Does Productivity Growth Threaten Employment? "Robocalypse Now?"

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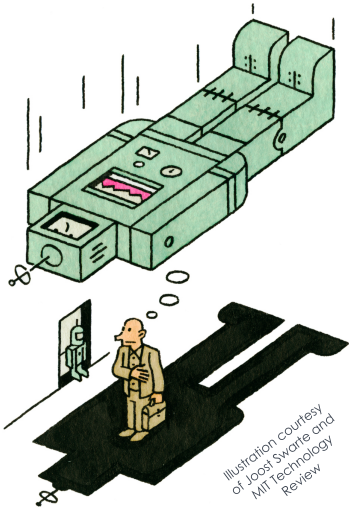
Longstanding concern: Automation threatens employment

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!



Fundamentally, does rising productivity mean fewer jobs?

Citizen, policy-maker, intellectual concern

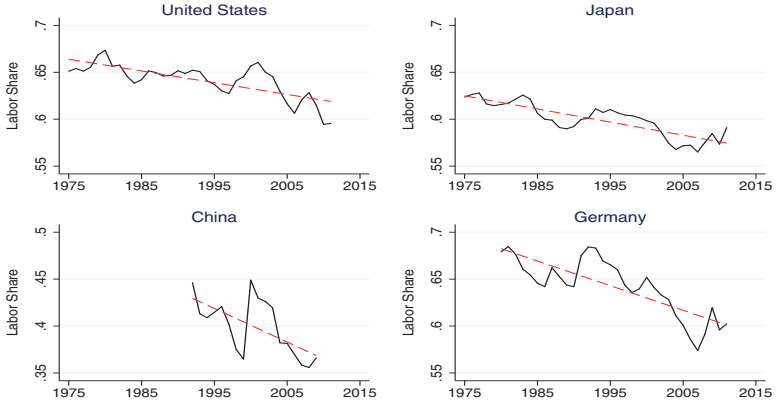
- The more work done by machines, the less work done by people
- Steam-powered hammer vs. "steel-driving man"

Professional economic opinion

1. Elastic demand: Advancing sectors may *expand* (Bessen '17)
2. Income effects: Rising wealth creates *new demands* (Clark '51)
3. Sectoral reallocation: Advancing sectors *contract*, but labor moves to lagging sectors (Baumol '67)

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 (Susskind '17)
3. New tasks *might* endogenously be created 'fast enough' – or perhaps not (Acemoglu & Restrepo '16, '17)

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 $\Delta's$

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

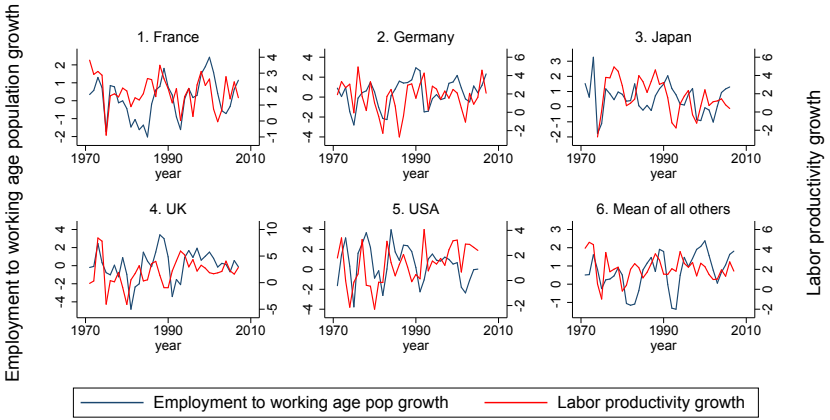
Outcomes

- Δ Employment by industry and overall (counts and e/pop)
- Δ Final consumption by industry—corroborating productivity effects
- Δ Skill inputs within industries
- Δ Skill inputs economy-wide—due to induced sectoral shifts

Outline

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

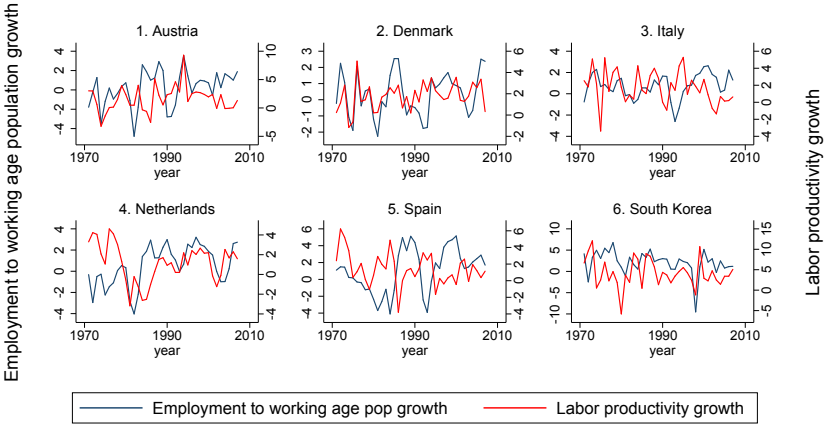
Employment growth, productivity growth positively covary, 1970–2007 (cf. Francis-Ramey '04)



Figures are for the total economy, excluding agriculture, public administration, private households and extraterritorial organizations. All growth rates obtained as log changes x 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

Of course – these macroeconomic correlations are not deeply informative



Figures are for the total economy, excluding agriculture, public administration, private households and extraterritorial organizations. All growth rates obtained as log changes x 100. 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**

Currently adding data through 2014 (EU KLEMS 2016)

Outline

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

$$\Delta lnE_{cit} = \beta_0 + \beta_1 \Delta lnLP_{cit} + [\alpha_c + \delta_t + \gamma_i] + \epsilon_{cit}$$

  - $\Delta lnLP_{cit}$ 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 $\Delta lnLP_{cit}$ 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:* $-1 < \frac{\partial \ln E_i}{\partial \ln LP_i} < 0$

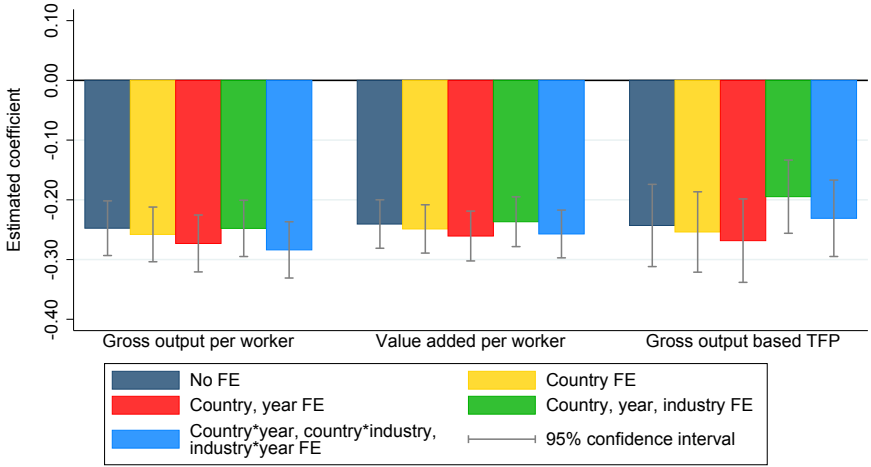
Employment robustly *falls* as labor productivity ↗

dep var: annual log change in employment by country-industry

	A. OLS				
	(1)	(2)	(3)	(4)	(5)
$\Delta lnLP_{cit}$	-0.248**	-0.259**	-0.275**	-0.249**	-0.248**
	(0.024)	(0.023)	(0.024)	(0.024)	(0.024)
$\Delta lnpopulation_{ct}$	–	–	–	–	0.895**
					(0.191)
Country fixed effects	NO	YES	YES	YES	YES
Year fixed effects	NO	NO	YES	YES	YES
Industry fixed effects	NO	NO	NO	YES	YES
R^2	0.110	0.155	0.201	0.300	0.305
N	19,451	19,451	19,451	19,451	19,451

*Standard errors in parentheses, ∼ p<0.10, * p<0.05, ** p<0.01*

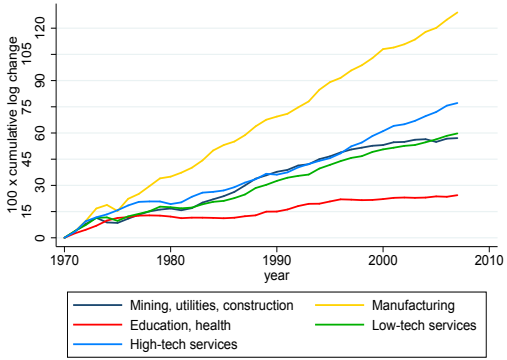
What **does** happen: Rising labor productivity → Falling industry employment



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

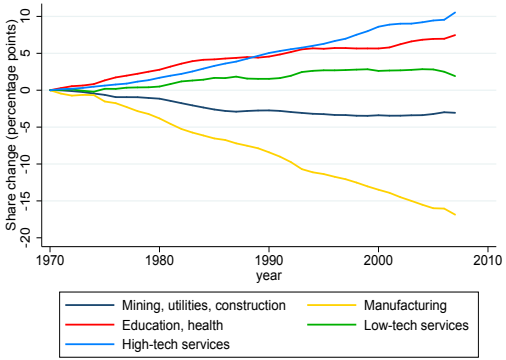
Unbalanced growth: Employment in 'advancing' sectors **shrinks**

Cumulative Productivity Growth



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

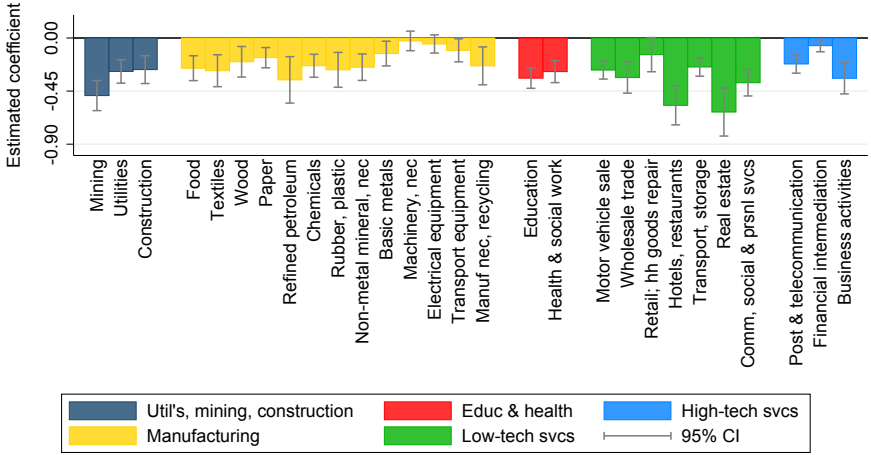
Cumulative Change in Employment



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

Rising labor productivity → Falling industry employment

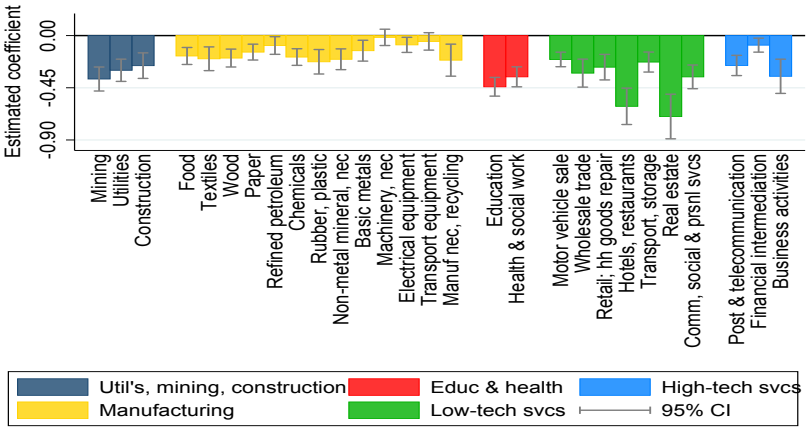
Using **gross-output** based labor productivity growth



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.

Rising labor productivity → Falling industry employment

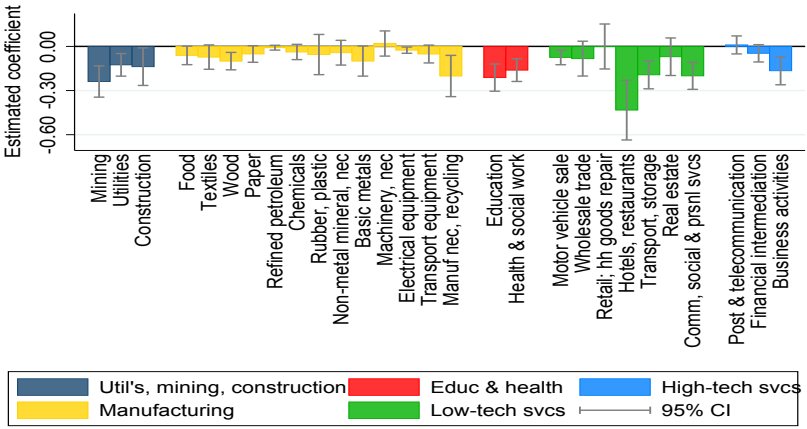
Using **value-added** based labor productivity growth



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 value added per worker.

Rising labor productivity → Falling industry employment

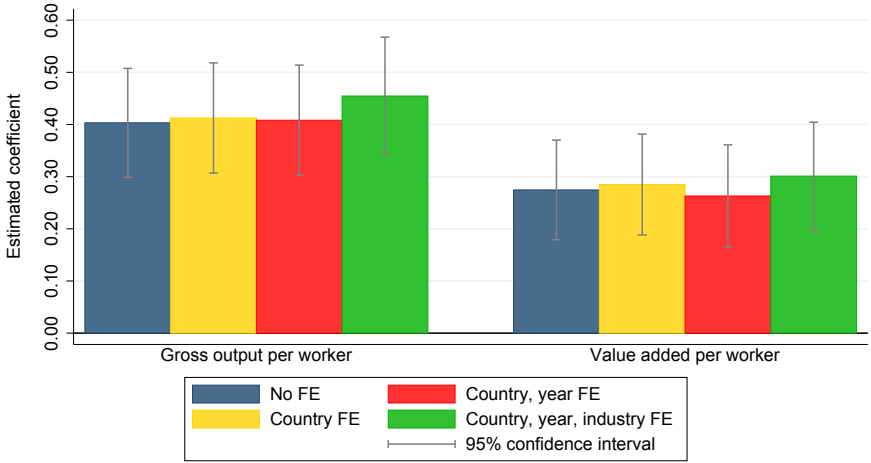
Using **Total Factor Productivity** growth



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 value added based TFP.

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.

Outline

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

Reconciling the evidence

- Plausible explanation: There are **employment spillovers** elsewhere in economy
  1. Rising final demand — income effects
  2. Rising inter-industry demand – input-output linkages

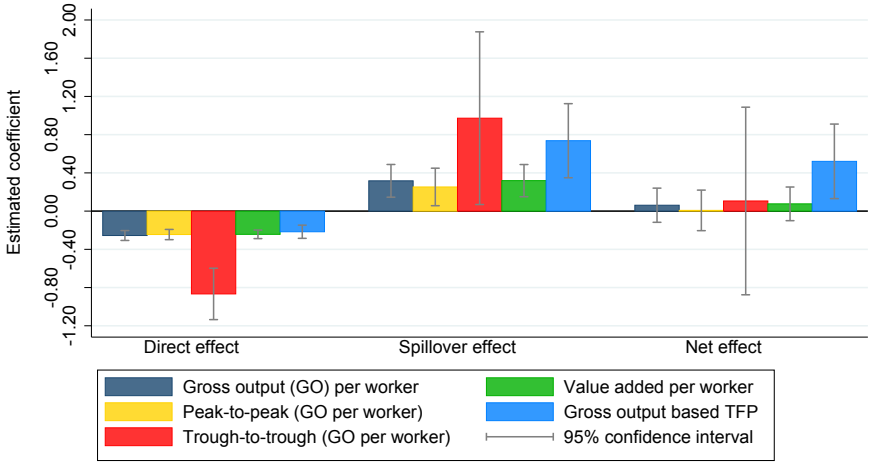
Use industry-level and country-level data to estimate

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

- $\widetilde{LP}_{ct-k,j\neq i}$ 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 offse**t 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*

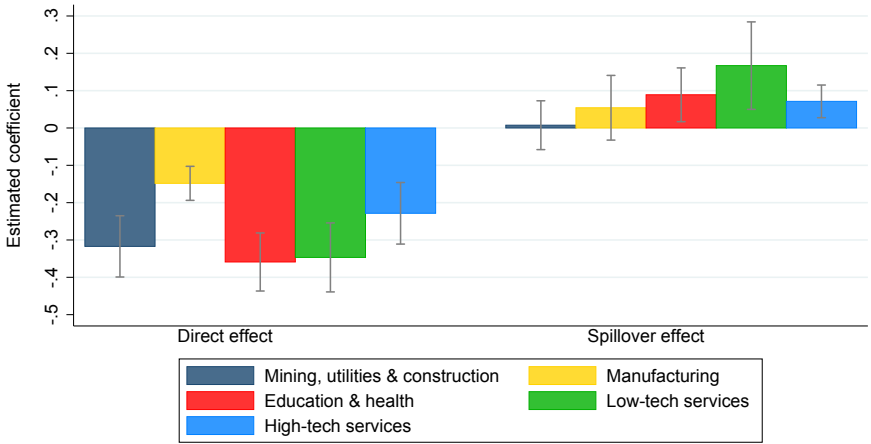
$$\Delta lnE_{ict} = \beta_0 + \sum_{s(i)=1}^{5} \beta_{1,s(i)} \Delta lnLP_{ict} + \sum_{s(i)=1}^{5} \sum_{k=0}^{3} \beta_{2+k,s(i)} \Delta ln\widetilde{LP}_{ct-k,s(i),j\neq i}$$

$$[+\alpha_c + \delta_t + \gamma_i] + \epsilon_{ict}$$

- $\hat{\beta}_{1,s(i)}$ 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.

Outline

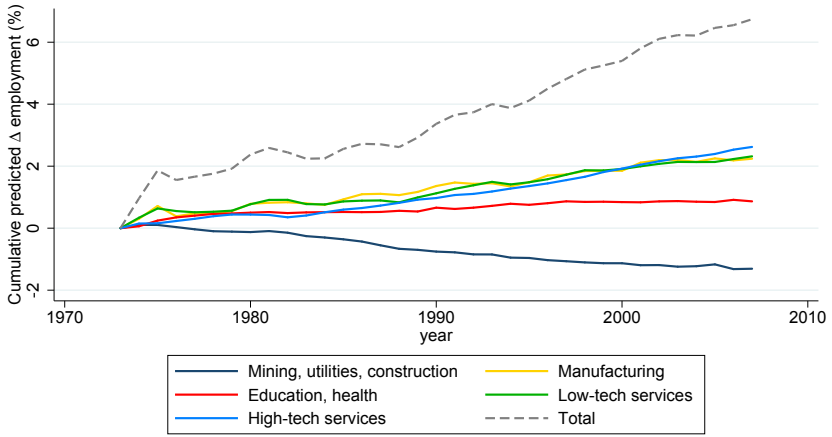
Translating direct+spillover effects into total emp/pop

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

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

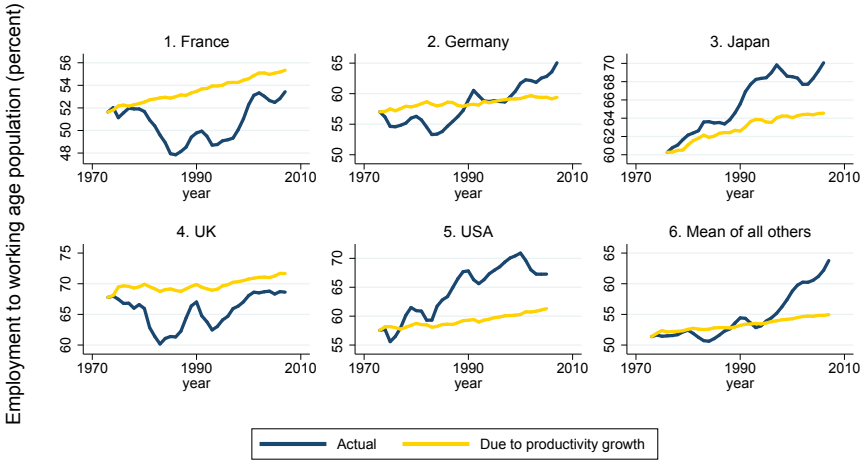
Implied cumulative **net effects** of productivity growth on Δ **employment** in % pts, 1970–2007



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

How **big** are these effects? Not negligible...

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.

Outline

Productivity ⇒ 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

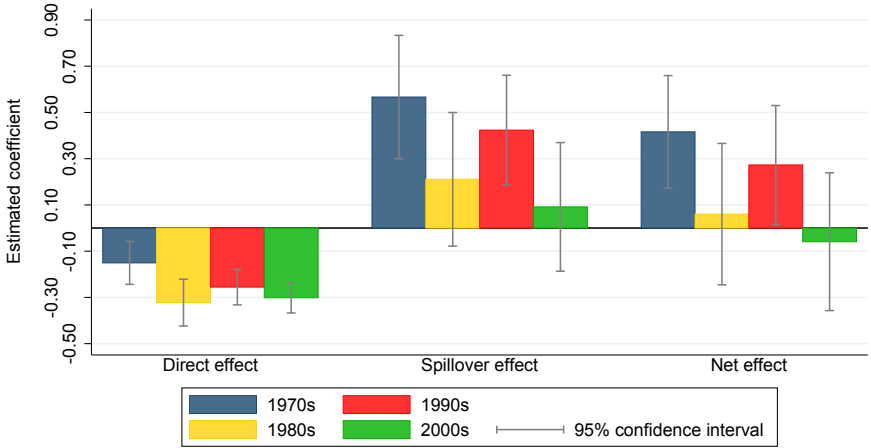
Add decade-specific effects to baseline equation

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

- where $d(t)$ indicates decades

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

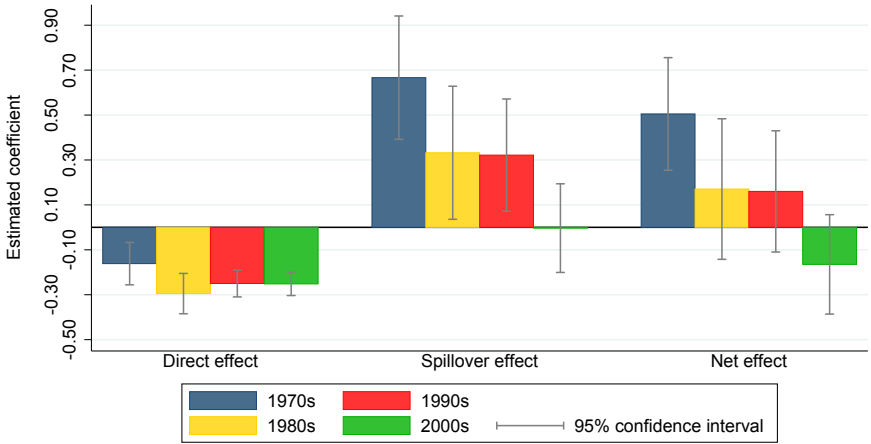
But 2000s do **not** look very **different from** the **1980s**



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

Patterns less encouraging using **VA-based** productivity

Spillover effects declining secularly—net effect becomes weekly negative in the 2000s



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

Outline

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

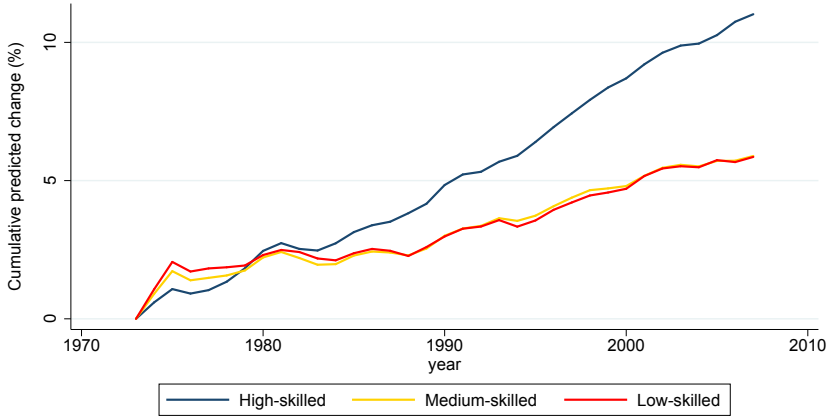
1. **Skill bias:** Firms may **differentially eliminate low-, medium-, or high-skill** workers
   - We find that this is **not quantitatively important**
2. **Sector bias:** 'Advancing' sectors **shrink** + 'lagging' sectors **grow**
   - High productivity growth in **manufacturing** and **primary** 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

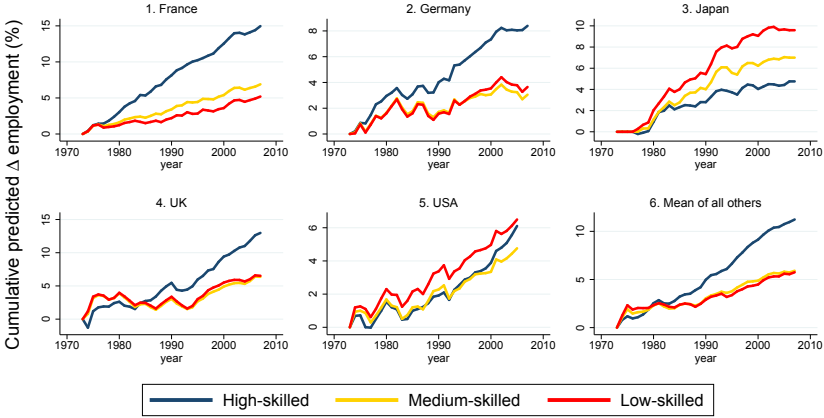
$$\Delta \widehat{E}^{q}_{ic,t=base} = \{E^{q}_{ic,t=base} \times 1(i \in s) \times \widehat{\beta}_{1,s(i)} \times \Delta lnLP_{ict}\}$$
$$+\{E^{q}_{ic,t=base} \times \sum_{s(i)=1}^{5} \sum_{k=0}^{3} \widehat{\beta}_{2+k,s(i)} \times \Delta ln\widetilde{LP}_{ct-k,s(i),j\neq i}\}$$

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.

Outline

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**
   - Virtuous relationship may have weakened in the 2000s—**"Robocalypse Later?"**
2. **Distribution of productivity growth across sectors matters**
   - Productivity growth in **services** produces **largest positive spillovers**
   - **Good news:** Robotics or AI 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

Next steps on this project (for *Brookings* Spring '2018)

1. **Further evidence on "is this time different?"**
   - Extend data to 2014 (new EU Klems)
2. **Are we missing intensive margin response?**
   - Investigate hours as well as employment
3. **Measuring demand using quantity and price**
   - Study wages by skill group alongside employment
4. **Digging deeper on spillovers**
   1. **Final demand spillovers:** Assess role of population aging in slackening spillovers
   2. **Industry linkages:** Use World Input Output Tables (WIOT) to identify
5. **Does a growing share of final demand accrue to non-OECD producers?**
   - Explore international input-output linkages using WIOT