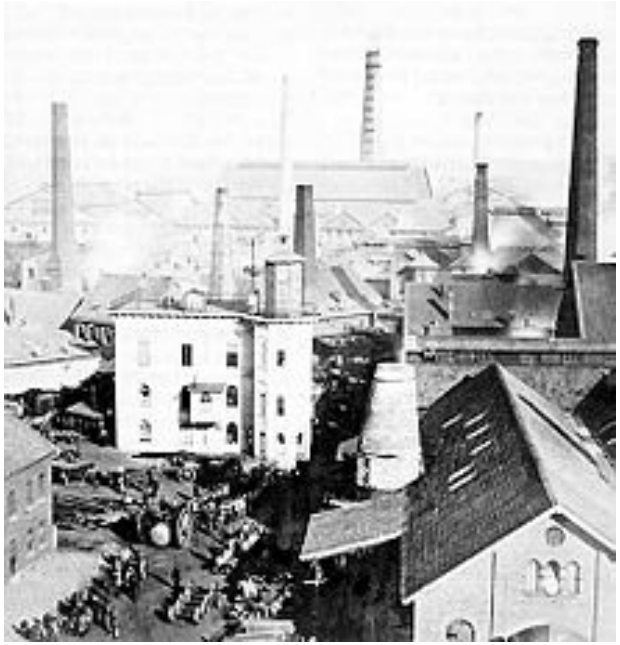
US Civil War



- 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.

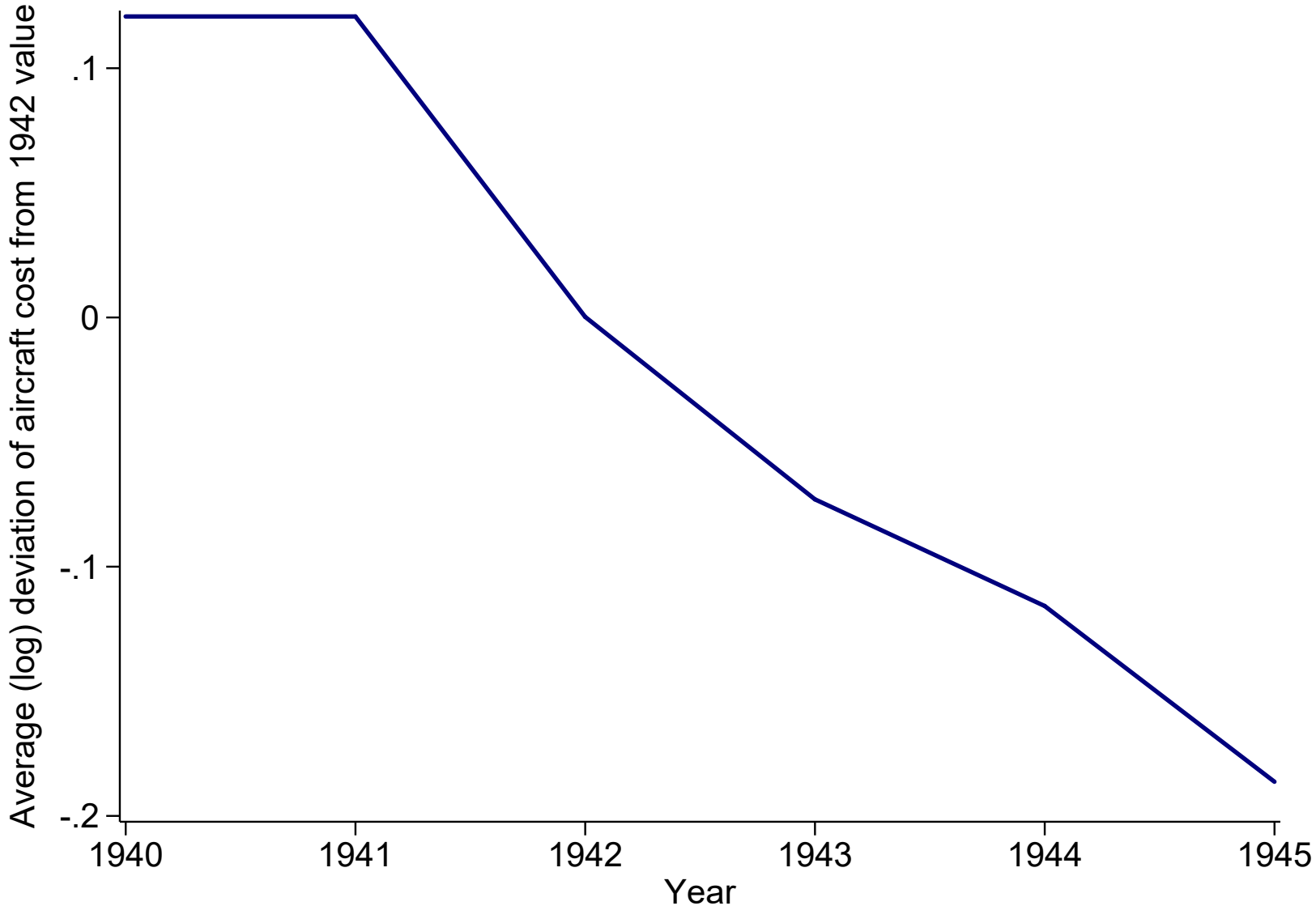
Photo: Krupp, 1964. http://www.preussen-chronik.de. Readings: Kennedy (1987), Berghahn (2005)

World War II

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

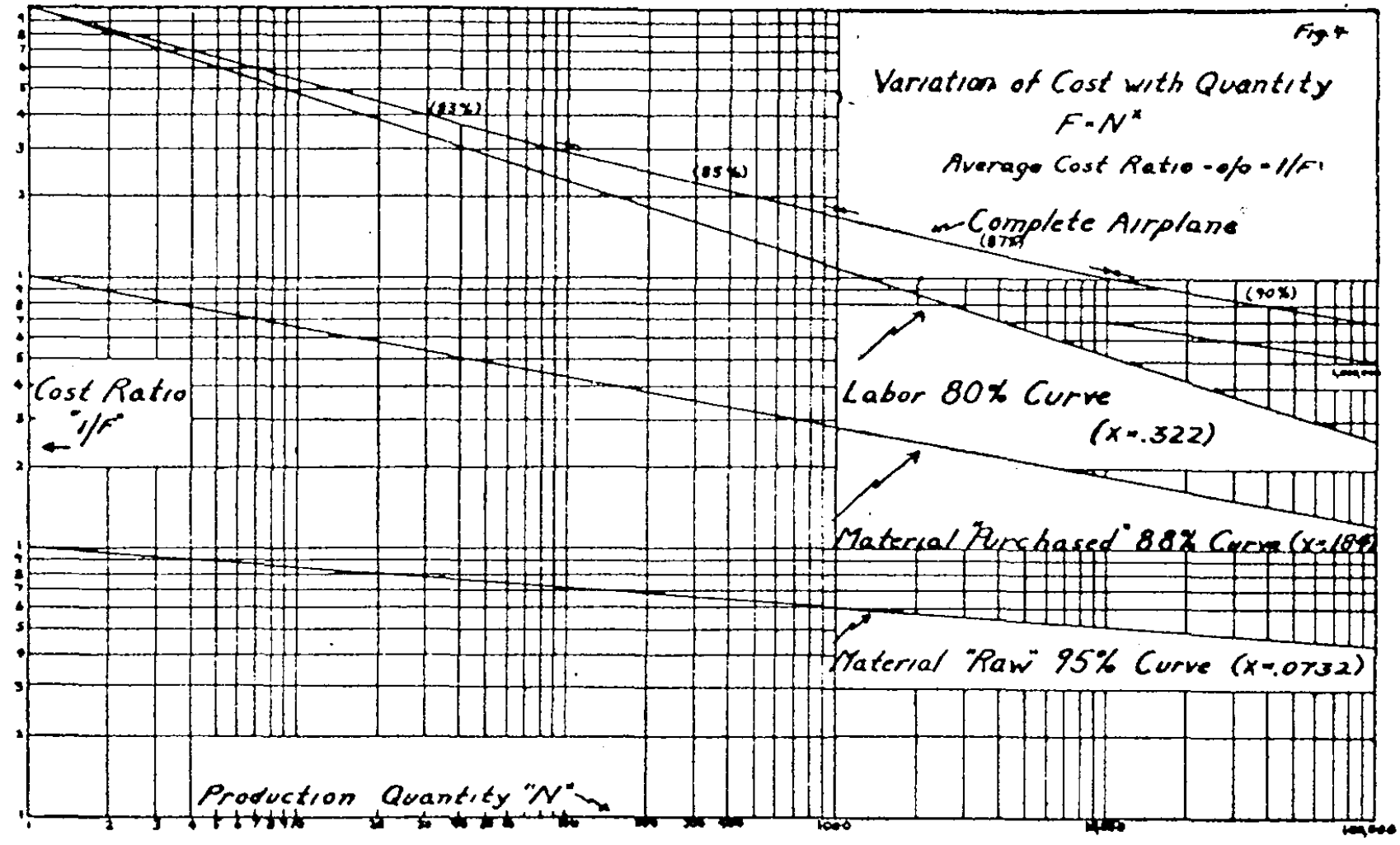
Photo: https://www.thehenryford.org/. Readings: Herman (2012), Klein (2013), Field (2002), references in Ilzetzki (2024)

Cost Reductions in Aircraft Production

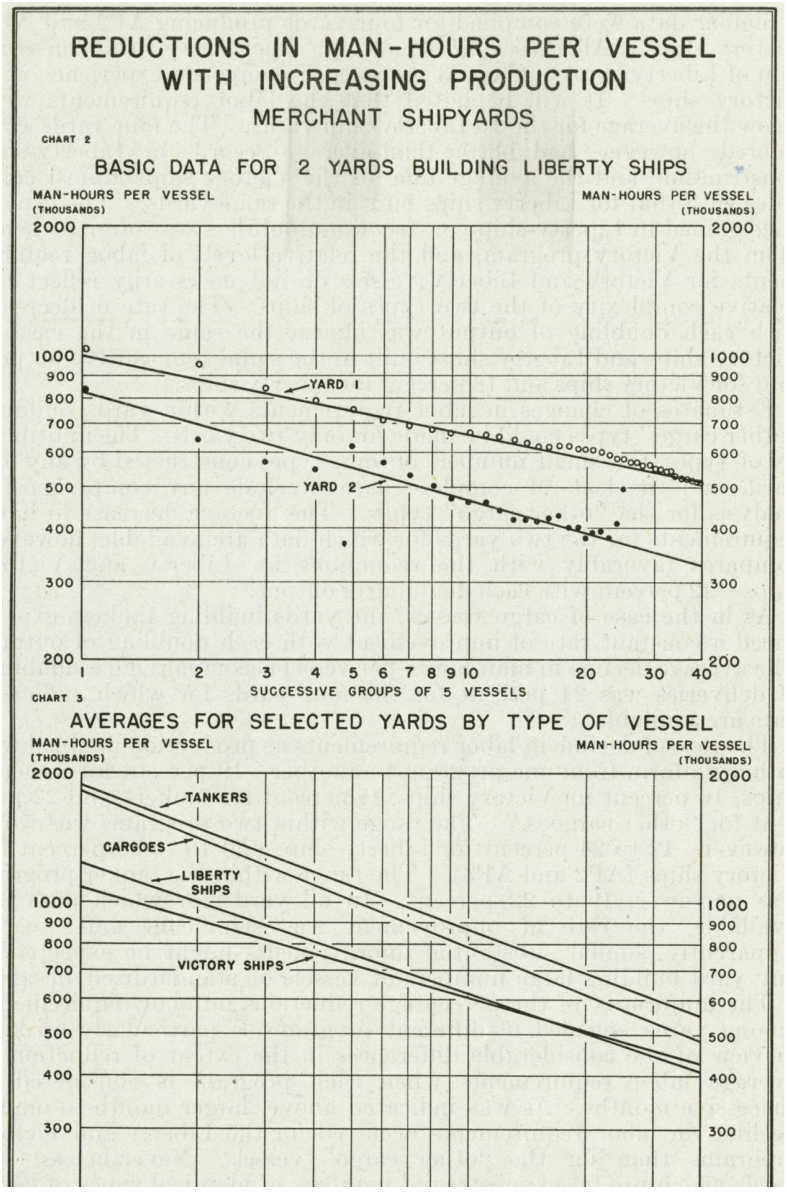


LEARNING BY DOING

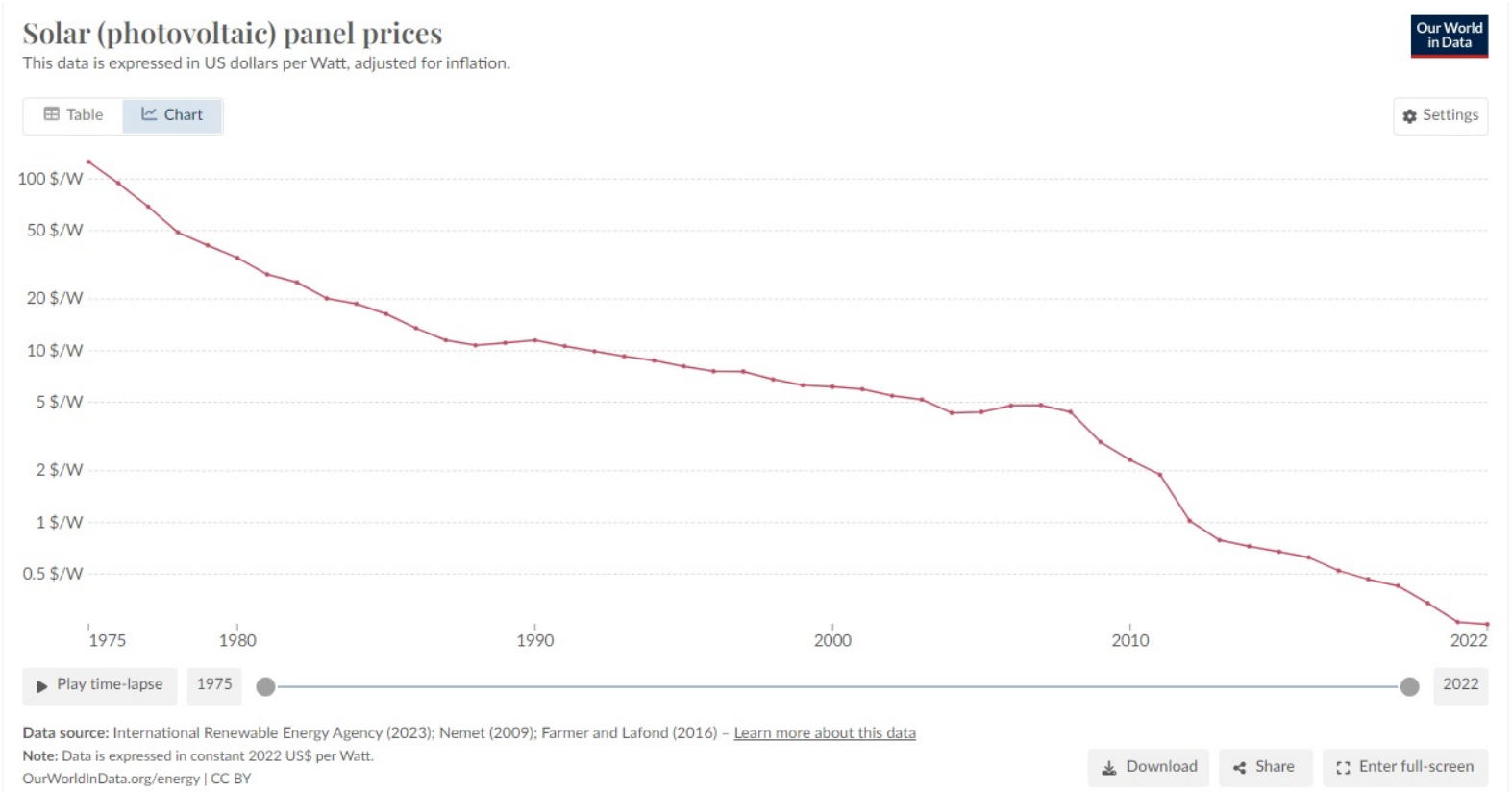
WRIGHT (1936): INTER-WAR AIRCRAFT



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

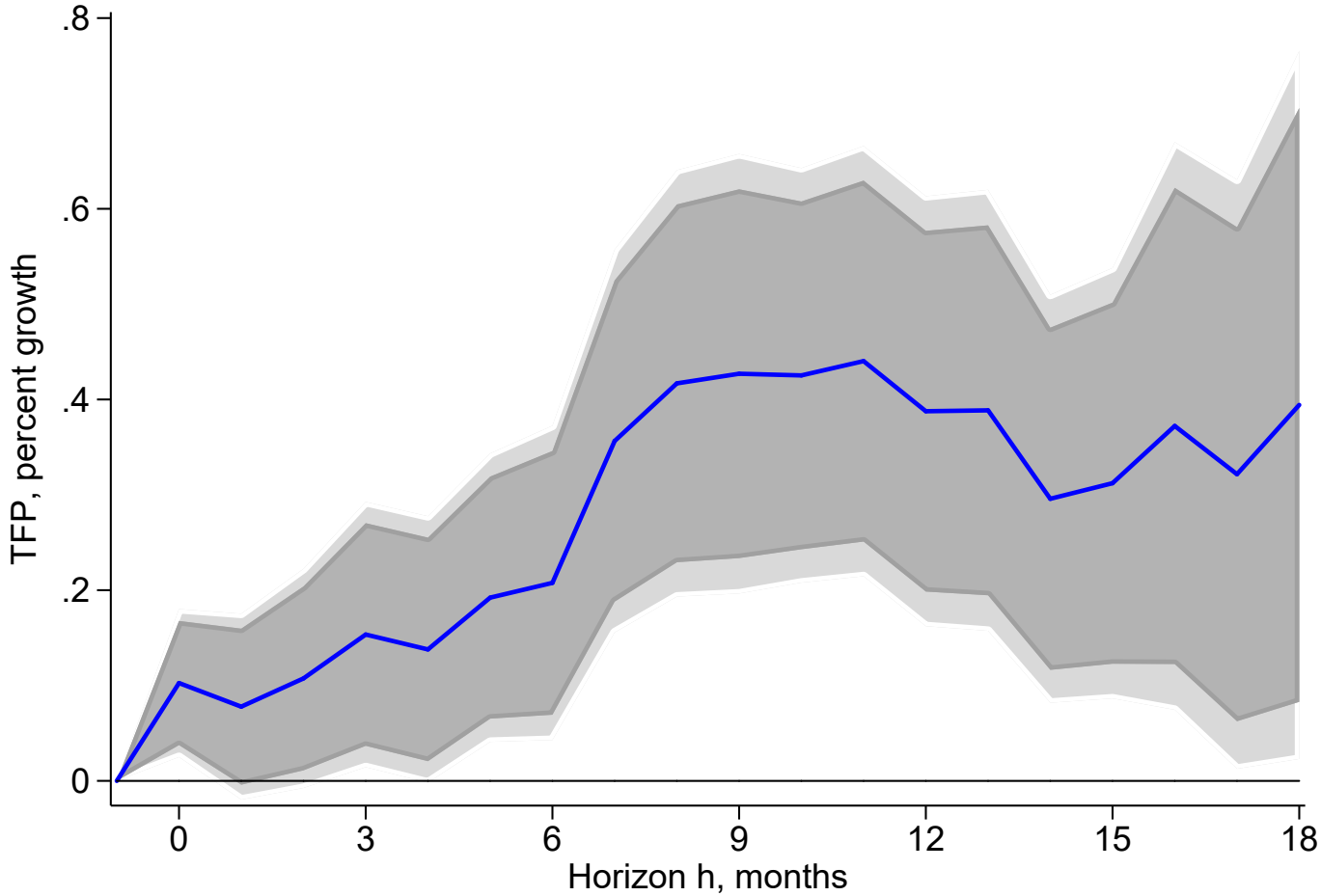
Theory of induced innovation where costly **high utilization** leads to **technology adoption**

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.

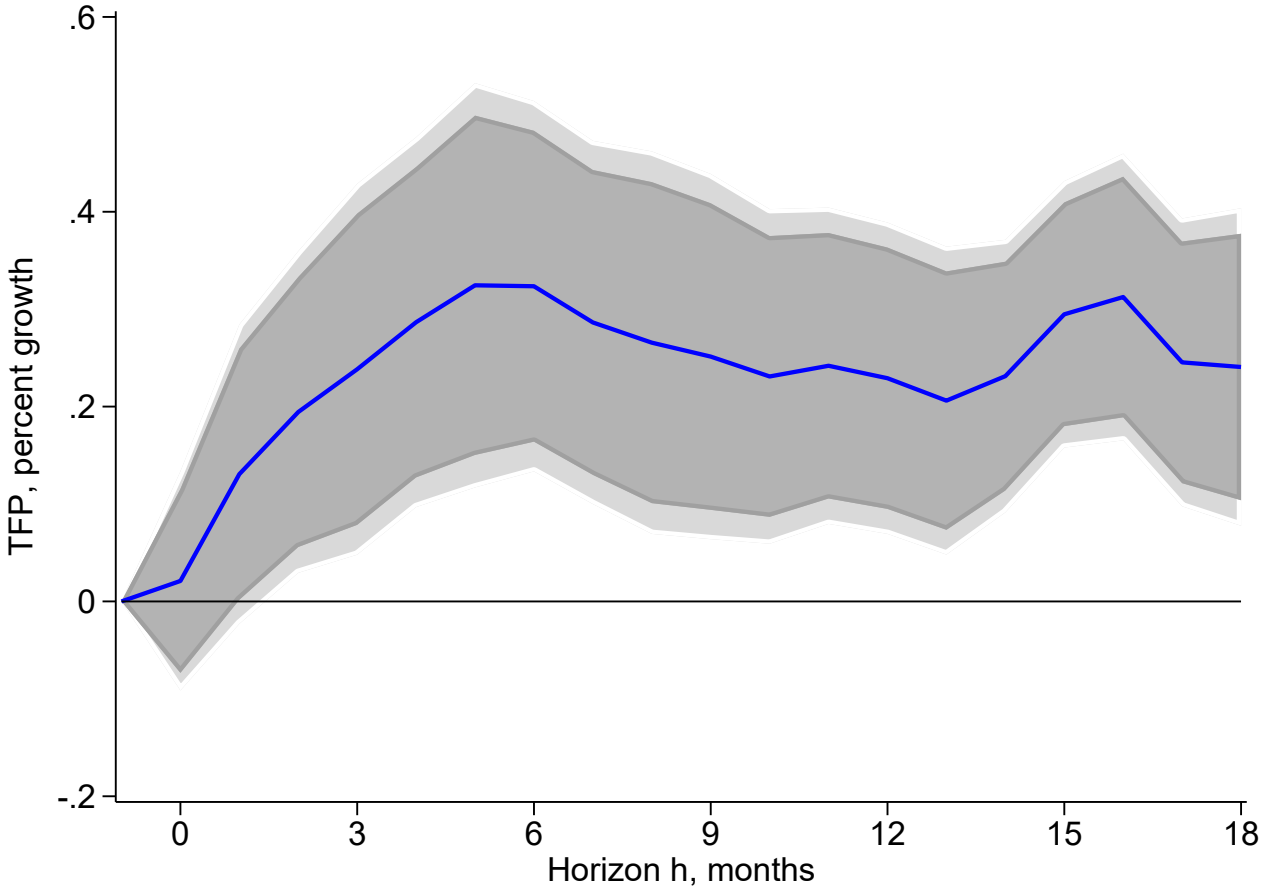
- Causal evidence
- Distinct from economies of scale.
- Suggests active learning.

TFP Response



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×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



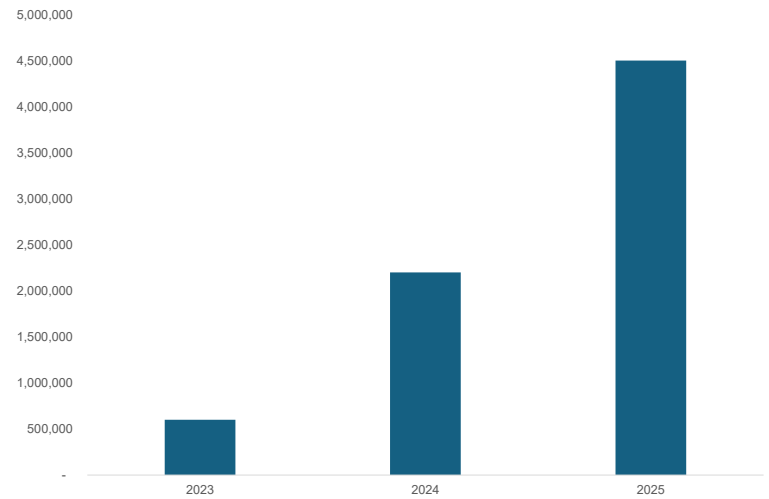
Local projections response of TFP to 1% shock to aircraft demand interacted with a dummy =1 if plant had above-median initial capacity utilization. These are instrumented with the ("leave one out") production of broad aircraft of the same broad type and its interaction with the capital utilization dummy. Includes month and plant×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

Ukrainian Drones



Sources: Forbes, David Axe, Mar 12, 2025; the Atlantic, Alan Taylor May 24, 2025

PUBLIC R&D

Public R&D Support: An intellectual history

Arrow (1962) gave an early, comprehensive, analysis of the multitude of 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
Romer (1986), Lucas (1988), Young (1991), Aghion & Howitt (1992)

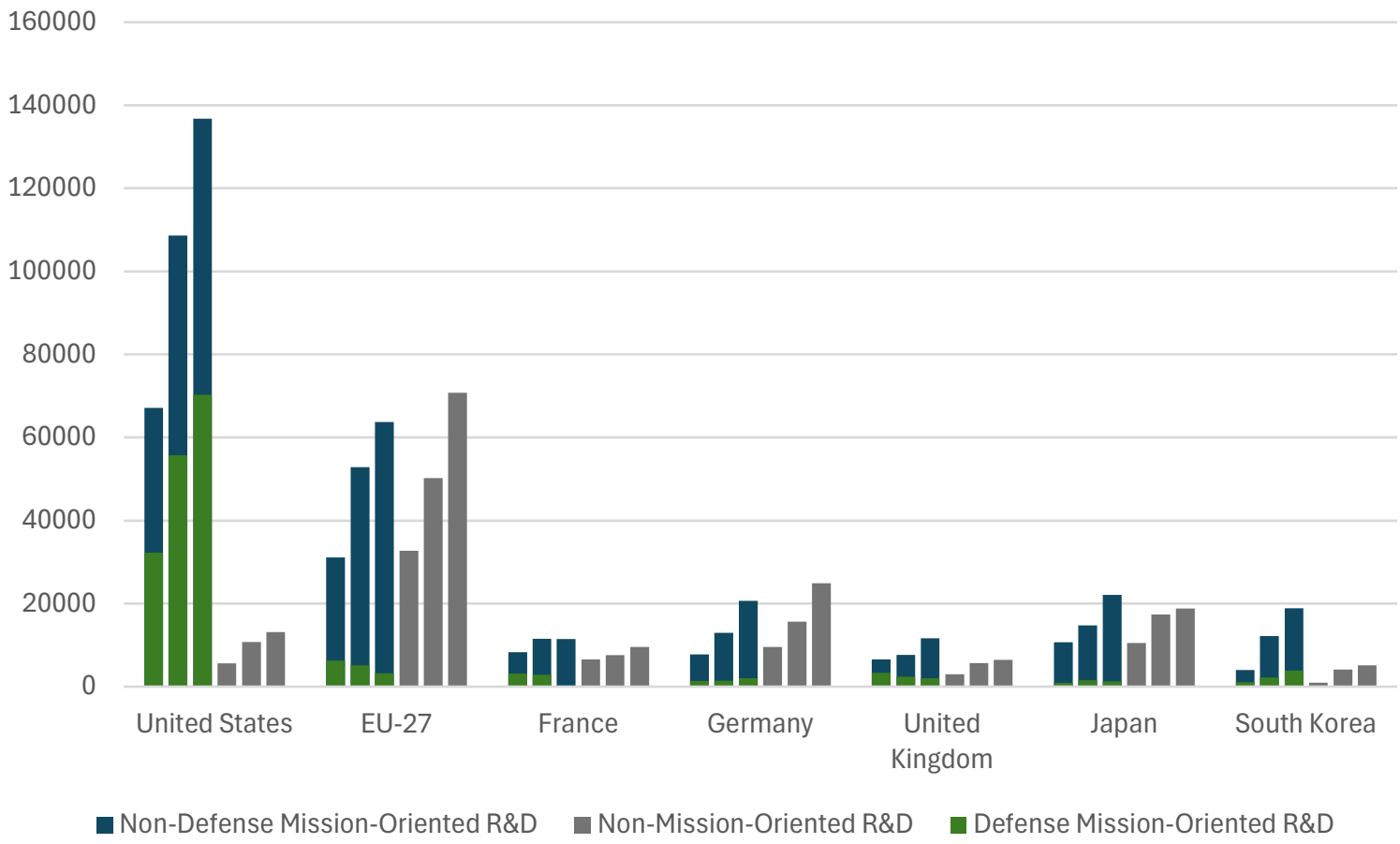
Modern view that R&D support should be **undirected** and supported through **tax policy.**

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 Importance 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 20th country in green technology makes contribution to climate goals.

Being 20th country in military technology isn't even in the race.

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× 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 21st century is more suitable for "spin-ons"

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

Gross & Sampat (2023)

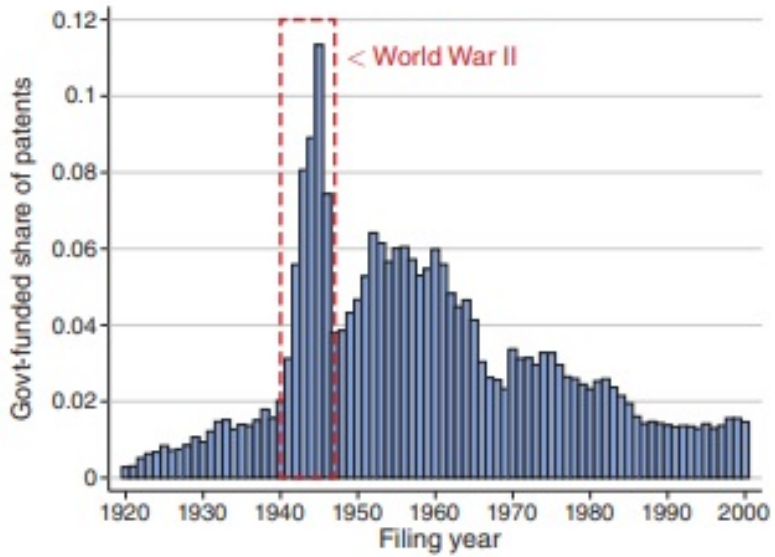
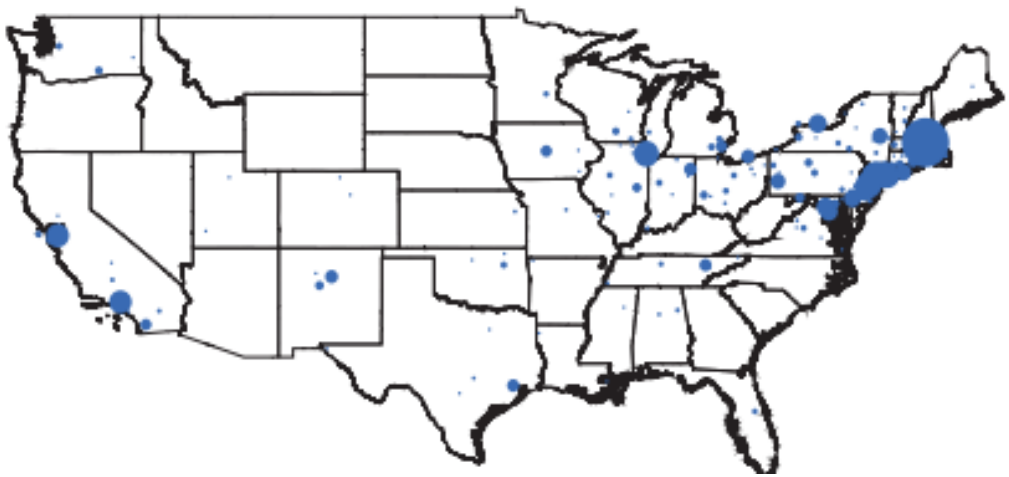
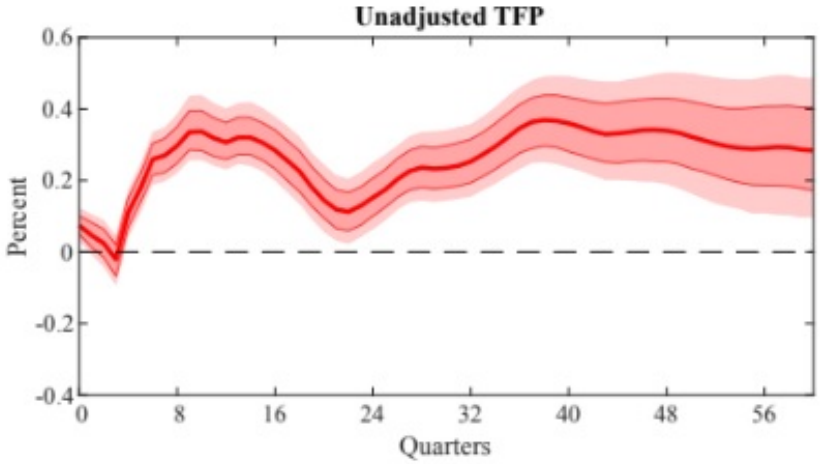
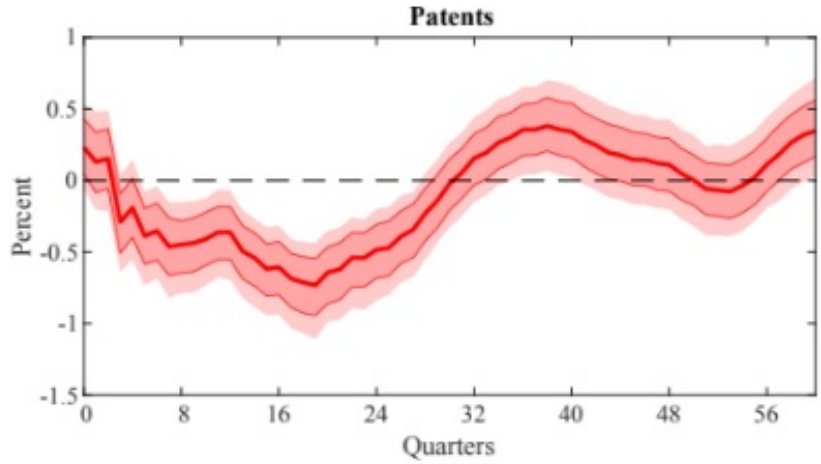


Figure 1. Government-Funded Share of US Patents, 1920 to 2000



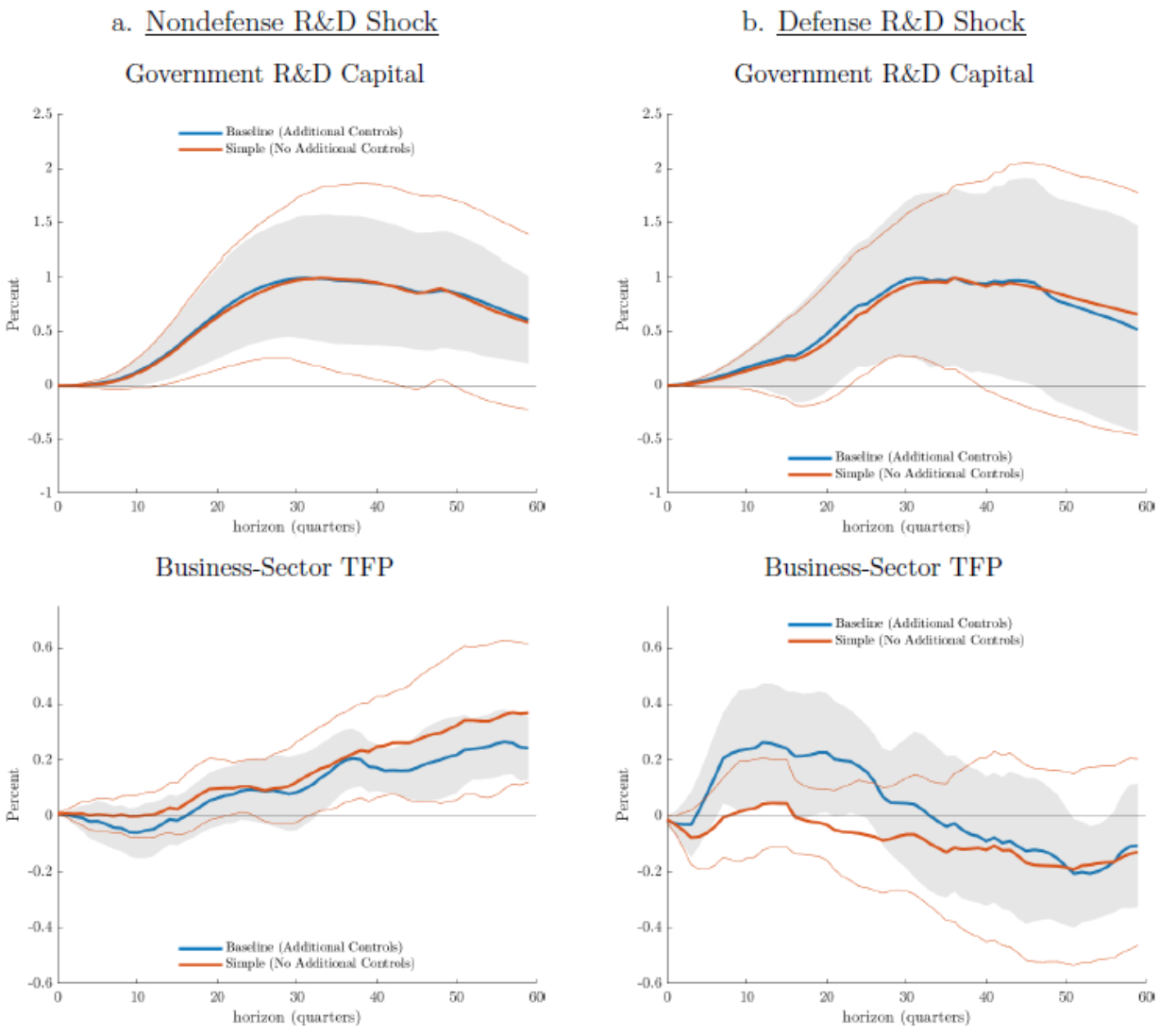
Antolin-Diaz & Surico (2025)





FIELDHOUSE & MERTENS (2023)

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



FINANCING DEFENSE BUILDUPS

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

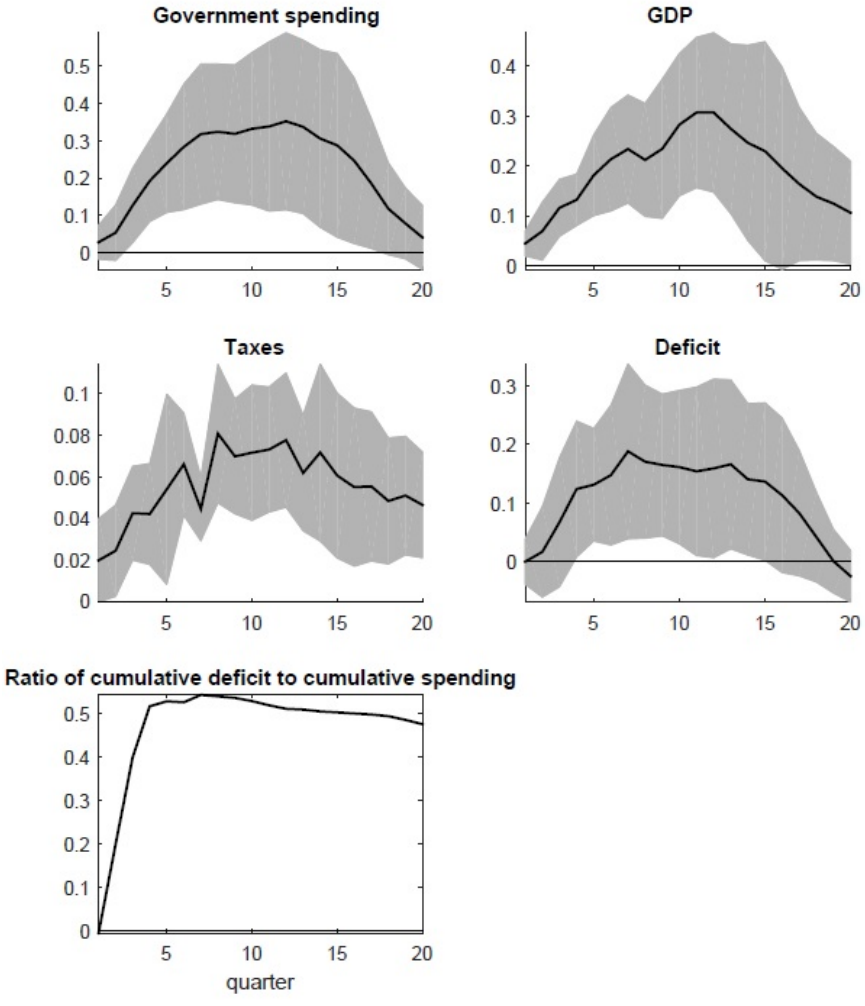
Optimal policy (Vietnam war sized shock):

- 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

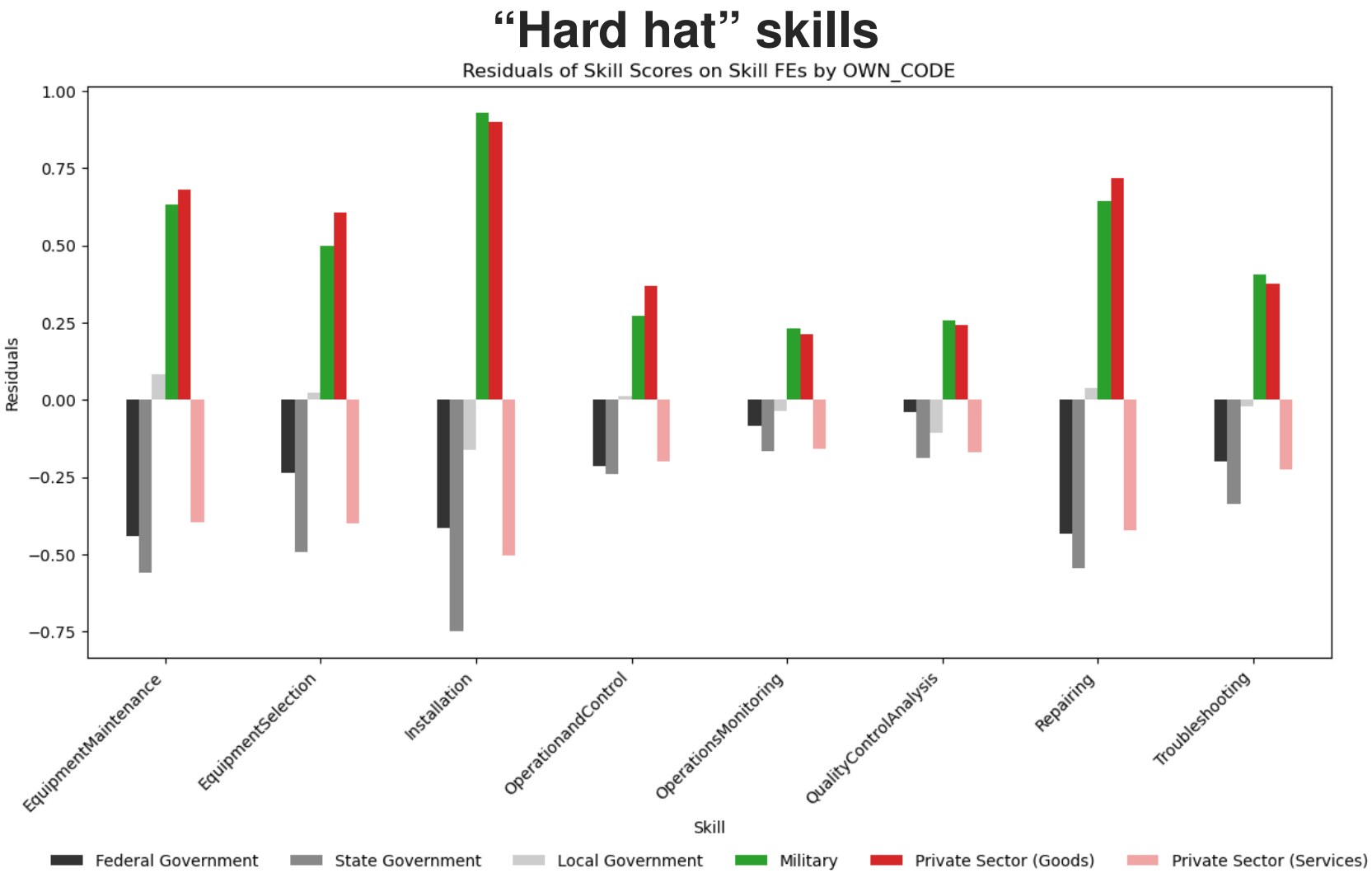
FINANCING IN THE AVERAGE US MILITARY BUILDUP



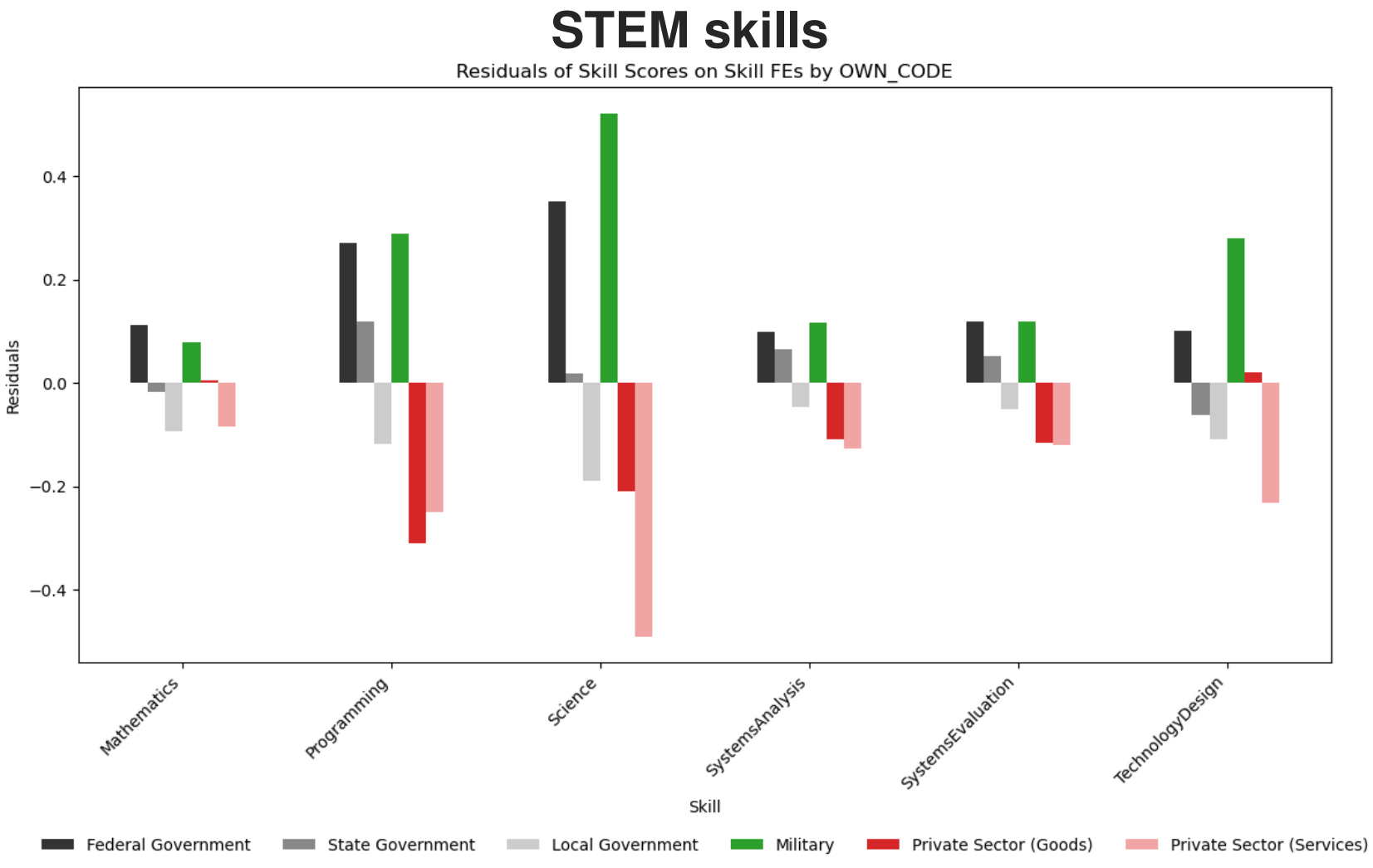
Ramey & Zubairy 2018

Military Jobs

REQUIRED SKILLS

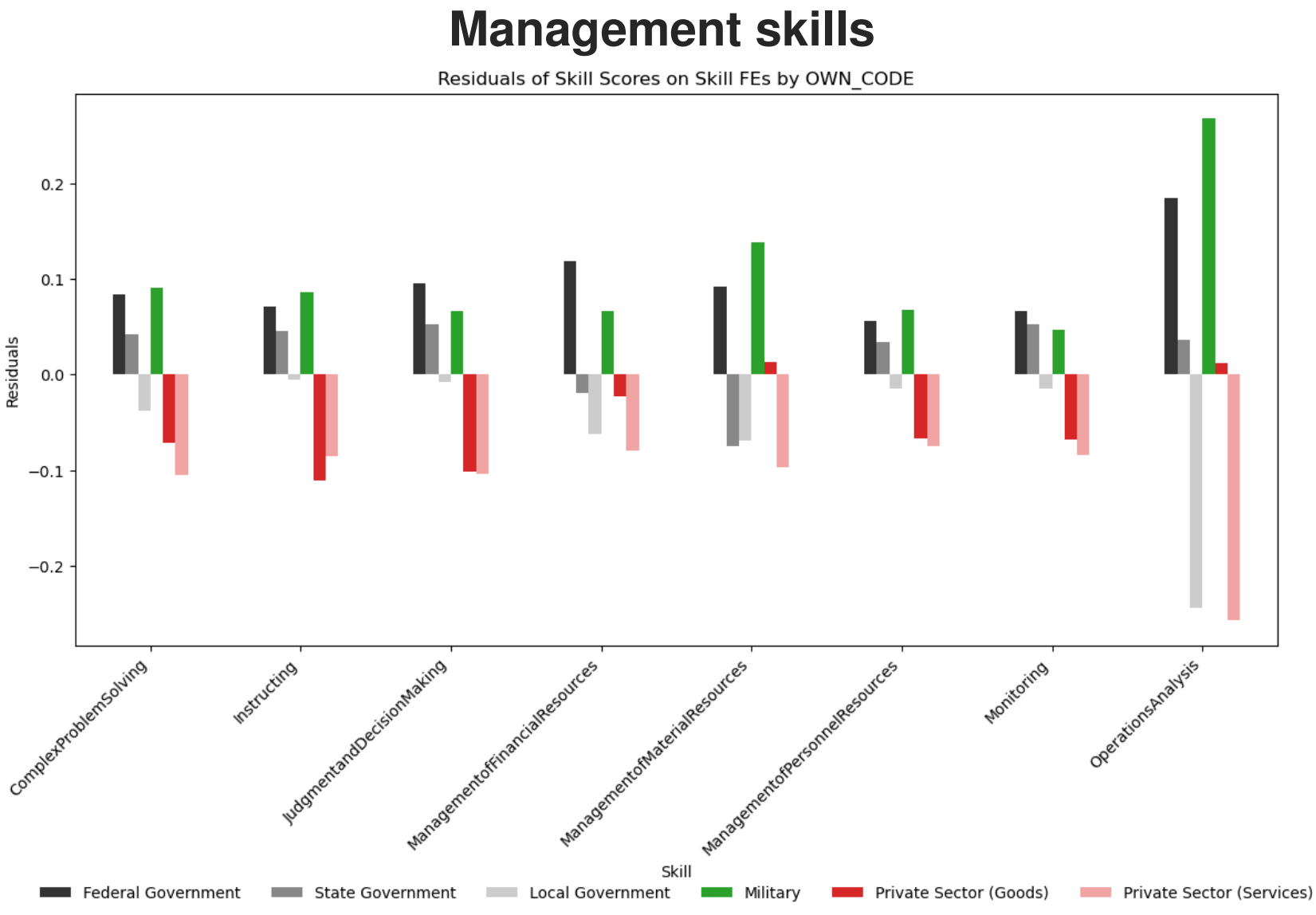


Required Skills

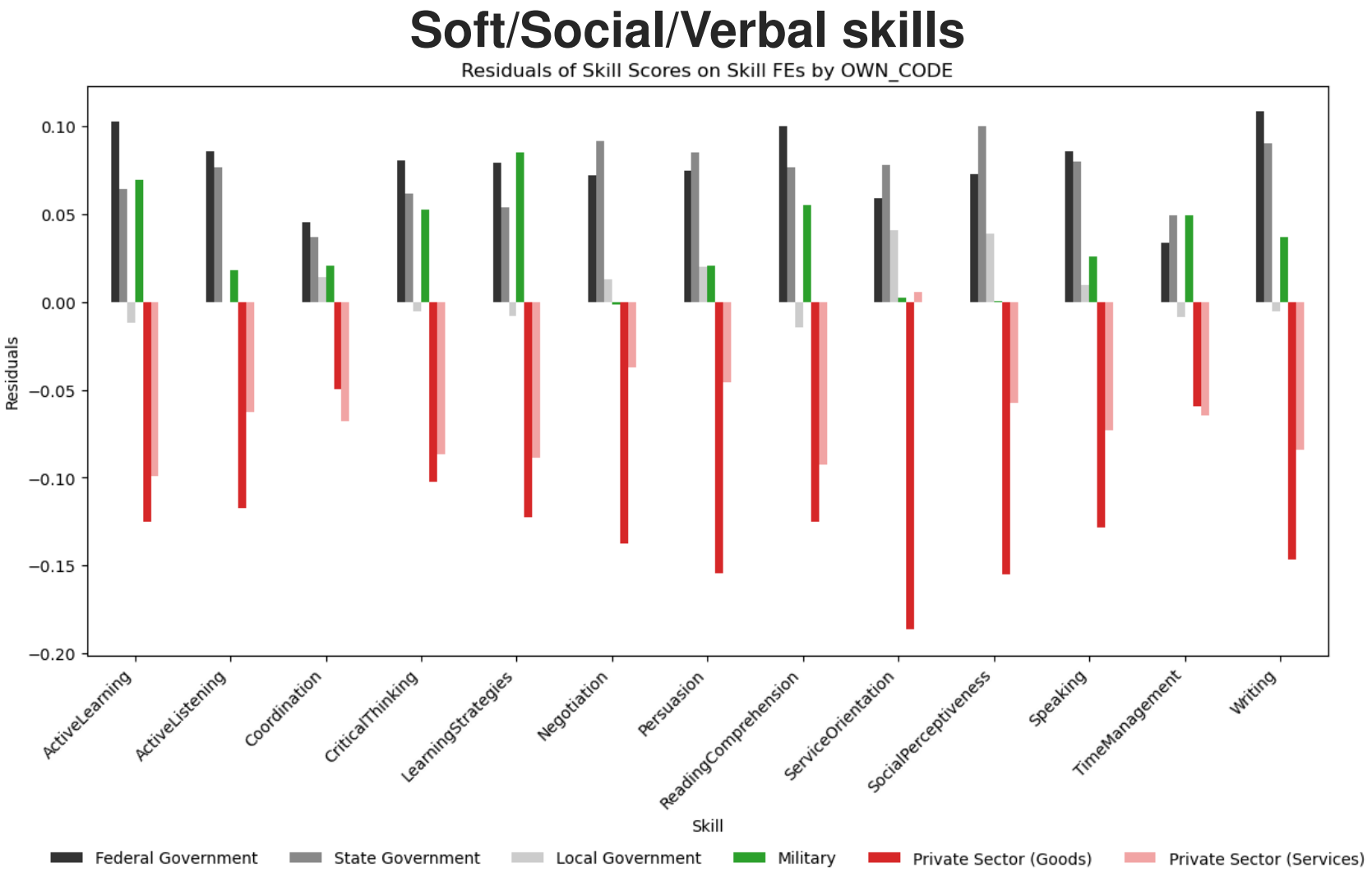


Source: Ilzetzki and Reichardt 2025

REQUIRED SKILLS



REQUIRED SKILLS



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

Inter-operability Problems

Leclerc (France)

Leopard 2 (Germany)

Distinct spares / maintenance pipelines.

Incompatible ammunition limit cross-supply.

Different communication and IT systems.

Different driving, gunnery and maintenance procedures.

Capacity Targets vs. Percent of GDP Targets

% of GDP Targets

Nato practice: % of GDP targets

- Might be necessary to monitor members' contributions

Not ideal:

- Declining costs over time
- Defense buildups are front-loaded
- Perverse procurement incentives
- Encourages pro-cyclical spending

Instead:

- Begin with desired capabilities
- Exploit government's monopsonistic power
- Attempt to *minimize* costs and share of GDP

SUMMARY

Defense Buildups

No Peace Dividend and No Free Lunch

Defense buildups: Potential Long Run Productivity Gains

Finance with Debt–Within Solid Fiscal Frameworks

Military jobs = Good Jobs

The Devil is in the Procurement Details

Capacity Targets not % GDP Targets

References [1]

Acemoglu, Daron, & Restrepo, Pascual. 2018. The Race between Man and Machine: Implications of Technology for Growth, Factor Shares, and Employment. *The American Economic Review*, **108**(6), 1488–1542.

Acemoglu, Daron, & Restrepo, Pascual. 2019. Automation and New Tasks: How Technology Displaces and Reinstates Labor. *The Journal of Economic Perspectives*, **33**(2), 3–30.

Aghion, Philippe, & Howitt, Peter. 1992. A Model of Growth Through Creative Destruction. *Econometrica*, **60**(2), 323–351.

Allen, Robert C. 2009. *The British Industrial Revolution in Global Perspective*. Cambridge, England: Cambridge University Press.

Angeletos, George-Marios, Collard, Fabrice, & Dellas, Harris. 2023. Public Debt as Private Liquidity: Optimal Policy. *Journal of Political Economy*, **131**(11), 3233–3264.

Angeletos, George-Marios, Lian, Chen, & Wolf, Christian K. 2024. Can Deficits Finance Themselves? *Econometrica*, **92**(5), 1351–1390.

Antolin-Diaz, Juan, & Surico, Paolo. 2025. The Long-Run Effects of Government Spending. *American Economic Review*, **forthcoming**.

Anzoategui, Diego, Comin, Diego, Gertler, Mark, & Martinez, Joseba. 2019. Endogenous technology adoption and R&D as sources of business cycle persistence. *American Economic Journal: Macroeconomics*, **11**(3), 67–110.

Arrow, Kenneth. 1962. *Economic Welfare and the Allocation of Resources for Invention*. Princeton University Press. Pages 609–626.

Auerbach, Alan J., & Gorodnichenko, Yuriy. 2012. Measuring the Output Responses to Fiscal Policy. *American Economic Journal: Economic Policy*, **4**(2), 1–27.

References [2]

Auerbach, Alan J, & Gorodnichenko, Yuriy. 2013. Fiscal multipliers in recession and expansion. *Pages 63–98 of: Fiscal policy after the financial crisis*. University of Chicago Press.

Auerbach, Alan J, Gorodnichenko, Yuriy, & Murphy, Daniel. 2020. Local Fiscal Multipliers and Fiscal Spillovers in the USA. *IMF Economic Review*, **68**(1), 195–229.

Baxter, Marianne, & King, Robert G. 1993. Fiscal policy in general equilibrium. *The American Economic Review*, 315–334.

Beard, Charles A., & Beard, Mary R. 1927. *The Rise of American Civilization*. The Macmillan Company.

Benigno, Gianluca, & Fornaro, Luca. 2018. Stagnation traps. *The Review of Economic Studies*, **85**(3), 1425–1470.

Berghahn, Volker Rolf. 2005. *Imperial Germany, 1871-1918: economy, society, culture, and politics*. Berghahn Books.

Bianchi, Francesco, Faccini, Renato, & Melosi, Leonardo. 2023a. A Fiscal Theory of Persistent Inflation*. *The Quarterly Journal of Economics*, **138**(4), 2127–2179.

Bianchi, Javier, Ottonello, Pablo, & Presno, Ignacio. 2023b. Fiscal Stimulus under Sovereign Risk. *Journal of Political Economy*, **131**(9), 2328–2369.

Born, Benjamin, D'Ascanio, Francesco, Müller, Gernot J., & Pfeifer, Johannes. 2024. Mr. Keynes Meets the Classics: Government Spending and the Real Exchange Rate. *Journal of Political Economy*, **132**(5), 1642–1683.

Bush, Vannevar. 1945. *Science, the Endless Frontier*. Princeton University Press.

Chodorow-Reich, Gabriel. 2019. Geographic Cross-Sectional Fiscal Spending Multipliers: What Have We Learned? *American Economic Journal: Economic Policy*, **11**(2), 1–34.

Christiano, Lawrence, Eichenbaum, Martin, & Rebelo, Sergio. 2011. When Is the Government Spending Multiplier Large? *Journal of Political Economy*, **119**(1), 78–121.

References [3]

Dyevre, Arnaud. 2023. *Public R&D spillovers and productivity growth*. Tech. rept. Working Paper.

Feiglin, Guy. 2020. New developments affecting military industries. *Pages 89–104 of:* Haddad, Sasson, Fedlon, Tomer, & Even, Samuel (eds), *The Israeli defense indusry and US assitance*. INSS, University of Tel Aviv.

Fellner, William. 1961. Two Propositions in the Theory of Induced Innovations. *The Economic Journal*, **71**(282), 305–308.

Fellner, William. 1971. Empirical Support for the Theory of Induced Innovations. *The Quarterly Journal of Economics*, **85**(4), 580–604.

Field, Alexander J. 2002. *The Economic Consequences of U.S. Mobilization for the Second World War*. New Haven, CT: Yale University Press.

Fieldhouse, Andrew J, & Mertens, Karel. 2023. *The Returns to Government R&D: Evidence from US Appropriations Shocks*. Federal Reserve Bank of Dallas, Research Department.

Gross, Daniel P., & Sampat, Bhaven N. 2023. America, Jump-Started: World War II RD and the Takeoff of the US Innovation System. *American Economic Review*, **113**(12), 3323–56.

Habakkuk, John. 1962. *American and British technology in the nineteenth century: the search for labour-saving inventions*. Cambridge, England: Cambridge University Press.

Herman, Arthur. 2012. *Freedom's Forge: How American Business Produced Victory in World War II*. New York, NY: Random House.

Hickman, Bert G. 1957. Capacity, Capacity Utilization, and the Acceleration Principle. *Chap. c5590 of: Problems of Capital Formation: Concepts, Measurement, and Controlling Factors*. NBER.

References [4]

Howard, Robert A. 1978. Interchangeable Parts Reexamined: The Private Sector of the American Arms Industry on the Eve of the Civil War. *Technology and Culture*, **19**(4), 633–649.

Howell, Sabrina T, Rathje, Jason, Van Reenen, John, & Wong, Jun. 2021 (April). *Opening up Military Innovation: Causal Effects of Reforms to U.S. Defense Research*. Working Paper 28700. National Bureau of Economic Research.

Ilzetzki, Ethan. 2024. Learning by necessity: Government demand, capacity constraints, and productivity growth. *American economic review*.

Ilzetzki, Ethan, Mendoza, Enrique G., & Végh, Carlos A. 2013. How big (small?) are fiscal multipliers? *Journal of Monetary Economics*, **60**(2), 239–254.

Jones, Benjamin F., & Summers, Lawrence H. 2022. A Calculation of the Social Returns to Innovation. *Pages 13–59 of:* Goolsbee, Austan, & Jones, Benjamin (eds), *Innovation and Public Policy*. University of Chicago Press.

Jones, Eric. 2003. *The European Miracle: Environments, Economies and Geopolitics in the History of Europe and Asia*. 3 edn. Cambridge University Press.

Kantor, Shawn, & Whalley, Alexander T. 2023. *Moonshot: Public R&D and growth*. Tech. rept. National Bureau of Economic Research.

Kennedy, Paul. 1987. *The Rise and Fall of the Great Powers*. Random House.

Klein, Maury. 2013. *A Call to Arms: Mobilizing America for World War II*. Bloomsbury Publishing USA.

Lucas, Robert E. Jr. 1988. On the mechanics of economic development. *Journal of Monetary Economics*, **22**(1), 3–42.

Marzian, Johannes, & Trebesch, Christoph. 2025. *Military Booms: A Macroeconomic History*. Unpublished Manuscript.

Mazzucato, Marina. 2021. *Mission Economy: A Moonshot Guide to Changing Capitalism*. New York: Harper Business.

References [5]

Moretti, Enrico, Steinwender, Claudia, & Van Reenen, John. 2019 (November). *The Intellectual Spoils of War? Defense RD, Productivity and International Spillovers*. Working Paper 26483. National Bureau of Economic Research.

Mowery, David C. 2010. Chapter 29 - Military RD and Innovation. *Pages 1219–1256 of:* Hall, Bronwyn H., & Rosenberg, Nathan (eds), *Handbook of the Economics of Innovation, Volume 2*. Handbook of the Economics of Innovation, vol. 2. North-Holland.

Mowery, David C, & Rosenberg, Nathan. 1991. *Technology and the pursuit of economic growth*. Cambridge University Press.

Mowery, David C., & Rosenberg, Nathan. 1999. *Paths of Innovation*. New York: Oxford University Press.

Myers, Kyle R., & Lanahan, Lauren. 2022. Estimating Spillovers from Publicly Funded RD: Evidence from the US Department of Energy. *American Economic Review*, **112**(7), 2393–2423.

Nakamura, Emi, & Steinsson, Jón. 2014. Fiscal Stimulus in a Monetary Union: Evidence from US Regions. *American Economic Review*, **104**(3), 753–792.

Newell, Richard, Jaffe, Adam, & Stavins, Robert. 1999. The Induced Innovation Hypothesis and Energy-Saving Technological Change. *The Quarterly Journal of Economics*, **114**(3), 941–975.

Popp, David. 2002. Induced Innovation and Energy Prices. *American Economic Review*, **92**(1), 160–180.

Ramey, Valerie A. 2019. Ten Years after the Financial Crisis: What Have We Learned from the Renaissance in Fiscal Research? *Journal of Economic Perspectives*, **33**(2), 89–114.

Romer, Paul M. 1986. Increasing Returns and Long-run Growth. *Journal of Political Economy*, **94**(5), 1002–1037.

REFERENCES [6]

ROMER, PAUL M. 1987. Crazy Explanations for the Productivity Slowdown. *Pages 163–210 of: NBER Macroeconomics Annual 1987, Volume 2*. NBER Chapters. National Bureau of Economic Research, Inc.

ROTHBARTH, E. 1946. Causes of the Superior Efficiency of U.S.A. Industry as Compared with British Industry. *The Economic Journal*, **56**(223), 383–390.

SEARLE, ALLAN D. 1945. Productivity changes in selected wartime shipbuilding programs. *Monthly Labor Review*, **61**, 1132–1147.

WILSON, DANIEL J. 2012. Fiscal Spending Jobs Multipliers: Evidence from the 2009 American Recovery and Reinvestment Act. *American Economic Journal: Economic Policy*, **4**(3), 251–82.

WILSON, MARK R. 2006. *The business of Civil War: Military mobilization and the state, 1861–1865*. JHU Press.

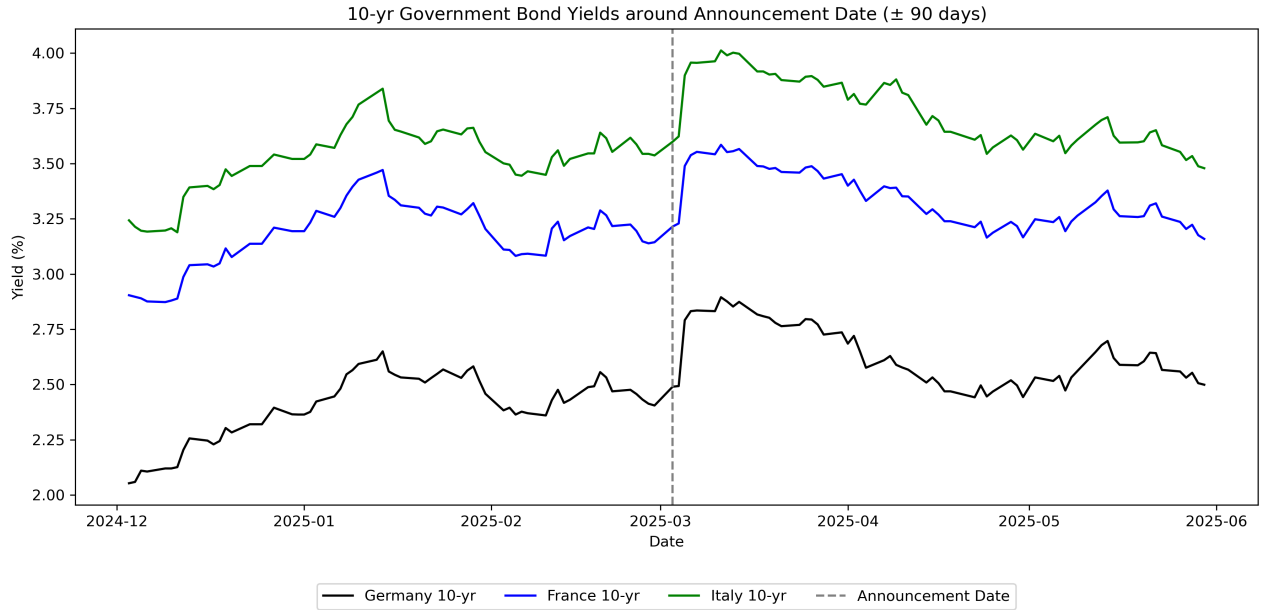
WRIGHT, GAVIN. 1978. *Political Economy of the Cotton South*. W. W. Norton & Company.

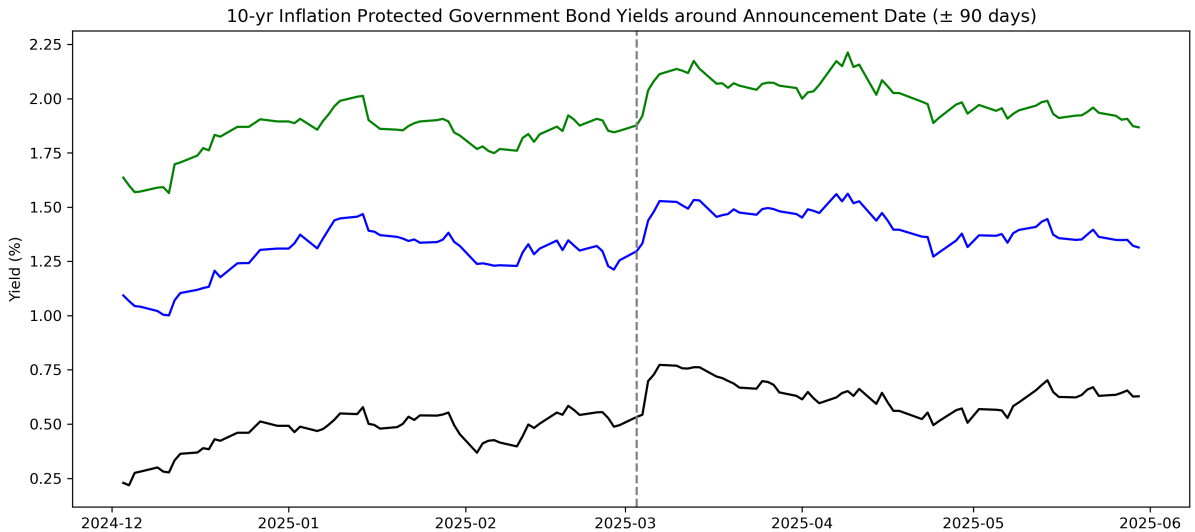
WRIGHT, THEODORE P. 1936. Factors affecting the cost of airplanes. *Journal of the aeronautical sciences*, **3**(4), 122–128.

YOUNG, ALWYN. 1991. Learning by doing and the dynamic effects of international trade. *The Quarterly Journal of Economics*, **106**(2), 369–405.

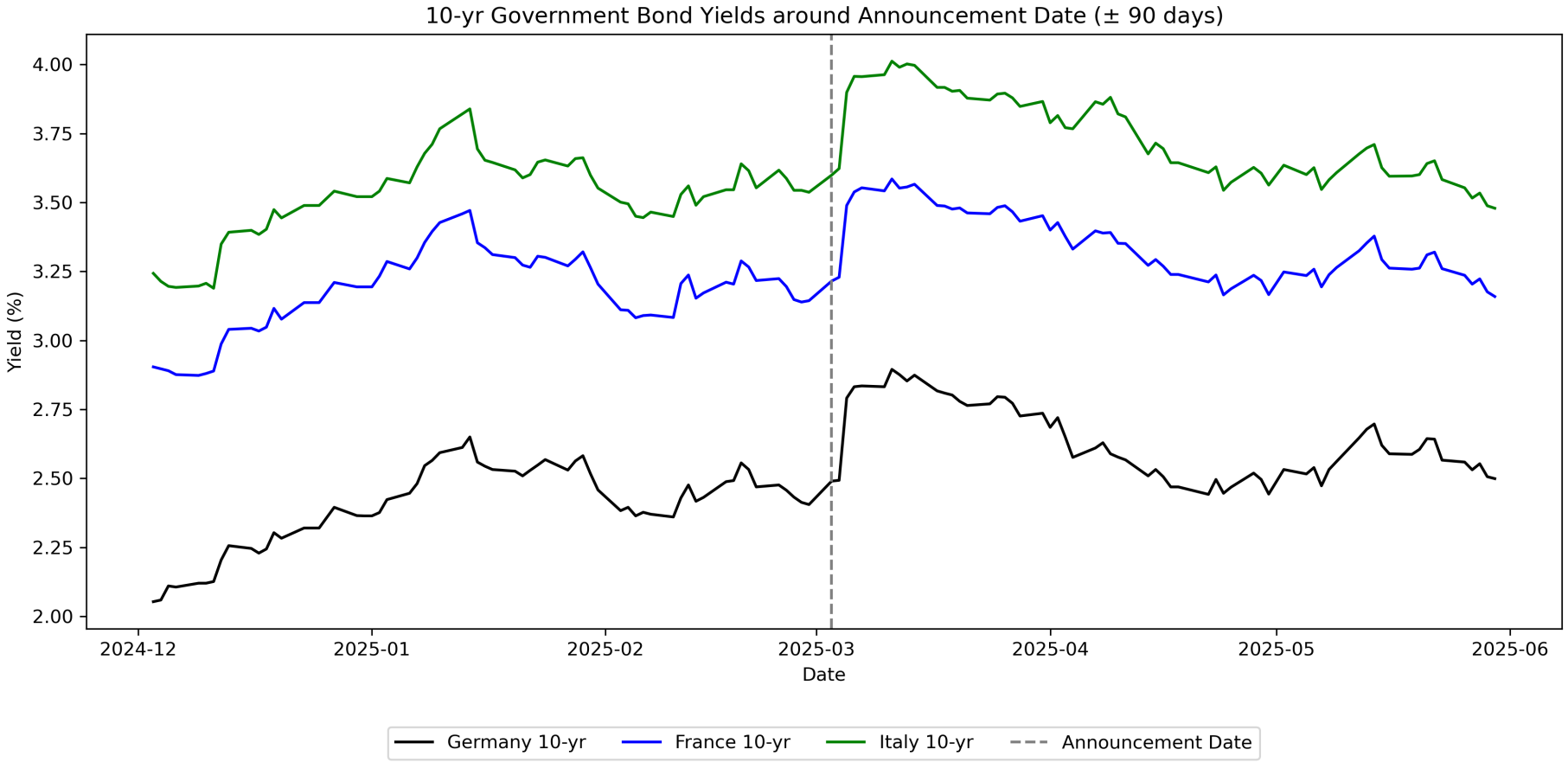
Additional Figures

REACTION TO GERMAN CONSTITUTIONAL CHANGE

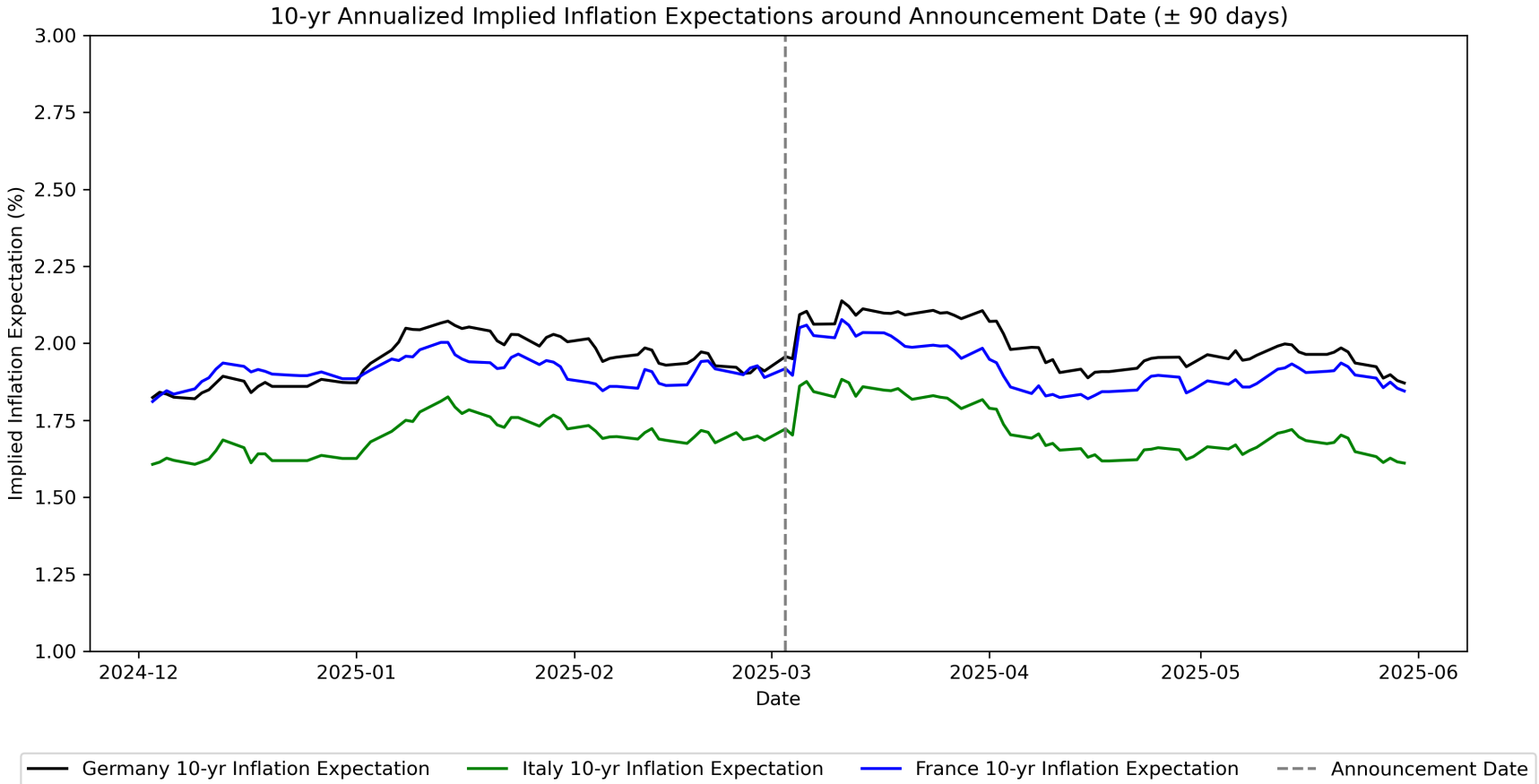




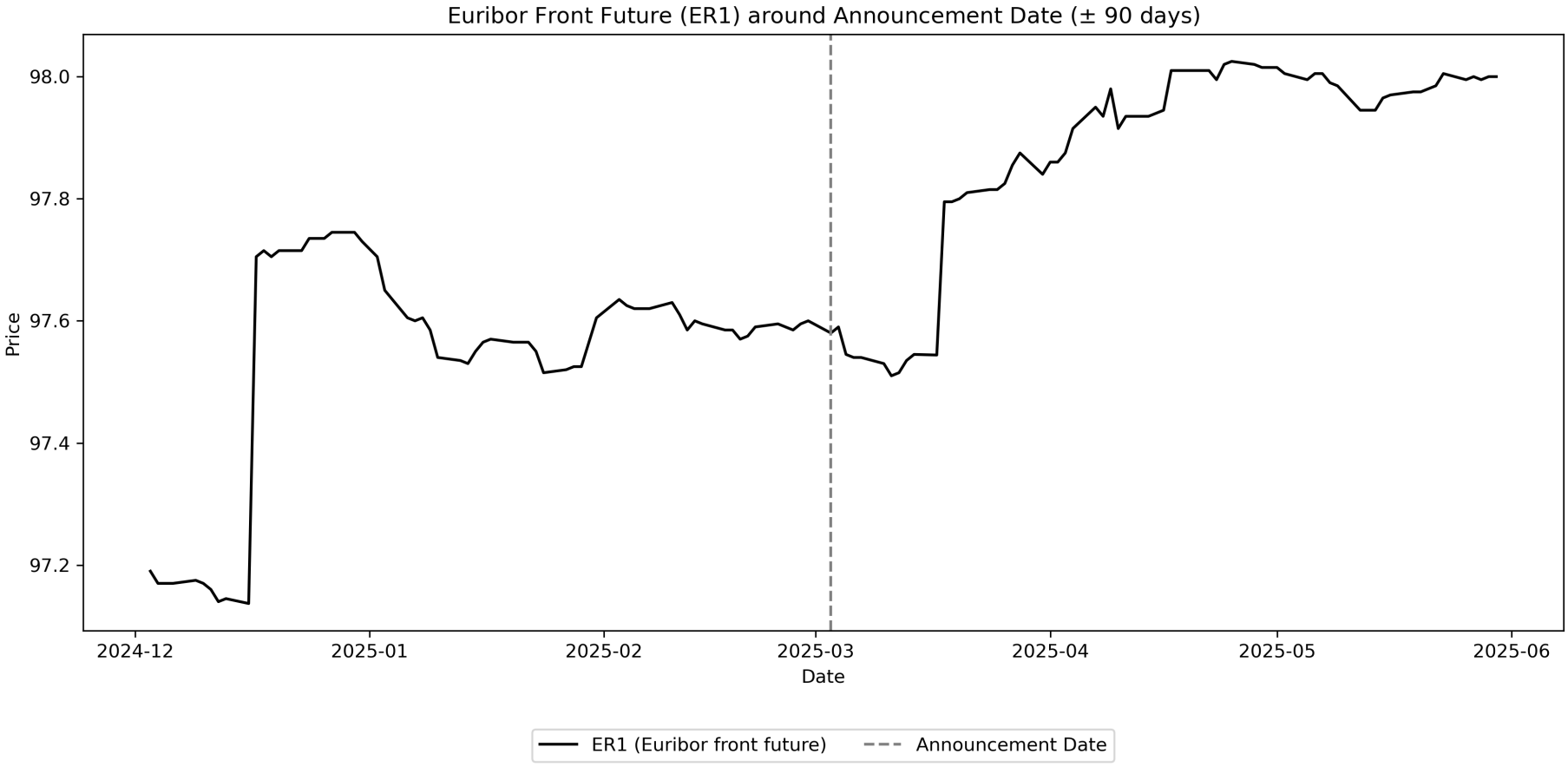
Reaction to German Constitutional Change



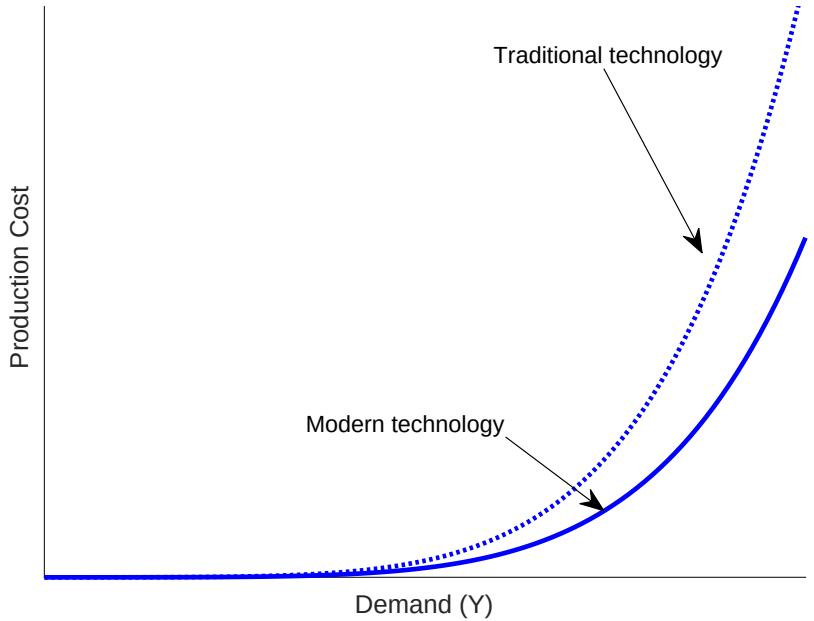
Reaction to German Constitutional Change

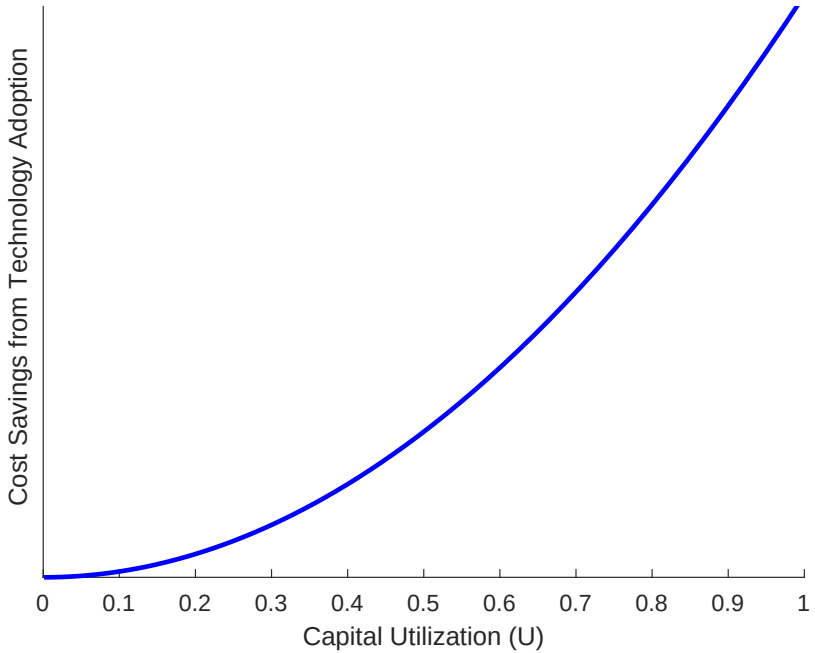


Reaction to German Constitutional Change

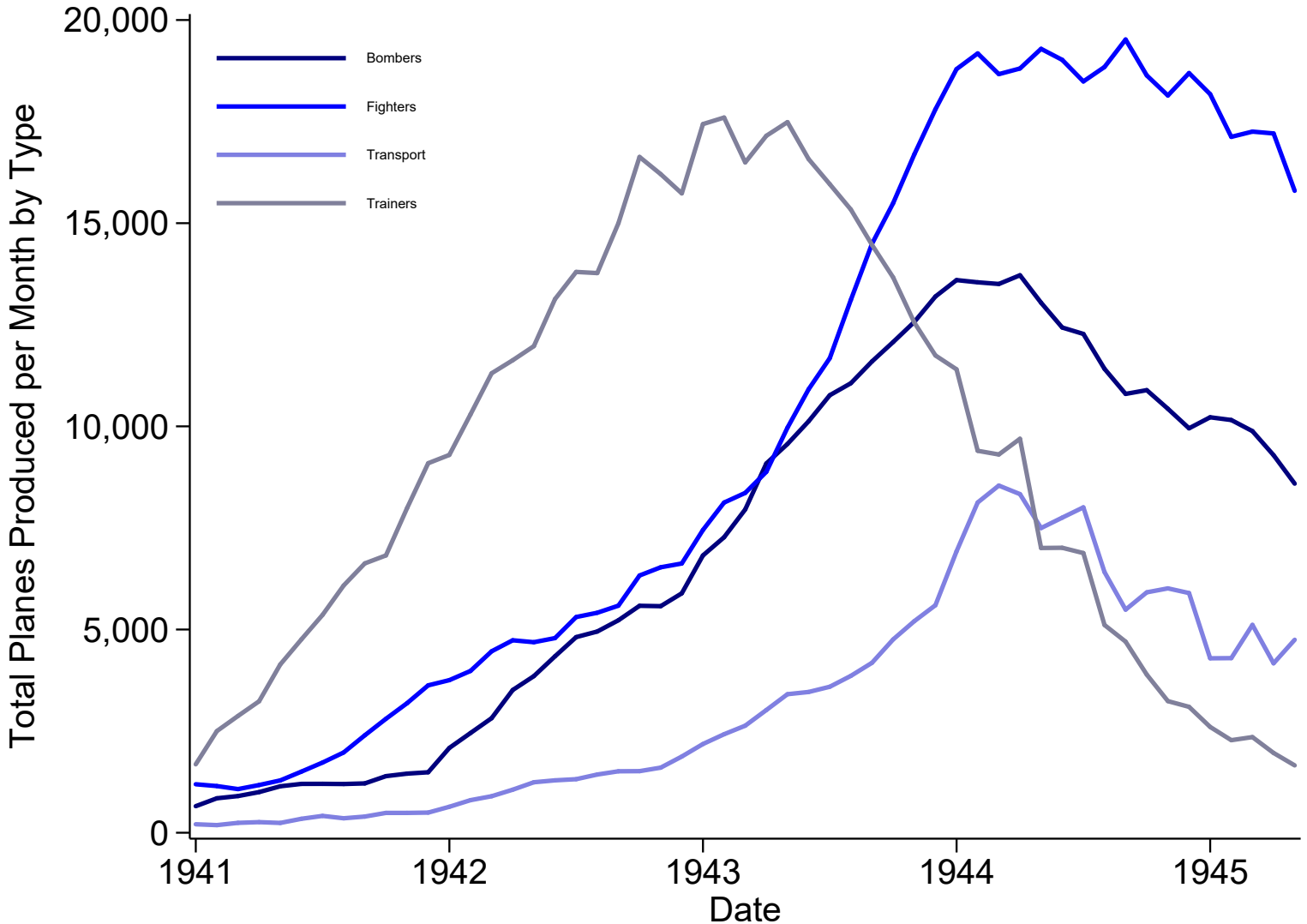


Learning by Necessity Theory in a Nutshell

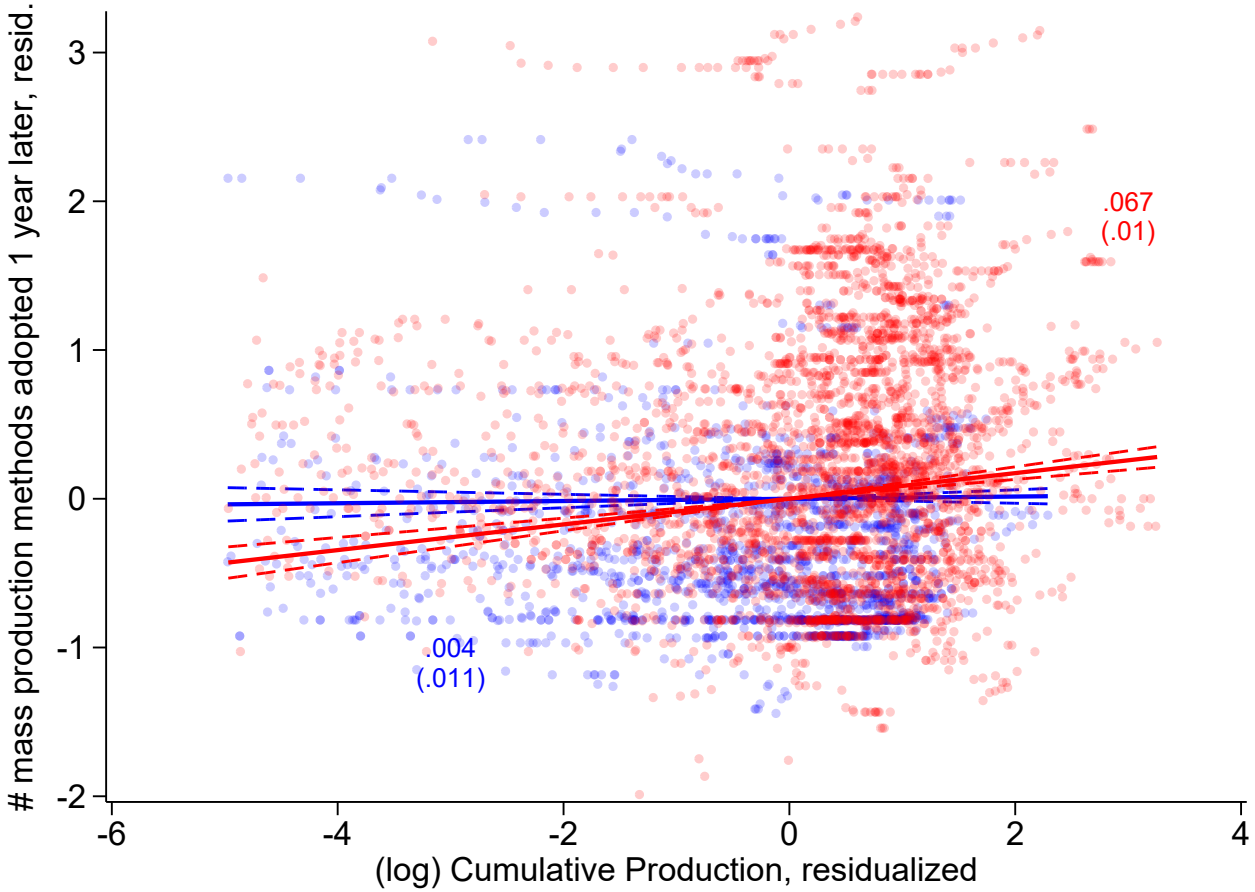




Production by Broad Aircraft Type

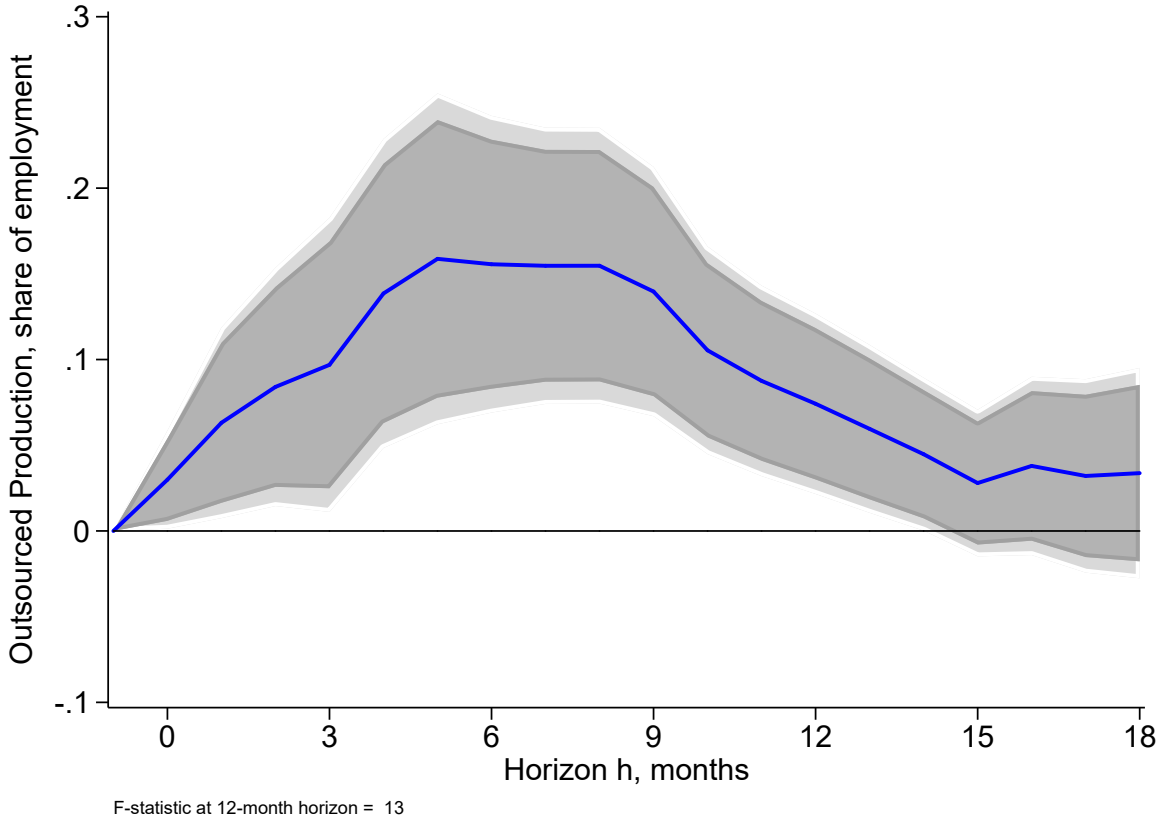


Mass Production Technique Adoption



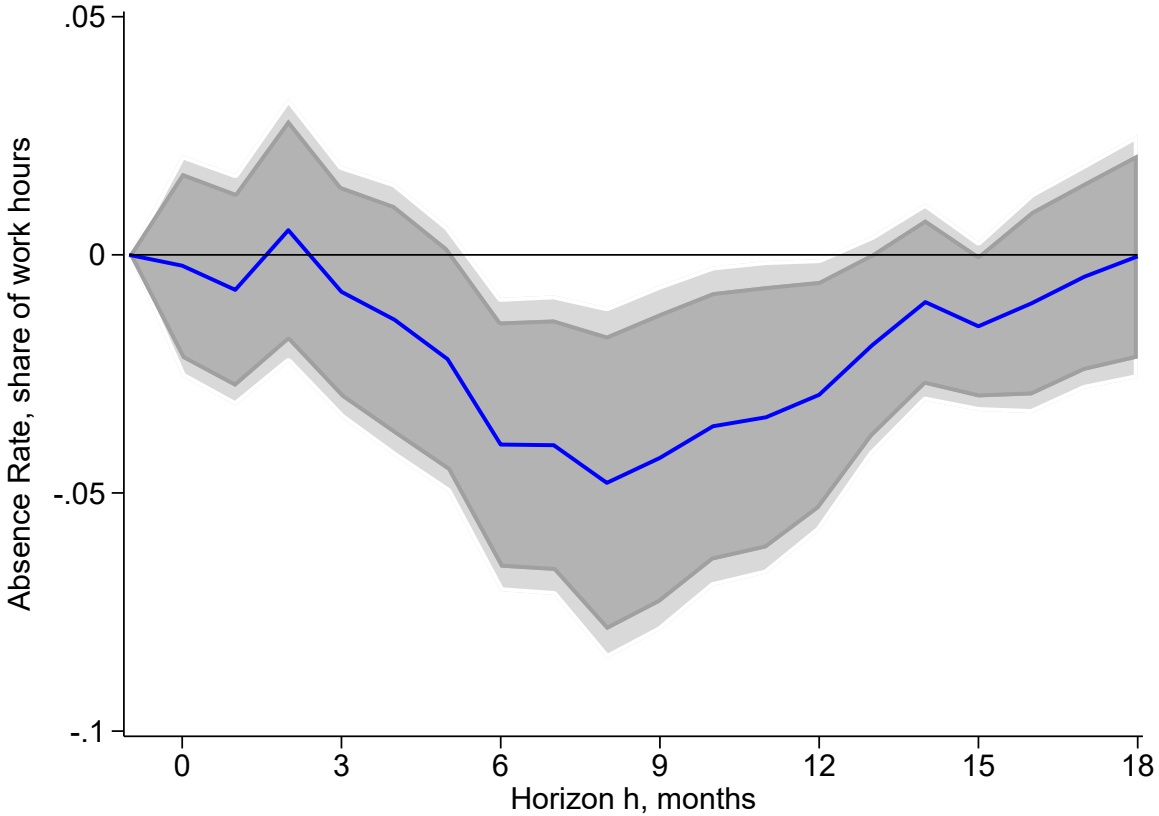
Number of mass-production methods adopted plotted against log cumulative production 12 months earlier. Both series are residualized from time, plant, and aircraft model fixed effects. Red dots and regression lines are for plants with above median

OUTSOURCING



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×model (production line) fixed effects, 6 monthly lags of output. 90% and 95% standard errors shaded. F-stat at 12-month horizon = 13

ABSENTEEISM



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.