Does Productivity Growth Threaten Employment?  
“Robocalypse Now?”

David Autor ¹  Anna Salomons ²

¹MIT  
²Utrecht University

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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


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 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

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<tr>
<td>Germany</td>
<td>.6</td>
<td>.7</td>
<td>1975</td>
<td>1985</td>
<td>1995</td>
<td>2005</td>
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The figure shows the labor share and its linear trend for the four largest economies in the world from 1975.
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)
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

- \( \Delta \) Employment by industry
- \( \Delta \) Employment to working-age population—i.e., overall employment
- \( \Delta \) Final consumption by industry—corroborating productivity effects
- \( \Delta \) Skill inputs within industries
- \( \Delta \) 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


![Graph showing employment and productivity growth for France, Germany, Japan, UK, USA, and the mean of all others over the years 1970 to 2010. The graph indicates a positive covary between employment to working age population growth and labor productivity growth across different countries.](image-url)

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 \textbf{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 x 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 $\Delta \ln L^P_{cit}$ rises?

1. **Lump-of-labor**
   - Could fall one-for-one with labor productivity growth: $\frac{\partial \ln E_i}{\partial \ln L^P_i} = -1$

2. **Demand surge (iPhone, textiles)**
   - Could surge as price/quality improve: $\frac{\partial \ln E_i}{\partial \ln L^P_i} > 0$

3. **Unbalanced growth (Baumol)**
   - Could fall somewhat less than one-for-one: $-1 < \frac{\partial \ln E_i}{\partial \ln L^P_i} < 0$
What **does** happen: Rising labor productivity → Falling industry employment

![Bar chart showing estimated coefficients for different models of labor productivity and industry employment. The x-axis represents different measures of productivity: Gross output per worker, Value added per worker, and Gross output based TFP. The y-axis represents the estimated coefficients ranging from -0.40 to 0.10. The chart includes different fixed effects: No FE, Country FE, Country, year FE, Country, year, industry FE, and Country*year, country*industry, industry*year FE. The 95% confidence interval is indicated for each coefficient.]

All models are estimated by OLS and control for population growth whenever country-year fixed effects are not included.
Rising labor productivity $\rightarrow$ Falling industry employment

Using \textit{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.
Do ‘advancing’ industries grow or shrink?

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.
Do ‘advancing’ industries grow or shrink?

**Unbalanced growth:** Employment in ‘advancing’ sectors shrinks

**Cumulative Productivity Growth**

**Cumulative Change in Employment**

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

Shares normalized to 0 in 1970. Unweighted average across all 19 countries.
Reconciling industry and aggregate-level evidence

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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
  - Rising final demand — income effects
  - Inter-industry demand linkages

**Use industry-level and country-level data to estimate**

\[
\Delta \ln E_{cit} = \beta_0 + \beta_1 \Delta \ln L\!P_{cit} + \sum_{k=0}^{3} \beta_{2+k} \Delta \ln \tilde{L}\!P_{ct-k, j \neq i} + \alpha_c + \delta_t + \gamma_i + \epsilon_{cit}
\]

- $\tilde{L}\!P_{ct-k, j \neq i}$ is aggregate labor productivity excluding own-industry $i$
- $L\!P_{cit}$ 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
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

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

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

<table>
<thead>
<tr>
<th>Sector</th>
<th>Direct Effect</th>
<th>Spillover Effect</th>
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<tbody>
<tr>
<td>Mining, utilities &amp; construction</td>
<td>-0.5</td>
<td>-0.4</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>-0.3</td>
<td>0.1</td>
</tr>
<tr>
<td>Education &amp; health</td>
<td>-0.2</td>
<td>0.3</td>
</tr>
<tr>
<td>High-tech services</td>
<td>0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>Low-tech services</td>
<td>0.3</td>
<td>0.1</td>
</tr>
</tbody>
</table>

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

\[
\Delta \hat{E}_{ict} = \{E_{ic,t=base} \times 1(i \in s) \times \hat{\beta}_{1,s(i)} \times \Delta \ln LP_{ict} \} \\
+ \{E_{ic,t=base} \times \sum_{s(i)=1}^{3} \sum_{k=0}^{5} \hat{\beta}_{2+k,s(i)} \times \Delta \ln \tilde{LP}_{ct-k,s(i),j \neq i} \}
\]
Implied cumulative **direct** effects of productivity growth on total $\Delta$ 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.
Adding it up

Implied cumulative **spillover** effects of productivity growth on total ∆ 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 $\Delta$ 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.
Adding it up

Implied cumulative net effects of productivity growth on $\Delta$ 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

1. France
2. Germany
3. Japan
4. UK
5. USA
6. Mean of all others

Employment to working age population (percent)

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

Autor & Salomons

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What’s the key driver of job growth? **Population growth!**

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

1. France
2. Germany
3. Japan
4. UK
5. USA
6. Sum of all others

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

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

- where \( d(t) \) indicates decades
Is this time (period) different?

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

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

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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 \hat{E}_{ic,t=\text{base}}^q = \{ E_{ic,t=\text{base}}^q \times 1(i \in s) \times \beta_{1,s(i)} \times \Delta \ln LP_{ict} \}
\]

$$

$$
+ \{ E_{ic,t=\text{base}}^q \times \sum_{s(i)=1}^{5} \sum_{k=0}^{3} \beta_{2+k,s(i)} \times \Delta \ln LP_{ct-k,s(i),j \neq i} \}
\]
Productivity growth has been strongly **skill-biased** 1970-2007 due to induced sectoral shifts.
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