

# Does Skill Abundance Still Matter?

The Evolution of Comparative Advantage in the 21st Century

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Shin Kikuchi, MIT

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# Skill Abundance and Comparative Advantage

- Skill Abundance: Central for comparative advantage (**Heckscher-Ohlin**)
  - Skill-abundant countries specialize in skill-intensive sectors

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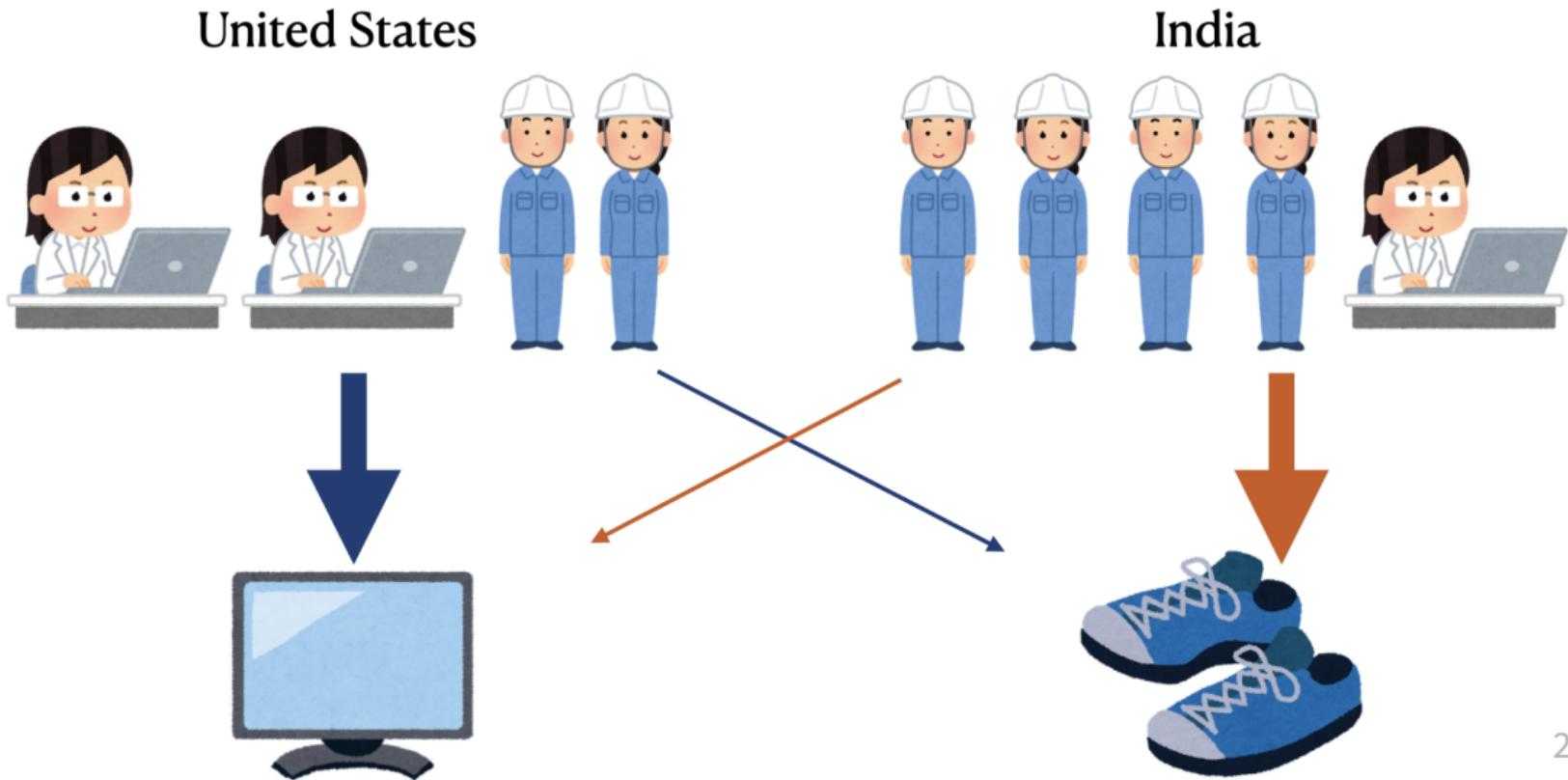
United States



India



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  - Keys for patterns of development (Ventura 1997)
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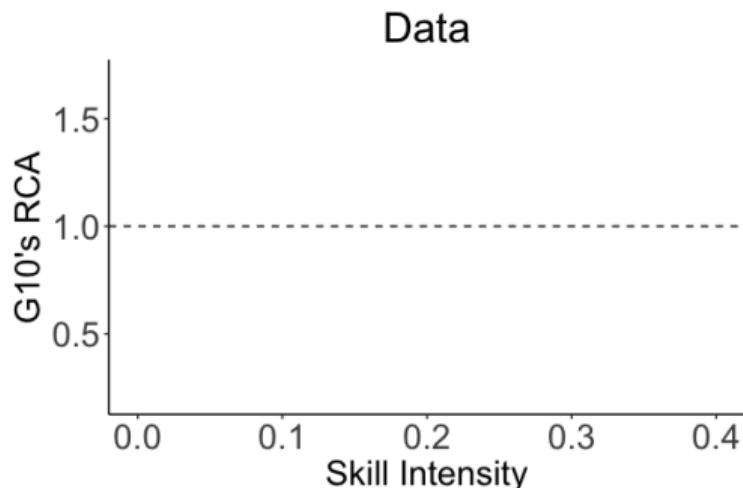
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- **This paper: What about the 21st century?**

# At a Glance: Skill Abundance and Comparative Advantage

**G10's Revealed Comparative Advantage (RCA) in Skill Intensive Sectors:**

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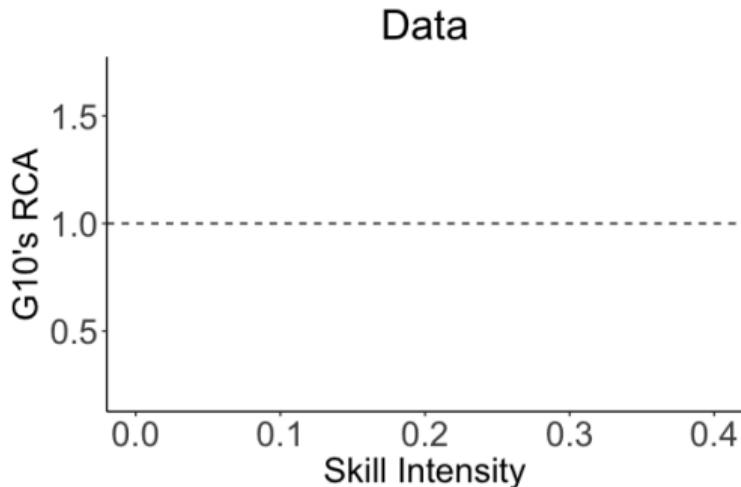


Note: Binned-scatter plots for 396 4-digit sectors. Data from UN Comtrade and NBER CES Manuf. DB

# At a Glance: Skill Abundance and Comparative Advantage

## G10's Revealed Comparative Advantage (RCA) in Skill Intensive Sectors:

G10's sectoral export share divided by global sectoral export share



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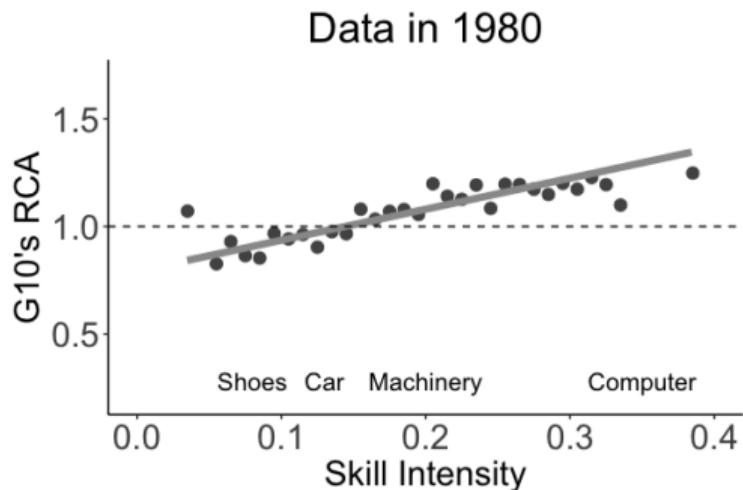
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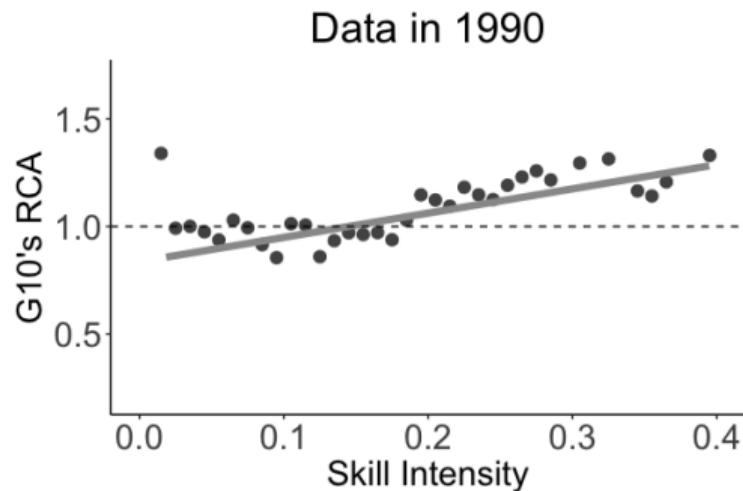
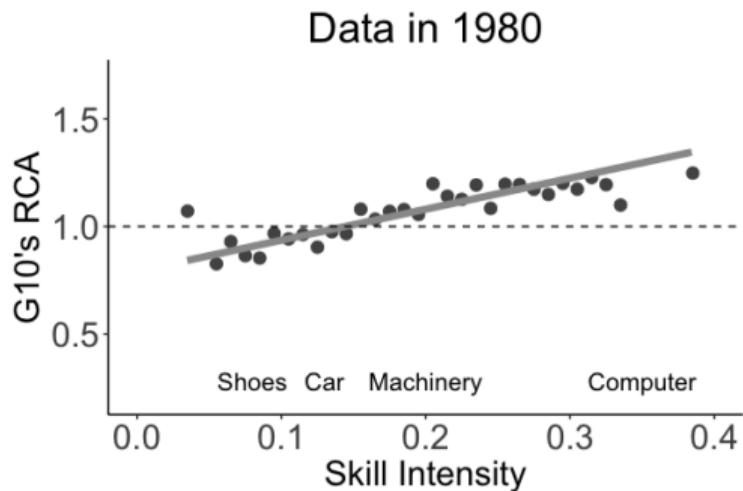
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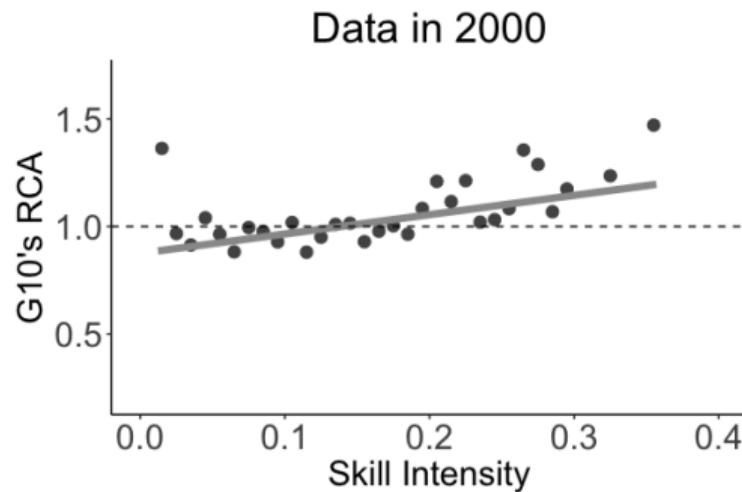
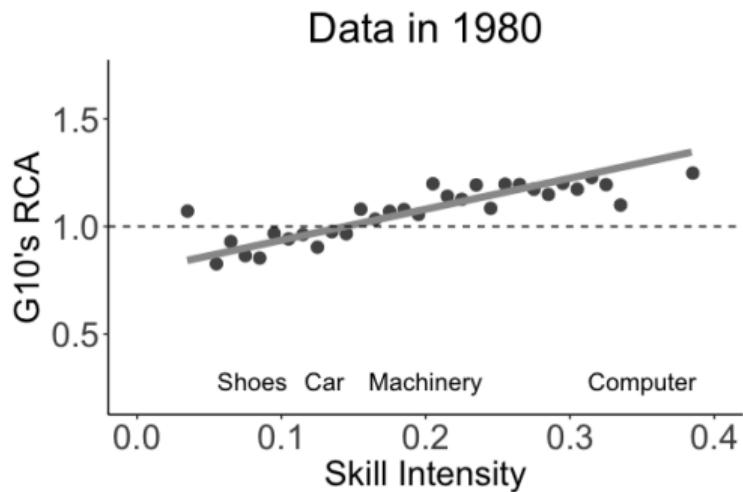


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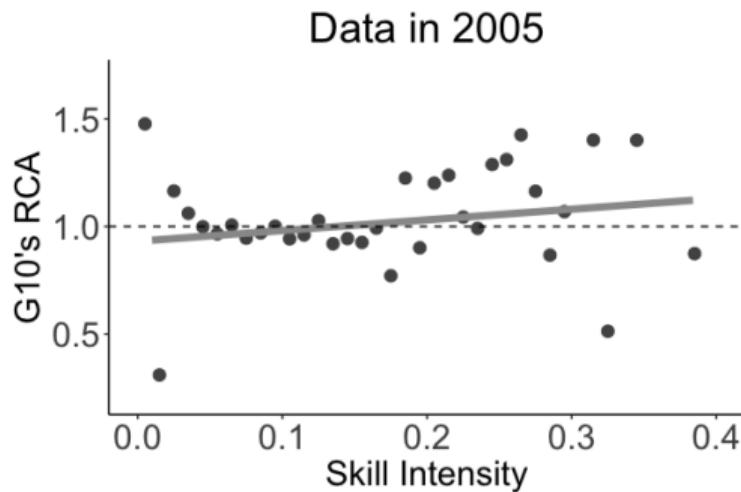
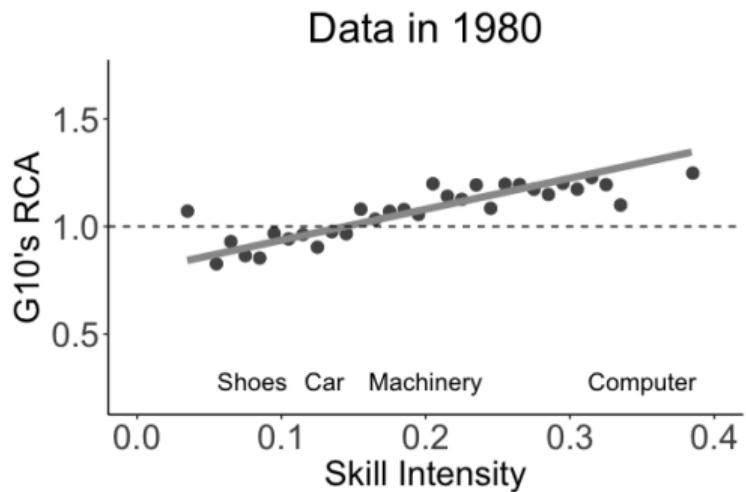


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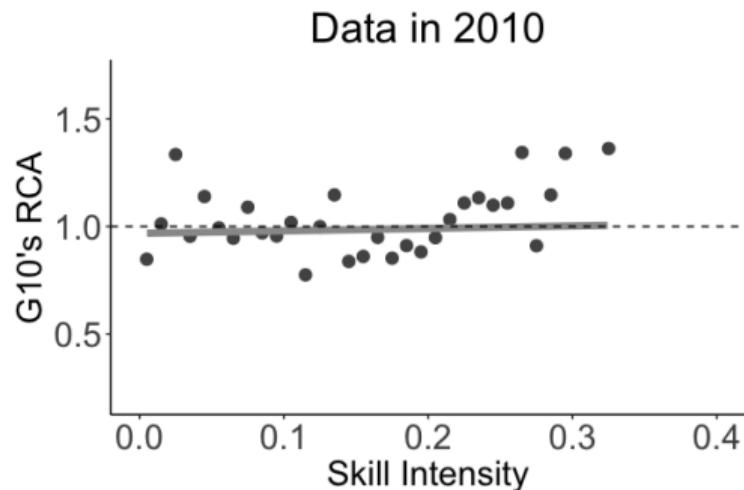
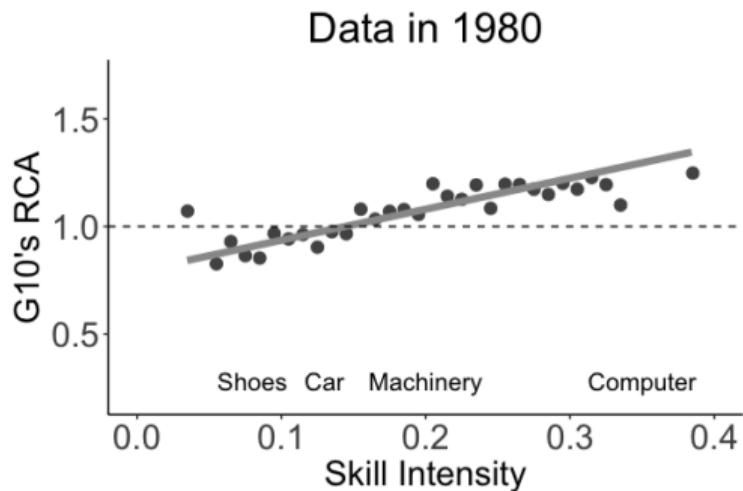


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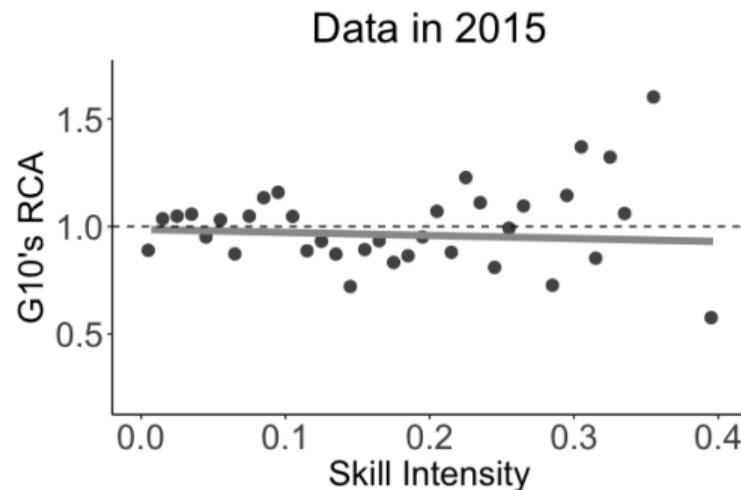
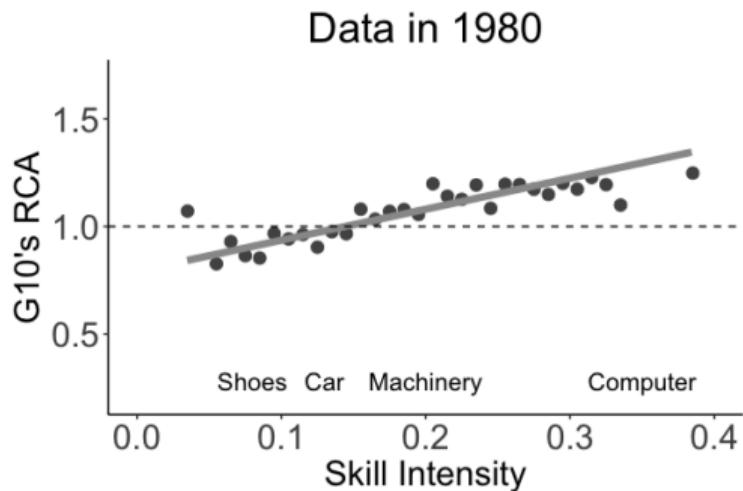


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3. What are the macro implications?
  - Manufacturing shifts to North; Inequality expands within & across countries

## Preview (1/2) New Facts on Comparative Advantage

- Follow the literature's state-of-the-art specification
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- **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
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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

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

# Specification: PPML

- What we want to run:

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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

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- $\text{Exports}_{i,j,s}$ : Bilateral trade flow  $i$  to  $j$  in  $s$ , from UN Comtrade
- $\text{Skill Intensity}_s$ :  $\alpha_{s,t}^H$  Share of skilled labor pay. in value-added, from NBER-CES
- $\text{Skill Abundance}_i$ :  $\ln(H_{i,t}/L_{i,t})$  College to Non-College ratio in  $i$ , from Barro-Lee
- $\eta_{i,j}$ : 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?**

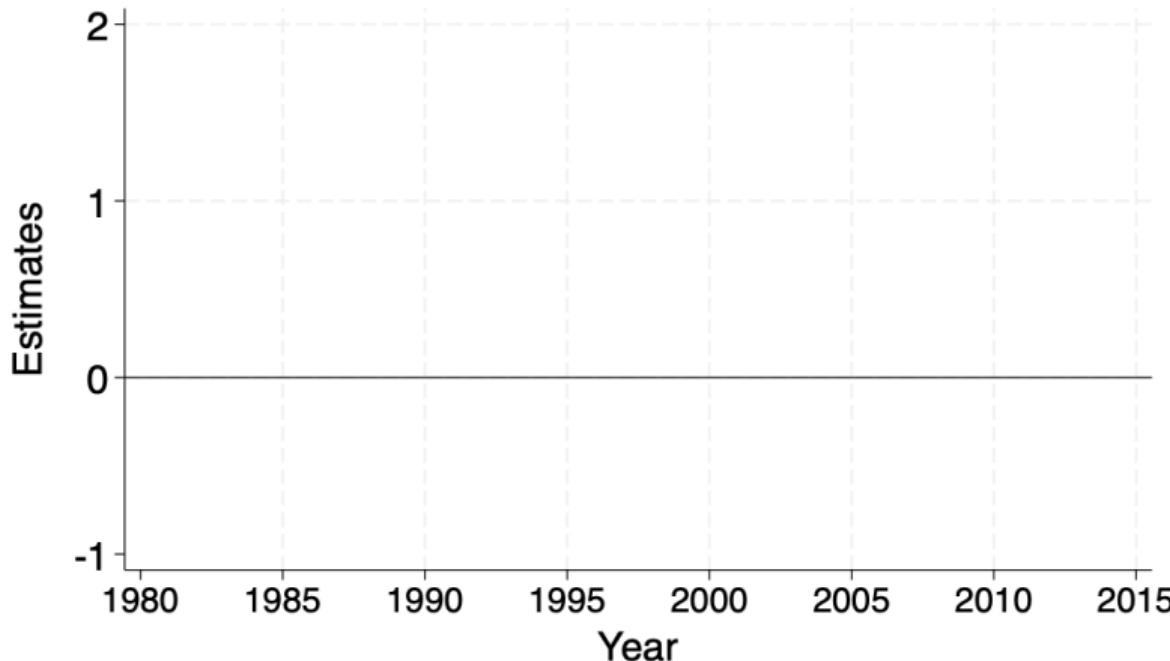
$$\ln \text{Exports}_{i,j,s,t} = \beta_t [\text{Skill Intensity}_{s,t} \times \text{Skill Abundance}_{i,t}] + \eta_{i,j,t} + \eta_{j,s,t},$$

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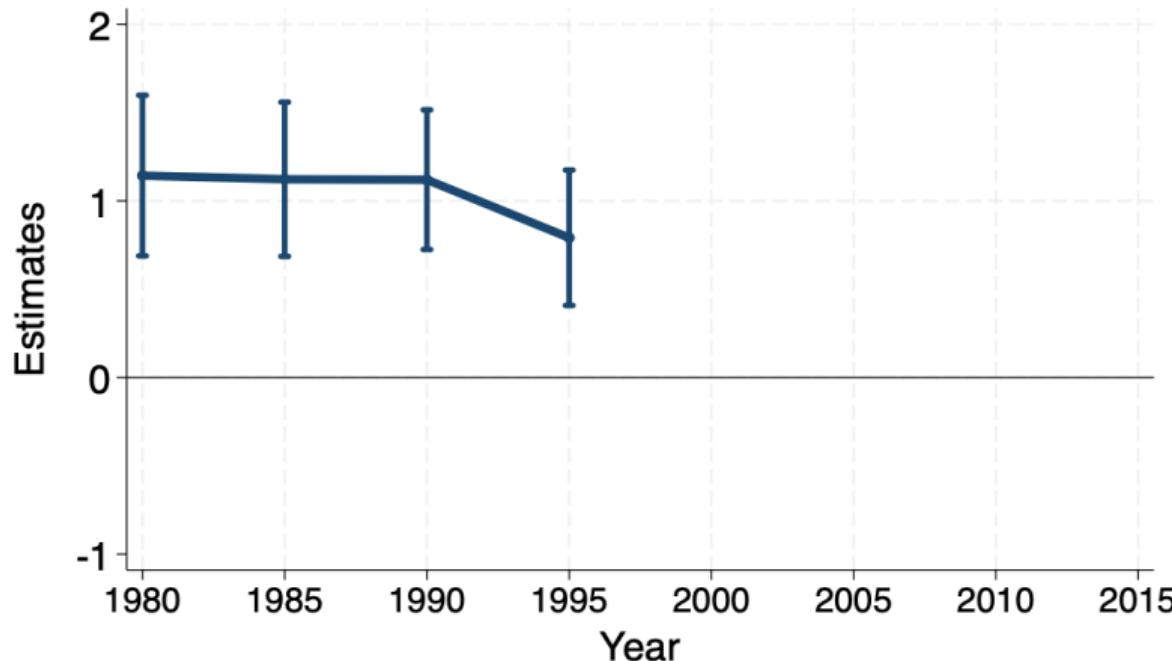
# Skill Abundance $\Rightarrow$ CA in Skill-Intensive Sectors?

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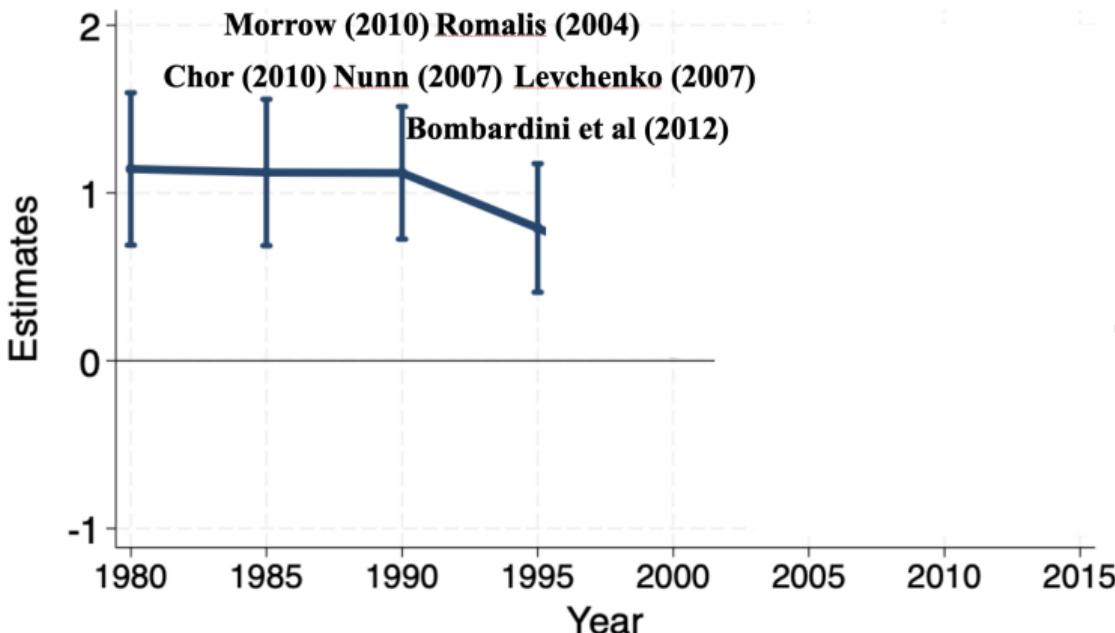
# Skill Abundance $\Rightarrow$ CA in Skill-Intensive Sectors before 2000

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



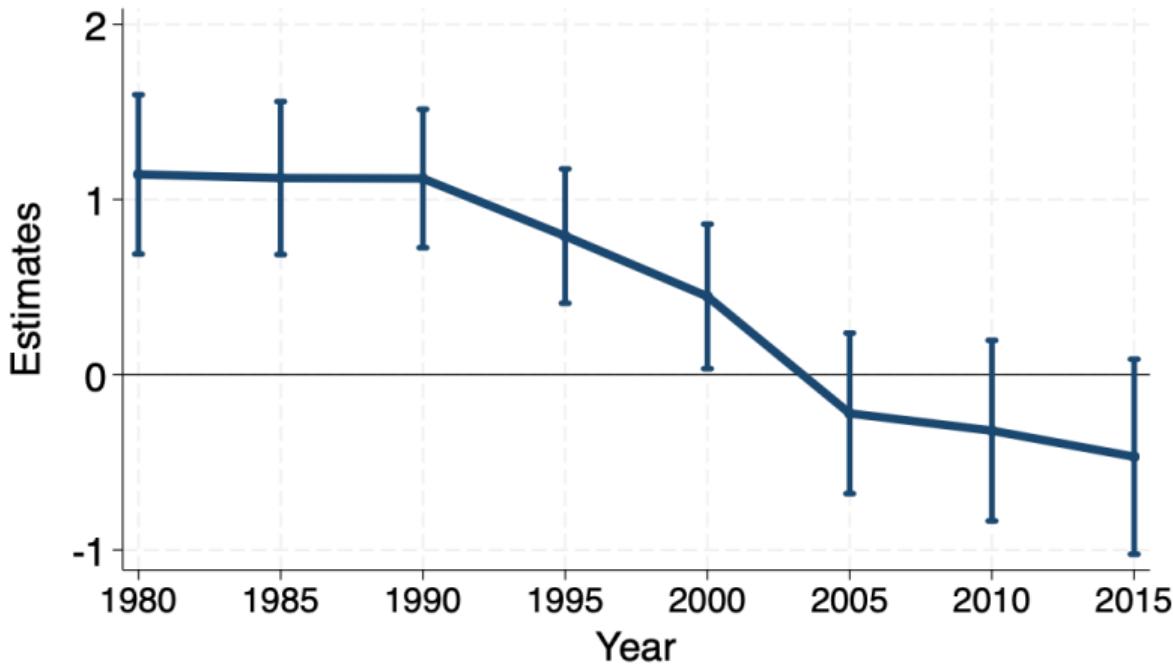
# Results before 2000 are Consistent with Previous Papers

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



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

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

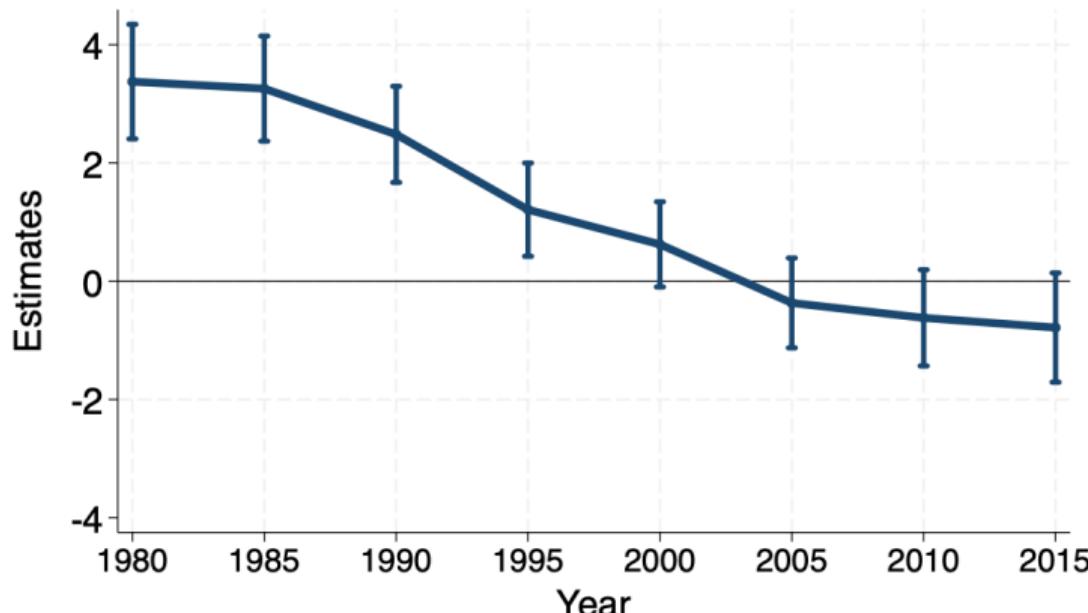


## Fixing RHS at 1980's values

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

# Change in Patterns of CA Comes from Exports

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

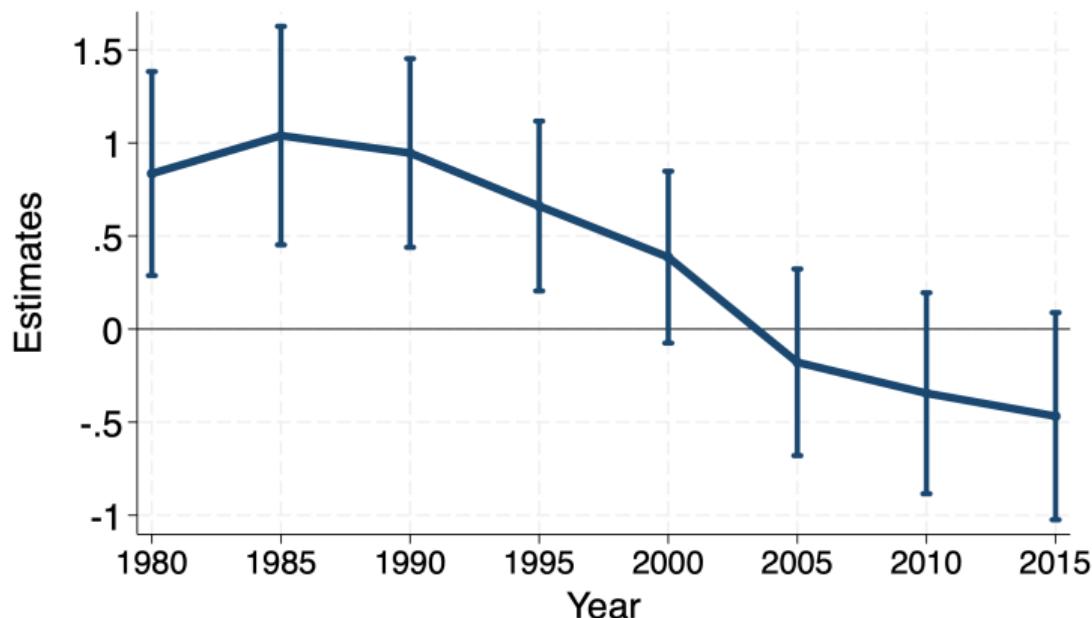


## Fixing RHS at 2015's values

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

# 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  $\alpha_s^H$  ( $\equiv$  Skilled Payroll Share to Value-Added) → go
- Including service sectors (WIOD, later in this presentation)

## POTENTIAL HYPOTHESES: AUTOMATION AND OFFSHORING

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## Potential Hypotheses: Automation and Offshoring

- 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

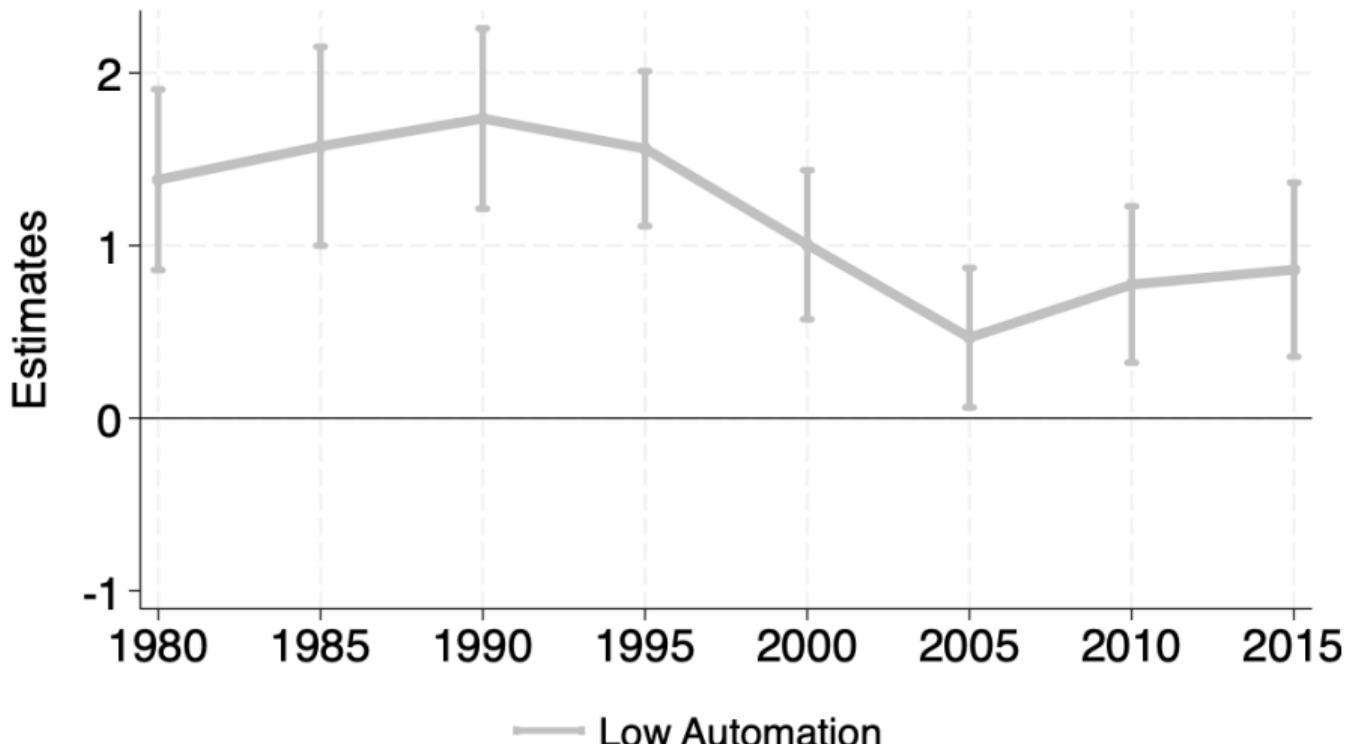
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- $HA_{i,s}$ : High-automation dummy (below/above the median robot adoption)
  - Robot adoption: Robot stock per workers from IFR & WIOD
- Expect  $\beta_t^A$  to decrease if there is a relationship btw change & automation

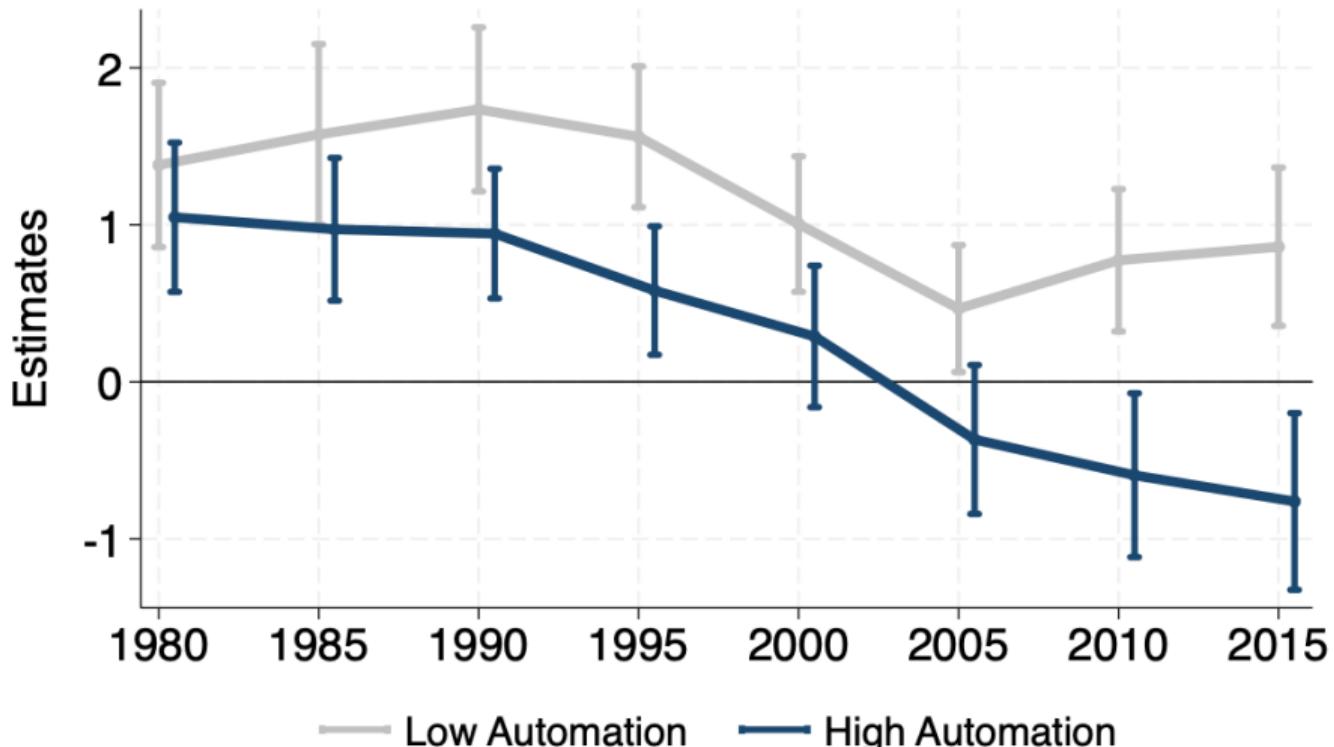
# Skill Abundance Still Matters Absent Automation

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



# Skill Abundance Still Matters Absent Automation

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



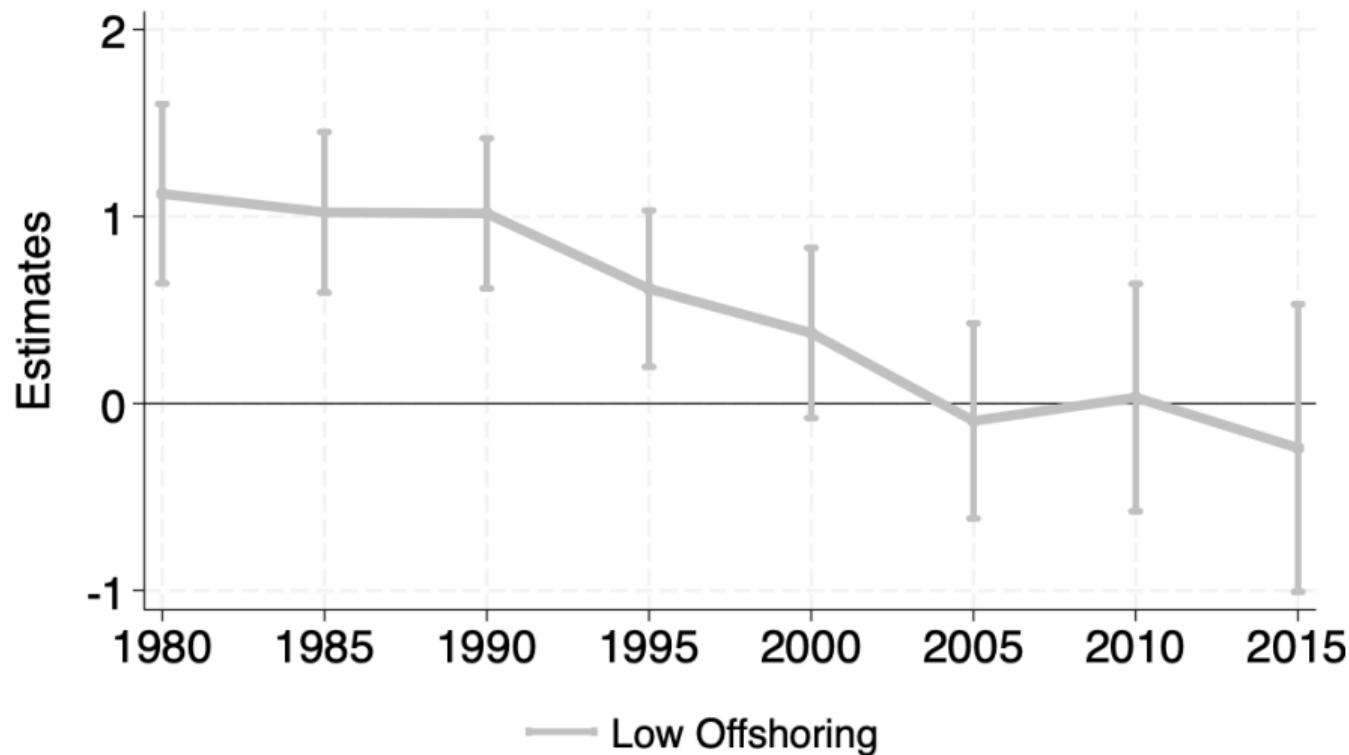
# Specification for Heterogeneous Effects: Offshoring

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

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

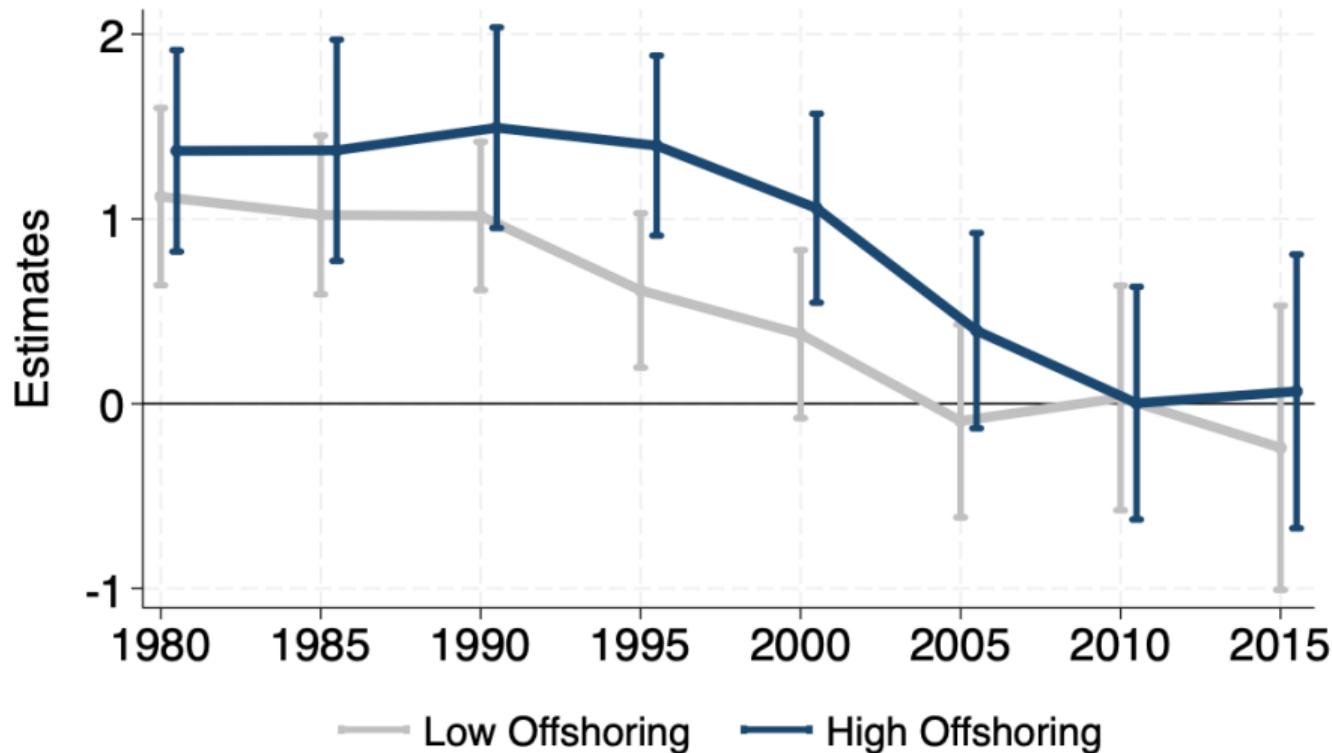
# Skill Abundance does not Matter Even Absent Offshoring

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



# Skill Abundance does not Matter Even Absent Offshoring

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



## Now, 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

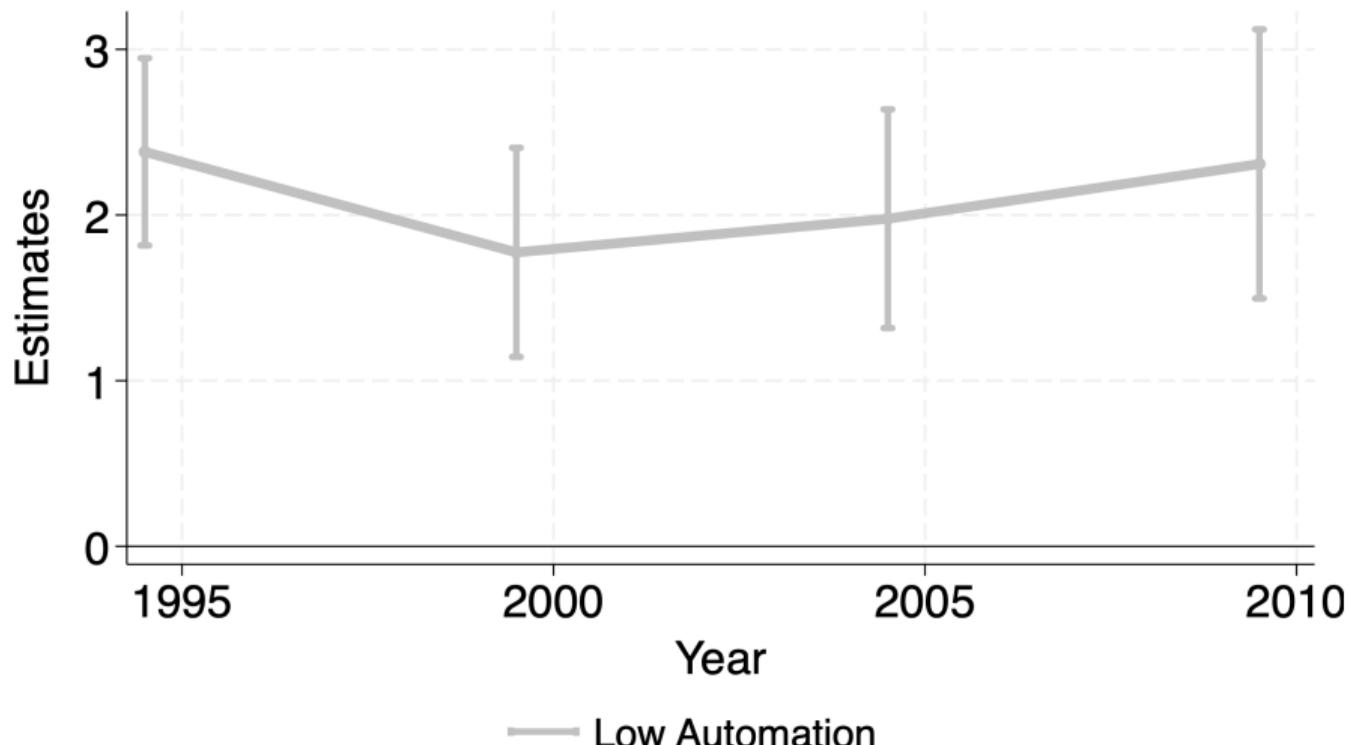
$$\ln \text{Exports}_{i,j,s,t} = \beta_t^0 (1 + \beta_t^A \text{Auto}_{i,s} + \beta_t^O \text{Ofs}_{i,s}) \cdot [\text{Skill Int.}_{s,t} \times \text{Skill Abd.}_{i,t}] + \eta_{i,j,t} + \eta_{j,s,t}$$

	1995	2010	1995	2010
Skill Intensity x Abundance	1.26 (0.23)	-0.33 (0.28)	3.00 (0.41)	<b>3.49</b> (0.57)
x Automation (log robot stock)			-0.19 (0.05)	<b>-0.35</b> (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

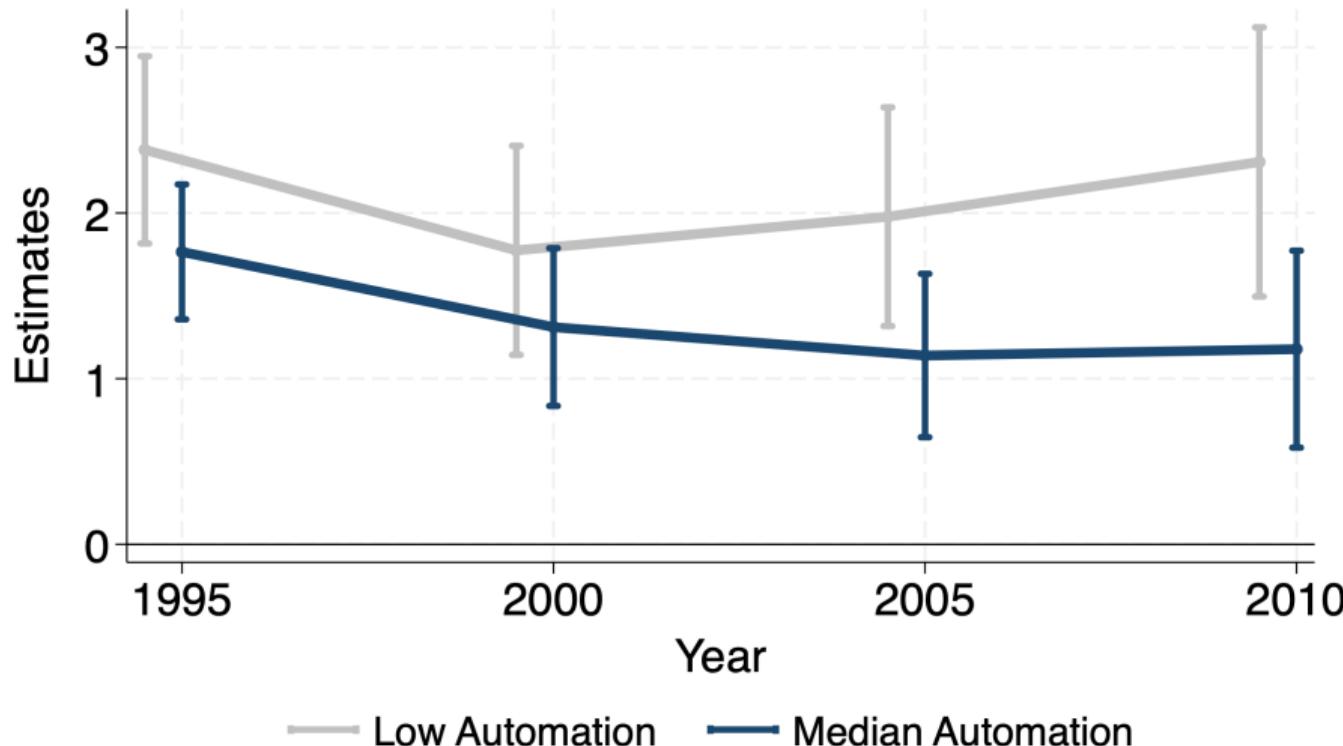
# Skill Abundance Still Matters Absent Automation

Fitted values for groups with automation of 10th percentiles (with zero offshoring)



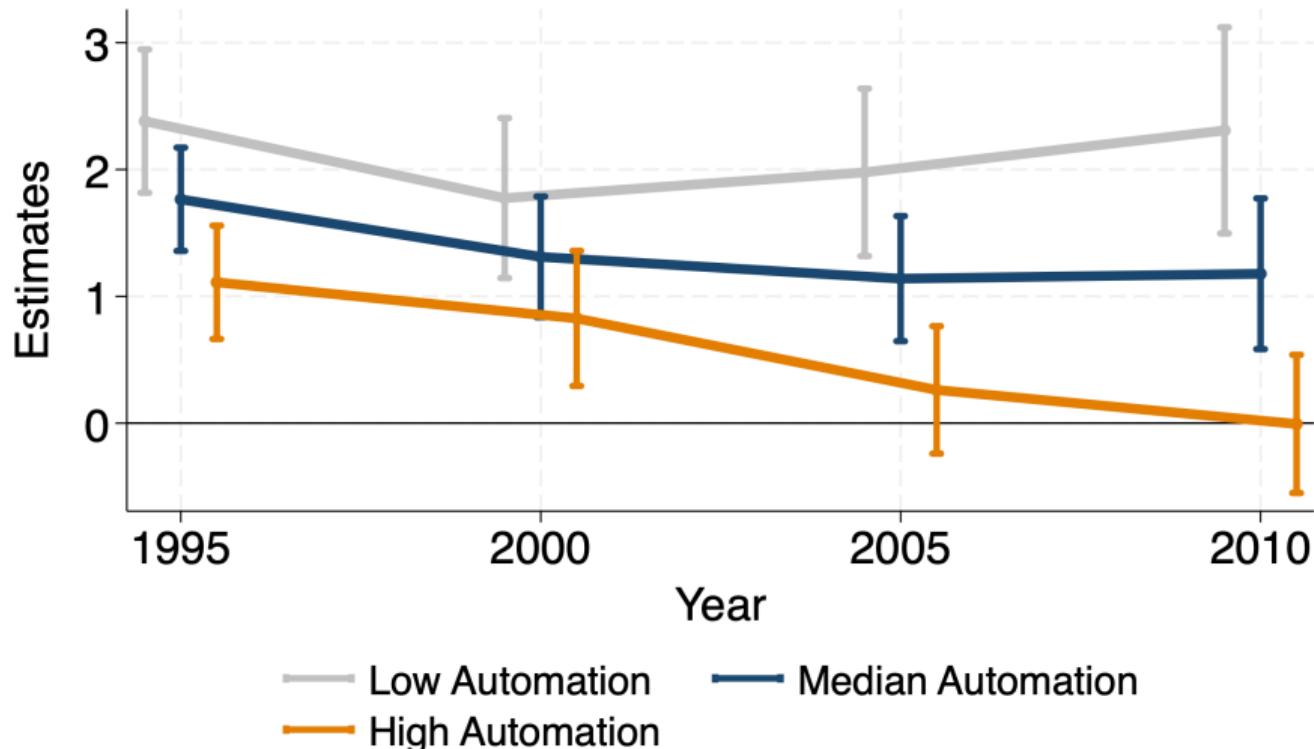
# Skill Abundance Still Matters with Median Automation

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



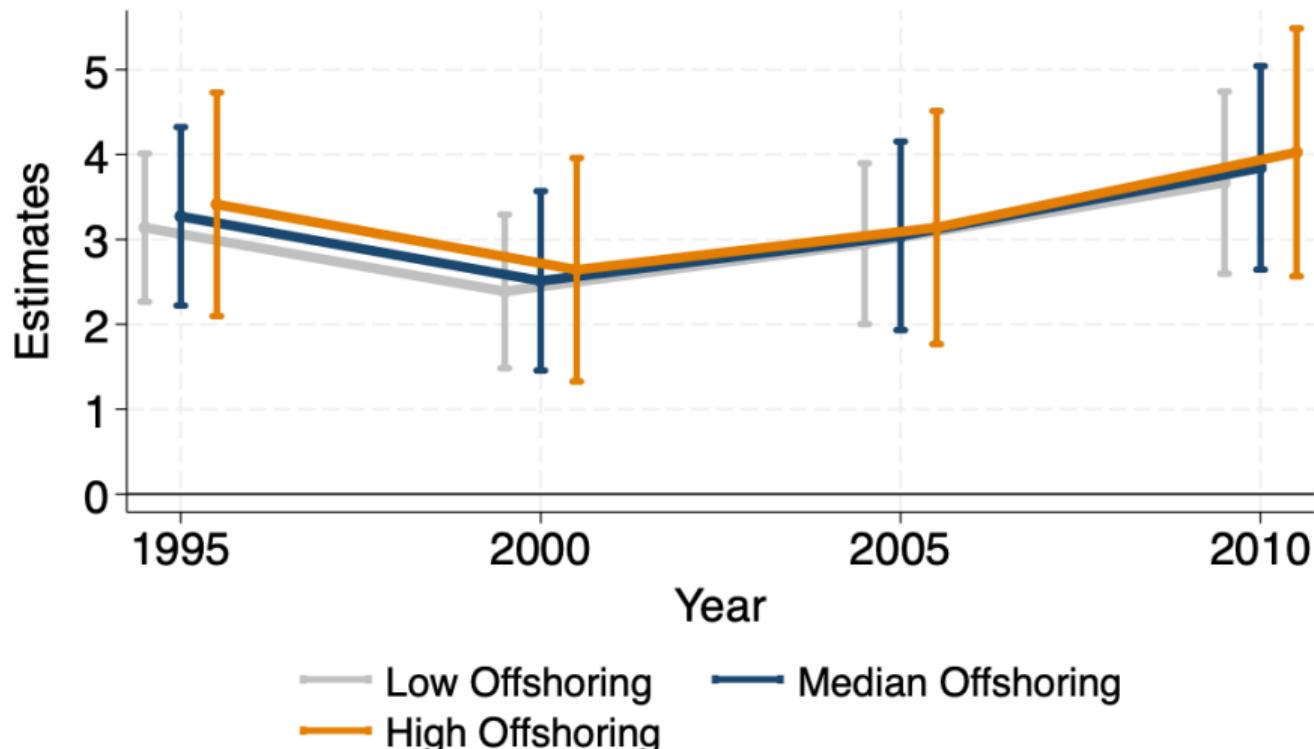
# Skill Abundance Still Matters Absent Automation

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		
	(0.23)	(0.28)		
x Automation (log robot stock)				
x Offshoring Share ( $\times 100$ )				
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	<b>3.51</b>
	(0.23)	(0.28)	(0.45)	(0.46)
x Automation (log robot stock)			-0.15	<b>-0.31</b>
			(0.05)	(0.05)
x Offshoring Share ( $\times 100$ )			0.03	0.11
			(0.05)	(0.06)
x China's RCA			0.20	<b>0.34</b>
			(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

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# 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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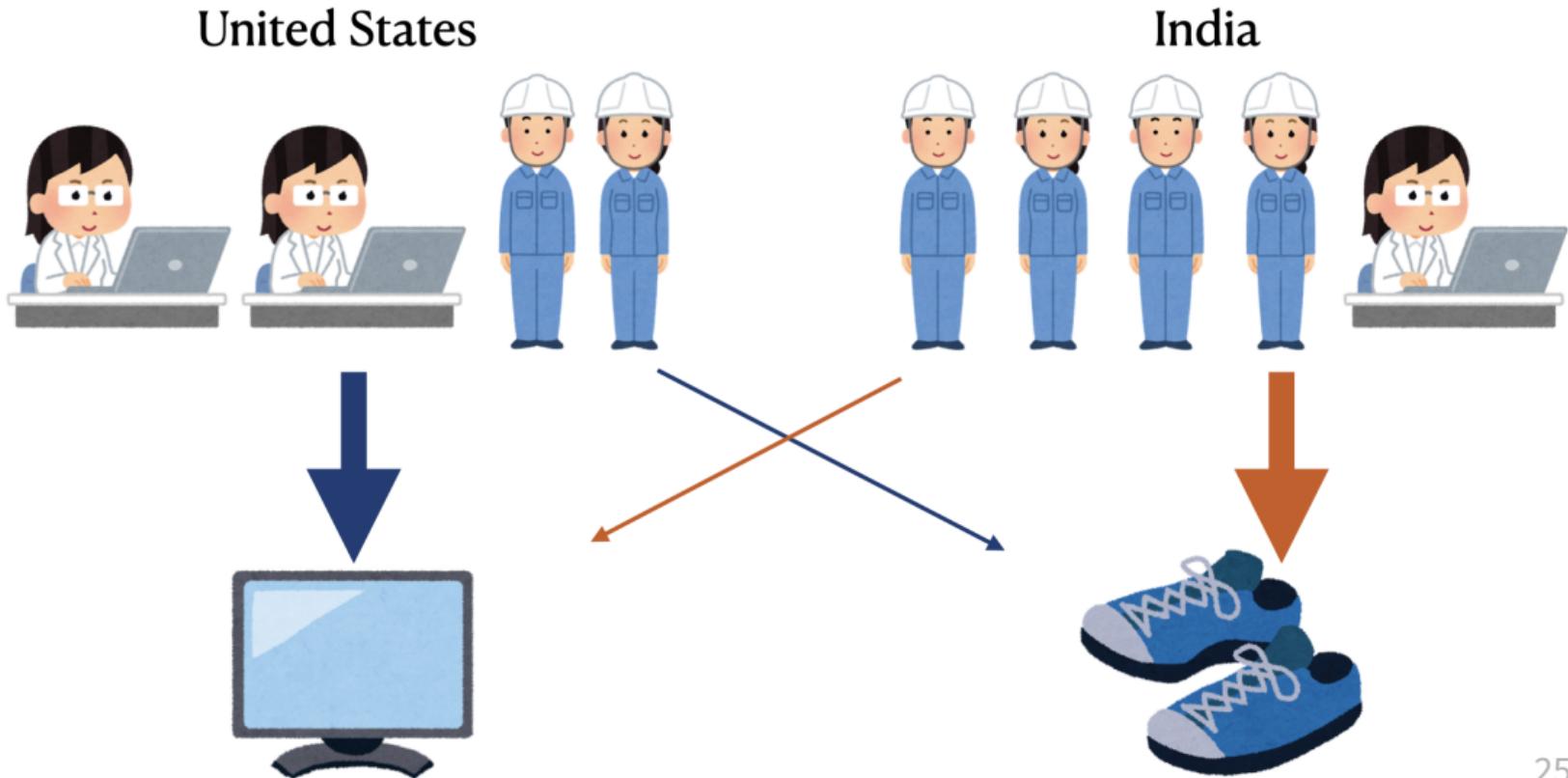
United States



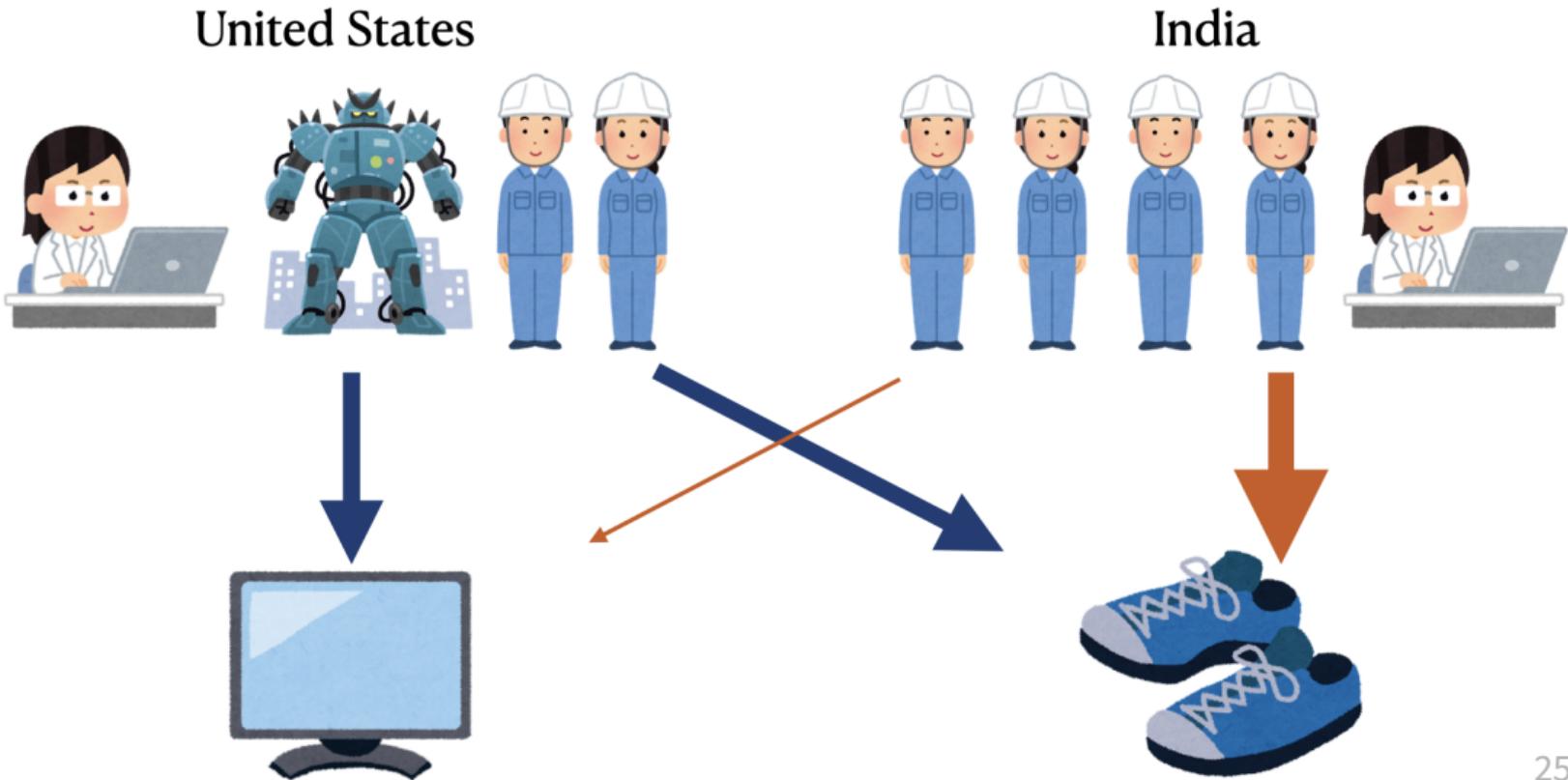
India



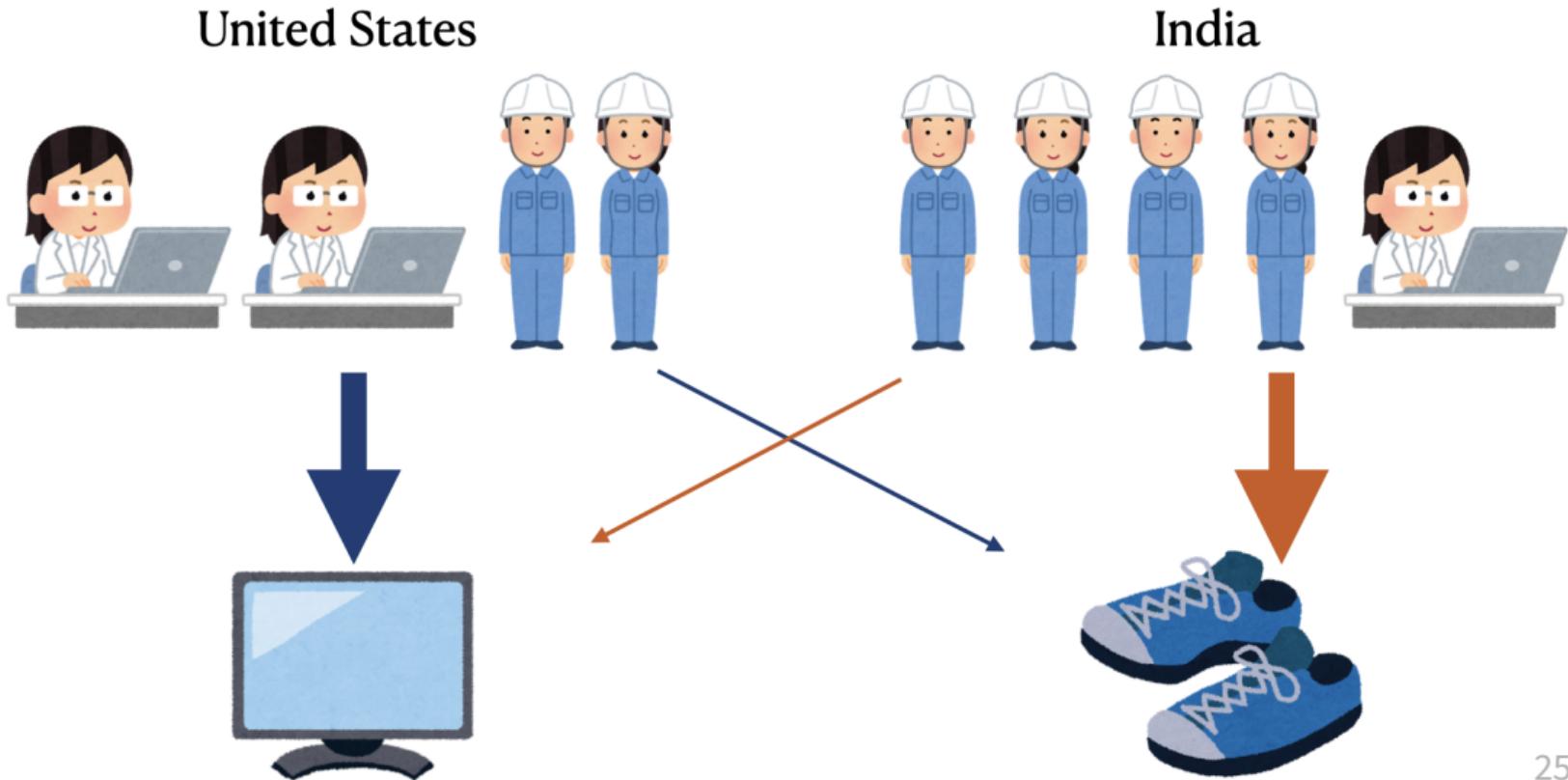
# US for Electronics, India for Shoes



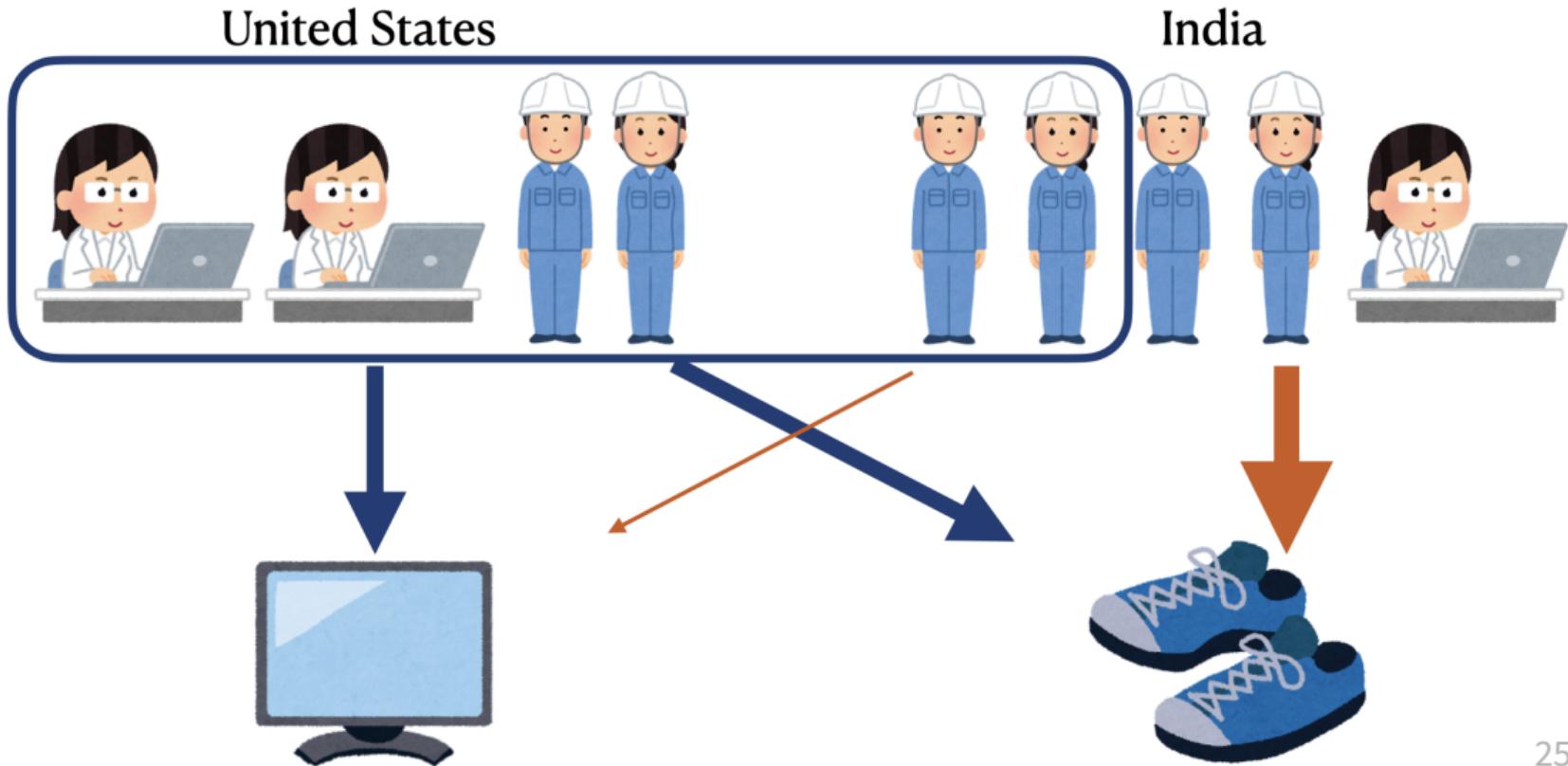
# With Robots, US is now Competitive in Shoes



# 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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# Model: Overview

- Multi-sector Eaton-Kortum model with input-output linkages
  - **New: Task framework for automation and offshoring**
- Trade and preference: Cobb-Douglas across sectors, CES (EK) within a sector
- Supply: Multiple production factors
  - Primary: Labor:  $H_{i,s}$  (high-skilled),  $L_{i,s}$  (low-skilled)
  - Additional (produced using outputs: roundabout)
    - ★ Automation Capital:  $A_{i,s}$
    - ★ Intermediate:  $X_{i,s}$  (domestic),  $O_{i,s}$  (foreign, offshored)

## 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  $\theta > 0$ 
  - ★ From the production side of Eaton-Kortum (same agg. from Armington)

# Supply 1/2: Task Framework in Production

- Eaton-Kortum + Task Framework

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

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

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- 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 $\Gamma_{i,s}^f$

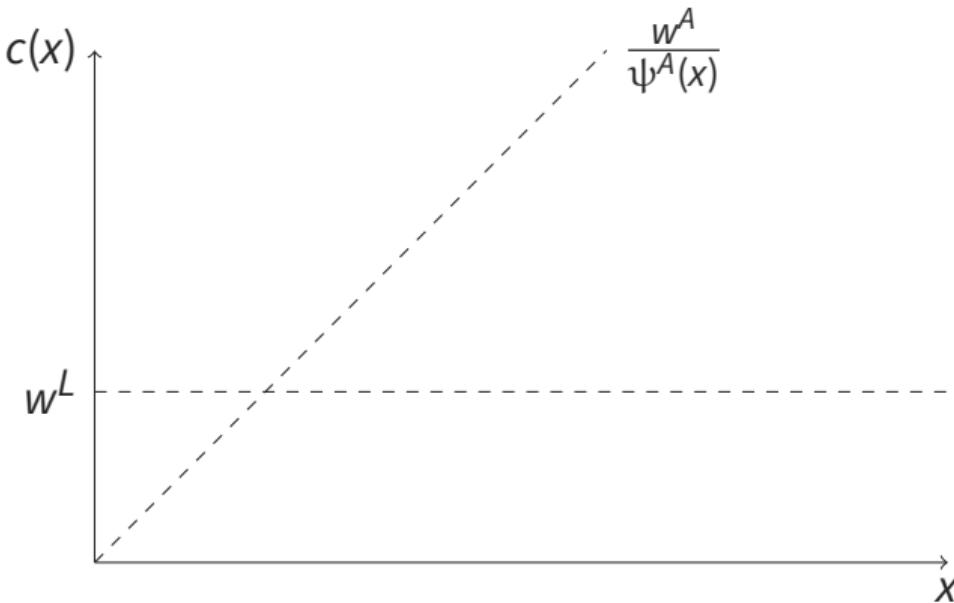
- Task production cost using factor  $f$ :  $c_{i,s}^f(x) \equiv w_{i,s}^f / (\psi_{i,s}^f(x))$  for  $f \in \{A, L, X, O\}$

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

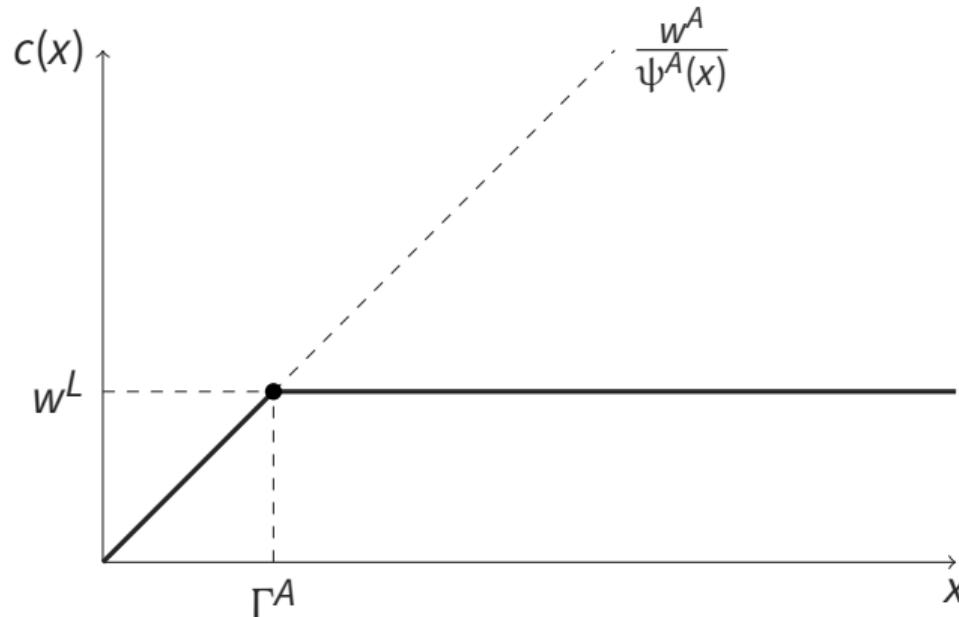
# At Glance: Task Allocation and Task Share

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



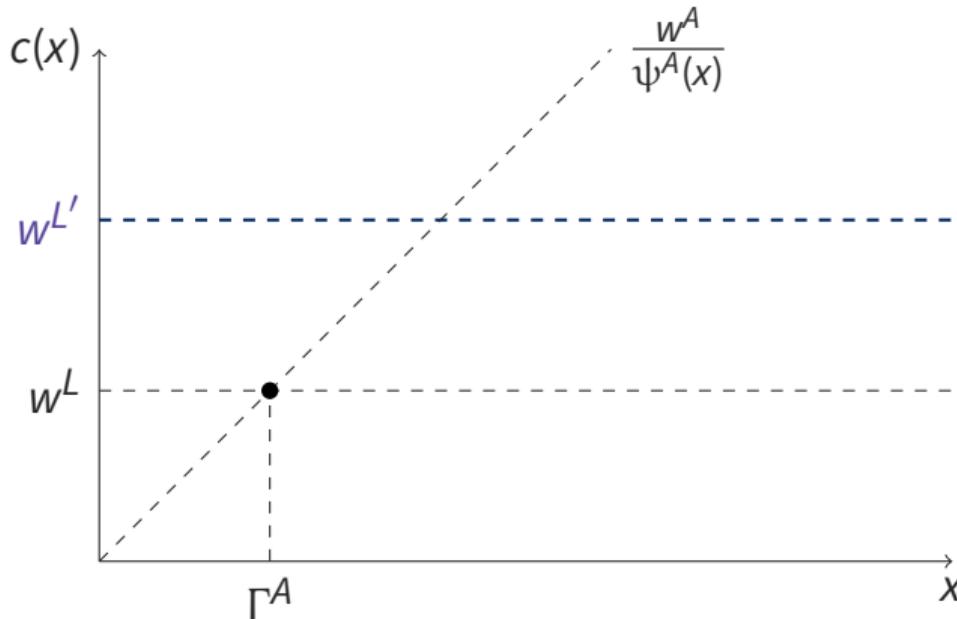
# At Glance: Task Allocation and Task Share

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



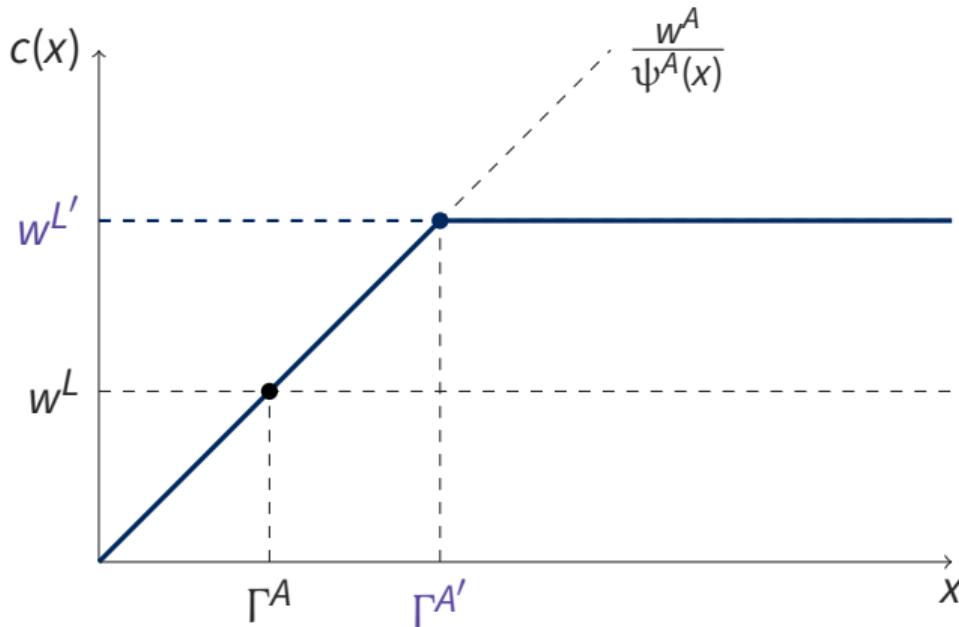
# At Glance: Task Allocation and Task Share

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



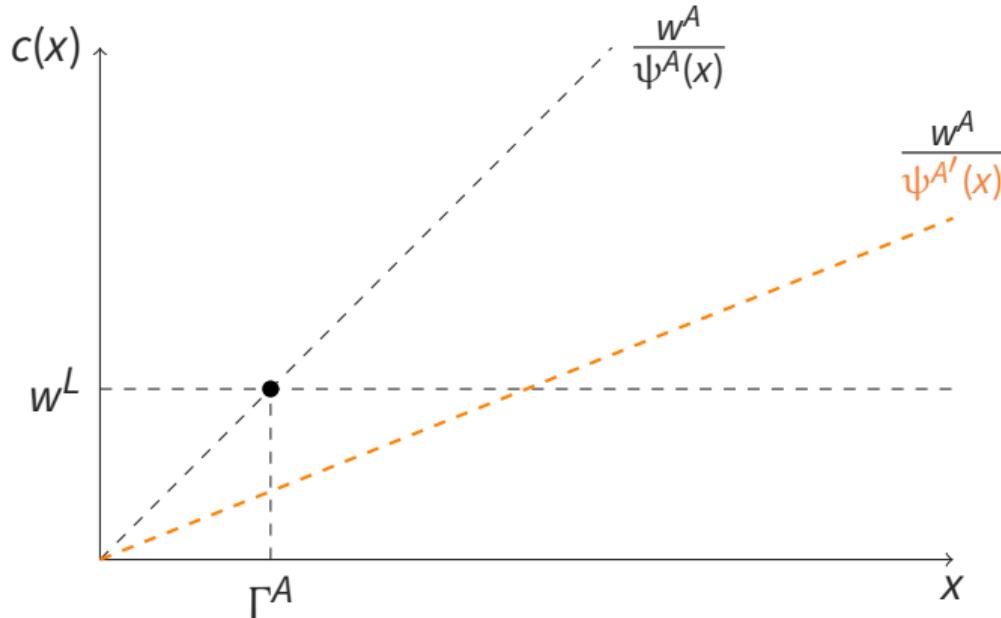
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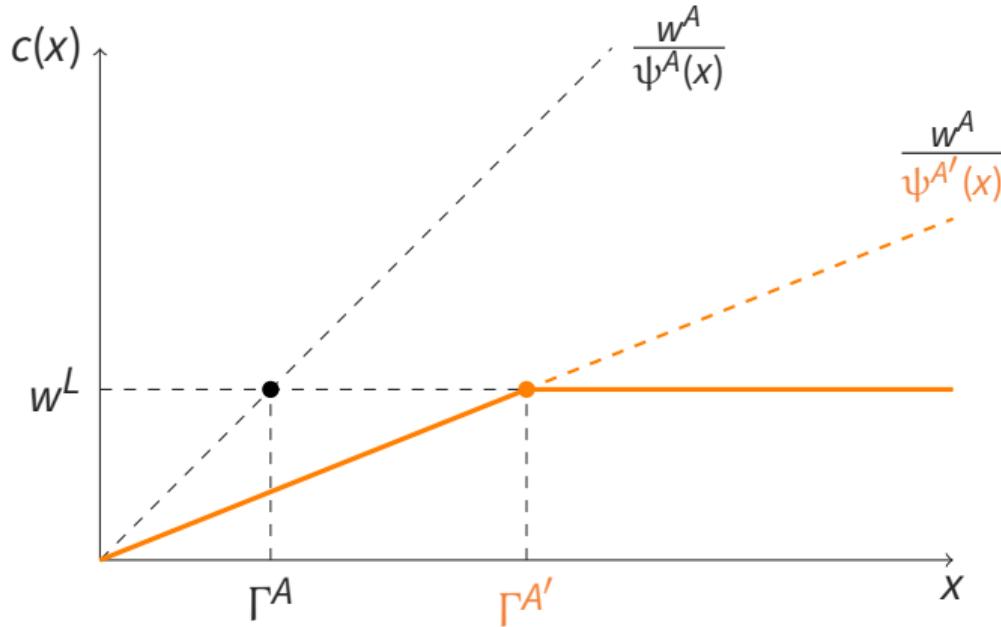
# At Glance: Task Allocation and Task Share

- 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 $\Gamma_{i,s}^f$

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

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# 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?

# Quantitative Analysis: Effects of Automation and Offshoring

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

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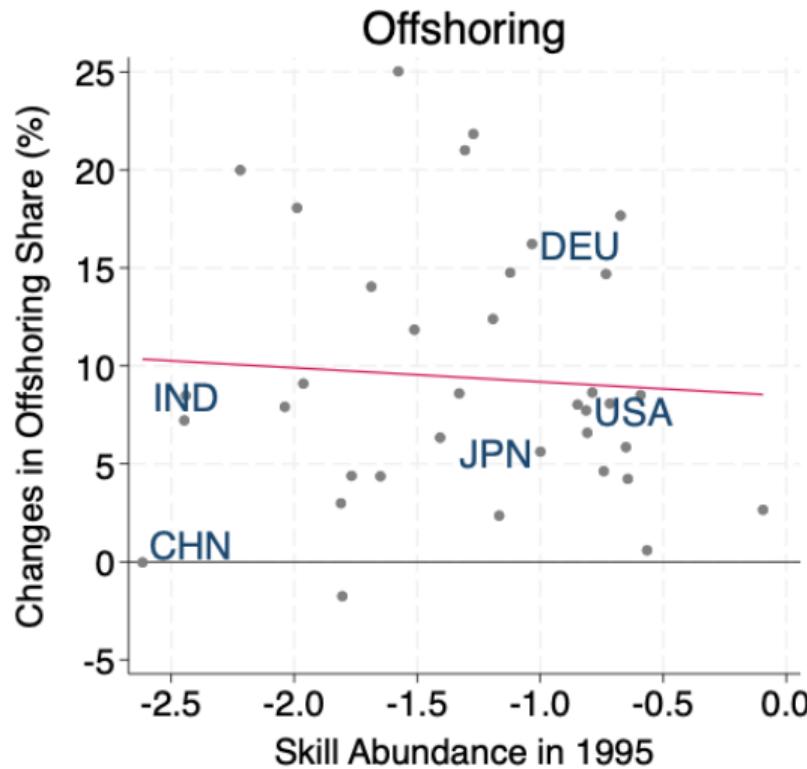
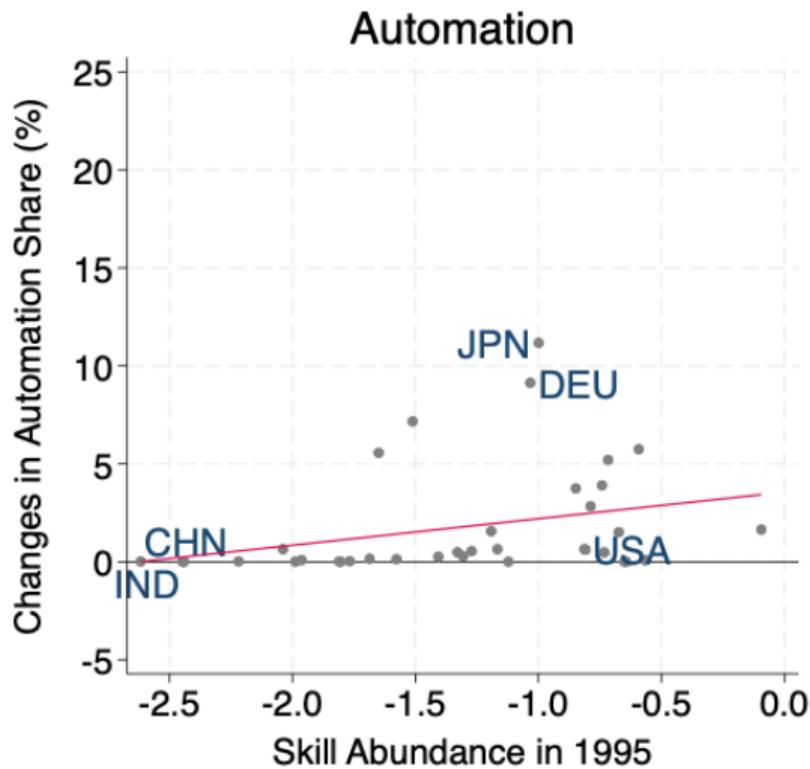
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  - Assume that  $\psi^A(x)$  and  $\psi^O(x)$  follow Fréchet distr.
    - ★ for automation, the shape param. to be 1.2
    - ★ for offshoring, it's EK's trade elasticity.

# Data: More Automation in Skill-Abundant Countries



# Calibration

Description	Parameter	Value & Source
Panel A: Time-Invariant Parameters (fixed in 1995)		
Trade Elas.	$\theta$	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

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# 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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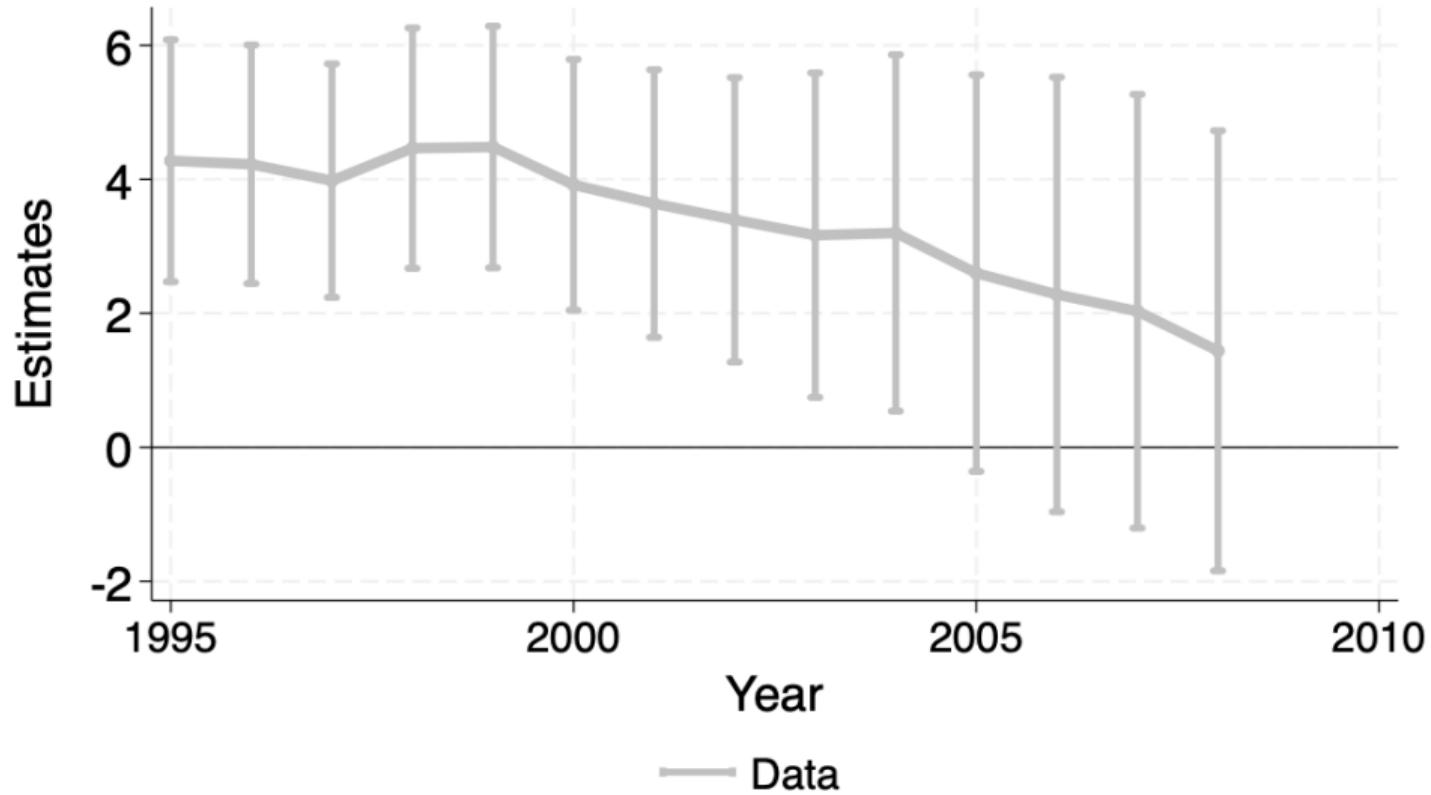
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  3. Construct counterfactual trade flow:  $(X_{i,j,s,t})'$ 
    - Data (World Input-Output Database, incl. Service)
    - Case 1. Only Automation: Change  $\Gamma_{i,s,t}^A$
    - Case 2. Only Offshoring: Change  $\Gamma_{i,s,t}^O$

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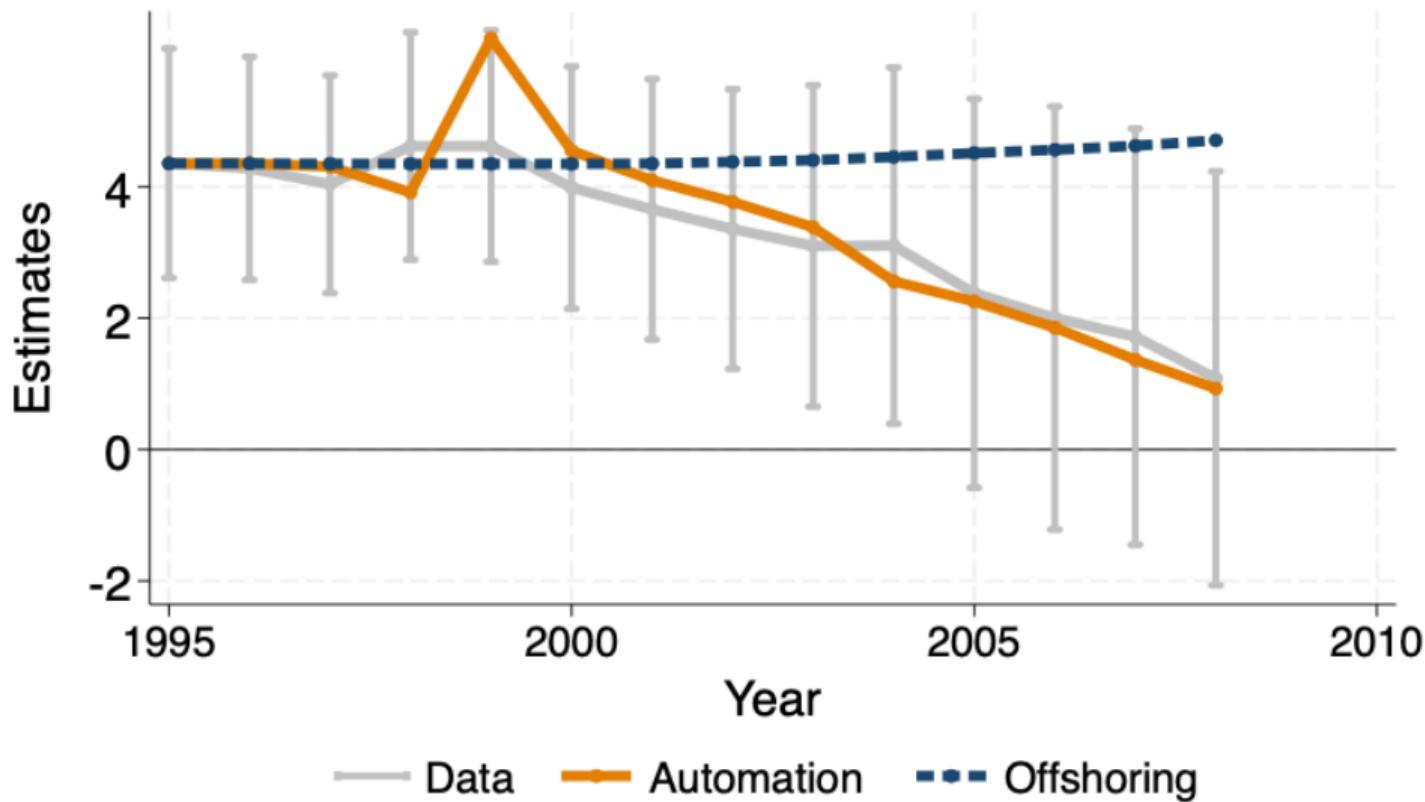
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  4. Run the same regression as in data but for counterfactual economies

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

# $\hat{\beta}_t$ 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?

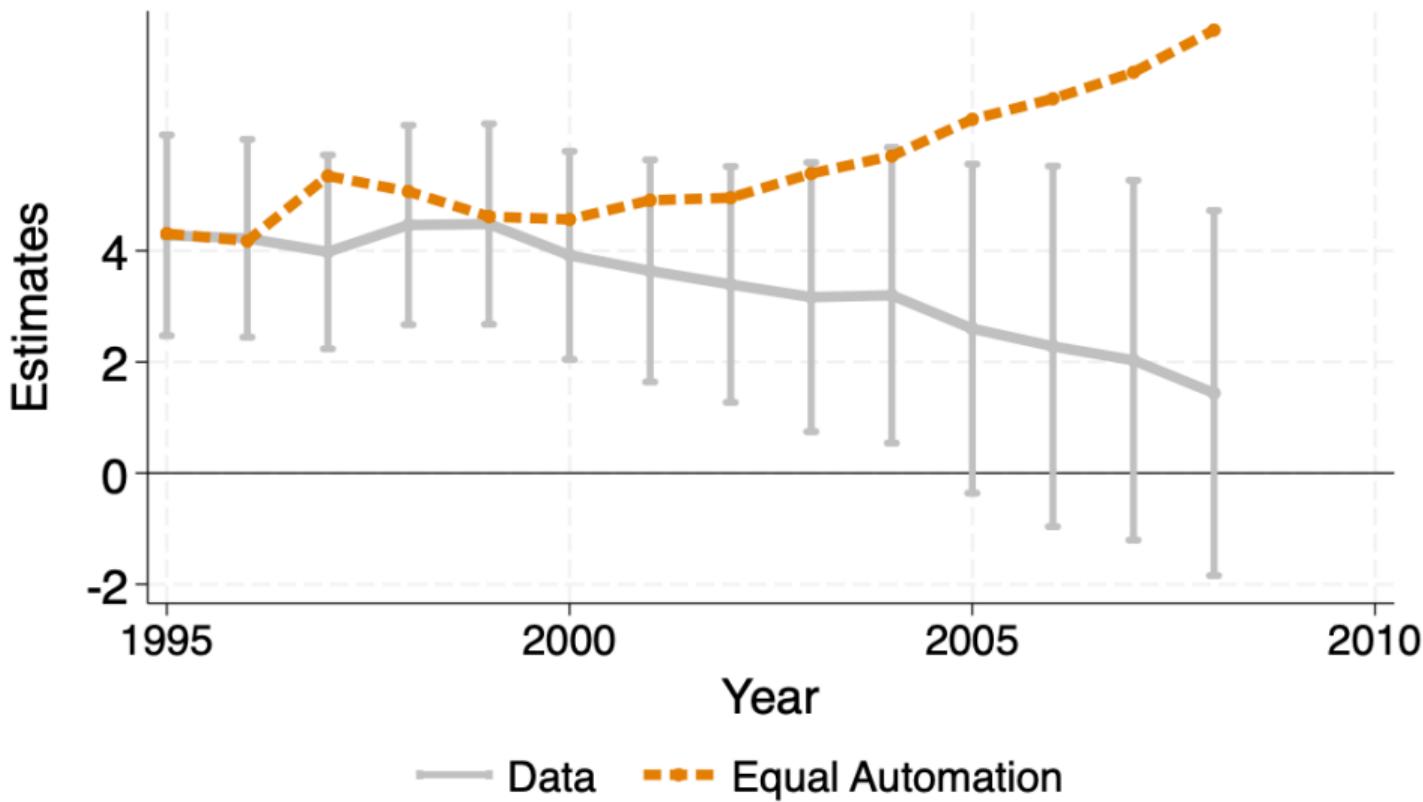
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- Sizes of automation are smaller than offshoring
- Why does automation, not offshoring, matter?
- One observation: Automation happens disproportionately in  $L$ - scarce countries
- Experiment: Suppose all the countries increase automation equally...

# Equal Automation Cannot Explain the Decline



## RESULTS: MACRO IMPLICATIONS OF AUTOMATION AND OFFSHORING

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# Macro Implications of Automation and Offshoring

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

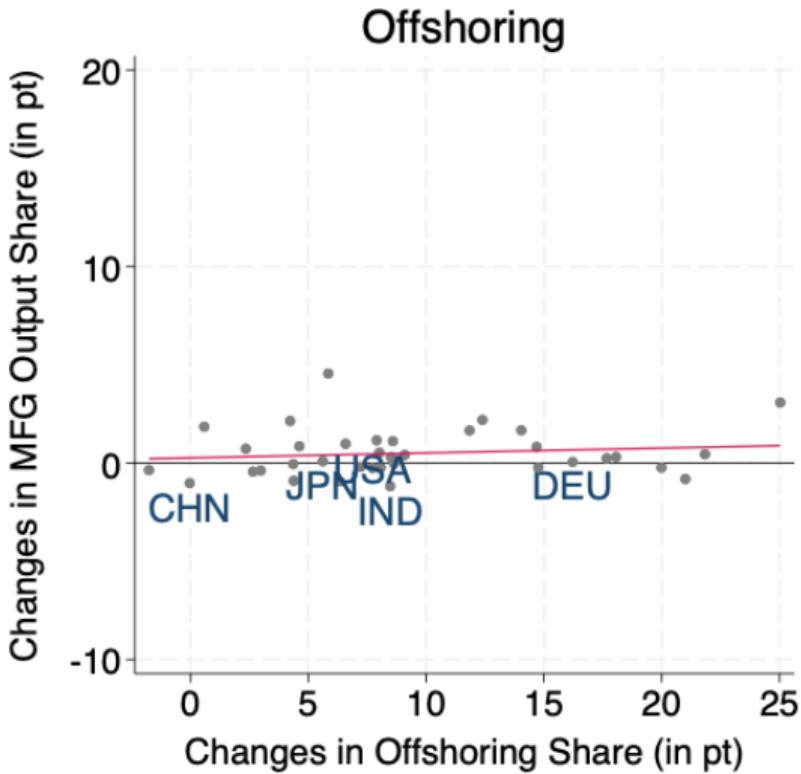
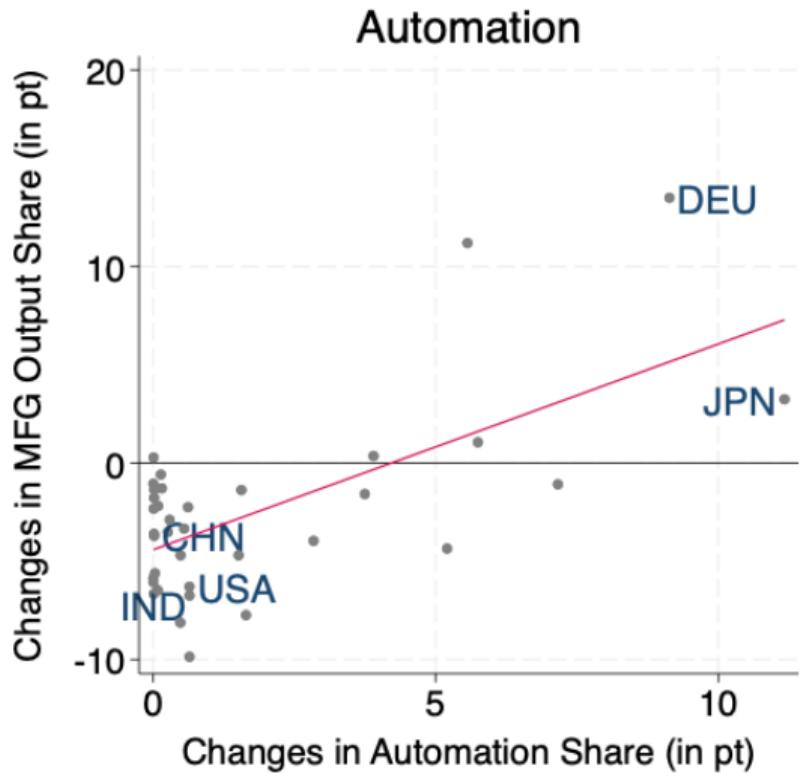
# Macro Implications of Automation and Offshoring

- 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)

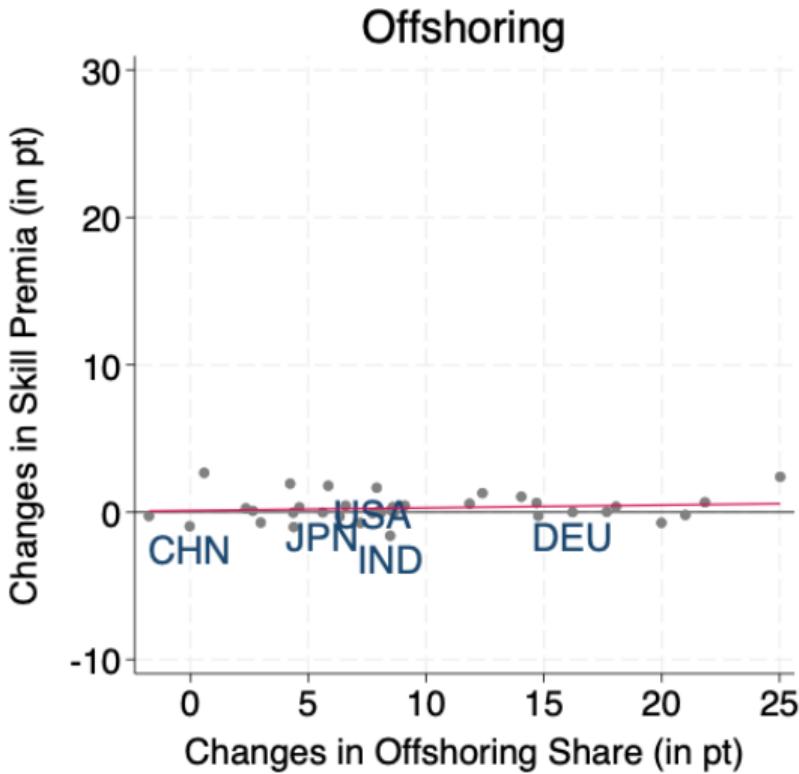
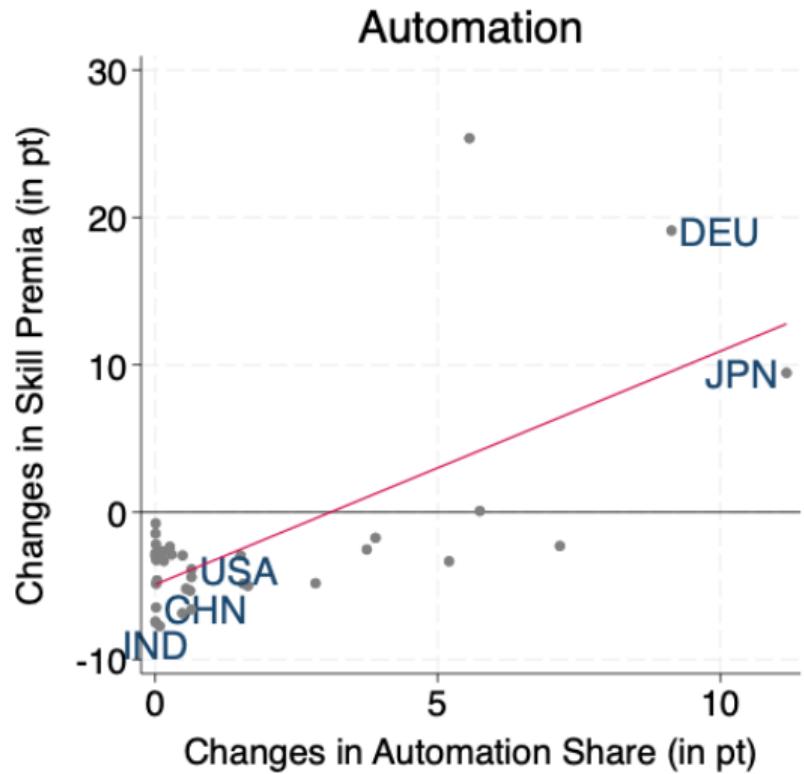
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- “Causal effect” (model prediction), not aiming to explain these macro trends

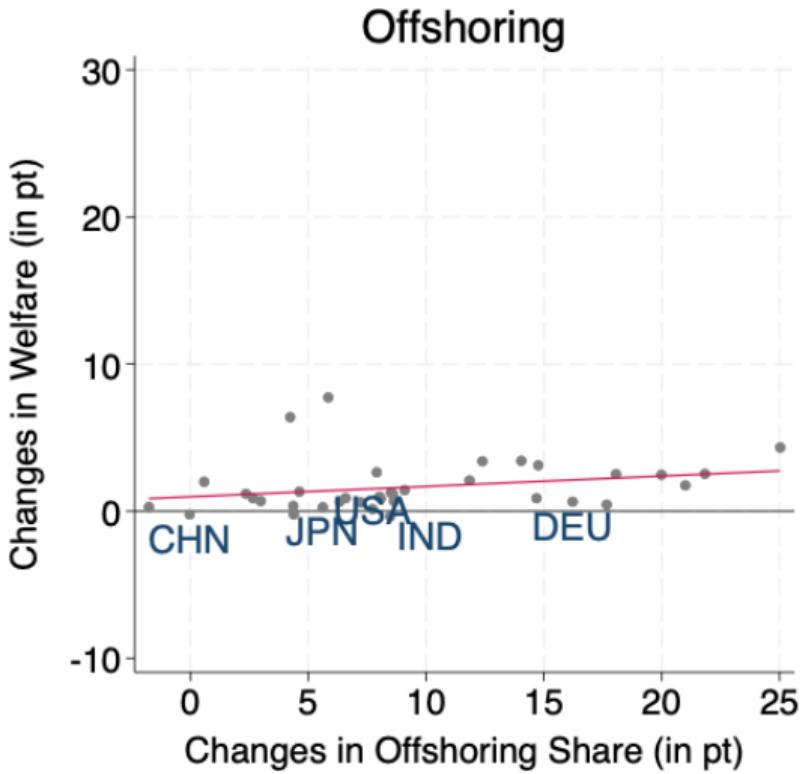
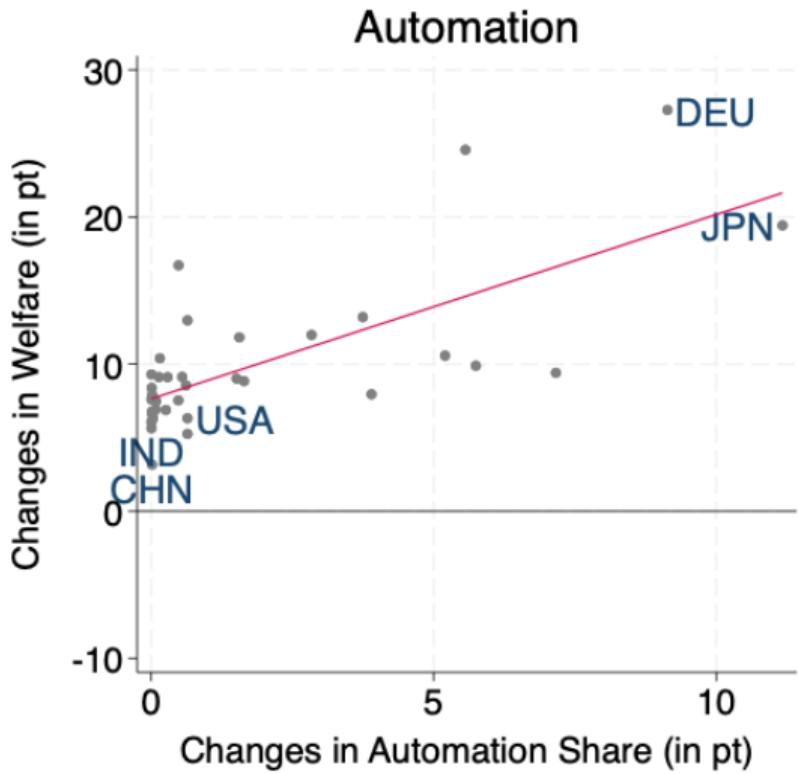
# Manufacturing Shifts to High-Automation Countries



# Skill Premia Increases Only in High-Automation Countries



# Welfare Increases Everywhere



# CONCLUSION

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

## APPENDIX

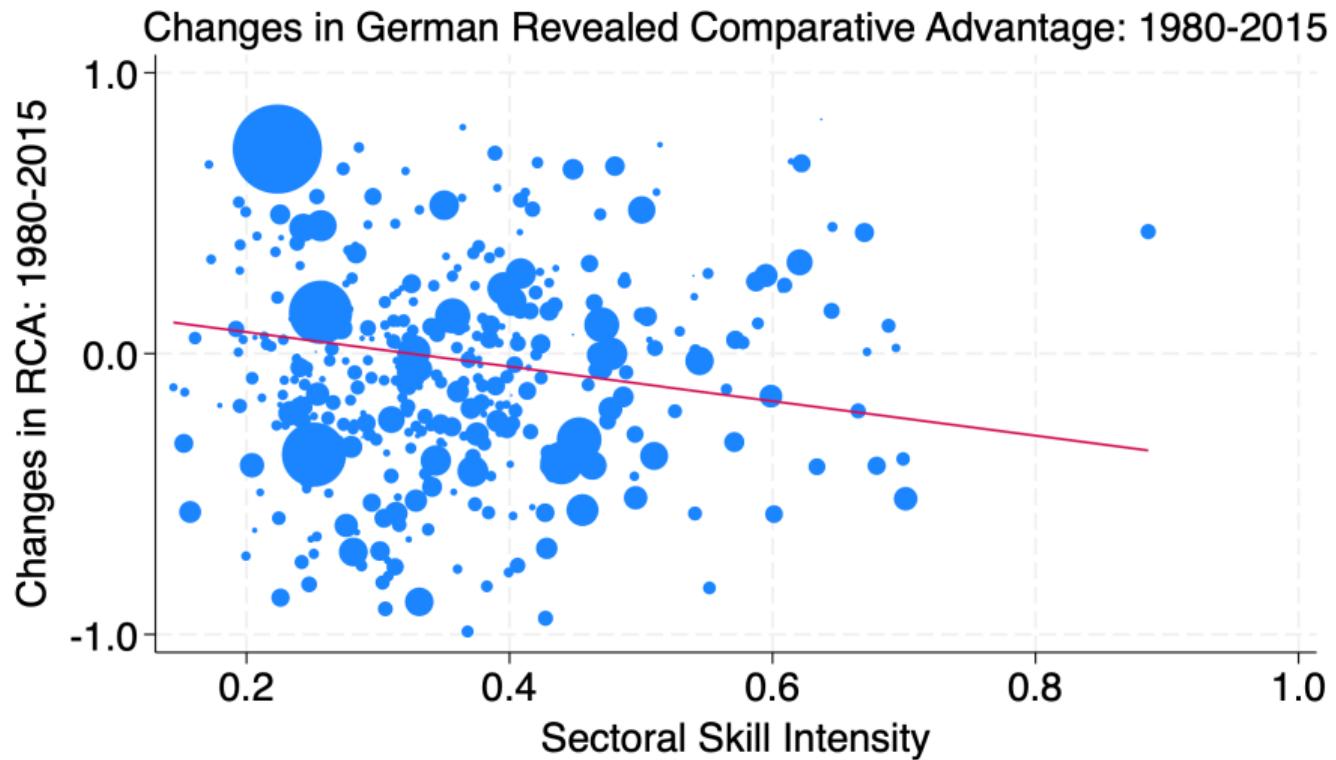
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## FACTS

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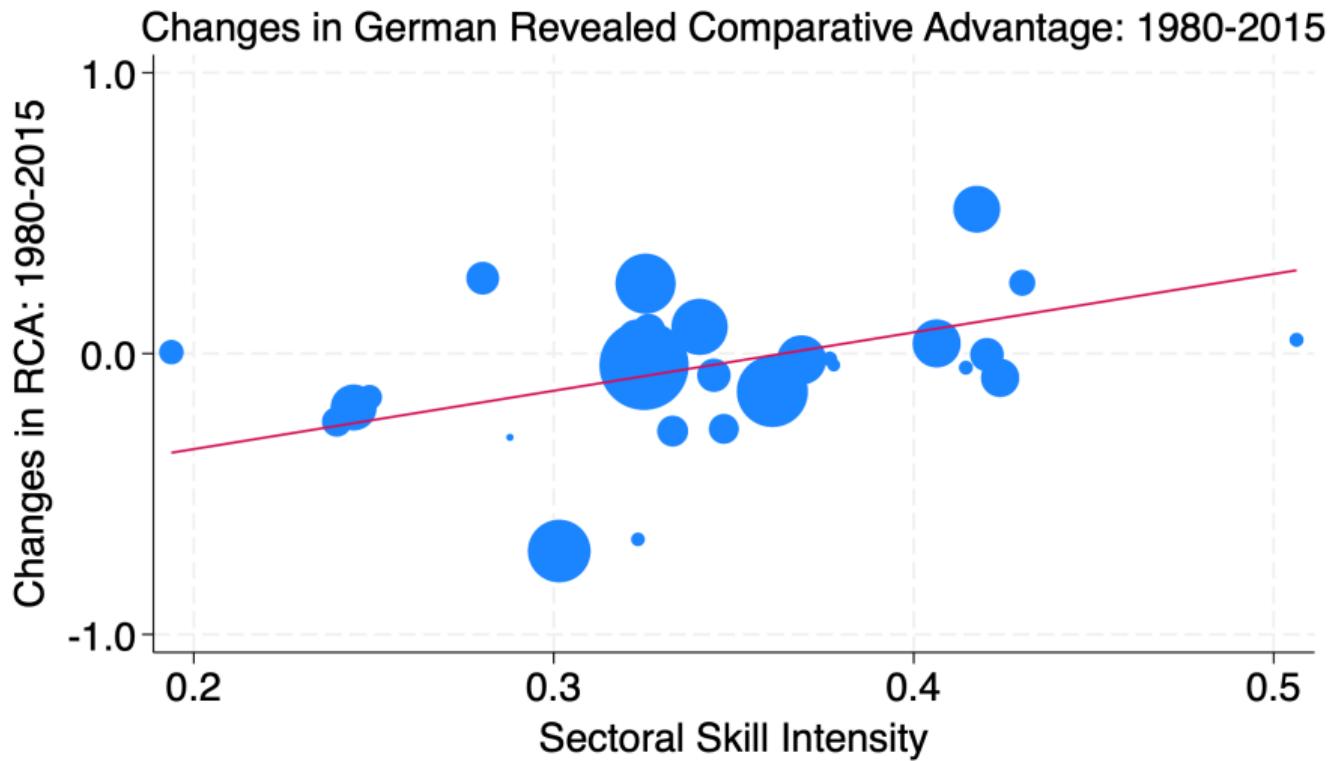
# Germany

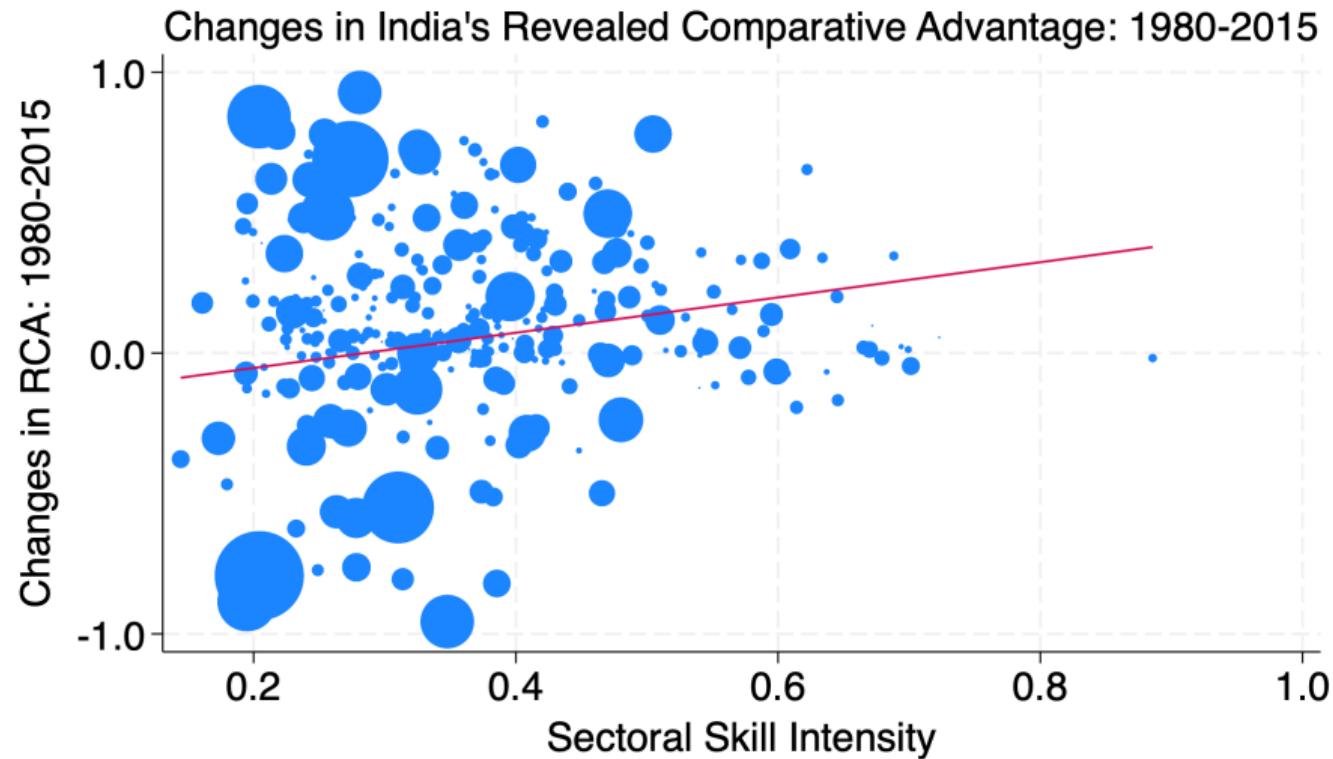
back



# Germany (Low-Automation)

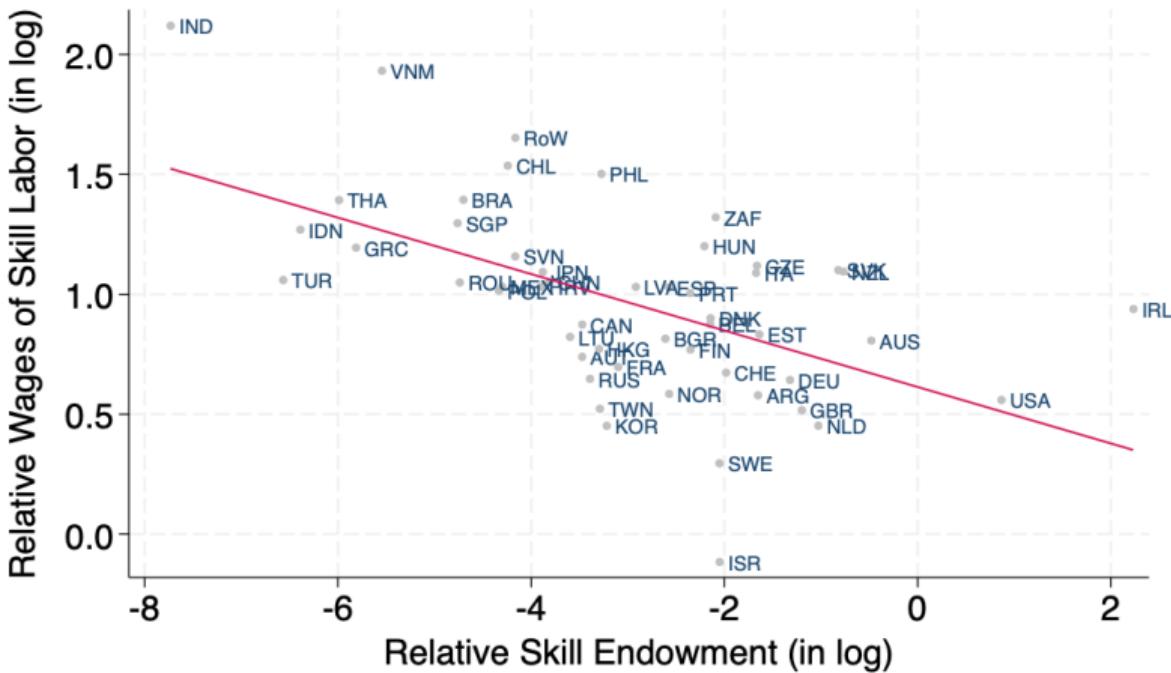
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# Relative Skilled Wages Decreasing in Skill Endowment

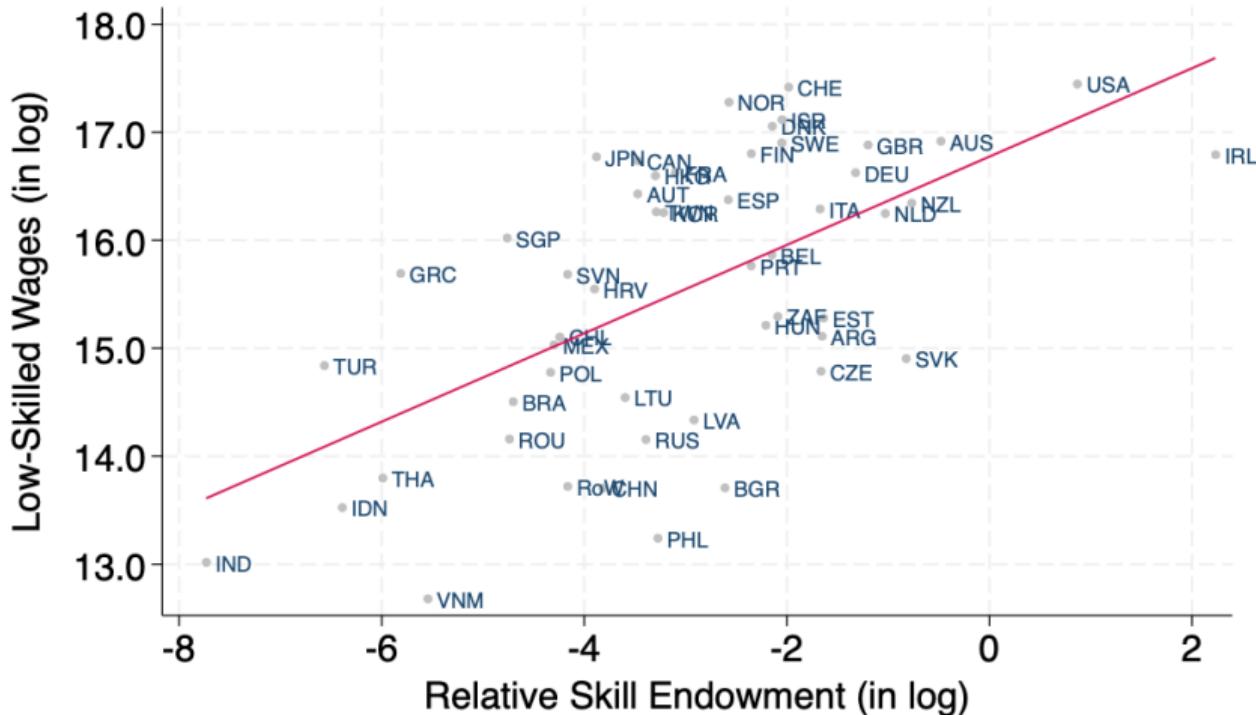
$$\ln(w_i^H/w_i^L) = -\gamma_{HL} \cdot \ln(H_i/L_i)$$



Note: Data from GTAP, 2004

# Unskilled Wages Increasing in Skill Endowment

► back



Note: Data from GTAP, 2004

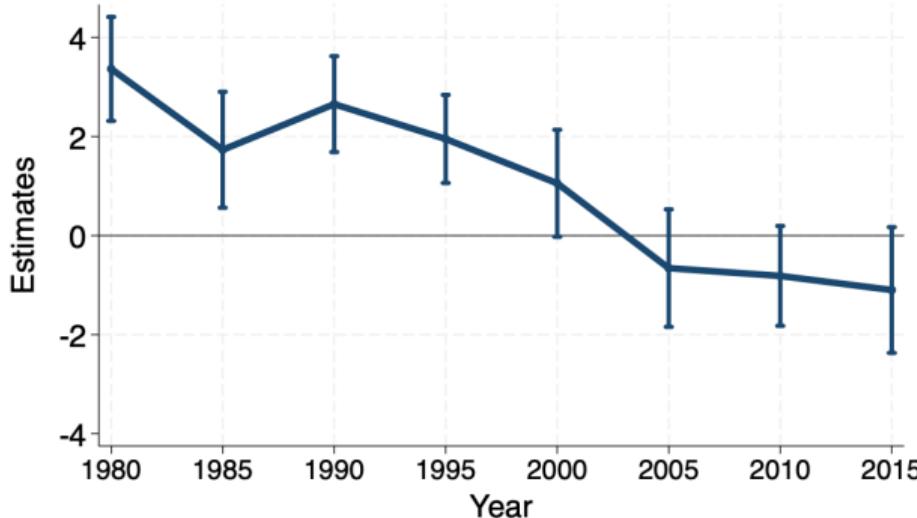
# ROBUSTNESS

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# Controlling Capital Intensity

› back

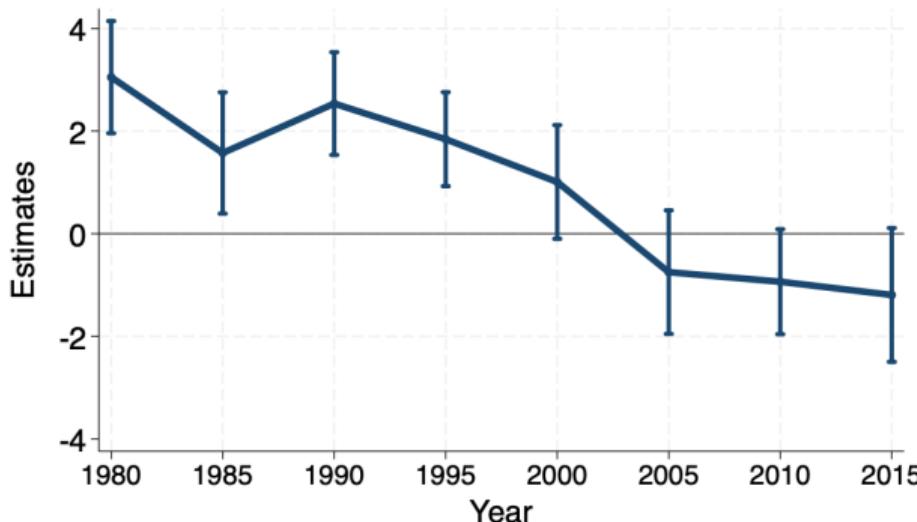
$$\ln X_{i,j,s,t} = \beta_t \left[ \alpha_{s,t}^H \times \ln \left( \frac{H_{i,t}}{L_{i,t}} \right) \right] + \beta_t^K \left[ \alpha_{s,t}^K \times \ln \left( \frac{K_{i,t}}{L_{i,t}} \right) \right] + \eta_{i,j,t} + \eta_{j,s,t}$$



# Controlling Capital Intensity and Institutions

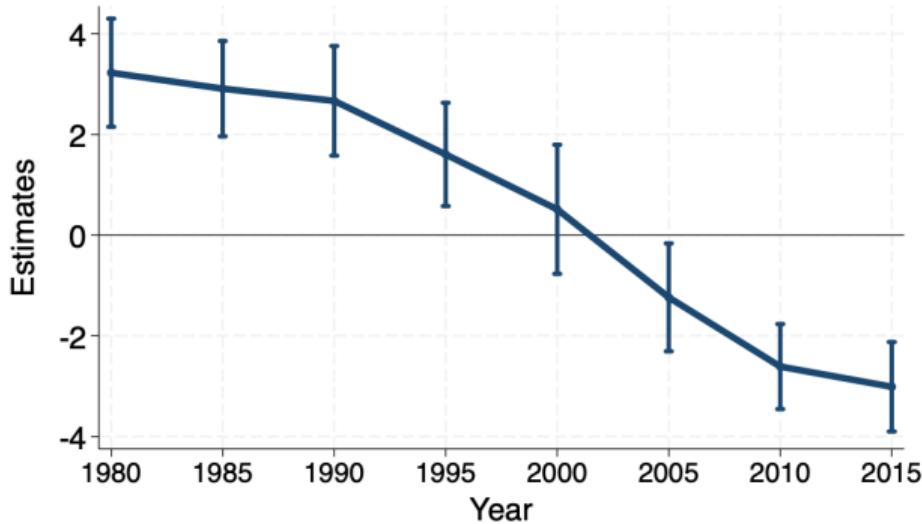
› back

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



# Weighted by Country Export

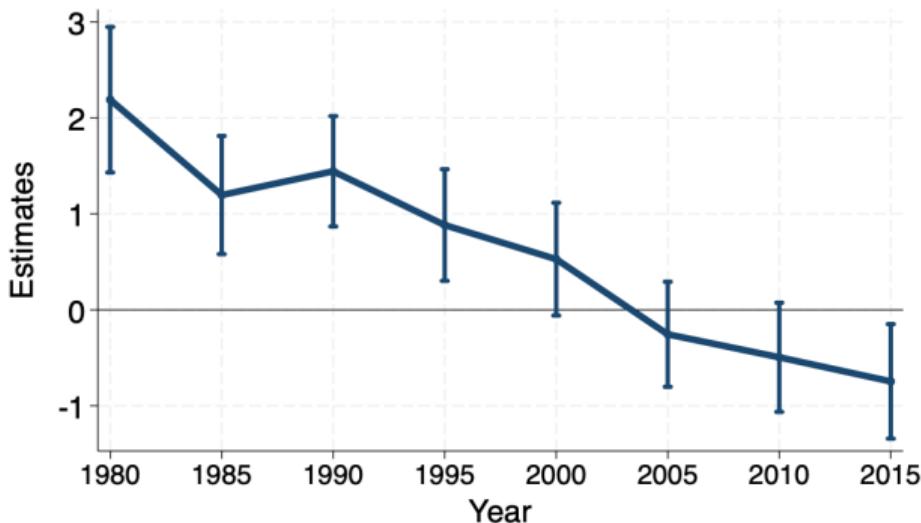
[back](#)



# Pool and control Origin-Sector FEs

» back

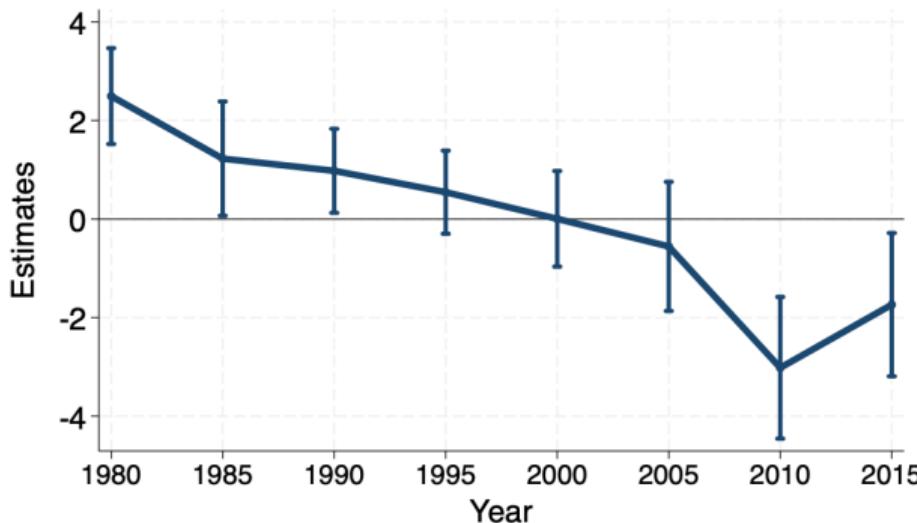
$$\ln X_{i,j,s,t} = \beta_t \left[ \alpha_{s,t}^H \times \ln \left( \frac{H_{i,t}}{L_{i,t}} \right) \right] + \eta_{i,s} + \eta_{i,j,t} + \eta_{j,s,t}$$



# High-school Graduates as Skilled

back

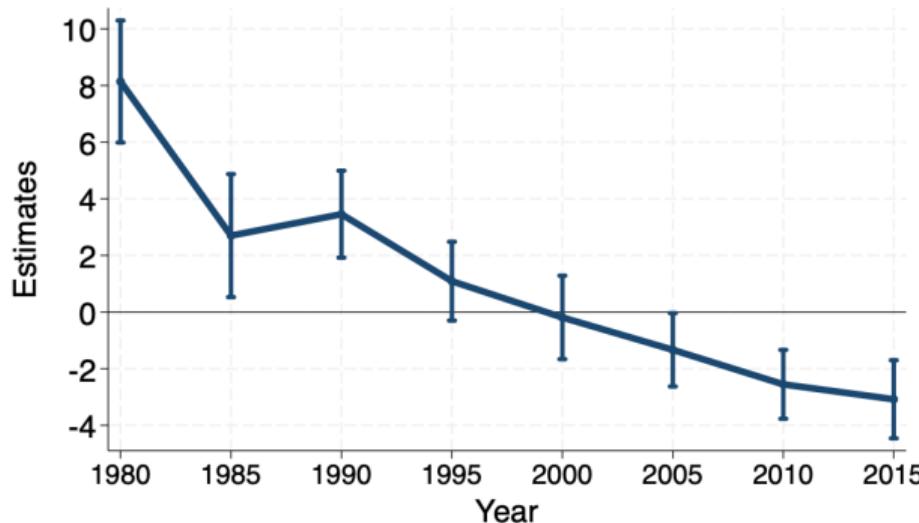
$$\ln X_{i,j,s,t} = \beta_t \left[ \alpha_{s,t}^H \times \ln \left( \frac{HS_{i,t}}{NHS_{i,t}} \right) \right] + \eta_{i,j,t} + \eta_{j,s,t}$$



# Instrument Skill Endowment by Cohort IV

› back

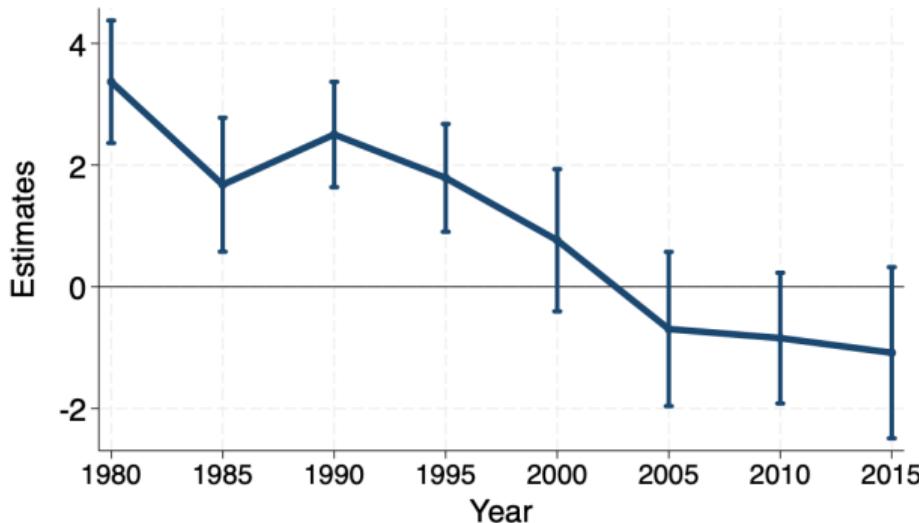
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# Romalis (2004): Total Export

» back

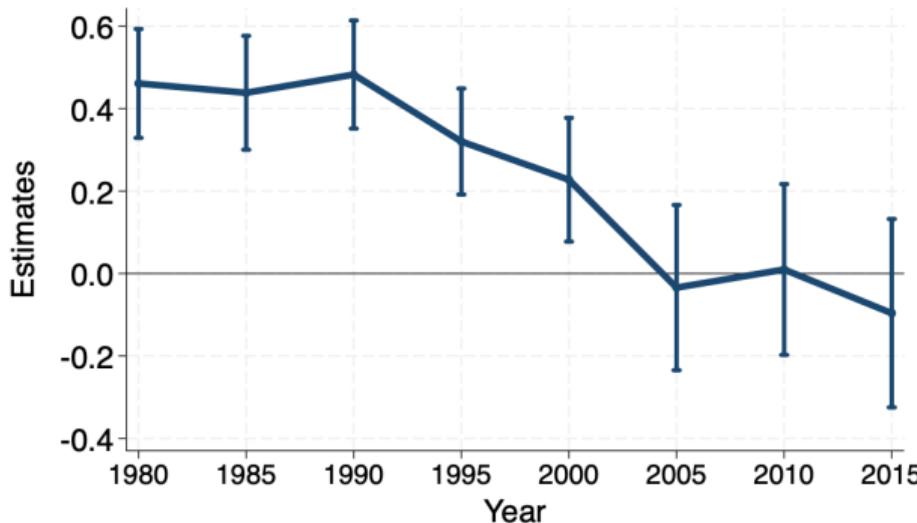
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# Chor (2011): Num of Workers as Factor Intensity

◀ back

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



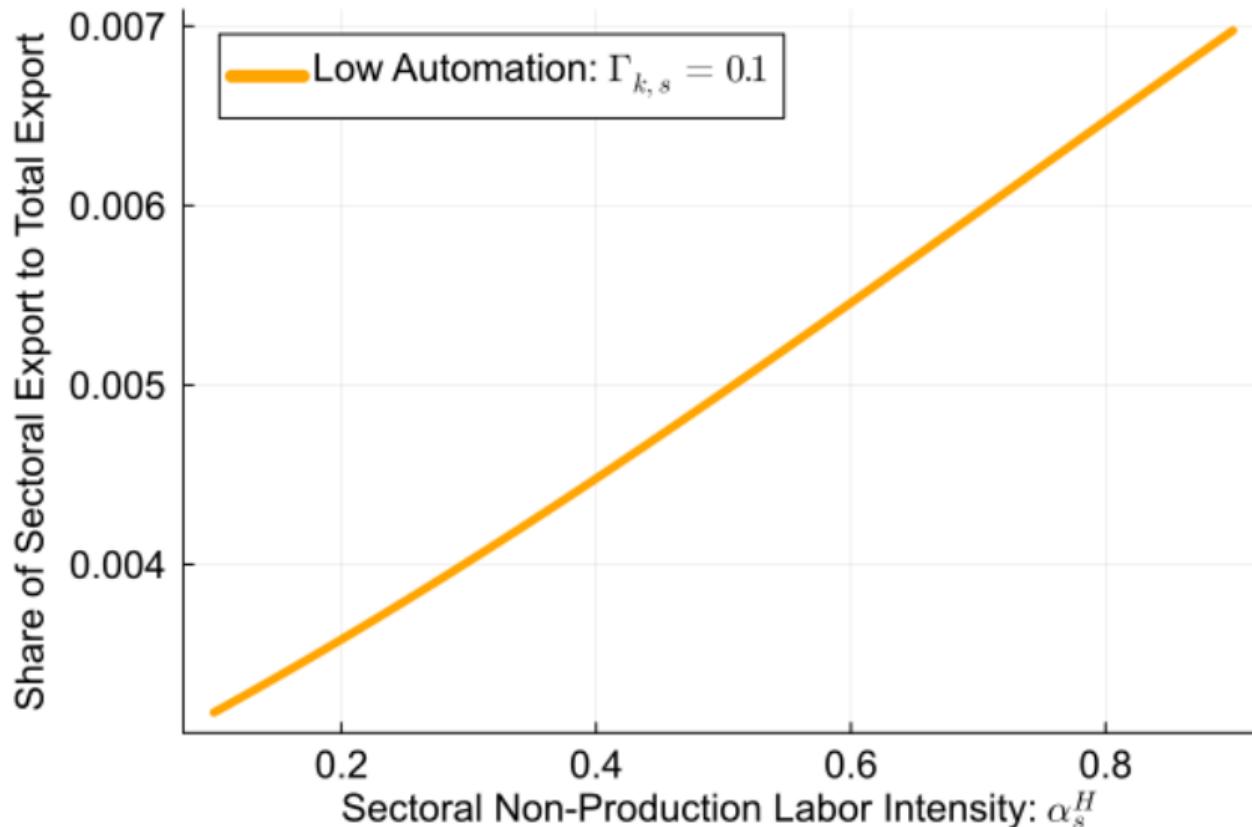
## TWO COUNTRY ILLUSTRATION: AUTOMATION

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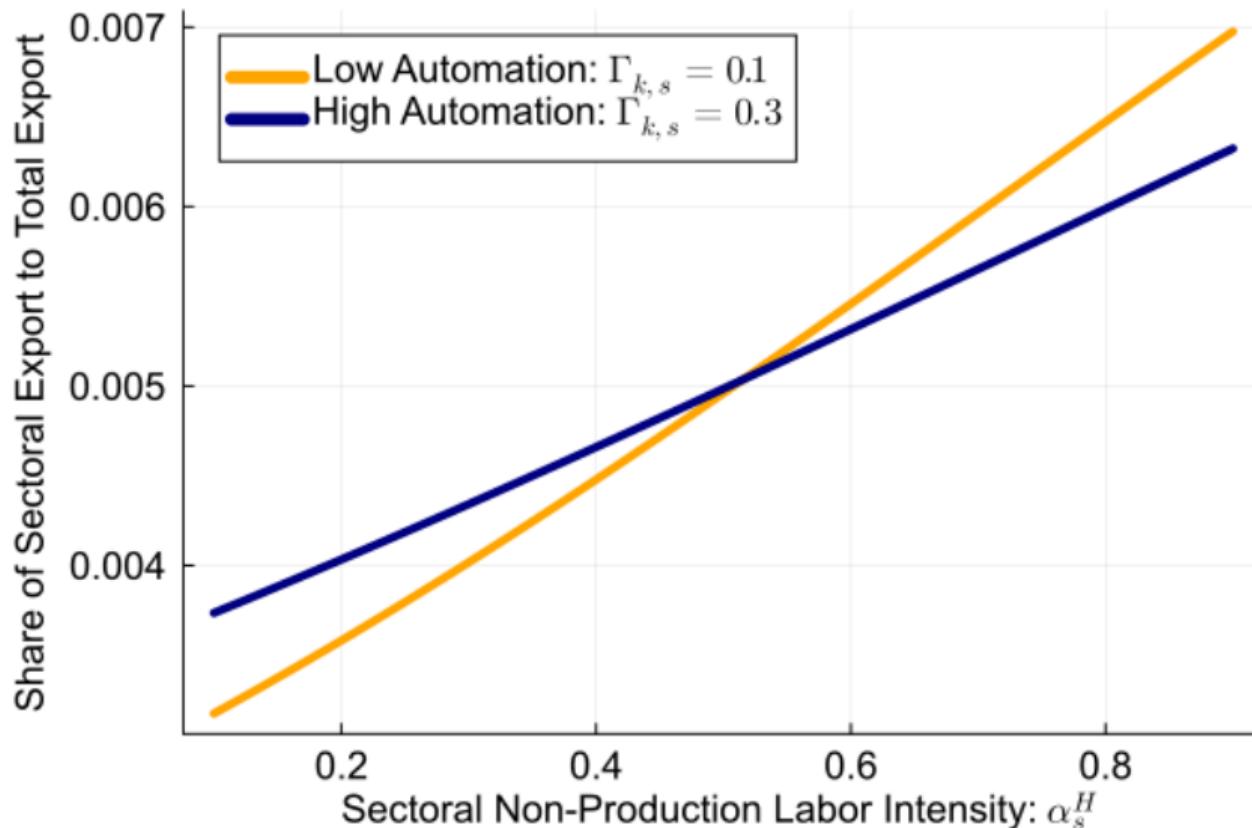
# Two Country Illustration: Automation

- 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  $\alpha_S^H$  – Slope is  $\beta^H$

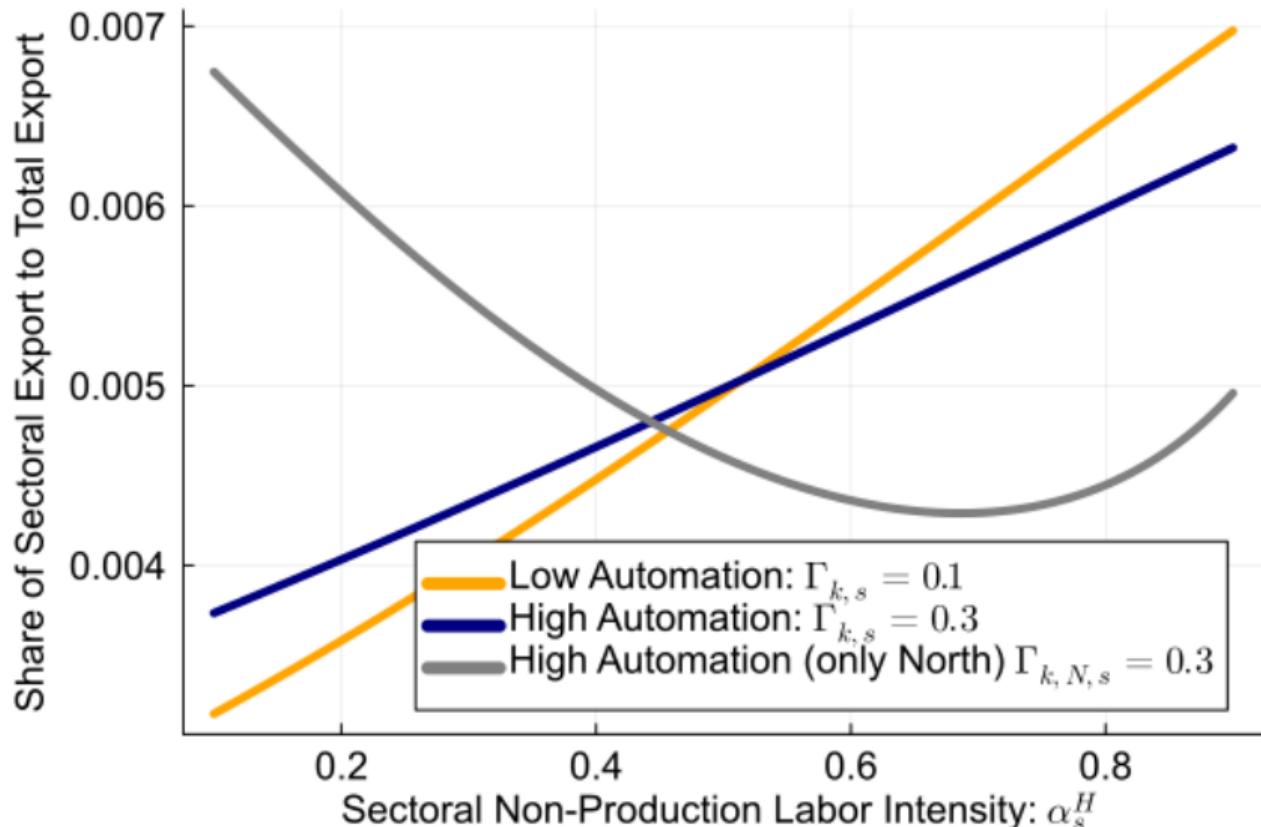
# North Specialize in Skill-Intensive Sectors



# Automation Makes Skills Less Important

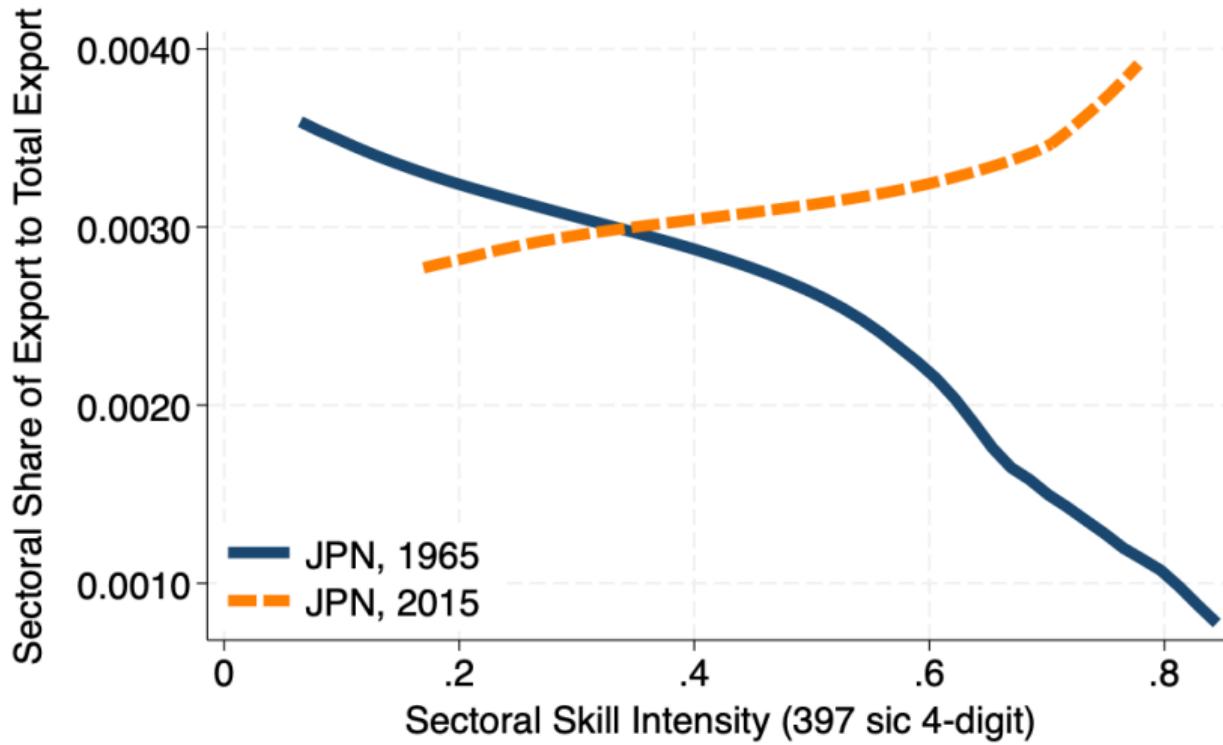


# If Only North Automates, Sign Flips

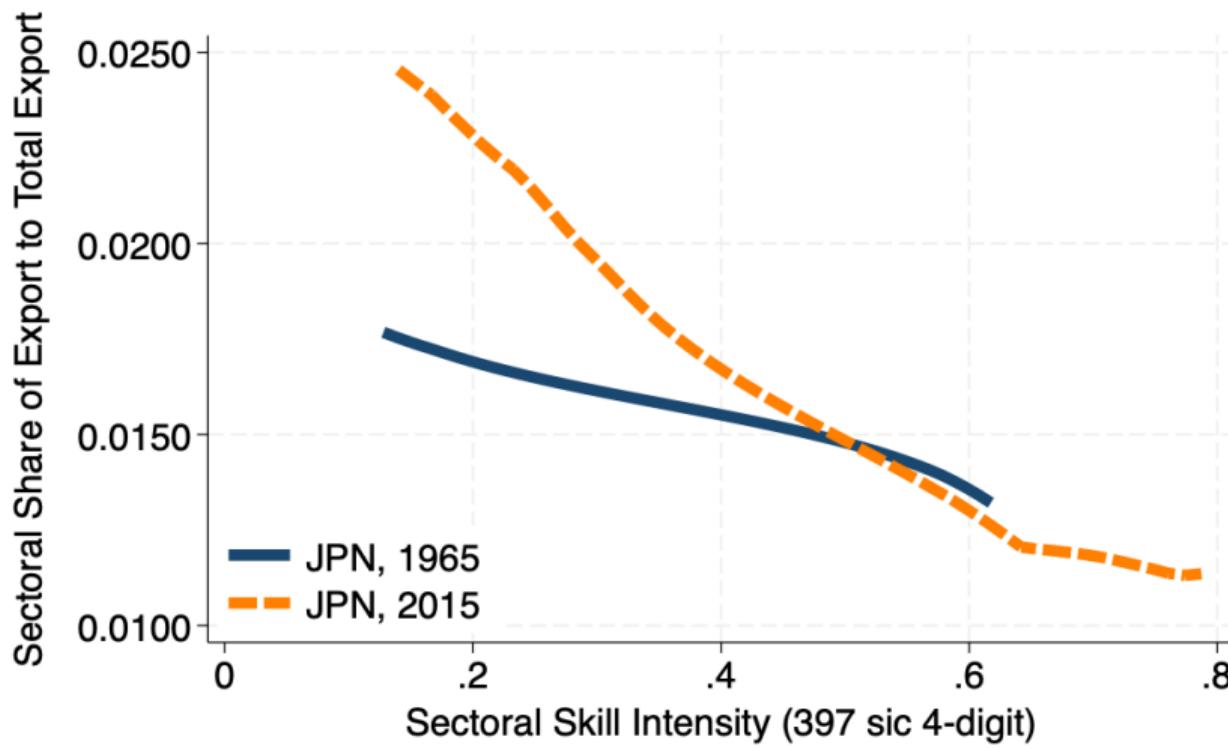


# Example: Within Low-Automation Sectors, Japan Specializes in Skill Intensive Industries

Back



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

[Back](#)

## TOY MODEL: TASK AND COMPARATIVE ADVANTAGE

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# 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  $\Gamma$  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  $\Gamma$ .

## ROLES OF CHANGES IN COMPARATIVE ADVANTAGE FOR INCIDENCE OF AUTOMATION

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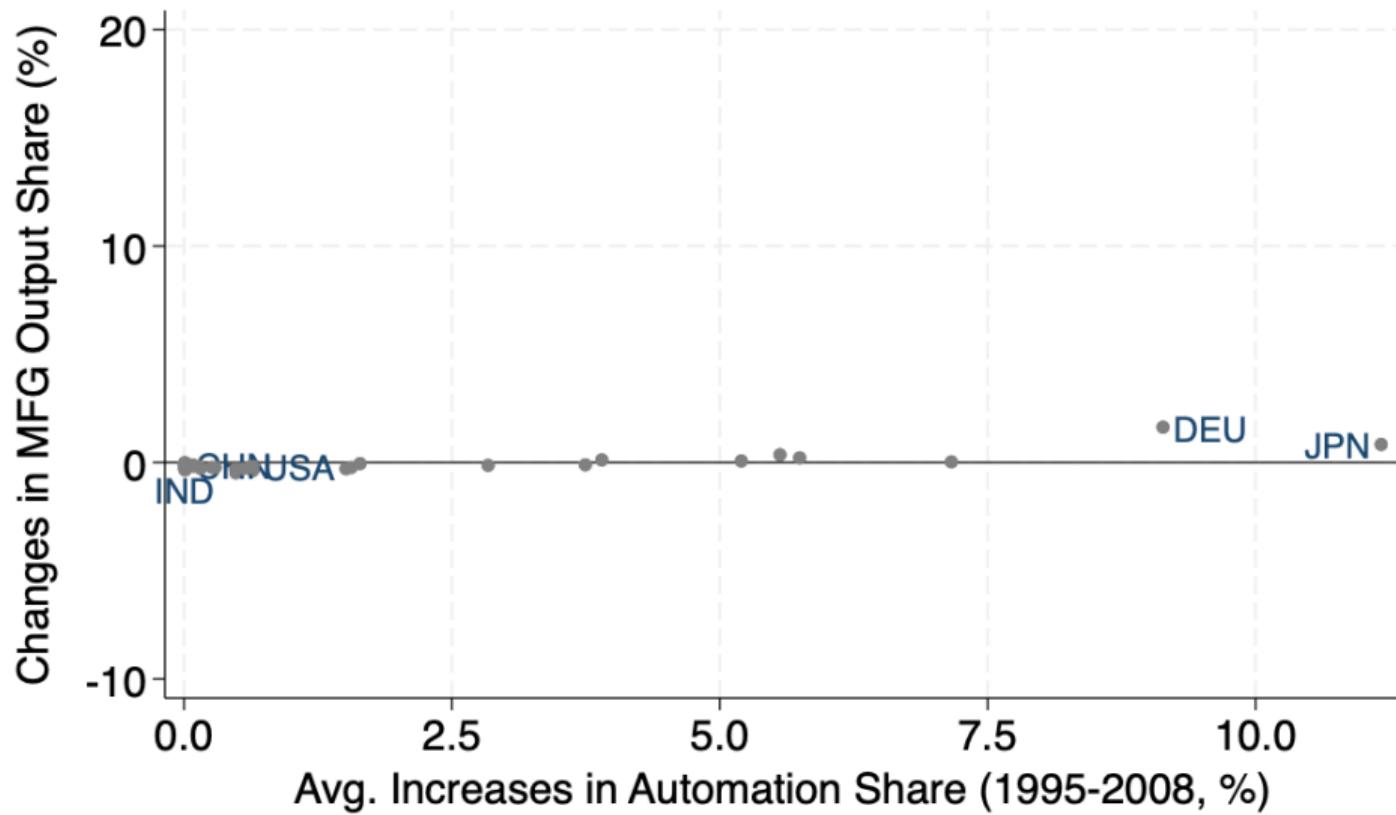
# Automation, Globalization, and Inequality

- 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

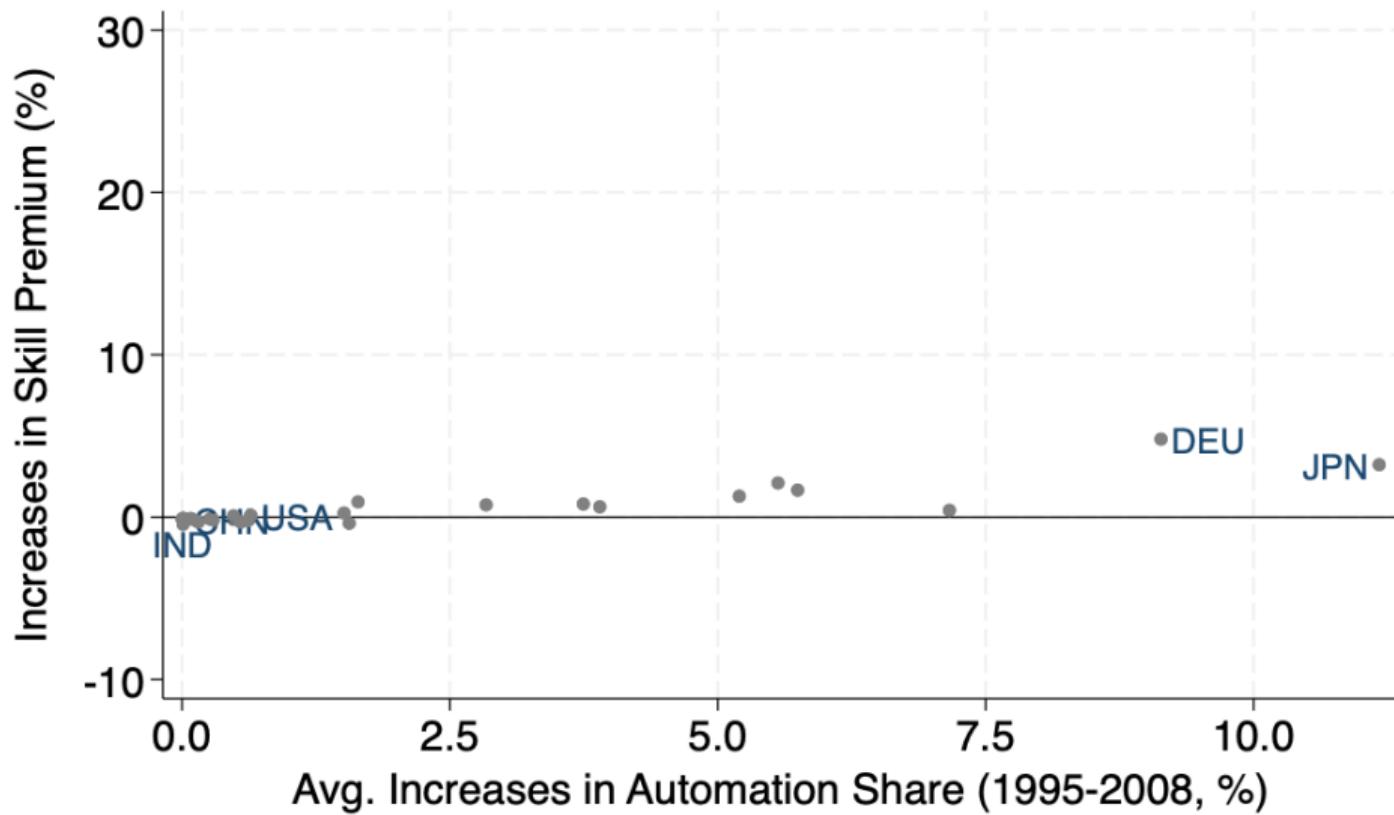
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- Roles of Trade?
  - Now, set the trade elasticity  $\theta = 1$ , instead of  $\theta = 4$
  - This kills sectoral reallocation via expenditure switch across countries

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



# $\theta = 1$ : Skill Premia Increases Everywhere



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

