

Does Skill Abundance Still Matter?

The Evolution of Comparative Advantage in the 21st Century

Shin Kikuchi, MIT

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Skill Abundance and Comparative Advantage

- Skill Abundance: Central for comparative advantage (**Heckscher-Ohlin**)
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 - Implications for globalization, technology, and inequality

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- **This paper: What about the 21st century?**

At a Glance: Skill Abundance and Comparative Advantage

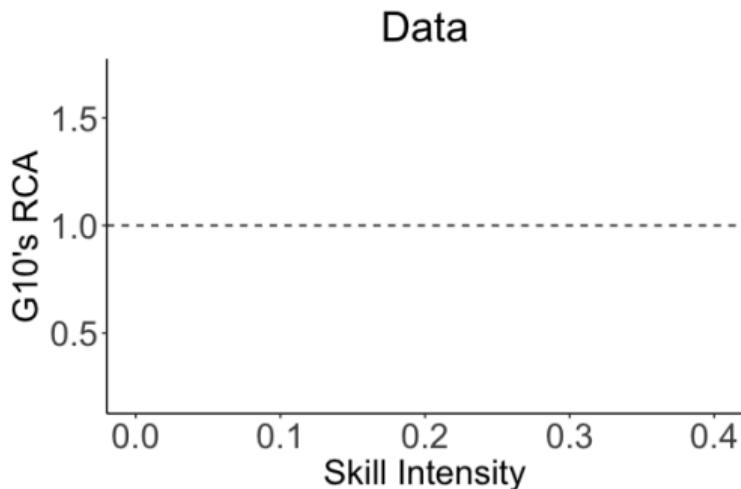
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G10's share of global exports in a sector divided by G10's share of total global exports

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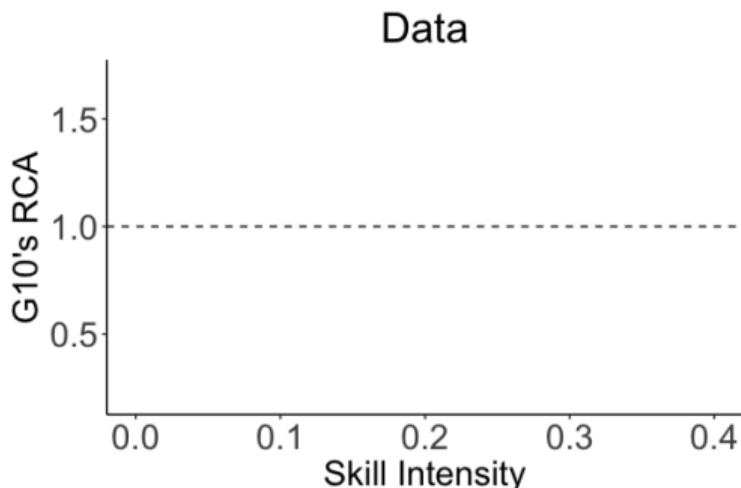


Note: Binned-scatter plots for 396 4-digit sectors. Data from UN Comtrade and NBER CES Manuf. DB

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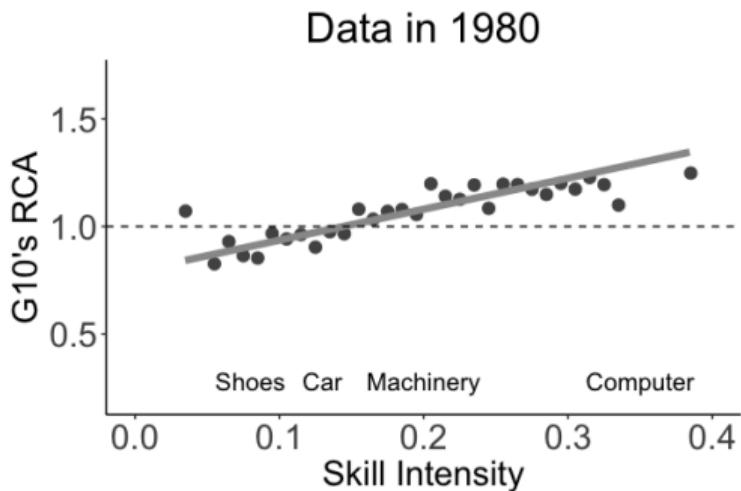
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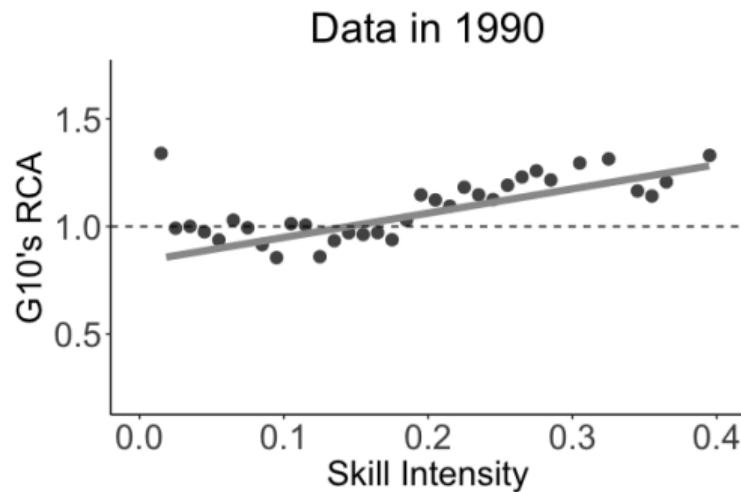
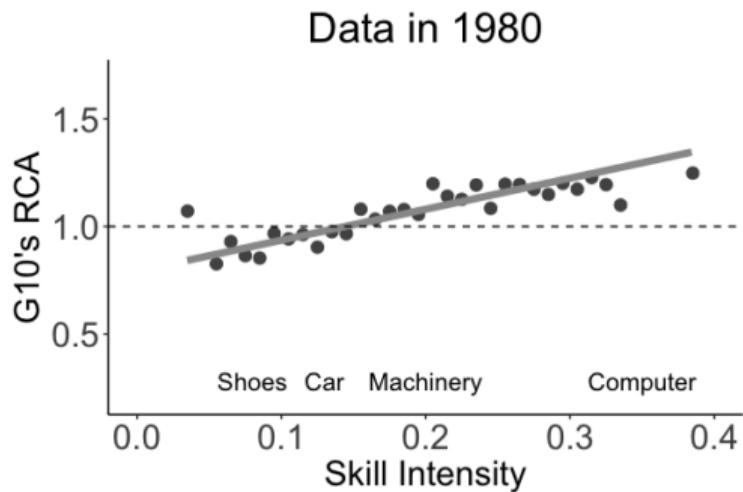
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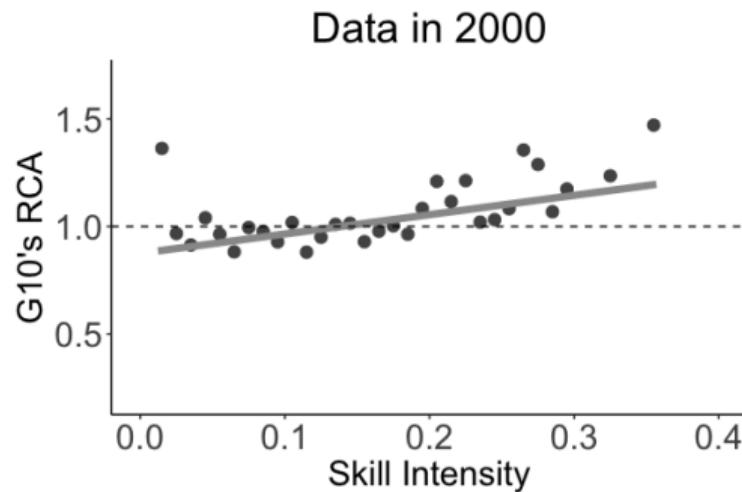
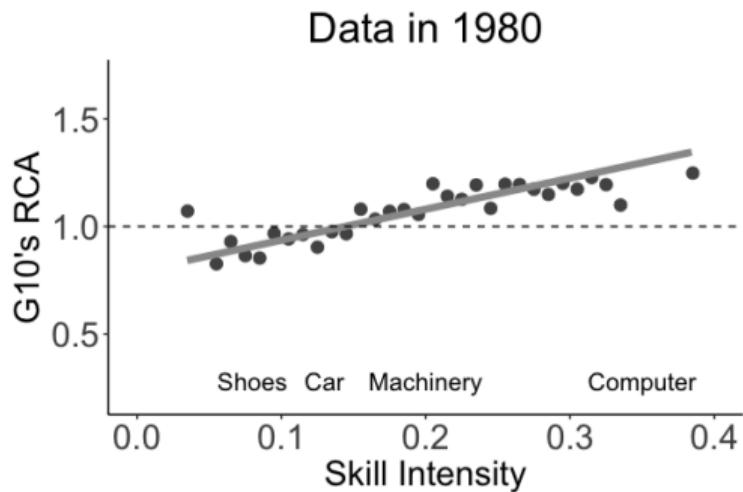


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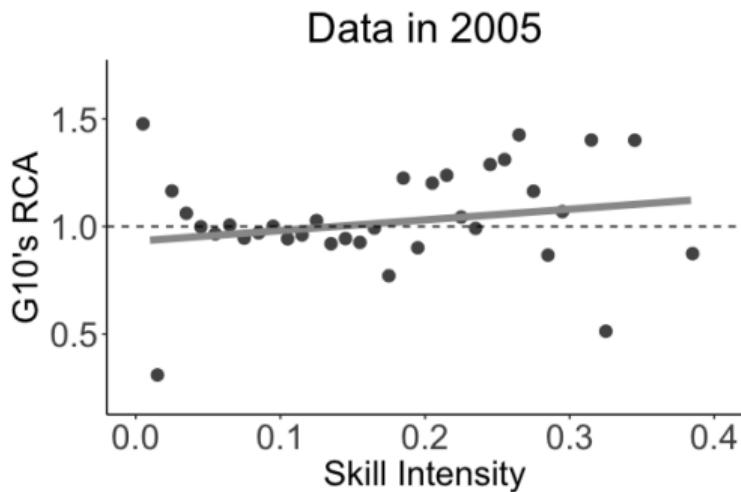
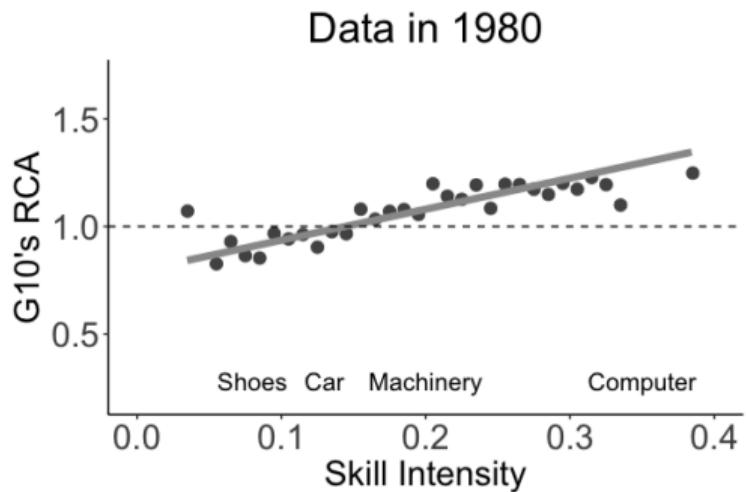


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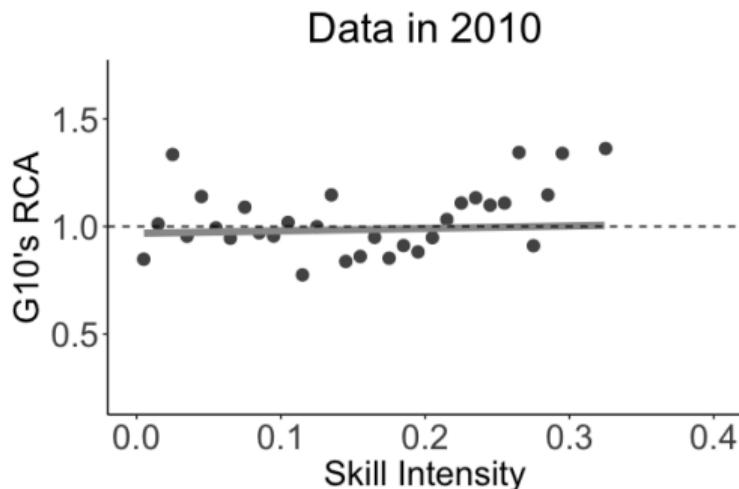
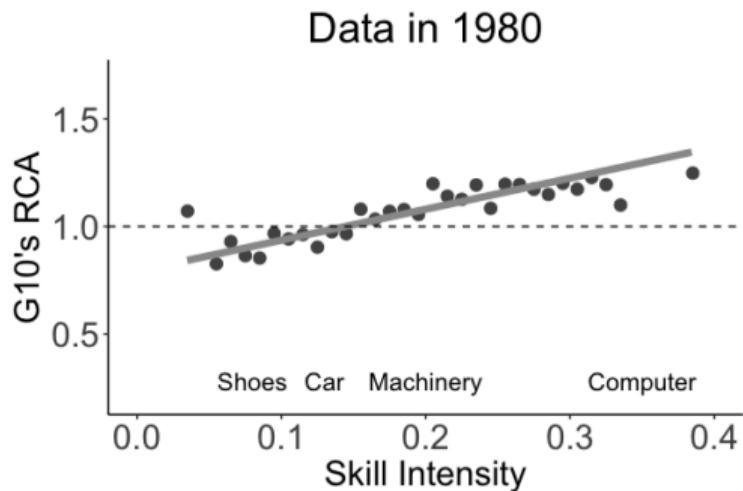


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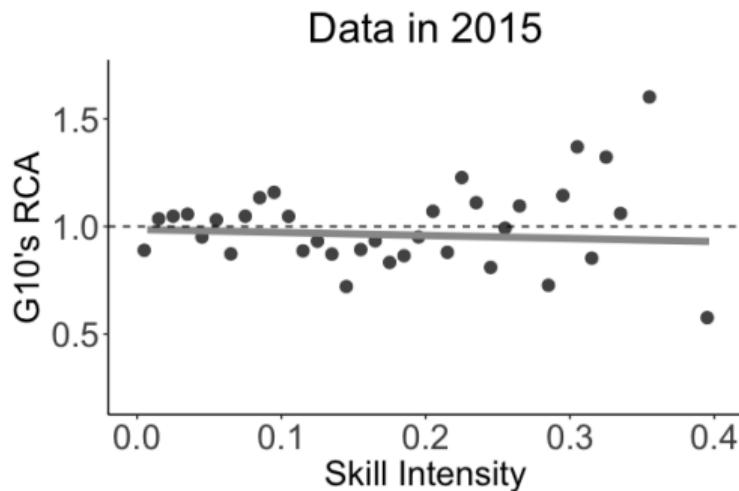
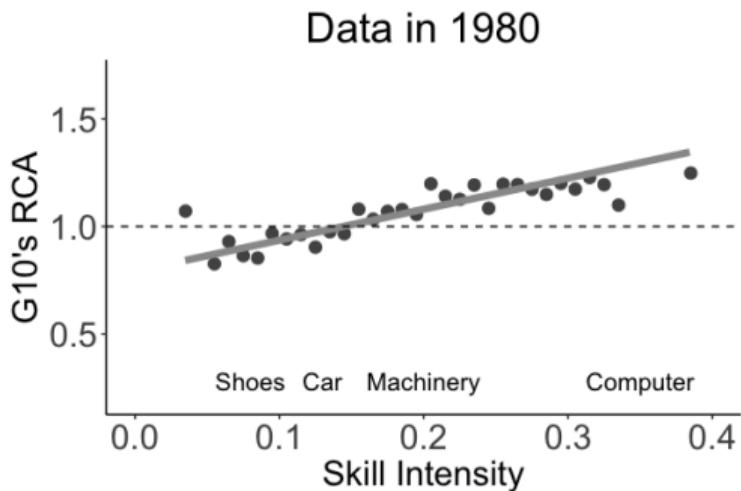


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This Paper

- Does skill abundance *systematically* matter for comparative advantage?
 - Yes and stable until 1990, No after 2000
- What can empirically and quantitatively explain the change in the pattern?
 - Automation, not offshoring
- What are the macro implications?
 - Manufacturing shifts to North; Inequality expands within & across countries

Preview (1/2) New Facts on Comparative Advantage

- Follow the literature's state-of-the-art specification
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- **Heterogeneous declines** across groups of countries & sectors
 - More declines among groups of countries & sectors with more automation
 - No such heterogeneity from offshoring

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- **Conditional on automation, HO-like predictions still survive**

Preview (2/2) Automation Explains the Change

- Quantitative analysis: Eaton-Kortum model with automation & offshoring
 - Task framework: Acemoglu & Restrepo + Grossman & Rossi-Hansberg
 - Low-skill labor can be replaced by machines or foreign labor

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- Implications of automation
 - Shifts of manufacturing from South to North
 - Increases in skill premia in North and welfare everywhere

Key Contributions

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→ **Skill abundance matter in 1980s; Not anymore post-2000.**

Key Contributions

1. New Facts on the sources of comparative advantage:
 2. **Consequences of technology and globalization on inequality:**
 - **Technology:** Katz & Murphy (1992), Berman et al (1994), Acemoglu (2002), Autor et al (2003), Acemoglu & Autor (2011), Autor & Dorn (2013), **Acemoglu & Restrepo (2018,2022)**
 - **Offshoring:** **Feenstra & Hanson (1997, 1999, 2001), Grossman Rossi-Hansberg (2008, 2012),** Hummels et al (2014), Boehm et al (2020)
 - **Interaction of Tech and Trade:** Xu (2001), Acemoglu (2002), Thoenig & Verdier (2003), Burstein et al (2013), Parro (2013), Burstein & Vogel (2017), Morrow & Trefler (2022)
 - **Automation and Trade:** Freud et al (2022), Artuc et al (2023), Fontagné et al (2024)
- **Automation ⇒ Comparative Advantage and Inequality**

FACTS: SKILL ABUNDANCE NO LONGER MATTERS

Identifying Comparative Advantage: Refresher

- Multi-sector Eaton-Kortum Model (Chor (2010), Costinot et al (2012))

Exporter i , Importer j , Sector s : $\ln \text{Export}_{i,j,s} = -\underbrace{\theta}_{\text{Trade Elas.}} \underbrace{\ln c_{i,s}}_{\text{Unit Cost}} + \underbrace{\tilde{\eta}_{i,j} + \tilde{\eta}_{j,s}}_{\text{FEs}}$

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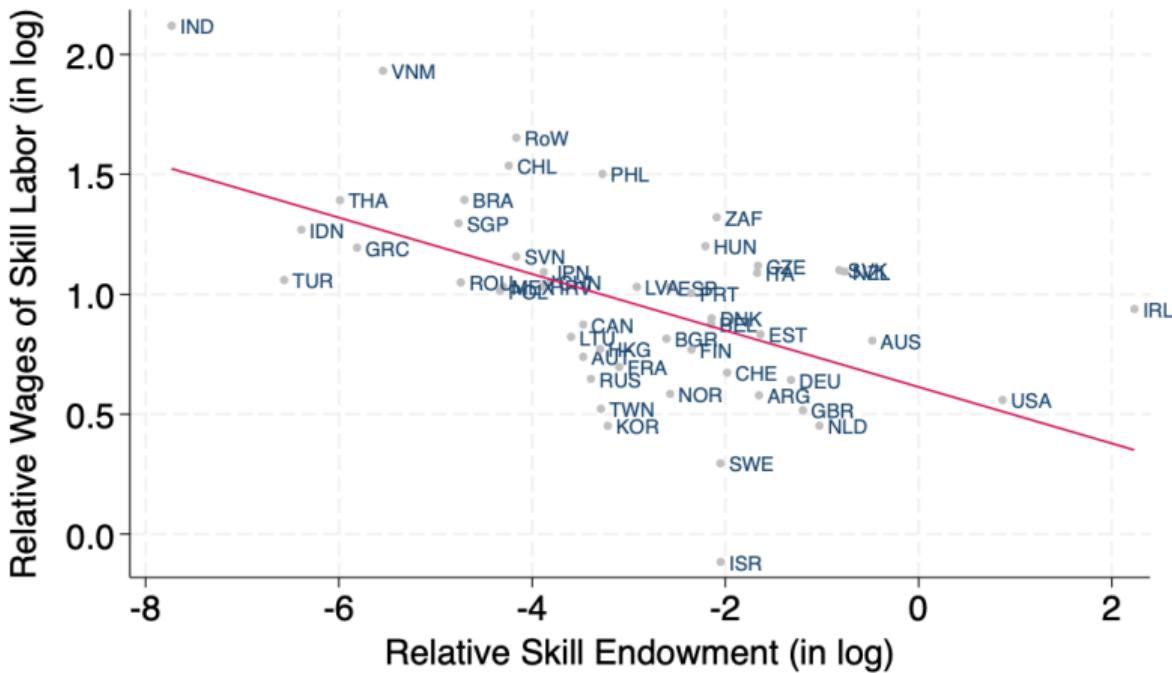
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Relative Skilled Wages Decreasing in Skill Endowment

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Note: Data from GTAP, 2004

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- $\beta > 0$: **Skill-abundant countries specialize in skill-intensive sectors**

Specification: PPML

- What we want to run:

$$\ln \text{Exports}_{i,j,s} = \beta [\text{Skill Intensity}_s \times \text{Skill Abundance}_i] + \eta_{i,j} + \eta_{j,s} + \varepsilon_{i,j,s}$$

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- This presentation: log-specification without the error term (to keep things tidy)
 - “Correct” structural relationship w/o errors

Skill Abundance as a Source of Comparative Advantage

Do skill-abundant countries export more skill-intensive goods?

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- $\eta_{i,j}$: Exporter-Importer FEs: control distances, productivity level diffs,...
- $\eta_{j,s}$: Importer-Sector FEs: control tariffs, expenditure shares,...

Expect $\beta > 0$: Skill-abundant countries export skill-intensive goods more

Skill Abundance as a Source of Comparative Advantage

Do skill-abundant countries export more skill-intensive goods?

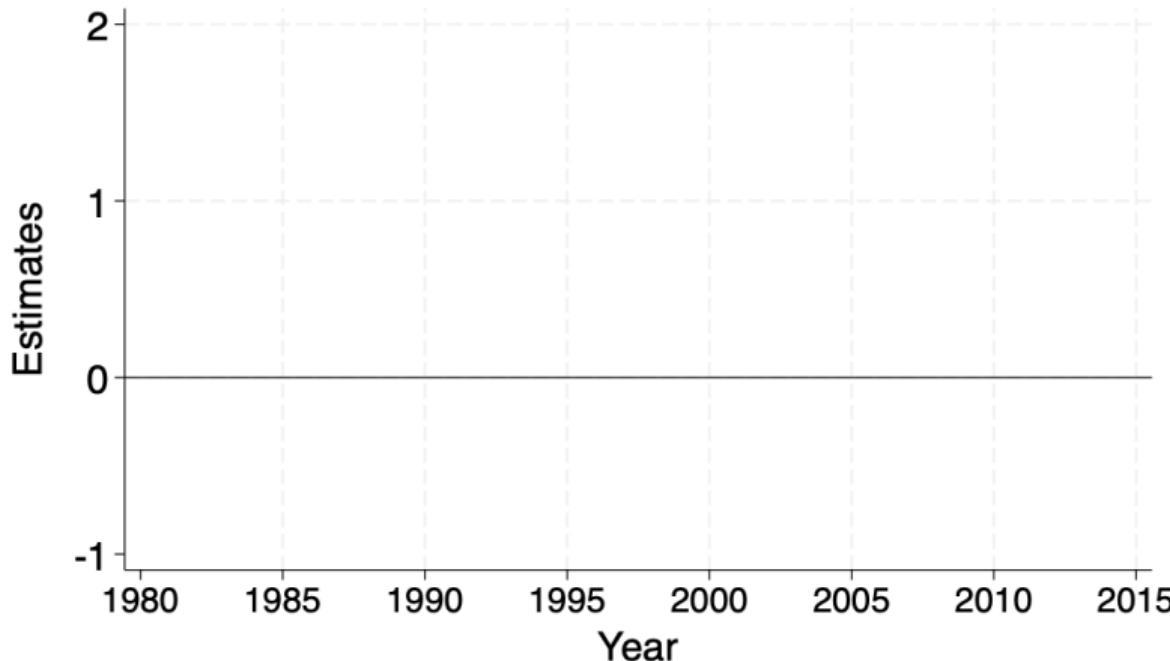
$$\ln \text{Exports}_{i,j,s,t} = \beta_t [\text{Skill Intensity}_{s,t} \times \text{Skill Abundance}_{i,t}] + \eta_{i,j,t} + \eta_{j,s,t},$$

- $\text{Exports}_{i,j,s,t}$: Bilateral trade flow i to j in s , from UN Comtrade
- $\text{Skill Intensity}_{s,t}$: $\alpha_{s,t}^H$ Share of skilled labor pay. in value-added, from NBER-CES
- $\text{Skill Abundance}_{i,t}$: $\ln(H_{i,t}/L_{i,t})$ College to Non-College ratio in i , from Barro-Lee
- $\eta_{i,j,t}$: Exporter-Importer FEs: control distances, productivity level diffs,...
- $\eta_{j,s,t}$: Importer-Sector FEs: control tariffs, expenditure shares,...

Expect $\beta_t > 0$: Skill-abundant countries export skill-intensive goods more

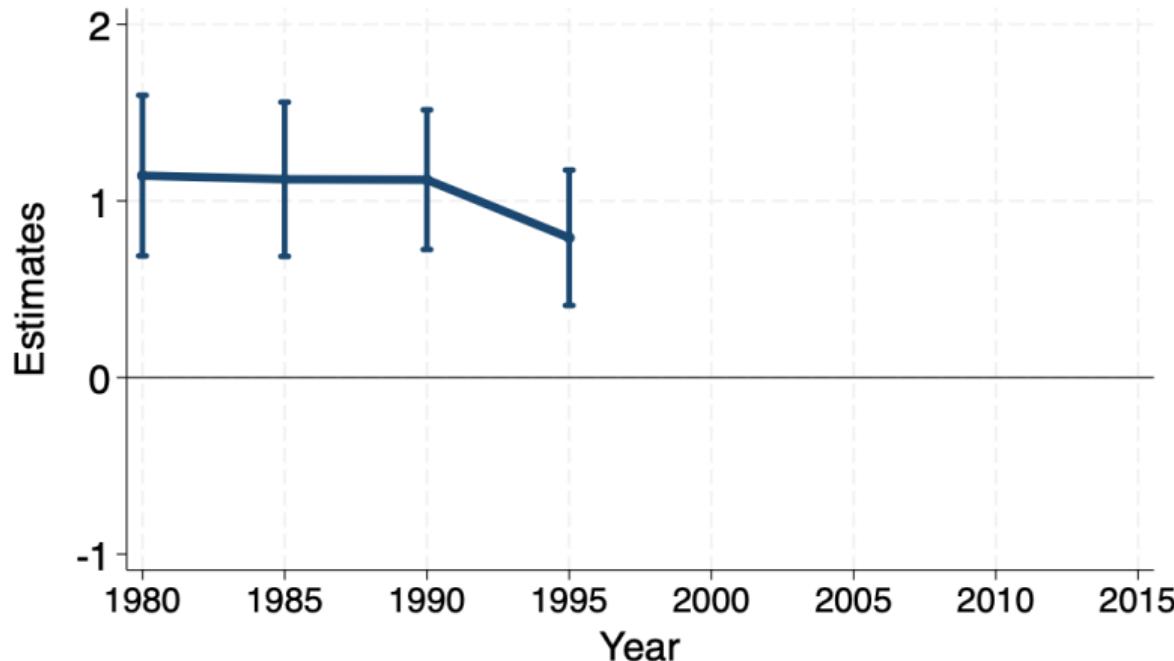
Skill Abundance \Rightarrow CA in Skill-Intensive Sectors?

$$\ln \text{Exports}_{i,j,s,t} = \beta_t [\text{Skill Intensity}_{s,t} \times \text{Skill Abundance}_{i,t}] + \eta_{i,j,t} + \eta_{j,s,t},$$



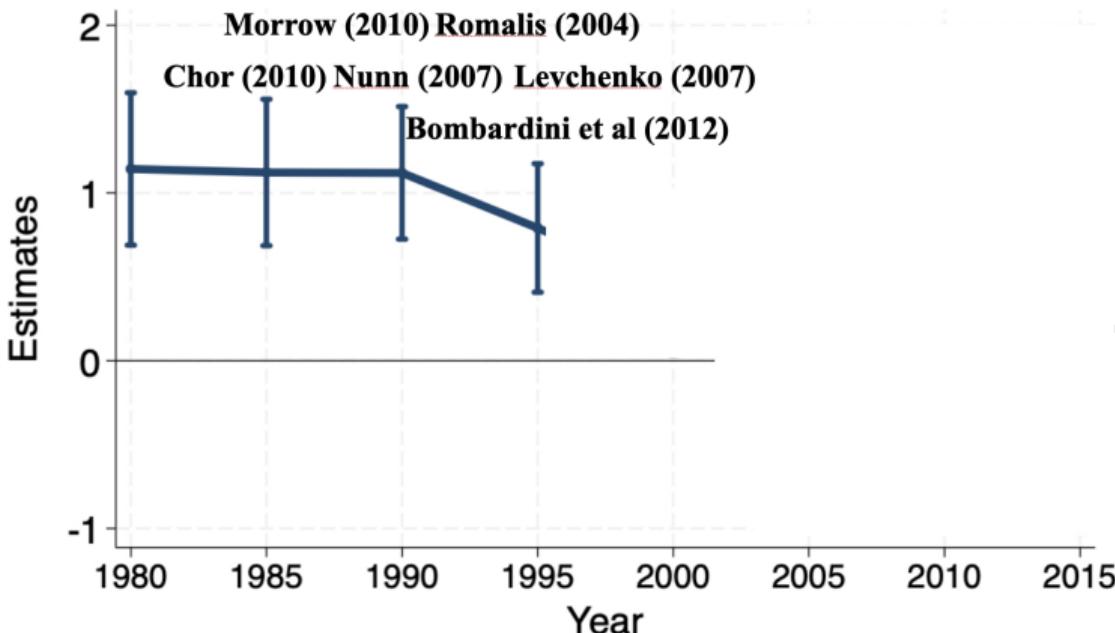
Skill Abundance \Rightarrow CA in Skill-Intensive Sectors before 2000

$$\ln \text{Exports}_{i,j,s,t} = \beta_t [\text{Skill Intensity}_{s,t} \times \text{Skill Abundance}_{i,t}] + \eta_{i,j,t} + \eta_{j,s,t},$$



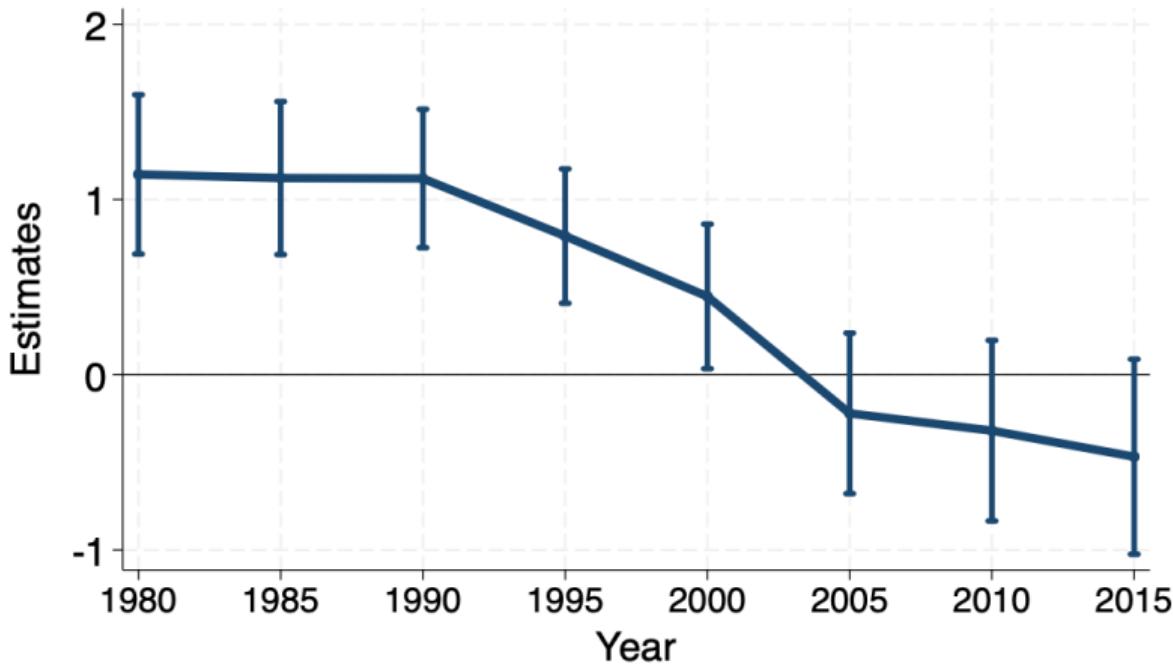
Results before 2000 are Consistent with Previous Papers

$$\ln \text{Exports}_{i,j,s,t} = \beta_t [\text{Skill Intensity}_{s,t} \times \text{Skill Abundance}_{i,t}] + \eta_{i,j,t} + \eta_{j,s,t},$$



Skill Abundance \Rightarrow CA in Skill-Intensive Sectors after 2000

$$\ln \text{Exports}_{i,j,s,t} = \beta_t [\text{Skill Intensity}_{s,t} \times \text{Skill Abundance}_{i,t}] + \eta_{i,j,t} + \eta_{j,s,t},$$

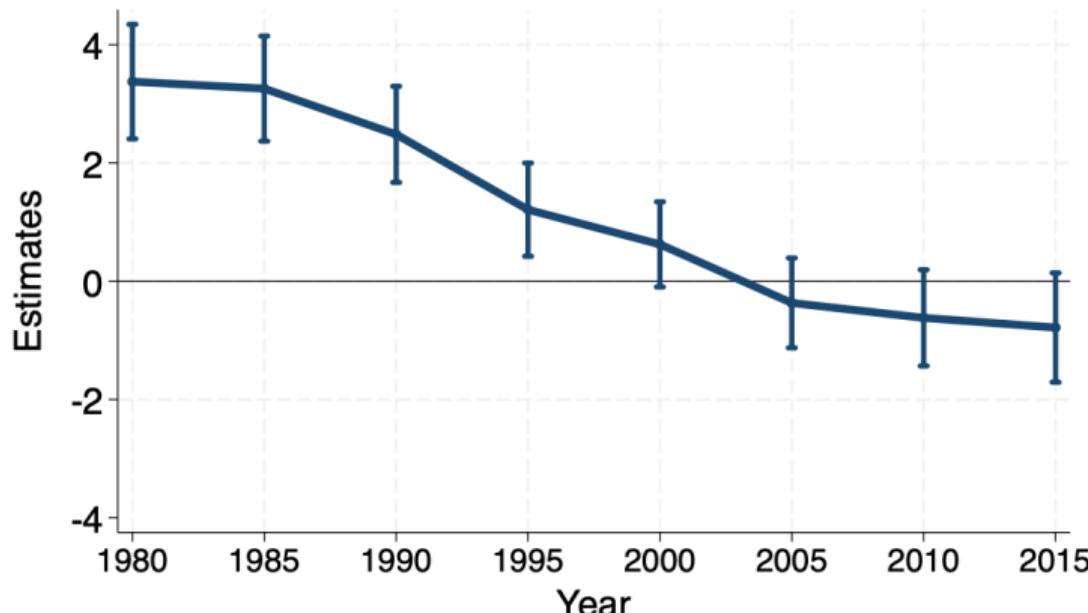


Fixing RHS at 1980's values

$$\ln \text{Exports}_{i,j,s,t} = \beta_t [\text{Skill Intensity}_{s,\mathbf{1980}} \times \text{Skill Abundance}_{i,\mathbf{1980}}] + \eta_{i,j,t} + \eta_{j,s,t},$$

Change in Patterns of CA Comes from Exports

$$\ln \text{Exports}_{i,j,s,t} = \beta_t [\text{Skill Intensity}_{s,1980} \times \text{Skill Abundance}_{i,1980}] + \eta_{i,j,t} + \eta_{j,s,t},$$

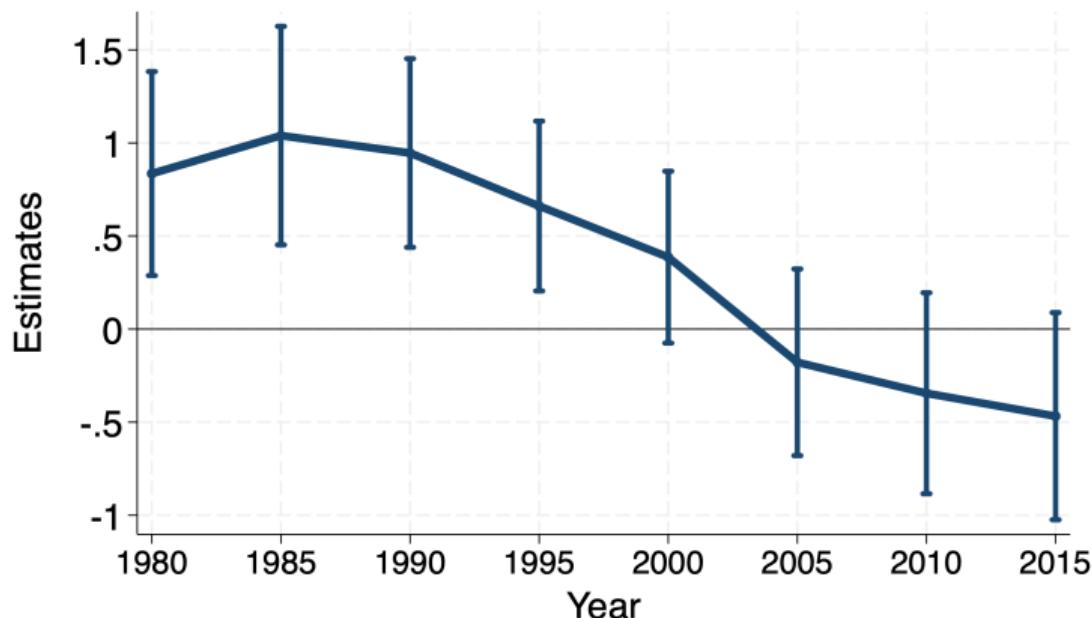


Fixing RHS at 2015's values

$$\ln \text{Exports}_{i,j,s,t} = \beta_t [\text{Skill Intensity}_{s,\mathbf{2015}} \times \text{Skill Abundance}_{i,\mathbf{2015}}] + \eta_{i,j,t} + \eta_{j,s,t},$$

NOT Driven by Attenuating Skill Measurement

$$\ln \text{Exports}_{i,j,s,t} = \beta_t [\text{Skill Intensity}_{s,2015} \times \text{Skill Abundance}_{i,2015}] + \eta_{i,j,t} + \eta_{j,s,t},$$



Robustness Checks

- Other sources of comparative advantage? → Capital → Institution
- Driven by small countries? → Weighted
- Some exporter-sector unobserved het., or IRS? → Pool years and i-s FEs
- Different skill measures? → High School → Predicted by Demographics
- Total exports, instead of bilateral exports (Romalis 2004, Nunn 2007,...) → go
- Different measures of sectoral factor intensity (Chor 2010)
 - $\ln(H_s/L_s)$, instead of α_s^H (\equiv Skilled Payroll Share to Value-Added) → go
- Including service sectors (WIOD, later in this presentation)

POTENTIAL HYPOTHESES: AUTOMATION AND OFFSHORING

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- What can make domestic skill abundance less relevant for CA after the 1990s?

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- Two massive technical progress, replacing low-skill labor
 - Automation: Replace low-skill labor with machines
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Potential Hypotheses: Automation and Offshoring

- What can make domestic skill abundance less relevant for CA after the 1990s?
- Two massive technical progress, replacing low-skill labor
 - Automation: Replace low-skill labor with machines
 - Offshoring: Replace low-skill labor with foreign inputs
- This section: Explore heterogeneous effects across countries and sectors
 - Descriptive analysis for heterogeneous effects (for now)
 - Causal analysis using the model (later)

Specification for Heterogeneous Effects: Automation

$$\ln \text{Exports}_{i,j,s,t} = \underbrace{\beta_t^0 (1 + \beta_t^A HA_{i,s})}_{=\beta_t} \cdot [\text{Skill Intensity}_{s,t} \times \text{Skill Abundance}_{i,t}] + \eta_{i,j,t} + \eta_{j,s,t},$$

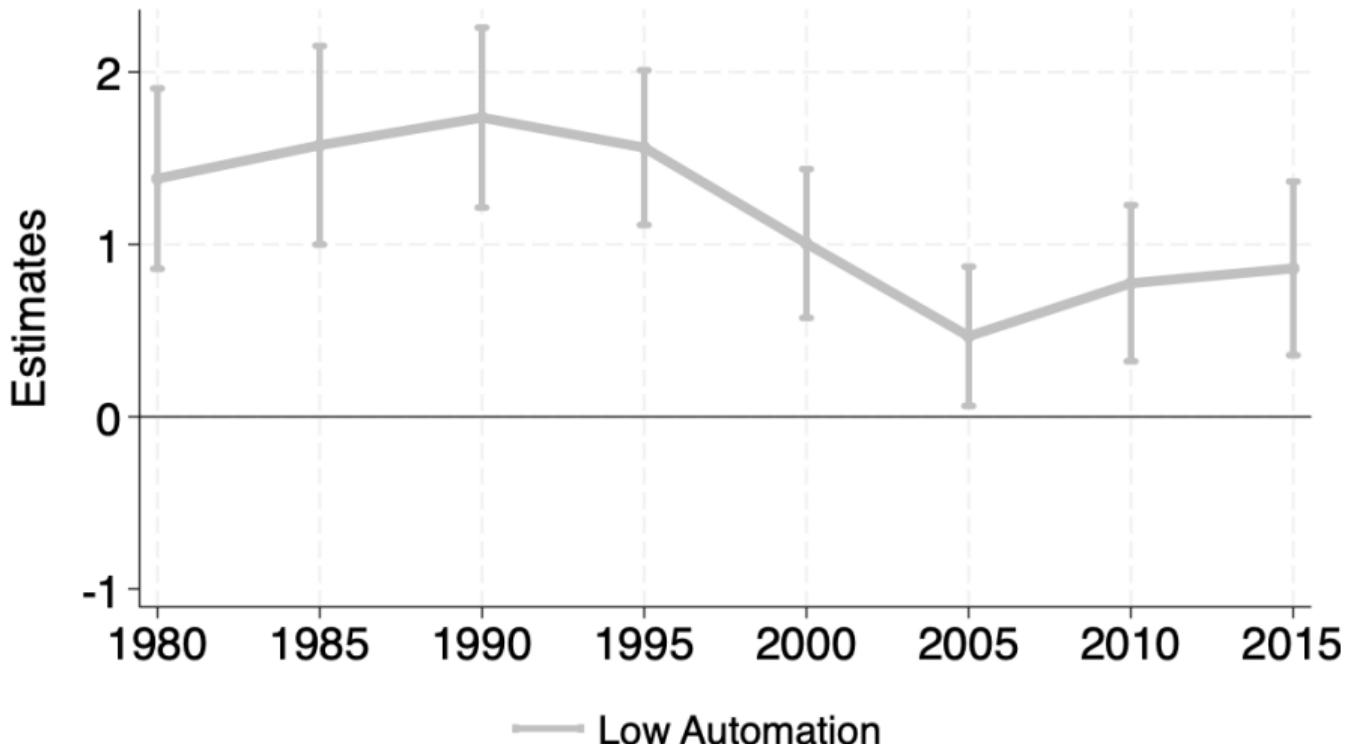
- $HA_{i,s}$: High-automation dummy (below/above the median robot adoption)
 - Robot adoption: Robot stock per workers from IFR & WIOD

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- $HA_{i,s}$: High-automation dummy (below/above the median robot adoption)
 - Robot adoption: Robot stock per workers from IFR & WIOD
- Expect β_t^A to decrease if there is a relationship btw change & automation

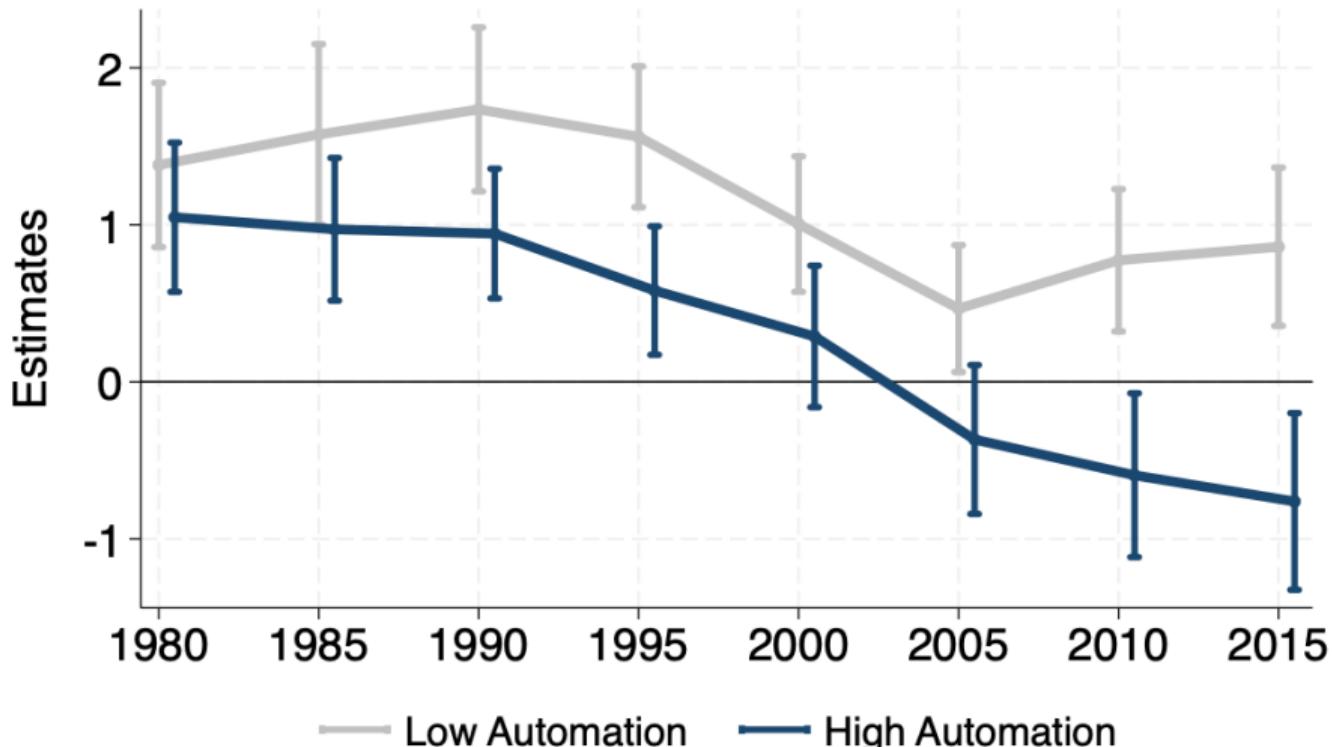
Skill Abundance Still Matters Absent Automation



Plot $\hat{\beta}_t^0$

Skill Abundance Still Matters Absent Automation

Plot $\hat{\beta}_t^0$ and $\hat{\beta}_t^0 + \hat{\beta}_t^A$



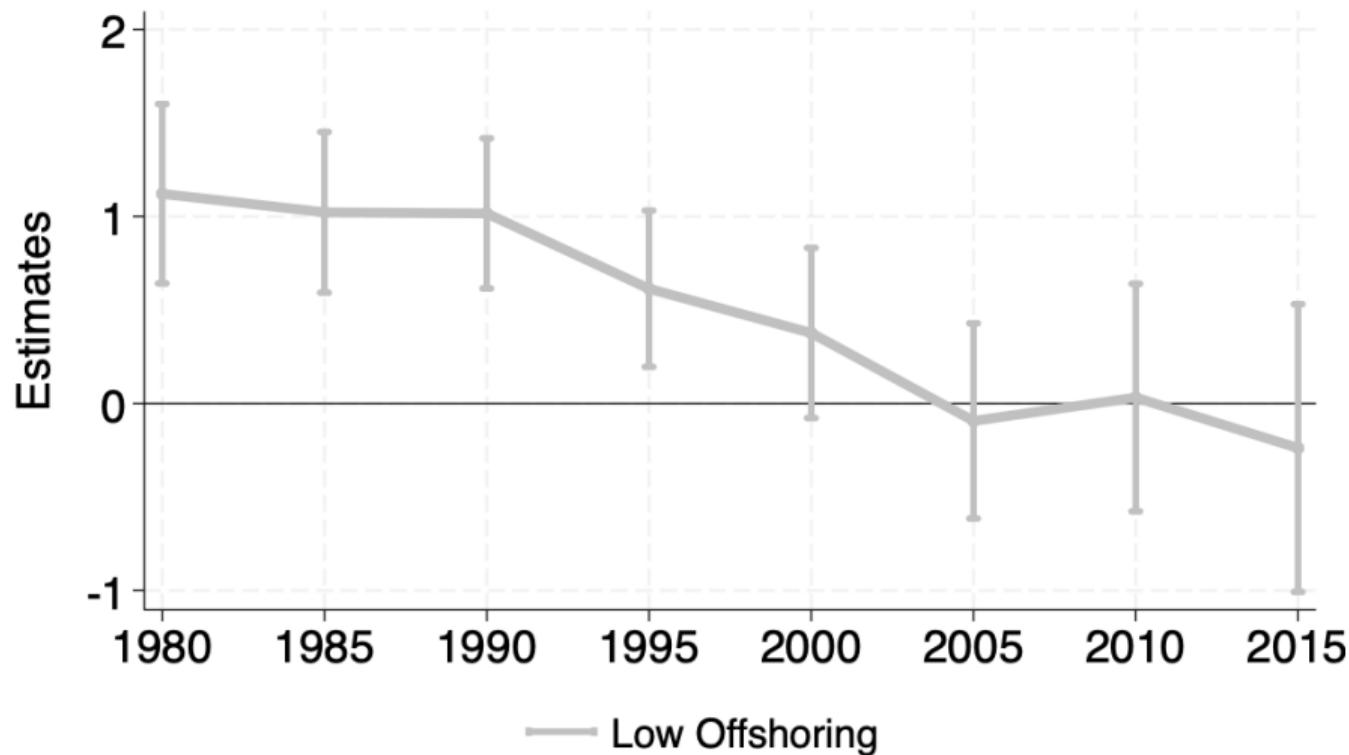
Specification for Heterogeneous Effects: Offshoring

$$\ln \text{Exports}_{i,j,s,t} = \underbrace{\beta_t^0 (1 + \beta_t^0 HO_{i,s})}_{=\beta_t} \cdot [\text{Skill Intensity}_{s,t} \times \text{Skill Abundance}_{i,t}] + \eta_{i,j,t} + \eta_{j,s,t},$$

- $HO_{i,s}$: High-offshoring dummy (below/above the median offshoring)
 - Offshoring share: (Intermediate imports) / (Total intermediates) from WIOD
- Expect β_t^0 to decrease if there is a relationship btw change & offshoring

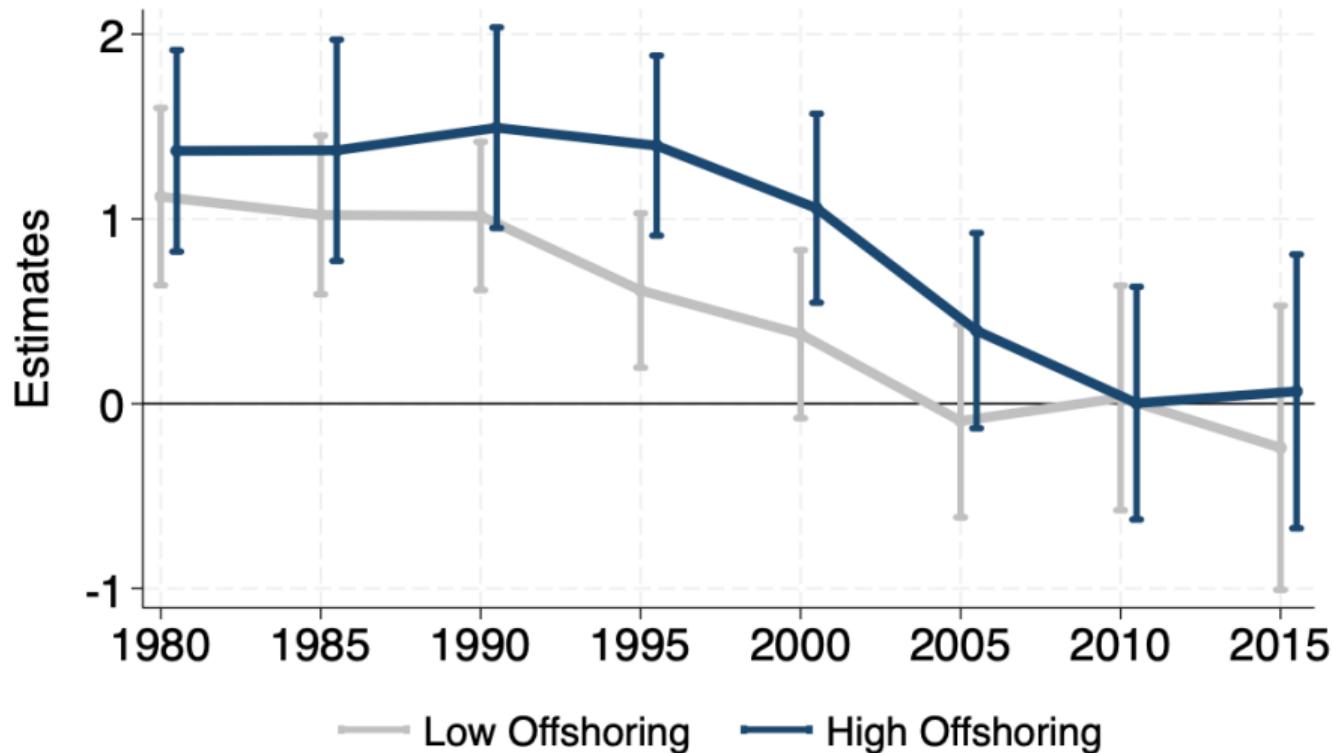
Skill Abundance does not Matter Even Absent Offshoring

Plot $\hat{\beta}_t^0$



Skill Abundance does not Matter Even Absent Offshoring

Plot $\hat{\beta}_t^0$ and $\hat{\beta}_t^0 + \hat{\beta}_t^O$



Using Continuous Measures,

$$\ln \text{Exports}_{i,j,s,t} = \beta_t^0 (1 + \beta_t^A \text{Auto}_{i,s} + \beta_t^O \text{Ofs}_{i,s}) \cdot [\text{Skill Int.}_{s,t} \times \text{Skill Abd.}_{i,t}] + \eta_{i,j,t} + \eta_{j,s,t}$$

| | 1995 | 2010 | 1995 | 2010 |
|-------------------------------------|--------|--------|------|------|
| Skill Intensity x Abundance | 1.26 | -0.33 | | |
| | (0.23) | (0.28) | | |
| x Automation (log robot stock) | | | | |
| x Offshoring Share ($\times 100$) | | | | |

Same Results from Continuous Measures

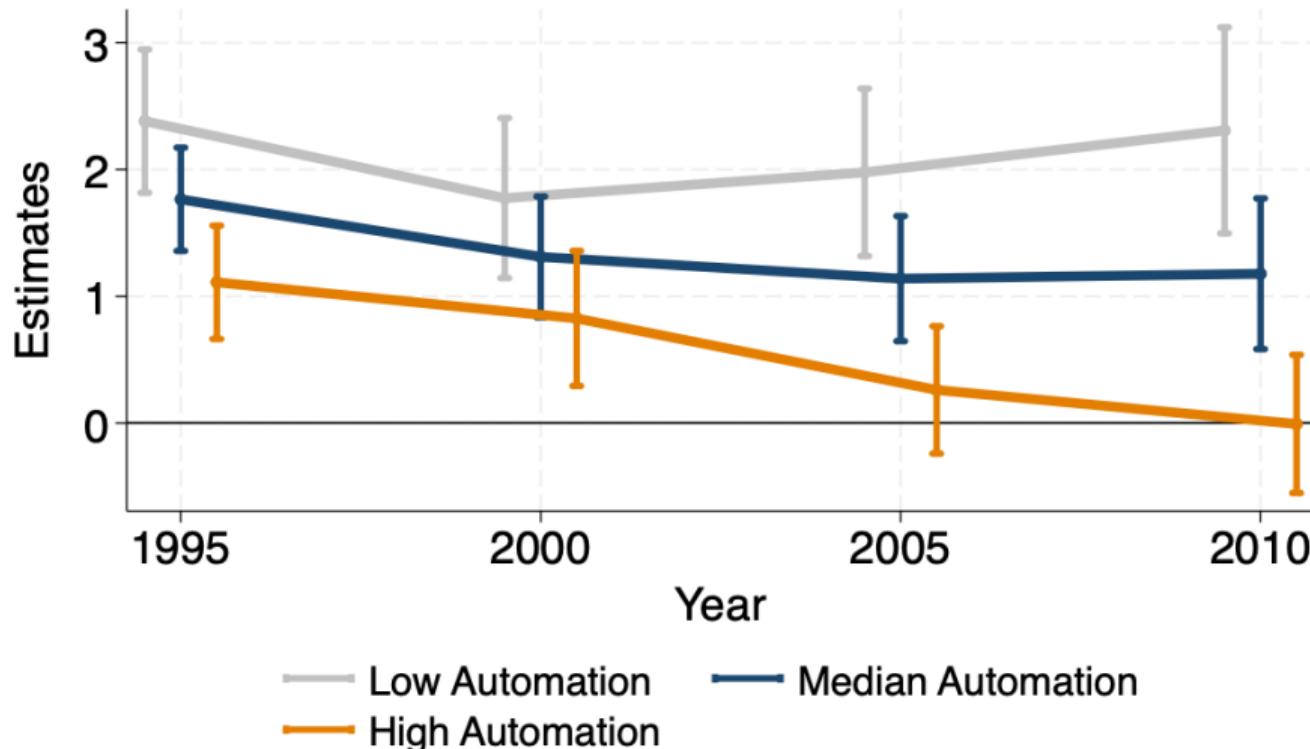
$$\ln \text{Exports}_{i,j,s,t} = \beta_t^0 (1 + \beta_t^A \text{Auto}_{i,s} + \beta_t^O \text{Ofs}_{i,s}) \cdot [\text{Skill Int.}_{s,t} \times \text{Skill Abd.}_{i,t}] + \eta_{i,j,t} + \eta_{j,s,t}$$

| | 1995 | 2010 | 1995 | 2010 |
|-------------------------------------|----------------|-----------------|-----------------|------------------------|
| Skill Intensity x Abundance | 1.26 (0.23) | -0.33 (0.28) | 3.00 (0.41) | 3.49 (0.57) |
| x Automation (log robot stock) | | | -0.19 (0.05) | -0.35 (0.06) |
| x Offshoring Share ($\times 100$) | | | 0.04 (0.05) | 0.05 (0.07) |

Note: Automation measure: 12.2 for German cars, 2.3 for Indian textiles

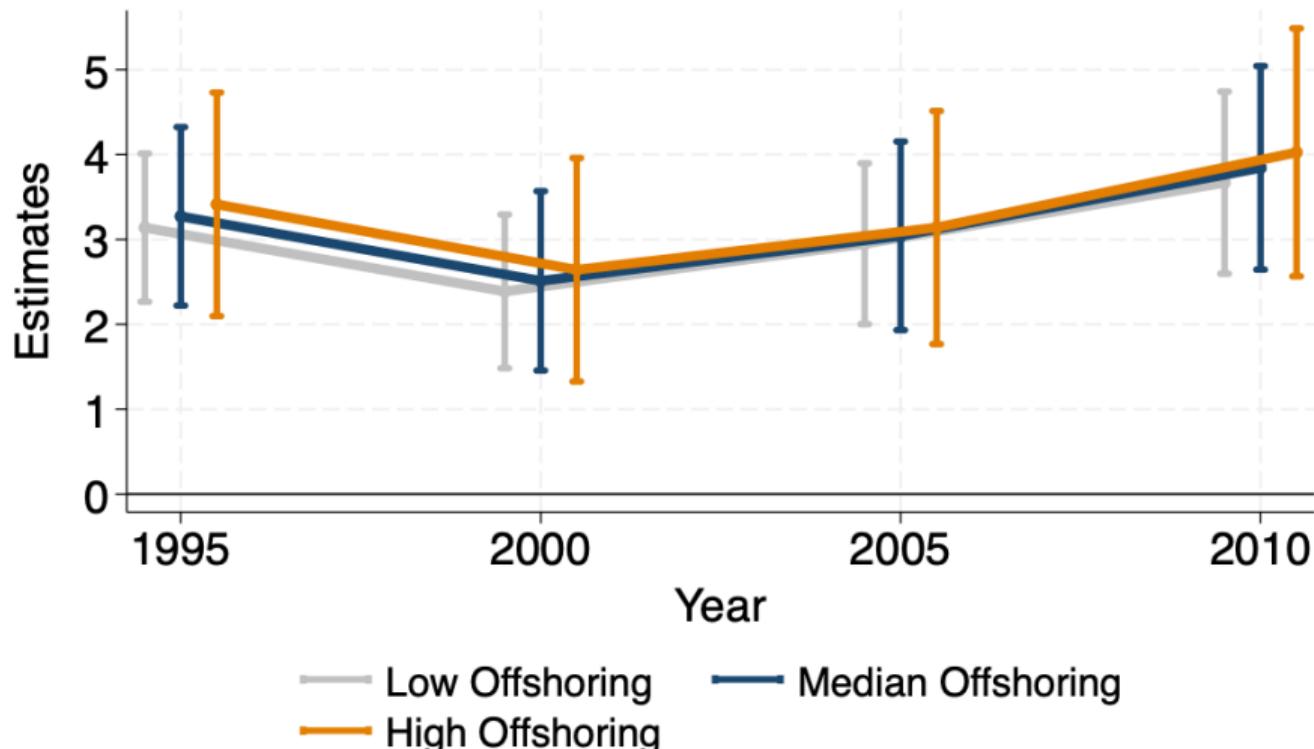
Skill Abundance Still Matters Absent Automation

Fitted values for groups with automation of 10th, 50th, and 90th percentiles



Offshoring Seems Unrelated to Change in Pattern

Fitted values for groups with offshoring of 10th, 50th, and 90th percentiles



Controlling China Shock does not Change Results

| | 1995 | 2010 | 1995 | 2010 |
|-------------------------------------|--------|--------|------|------|
| Skill Intensity x Abundance | 1.26 | -0.33 | | |
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| x China's RCA | | | | |

Controlling China Shock does not Change Results

| | 1995 | 2010 | 1995 | 2010 |
|-------------------------------------|--------|--------|--------|--------------|
| Skill Intensity x Abundance | 1.26 | -0.33 | 2.43 | 3.51 |
| | (0.23) | (0.28) | (0.45) | (0.46) |
| x Automation (log robot stock) | | | -0.15 | -0.31 |
| | | | (0.05) | (0.05) |
| x Offshoring Share ($\times 100$) | | | 0.03 | 0.11 |
| | | | (0.05) | (0.06) |
| x China's RCA | | | 0.20 | 0.34 |
| | | | (0.12) | (0.13) |

Takeaway: **China shocks strengthen the Heckscher-Ohlin force**

Summary of Empirical Facts

- Skill abundance becomes less important in comparative advantage over time
 - Less important with higher automation
 - Offshoring has surprisingly no relationship

MODEL: TRADE WITH AUTOMATION AND OFFSHORING

Model: Big Picture

- Purpose of the model:
 - Quantify the roles of automation and offshoring in the change in CA
 - Demonstrate the causal effect of automation and offshoring
- Basic idea:
 - Producing low-skill intensive goods used to require production labor
 - Automation & offshoring \Rightarrow Skill-abundant countries become competitive
 - ★ e.g. Germany, South Korea, Japan
 - ★ e.g. Shoes, Car assembling...

Model: “Illustrating” The Idea

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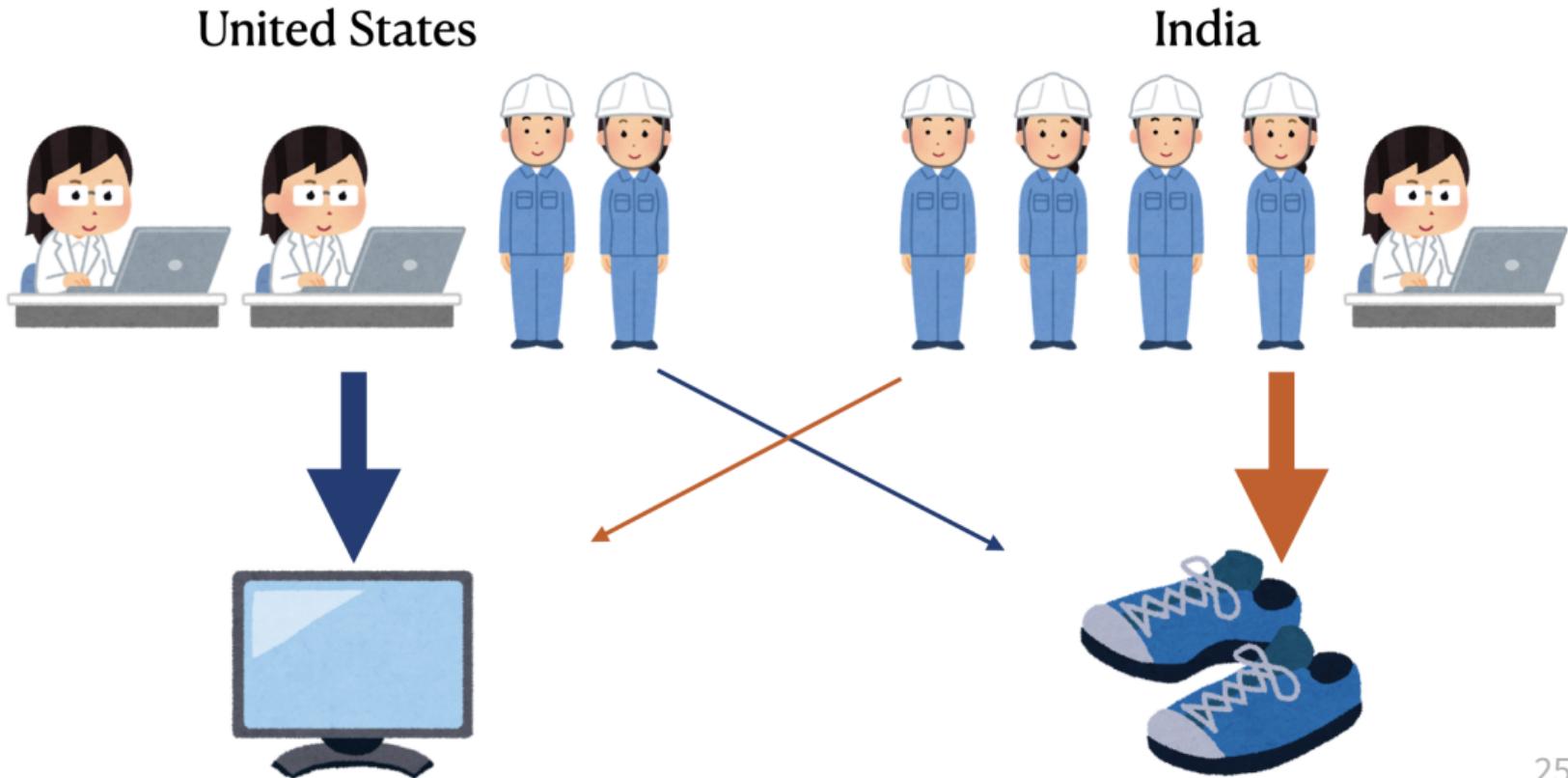
United States



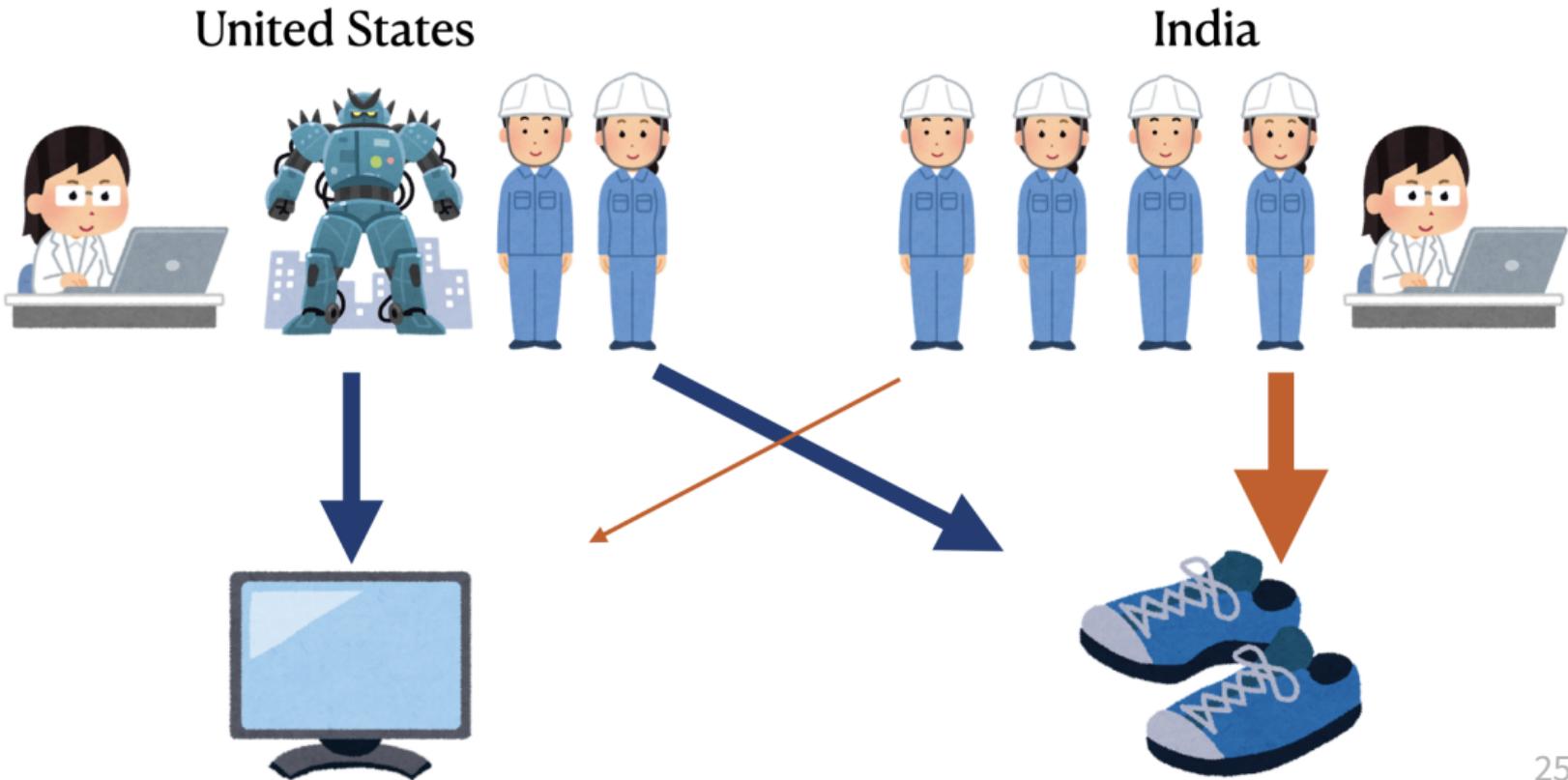
India



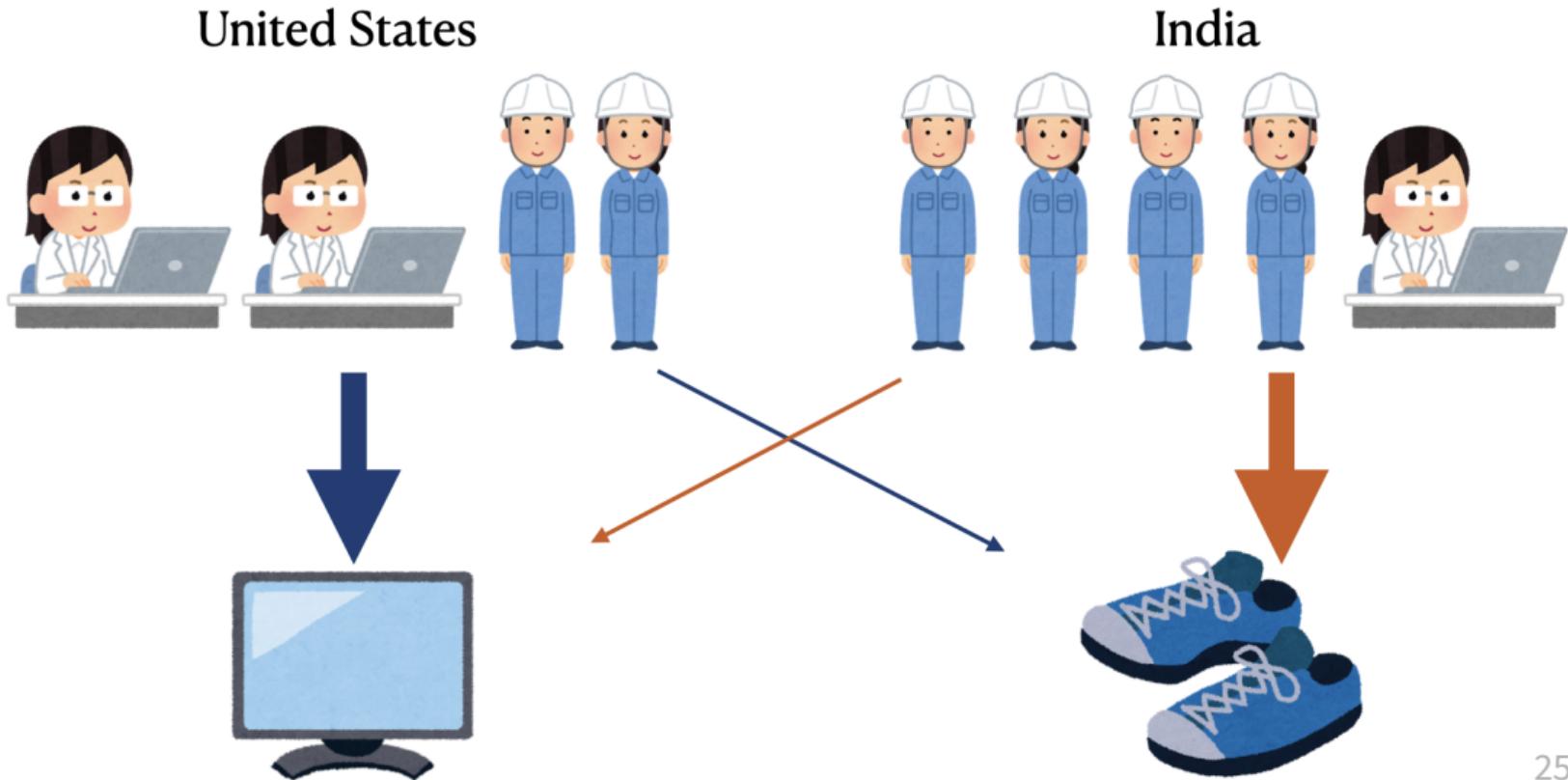
US for Electronics, India for Shoes



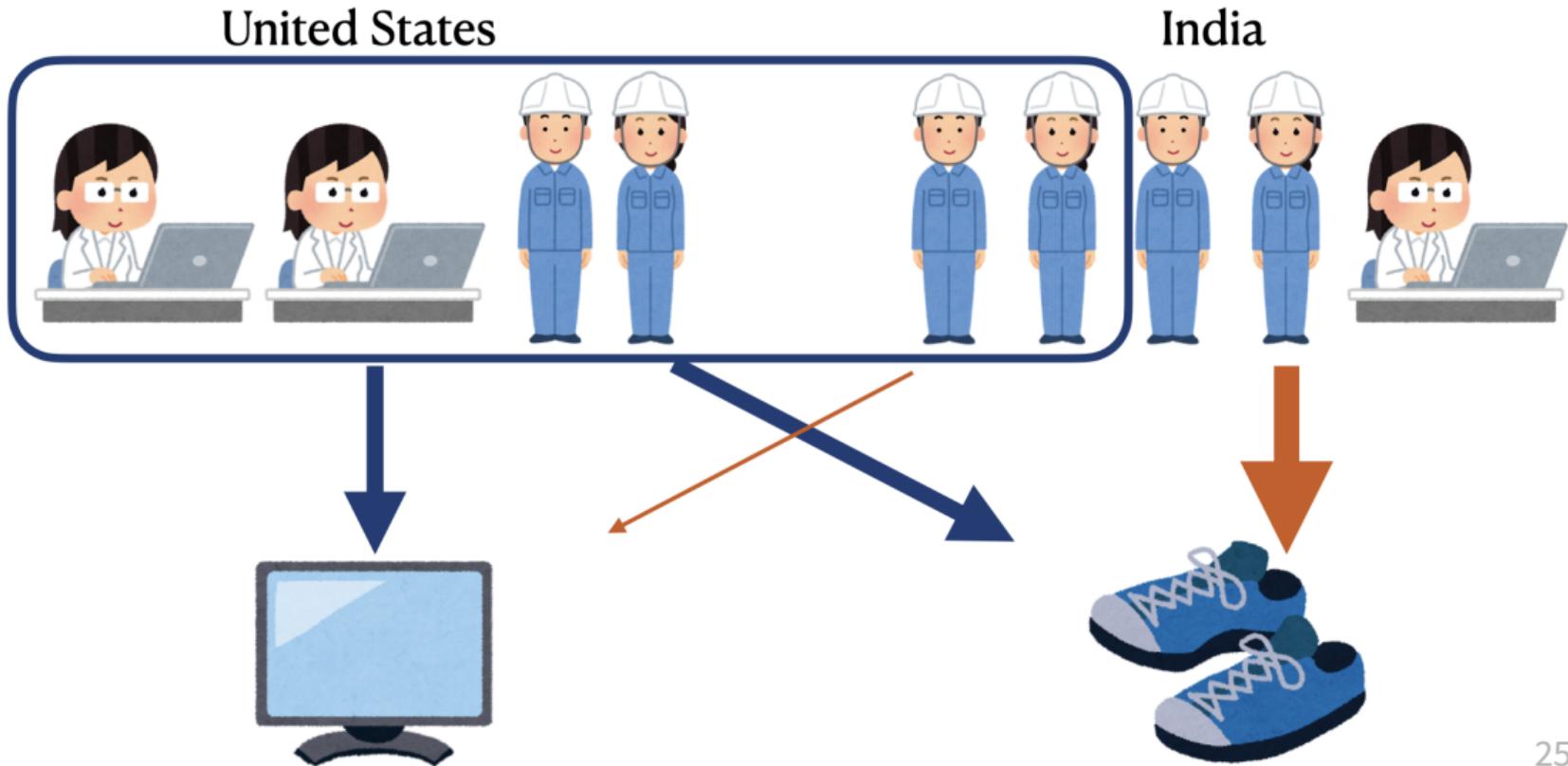
With Robots, US is now Competitive in Shoes



Model: “Illustrating” The Idea



With Offshoring, US is now Competitive in Shoes



Model: Overview

- Multi-sector Eaton-Kortum model with input-output linkages

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 - **New: Task framework for automation and offshoring**

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- Primary factors:
 - Labor: $H_{i,s}$ (high-skilled), $L_{i,s}$ (low-skilled)

Model: Overview

- Multi-sector Eaton-Kortum model with input-output linkages
 - **New: Task framework for automation and offshoring**
- Primary factors:
 - Labor: $H_{i,s}$ (high-skilled), $L_{i,s}$ (low-skilled)
- Additional production factors (produced using outputs: roundabout)
 - Automation Capital: $A_{i,s}$
 - Intermediate: $X_{i,s}$ (domestic), $O_{i,s}$ (foreign, offshored)
 - ★ including non-automation capital (buildings, land)

Demand: Standard Multi-Sector Eaton Kortum Model

- Country i, j , Sector s
- Preference across sectors: Cobb-Douglas with expenditure share of $\mu_{j,s}$

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- Country i, j , Sector s
- Preference across sectors: Cobb-Douglas with expenditure share of $\mu_{j,s}$
- Trade share (gravity equation) within sectors:

$$\pi_{i,j,s}^F = \frac{(c_{i,s} \cdot \tau_{i,j,s})^{-\theta}}{\sum_l^J (c_{l,s} \cdot \tau_{l,j,s})^{-\theta}}$$

- Unit cost: $c_{i,s}$ —endogenously determined from production processes (next)
- Trade cost: $\tau_{i,j,s}$
- Trade elasticity $\theta > 0$

Supply 1/2: Task Framework in Production

- Eaton-Kortum + Task Framework

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- Gross Output ($z_{i,s}(\omega)$: Fréchet) for variety ω

$$Y_{i,s}(\omega) = z_{i,s}(\omega) \cdot (H_{i,s}(\omega))^{\alpha_s^H} \cdot (T_{i,s}(\omega))^{1-\alpha_s^H}.$$

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Supply 1/2: Task Framework in Production

- Eaton-Kortum + Task Framework
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- Production function for each task ($\psi_{i,s}^f(x)$ task-specific tech)

$$T_{i,s}(x) = \underbrace{\psi_{i,s}^A(x)A_{i,s}(x)}_{\text{Automation Capital}} + \underbrace{\psi_{i,s}^L(x)L_{i,s}(x)}_{\text{Production Labor}} + \underbrace{\psi_{i,s}^X(x)X_{i,s}(x)}_{\text{Domestic Input}} + \underbrace{\psi_{i,s}^O(x)O_{i,s}(x)}_{\text{Foreign Input}}$$

Suppl 2/2: Task Allocation $\mathcal{T}_{i,s}^f$, Task Share $\Gamma_{i,s}^f$

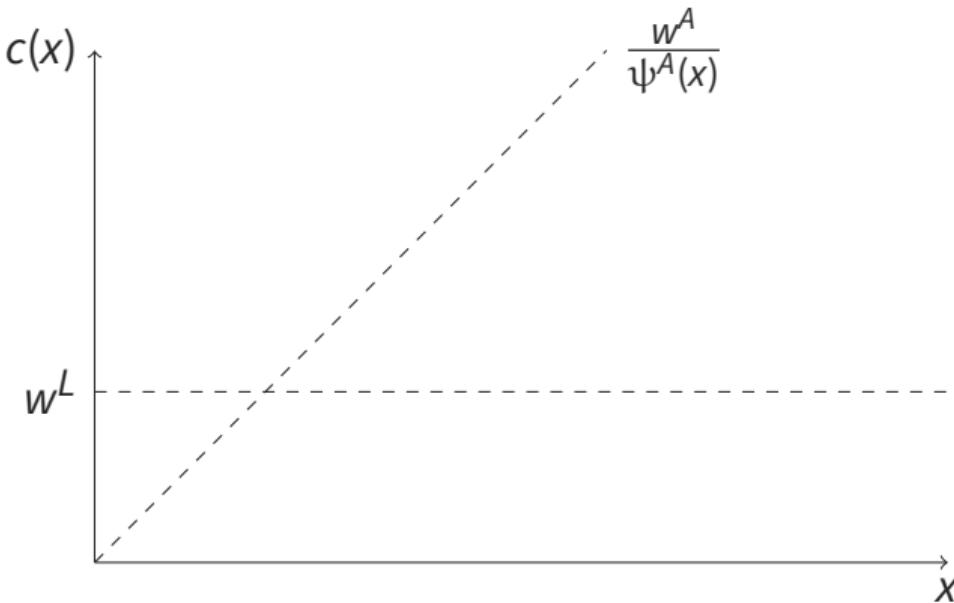
- Task production cost using factor f : $c_{i,s}^f(x) \equiv w_{i,s}^f / (\psi_{i,s}^f(x))$ for $f \in \{A, L, X, O\}$

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- Cost minimization \Rightarrow Task Allocation and Task Share
$$\mathcal{T}_{i,s}^f = \left\{ x : f = \operatorname{argmin}_{f'} c_{i,s}^{f'}(x) \right\}, \quad \rightarrow \Gamma_{i,s}^f : \text{measure of } \mathcal{T}_{i,s}^f, \quad \text{for } f \in \{A, L, X, O\}$$

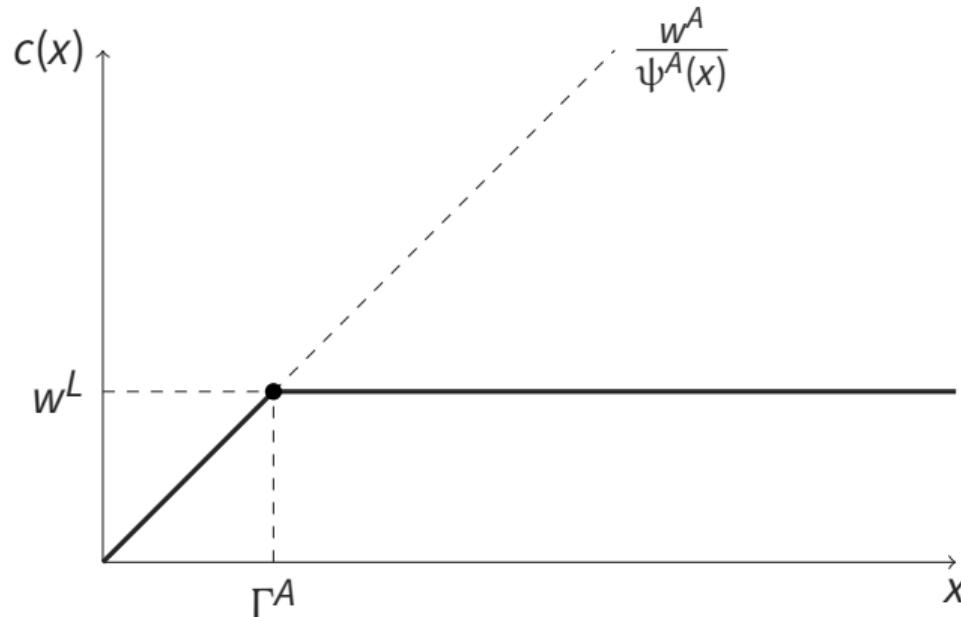
At Glance: Task Allocation and Task Share

- Suppose no intermediate and constant labor productivity $\psi^L(x) = 1$.



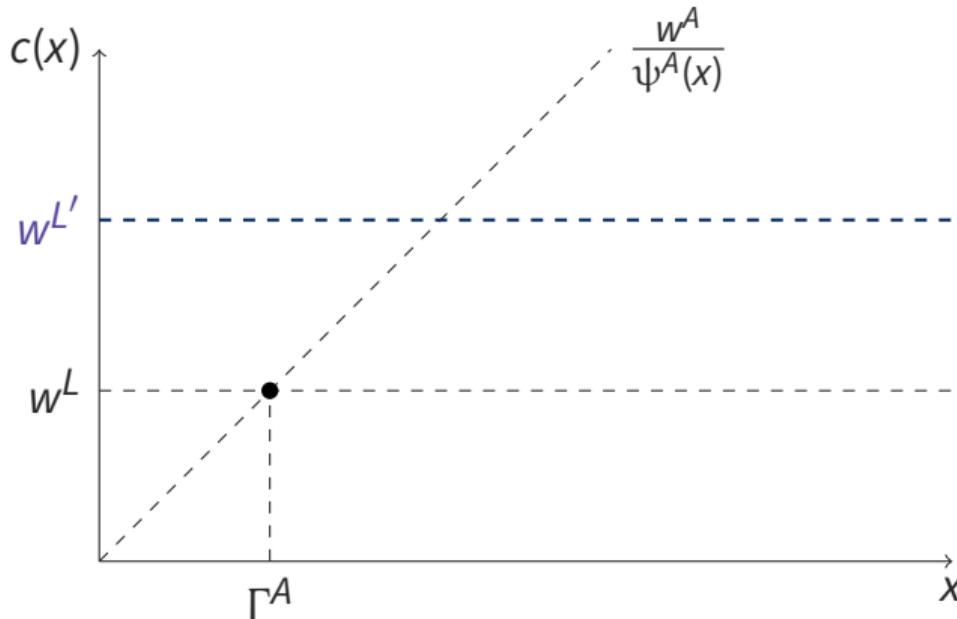
At Glance: Task Allocation and Task Share

- Suppose no intermediate and constant labor productivity $\psi^L(x) = 1$.
- Cost minimization (task allocation) \Rightarrow Automation share $\Gamma_i^A = \Gamma^A$



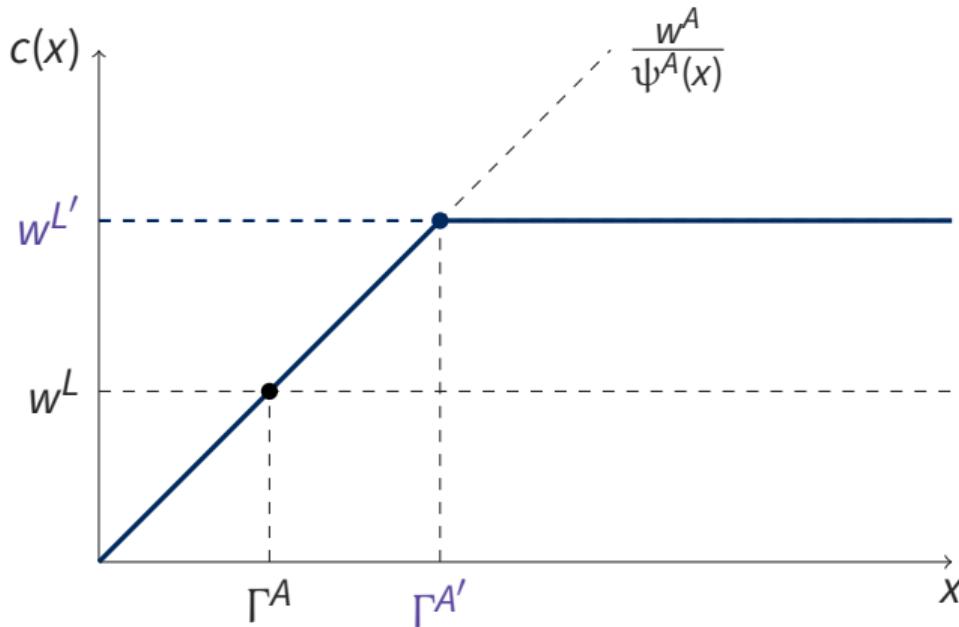
At Glance: Task Allocation and Task Share

- Suppose no intermediate and constant labor productivity $\psi^L(x) = 1$.
- Suppose wage increases to $w^{L'}$



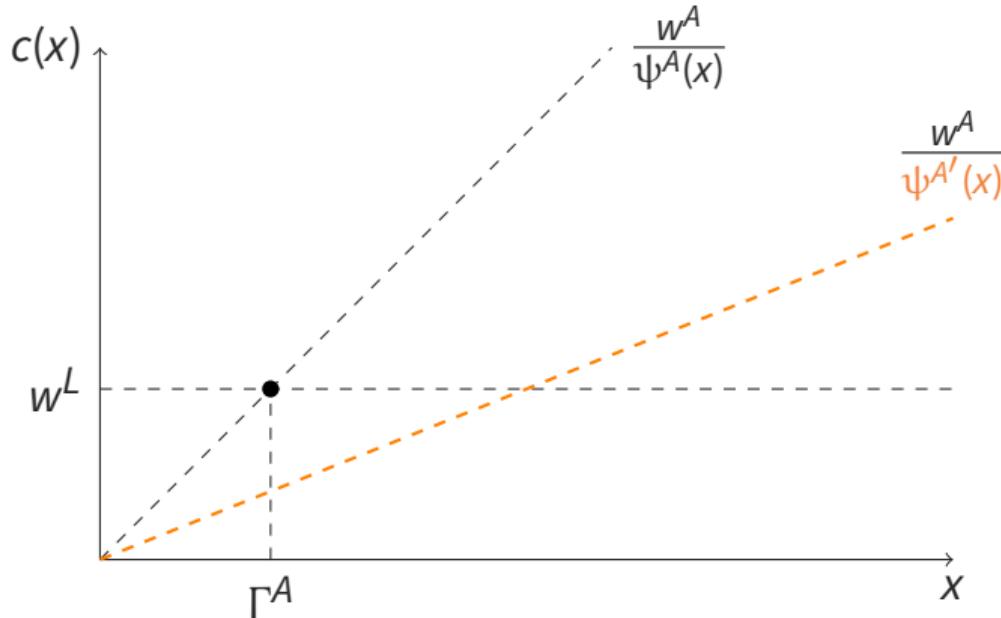
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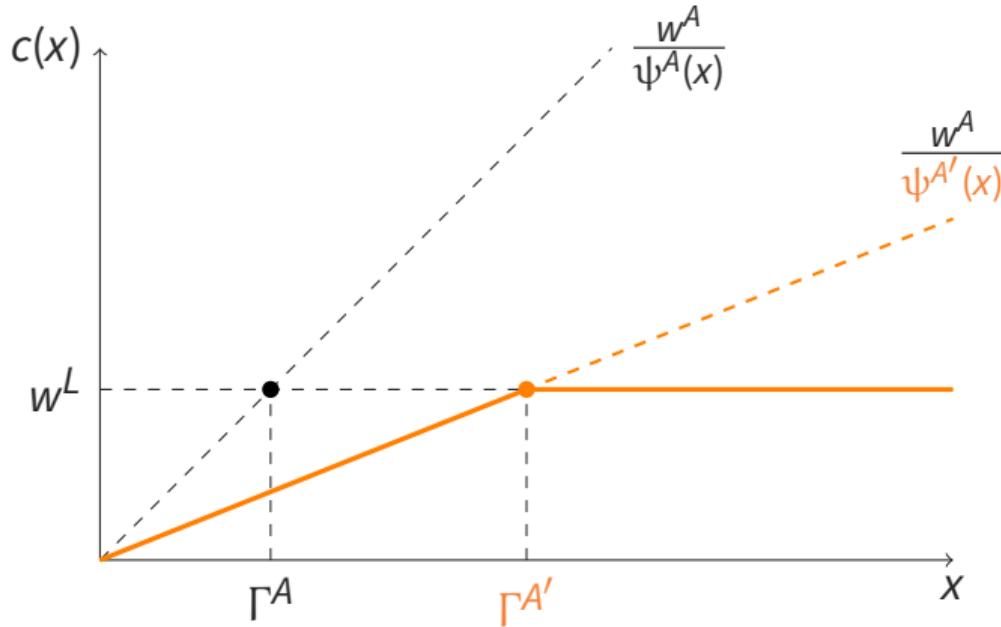
At Glance: Task Allocation and Task Share

- Suppose no intermediate and constant labor productivity $\psi^L(x) = 1$.
- Now, consider automation shock $\psi^A(x)$ from $\psi^{A'}(x)$



At Glance: Task Allocation and Task Share

- Suppose no intermediate and constant labor productivity $\psi^L(x) = 1$.
- Automation share increases to $\Gamma^{A'}$



Suppl 2/2: Task Allocation $\mathcal{T}_{i,s}^f$, Task Share $\Gamma_{i,s}^f$

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- Unit cost of production:

$$c_{i,s} = \Lambda_s \cdot (w_i^H)^{\alpha_s^H} \cdot \left[\left(\frac{w_{i,s}^A}{\Gamma_{i,s}^A} \right)^{\Gamma_{i,s}^A} \cdot \left(\frac{w_{i,s}^L}{\Gamma_{i,s}^L} \right)^{\Gamma_{i,s}^L} \cdot \left(\frac{w_{i,s}^X}{\Gamma_{i,s}^X} \right)^{\Gamma_{i,s}^X} \cdot \left(\frac{w_{i,s}^O}{\Gamma_{i,s}^O} \right)^{\Gamma_{i,s}^O} \right]^{1-\alpha_s^H}$$

Equilibrium Conditions

Two Country

Given factor endowments $\{H_i, L_i\}$, an equilibrium is a set of wages $\{w_i^H, w_i^L\}$

- Consumers maximize utility by choosing from which countries to buy
→ trade share $\pi_{i,j,s}$, as a function of unit cost $\{c_{i,s}\}$
- Unit cost, $c_{i,s}$, as a function of $\{w_i^H, w_i^L\}$
 - $\{w_{i,s}^A, w_{i,s}^X, w_{i,s}^O\}$ are functions of $\{w_i^H, w_i^L\}$ with IO coef.
- Goods and Labor Markets Clear

QUANTIFICATION

Quantitative Analysis: Effects of Automation and Offshoring

- Two Exercises:
 1. Can changes in $\Gamma_{i,s,t}^A$ (automation) and $\Gamma_{i,s,t}^O$ (offshoring) explain $\hat{\beta}_t$?
 2. Using the same model, what are the macro implications?

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 - $\Gamma_{i,s,t}^A$ (automation, constructed)

$$p_{i,s,t}^A A_{i,s,t} = \underbrace{p_{i,s,t0}^K K_{i,s,t0}}_{\text{Capital Income}} \cdot \underbrace{\frac{p_{US,s,t0}^M M_{US,s,t0}}{p_{US,s,t0}^K K_{US,s,t0}}}_{\text{Machine-Capital Ratio}} \cdot \underbrace{\frac{p_{i,s,t}^R R_{i,s,t}}{p_{i,s,t0}^R R_{i,s,t0}}}_{\text{Increases in Robots}}.$$

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 - $\Gamma_{i,s,t}^O$ (offshoring, just data), fixing $\Gamma_{i,s,t}^X$ (domestic intermediate share)

Quantitative Analysis: Effects of Automation and Offshoring

- Two Exercises:
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- Countries and Sectors: 40 countries, 18 sectors (WIOD, 1995-2008)
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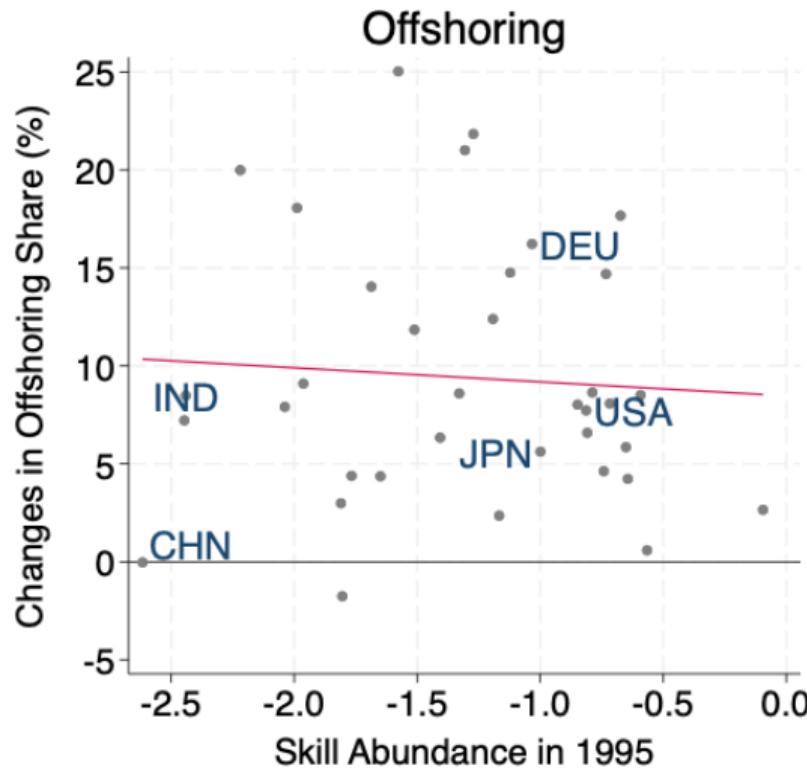
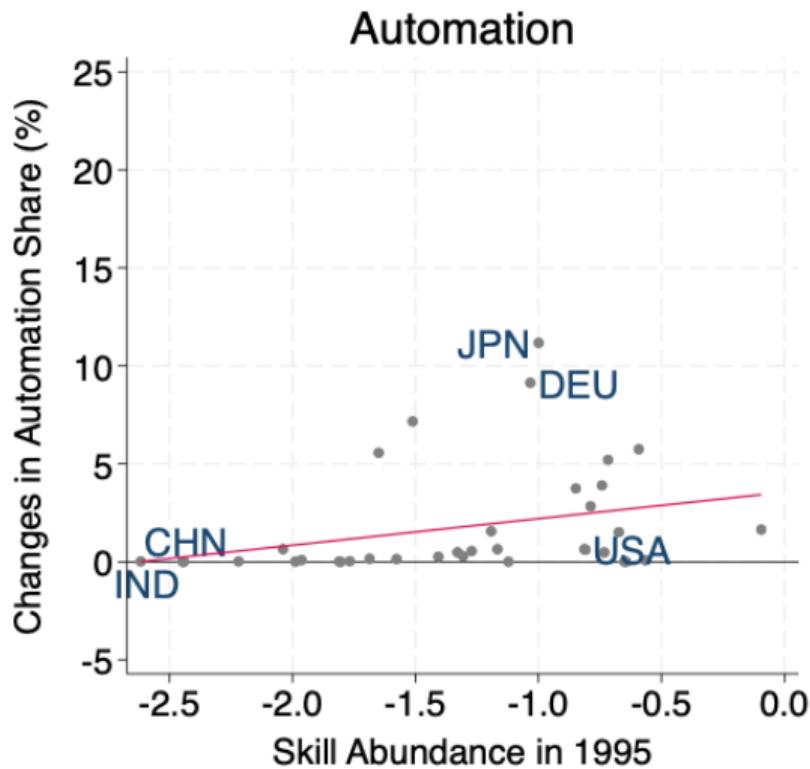
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 - Assume that $\psi^A(x)$ and $\psi^O(x)$ follow Fréchet distr.
 - ★ for automation, the shape param. to be 1.2
 - ★ for offshoring, it's EK's trade elas.

Data: More Automation in Skill-Abundant Countries



Calibration

| Description | Parameter | Value & Source |
|--|--------------------------------------|----------------------------------|
| Panel A: Time-Invariant Parameters (fixed in 1995) | | |
| Trade Elas. | θ | 4 (Standard) |
| Expenditure Share | $\mu_{i,s}$ | Data (WIOT) |
| Factor Endowment | H_i, L_i | Data (WIOT) |
| Factor Share | $\alpha_{i,s}^H$ | Data (WIOT) |
| Input-Output Coef. | $\alpha_{i,r,s}^X, \alpha_{i,r,s}^A$ | Data (WIOT) & Ding (2023) |
| Panel B: Time-Variant Shocks | | |
| Automation Productivity | $\widehat{\psi}_{i,s}^A$ | Match $\widehat{\Gamma}_{i,s}^A$ |
| Offshoring Productivity (1/Cost) | $\widehat{\psi}_{i,s}^O$ | Match $\widehat{\Gamma}_{i,s}^O$ |

RESULTS: CHANGES IN COMPARATIVE ADVANTAGE

1. Automation and Offshoring on Changes in $\hat{\beta}$

- Question: How much can $\Gamma_{i,s,t}^A$ and $\Gamma_{i,s,t}^O$ explain the path of $\hat{\beta}_t$?

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 2. Shock the economy (change ψ to match $\Gamma_{i,s,t}^A$ and $\Gamma_{i,s,t}^O$)

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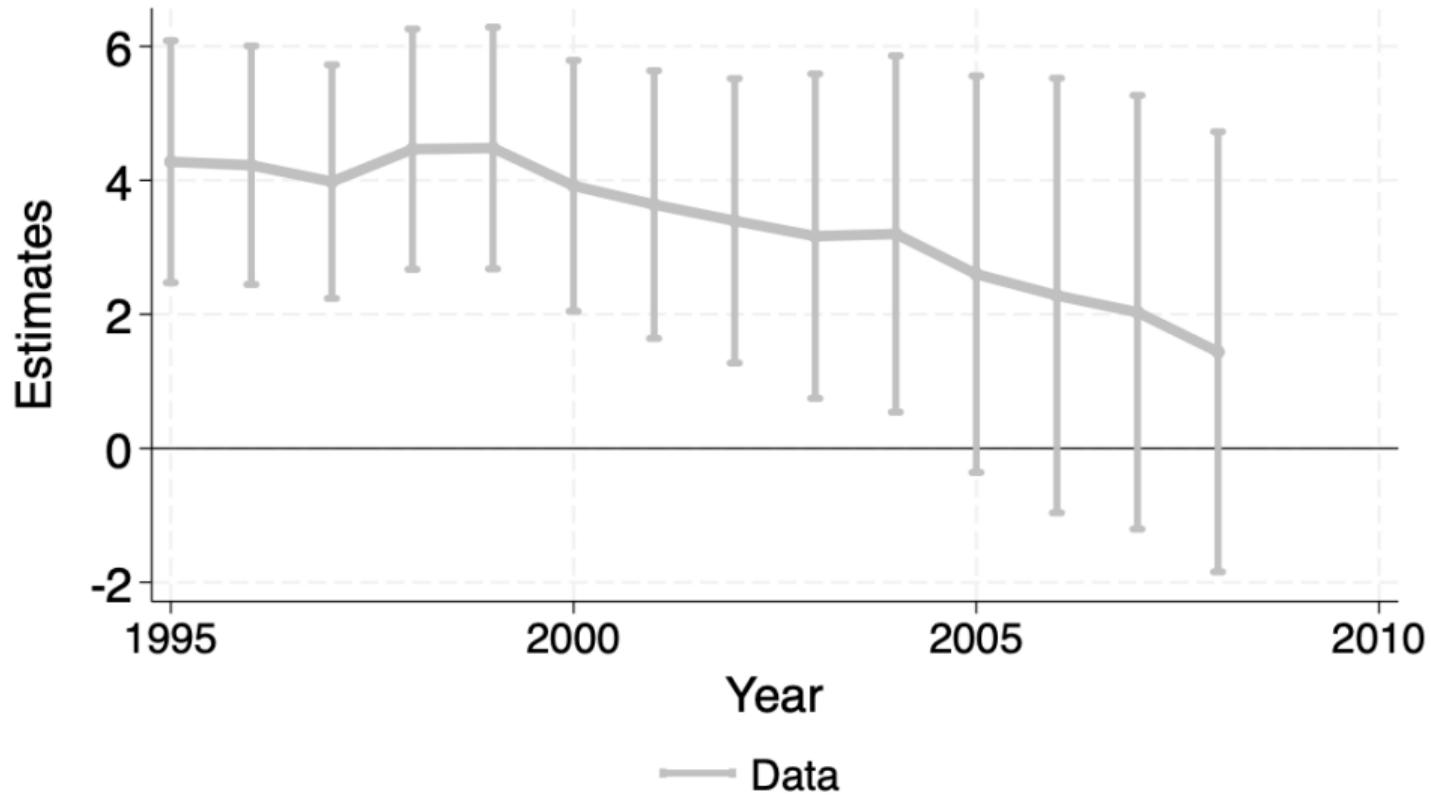
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 1. Calibrate the model to 1995
 2. Shock the economy (change ψ to match $\Gamma_{i,s,t}^A$ and $\Gamma_{i,s,t}^O$)
 3. Construct counterfactual trade flow: $(X_{i,j,s,t})'$
 - Data (World Input-Output Database, incl. Service)
 - Case 1. Only Automation: Change $\Gamma_{i,s,t}^A$
 - Case 2. Only Offshoring: Change $\Gamma_{i,s,t}^O$

1. Automation and Offshoring on Changes in $\hat{\beta}$

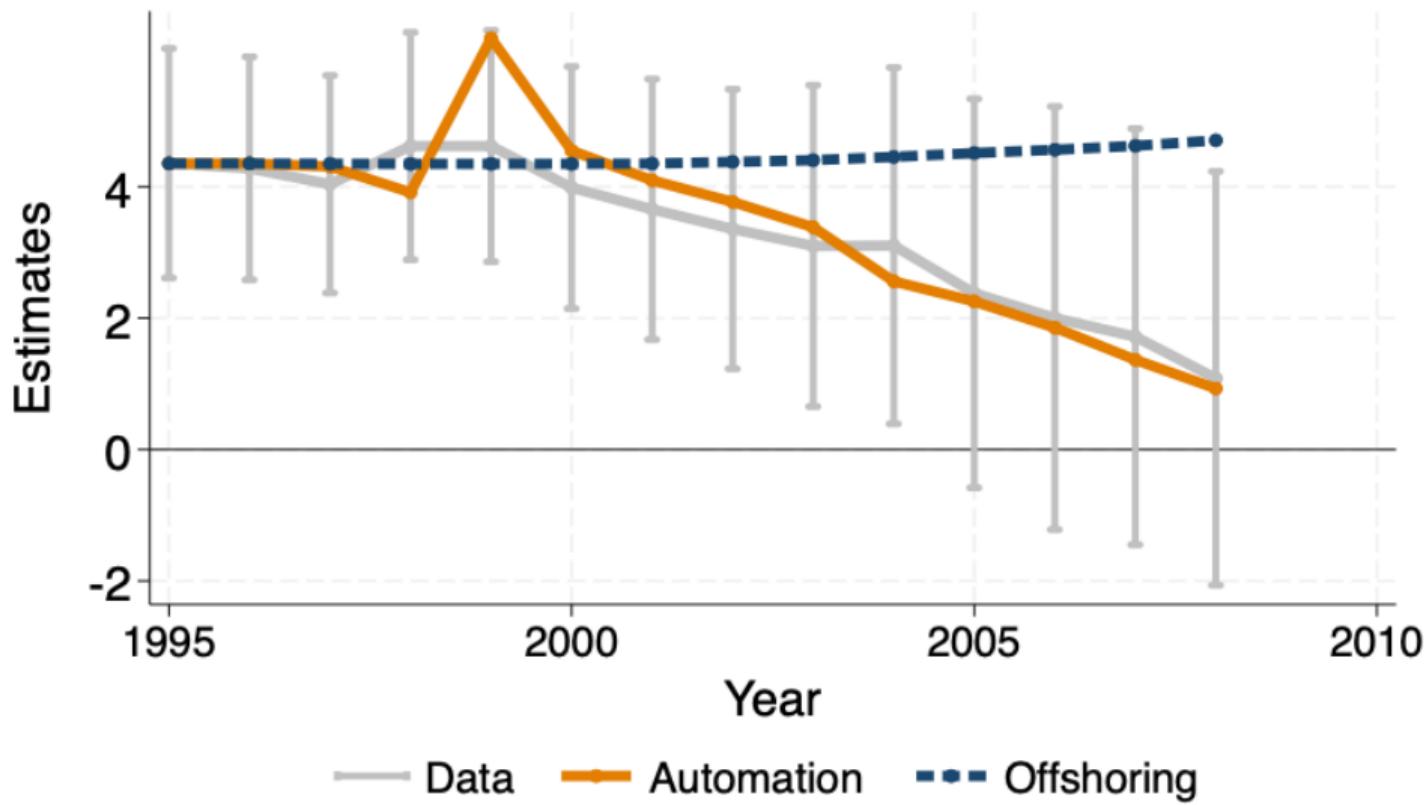
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 - Case 1. Only Automation: Change $\Gamma_{i,s,t}^A$
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 4. Run the same regression as in data but for counterfactual economies

$$\ln(X_{i,j,s,t})' = \beta_t \left[\alpha_{s,t_0}^H \times \ln \left(\frac{H_{i,t_0}}{L_{i,t_0}} \right) \right] + \eta_{i,j,t} + \eta_{j,s,t} + \varepsilon_{i,j,s,t}.$$

$\hat{\beta}_t$ Decreases Even Using WIOD



Automation, Not Offshoring, Causes the Decline



Why Automation?

- Sizes of automation are smaller than offshoring
- Why does automation, not offshoring, matter?

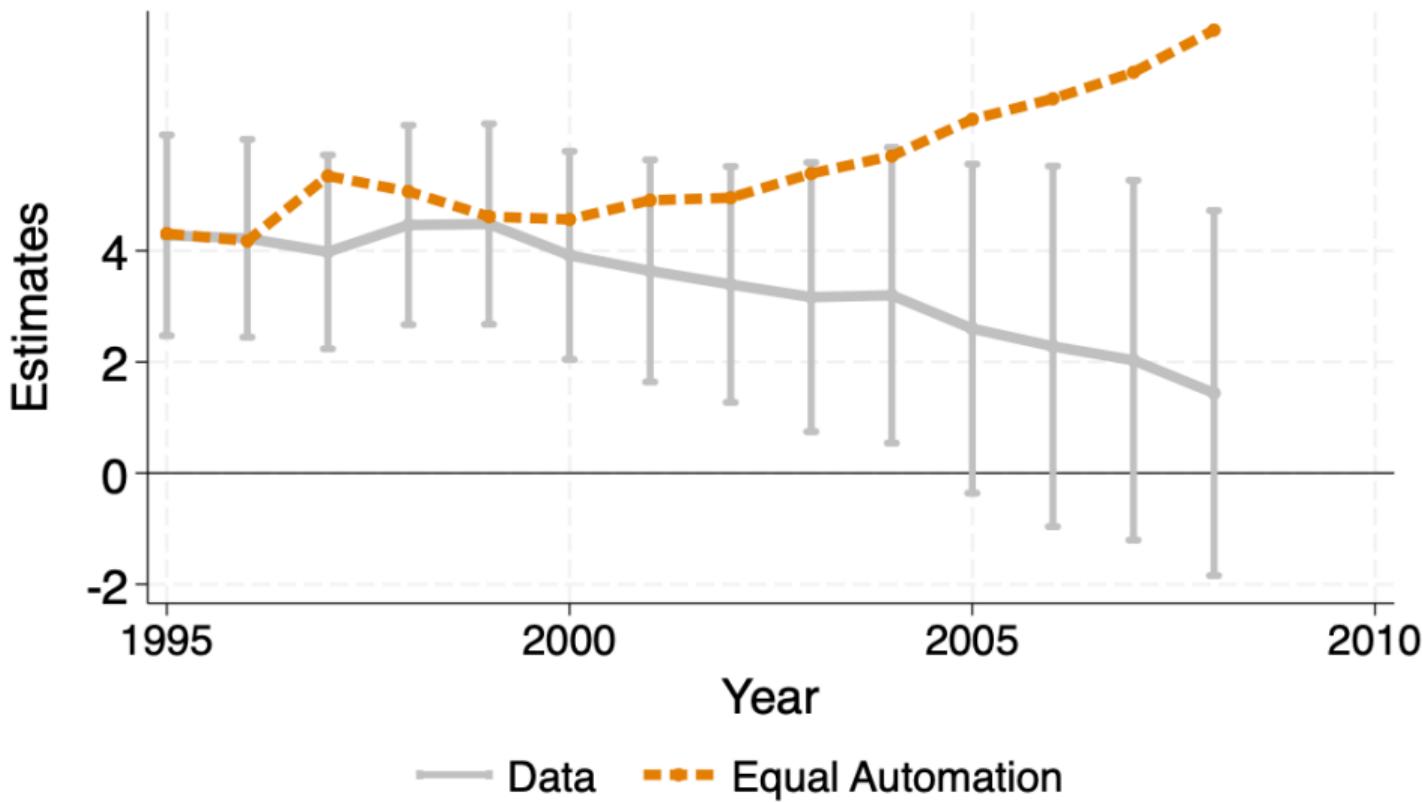
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- Sizes of automation are smaller than offshoring
- Why does automation, not offshoring, matter?
- One observation: Automation happens disproportionately in L - scarce countries
- Experiment: Suppose all the countries increase automation equally...

Equal Automation Cannot Explain the Decline



RESULTS: MACRO IMPLICATIONS OF AUTOMATION AND OFFSHORING

Macro Implications of Automation and Offshoring

- Through the lens of the model, causal effect of automation and offshoring?

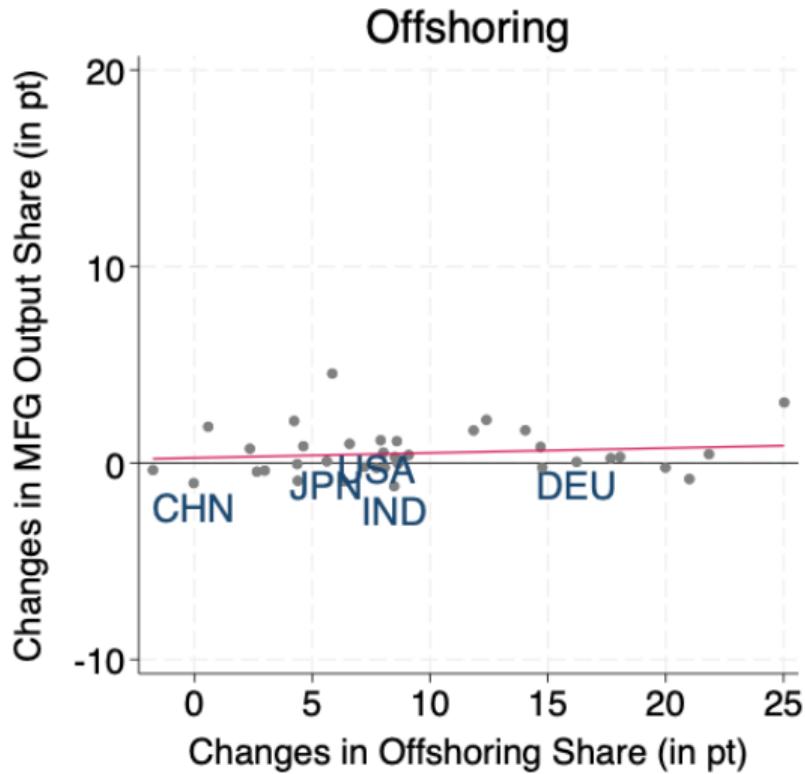
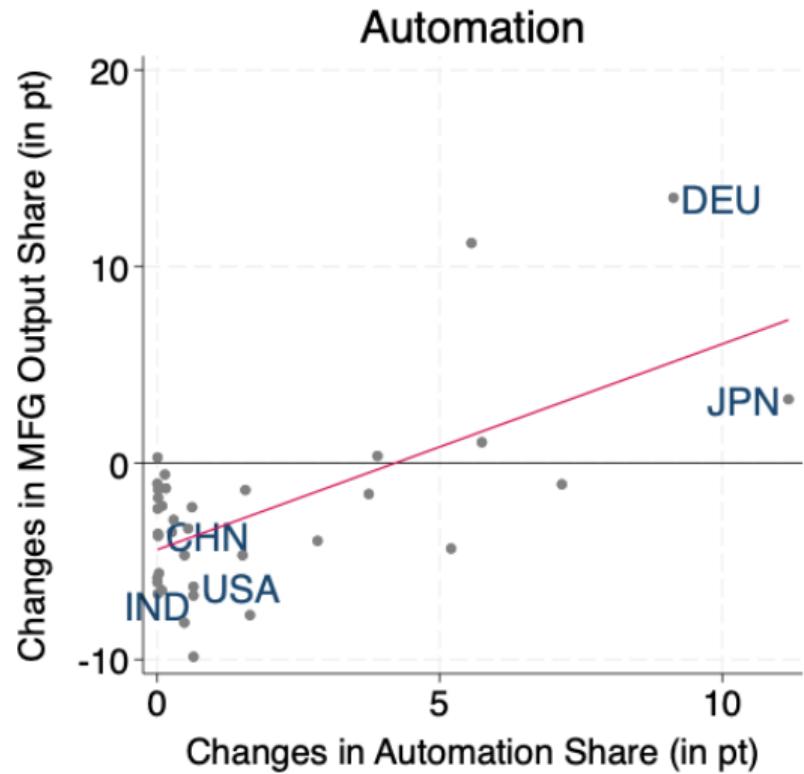
Macro Implications of Automation and Offshoring

- Through the lens of the model, causal effect of automation and offshoring?
- Three macro variables:
 - Output share of manufacturing (sectoral share within a country)
 - Skill premium (inequality within a country)
 - Welfare (inequality across countries)

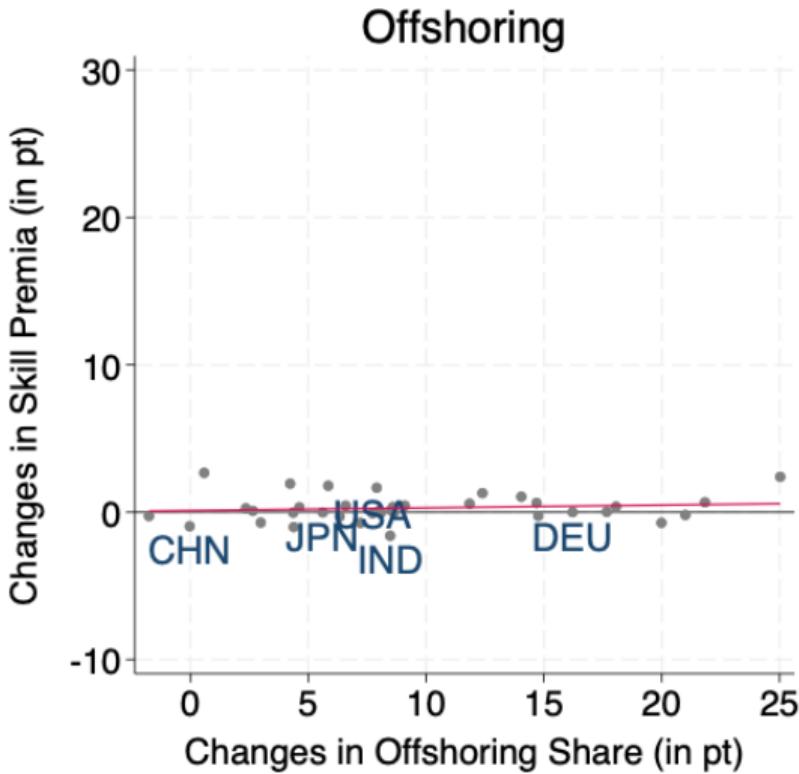
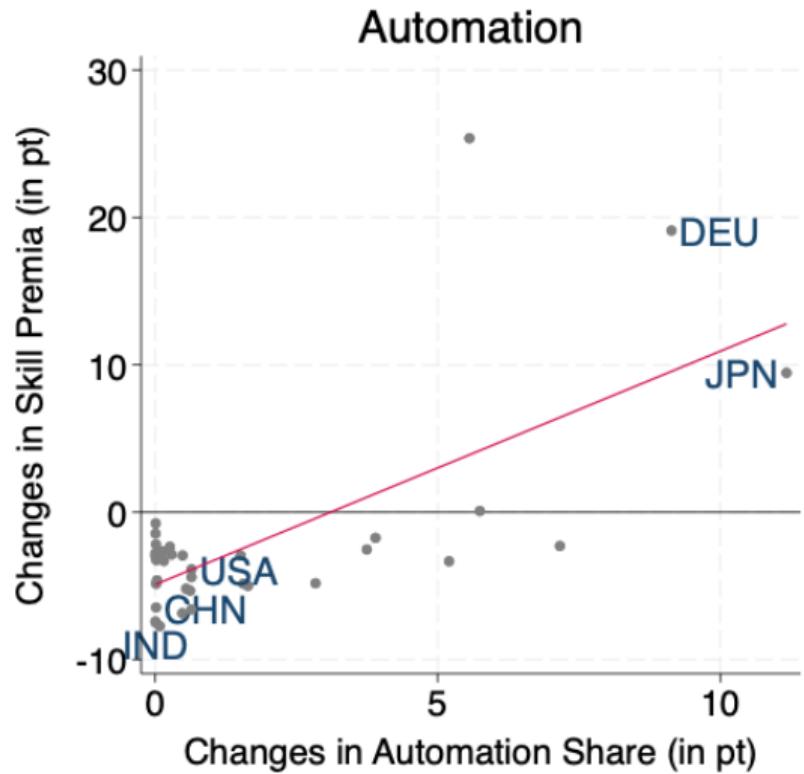
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- Through the lens of the model, causal effect of automation and offshoring?
- Three macro variables:
 - Output share of manufacturing (sectoral share within a country)
 - Skill premium (inequality within a country)
 - Welfare (inequality across countries)
- “Causal effect” (model prediction), not aiming to explain these macro trends

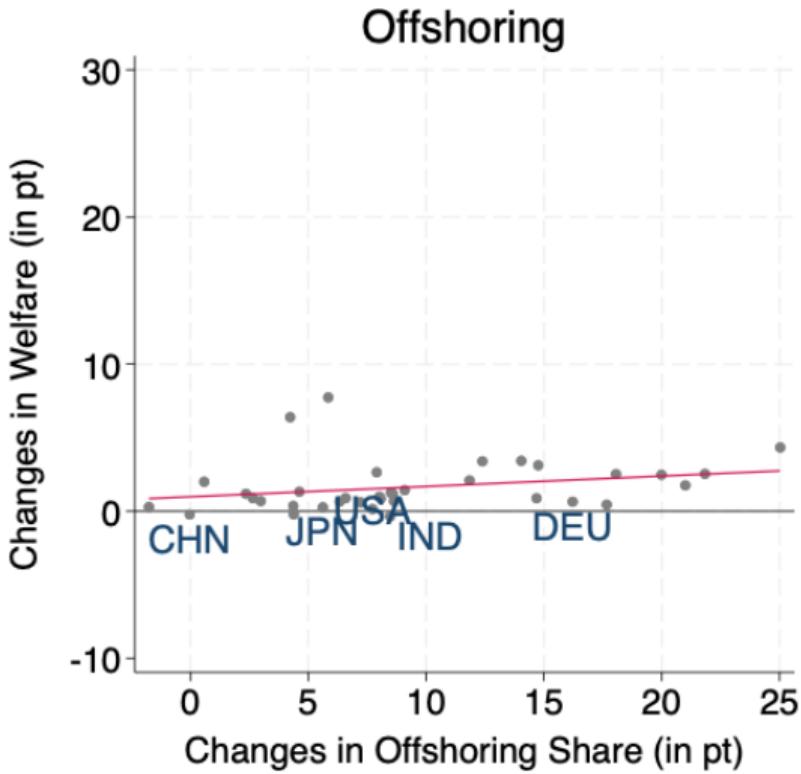
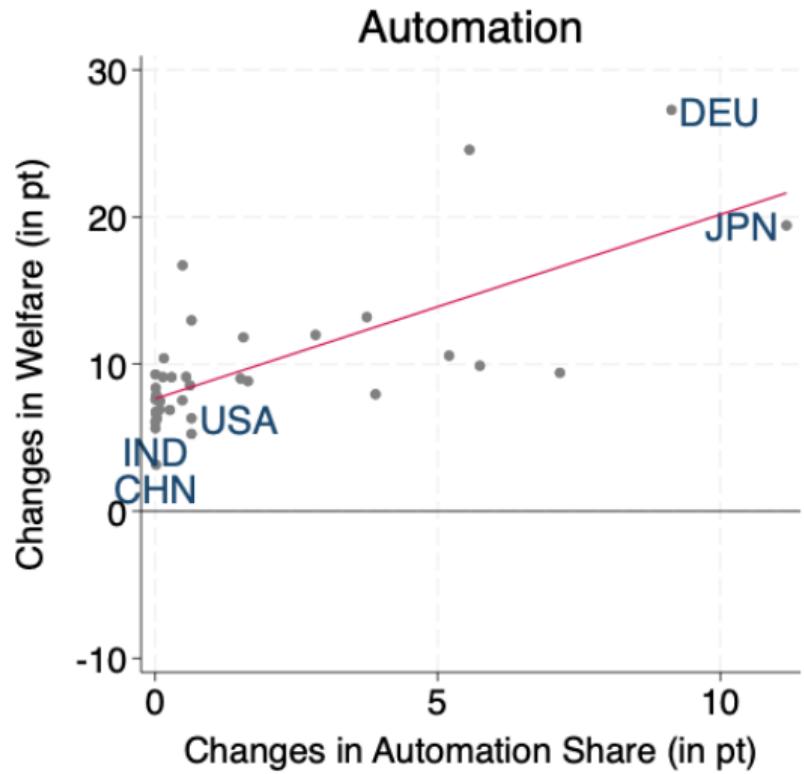
Manufacturing Shifts to High-Automation Countries



Skill Premia Increases Only in High-Automation Countries



Welfare Increases Everywhere



CONCLUSION

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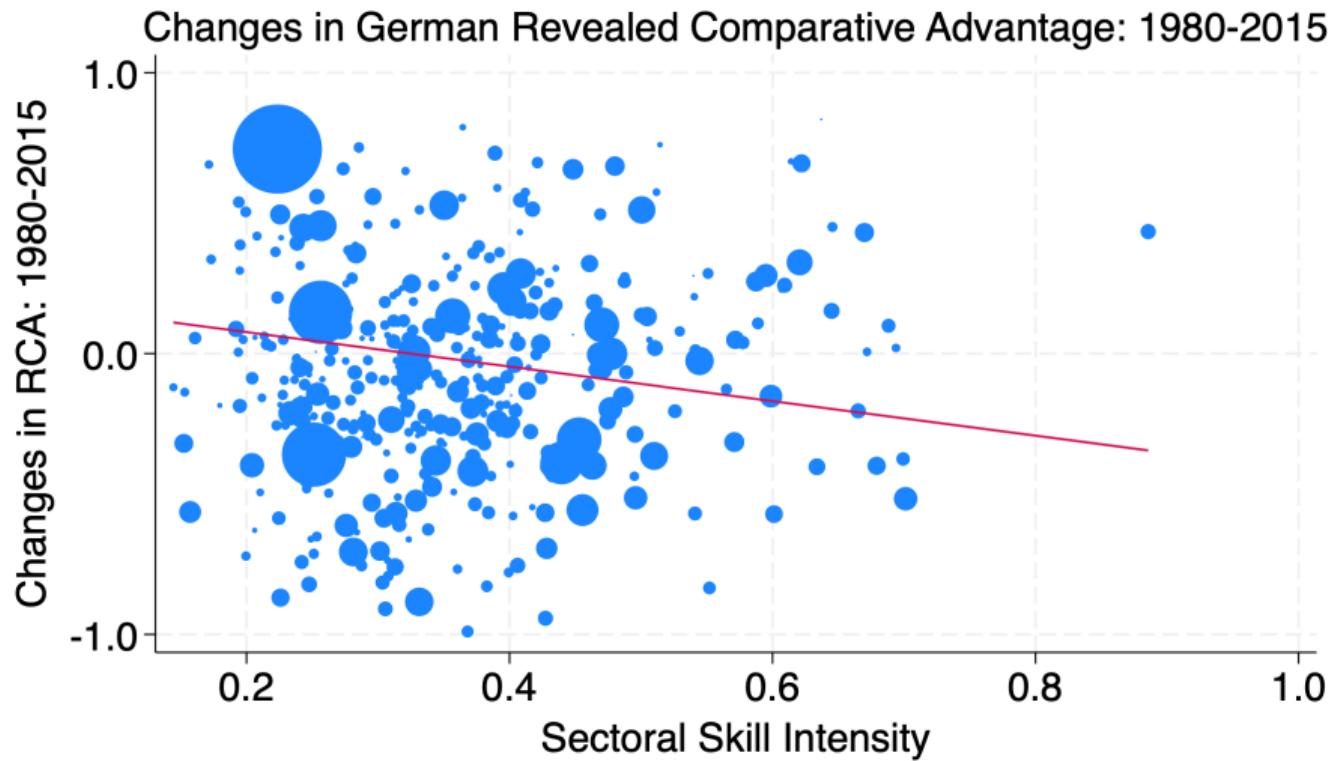
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 - **Automation** causes the decline; Offshoring has small effects
- Automation relocates manufacturing from South to North
 - Inequality within & across countries increases
- Work in progress:
 - Does a robot tax *import* China shocks and backfire in an open economy?
 - Does automation facilitate reshoring and reduce the costs of decoupling?
 - Will clean technology erode the comparative advantage of oil-rich countries?

APPENDIX

FACTS

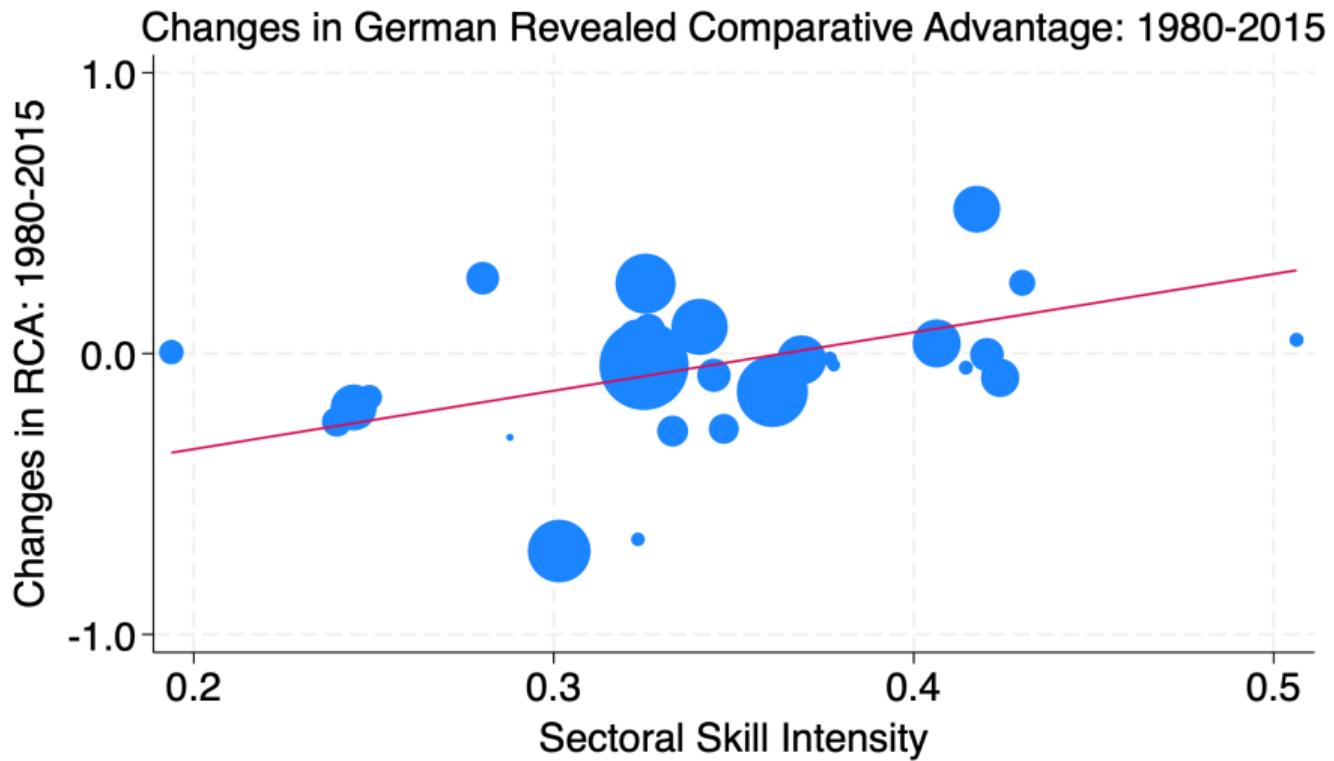
Germany

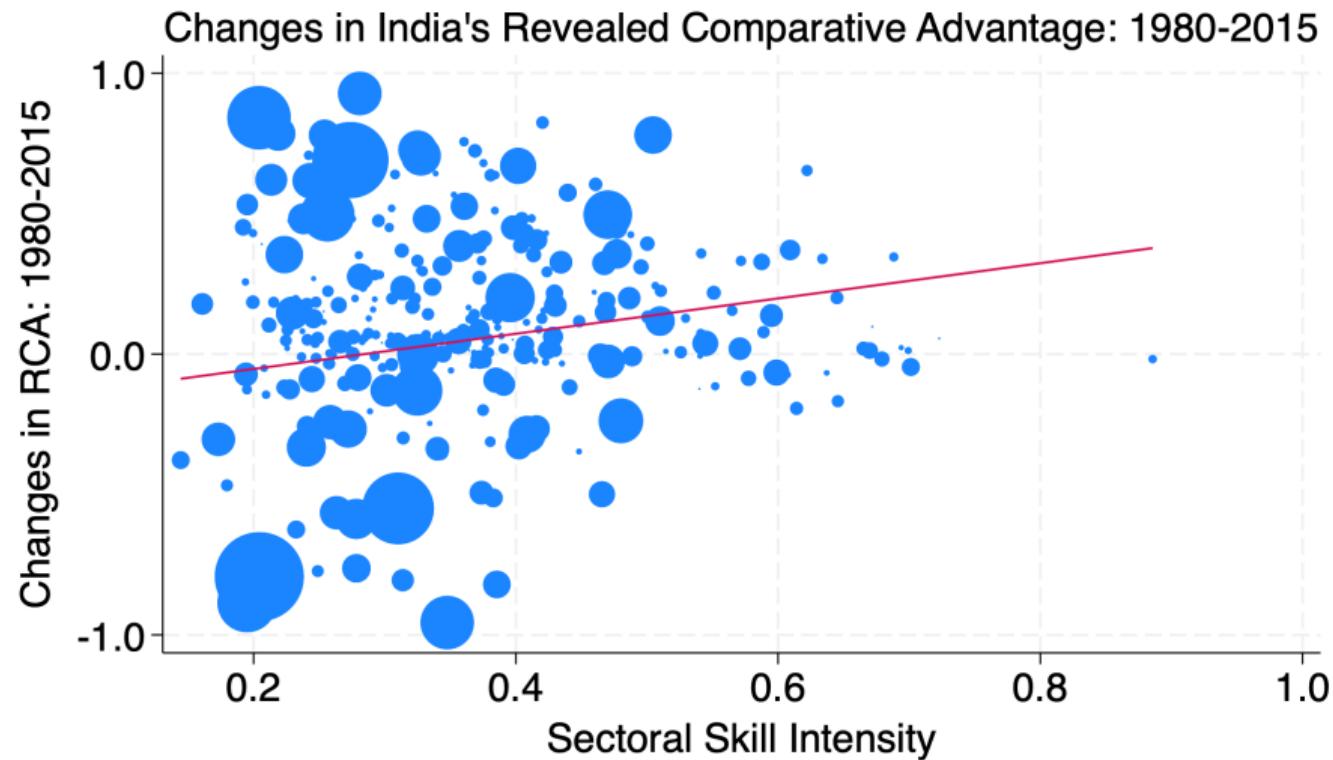
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Germany (Low-Automation)

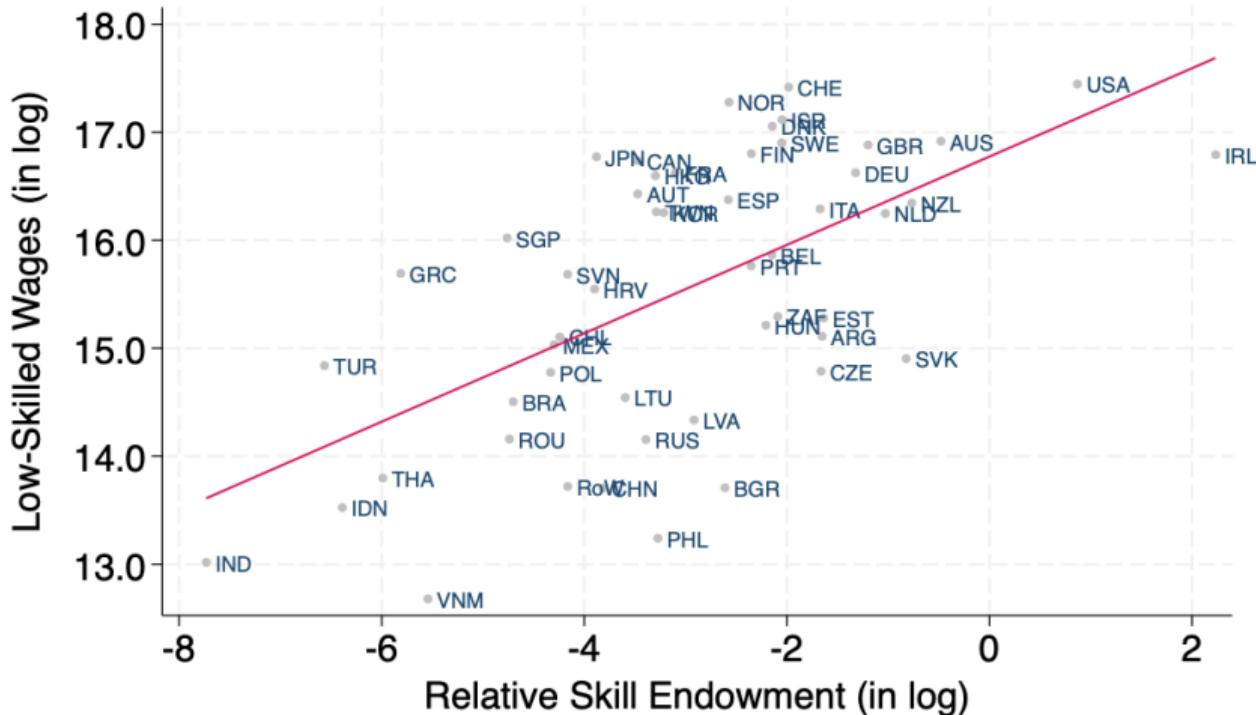
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Unskilled Wages Increasing in Skill Endowment

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Note: Data from GTAP, 2004

REGRESSION

Simplified Structural Interpretation

- Gravity Equation + Unit Production Cost

$$X_{i,j,s} = ((c_{i,s} \tau_{i,j} \tau_{j,s}))^{1-\sigma} \cdot (P_{j,s})^{\sigma-1} X_{j,s}, \quad \ln X_{i,j,s} = (1 - \sigma) \cdot \ln c_{i,s} + \mu_{i,j} + \mu_{j,s}$$
$$c_{i,s} = (w_i^H)^{\alpha_s^H} (w_i^L)^{1-\alpha_s^H}, \quad \ln c_{i,s} = \underbrace{\frac{d \ln(w^H/w^L)}{d \ln(H/L)}}_{\equiv \epsilon^w: \text{Rel. Wage Elas.} < 0} \cdot \alpha_s^H \cdot \ln \left(\frac{H_i}{L_i} \right) + \ln w_i^L$$

- Regression

$$\ln X_{i,j,s} = (1 - \sigma) \epsilon^w \left[\alpha_s^H \times \ln \left(\frac{H_i}{L_i} \right) \right] + \mu_{i,j} + \mu_{j,s} + \ln w_i^L$$

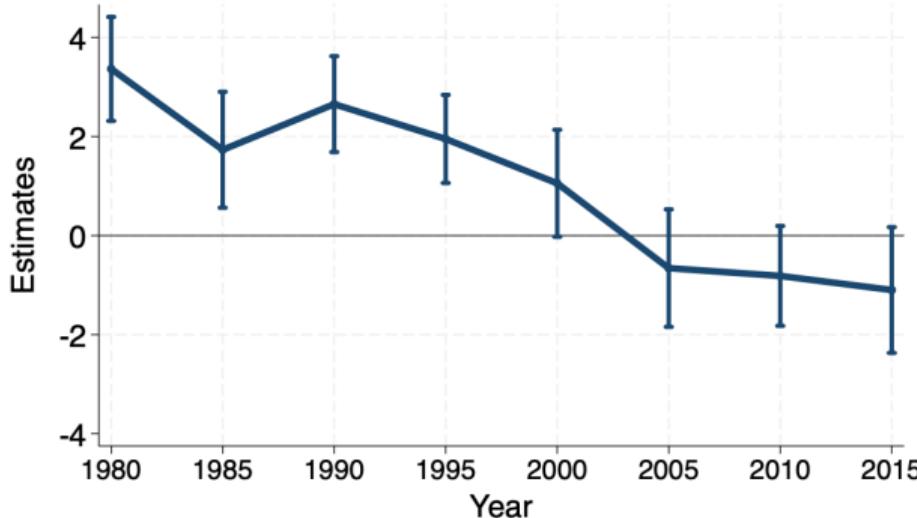
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ROBUSTNESS

Controlling Capital Intensity

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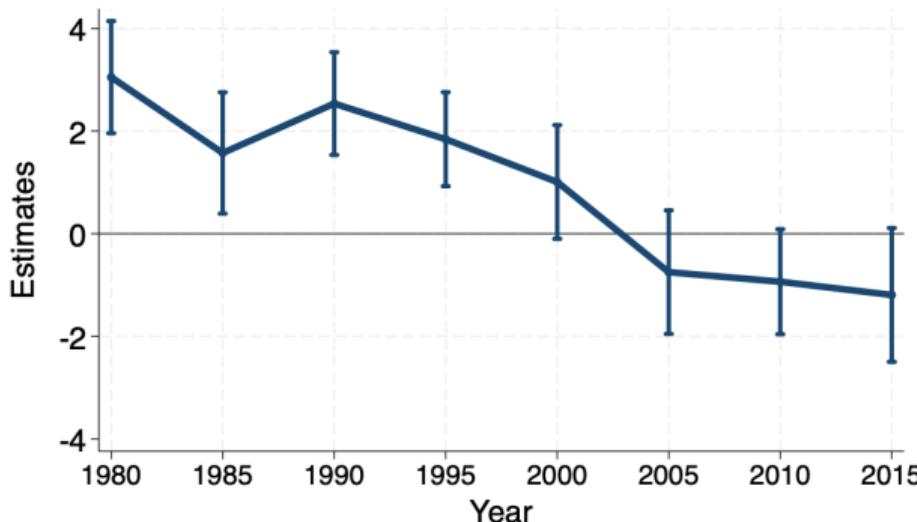
$$\ln X_{i,j,s,t} = \beta_t \left[\alpha_{s,t}^H \times \ln \left(\frac{H_{i,t}}{L_{i,t}} \right) \right] + \beta_t^K \left[\alpha_{s,t}^K \times \ln \left(\frac{K_{i,t}}{L_{i,t}} \right) \right] + \eta_{i,j,t} + \eta_{j,s,t}$$



Controlling Capital Intensity and Institutions

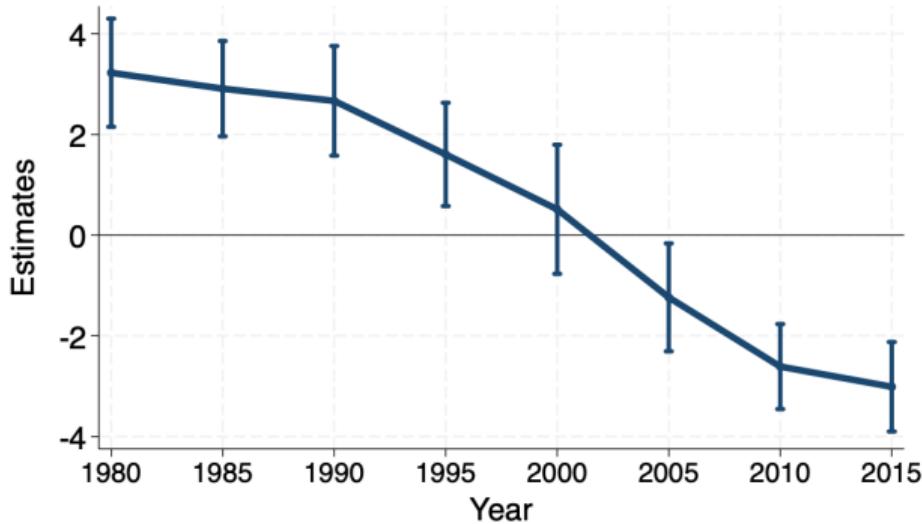
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$$\ln X_{i,j,s,t} = \beta_t \left[\alpha_{s,t}^H \times \ln \left(\frac{H_{i,t}}{L_{i,t}} \right) \right] + \sum_{f \in \{K,L\}} \beta_t^F \left[\alpha_{s,t}^F \times \ln \left(\frac{F_{i,t}}{L_{i,t}} \right) \right] + \eta_{i,j,t} + \eta_{j,s,t}$$



Weighted by Country Export

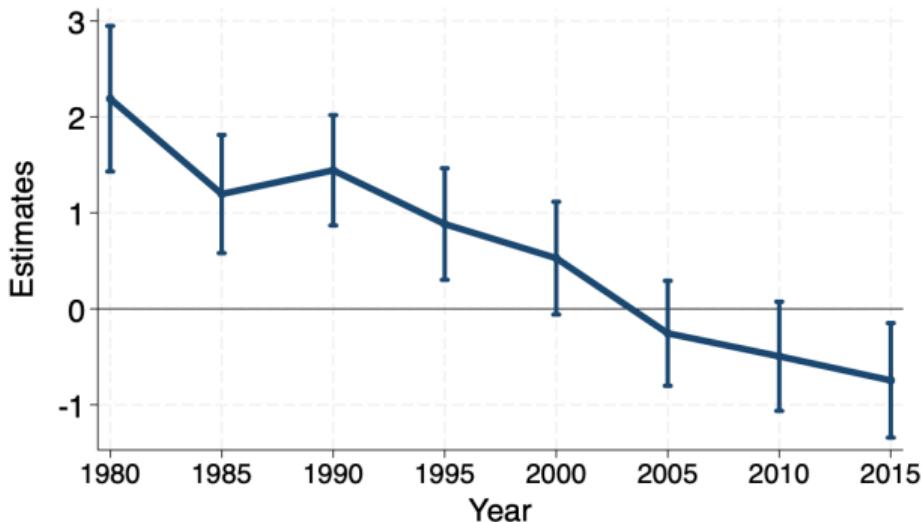
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Pool and control Origin-Sector FEs

» back

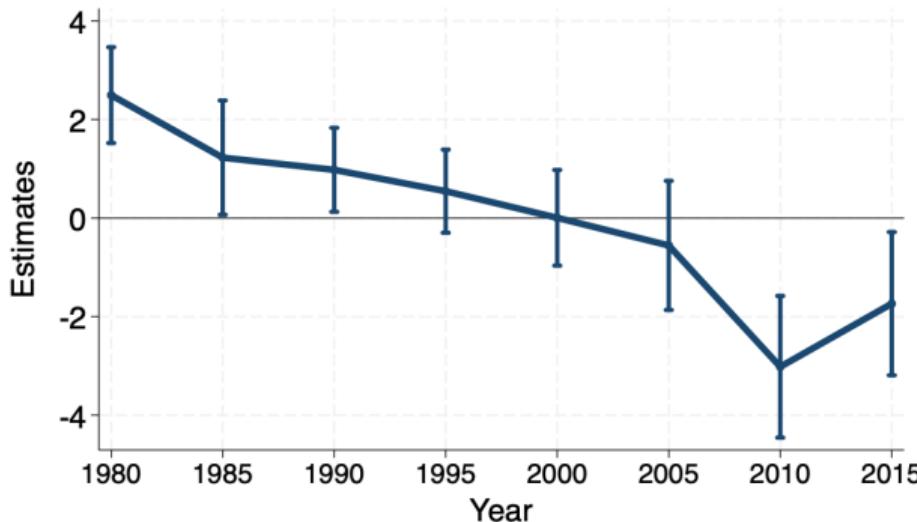
$$\ln X_{i,j,s,t} = \beta_t \left[\alpha_{s,t}^H \times \ln \left(\frac{H_{i,t}}{L_{i,t}} \right) \right] + \eta_{i,s} + \eta_{i,j,t} + \eta_{j,s,t}$$



High-school Graduates as Skilled

back

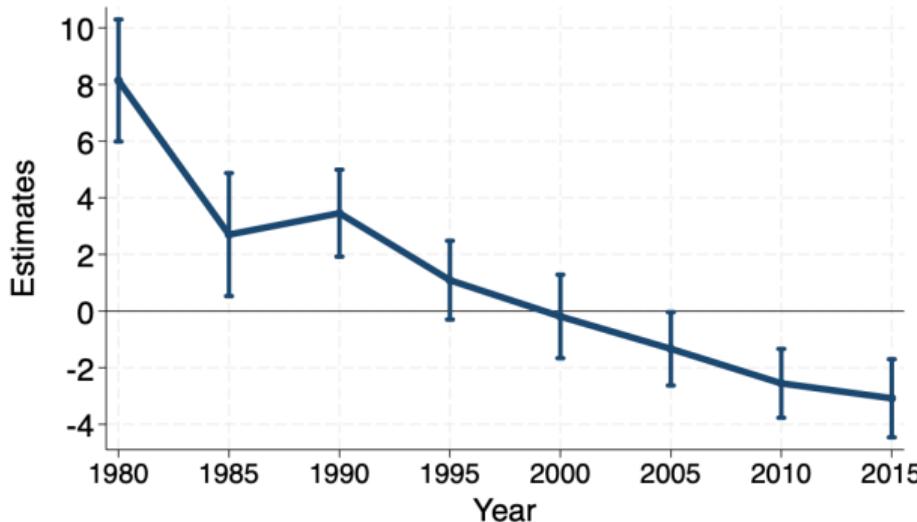
$$\ln X_{i,j,s,t} = \beta_t \left[\alpha_{s,t}^H \times \ln \left(\frac{HS_{i,t}}{NHS_{i,t}} \right) \right] + \eta_{i,j,t} + \eta_{j,s,t}$$



Instrument Skill Endowment by Cohort IV

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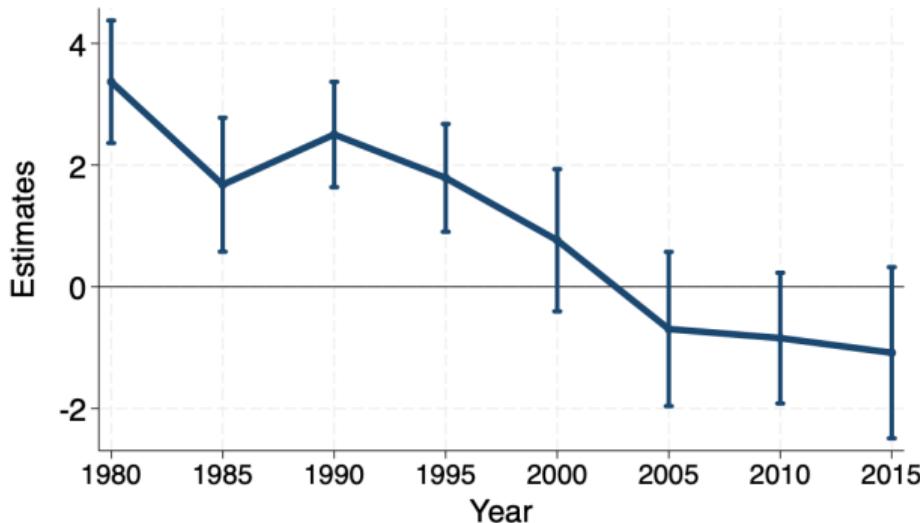
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Romalis (2004): Total Export

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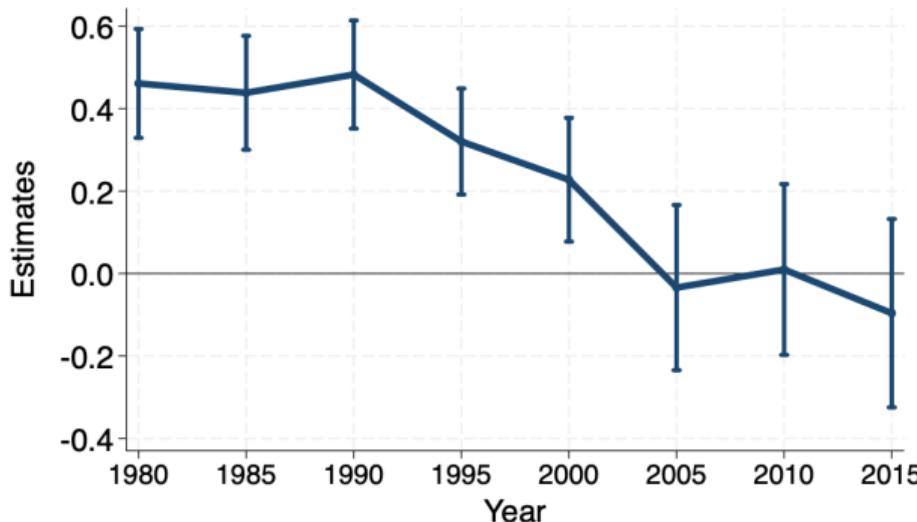
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Chor (2011): Num of Workers as Factor Intensity

◀ back

$$\ln X_{i,j,s,t} = \beta_t \left[\ln \left(\frac{H_{s,t}}{L_{s,t}} \right) \times \ln \left(\frac{H_{i,t}}{L_{i,t}} \right) \right] + \eta_{i,j,t} + \eta_{j,s,t}$$

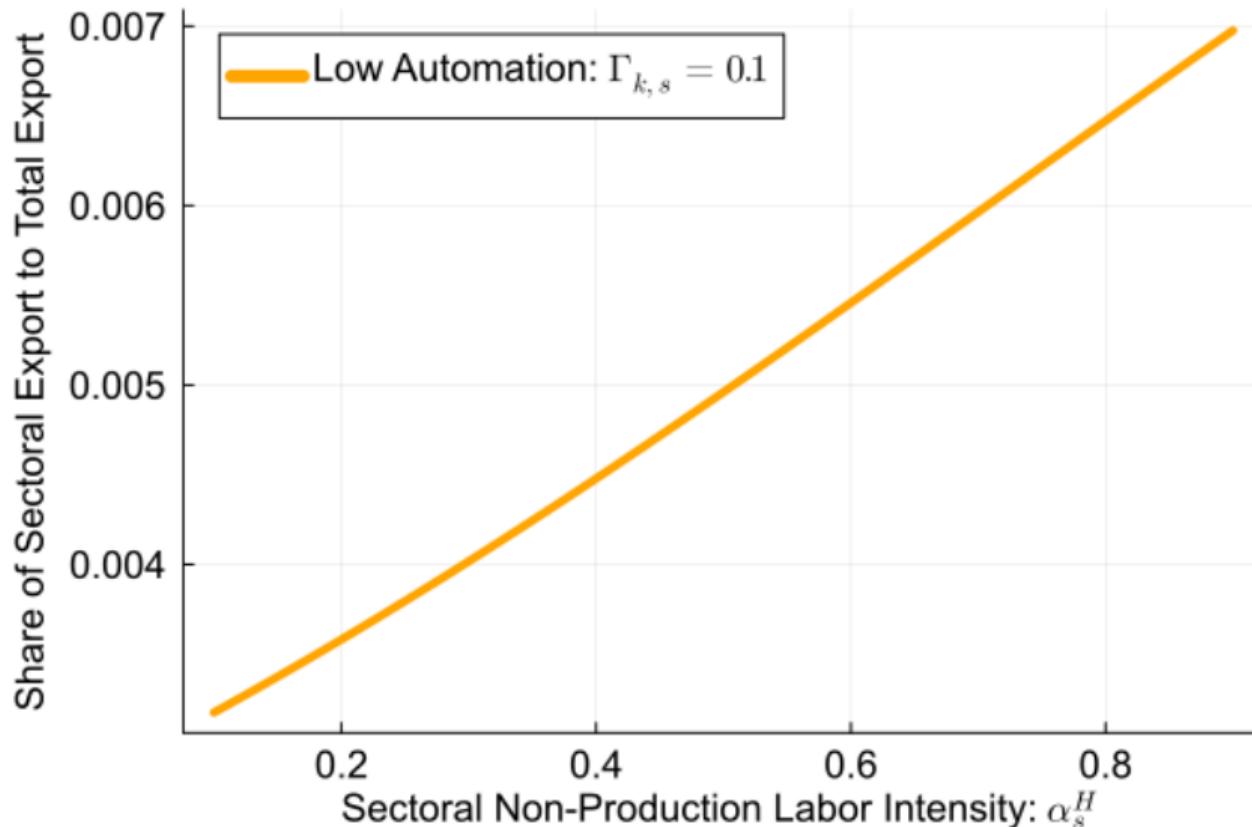


TWO COUNTRY ILLUSTRATION: AUTOMATION

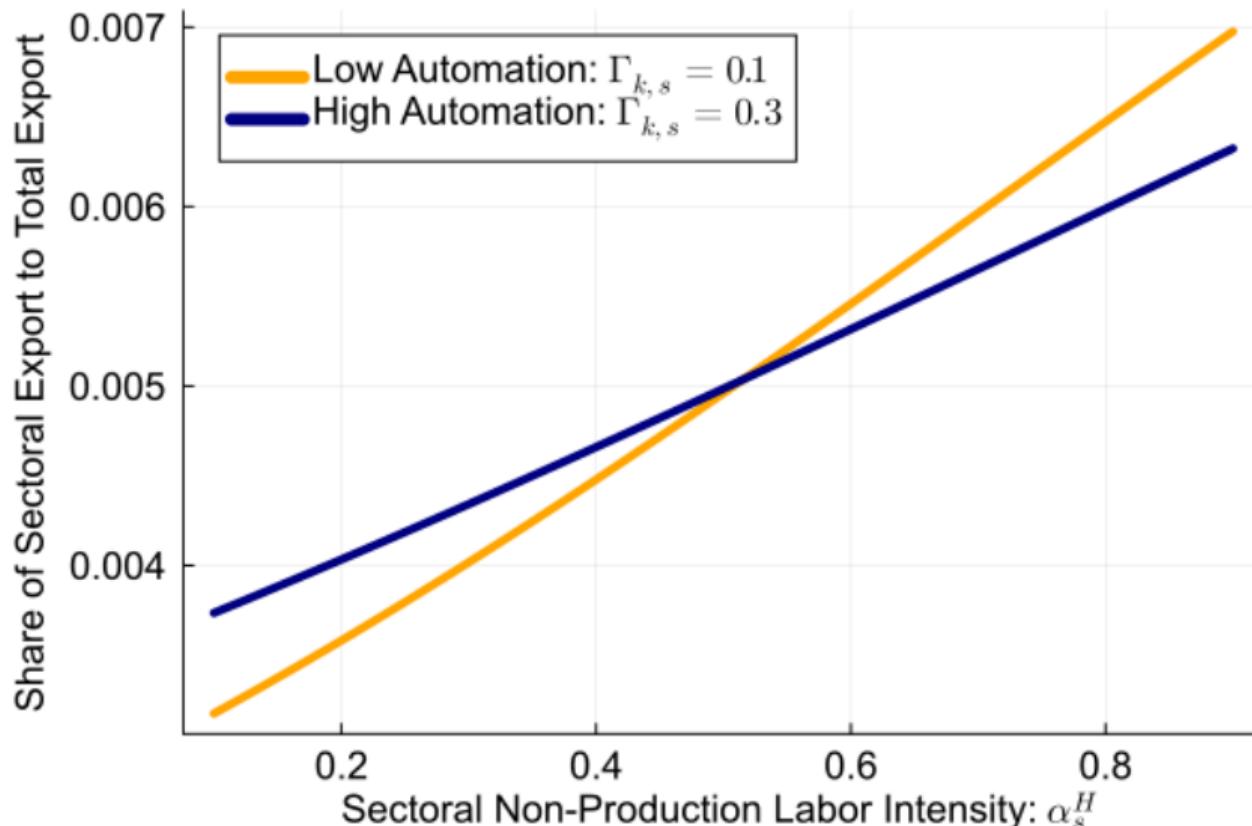
Two Country Illustration: Automation

- North (40% are H) and South (25% are H)
- Actual factor intensity across 397 SIC sectors
- Set $\alpha_S^G = \alpha_S^M = 0$ (focus on value-added)
- Exogenous changes in factor intensity common across sectors & countries
 - Automation: Increase $\Gamma_{i,S}^K$ = 0.1 to 0.3
- Show export share of each sector in North against α_S^H – Slope is β^H

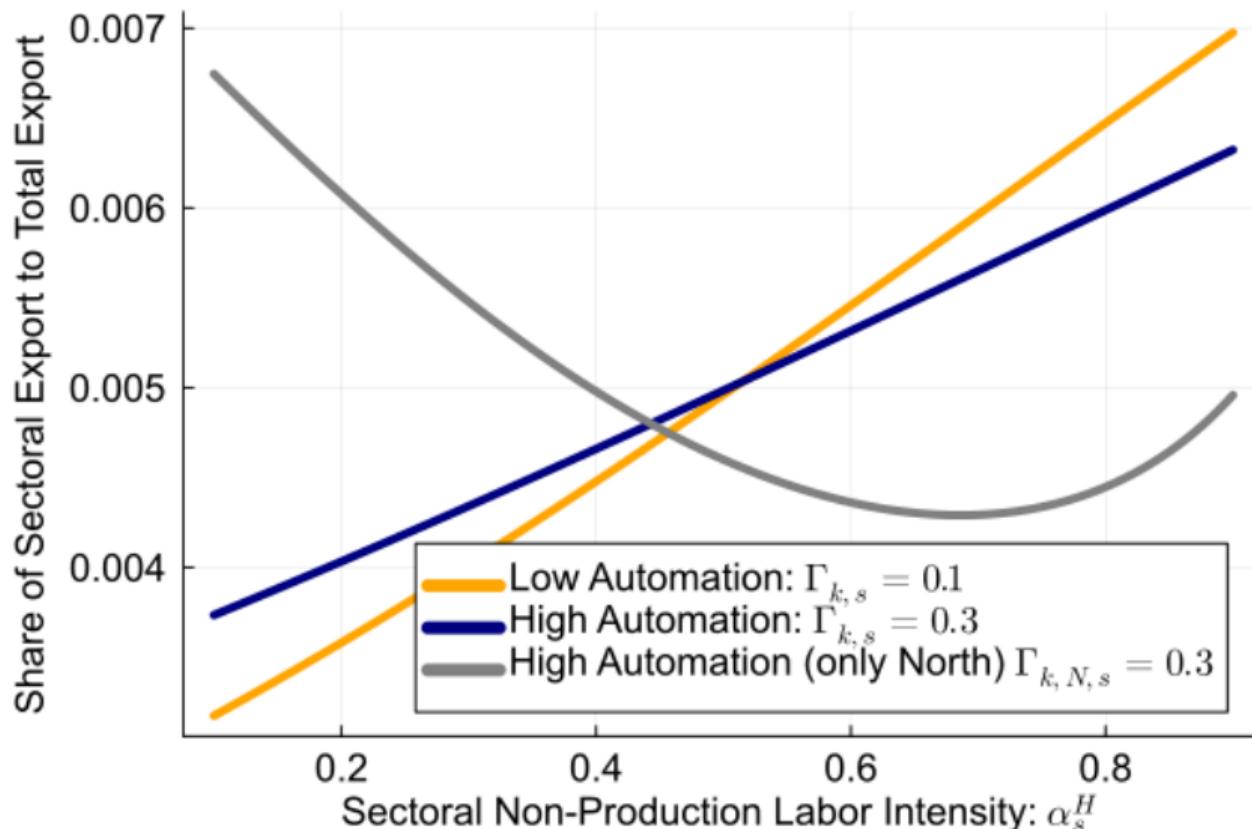
North Specialize in Skill-Intensive Sectors



Automation Makes Skills Less Important

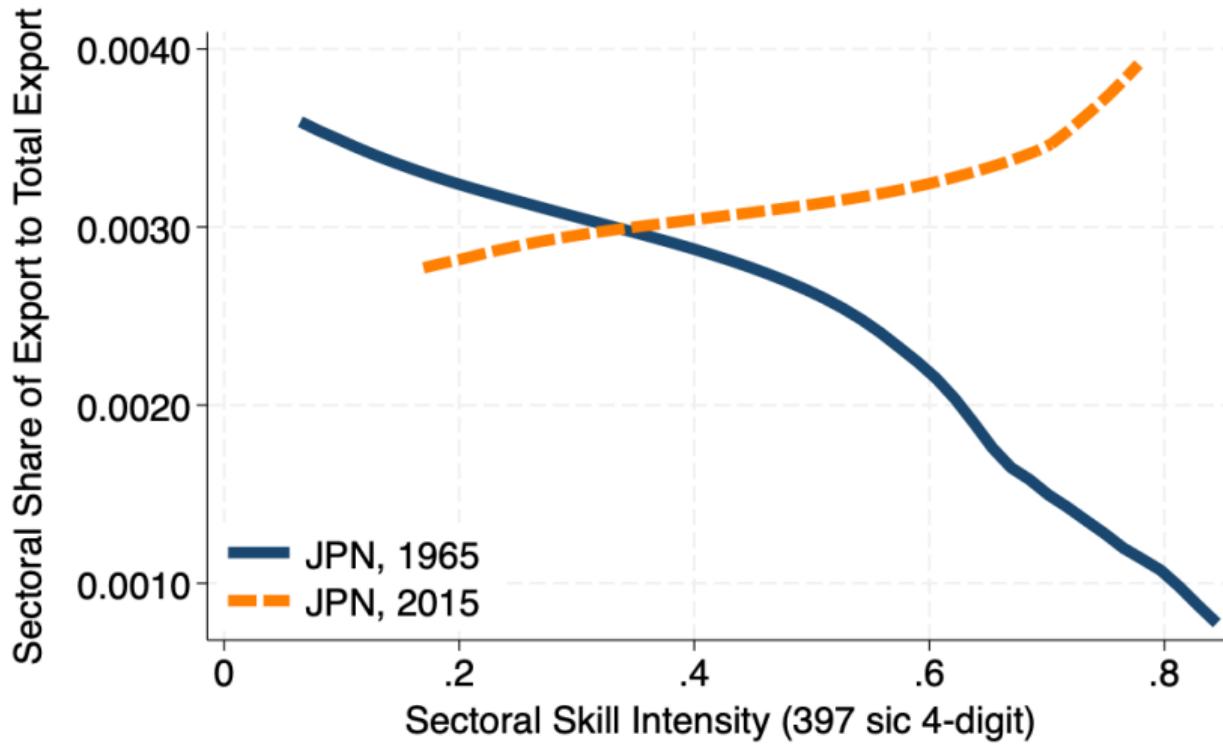


If Only North Automates, Sign Flips

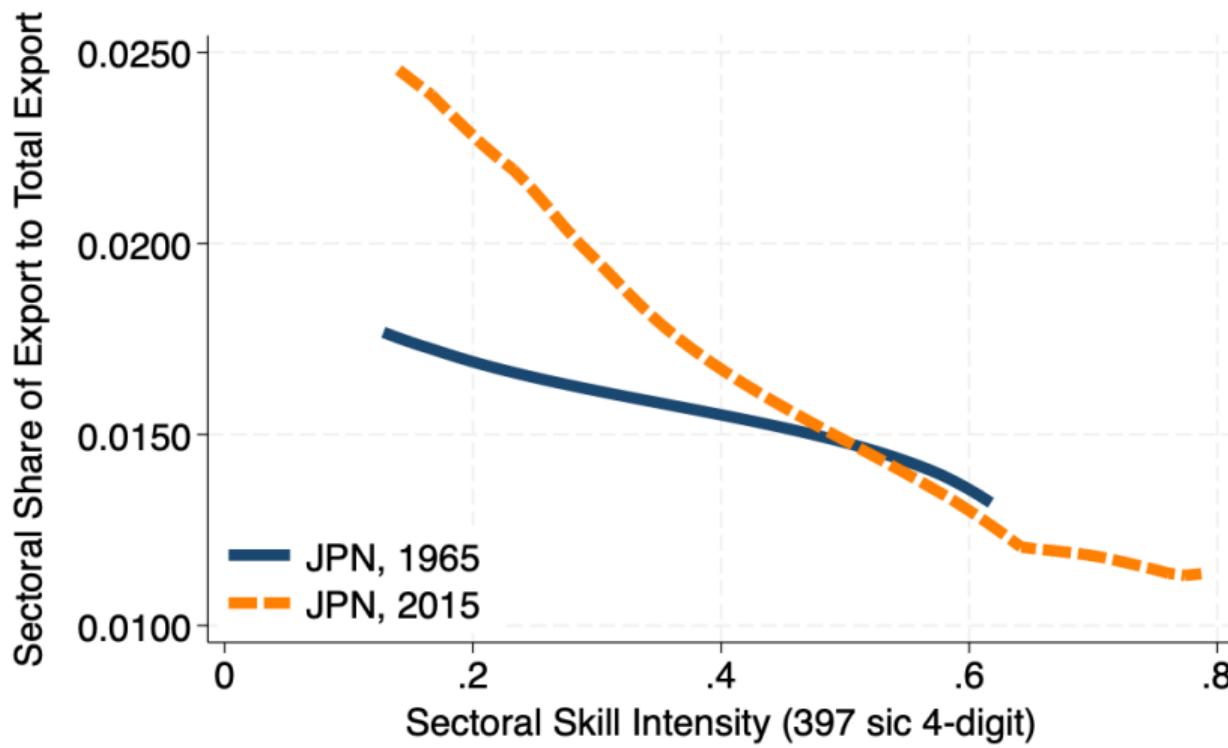


Example: Within Low-Automation Sectors, Japan Specializes in Skill Intensive Industries

Back



Example: Within High-Automation Sectors, Japan Specializes in Low-Skill Intensive Industries

[Back](#)

TOY MODEL: TASK AND COMPARATIVE ADVANTAGE

Model

- Small open economy with two sectors ($s = 1, 2$)
- Demand

$$q_s = (c_s)^{1-\sigma} \cdot \overline{Q_s}$$

- Production (micro-foundation = task framework)

$$Y_s = \zeta \cdot (H_s)^{\alpha_s} \left((L_s)^{\Gamma} (M_s)^{1-\Gamma} \right)^{1-\alpha_s}, \quad \alpha_1 = 1 - \alpha_2 = \alpha > 1/2$$

- M_s : machines or foreign factors supplied at a fixed price r
- Factor market clearing

$$\sum_{s=1,2} H_s = H, \quad \sum_{s=1,2} L_s = L$$

Equilibrium

- Wages $\{w^L, w^H\}$ that satisfy

$$w^L L = \Gamma(1 - \alpha)(c_1)^{1-\sigma} + \Gamma\alpha(c_2)^{1-\sigma}, \quad w^H H = \alpha(c_1)^{1-\sigma} + (1 - \alpha)(c_2)^{1-\sigma}$$

- Unit cost

$$c_s = \left(w^H\right)^{\alpha_s} \left((w^L)^{\Gamma} (r)^{1-\Gamma}\right)^{1-\alpha_s}$$

Comparative Advantage

- A change in factor endowment $\hat{H} = -\hat{L}$ (=compare two small countries)
- Up to 1st order, CA in H-intensive sector ($s = 1$)

$$\hat{c}_2 - \hat{c}_1 = \underbrace{-(2\alpha - 1)\hat{\omega}}_{\text{Skill Premium} < 0} \underbrace{-(1 - \Gamma)(2\alpha - 1)\hat{w}^L}_{\text{Task Displacement}}$$

- Skill premium ($\hat{\omega} \equiv \hat{w}^H - \hat{w}^L$) and wages

$$\hat{\omega} = \underbrace{-2\hat{H}}_{\text{Labor Supply}} + \underbrace{(2\alpha - 1)(\sigma - 1)}_{\text{GE Effect}} (\hat{c}_2 - \hat{c}_1), \quad \hat{w}^L = \frac{(\sigma - 1)(2\alpha - 1) - 1}{2 + (1 - \Gamma)(\sigma - 1)(2\alpha - 1)} \hat{\omega}$$

Comparative Advantage if $\Gamma = 1$

Proposition 1: Rybczynski (1955)

An increase in skilled labor $\hat{H} > 0$ strengthens comparative advantage in a skill-intensive sector.

$$\hat{c}_2 - \hat{c}_1 = \frac{2(2\alpha - 1)}{1 + (2\alpha - 1)^2(\sigma - 1)} \hat{H}$$

Comparative Advantage if $\Gamma < 1$

Proposition 2: Acemoglu-Restrepo meets Rybczynski

An increase in skilled labor $\widehat{H} > 0$ strengthens comparative advantage in a skill-intensive sector. However, the elasticity is lower when labor share Γ is lower.

$$\widehat{c}_2 - \widehat{c}_1 = \frac{2(2\alpha - 1)}{\frac{1}{\eta(\Gamma)} + (2\alpha - 1)^2(\sigma - 1)} \widehat{H} \quad (1)$$

where $\eta(\Gamma) = 1 - \frac{1-(\sigma-1)(2\alpha-1)}{\frac{2}{1-\Gamma} + (\sigma-1)(2\alpha-1)} \in (0, 1)$ is increasing in Γ .

ROLES OF CHANGES IN COMPARATIVE ADVANTAGE FOR INCIDENCE OF AUTOMATION

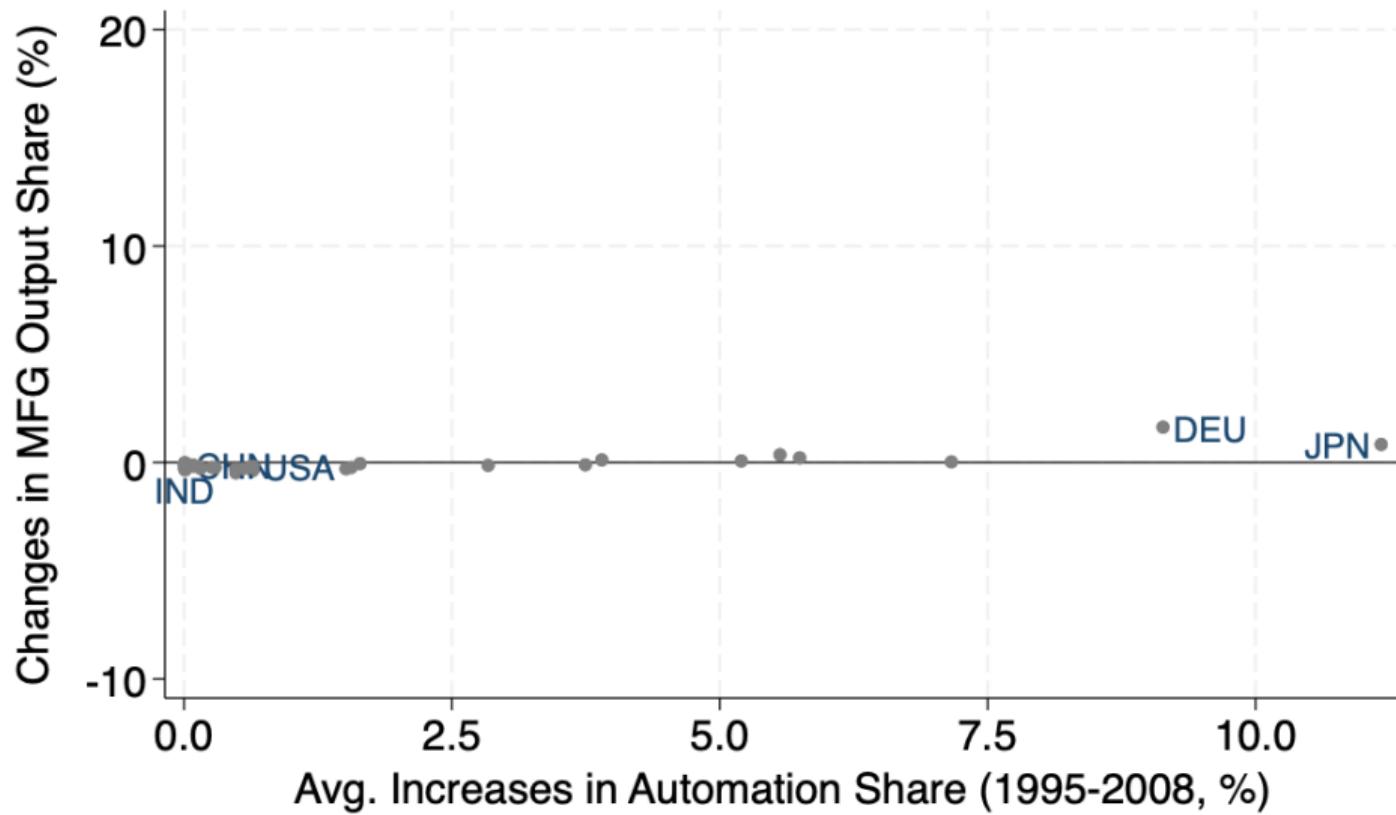
Automation, Globalization, and Inequality

- Automation → shifts MFG to High-Automation countries
- Demand for H increases in High-Automation countries
- Demand for L increases in Low-Automation countries
 - Move to Service sectors, which are more L -intensive

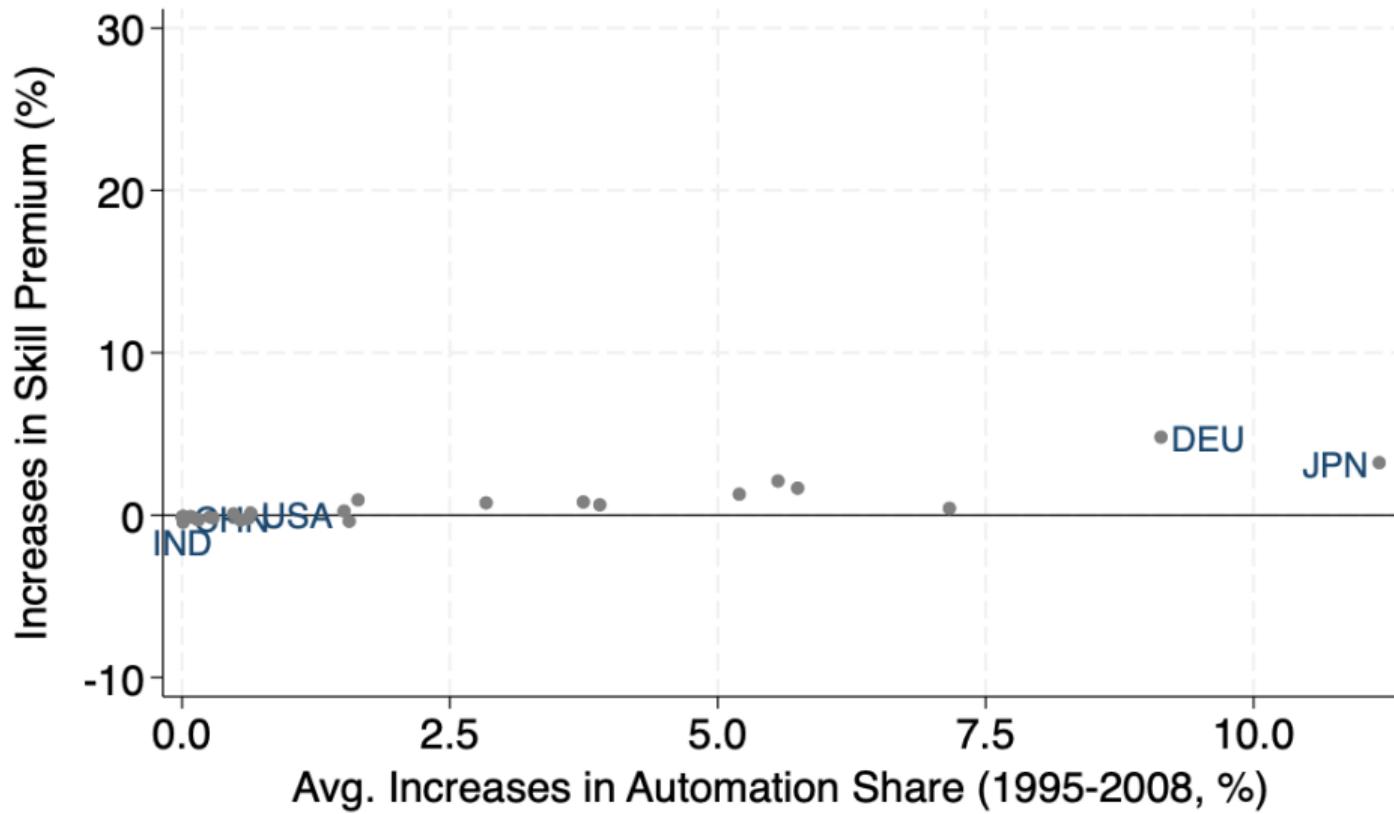
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- Demand for L increases in Low-Automation countries
 - Move to Service sectors, which are more L -intensive
- Roles of Trade?
 - Now, set the trade elasticity $\theta = 1$, instead of $\theta = 4$
 - This kills sectoral reallocation via expenditure switch across countries

$\theta = 1$: Lower Elas. Makes MFG Shifts Less



$\theta = 1$: Skill Premia Increases Everywhere



$\theta = 1$: Welfare Increases Everywhere, but Less

