Does Skill Abundance Still Matter?

The Evolution of Comparative Advantage in the 21st Century

Shin Kikuchi, MIT

December 26, 2024

Skill Abundance and Comparative Advantage

- Skill Abundance: Central for Comparative Advantage (e.g., **Heckscher–Ohlin**)
  - Developed (Skill-Abundant) Countries—Specialize in Skill-Intensive Sectors
  - e.g.) Electronics in the US v.s. Textiles in India

Skill Abundance and Comparative Advantage

- Skill Abundance: Central for Comparative Advantage (e.g., **Heckscher–Ohlin**)
  - Developed (Skill-Abundant) Countries—Specialize in Skill-Intensive Sectors
  - e.g.) Electronics in the US v.s. Textiles in India
- Important relationship in Trade and Growth/Development
  - Keys for Patterns of Development (Ventura 1997)
  - Implications for Globalization, Technology, and Inequality

Skill Abundance and Comparative Advantage

- Skill Abundance: Central for Comparative Advantage (e.g., **Heckscher–Ohlin**)
  - Developed (Skill-Abundant) Countries—Specialize in Skill-Intensive Sectors
  - e.g.) Electronics in the US v.s. Textiles in India
- Important relationship in Trade and Growth/Development
  - Keys for Patterns of Development (Ventura 1997)
  - Implications for Globalization, Technology, and Inequality
- Thousands of papers, but almost all use data before 2000
  - After 2000, many drastic changes: China, Offshoring, Technology, etc.

Skill Abundance and Comparative Advantage

- Skill Abundance: Central for Comparative Advantage (e.g., **Heckscher–Ohlin**)
  - Developed (Skill-Abundant) Countries—Specialize in Skill-Intensive Sectors
  - e.g.) Electronics in the US v.s. Textiles in India
- Important relationship in Trade and Growth/Development
  - Keys for Patterns of Development (Ventura 1997)
  - Implications for Globalization, Technology, and Inequality
- Thousands of papers, but almost all use data before 2000
  - After 2000, many drastic changes: China, Offshoring, Technology, etc.
- **This paper:** What about the 21st century?

At a Glance: Skill Abundance and Comparative Advantage

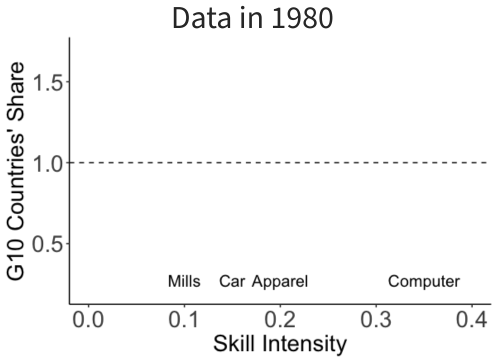
Revealed Comparative Advantage (RCA) in Skill Intensive Sectors:

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

At a Glance: Skill Abundance and Comparative Advantage

Revealed Comparative Advantage (RCA) in Skill Intensive Sectors:

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

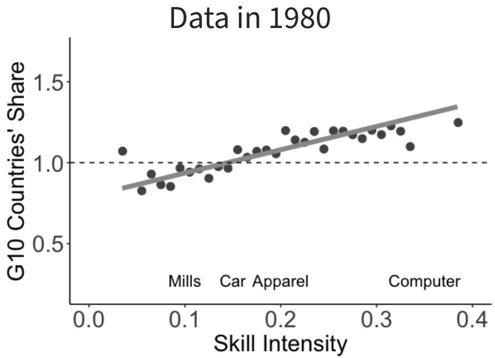


$$\text{G10's RCA}_s \equiv \frac{\frac{\text{G10 Export}_s}{\text{G10 Export}}}{\frac{\text{World Export}_s}{\text{World Export}}}$$

At a Glance: Skill Abundance and Comparative Advantage

Revealed Comparative Advantage (RCA) in Skill Intensive Sectors:

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



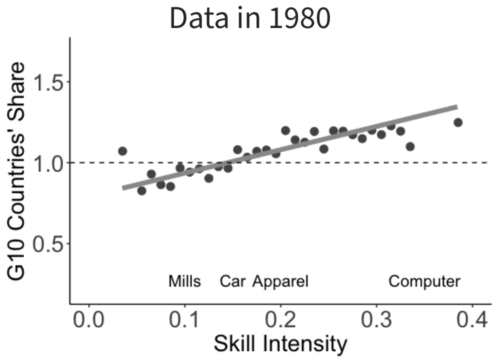
$$\text{G10's RCA}_s \equiv \frac{\frac{\text{G10 Export}_s}{\text{G10 Export}}}{\frac{\text{World Export}_s}{\text{World Export}}}$$

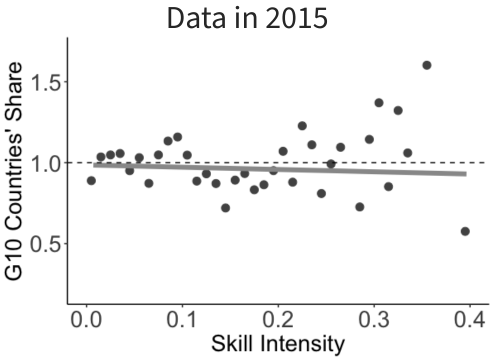
Skill Intensity: Non-production Workers' Payroll divided by Value-Added, from NBER-CES Data

At a Glance: Skill Abundance and Comparative Advantage

Revealed Comparative Advantage (RCA) in Skill Intensive Sectors:

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





Skill Intensity: Non-production Workers' Payroll divided by Value-Added, from NBER-CES Data

Research Questions

- Does skill abundance *systematically* no longer matter for comparative advantage?
- What forces can empirically and quantitatively explain the pattern?
  - Potential hypotheses: Automation, Offshoring
- What are the macro implications?
  - Manufacturing shares, Skill premia, Welfare

Preview (1/2) New Facts on Comparative Advantage

- Follow the literature's state-of-the-art specification
  - Based on a multi-sector Eaton-Kortum model (Chor 2010, Costinot et al 2012)

Preview (1/2) New Facts on Comparative Advantage

- Follow the literature's state-of-the-art specification
  - Based on a multi-sector Eaton-Kortum model (Chor 2010, Costinot et al 2012)
- Regress bilateral, 4-digit sectoral trade flows on the interaction
  - Sector's skill intensity $\times$ Exporter's skill abundance

Preview (1/2) New Facts on Comparative Advantage

- Follow the literature's state-of-the-art specification
  - Based on a multi-sector Eaton-Kortum model (Chor 2010, Costinot et al 2012)
- Regress bilateral, 4-digit sectoral trade flows on the interaction
  - Sector's skill intensity $\times$ Exporter's skill abundance
- **Vanishing Importance of Skill Abundance in Comparative Advantage**

Preview (1/2) New Facts on Comparative Advantage

- Follow the literature's state-of-the-art specification
  - Based on a multi-sector Eaton-Kortum model (Chor 2010, Costinot et al 2012)
- Regress bilateral, 4-digit sectoral trade flows on the interaction
  - Sector's skill intensity $\times$ Exporter's skill abundance
- **Vanishing Importance of Skill Abundance in Comparative Advantage**
- **Heterogeneous declines** across groups of countries & sectors
  - More declines among groups of countries & sectors with more automation
  - No such heterogeneity from offshoring

Preview (2/2) Causes are Automation, Not Offshoring

- Theory: A multi-sector Eaton-Kortum model with automation & offshoring
  - Low-skill labor can be replaced by machines or foreign labor

Preview (2/2) Causes are Automation, Not Offshoring

- Theory: A multi-sector Eaton-Kortum model with automation & offshoring
  - Low-skill labor can be replaced by machines or foreign labor
- Counterfactual with/without automation/offshoring shocks

Preview (2/2) Causes are Automation, Not Offshoring

- Theory: A multi-sector Eaton-Kortum model with automation & offshoring
  - Low-skill labor can be replaced by machines or foreign labor
- Counterfactual with/without automation/offshoring shocks
- **Quantitatively, automation, not offshoring, explains the empirical facts**

Preview (2/2) Causes are Automation, Not Offshoring

- Theory: A multi-sector Eaton-Kortum model with automation & offshoring
  - Low-skill labor can be replaced by machines or foreign labor
- Counterfactual with/without automation/offshoring shocks
- **Quantitatively, automation, not offshoring, explains the empirical facts**
- Implications of Automation
  - Shifts of manufacturing from South to North
  - Increases in skill premia in North and welfare everywhere

Preview (2/2) Causes are Automation, Not Offshoring

- Theory: A multi-sector Eaton-Kortum model with automation & offshoring
  - Low-skill labor can be replaced by machines or foreign labor
- Counterfactual with/without automation/offshoring shocks
- **Quantitatively, automation, not offshoring, explains the empirical facts**
- Implications of Automation
  - Shifts of manufacturing from South to North
  - Increases in skill premia in North and welfare everywhere
- Implications of Offshoring
  - No big shift in manufacturing as a whole
  - Smaller changes in skill premia & welfare

Key Contributions

1. Sources of Comparative Advantage:
   - Ricardian: MacDougall (1951), Stern (1962), Balassa (1963), Golub and Hsieh (2000), Nunn (2007), Levchenko (2007), Manova (2008), Costinot (2009), Costinot et al (2012)
   - HO: Leamer (1980, 1984), Bowen et al (1987), Trefler (1993, 1995), Harrigan (1997), Davis & Weinstein (2001), Schott (2001), Romalis (2004), Morrow (2010), Chor (2010)
   - Mean Reversion: Levchenko & Zhang (2016), Hanson et al (2016)

   $\rightarrow$ **New Facts: Skill Abundance Matter in 1980s, Not Anymore post-2000.**
2. Consequences of Technology and Globalization on Inequality:

Key Contributions

1. Sources of Comparative Advantage:
2. Consequences of Technology and Globalization on Inequality:
   - Technology: Katz & Murphy (1992), Feenstra & Hanson (1999), Acemoglu (2002), Autor et al (2003), Acemoglu & Autor (2011), Autor & Dorn (2013), Acemoglu & Restrepo (2018,2022), Webb (2020), Loebbing (2021)
   - Offshoring: Lawrence & Slaughter (1993), Berman et al (1994), Feenstra & Hanson (1997, 1999, 2001), Becker & Muendler (2014), Hummels et al (2014), Alfaro-Urena et al (2021)
   - Interaction of Tech and Trade: Xu (2001), Acemoglu (2002), Thoenig & Verdier (2003), Burstein et al (2013), Parro (2013), Burstein & Vogel (2017), Morrow & Trefler (2022)

$\rightarrow$ **Automation Changes Comparative Advantage and Big Effects on Inequality**

FACTS: DOES SKILL ABUNDANCE STILL MATTER?

Revealing Comparative Advantage: Refresher

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

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

Revealing Comparative Advantage: Refresher

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

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

- Unit cost (α_s^H: Skill Intensity = the share of skilled labor payroll in value-added)

$$c_{i,s} = (w_i^H)^{\alpha_s^H} (w_i^L)^{1-\alpha_s^H} \quad \rightarrow \quad \ln c_{i,s} = \alpha_s^H \times \ln(w_i^H / w_i^L) + \ln w_i^L$$

Revealing Comparative Advantage: Refresher

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

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

- Unit cost (α_s^H: Skill Intensity = the share of skilled labor payroll in value-added)

$$c_{i,s} = (w_i^H)^{\alpha_s^H}(w_i^L)^{1-\alpha_s^H} \quad \rightarrow \quad \ln c_{i,s} = \alpha_s^H \times \ln(w_i^H/w_i^L) + \ln w_i^L$$

- If relative wage is some (log-linear) function of Skill Abundance$_i$,

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

- Canonical specification to reveal the source of comparative advantage

Skill Abundance as a Source of Comparative Advantage

Do Skill-Abundant Countries Export More Skill-Intensive Goods?

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

Skill Abundance as a Source of Comparative Advantage

Do Skill-Abundant Countries Export More Skill-Intensive Goods?

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

- $\text{Exports}_{i,j,s,t}$: Bilateral trade flow *i* to *j* in *s*, from UN Comtrade
- $\text{Skill Intensity}_{s,t}$: $\alpha^H_{s,t}$ 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

Skill Abundance as a Source of Comparative Advantage

Do Skill-Abundant Countries Export More Skill-Intensive Goods?

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

- $\text{Exports}_{i,j,s,t}$: Bilateral trade flow *i* to *j* in *s*, from UN Comtrade
- $\text{Skill Intensity}_{s,t}$: $\alpha^H_{s,t}$ 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,...

Skill Abundance as a Source of Comparative Advantage

Do Skill-Abundant Countries Export More Skill-Intensive Goods?

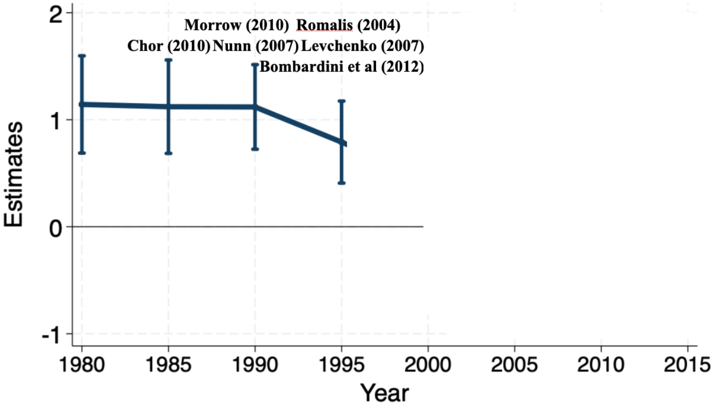
$$\ln \text{Exports}_{i,j,s,t} = \beta_t \left[\text{Skill Intensity}_{s,t} \times \text{Skill Abundance}_{i,t}\right] + \eta_{i,j,t} + \eta_{j,s,t} + \varepsilon_{i,j,s,t},$$

- $\text{Exports}_{i,j,s,t}$: Bilateral trade flow i to j in s, from UN Comtrade
- $\text{Skill Intensity}_{s,t}$: $\alpha^H_{s,t}$ 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

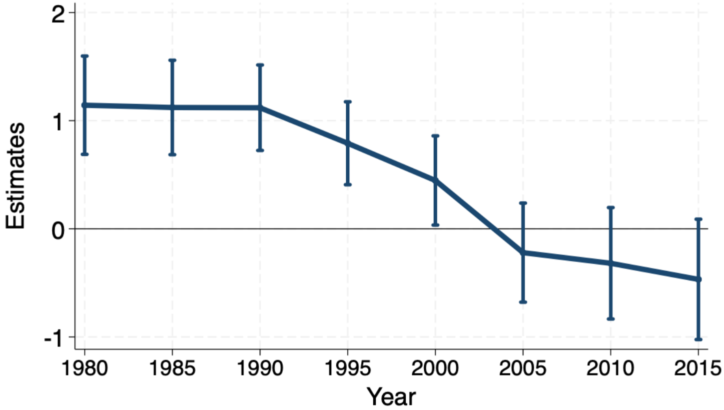
Skill Abundance Used to be Important before 2000

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



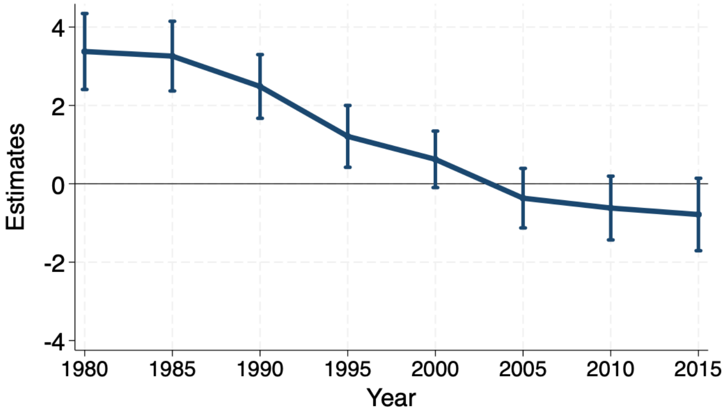
Skill Abundance $\not\Rightarrow$ CA in Skill-Intensive Sectors after 2000

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



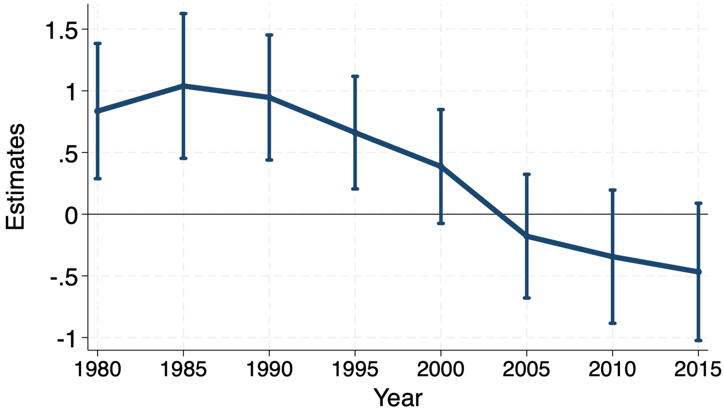
The Change Comes from Export Patterns

$$X_{i,j,s,t} = \exp\left(\beta_t \left[\alpha^H_{s,1980} \times \ln\left(\frac{H_{i,1980}}{L_{i,1980}}\right)\right] + \eta_{i,j,t} + \eta_{j,s,t}\right) + u_{i,j,s,t}$$



NOT Driven by Attenuating Skill Measurement

$$X_{i,j,s,t} = \exp\left(\beta_t\left[\alpha^H_{s,2015} \times \ln\left(\frac{H_{i,2015}}{L_{i,2015}}\right)\right] + \eta_{i,j,t} + \eta_{j,s,t}\right) + u_{i,j,s,t}$$



Robustness Checks

- Other sources of comparative advantage? ‣ Capital ‣ Institution
- Driven by small countries? ‣ Weighted
- Some exporter-sector unobserved het., or IRS? ‣ Pool years and 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

POTENTIAL HYPOTHESES: AUTOMATION AND OFFSHORING

Potential Hypotheses: Automation and Offshoring

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

Potential Hypotheses: Automation and Offshoring

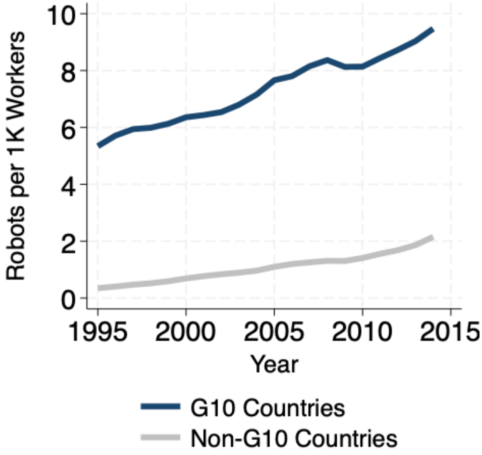
- What can make domestic skill abundance less relevant for CA after the 1990s?
- Two mega-trends, replacing low-skill labor
  - Automation: Replace low-skill labor with machines
  - Offshoring: Replace low-skill labor with foreign inputs

Potential Hypotheses: Automation and Offshoring

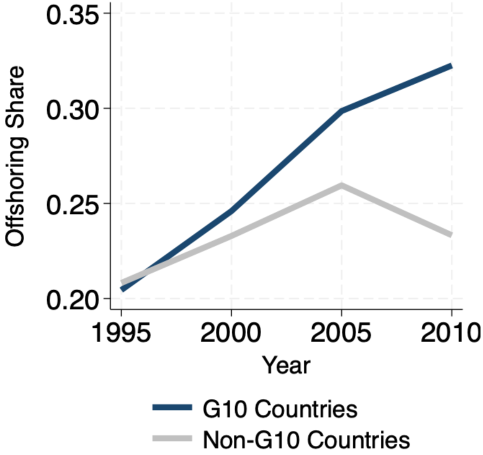
- What can make domestic skill abundance less relevant for CA after the 1990s?
- Two mega-trends, replacing low-skill labor
  - Automation: Replace low-skill labor with machines
  - Offshoring: Replace low-skill labor with foreign inputs
- This section: Explore heterogeneous effects across countries and sectors
  - Caution: Just descriptive analysis for potential hypotheses
  - Causal interpretation using the model later

Potential Hypotheses: Automation and Offshoring

Robots per 1K Workers



Offshoring Share



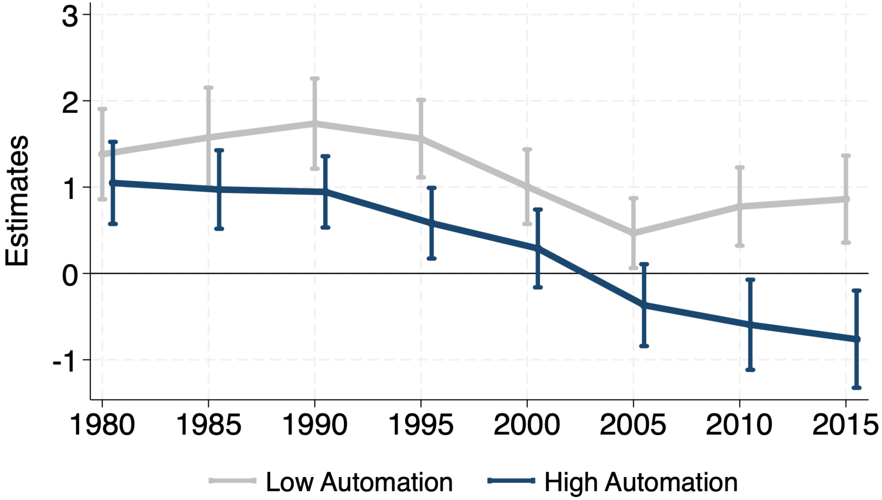
Specification for Heterogeneous Effects

$$X_{i,j,s,t} = \exp\left[\underbrace{\beta_t^0\left(1+\beta_t^A HA_{i,s}\right)}_{=\beta_t}\cdot\left(\alpha_{s,t}^H \times \ln\left(\frac{H_{i,t}}{L_{i,t}}\right)\right)+\eta_{i,j,t}+\eta_{j,s,t}\right]+\varepsilon_{i,j,s,t}$$

- $HA_{i,s}$: High-automation dummy (below/above the median robot adoption)
- Expect β_t^A to be decreasing over time
- Same for offshoring: replace $HA_{i,s}$ with $HO_{i,s}$ based on offshoring share

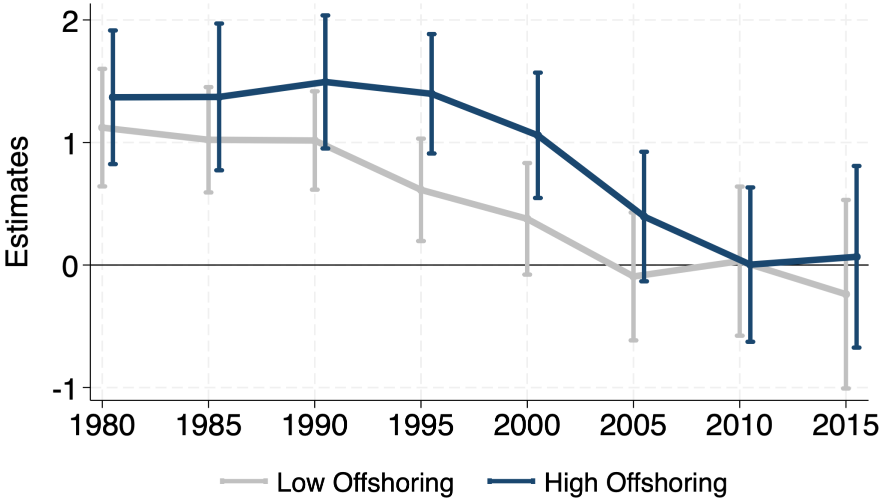
Skills Abundance Matters in Low-Automation Country/Sector

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



No Heterogeneous Effects from Offshoring

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



Same Results from Continuous Measures

$$X_{i,j,s,t} = \exp\left[\beta_t^0\left(1+\beta_t^A \text{Auto}_{i,s} + \beta_t^O \text{Ofs}_{i,s}\right)\cdot\left(\alpha_{s,t}^H \times \ln\left(\frac{H_{i,t}}{L_{i,t}}\right)\right) + \eta_{i,j,t} + \eta_{j,s,t}\right] + \varepsilon_{i,j,s,t},$$

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

Same Results from Continuous Measures

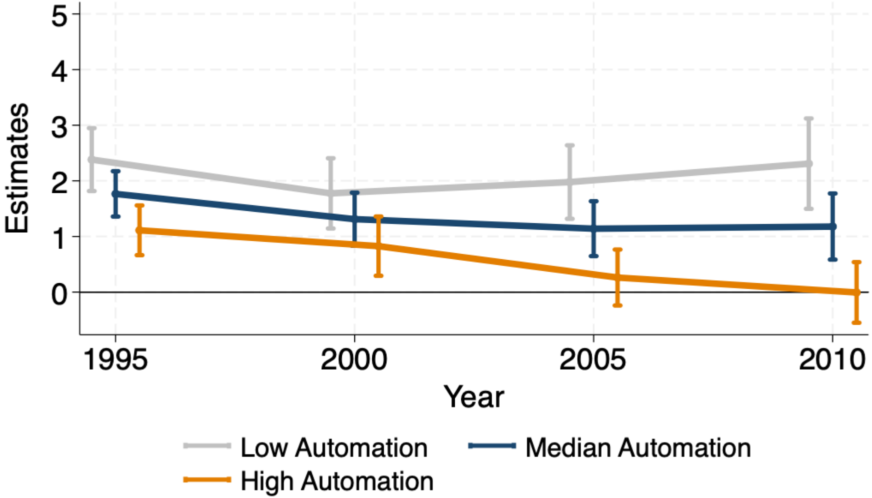
$$X_{i,j,s,t} = \exp\left[\beta_t^0\left(1 + \beta_t^A \text{Auto}_{i,s} + \beta_t^O \text{Ofs}_{i,s}\right) \cdot \left(\alpha_{s,t}^H \times \ln\left(\frac{H_{i,t}}{L_{i,t}}\right)\right) + \eta_{i,j,t} + \eta_{j,s,t}\right] + \varepsilon_{i,j,s,t},$$

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

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

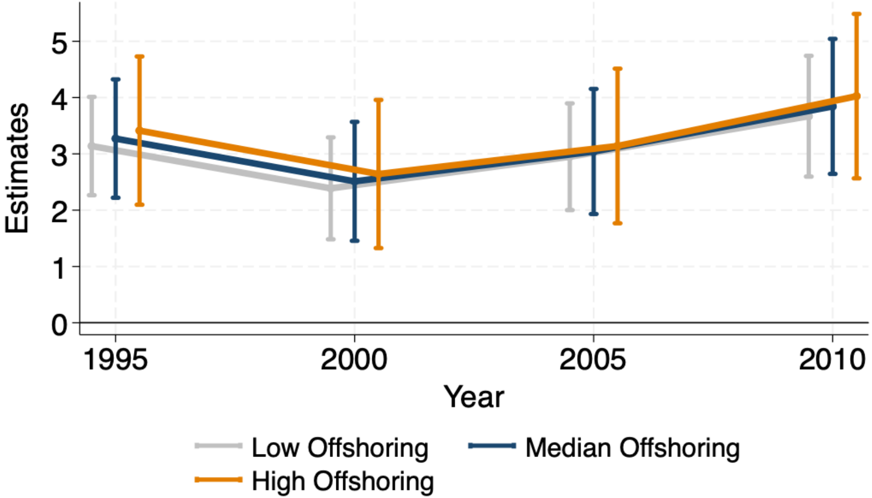
Decreases among High Automation Groups

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



No Clear Heterogeneity by Offshoring

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



Controlling China Shock does not Change Results

Add China's RCA (revealed comparative advantage) as a control

	1995	2010	1995	2010
Skill Intensity x Abundance	1.26	-0.33		
	(0.23)	(0.28)		
x Automation (log robot stock)				
x Offshoring Share (×100)				
x China's RCA				

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

Controlling China Shock does not Change Results

Add China's RCA (revealed comparative advantage) as a control

	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 (×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 Heckscher-Ohlin**

Summary of Empirical Facts

Summary

- **Skill abundance become less important in comparative advantage** over time
- Less important with higher **Automation**
- **Offshoring** has surprisingly, small effects

MODEL: TRADE WITH AUTOMATION AND OFFSHORING

Overview

- Multi-sector Eaton-Kortum Model with Input-Output Linkages

Overview

- Multi-sector Eaton-Kortum Model with Input-Output Linkages
- **New: Unit Cost function with Automation and Offshoring**

Overview

- Multi-sector Eaton-Kortum Model with Input-Output Linkages
- **New: Unit Cost function with Automation and Offshoring**
- Primary factors:
  - Labor: $H_{i,s}$ (high-skilled), $L_{i,s}$ (low-skilled)

Overview

- Multi-sector Eaton-Kortum Model with Input-Output Linkages
- **New: Unit Cost function with Automation and Offshoring**
- Primary factors:
  - Labor: $H_{i,s}$ (high-skilled), $L_{i,s}$ (low-skilled)
- Additional Production factors (produced using outputs)
  - Automation Capital: $M_{i,s}$
  - Intermediate: $XD_{i,s}$ (domestic), $XF_{i,s}$ (foreign)
    - ⋆ including non-automation capital (buildings, land)

Standard Multi-Sector Eaton Kortum Model

- Country i, j, Sector s
- Trade share (gravity equation) is given by

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

  - Trade share: $\pi^F_{i,j,s} \equiv X_{i,j,s} / \sum_l X_{l,j,s}$
  - Unit cost: $c_{i,s}$; Trade cost: $\tau_{i,j,s}$; Trade elasticity $\theta > 0$

Unit Cost Function with Automation and Offshoring Shock

Unit production cost:

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

- Production task can be completed by one of the factors
  - machine M, low-skilled labor L, domestic inputs XD, foreign inputs XF
  - $\Gamma_{i,s}^F$: task shares within production-task for factor $F \in \{M, L, XD, XF\}$
  - Micro-foundation in the paper based on the task model
    - ⋆ *Endogenous* adoption of automation/offshoring in Appendix
- Machines and intermediates are produced using final goods

Goods & Labor Market Clearing

Goods Market Clearing (Output $Y_{i,s}$, sectoral exp. share $\mu_{i,s}$, IO coef. α)

$$
\begin{aligned}
Y_{i,s} = & \underbrace{\sum_j \pi^F_{ij,s}\mu_{j,s}(w^L_j L_j + w^H_j H_j)}_{\text{Final Consumption in } j} + \underbrace{\sum_j \sum_r \pi^M_{ij,r}\alpha^M_{j,sr}(1-\alpha^H_r)\Gamma^M_{j,r} Y_{j,r}}_{\text{Machine in } j-r} \\
& + \underbrace{\sum_r \alpha^X_{i,sr}(1-\alpha^H_r)\Gamma^{XD}_{i,r} Y_{i,r}}_{\text{Domestic Intermediates in } i-r} + \underbrace{\sum_j \sum_r \pi^X_{ij,r}\alpha^X_{j,sr}(1-\alpha^H_r)\Gamma^{XF}_{j,r} Y_{j,r}}_{\text{Foreign Intermediates in } j(\neq i)-r}
\end{aligned}
$$

Goods & Labor Market Clearing

Goods Market Clearing (Output $Y_{i,s}$, sectoral exp. share $\mu_{i,s}$, IO coef. α)

$$Y_{i,s} = \underbrace{\sum_j \pi^F_{ij,s}\mu_{j,s}(w^L_j L_j + w^H_j H_j)}_{\text{Final Consumption in } j} + \underbrace{\sum_j \sum_r \pi^M_{ij,r}\alpha^M_{j,sr}(1-\alpha^H_r)\Gamma^M_{j,r} Y_{j,r}}_{\text{Machine in } j-r}$$

$$+ \underbrace{\sum_r \alpha^X_{i,sr}(1-\alpha^H_r)\Gamma^{XD}_{i,r} Y_{i,r}}_{\text{Domestic Intermediates in } i-r} + \underbrace{\sum_j \sum_r \pi^X_{ij,r}\alpha^X_{j,sr}(1-\alpha^H_r)\Gamma^{XF}_{j,r} Y_{j,r}}_{\text{Foreign Intermediates in } j(\neq i)-r}$$

Labor Market Clearing

$$w^L_i L_i = \sum_s (1-\alpha^H_s)\Gamma^L_{i,s} Y_{i,s}$$

$$w^H_i H_i = \sum_s \alpha^H_s Y_{i,s}$$

Equilibrium Conditions ‣ Two Country

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

- Consumers maximize utility by choosing from which countries to buy
  $\rightarrow$ trade share $\pi_{i,j,s}$, as a function of unit cost $\{c_{i,s}\}_{i\in\mathcal{I},s\in\mathcal{S}}$
- Unit cost, $c_{i,s}$, as a function of $\{w_i^H, w_i^L\}_{i\in\mathcal{I}}$
  - $\{w_{i,s}^M, w_{i,s}^{XD}, w_{i,s}^{XF}\}$ are functions of $\{w_i^H, w_i^L\}_{i\in\in\mathcal{I}}$ with IO coef.
- Goods and Labor Markets Clear
- Trade is balanced

QUANTIFICATION

Quantitative Analysis: Hat Algebra

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

Quantitative Analysis: Hat Algebra

- Two Exercises:
  1. Can changes in $\Gamma^{M}_{i,s,t}$ (automation) and $\Gamma^{XF}_{i,s,t}$ (offshoring) explain $\widehat{\beta}_t$?
  2. Using the same model, what are the macro implications?
- Calibration: 40 countries, 18 sectors (WIOD, 1995-2008)

Quantitative Analysis: Hat Algebra

- Two Exercises:
  1. Can changes in $\Gamma^{M}_{i,s,t}$ (automation) and $\Gamma^{XF}_{i,s,t}$ (offshoring) explain $\widehat{\beta}_t$?
  2. Using the same model, what are the macro implications?
- Calibration: 40 countries, 18 sectors (WIOD, 1995-2008)
- Automation and Offshoring Shocks since 1995

Quantitative Analysis: Hat Algebra

- Two Exercises:
  1. Can changes in $\Gamma^{M}_{i,s,t}$ (automation) and $\Gamma^{XF}_{i,s,t}$ (offshoring) explain $\widehat{\beta}_t$?
  2. Using the same model, what are the macro implications?
- Calibration: 40 countries, 18 sectors (WIOD, 1995-2008)
- Automation and Offshoring Shocks since 1995
  - $\Gamma^{M}_{i,s,t}$ (automation, constructed)

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

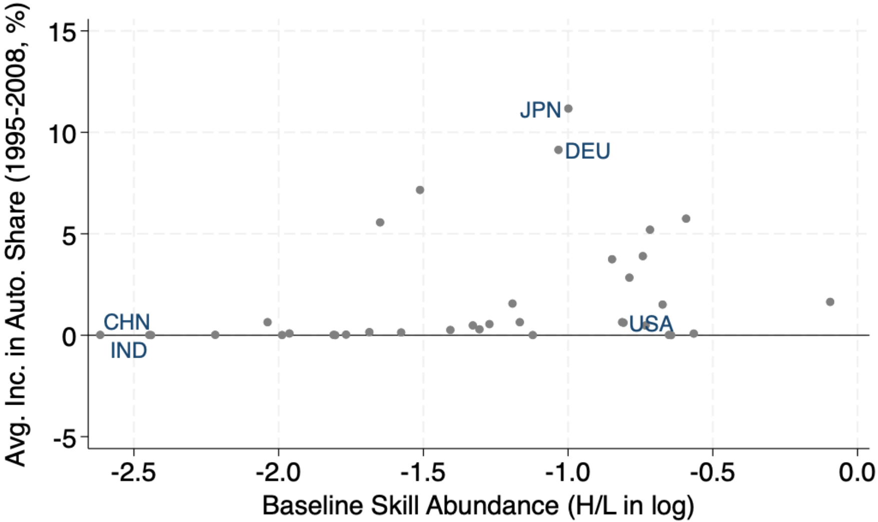
Quantitative Analysis: Hat Algebra

- Two Exercises:
  1. Can changes in $\Gamma^{M}_{i,s,t}$ (automation) and $\Gamma^{XF}_{i,s,t}$ (offshoring) explain $\widehat{\beta}_t$?
  2. Using the same model, what are the macro implications?
- Calibration: 40 countries, 18 sectors (WIOD, 1995-2008)
- Automation and Offshoring Shocks since 1995
  - $\Gamma^{M}_{i,s,t}$ (automation, constructed)
  - $\Gamma^{XF}_{i,s,t}$ (offshoring, just data), fixing $\Gamma^{XD}_{i,s,t}$ (domestic intermediate share)

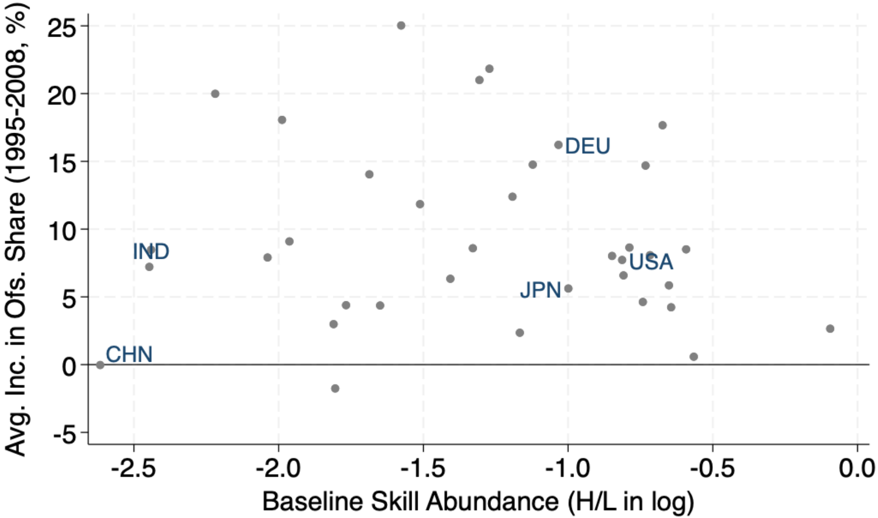
Quantitative Analysis: Hat Algebra

- Two Exercises:
  1. Can changes in $\Gamma^{M}_{i,s,t}$ (automation) and $\Gamma^{XF}_{i,s,t}$ (offshoring) explain $\widehat{\beta}_t$?
  2. Using the same model, what are the macro implications?
- Calibration: 40 countries, 18 sectors (WIOD, 1995-2008)
- Automation and Offshoring Shocks since 1995
  - $\Gamma^{M}_{i,s,t}$ (automation, constructed)
  - $\Gamma^{XF}_{i,s,t}$ (offshoring, just data), fixing $\Gamma^{XD}_{i,s,t}$ (domestic intermediate share)
  - Adjust $\Gamma^{L}_{i,s,t}$ (low-skilled labor share) to make $\sum_{F=L,M,XD,XF} \Gamma^{F}_{i,s,t} = 1$

Shock: More Automation in Skill-Abundant Countries



Shock: Offshoring is More Equally Distributed



RESULTS: CHANGES IN COMPARATIVE ADVANTAGE

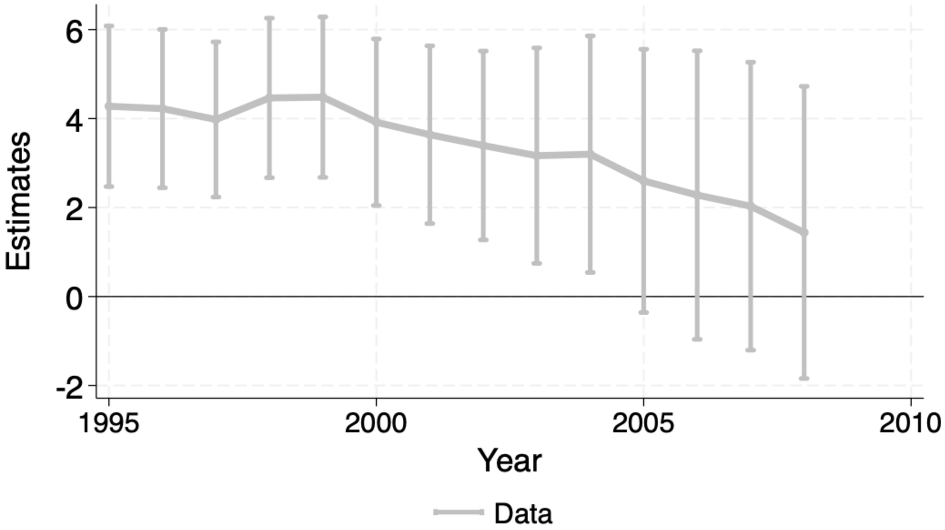
1. Automation and Offshoring on Changes in $\widehat{\beta}$

- Question: How much can $\Gamma^{M}_{i,s,t}$ and $\Gamma^{XF}_{i,s,t}$ explain the path of $\widehat{\beta}_t$?
- Calibrate the model to 1995, and hat algebra
- Run the same regression as in data but for counterfactual economies

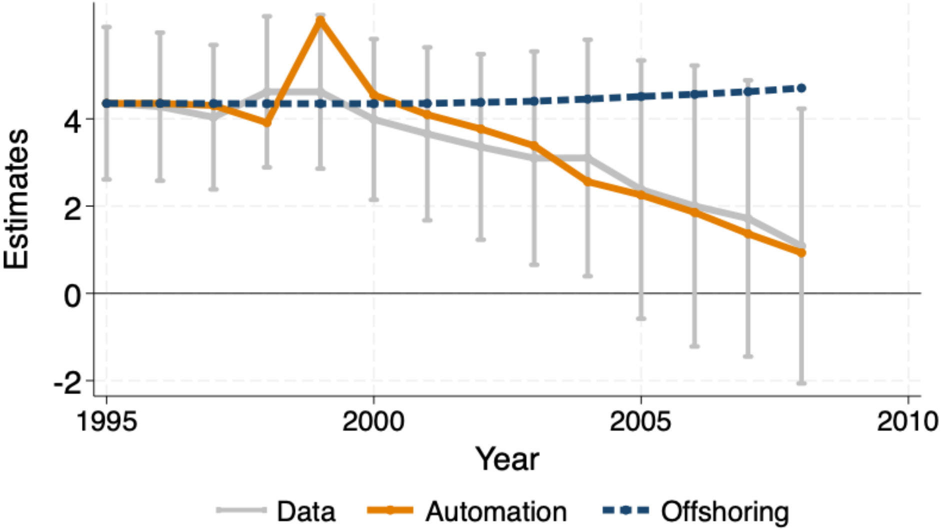
$$\ln(X_{i,j,s,t})' = \beta_t \left[\alpha^{H}_{s,t_0} \times \ln\left(\frac{H_{i,t_0}}{L_{i,t_0}}\right)\right] + \eta_{i,j,t} + \eta_{j,s,t} + \varepsilon_{i,j,s,t}.$$

- Counterfactual trade flow: $(X_{i,j,s,t})'$
  - Data (World Input-Output Database)
  - Case 1. Only Automation: Change $\Gamma^{M}_{i,s,t}$
  - Case 2. Only Offshoring: Change $\Gamma^{XF}_{i,s,t}$

In Data, $\widehat{\beta}_t$ decreases



Automation, Not Offshoring, Causes the Decline



Why Automation?

- Sizes of automation & offshoring similar
- Why automation, not offshoring, matter?

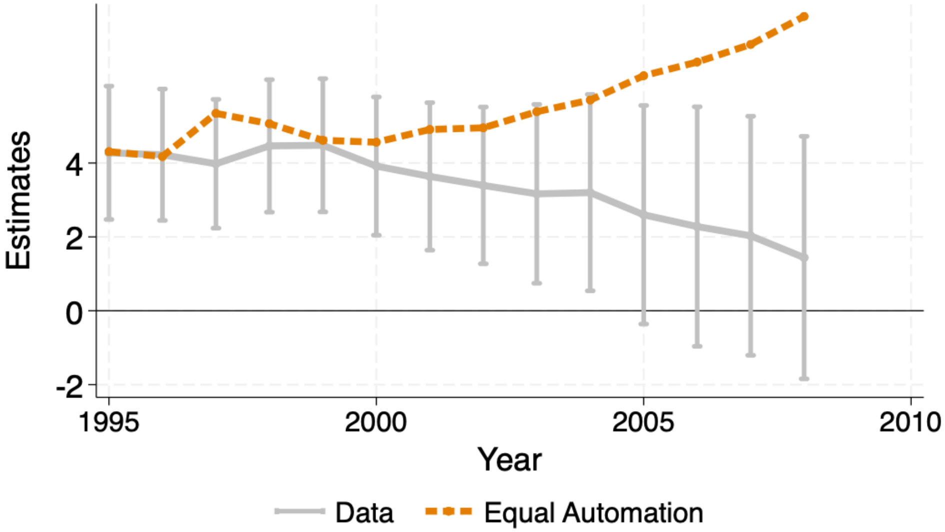
Why Automation?

- Sizes of automation & offshoring similar
- Why automation, not offshoring, matter?
- One observation: Automation happens disproportionately in L– scarce countries

Why Automation?

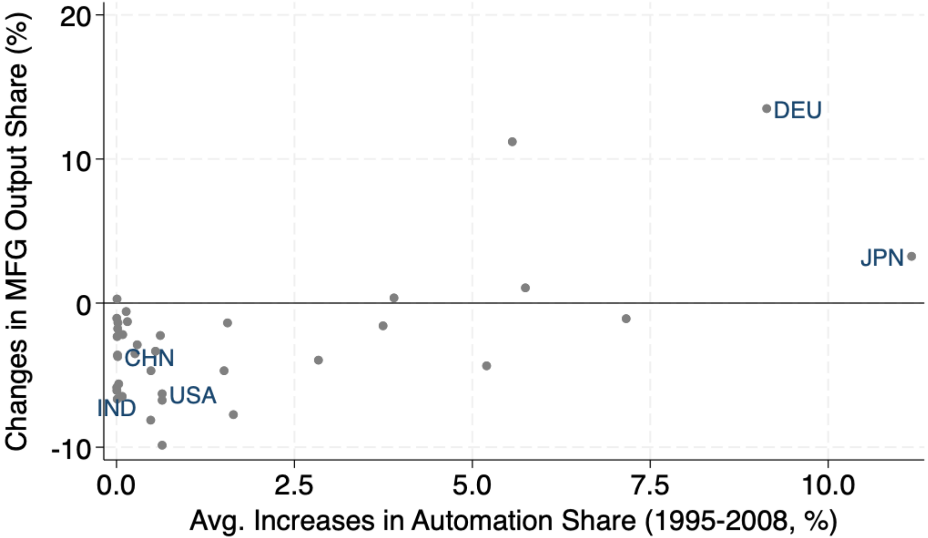
- Sizes of automation & offshoring similar
- Why automation, not offshoring, matter?
- One observation: Automation happens disproportionately in L– scarce countries
- Experiment: Suppose all the countries increase automation equally...

Equal Automation Cannot Explain the Decline

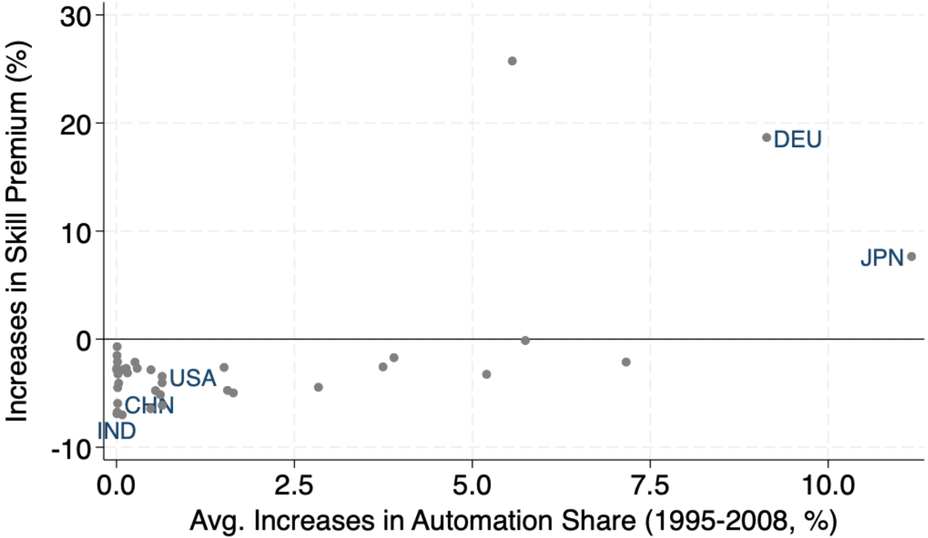


RESULTS: MACRO IMPLICATIONS OF AUTOMATION

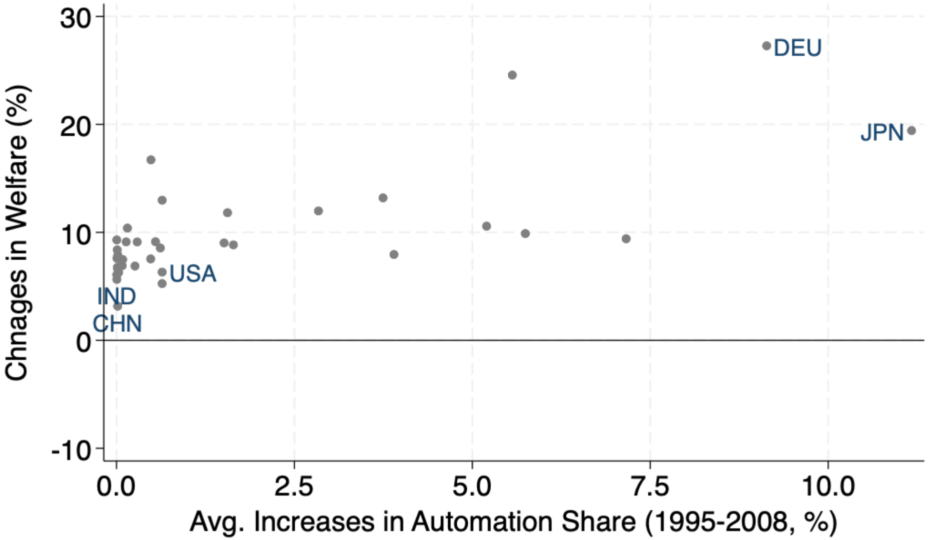
Manufacturing Shifts to High-Automation Countries



Skill Premia Increases Only in High-Automation Countries

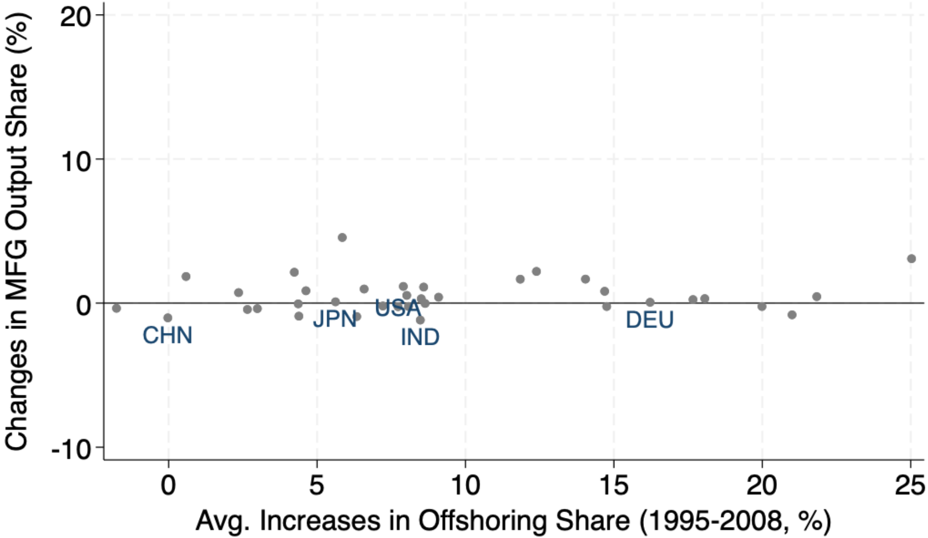


Welfare Increases Everywhere

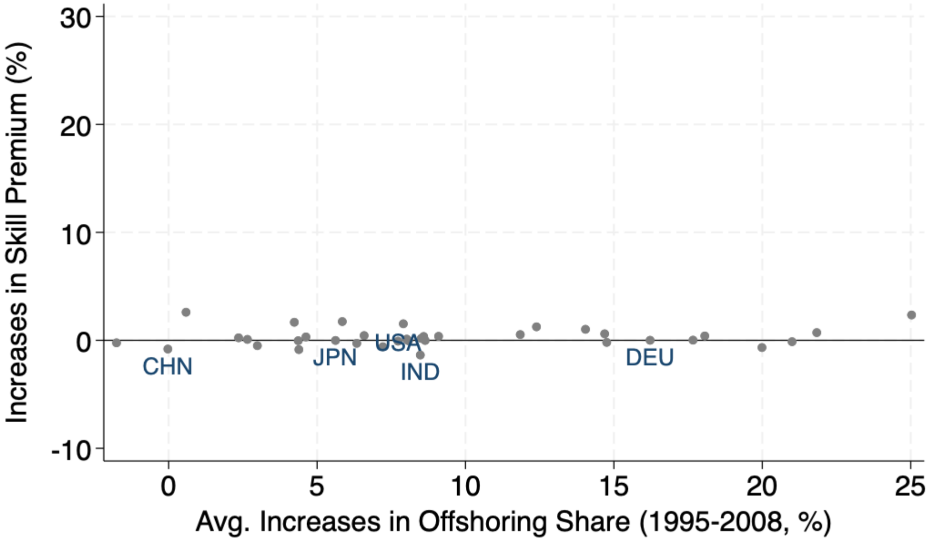


RESULTS: MACRO IMPLICATIONS OF OFFSHORING

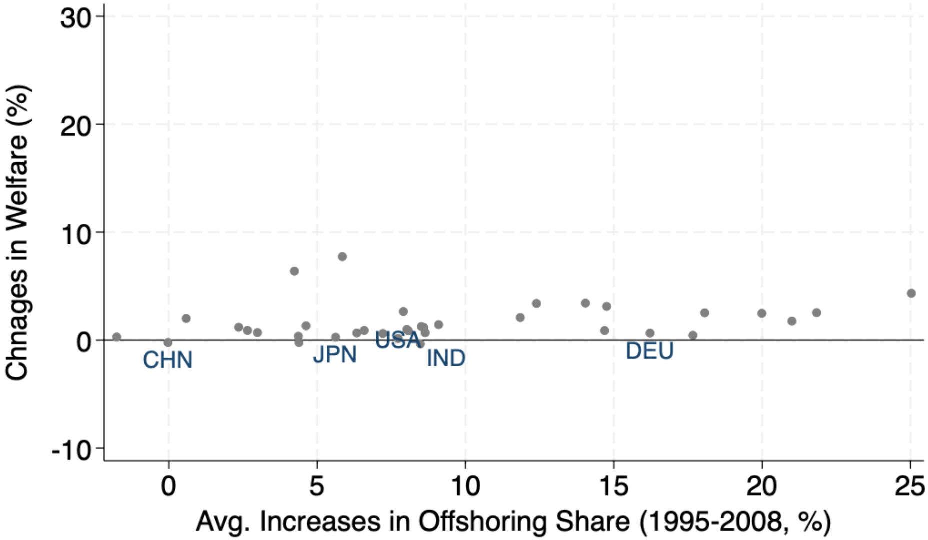
Manufacturing Shifts Less



Skill Premia Increases Everywhere, but Less



Welfare Increases Everywhere, but Less



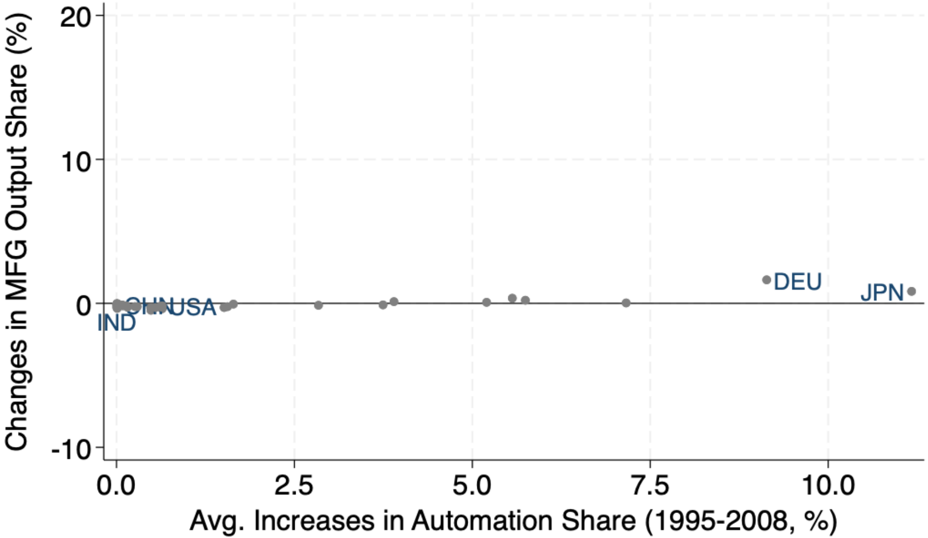
The Relationship between Automation, Globalization, and Inequality

- Automation $\rightarrow$ 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

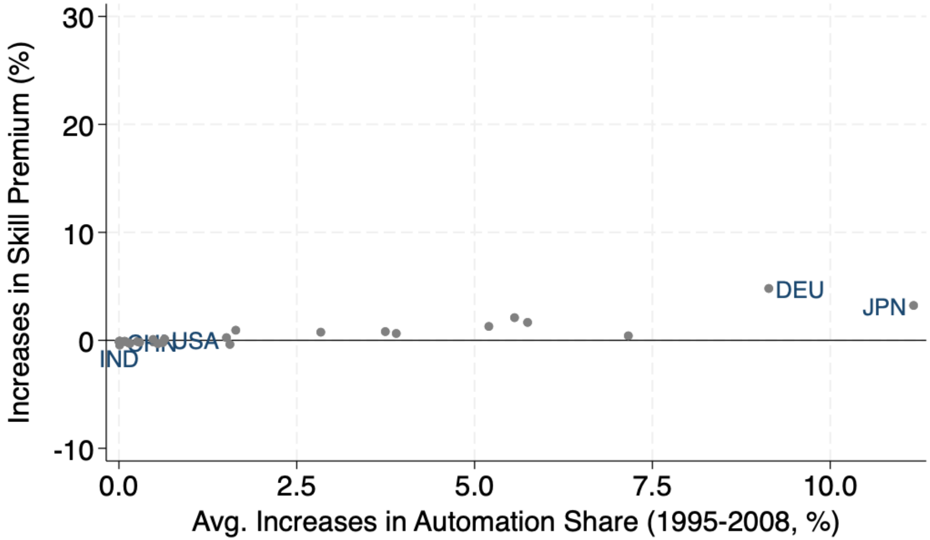
The Relationship between Automation, Globalization, and Inequality

- Automation $\rightarrow$ 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
- Roles of Trade?
- Now, set the trade elasticity $\theta = 1$, instead of $\theta = 4$

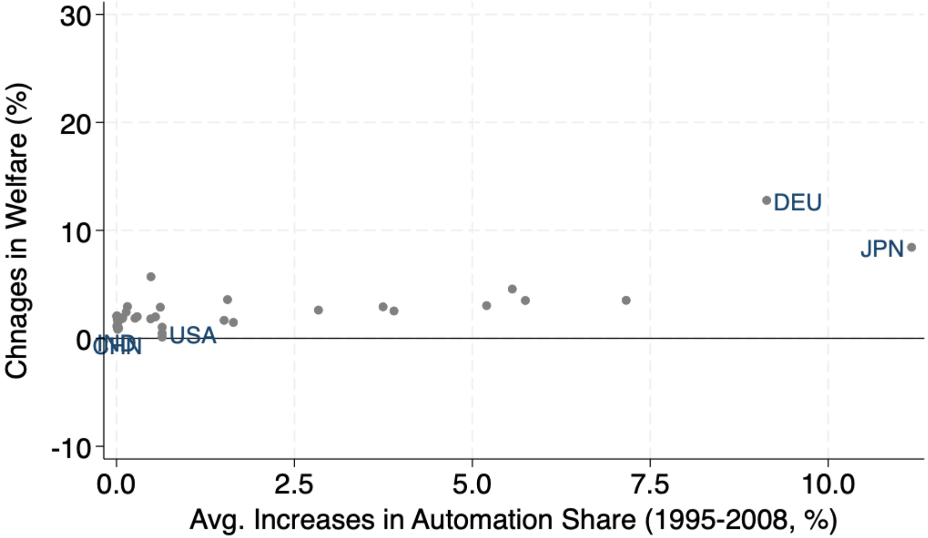
θ = 1: Lower Elas. Makes MFG Shifts Less



θ = 1: Skill Premia Increases Everywhere



θ = 1: Welfare Increases Everywhere, but Less



Conclusion

- Have patterns of comparative advantage changed or not?

Conclusion

- Have patterns of comparative advantage changed or not?
  - **It did.** Skill abundance no longer matters for CA

Conclusion

- Have patterns of comparative advantage changed or not?
  - **It did.** Skill abundance no longer matters for CA
  - **Automation** causes the decline, Offshoring has small effects

Conclusion

- Have patterns of comparative advantage changed or not?
  - **It did.** Skill abundance no longer matters for CA
  - **Automation** causes the decline, Offshoring has small effects

- Automation relocates
  - Global MFG from South (skill-scarce) to North (skill-abundant) countries
  - Labor demand from South's low-skilled to North's high-skilled within MFG

    $\rightarrow$ Skill premia increase only in High-Automation countries

Conclusion

- Have patterns of comparative advantage changed or not?
  - **It did.** Skill abundance no longer matters for CA
  - **Automation** causes the decline, Offshoring has small effects

- Automation relocates
  - Global MFG from South (skill-scarce) to North (skill-abundant) countries
  - Labor demand from South's low-skilled to North's high-skilled within MFG

    $\rightarrow$ Skill premia increase only in High-Automation countries

- Offshoring has a smaller aggregate effect

Conclusion

- Have patterns of comparative advantage changed or not?
  - **It did.** Skill abundance no longer matters for CA
  - **Automation** causes the decline, Offshoring has small effects

- Automation relocates
  - Global MFG from South (skill-scarce) to North (skill-abundant) countries
  - Labor demand from South's low-skilled to North's high-skilled within MFG

    $\rightarrow$ Skill premia increase only in High-Automation countries

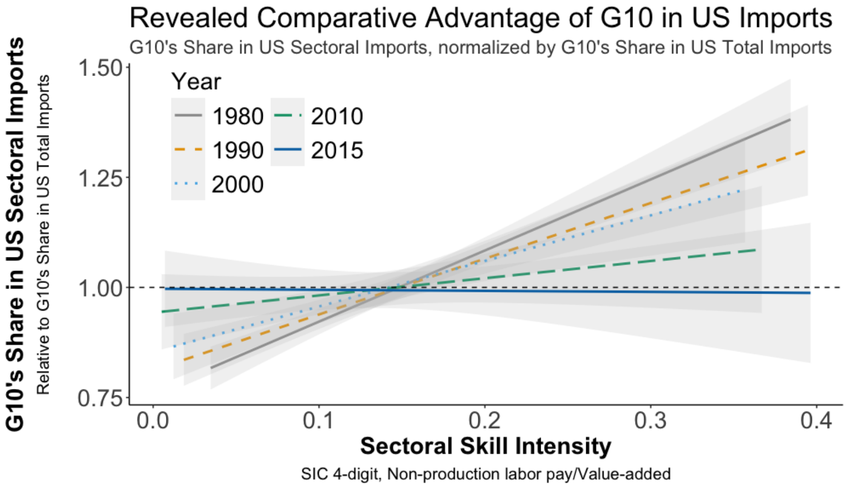
- Offshoring has a smaller aggregate effect

- **NEXT:** Policy implications? Clean-dirty tech v.s. oil-rich countries?

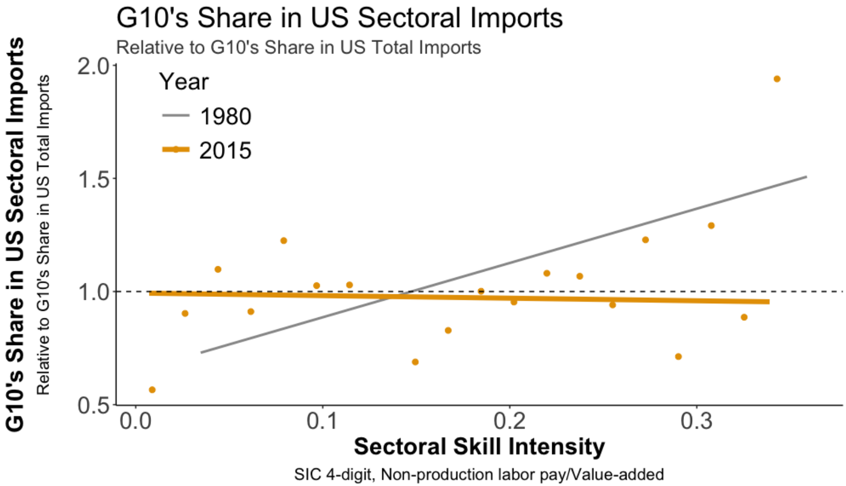
APPENDIX

FACTS

It’s Not Just 1980 vs 2015. It’s the Trend!

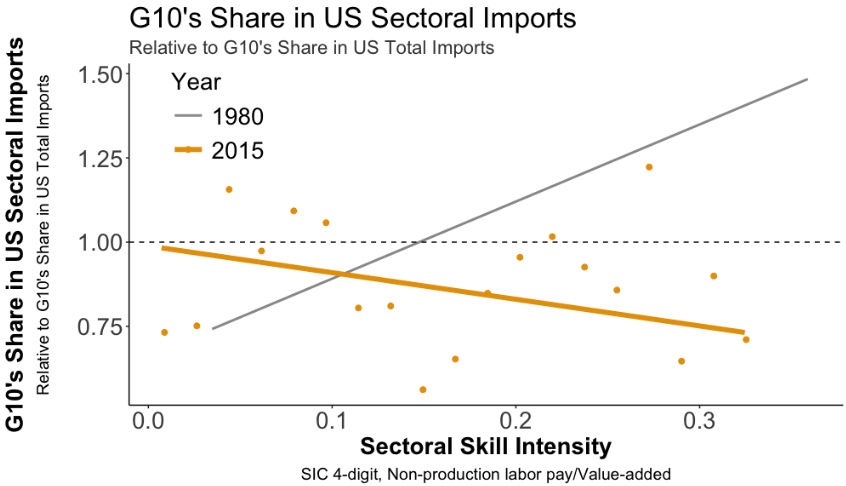


Dropping China Does Not Change the Result



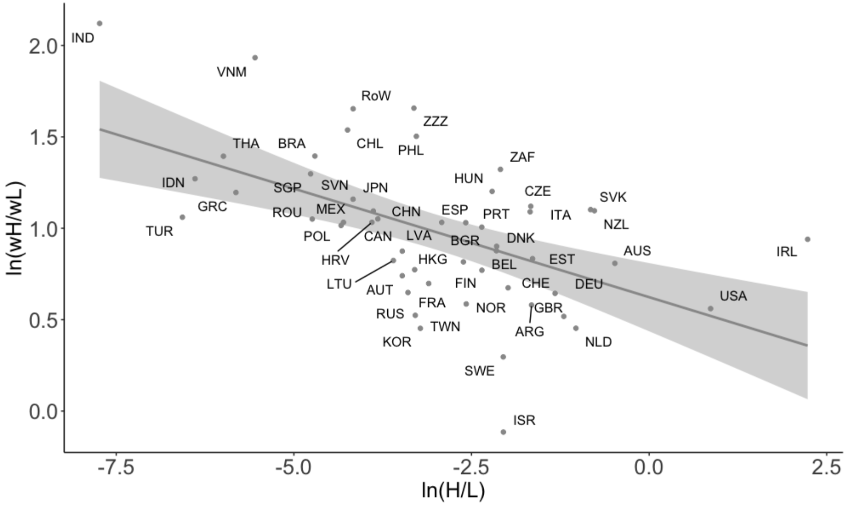
Back

Dropping Japan Does Not Change the Result (if any, cleaner)



‣ Back

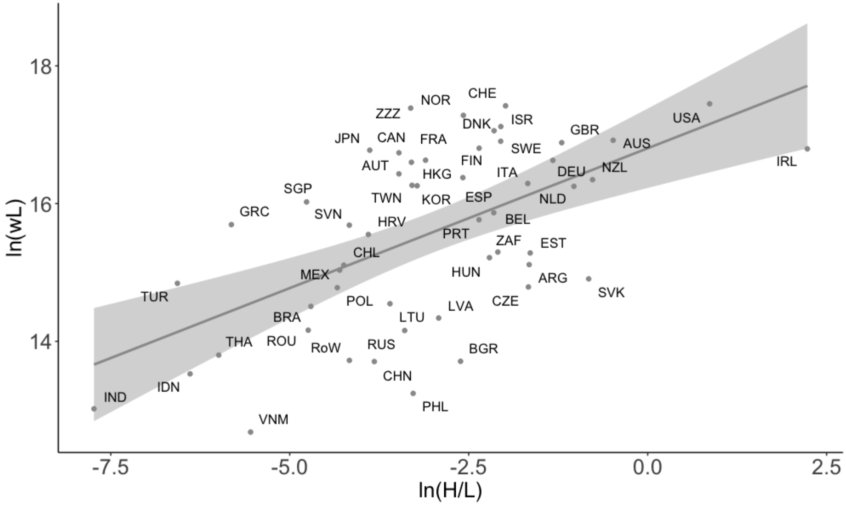
Relative Skilled Wages and Skill Endowment ‣ back



Note: Data from GTAP, 2004

Levels of Unskilled Wages and Skill Endowment

▸ back



Note: Data from GTAP, 2004

REGRESSION

Simplified Structural Interpretation

- Gravity Equation + Unit Production Cost

$$X_{i,j,s} = \left((c_{i,s}\tau_{i,j}\tau_{j,s})\right)^{1-\sigma} \cdot (P_{j,s})^{\sigma-1} X_{j,s}, \quad \ln X_{i,j,s} = (1-\sigma)\cdot \ln c_{i,s} + \mu_{i,j} + \mu_{j,s}$$

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

- Regression

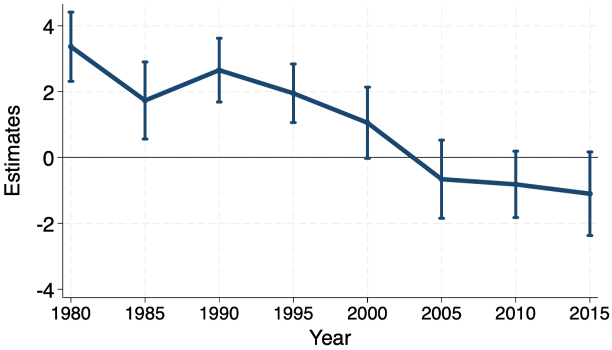
$$\ln X_{i,j,s} = (1-\sigma)\epsilon^W \left[\alpha_s^H \times \ln\left(\frac{H_i}{L_i}\right)\right] + \mu_{i,j} + \mu_{j,s} + \ln w_i^L$$

back

ROBUSTNESS

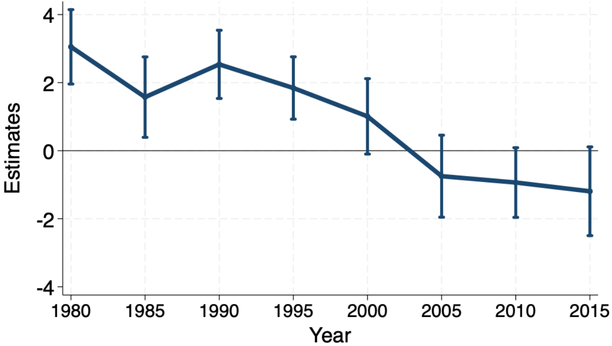
Controlling Capital Intensity ▸ back

$$X_{i,j,s,t} = \exp\left(\beta_t\left[\alpha^H_{s,t}\times\ln\left(\frac{H_{i,t}}{L_{i,t}}\right)\right] + \beta^K_t\left[\alpha^K_{s,t}\times\ln\left(\frac{K_{i,t}}{L_{i,t}}\right)\right] + \eta_{i,j,t} + \eta_{j,s,t}\right) + u_{i,j,s,t}$$

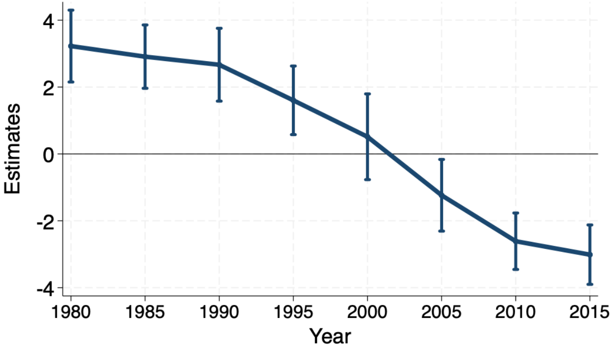


Controlling Capital Intensity and Institutions ▸ back

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

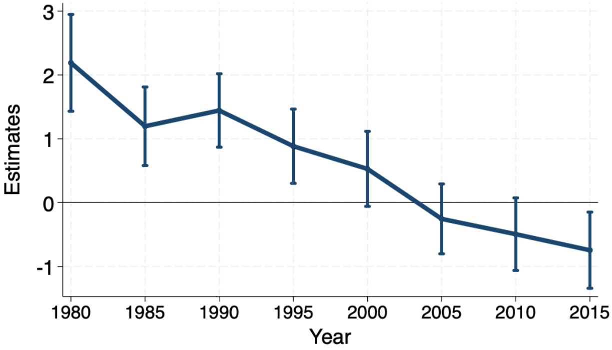


Weighted by Country Export ‣ back



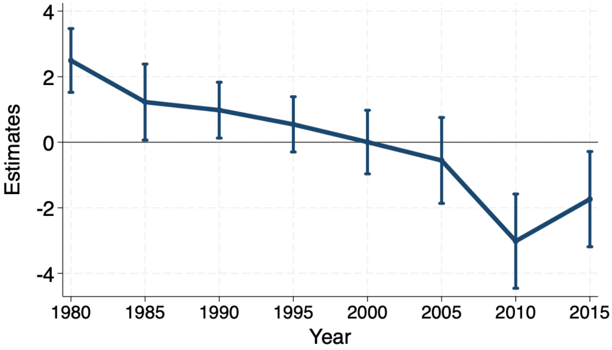
Pool and control Origin-Sector FEs ▸ back

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



High-school Graduates as Skilled ▸ back

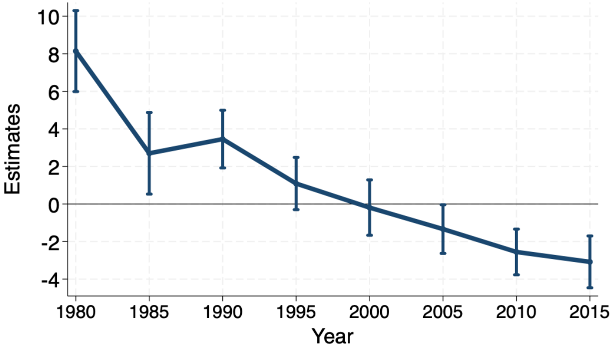
$$X_{i,j,s,t} = \exp\left(\beta_t \left[\alpha^H_{s,t} \times \ln\left(\frac{HS_{i,t}}{NHS_{i,t}}\right)\right] + \eta_{i,j,t} + \eta_{j,s,t}\right) + u_{i,j,s,t}$$



Instrument Skill Endowment by Cohort IV

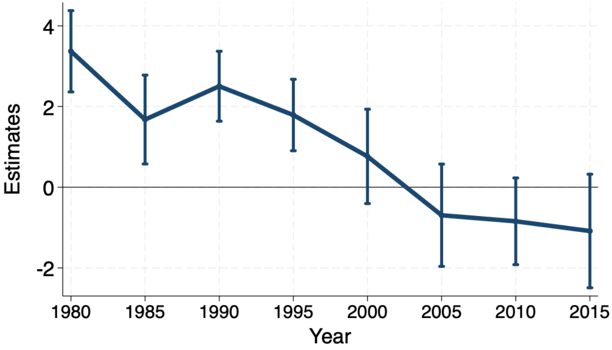
▸ back

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



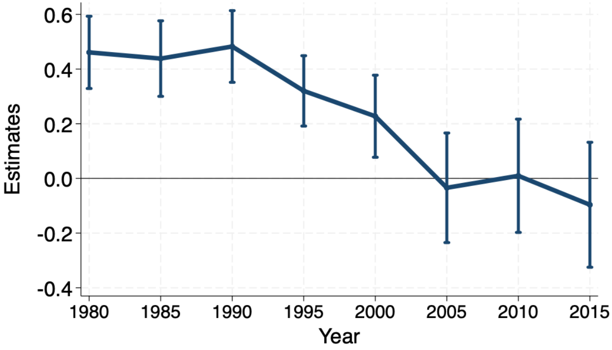
Romalis (2004): Total Export ▸ back

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



Chor (2011): Num of Workers as Factor Intensity ▸ back

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

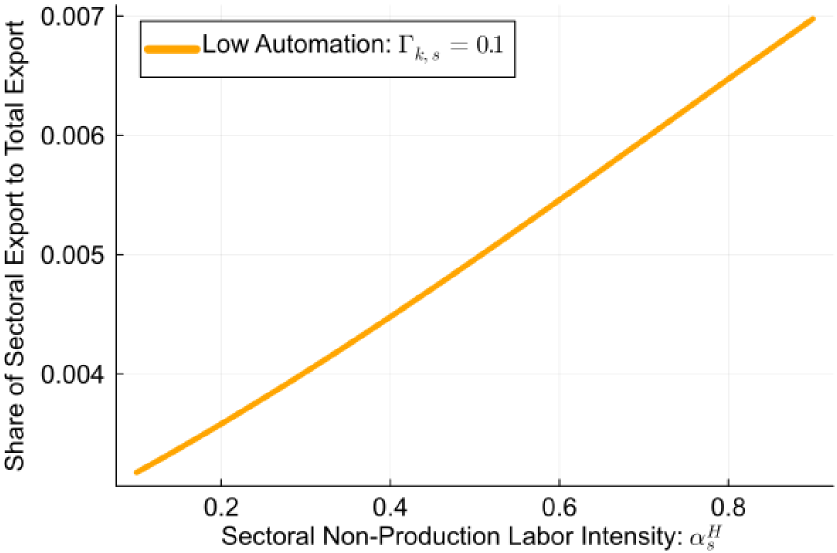


TWO COUNTRY ILLUSTRATION: AUTOMATION

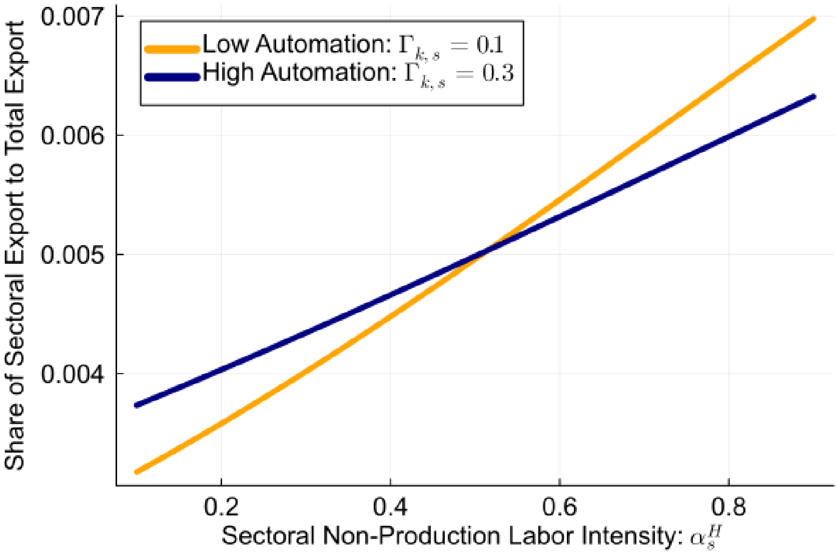
Two Country Illustration: Automation

- 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

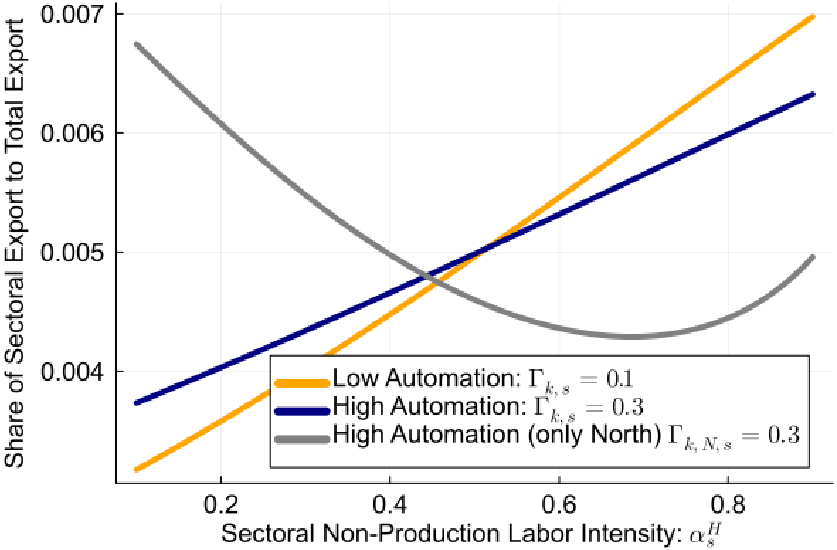
North Specialize in Skill-Intensive Sectors



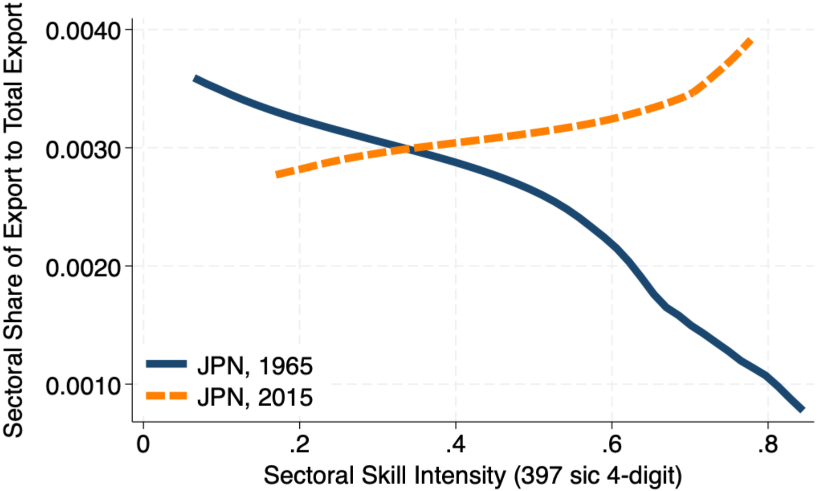
Automation Makes Skills Less Important



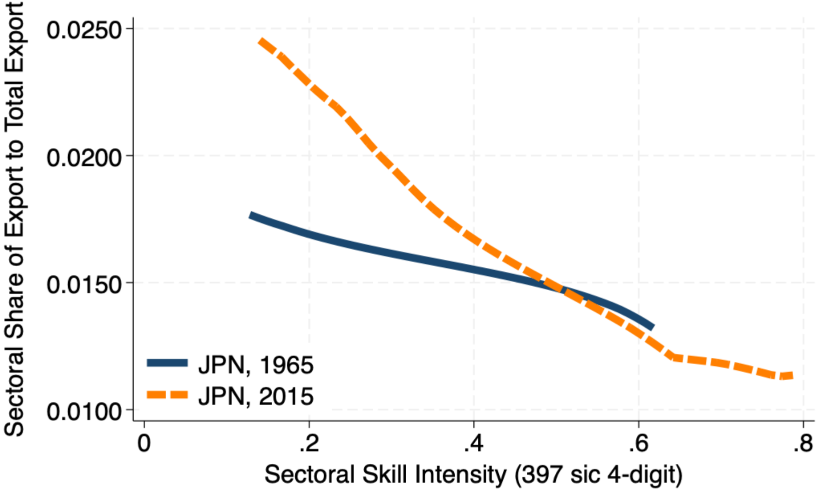
If Only North Automates, Sign Flips



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



CALIBRATION

Calibration ‣ back

Description	Parameter	Values	Source
Panel A: Time-Invariant Parameters			
Trade Elas.	θ	4	Standard
Expenditure Share	$\mu_{i,s}$	Data	WIOT
Panel B: Time-Variant Parameters			
Factor Endowment	H_{it}, L_{it}	Data	WIOT
Factor Share	$\alpha^{H}_{i,s,t}, \Gamma^{F}_{i,s,t}$	Data	WIOT

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

$$\widehat{c_2} - \widehat{c_1} = \underbrace{-(2\alpha - 1)\widehat{\omega}}_{\text{Skill Premium<0}} \underbrace{-(1 - \Gamma)(2\alpha - 1)\widehat{w^L}}_{\text{Task Displacement}}$$

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

$$\widehat{\omega} = \underbrace{-2\widehat{H}}_{\text{Labor Supply}} + \underbrace{(2\alpha - 1)(\sigma - 1)\left(\widehat{c_2} - \widehat{c_1}\right)}_{\text{GE Effect}}, \quad \widehat{w^L} = \frac{(\sigma - 1)(2\alpha - 1) - 1}{2 + (1 - \Gamma)(\sigma - 1)(2\alpha - 1)}\widehat{\omega}$$

Comparative Advantage if $\Gamma = 1$

Proposition 1: Rybczynski (1955)

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

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

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.

$$\widehat{c_2} - \widehat{c_1} = \frac{2(2\alpha - 1)}{\frac{1}{\eta(\Gamma)} + (2\alpha - 1)^2(\sigma - 1)}\widehat{H} \tag{1}$$

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.