Does Skill Abundance Still Matter?

The Evolution of Comparative Advantage in the 21st Century

Shin Kikuchi, MIT

November 11, 2024

Skill Abundance and Comparative Advantage

- Skill Abundance: Central for Comparative Advantage (e.g., Heckscher–Ohlin)

Skill Abundance and Comparative Advantage

- Skill Abundance: Central for Comparative Advantage (e.g., Heckscher–Ohlin)
  - Developed (Skill-Abundant) Countries—Specialize in Skill-Intensive Sectors
  - Developing (Skill-Scarce) Countries—Specialize in Low-skill Intensive Sectors

Skill Abundance and Comparative Advantage

- Skill Abundance: Central for Comparative Advantage (e.g., Heckscher–Ohlin)
  - Developed (Skill-Abundant) Countries—Specialize in Skill-Intensive Sectors
  - Developing (Skill-Scarce) Countries—Specialize in Low-skill Intensive Sectors
    - ⋆ Keys for Patterns of Development (e.g., East Asian Miracles)
    - ⋆ Implications for Globalization, Technology, and Inequality

At a Glance: Skill Abundance and Comparative Advantage

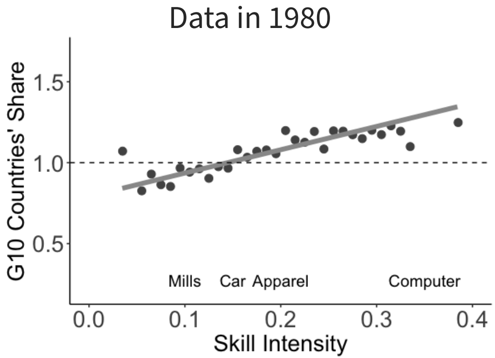
Revealed Comparative Advantage (RCA) in Skill Intensive Sectors:

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



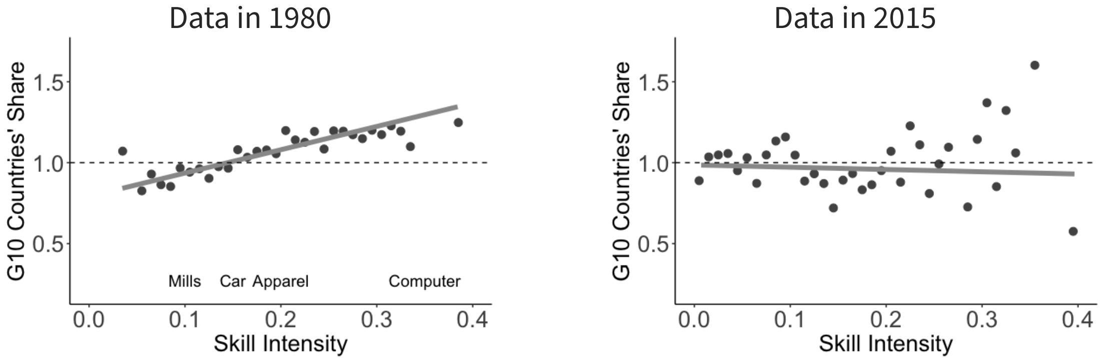
$$\text{G10's RCA}_s \equiv \frac{\frac{\text{G10 Export}_s}{\text{G10 Export}}}{\frac{\text{World Export}_s}{\text{World Export}}}$$

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

Higher Exports in Skill-Intensive Goods from Skill-Abundant Countries?

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

Skill Abundance as a Source of Comparative Advantage

Higher Exports in Skill-Intensive Goods from Skill-Abundant Countries?

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

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

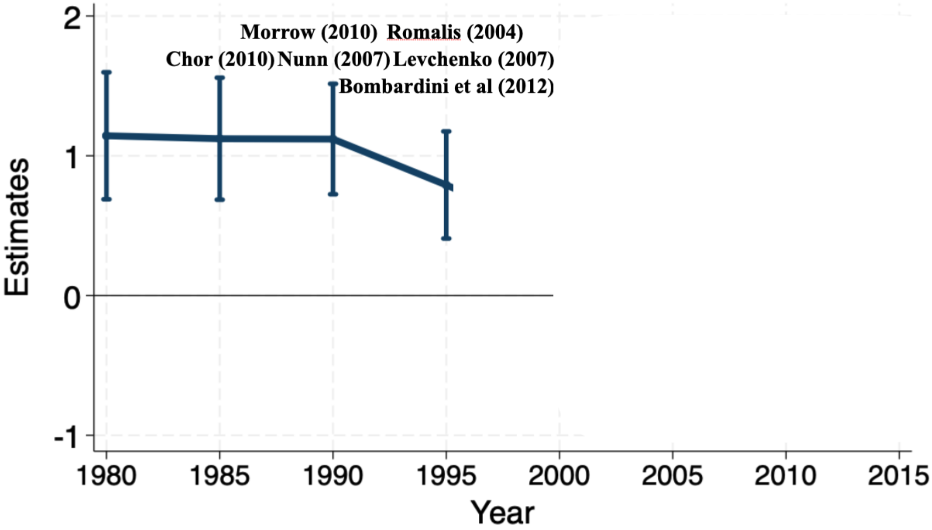
Skill Abundance as a Source of Comparative Advantage

Higher Exports in Skill-Intensive Goods from Skill-Abundant Countries?

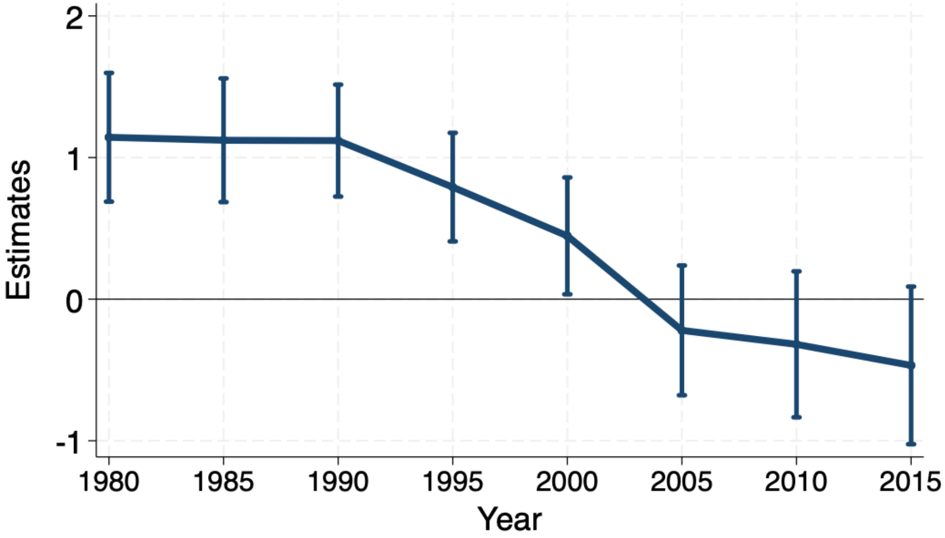
$$\ln \text{Exports}_{i,j,s,t} = \beta_t \left[\text{Skill Intensity}_{s,t} \times \text{Skill Abundance}_{i,t}\right] + \eta_{i,j,t} + \eta_{j,s,t} + \varepsilon_{i,j,s,t},$$

- Expect $\beta_t > 0$: Skill-abundant countries export skill-intensive goods more
- $\text{Exports}_{i,j,s,t}$: Bilateral trade flow i to j in s, from UN Comtrade
- $\text{Skill Intensity}_{s,t}$: Share of skilled labor pay. in value added, from NBER-CES
- $\text{Skill Abundance}_{i,t}$: Ratio of College- to Non-college-educated 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 Used to be Important before 2000



Skill Abundance $\neq$ CA in Skill-Intensive Sectors after 2000

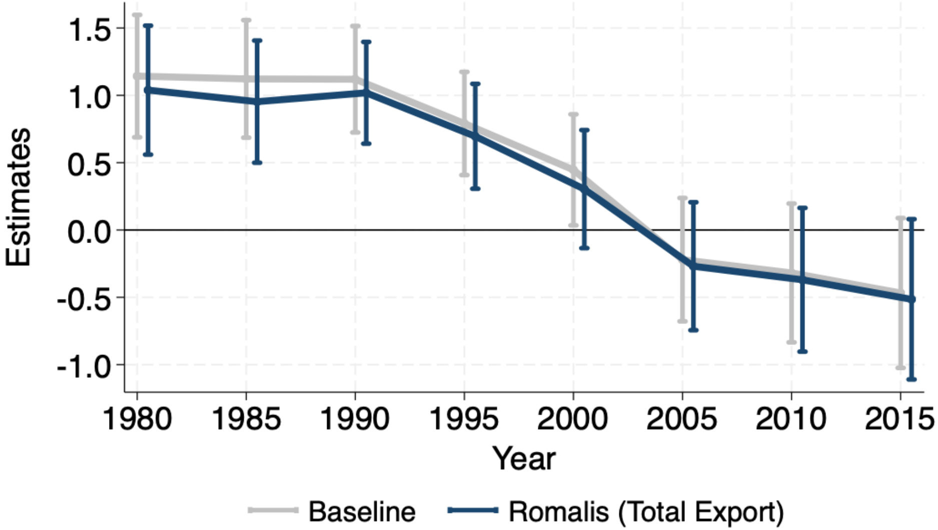


Robustness (1) Other Papers' Specifications

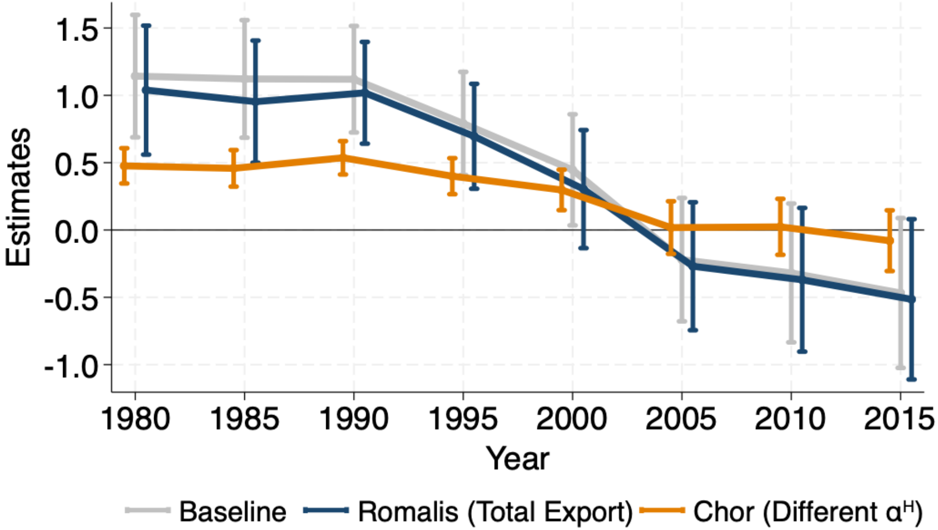
1. Total exports, instead of bilateral exports (Romalis 2004, Nunn 2007,...)

2. 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)

Using Total Exports Does Not Change Results



Using Different Intensity Measures Does Not Change Trends



Robustness (2)

- Other sources of comparative advantage? ▸ Capital ▸ Institution
- Driven by small countries? ▸ Weighted
- Some exporter-sector unobserved het., or IRS? ▸ Pool years and FEs
- “Endogenous” skill abundance? ▸ Use 1980 Value
- “Endogenous” skill intensity *in the US*? ▸ Use 1980 Value
  - “Endogenous” interaction? ▸ Use 1980 Values for Both
  - but, 1980’s measure becomes less relevant by construction? ▸ Use 2015 Value
- Different skill measures? ▸ High School ▸ Predicted by Demographics

SOME 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?

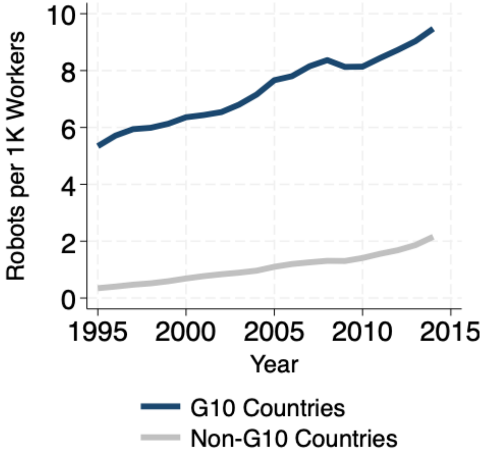
- Two mega-trends, replacing low-skill labor
  - Automation: Replace low-skill labor with machines
  - Offshoring: Replace low-skill labor with foreign inputs

Potential Hypotheses: Automation and Offshoring

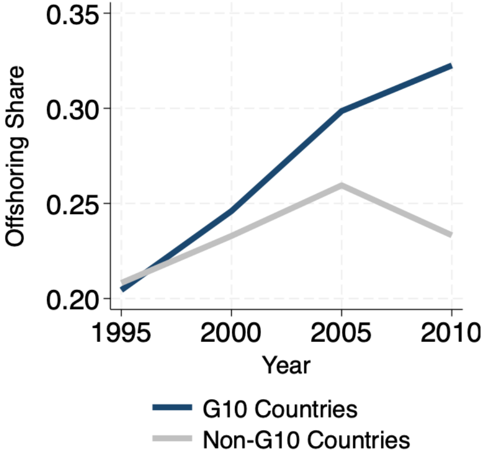
- What can make domestic skill abundance less relevant for CA after the 1990s?
- Two mega-trends, replacing low-skill labor
  - Automation: Replace low-skill labor with machines
  - Offshoring: Replace low-skill labor with foreign inputs
- This section: Explore heterogeneous effects across countries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



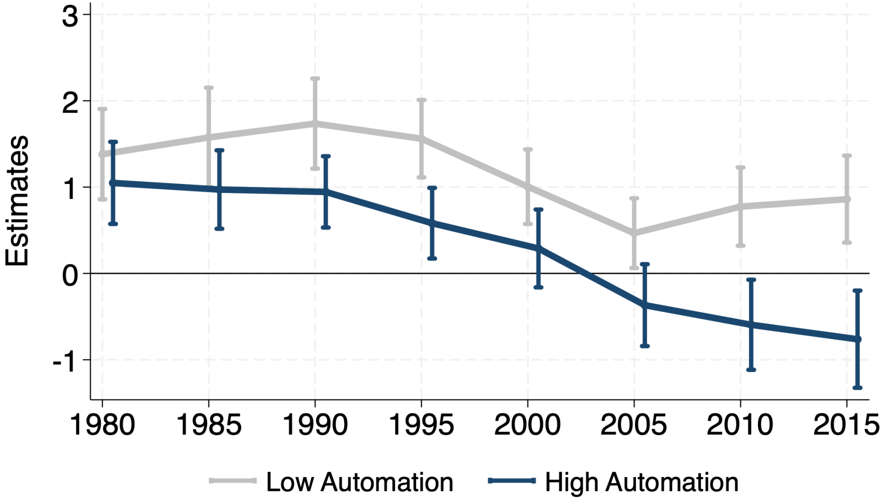
Specification for Heterogeneous Effects

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

- $HA_{i,s}$: 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

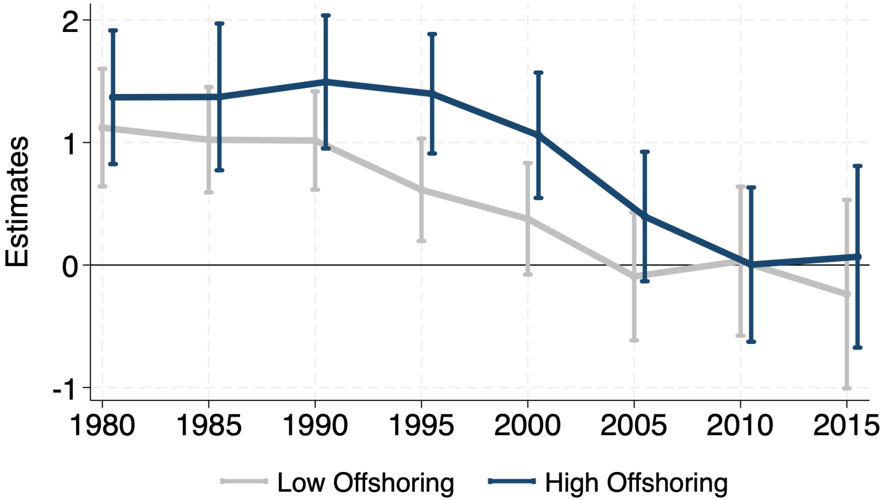
Skills Abundance Matters in Low-Automation Country/Sector

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

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: task model (Acemoglu & Restrepo)
- 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)

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

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

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

- 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

- 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: Data for 40 countries, 18 sectors (WIOD+GTAP, 1995-2008)
  - $\Gamma^{M}_{i,s,t} \equiv \frac{p^{M}_{i,s,t} M_{i,s,t}}{\text{Total Cost}_{i,s,t}}$ (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

- 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: Data for 40 countries, 18 sectors (WIOD+GTAP, 1995-2008)
  - $\Gamma^{M}_{i,s,t} \equiv \frac{p^{M}_{i,s,t} M_{i,s,t}}{\text{Total Cost}_{i,s,t}}$ (automation, constructed)

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

  - $\Gamma^{XF}_{i,s,t}$ (offshoring, just data), fixing $\Gamma^{XD}_{i,s,t}$ (domestic intermediate share)

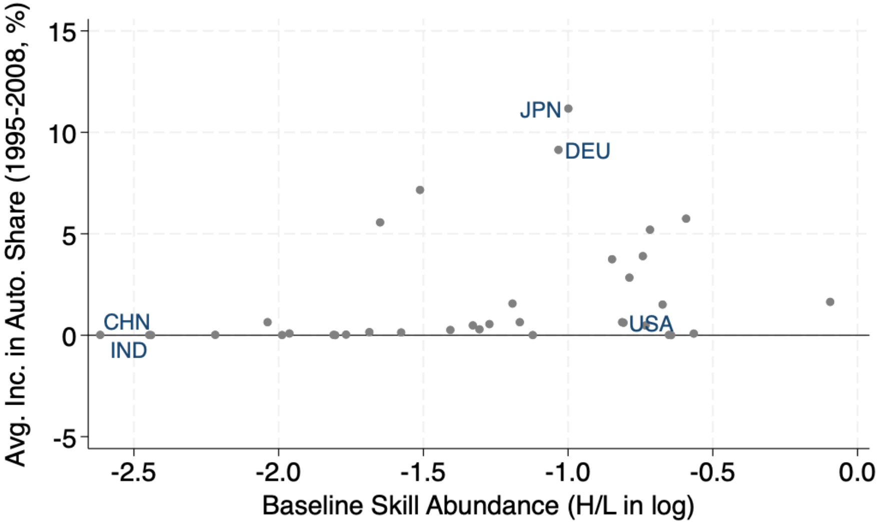
Quantitative Analysis

- 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: Data for 40 countries, 18 sectors (WIOD+GTAP, 1995-2008)
  - $\Gamma^{M}_{i,s,t} \equiv \frac{p^{M}_{i,s,t} M_{i,s,t}}{\text{Total Cost}_{i,s,t}}$ (automation, constructed)

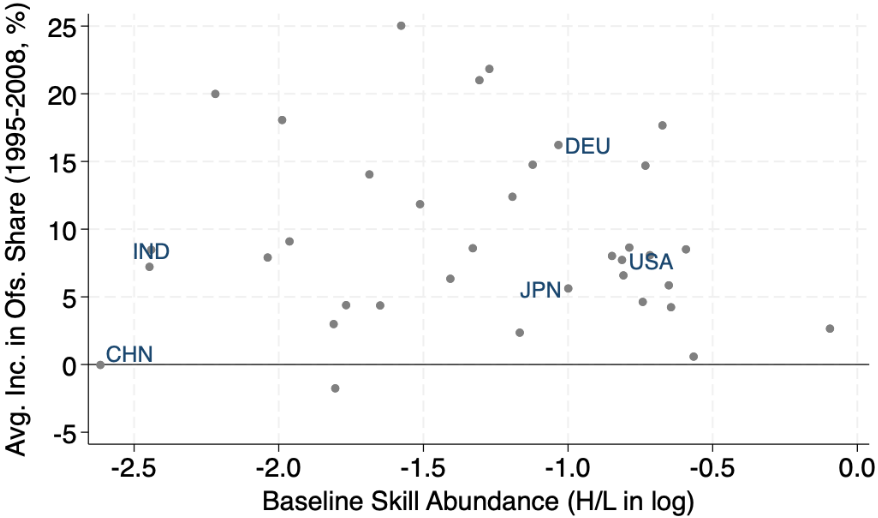
$$p^{M}_{i,s,t} M_{i,s,t} = \underbrace{p^{K}_{i,s,t0} K_{i,s,t0}}_{\text{Capital Income}} \cdot \underbrace{\frac{p^{M}_{US,s,t0} M_{US,s,t0}}{p^{K}_{US,s,t0} K_{US,s,t0}}}_{\text{Machine-Capital Ratio}} \cdot \underbrace{\frac{p^{R}_{i,s,t} R_{i,s,t}}{p^{R}_{i,s,t0} R_{i,s,t0}}}_{\text{Increases in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

  - $\Gamma^{XF}_{i,s,t}$ (offshoring, just data), fixing $\Gamma^{XD}_{i,s,t}$ (domestic intermediate share)
  - Adjust $\Gamma^{L}_{i,s,t}$ (low-skilled labor share) to make $\sum_{F=L,M,XD,XF} \Gamma^{F}_{i,s,t} = 1$

More Automation in Skill-Abundant Countries



Offshoring is More Equally Distributed



CHANGES IN COMPARATIVE ADVANTAGE

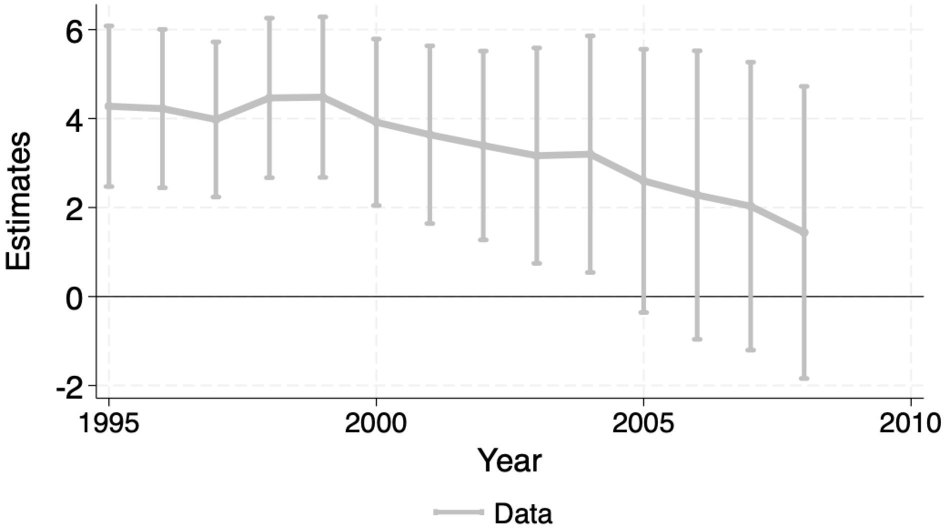
1. Automation and Offshoring on Changes in $\widehat{\beta}$

- 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

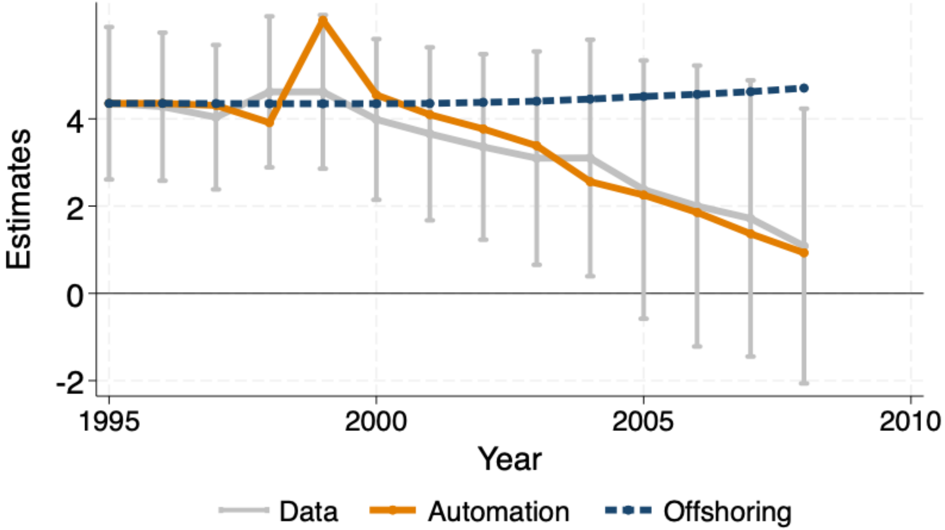
$$\ln(X_{i,j,s,t})' = \beta_t \left[\alpha^{H}_{s,t_0} \times \ln\left(\frac{H_{i,t_0}}{L_{i,t_0}}\right)\right] + \eta_{i,j,t} + \eta_{j,s,t} + \varepsilon_{i,j,s,t}.$$

- 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
  - If any, offshoring is larger
- Why automation, not offshoring, matter?

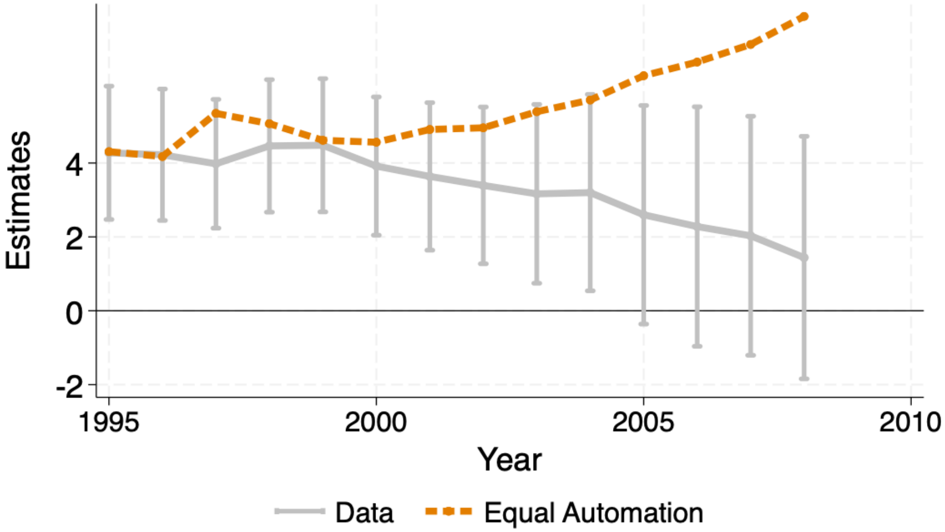
Why Automation?

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

Why Automation?

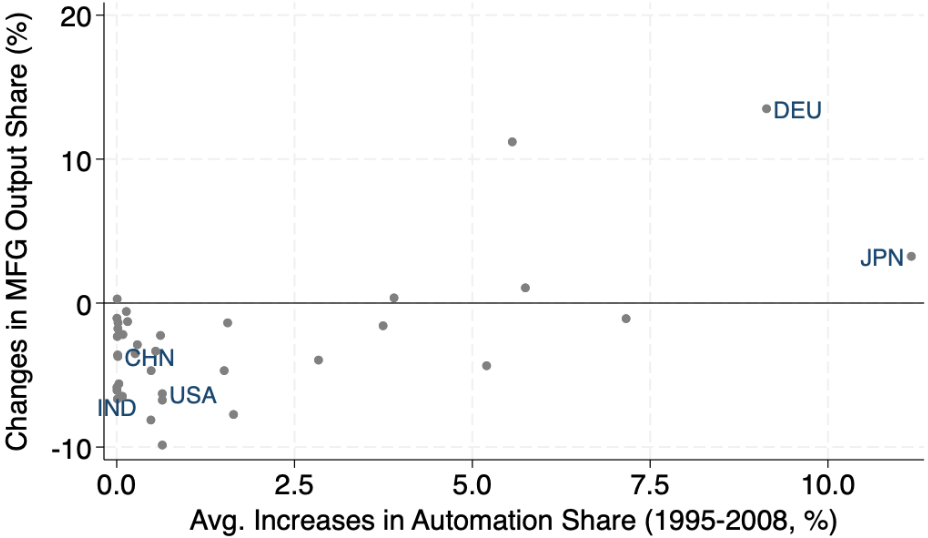
- Sizes of automation & offshoring similar
  - If any, offshoring is larger
- Why automation, not offshoring, matter?
- One observation: Automation happens disproportionately in L– scarce countries
- Experiment: Suppose all the countries increase automation equally...

Equal Automation Cannot Explain the Decline

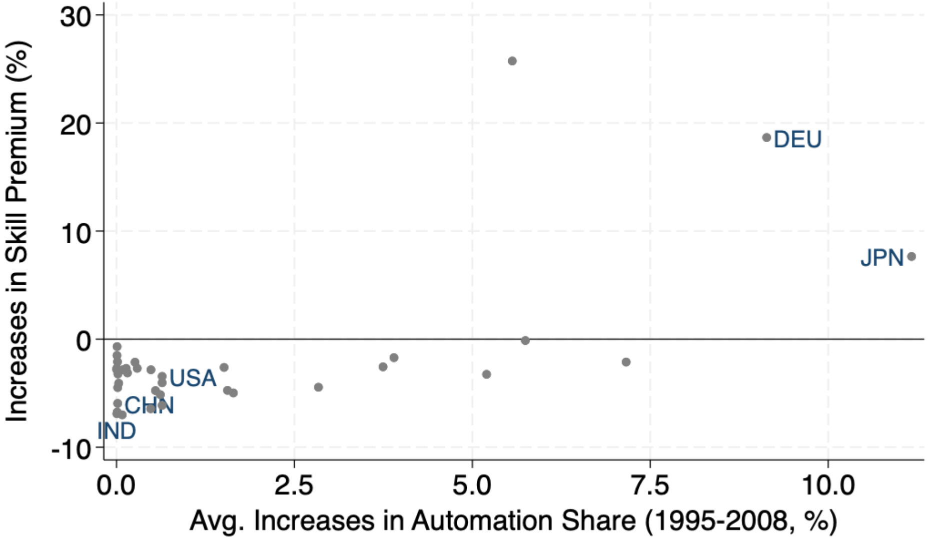


MACRO IMPLICATIONS OF AUTOMATION

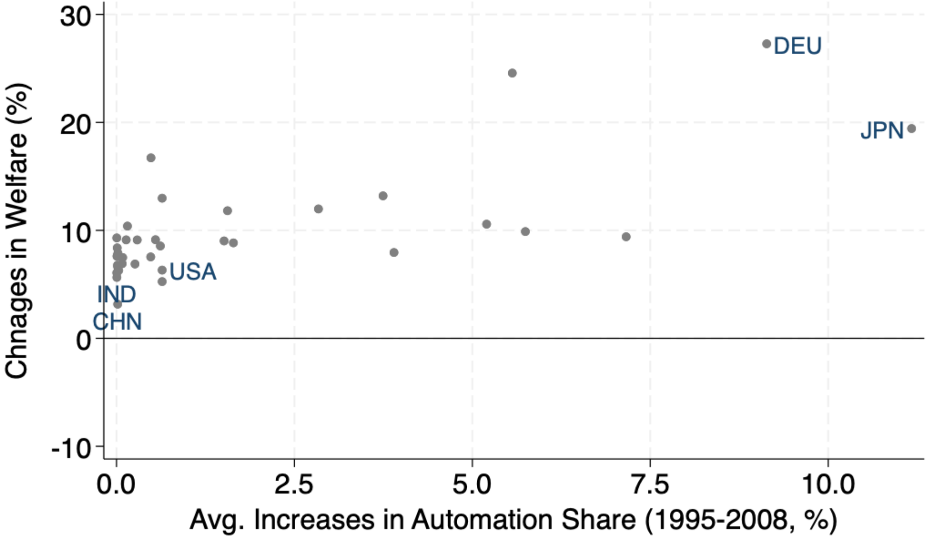
Manufacturing Shifts to High-Automation Countries



Skill Premia Increases Only in High-Automation Countries

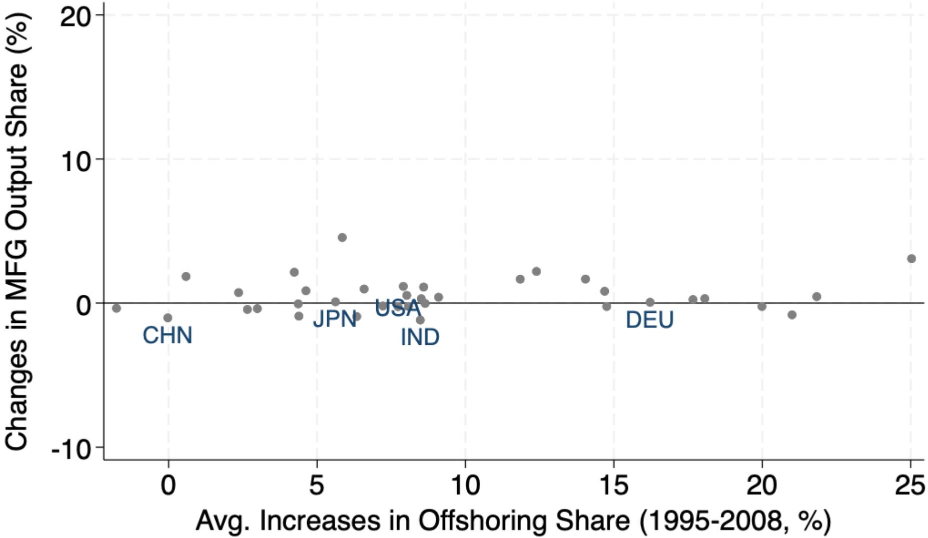


Welfare Increases Everywhere

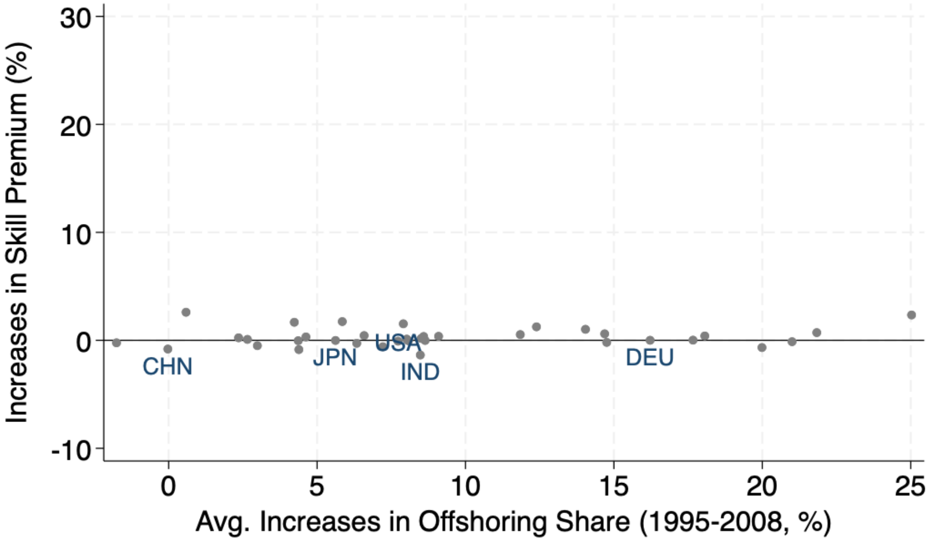


MACRO IMPLICATIONS OF OFFSHORING

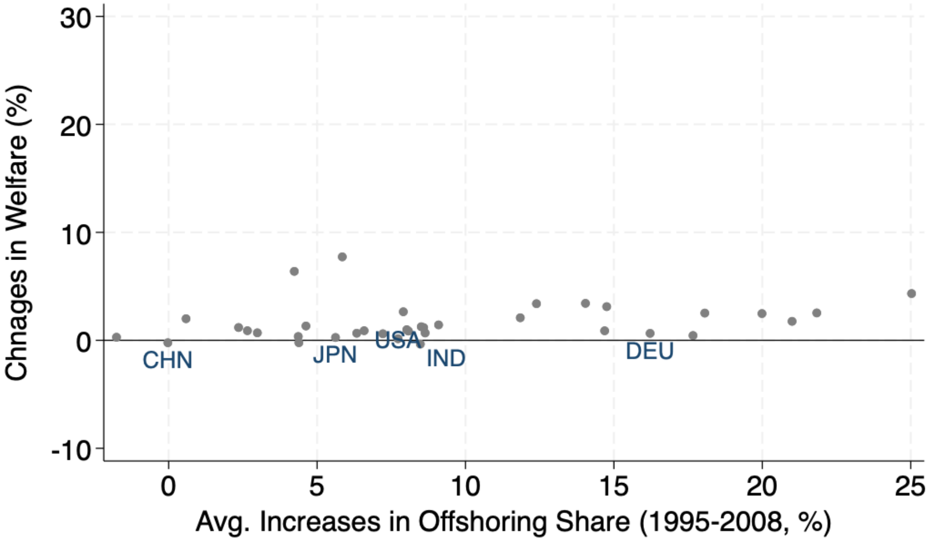
Manufacturing Shifts Less



Skill Premia Increases Everywhere, but Less



Welfare Increases Everywhere, but Less



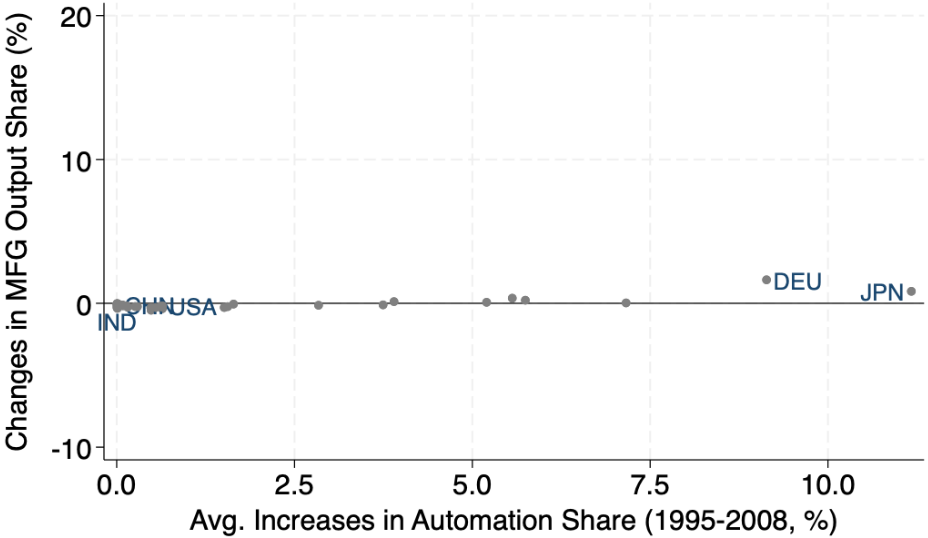
The Relationship between Automation, Globalization, and Inequality

- 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

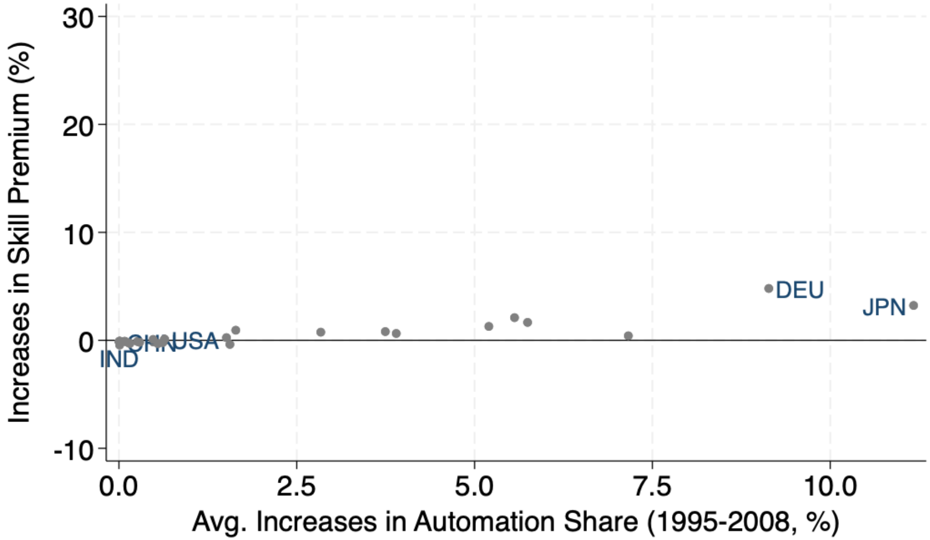
The Relationship between Automation, Globalization, and Inequality

- 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 $\theta = 4$

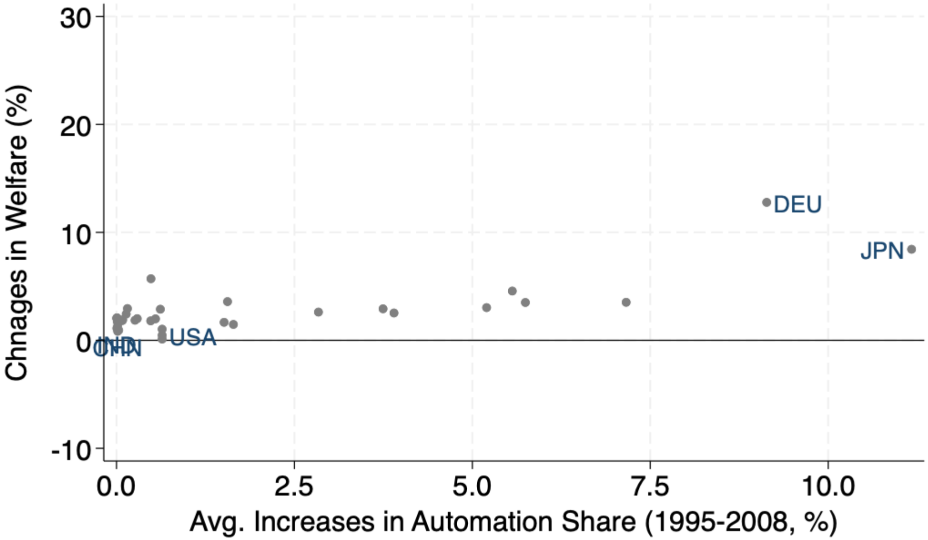
θ = 1: Lower Elas. Makes MFG Shifts Less



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

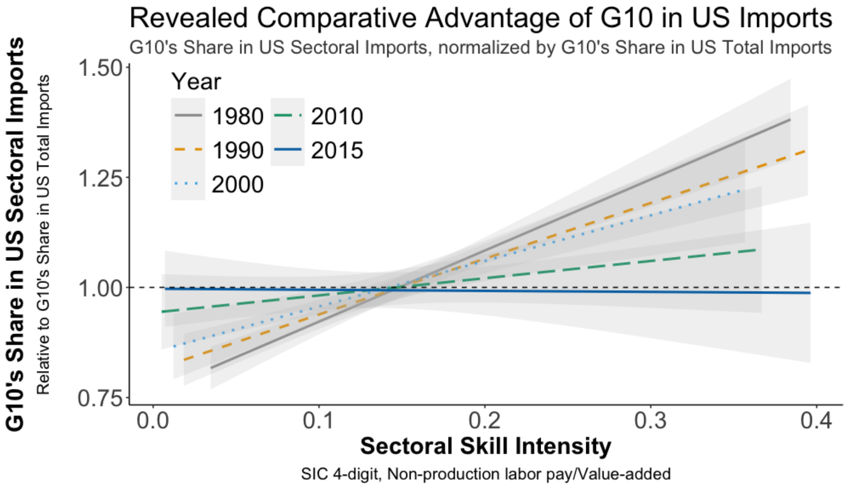
- Offshoring has a smaller aggregate effect

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

APPENDIX

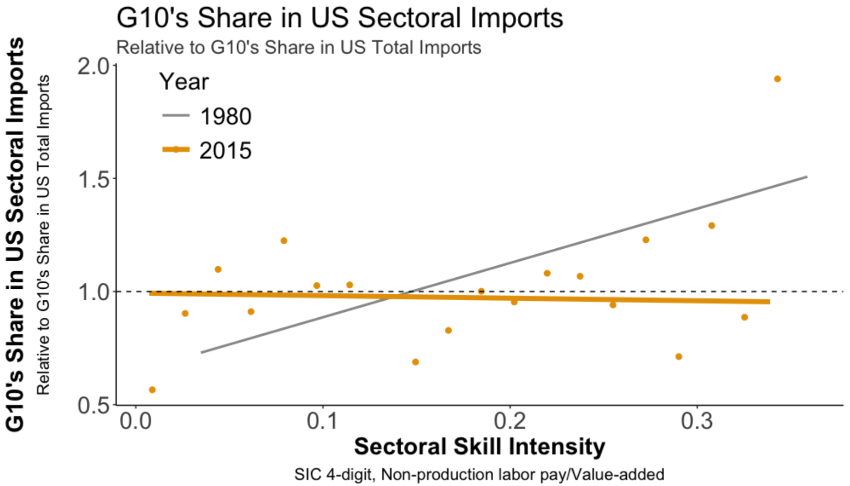
FACTS

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



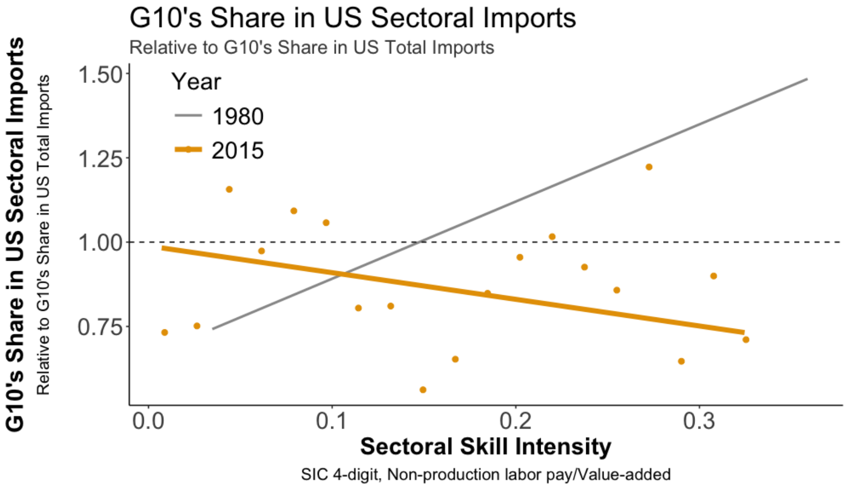
Back

Dropping China Does Not Change the Result



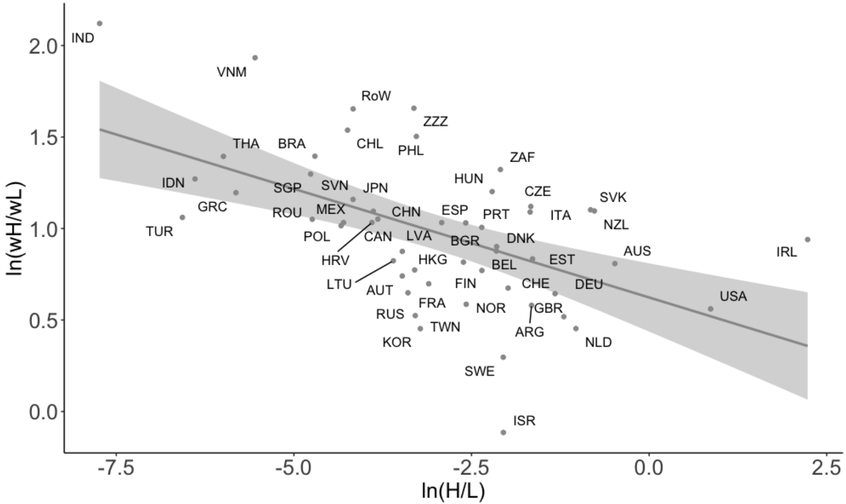
‣ Back

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



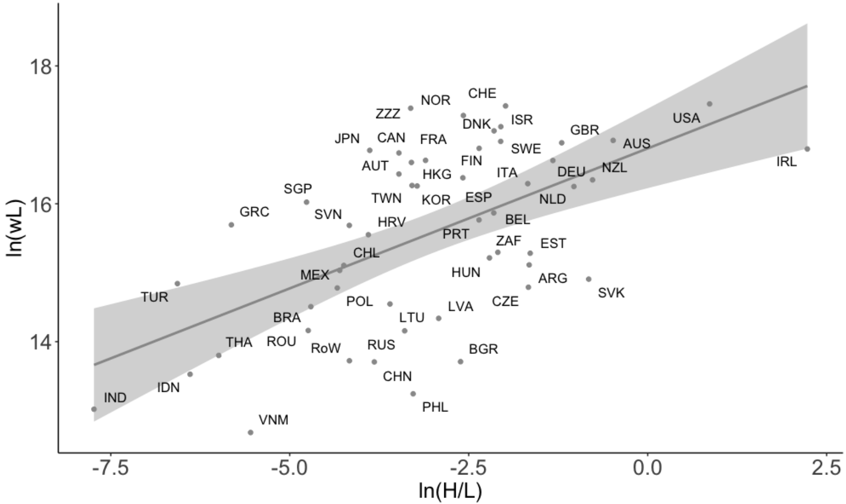
‣ Back

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

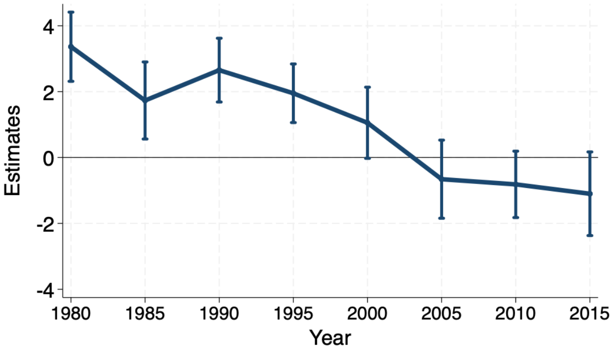
$$\ln X_{i,j,s} = (1-\sigma)\epsilon^w \left[\alpha_s^H \times \ln\left(\frac{H_i}{L_i}\right)\right] + \mu_{i,j} + \mu_{j,s} + \ln w_i^L$$

back

ROBUSTNESS

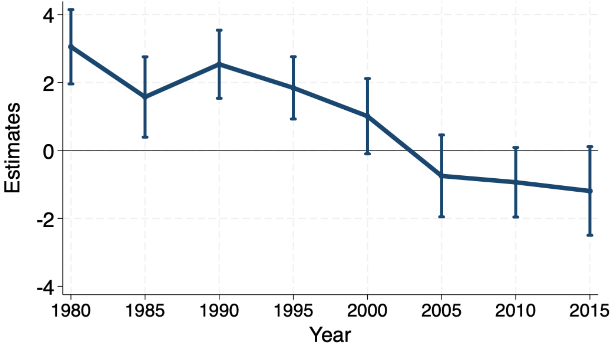
Controlling Capital Intensity ▸ back

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

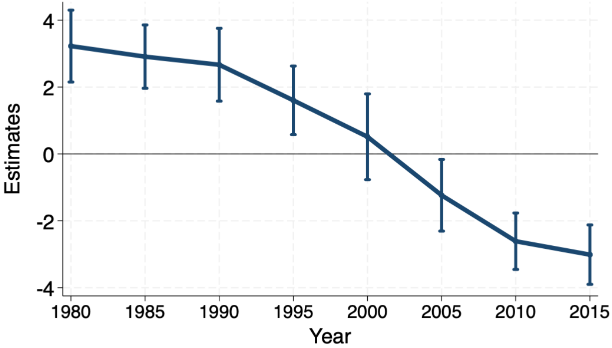


Controlling Capital Intensity and Institutions ▸ back

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

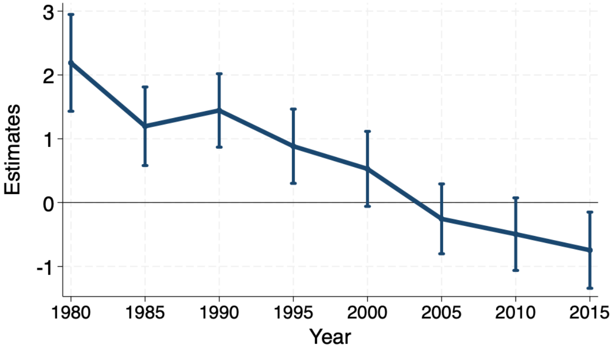


Weighted by Country Export ▸ back



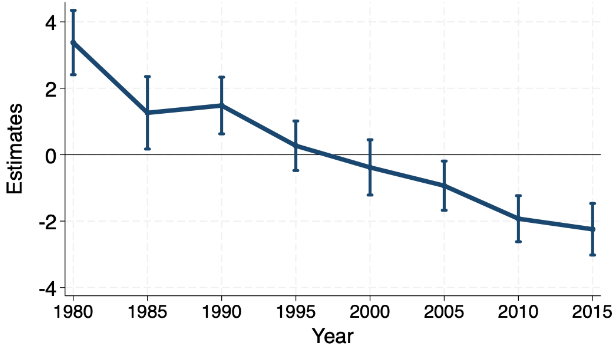
Pool and control Origin-Sector FEs ▸ back

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



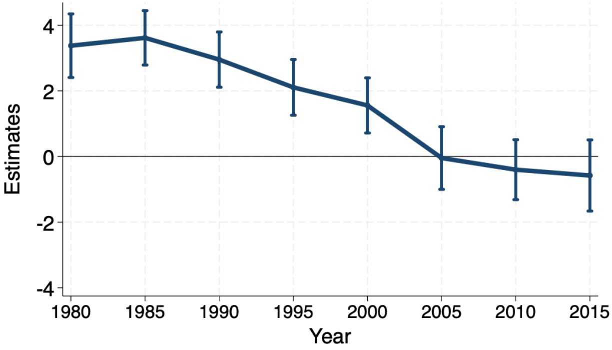
Use 1980's Factor Endowment ▸ back

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



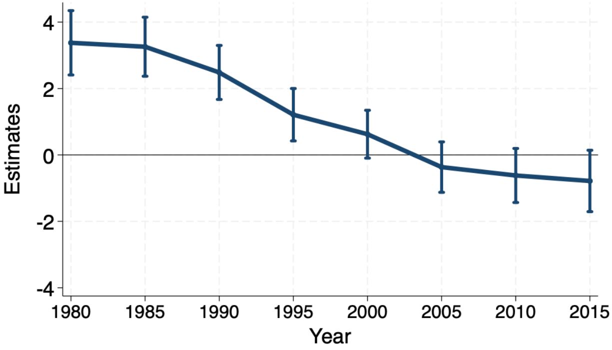
Use 1980's Factor Intensity ▸ back

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



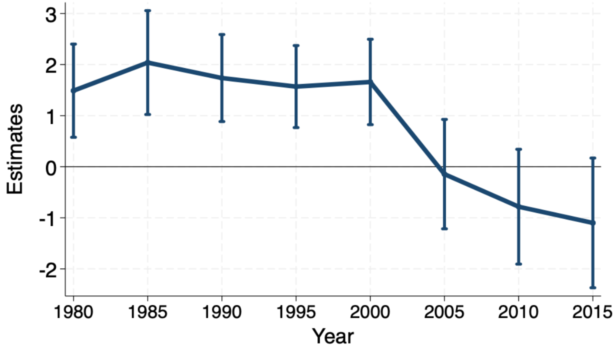
Use 1980's Factor Endowment and Intensity ▸ back

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



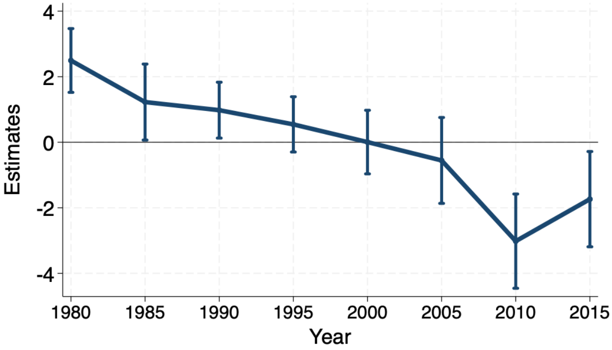
Use 2015's Factor Intensity ▸ back

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



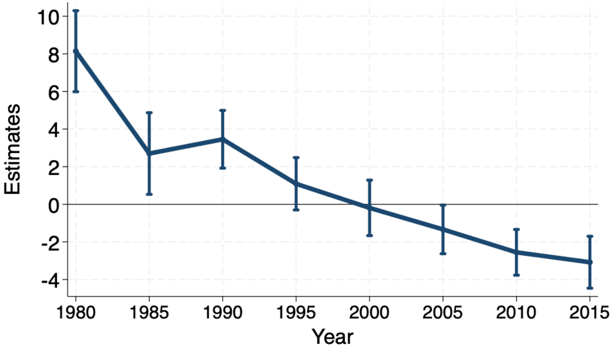
High-school Graduates as Skilled ‣ back

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



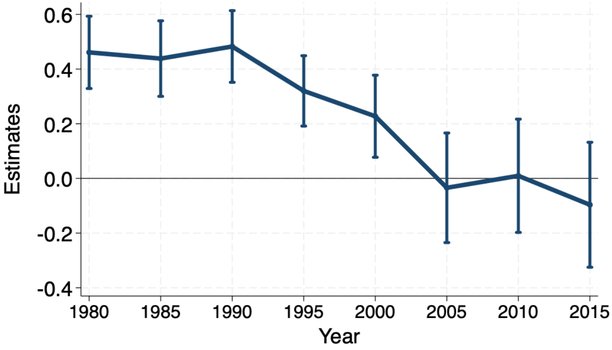
Instrument Skill Endowment by Cohort IV ▸ back

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



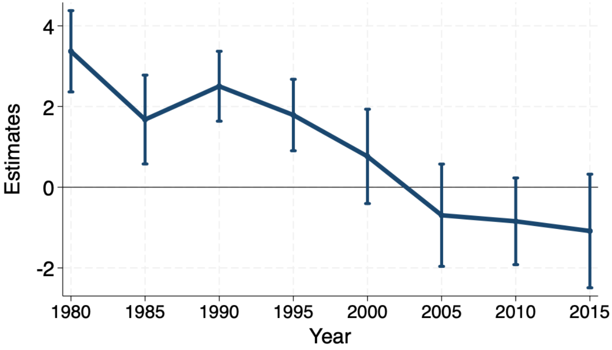
Chor (2011): Num of Workers as Factor Intensity ▸ back

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



Romalis (2004): Total Export ‣ back

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

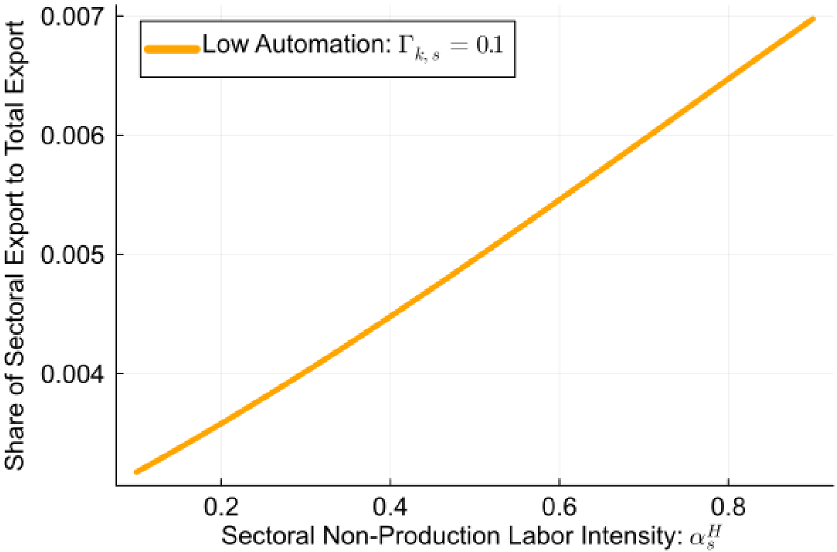


TWO COUNTRY ILLUSTRATION: AUTOMATION

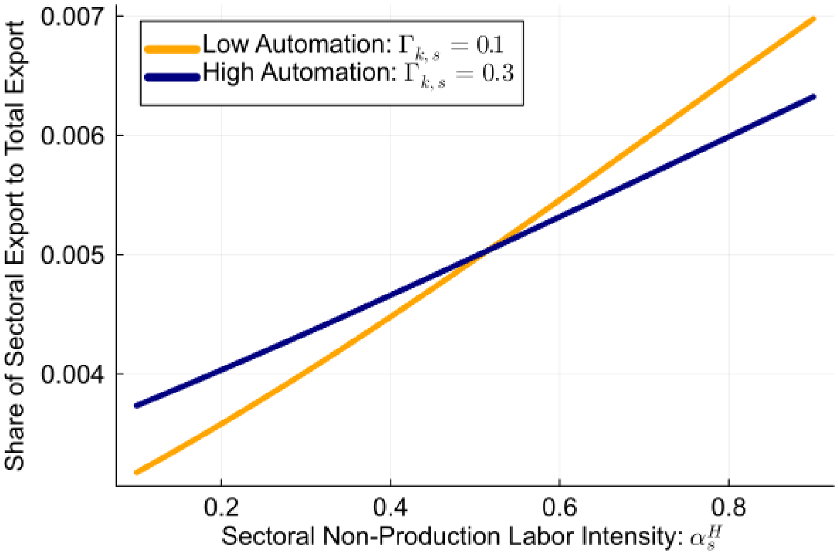
Two Country Illustration: Automation

- 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

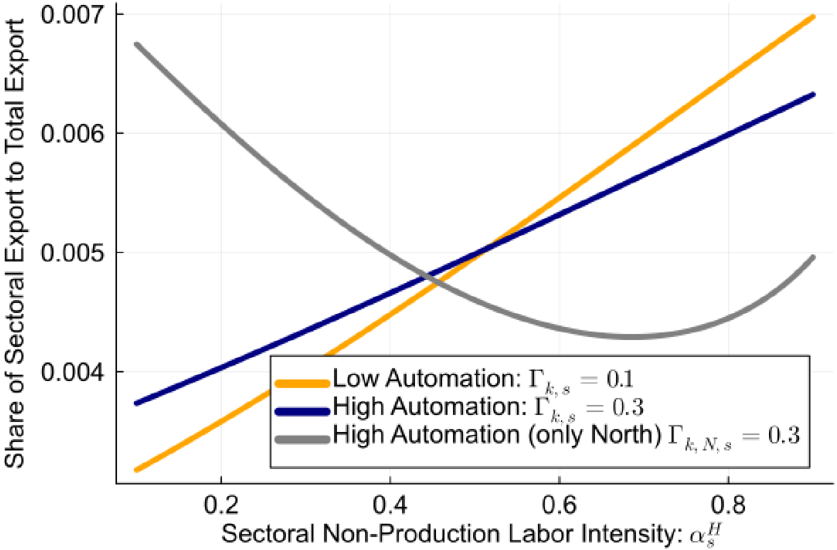
North Specialize in Skill-Intensive Sectors



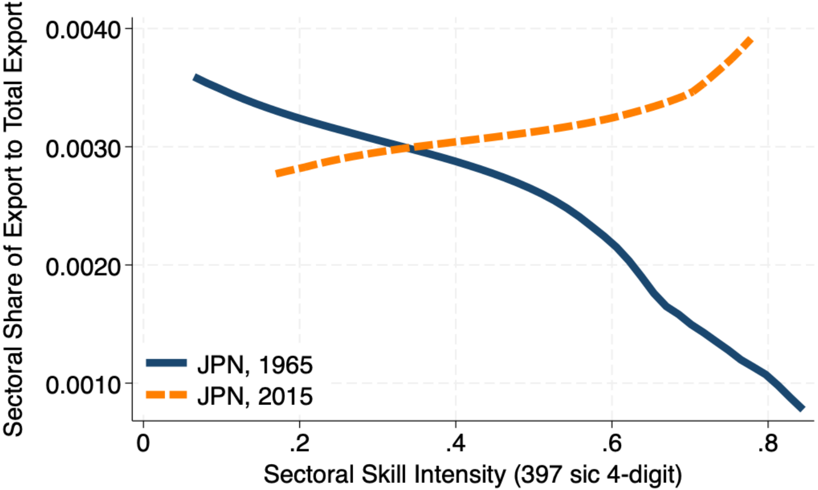
Automation Makes Skills Less Important



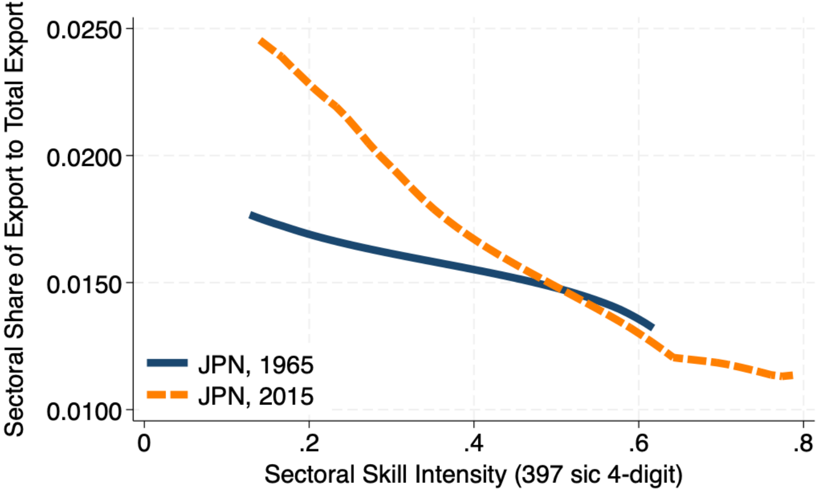
If Only North Automates, Sign Flips



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.