

Does Productivity Growth Threaten Employment? “Robocalypse Now?”

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European Central Bank Annual Conference, Sintra, Portugal
27 June 2017

Longstanding concern: Automation threatens employment

Automation and Jobs: 200 Years of Concern

1. Luddites—Skilled weavers in the 19th century
2. U.S. Labor Secretary James Davis in 1927
3. Lyndon Johnson 1964 “Blue-Ribbon Presidential Commission on Technology, Automation, and Economic Progress”
4. Wassily Leontief in 1982:
Role of workers will diminish — like horses
5. Right now!

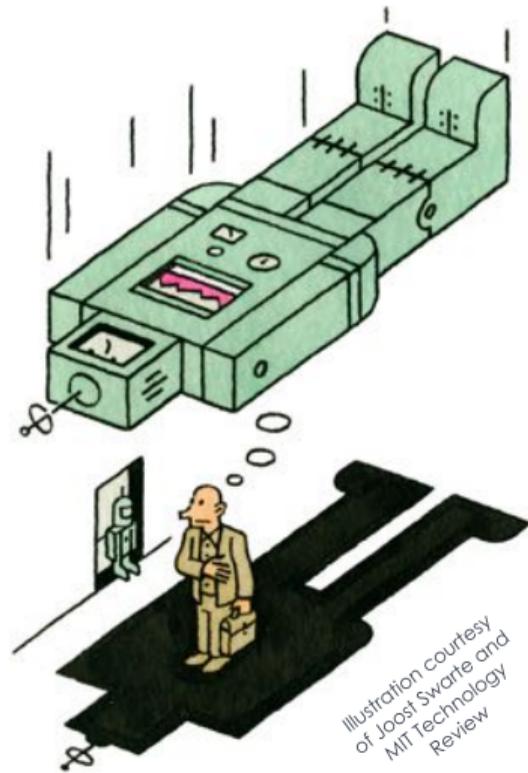


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of Joost Swarte and
MIT Technology
Review

Fundamentally, does rising productivity mean fewer jobs?

Citizen, policy-maker, intellectual concern

- The more work done by machines, the less work done by people
- Steam-powered hammer vs. “steel-driving man”

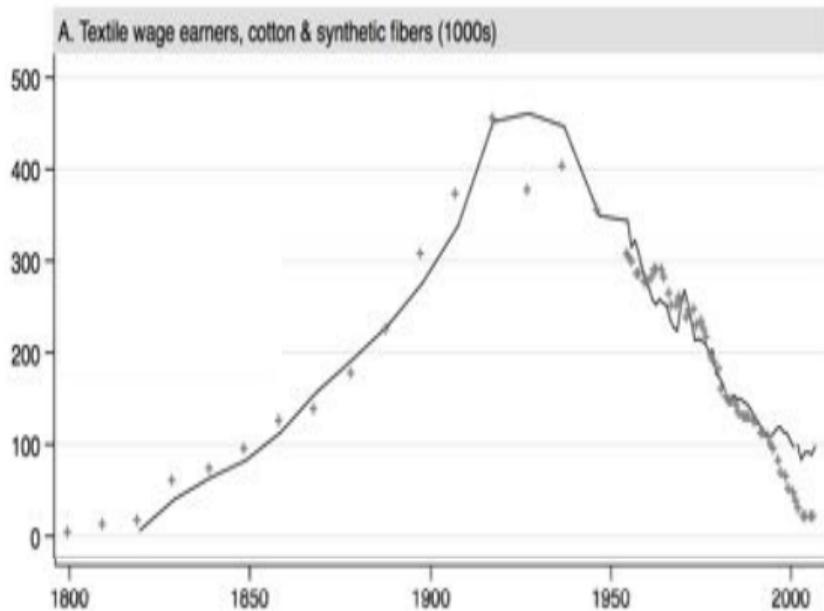
Professional economic opinion

- ① Elastic demand: Advancing sectors may *expand* (Bessen 2017)
- ② Income effects: Rising wealth creates *new demands* (Clark 1951)
- ③ Sectoral reallocation: Advancing sectors *contract*, but labor moves to lagging sectors (Baumol 1967)

Productivity → Employment: An 'Inverted U' (Bessen '17)

Employment first expands then contracts as productivity rises in textiles, iron, steel

Textile, Cotton, Fiber Workers

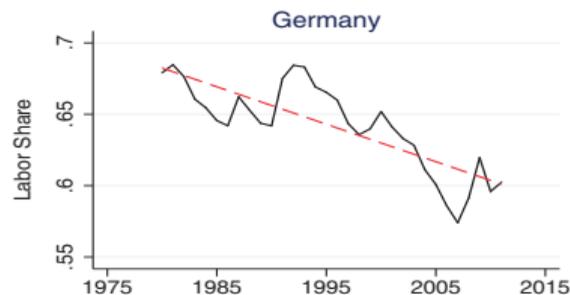
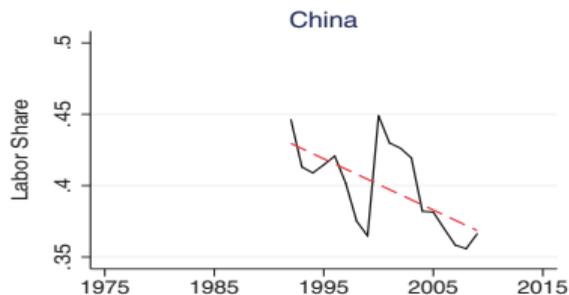
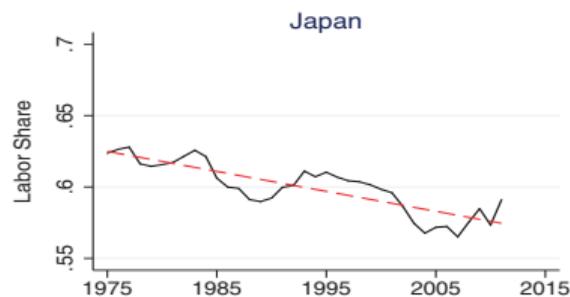
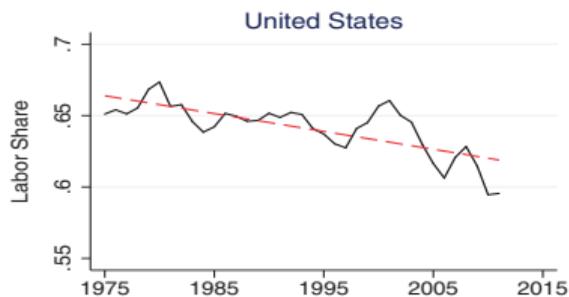


Primary Iron & Steel Workers



Economists appear to be losing confidence in these long-held theories: “Robocalypse Now?”

Labor’s share of national income falling cross-nationally



It's not just the falling labor share that has scholars worried...

An age of 'brilliant machines' (Brynjolfsson-McAfee '14)

- 1 Computers managing financial portfolios, beating 'Go' players
- 2 Websites and drones eliminating sales workers, warehouse workers
- 3 Robots leaving the assembly lines, coming for your jobs...

Economists have taken notice...

Emerging understanding makes clear that this can happen

- Machines can directly *replace* specific job tasks, *complement* workers in other job tasks, possibly spur creation of *new* labor-using tasks
- Autor-Levy-Murnane '03, Acemoglu-Autor '11, Acemoglu-Restrepo '16

Growing literature: models of labor immiseration

- ① Inter-generational market failure: Sachs & Kotlikoff '12, Berg et al. '17
- ② Task encroachment: No place left to hide (Suskind '17)
- ③ New tasks *might* endogenously be created 'fast enough' – or perhaps not (Acemoglu & Restrepo '16)

Evidence does not (yet) strongly support immiseration view

Vast literature makes clear that computerization has been skill-biased

- Autor-Katz-Kearney '08; Akerman-Kostol-Mogstad, '14

But little work on overall employment impact of technological Δ 's

- 1 Alexopoulos-Cohen '16: Technological progress strongly *employment-creating* — but in the 1910s–1940s
- 2 Gregory-Salomons-Zierahn '16: Employment-reducing effects of Routine-Replacing Technical Change (RRTC) *offset* by compensatory demand + local spillover effects
- 3 Graetz-Michaels '15: Industrial robots raising wages and value-added, *raising* demand for skilled workers across Europe (industry-level data)
- 4 Acemoglu-Restrepo '17: Industrial robots *lowering wages and employment* in U.S. local labor markets

This paper asks: Is recent labor-augmenting technological progress eroding employment?

- 1 Does productivity growth cause advancing industries to grow or shrink?
- 2 Do cross-industry spillovers offset or augment direct own-industry effects—and what's the net effect?
- 3 Has the employment-productivity relationship changed in the 2000's?
- 4 Is productivity-growth skill-biased—should we worry about jobs or skills?

Is recent labor-augmenting technological progress eroding employment?

Approach

- Study the **impact of productivity growth on employment** across 19 countries, 37 years
- Focus on **overall** productivity growth: (1) output per worker, (2) value-added per worker, (3) total factor productivity

Outcomes

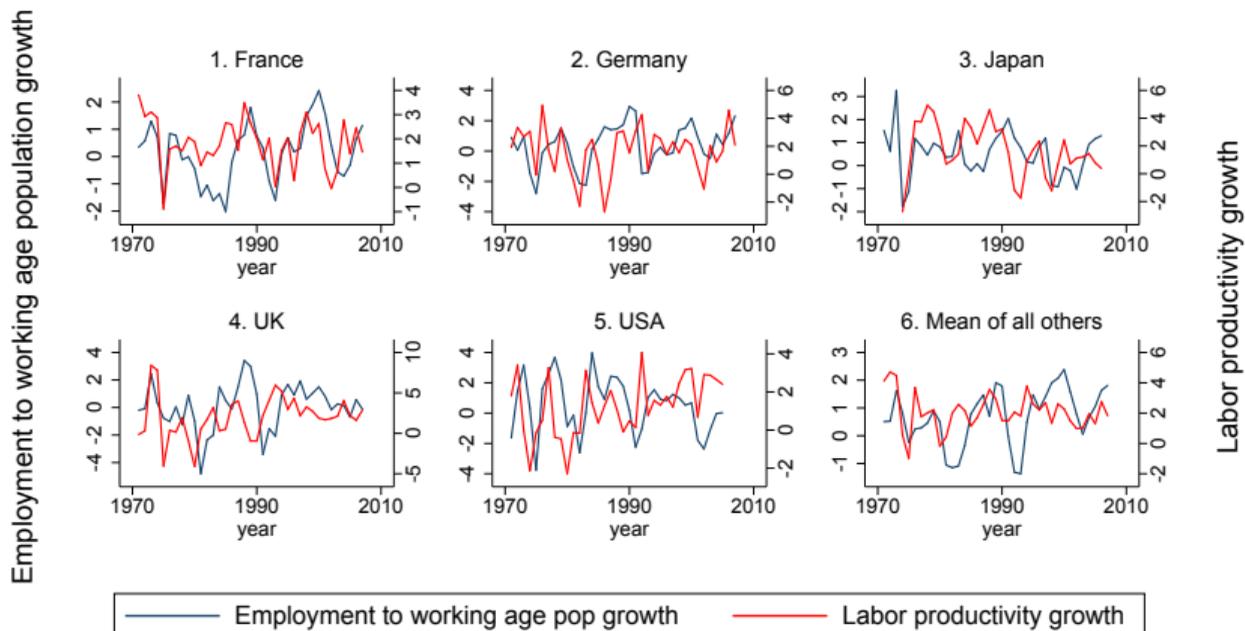
- Δ Employment by industry
- Δ Employment to working-age population—i.e., overall employment
- Δ Final consumption by industry—corroborating productivity effects
- Δ Skill inputs within industries
- Δ Skill inputs economy-wide—due to induced sectoral shifts

Outline

- 1 Data sources and the 'big picture'
- 2 Do 'advancing' industries grow or shrink?
- 3 Reconciling industry and aggregate-level evidence
- 4 Adding it up
- 5 Is this time (period) different?
- 6 Should we worry about jobs or skills?
- 7 Conclusions

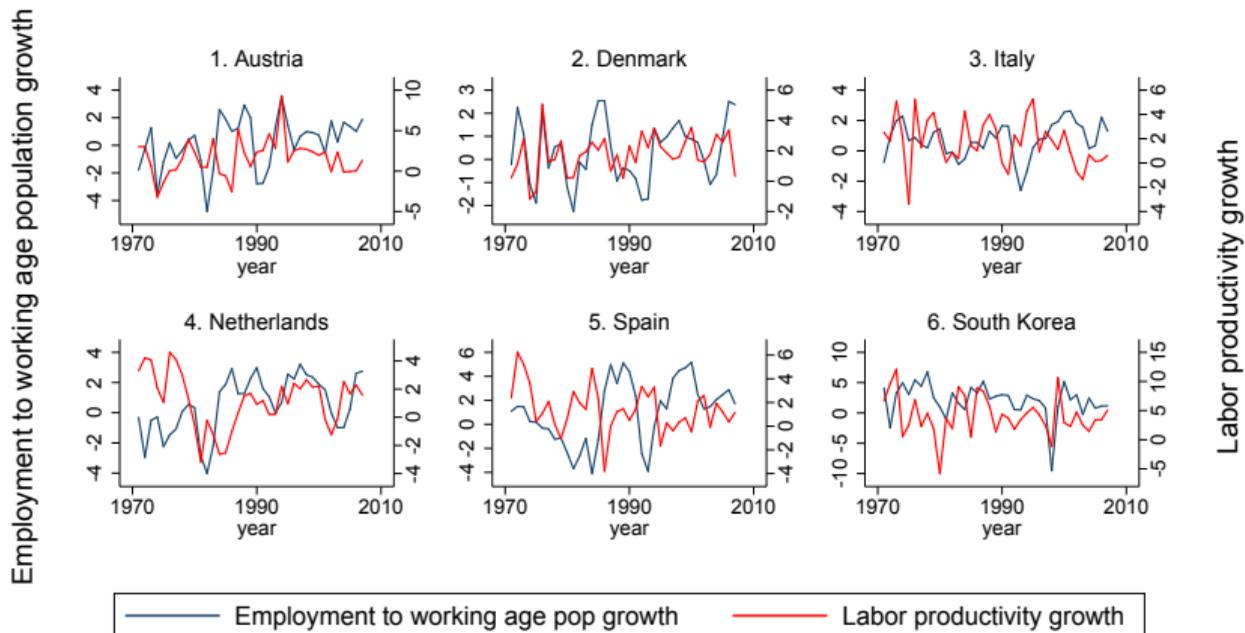
Big picture: Employment rate usually **rises** with productivity

Employment growth, productivity growth positively covary, 1970–2007 (cf. Francis-Ramey '04)



Figures are for the total economy, excluding agriculture, public administration, private households and extraterritorial organizations. All growth rates obtained as log changes $\times 100$. Graph 6 reports unweighted mean growth rates across the remaining 14 countries. Productivity is gross output per worker.

Not just the 'Big Five' countries: Employment rates **rise** with productivity



Figures are for the total economy, excluding agriculture, public administration, private households and extraterritorial organizations. All growth rates obtained as log changes $\times 100$. Graph 6 reports unweighted mean growth rates across the remaining 14 countries. Productivity is gross output per worker.

Data sources

Primary: EU KLEMS 1970-2007 (O'Mahony & Timmer '09)

- **19 developed countries**

- AUS, AUT, BEL, DNK, ESP, FIN, FRA, GER, GRC, IRL, ITA, JPN, KOR, LUX, NLD, PRT, SWE, UK, USA

- **28 industries**

- All non-farm employment except public administration, private households, and extraterritorial organizations

- **Employment and labor productivity**

- Real gross output per worker, real value added per worker, total factor productivity (TFP) by country-industry-year

Additional measures: World Input Output Tables (WIOT)

- **Measuring consumption responses to productivity gains**

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Do 'advancing' industries grow or shrink?

Testing whether rising productivity raises or lowers employment...

- Using KLEMS data for 17 countries, 25 industries, 37 years, fit country- by-industry- by-year stacked first-difference OLS model

$$\Delta \ln E_{cit} = \beta_0 + \beta_1 \Delta \ln LP_{cit} + [\alpha_c + \delta_t + \gamma_i] + \epsilon_{cit}$$

- $\Delta \ln LP_{cit}$ is **growth** in labor productivity
- i indexes industries
- c indexes countries
- t indexes years
- E is employment

Models are weighted by the time-averaged employment shares of industries within countries

Do 'advancing' industries grow or shrink?

What should happen to industry employment as $\Delta \ln LP_{cit}$ rises?

① Lump-of-labor

- Could *fall one-for-one* with labor productivity growth: $\frac{\partial \ln E_i}{\partial \ln LP_i} = -1$

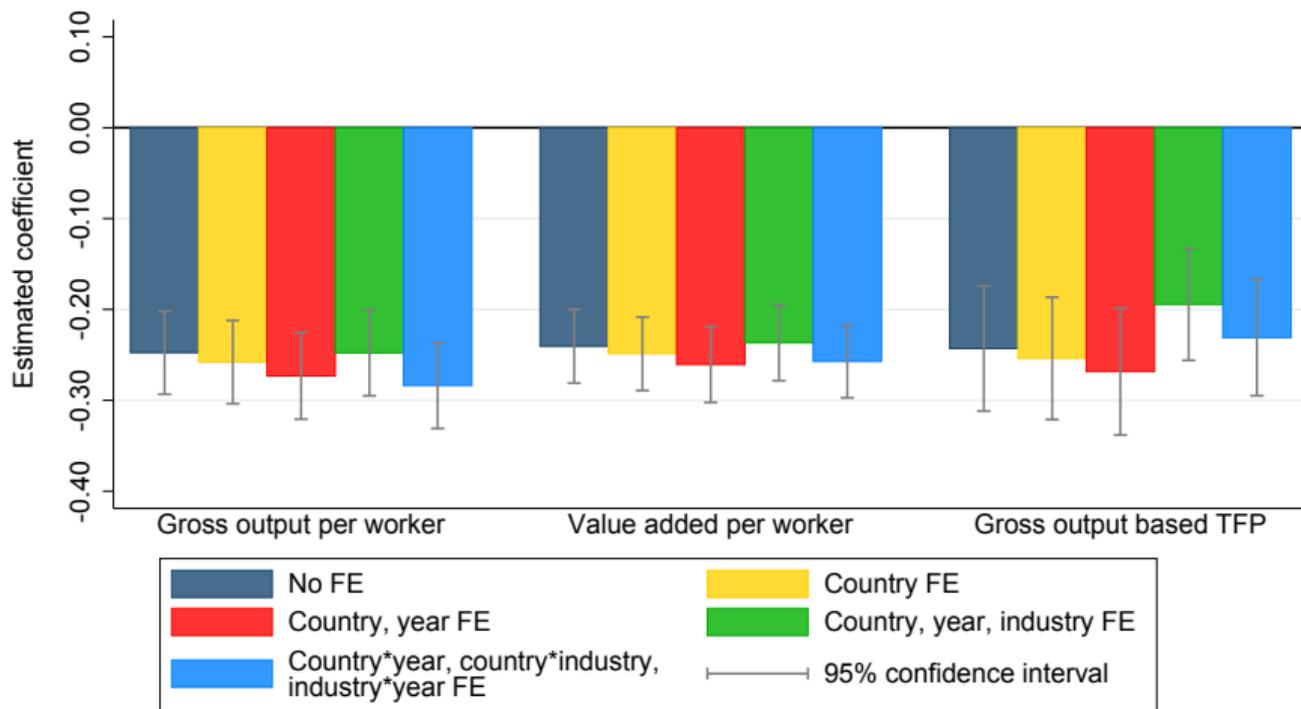
② Demand surge (iPhone, textiles)

- Could *surge* as price/quality improve: $\frac{\partial \ln E_i}{\partial \ln LP_i} > 0$

③ Unbalanced growth (Baumol)

- Could *fall* somewhat less than *one-for-one*: $-1 < \frac{\partial \ln E_i}{\partial \ln LP_i} < 0$

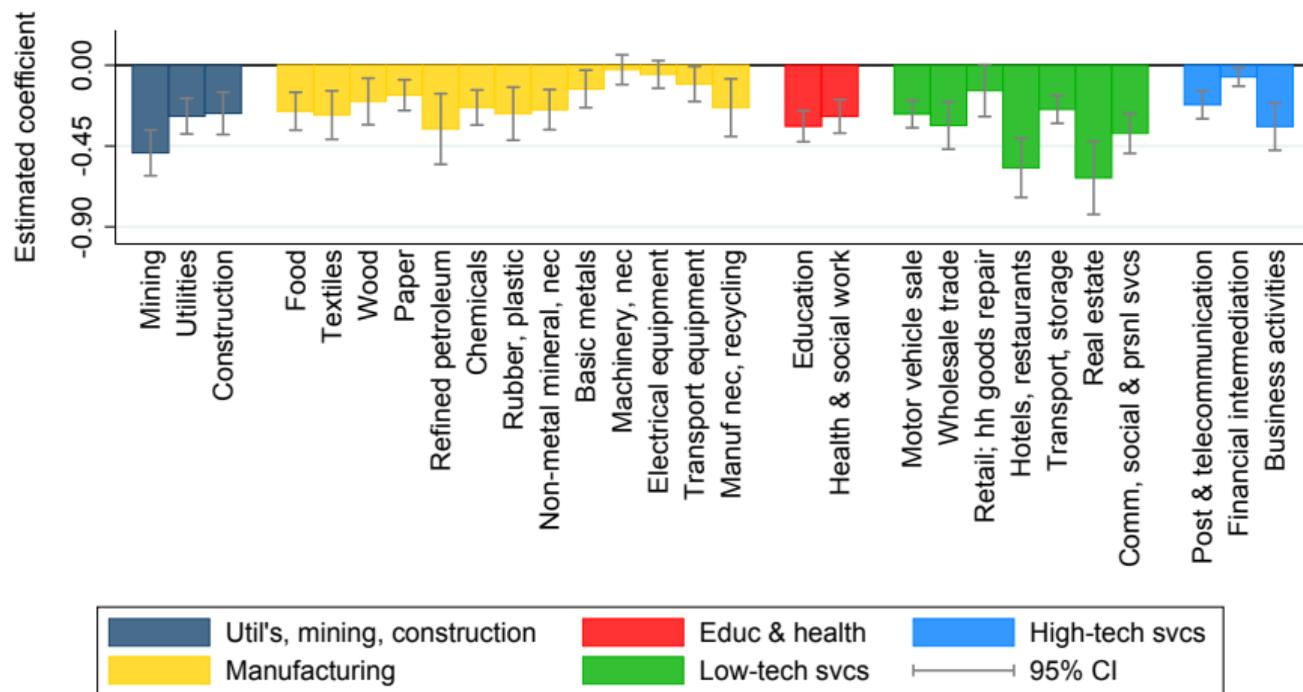
What **does** happen: Rising labor productivity → Falling industry employment



All models are estimated by OLS and control for population growth whenever country-year fixed effects are not included.

Rising labor productivity → Falling industry employment

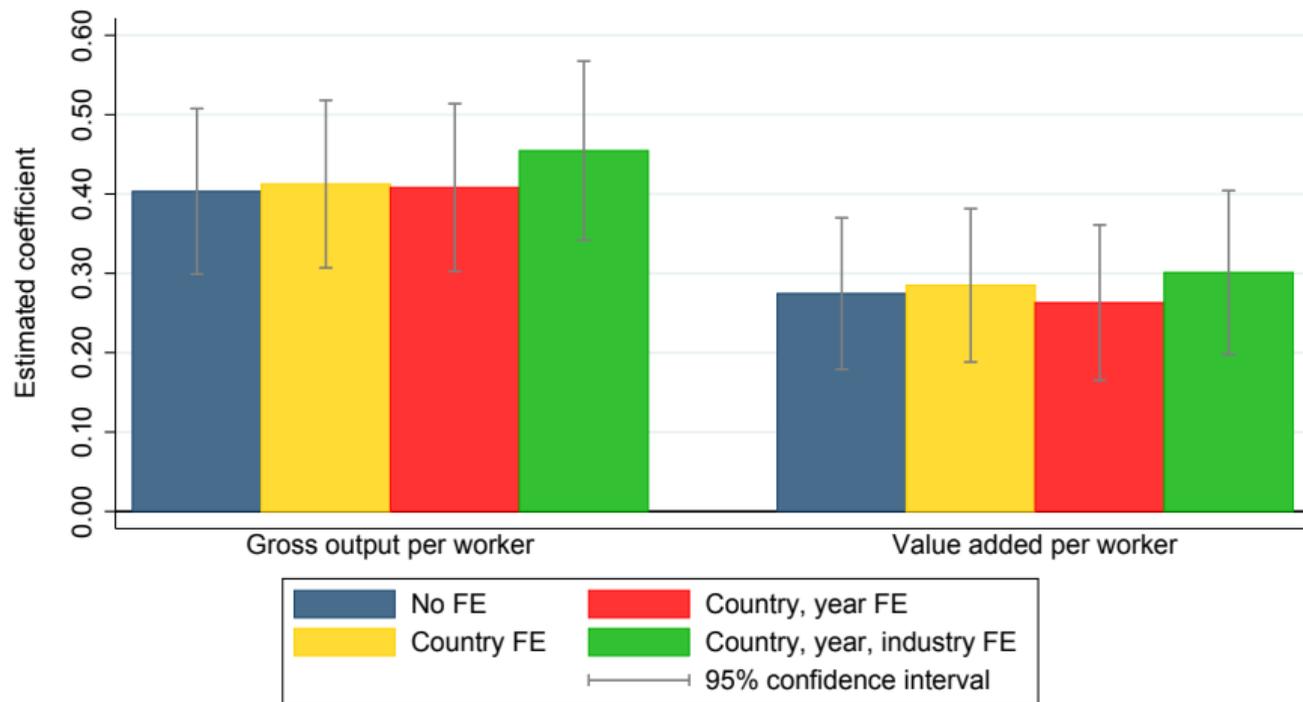
Using **gross-output** based labor productivity growth: Found in every industry



From a model with a full set of industry interactions in all productivity terms; country, industry, and year fixed effects; and controlling for population growth. Productivity is gross output per worker.

Reality check: Is there a consumption response? Check!

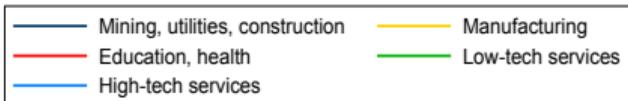
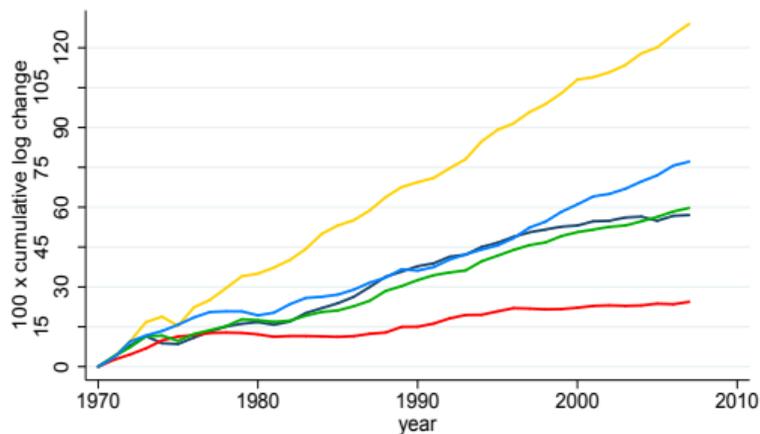
Consumption of industry output **rises** with industry productivity, even as employment **falls**



WIOD, 1995-2009. Models are estimated by OLS; contain country, year, and industry FE; and control for population growth.

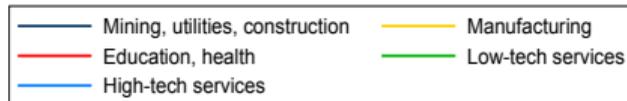
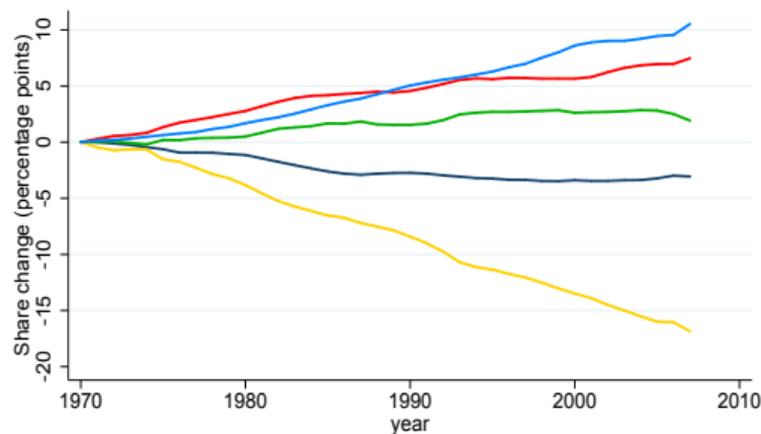
Unbalanced growth: Employment in 'advancing' sectors shrinks

Cumulative Productivity Growth



Unweighted average across all 19 countries. Productivity is gross output based.

Cumulative Change in Employment



Shares normalized to 0 in 1970. Unweighted average across all 19 countries.

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Negative employment impact at **industry** level but seemingly **not** at **aggregate** level. **Why not?**

Reconciling the evidence

- Perhaps there are **employment spillovers** elsewhere in economy
 - ① Rising final demand — income effects
 - ② Inter-industry demand linkages

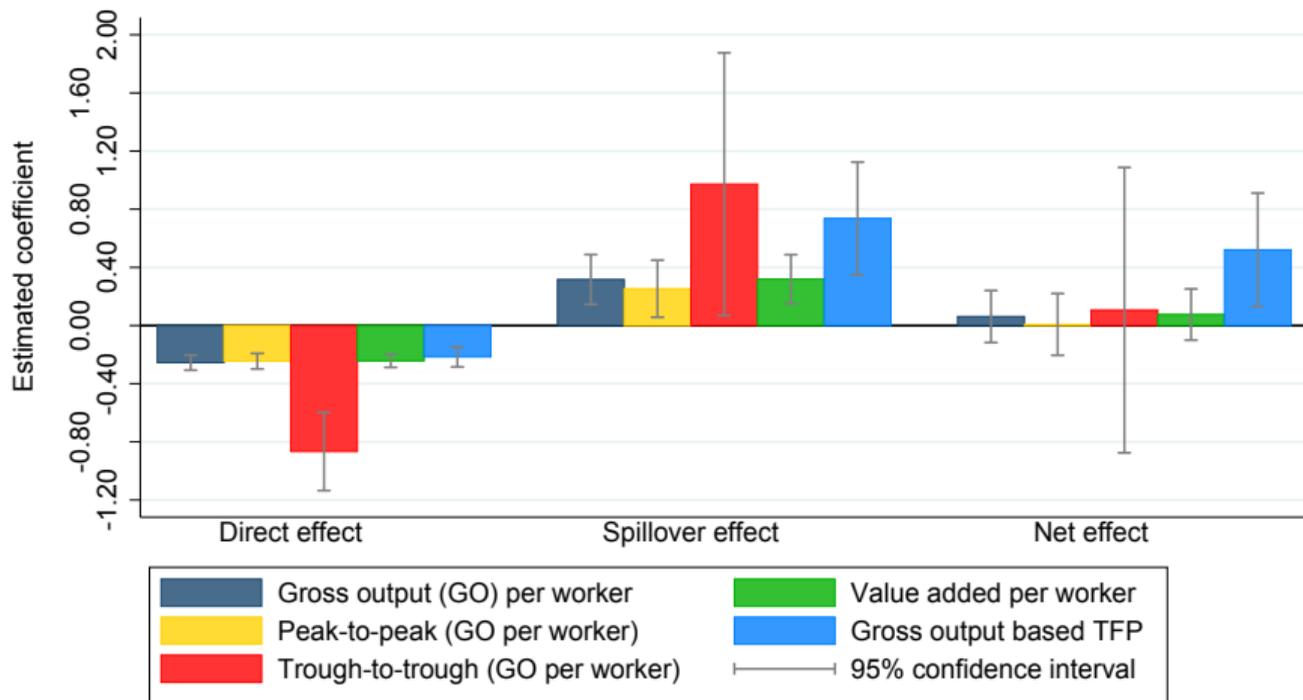
Use industry-level and country-level data to estimate

$$\Delta \ln E_{cit} = \beta_0 + \beta_1 \Delta \ln LP_{cit} + \sum_{k=0}^3 \beta_{2+k} \Delta \ln \widetilde{LP}_{ct-k, j \neq i} [+ \alpha_c + \delta_t + \gamma_i] + \epsilon_{cit}$$

- $\widetilde{LP}_{ct-k, j \neq i}$ is aggregate labor productivity excluding own-industry i
- LP_{cit} is own-industry labor productivity
- c indexes countries
- t indexes years

Direct *and* spillover effects of productivity growth

Spillover effects **fully offset** internal effects: Net impact on emp/pop is weakly **positive**



All models are estimated by OLS; contain country, year, and industry FE; and control for population growth.

Is all productivity growth equally job-creating?

Industry productivity growth raises aggregate employment on average—but does it matter where productivity originates?

- We have so far restricted effects of industry productivity to have **uniform** impacts
- But **internal and external** effects of productivity growth **may vary across sectors**
 - Relative weight in the economy
 - Product market competition
 - Demand saturation
 - Integration in international production chains.

Is all productivity growth equally job-creating?

Allow direct effects and spillovers to differ by sector

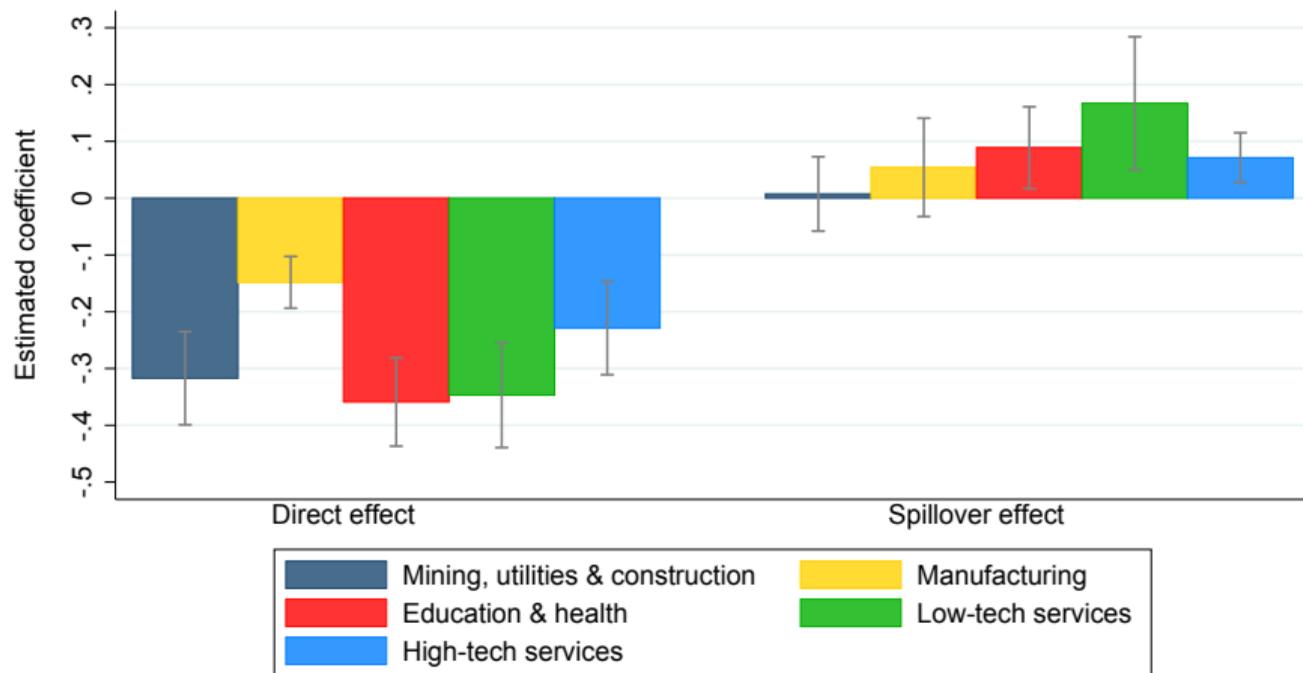
- ① *Mining, utilities and construction*
- ② *Manufacturing*
- ③ *Education and health*
- ④ *Low-tech services: Retail, sales, hotels, restaurants, etc.*
- ⑤ *High-tech services: Finance, business services, telecoms*

$$\Delta \ln E_{ict} = \beta_0 + \sum_{s(i)=1}^5 \beta_{1,s(i)} \Delta \ln LP_{ict} + \sum_{s(i)=1}^5 \sum_{k=0}^3 \beta_{2+k,s(i)} \Delta \ln \widetilde{LP}_{ct-k,s(i),j \neq i} \\ [+ \alpha_c + \delta_t + \gamma_i] + \epsilon_{ict}$$

- $\hat{\beta}_{1,s(i)}$ are **sector-specific** effects of **own-industry** labor productivity
- $\hat{\beta}_{2+k,s(i)}$ are **sector-specific** spillovers to **other** industries

Sizes of direct and spillover effects differ by sector

Manufacturing has **least negative** direct effect; low-tech services has **largest positive** spillovers



Model is estimated by OLS; includes country, industry, and year FE; and controls for population growth. Productivity is gross output per worker.

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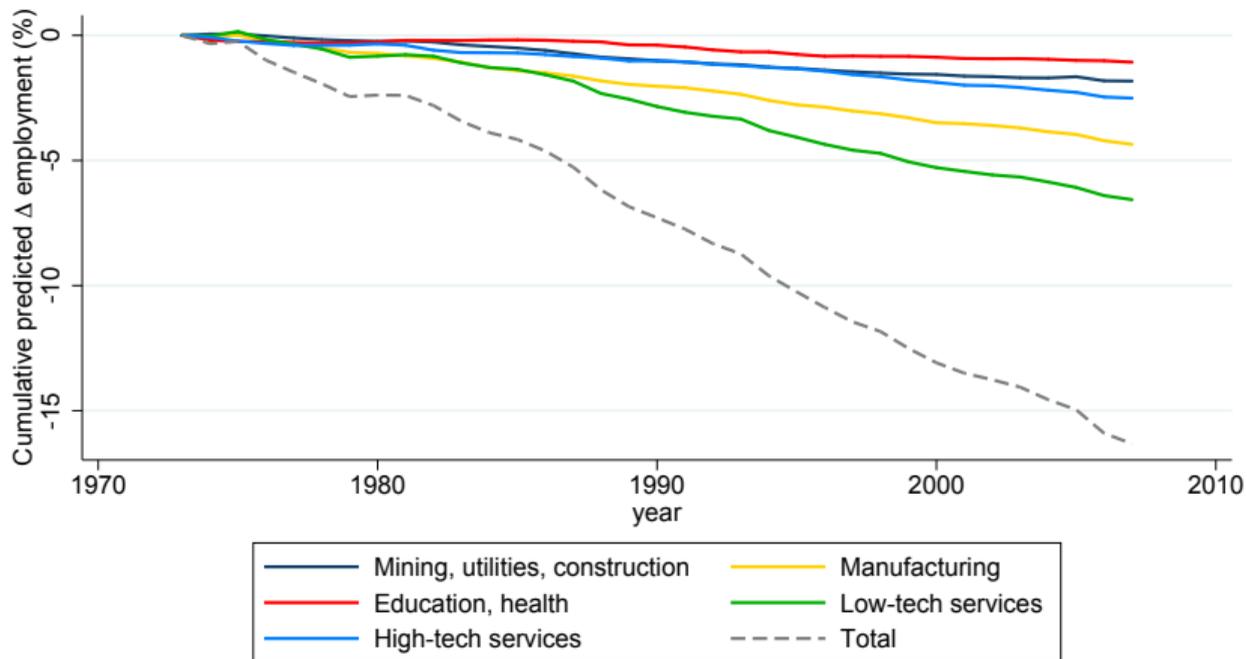
Translating direct+spillover effects into total emp/pop

What do direct + spillover effects imply for emp/pop in net?

- Use estimates to infer how much **each sector's productivity** growth has augmented or decreased **total** employment-to-population

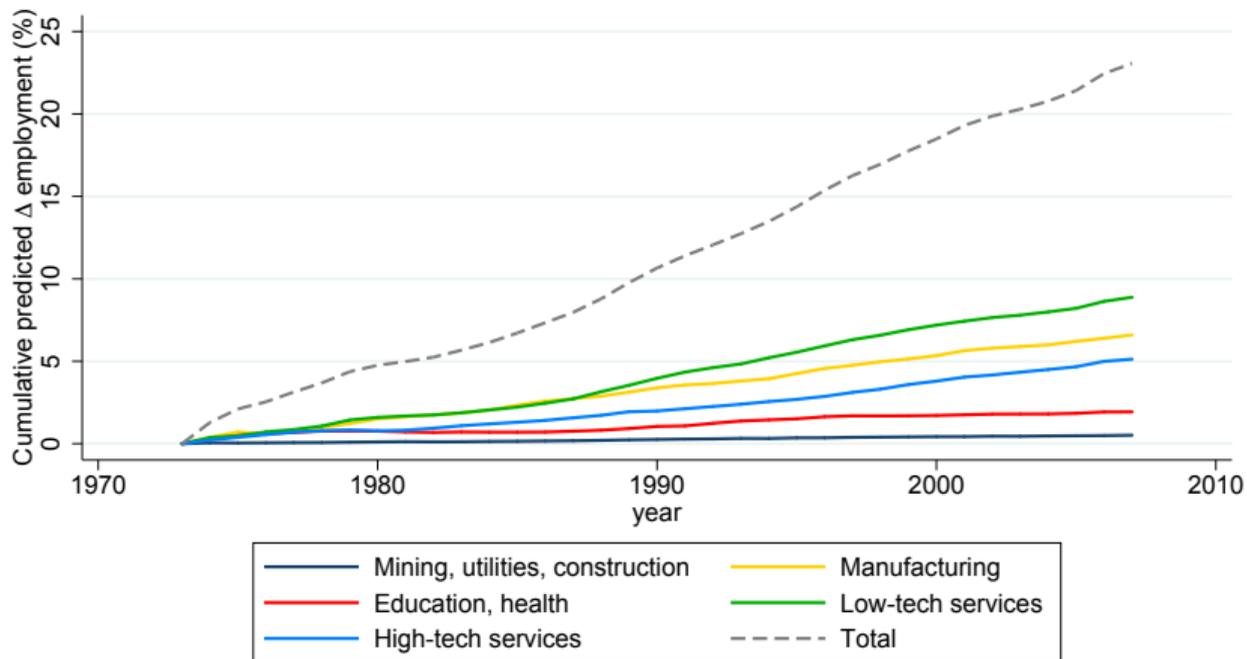
$$\Delta \hat{E}_{ict} = \{E_{ic,t=base} \times 1(i \in s) \times \hat{\beta}_{1,s(i)} \times \Delta \ln LP_{ict}\} \\ + \{E_{ic,t=base} \times \sum_{s(i)=1}^5 \sum_{k=0}^3 \hat{\beta}_{2+k,s(i)} \times \Delta \ln \tilde{LP}_{ct-k,s(i),j \neq i}\}$$

Implied cumulative **direct** effects of productivity growth on **total** Δ employment-to-population in % pts, 1970–2007



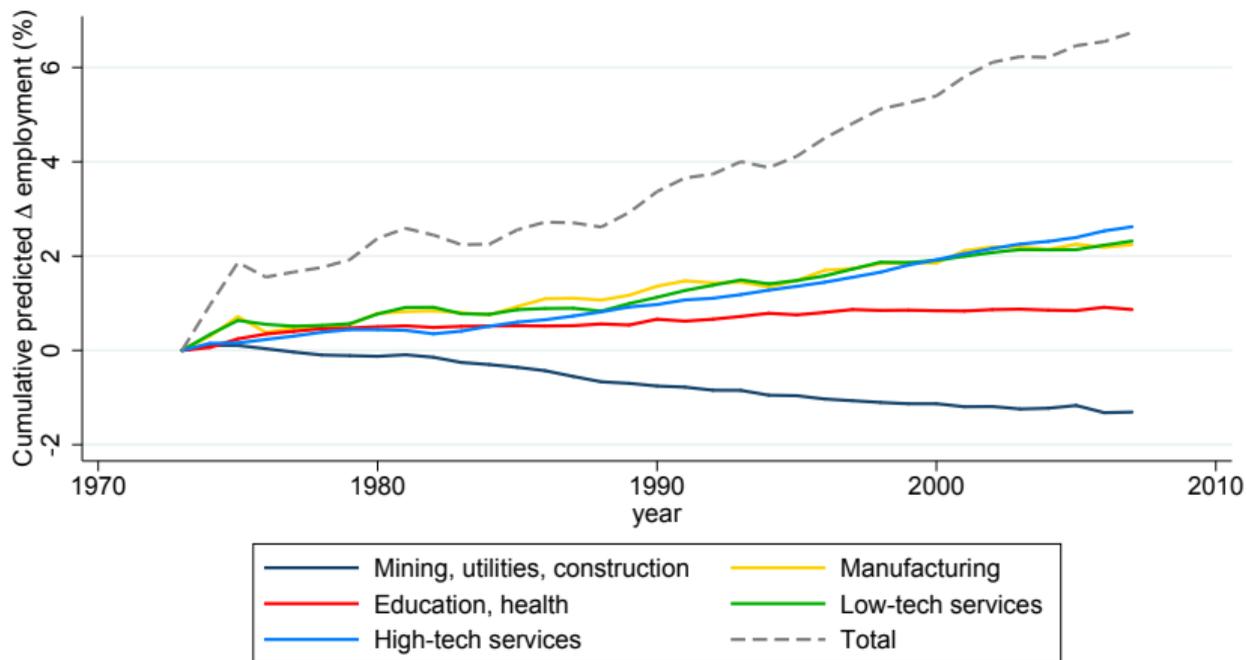
Based on model 5 from Table 7; prediction averaged across all 19 countries. Productivity is gross output per worker.

Implied cumulative **spillover** effects of productivity growth on **total Δ employment-to-population** in % pts, 1970–2007



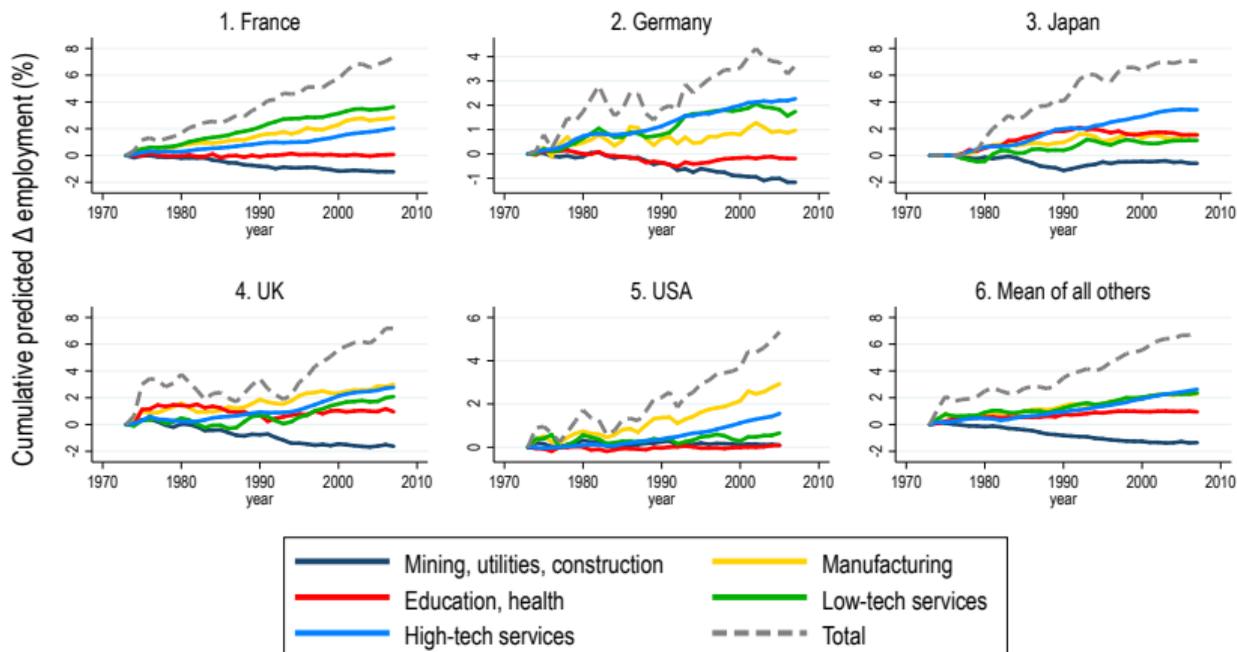
Based on model 5 from Table 7; prediction averaged across all 19 countries. Productivity is gross output per worker.

Implied cumulative **net effects** of productivity growth on Δ employment-to-population in % pts, 1970–2007



Based on model 5 from Table 7; prediction averaged across all 19 countries. Productivity is gross output per worker.

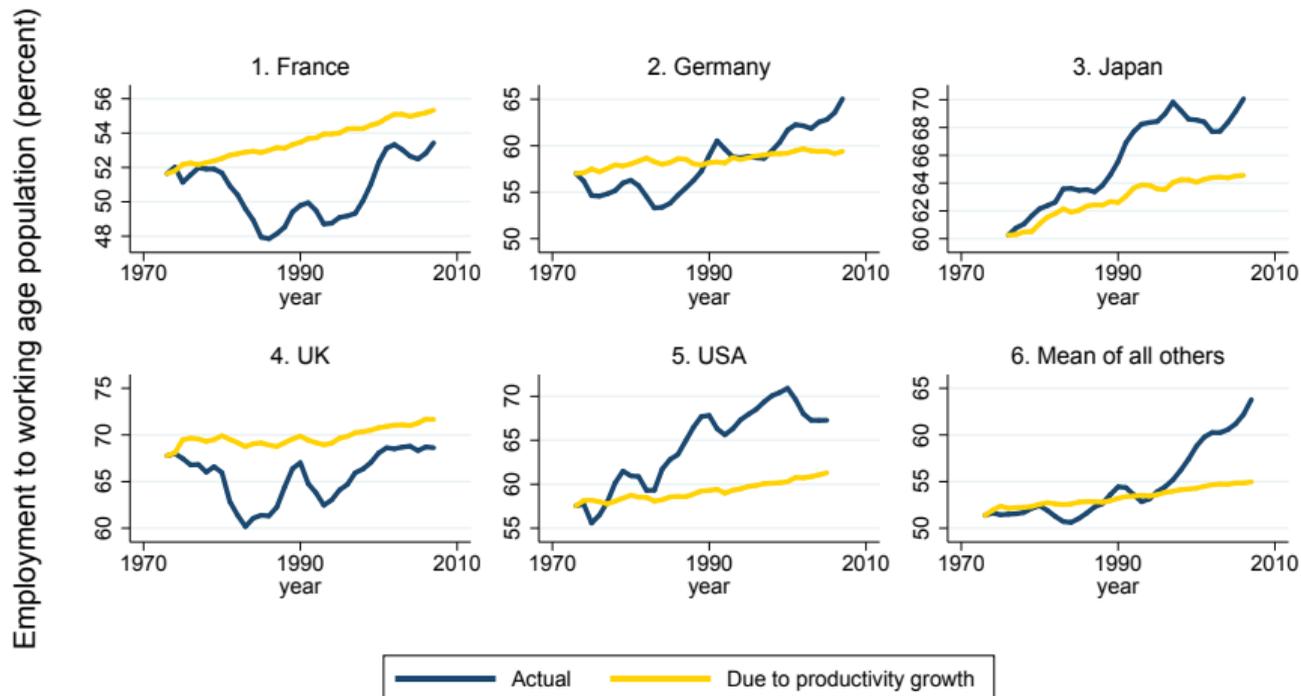
Implied cumulative **net effects** of productivity growth on Δ employment-to-population in % pts: Five largest economies



Based on model 5 from Table 7. Productivity is gross output per worker.

How **big** are these effects? Pretty big actually...

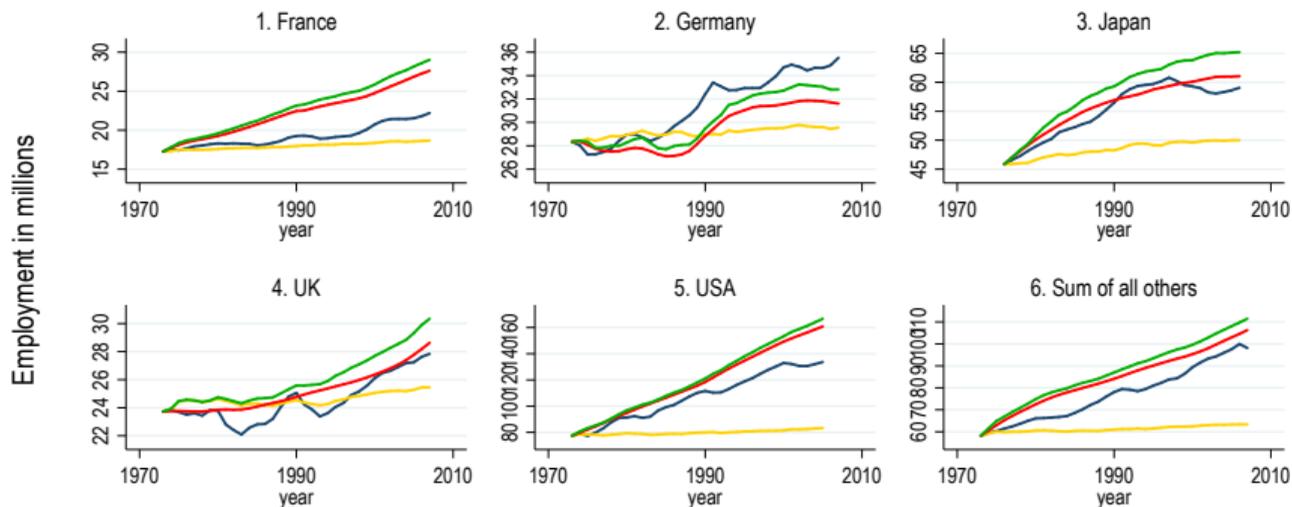
Actual changes in emp-to-pop vs. contribution of productivity growth: Five largest economies



Figures are for the total economy, excluding agriculture, public administration, private households and extraterritorial organizations. Productivity is gross output per worker.

What's the key driver of job growth? Population growth!

Actual growth in total workers vs. contribution of population growth & productivity growth



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Productivity \Rightarrow Job growth: Is this time (period) different?

Productivity and job growth appear to diverge in some countries in 2000s (e.g., U.S.)

- Consider whether the **productivity-employment relationship has changed over time**
- **Why?** Changing technologies, growing global production chains, shifting market structure, demand saturation

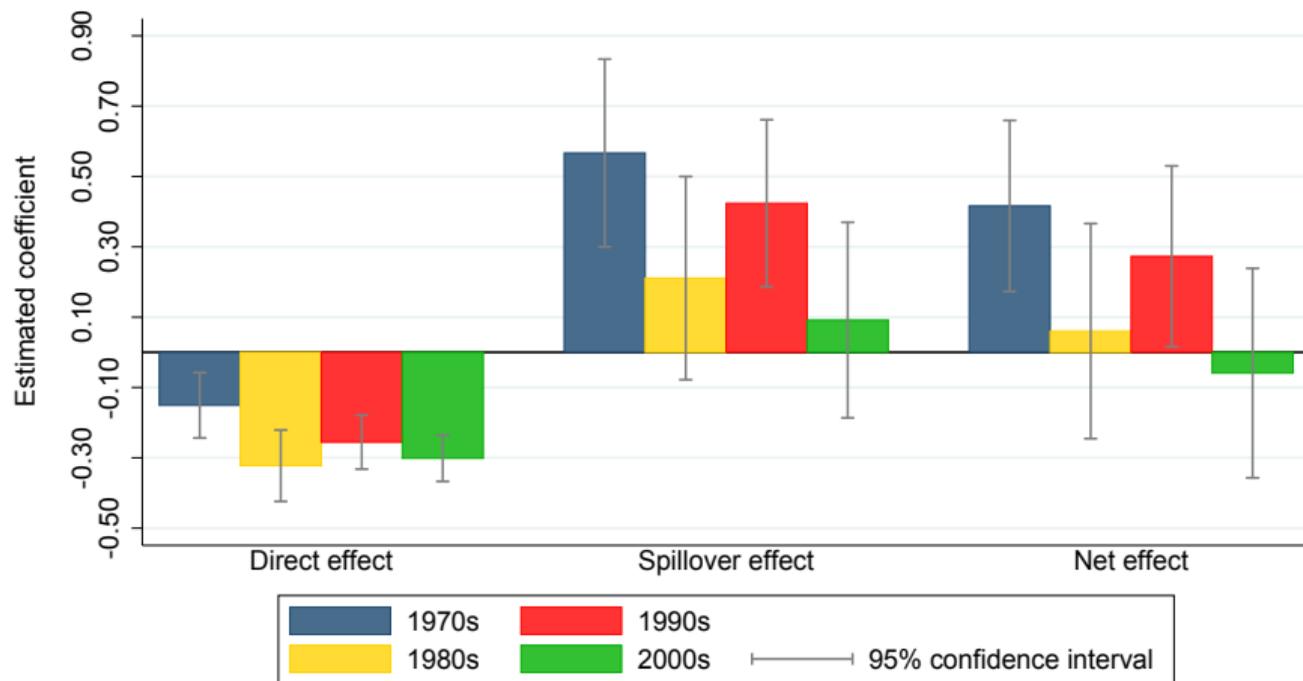
Add decade-specific effects to baseline equation

$$\Delta \ln E_{ict} = \beta_0 + \sum_{d(t)=1}^4 \beta_{1,d(t)} \Delta \ln LP_{ict} + \sum_{d(t)=1}^4 \sum_{k=0}^3 \beta_{2+k,d(t)} \Delta \ln \widetilde{LP}_{ct-k,j \neq i} + \alpha_c + \delta_t + \gamma_i + \epsilon_{ict}$$

- where $d(t)$ indicates decades

Internal effect **more** (–) and spillover **less** (+) in 2000s

But 2000s do **not** look very **different** from the 1980s



Model is estimated by OLS; contains country, year, and industry FE; and controls for population growth. Productivity is gross output based.

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Even if productivity growth is **neutral for employment**, may be **non-neutral for skill demand**

Labor productivity growth may shift skill demands in two ways

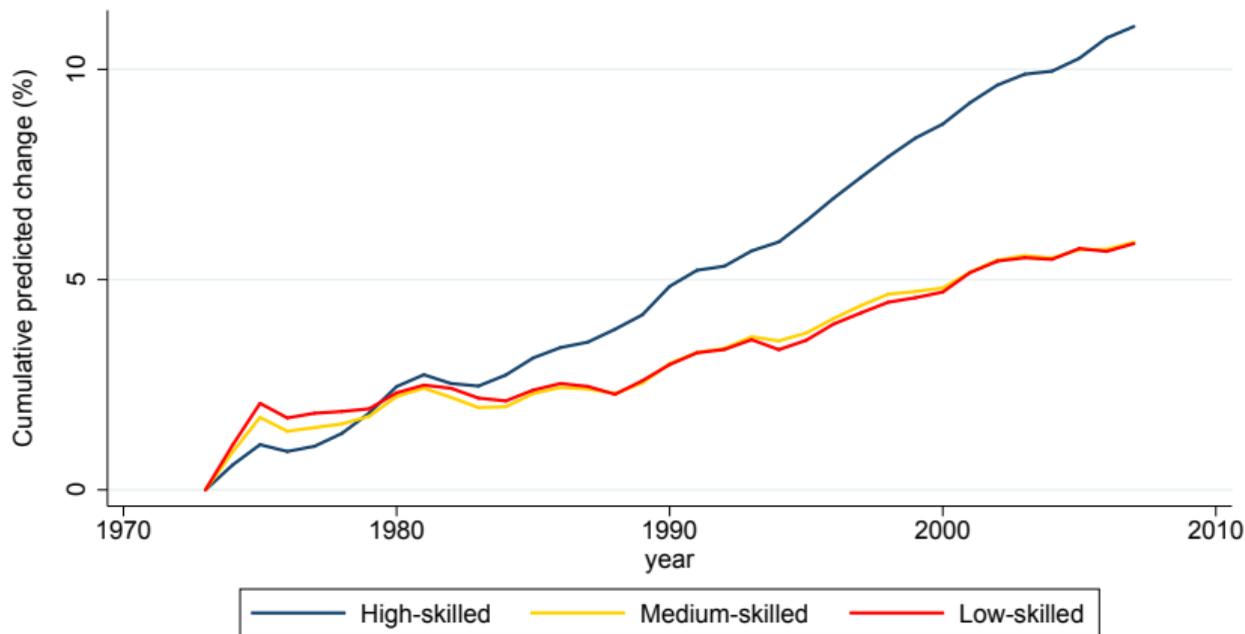
- 1 **Skill bias:** Firms may **differentially eliminate low-, medium-, or high-skill** workers
 - We find that this is **not quantitatively important**
- 2 **Sector bias:** 'Advancing' sectors **shrink** + 'lagging' sectors **grow**
 - High productivity growth in **manufacturing** and **primary** industries **may shift the weight of employment** towards more **skill-intensive sectors**
 - This turns out to be **quite important**

Even if productivity growth is neutral for employment, may be **non-neutral for skill** demand

Scale predicted employment growth by industry by average share of low-, middle-, and high- education workers

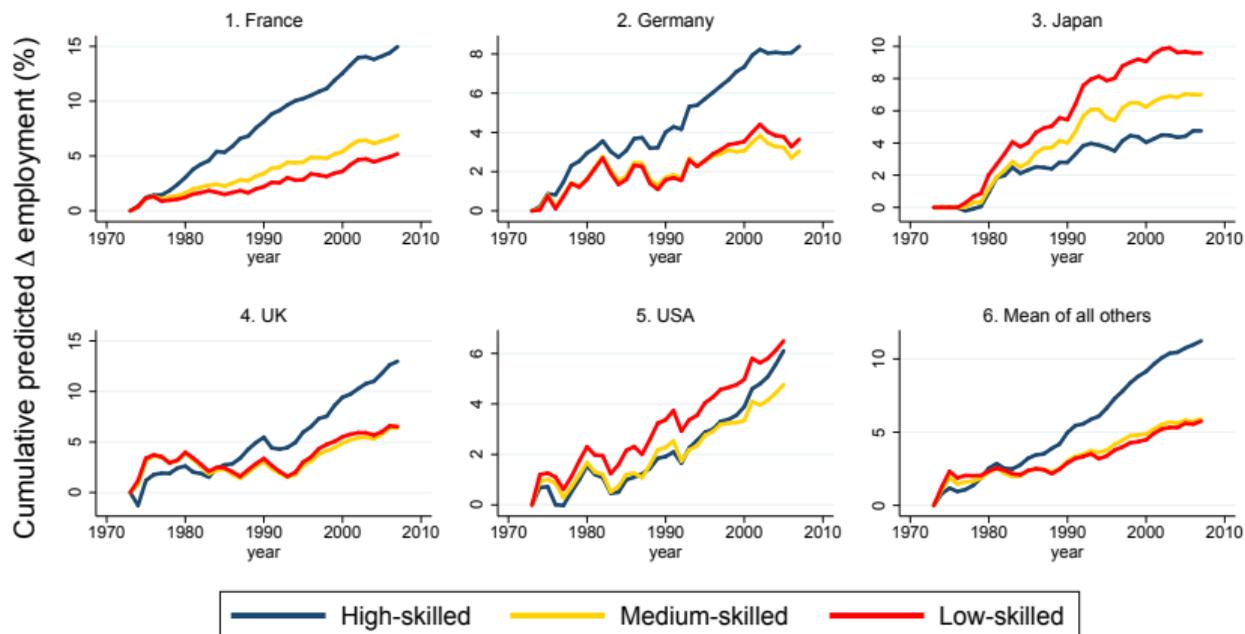
$$\Delta \widehat{E}_{ic,t=base}^q = \{E_{ic,t=base}^q \times 1(i \in s) \times \widehat{\beta}_{1,s(i)} \times \Delta \ln LP_{ict}\} \\ + \{E_{ic,t=base}^q \times \sum_{s(i)=1}^5 \sum_{k=0}^3 \widehat{\beta}_{2+k,s(i)} \times \Delta \ln \widetilde{LP}_{ct-k,s(i),j \neq i}\}$$

Productivity growth has been strongly **skill-biased** 1970-2007 due to **induced sectoral shifts**



Based on model 5 from Table 7; prediction averaged across all 19 countries.
Productivity is gross output based.

U.S. stands out for having most **'polarized'** sectoral shifts: Reallocation towards **high- and low-skill** intensive sectors



Based on model 5 from Table 7. 'Mean of all others' is unweighted average across all remaining 14 countries. Productivity is gross output based.

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Is productivity growth threatening employment? Not so far...

- 1 Employment shrinks in advancing sectors—but spillovers offset in lagging sectors
 - **Net effect:** Productivity growth modestly contributes to **rising employment-to-population**—as well as **rising consumption**
 - **“Robocalypse Later?”** Virtuous relationship may have weakened in the 2000s. But see Hall (2017)
- 2 **Distribution of productivity growth across sectors matters**
 - Productivity growth in **services** produces **largest positive spillovers**
 - **Good news:** Robotics have potential to **raise productivity in services**
- 3 **Productivity growth good for employment, skill impacts non-neutral**
 - Challenge is **not quantity** of jobs
 - Challenge is **quality** of jobs available to low- and medium-skill workers