Demographics and Automation

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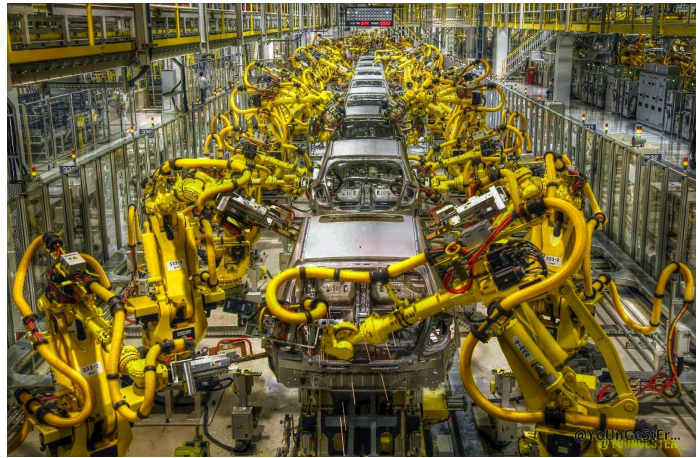
NBER, November, 2019

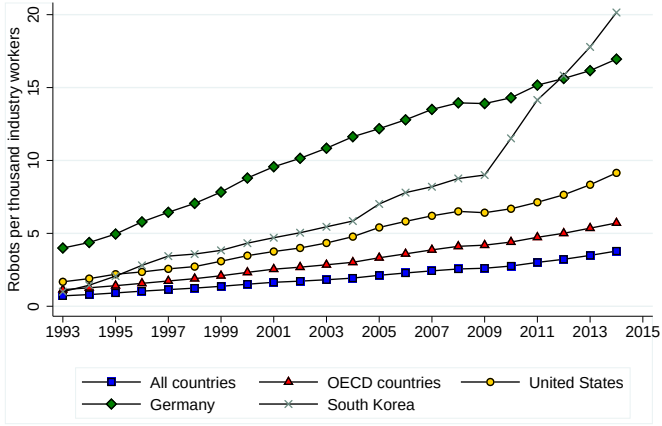
Boom in automation technologies: why now?

- Industrial automation techs:
  - industrial robots
  - computer numerical control
- Some popular explanations:
  - driven by silicon chip
  - technology is exogenous
  - technology has always been about automation



Boom in automation technologies: country trends.

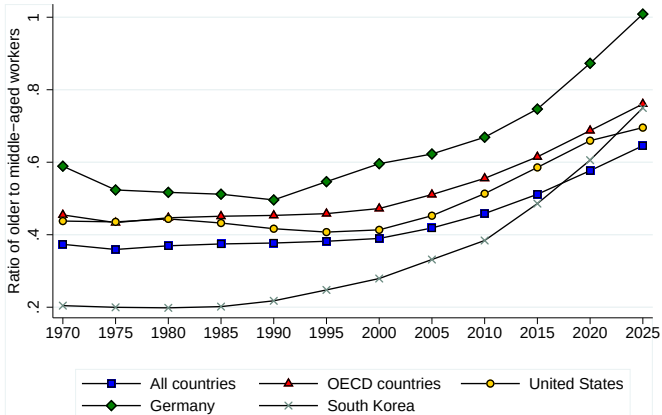
- Marked regional differences:
  - Japan, Italy, Korea and Germany lead
  - US laggard when it comes to industrial automation
- Not only in adoption, but also development:
  - Japan and Germany house biggest robot producers
- What explains these patterns?



Use of industrial robots. Source: International Federation of Robotics.

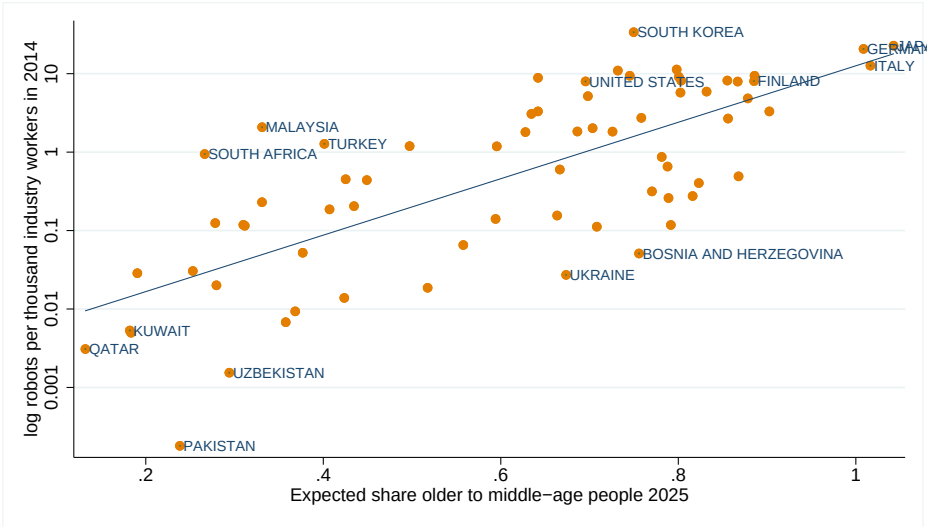
Our answer: automation induced by demographics

- Adverse demographic trends.
- Population aging rapidly.
- Ratio of older ($\geq$56 years) to middle-age ($\geq$21 and $\leq$ 55).
  - Japan, Italy, Korea and Germany worst trends
  - US milder trends
- Aging$\rightarrow$ industrial automation



Current and expected aging. Source: United Nations.

Our answer: automation induced by demographics

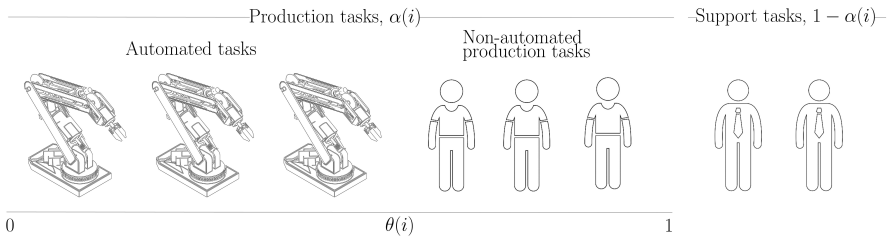


This paper:

- Directed tech model—aging induces adoption and development of automation techs.
- Use several sources of data to document aging leads to:
  - adoption of industrial robots and other automation technologies
  - development and patenting of automation technologies
  - exports of automation technologies to rest of world
- Study implications for productivity and labor demand across countries

Model and mechanisms

Model and mechanisms



- Production requires $\alpha(i)$ production tasks and $1-\alpha(i)$ support tasks.
- A fraction $\theta(i)$ of tasks are technologically automated.
- Firms decide whether to use machinery in automated tasks (adoption) or buy technologies that increase $\theta(i)$ (from innovators).
- Cobb-Douglas aggregator of tasks.

Model and mechanisms

Firm profits (adoption vs no adoption):

$$\pi_i^A = \max_{p_i} D_i(p_i) \left(p_i - R^{\alpha_i \theta_i} W_P^{\alpha_i (1-\theta_i)} W_S^{1-\alpha_i} \right); \qquad \pi_i^N = \max_{p_i} D_i(p_i) \left(p_i - W_P^{\alpha_i} W_S^{1-\alpha_i} \right)$$

- R = fixed machinery cost in production tasks.
- W_P =labor cost in production tasks.
- W_S =labor cost in support tasks.

Key mechanism:

- Firms adopt automation technologies if $W_P > R$.
- Willingness to create new automation techs (expand θ) is $\ln D_i(p_i) + \alpha_i(\ln W_p - \ln R)$.

Model and mechanisms

- **Key assumption:** relative to older workers, middle-age workers have comparative advantage in production tasks

  Implication: as population ages, $W_P \uparrow$ and $W_S \downarrow$.

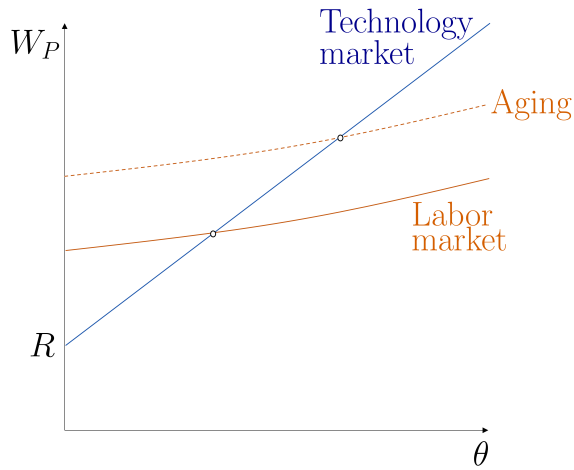
- Is the **key assumption** plausible?

1. Middle-age workers specialize in production occupations (US Census and ACS)

2. Middle-age workers fared worst in terms of wages and employment following introduction of industrial robots in US.

A Model of Automation

- Tech market locus
  - always increasing
  - willingness to purchase automation technologies increases with W_P
- Labor market locus
  - might be increasing or decreasing
  - increasing: automation very productive
  - decreasing: automation so-so
- Aging shifts labor market locus up
  - as population ages, W_P and θ increase



Equilibrium determination.

Evidence linking aging to adoption of automation technologies

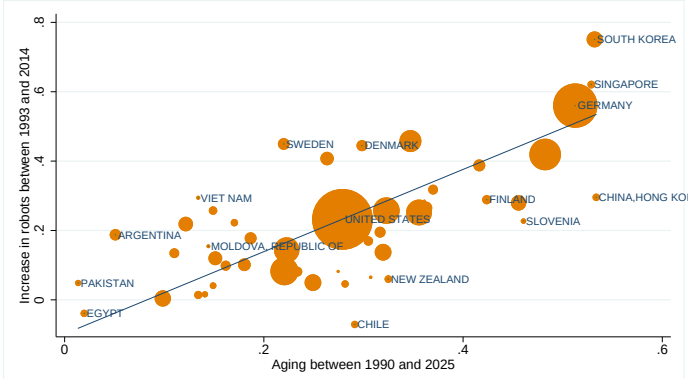
Cross-country Evidence:

$$\Delta Y_c = \beta \text{Aging}_c + \Gamma X_{c,1990} + \varepsilon_c. \quad (1)$$

- ΔY_c =increase use of automation technologies 1990-2015
- Aging_c =trend in aging 1990-2025
- $X_{c,1990}$ =GDP, human capital, demographics, and economic structure in 1990
- IVs: birthrates 1950-1955, 1955-1960, ..., 1980-1985
- Estimates weighted by manufacturing value added
- β =are countries experiencing adverse demographic trends since 1990 due to past birth rates adopting more automation technologies?

Cross-country Evidence: stock of robots

- Yearly increase in robots per 1k industry workers 1993-2014.
- Data from the International Federation of Robotics.
- Consistent data for 52 countries.
- 1 robot $\equiv$ 3 workers.



Correlation between aging and use of industrial robots, $\hat{\beta} = 0.7$ (se=0.25).

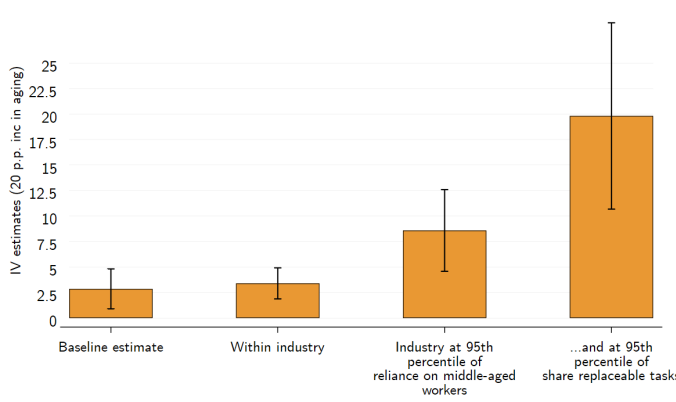
Cross-country Evidence: stock of robots

Increase in aging of 20 p.p. (US-Germany gap) leads to 3 (s.e.=1) robots per 1k workers (40% US-Germany gap).

- Aging alone explains 40% of variation
- OLS and IV estimates similar
- Estimates for 30 OECD countries similar
- Estimates using stacked difs with country trends similar
- Past aging uncorrelated with adoption
- Contemporary and expected trends in aging predict robot adoption

Heterogeneity by industry

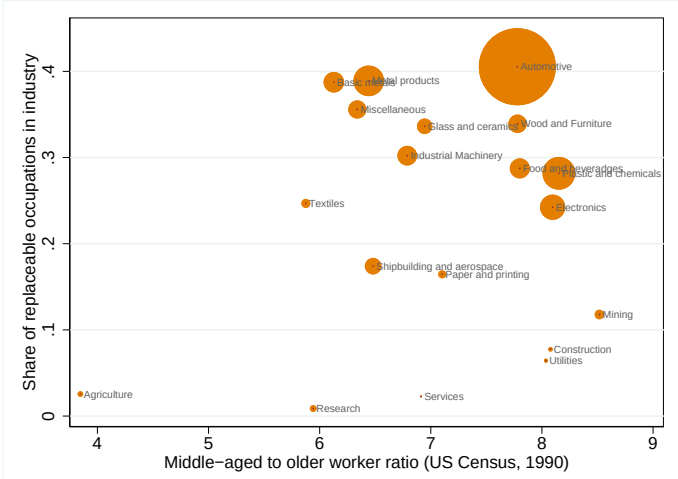
- IFR data for 19 industries and 21 countries on robot installations.
- Effect driven by within-industry adoption.
- Reliance on middle-aged workers from baseline age composition.
- Share replaceable tasks from Graetz-Michaels-2018.



Implied effect of a 20 p.p. increase in aging on robot adoption per 1k workers between 1993-2014.

Heterogeneity by industry

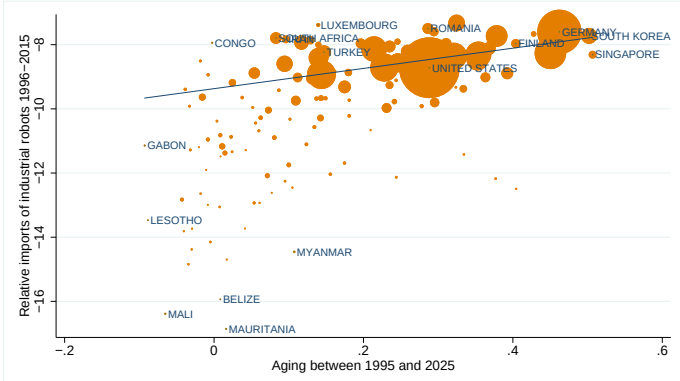
- Marker size indicates robot adoption in industry.
- High adoption: automotive, plastic and chemicals
  - housed by aging countries
  - technically feasible to automate
  - high reliance on middle-aged workers



Industry characteristics and robot adoption

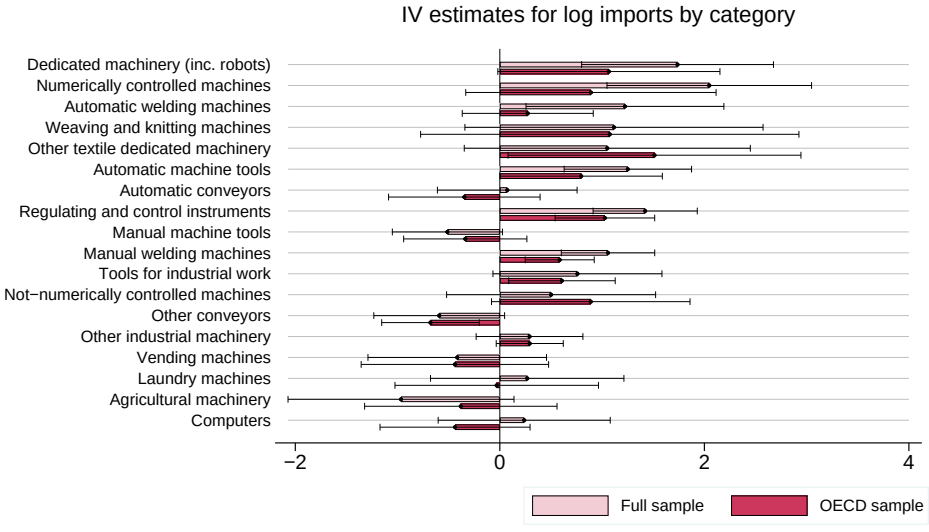
Cross-country Evidence: Imports of automation techs

- log imports of industrial robots between 1996-2015.
- Use HS code 847950.
- Comtrade data for 130 countries.
- Normalized by total intermediate imports.
- A 20 p.p. increase in aging leads to 44% higher robot imports (a third of the Germany-US gap).



Correlation between aging and log imports of industrial robots.

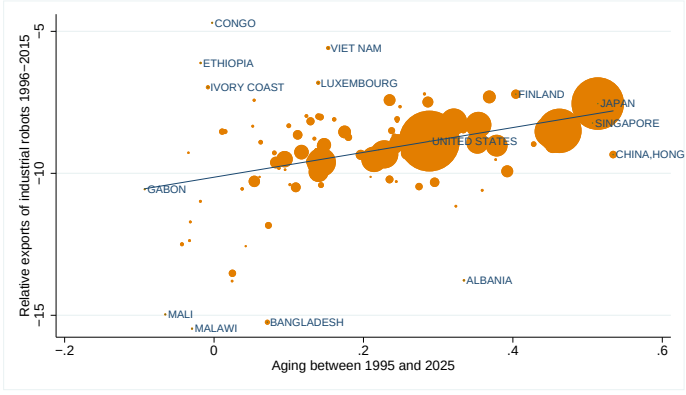
Cross-country Evidence: Imports of automation techs



Evidence linking aging to development of automation technologies.

Cross-country Evidence: Exports of automation techs

- log imports of industrial robots between 1996-2015.
- Data from Comtrade for 103 countries.
- Normalized by total intermediate exports.
- A 20 p.p. increase in aging leads to 80% rise in robot exports (the Germany-US gap).



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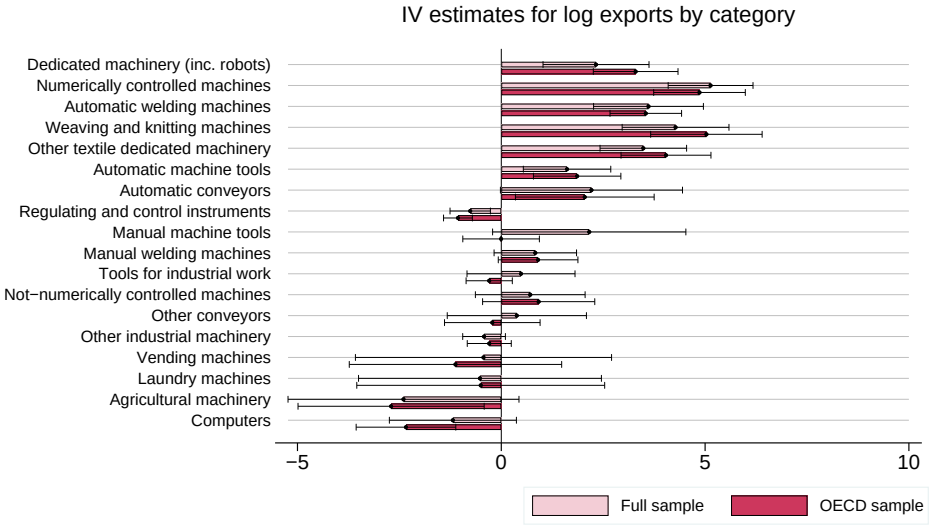
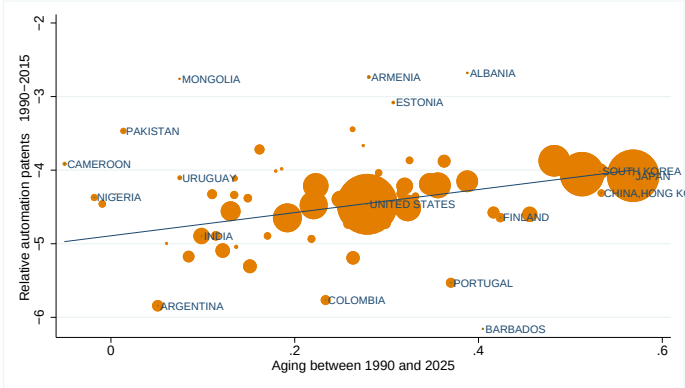
Cross-country Evidence: Exports of automation techs



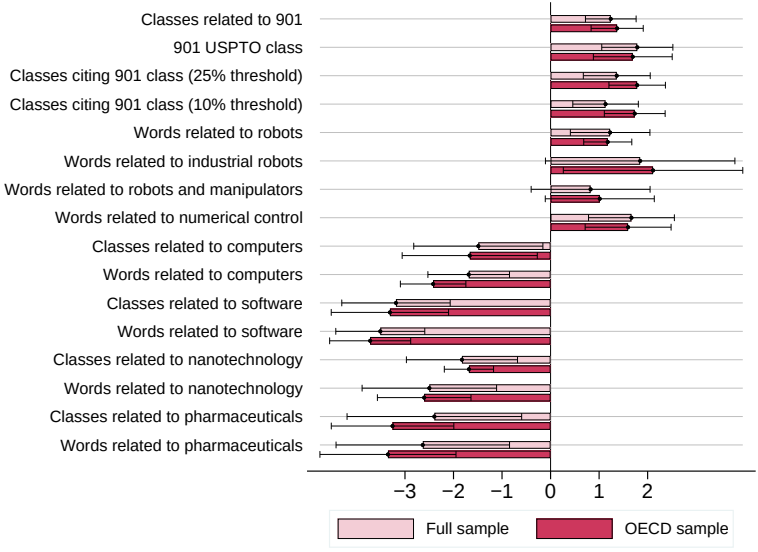
Cross-country Evidence: Patents

- log robot-related patents granted to a country 1990-2015.
- USPTO data for 68 countries.
- Robot-related patents: class 901.
- Normalized by total patents granted at USPTO.
- A 20 p.p. increase in aging leads to 32% rise in automation patents (half Germany-US gap).



Correlation between aging and log robot-related patents.

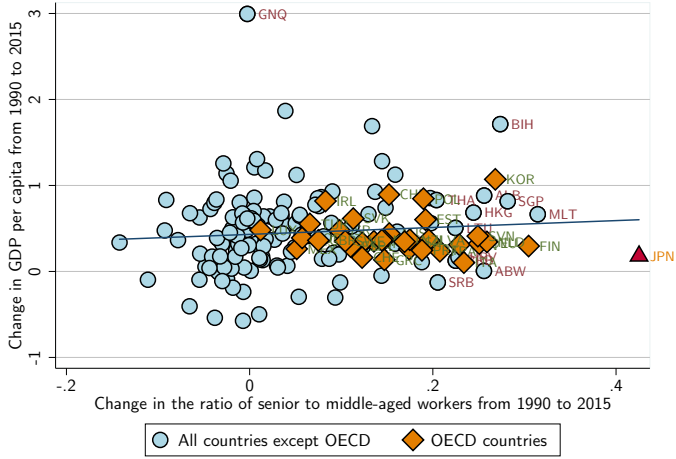
Cross-country Evidence: Patents



Implications for productivity and labor demand

Aging as a headwind for economic growth

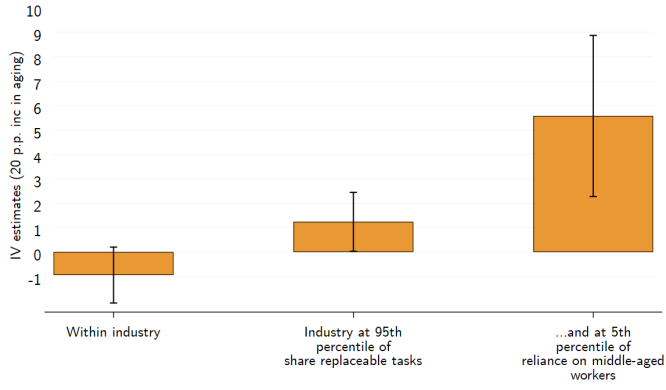
- Aging could reduce potential output or output gap.
- But induced technological response helps propel growth.
- Automation generates investment opportunities.
- Could be one of the many reasons why aging is not associated with slow growth of output per capita across countries.



Correlation between aging and growth in the log of GDP per capita between 1990 and 2015.

Aging as a headwind for economic growth

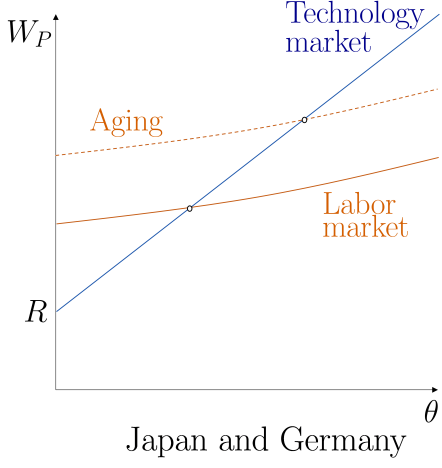
- Can be seen across industries in aging countries (EUKLEMS)
- Growth of value added per worker (19 industries and 21 countries).
- Industries with greater opportunities for automation remain productive as countries grow older.
- More so if they do not rely on young workers.

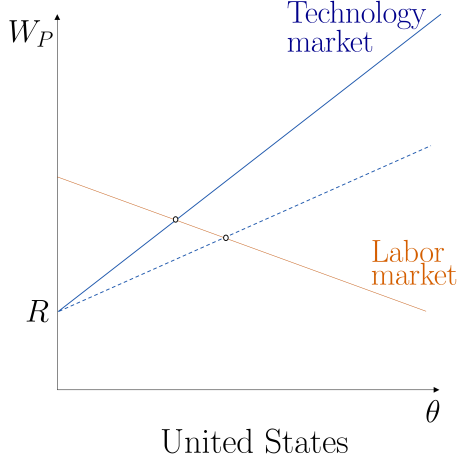


Implied effect of a 20 p.p. increase in aging on industry value-added growth 1995-2007.

Cross-country spillovers

- Countries with different demographic trends interact through tech markets.





Cross-country spillovers

- US adopting technologies optimized for the demographic structure of Japan and Germany.
- Effect of automation depends on context:
  - big product and wage gains when automation induced by demographics (Germany, Japan)
  - small productivity gains and declining wages when automation coming from abroad (US)
- Neg effect of ind robots in US [Acemoglu-Restrepo]; no effects for Germany [Dauth et al.]

Other potential mechanisms linking demographics to automation

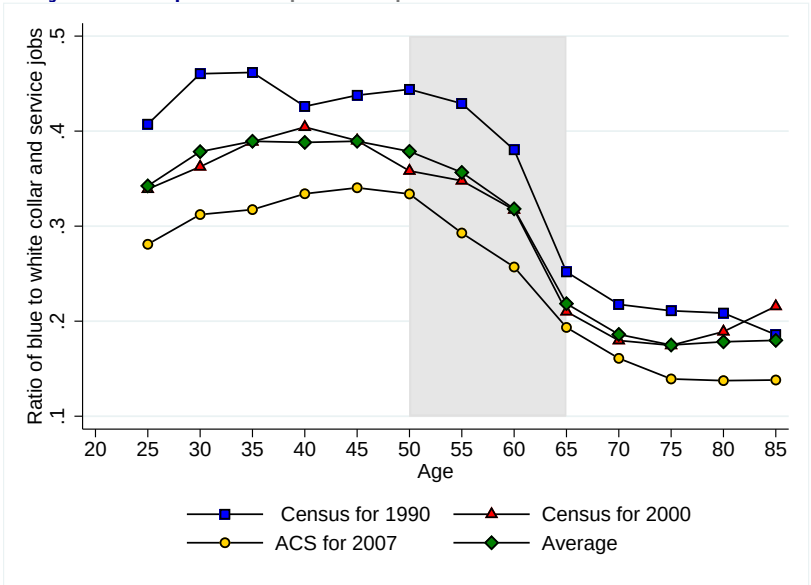
- Increase in savings by older people:
  - integrated financial markets for OECD sample
  - why would aging countries export technologies?
  - effects concentrate in very specific types of equipment and capital
- Unions and labor market institutions:
  - unionization rates also predict robot adoption
  - this is in line with our model
  - demographics independently important

Thank you!

Modeling comparative advantage [return]

- Several ways of modeling comparative advantage
  - at age a, $\ell_P(a)$ units of labor for production tasks and $\ell_S(a)$ units of labor for support tasks
  - comparative advantage $\ell'_P(a) < \ell'_S(a)$
  - wage at age a is $W_P\ell_P(a) + W_S\ell_S(a)$
  - $\ell'_P(a) < \ell'_S(a)$ implies that as people ages, they earn more of their wage from support tasks.

Support for key assumption I [return]



Support for key assumption II [return]