Global Value Chains and Inequality with Endogenous Labor Supply

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[1] The views expressed here are those of the authors and are not necessarily reflective of views of the Federal Reserve Banks of Dallas, Minneapolis, or the Federal Reserve System.

Motivation

- Key feature of increased international trade is increased prevalence of global value chains (GVCs)
  - Value-added exports as share of total exports fell 10 percentage points between 1970 and 2009 (Johnson and Noguera, 2016)
  - GVC generates magnified effects of trade costs and decline in trade costs on trade flows (e.g., Yi, 2003, 2010)
- Much research has shown that increased international trade has increased inequality
  - Goldberg and Pavcnik (2007) survey suggests that more countries experience increase in inequality than implied by Heckscher-Ohlin model and Stolper-Samuelson implications
- What is role of GVCs in increased inequality?

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This Paper

- What We Do
  1. Develop **multi-sector model of GVCs with endogenous occupational choice**
     - ★ Two GVC mechanisms: “roundabout" and “snake"
     - ★ Roy mechanism: Facilitates general sorting pattern among workers
  2. Quantitatively assess role of GVCs in propagating globalization shocks on aggregate and distributional outcomes within and across countries
- In response to decline in China's trade costs, calibrated model implies:
  - Increase in skill premium in both China and the U.S.
    - ★ GVCs lead to increased specialization across stages, which leads to skill upgrading in both countries
  - GVCs magnify aggregate and increase distributional outcomes in China and U.S.

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Related Research

- Aggregate effects of **vertical specialization**
  - Documentation and models: Hummels et al. (2001), Yi (2003;2010), Johnson and Noguera (2012; 2016), Antras et al. (2013), Fally and Hillberry (2014), Johnson and Moxnes (2015)
  - Recently: **Antras and de Gortari (2017), de Gortari (2017)**
- **Roy-like assignment framework**
  - Theory: Costinot and Vogel (2010)
  - Quantitative approach: Lagakos and Waugh (2013), Hsieh et al. (2016), Burstein et al. (2016), **Lee (2017)**, Galle et al. (2017)
- Sectoral linkage of production: Caliendo and Parro (2015)
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Outline

1. Introduction
2. 2^5 Version of Model
3. Numerical Exercises with 2^5 Model
4. Calibration and Estimation of Baseline Model
5. Counterfactuals

Outline

Basic Setup

- 2 countries ($i = 1, 2$: source; $n = 1, 2$: destination)
- 2 sectors ($s = 1, 2$)
- 2 occupations ($o = L, H$)
- 2 stages of production ($j = 1, 2$)
- 2 worker types ($t = L, H$)

Goods market: Comparative advantage determines which goods and stages are made in which source country and are shipped to which destination country

Labor market: Firms' occupational demands interact with workers' occupational supply (Roy model)

Preferences

- Nested preferences
  - Cobb-Douglas preferences across sectors with expenditure share $b^s \in [0, 1]$
  - CES preferences over products within sector with elasticity of substitution $\sigma > 0$

Production Functions

There is a continuum of goods ω on the unit interval in each sector

- Production function for each stage:

$$f_i^{s,1}(\omega) = z_i^{s,1}(\omega)(x_i^{s,1})^{1-\alpha_i^s}((L_i^{s,1,H}(\omega))^{\beta^{1,H}}(L_i^{s,1,L}(\omega))^{\beta^{1,L}})^{\alpha_i^s}$$

$$f_i^{s,2}(\omega) = z_i^{s,2}(\omega)[(x_i^{s,2})^{1-\alpha_i^s}((L_i^{s,2,H}(\omega))^{\beta^{2,H}}(L_i^{s,2,L}(\omega))^{\beta^{2,L}})^{\alpha_i^s}]^{\gamma^s}(m_i^{s,1}(\omega))^{1-\gamma^s}$$

- $z_i^{s,j}$: Fréchet productivity parameter
- $x_i^{s,j}$: Composite intermediate used in production ("roundabout")
- $L_i^{s,j,o}$: Occupational input o used in production
- $m_i^{s,1}$: Stage 1-good used in stage-2 production ("snake")
- $1-\gamma^s \in [0,1]$: share of stage-1 good in stage-2 production
- $\alpha_i^s \in [0,1]$: value-added share (1-composite intermediate share)
- $\beta^{j,o} \in [0,1]$: occupation intensity for occupation o
  - $\beta^{j,H} + \beta^{j,L} = 1$ for every j

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Sourcing Problem

- Perfect competition
- Stage 2 producers buy stage 1 materials from home or abroad, and composite intermediate "aggregator" firms buy stage 2 goods from home or abroad
- Iceberg trade costs: $\tau_{in}^{s} \geq 1$
- Productivity draws as in Eaton and Kortum (2002) and Antras and de Gortari (2017)

$$z_i^{s,j}(\omega) \sim F_i^{s,j}(z) = \exp(-A_i^s z^{-\nu\tilde{\gamma}^{s,j}}),$$

  where $\tilde{\gamma}^{s,1} \equiv 1 - \gamma^s$ and $\tilde{\gamma}^{s,2} \equiv 1$
- We draw from decentralized approach of Antras and de Gortari (2017)
  - Independent sourcing
  - Limited information on upstream productivities Sourcing Equilibrium
- Composite sectoral good is consumed, or aggregated with other composite sectoral goods to form an overall composite intermediate, which is used in stage-1 and stage-2 production (roundabout channel)

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Heterogeneous Workers

- Type-level labor supply $\bar{L}_{i,t}$ is exogenously given
- Within each type, workers are heterogeneous in (sector, occupation)-specific productivities
  - $\Rightarrow$ **"Roy" mechanism**
- $\epsilon^{s,o}$: Idiosyncratic productivity of individual worker for (s, o)
  - Randomly drawn from a Fréchet distribution:

$$G_t^{s,o}(\epsilon) = \exp(-T_t^{s,o}\epsilon^{-\theta_t})$$

  - Interpretation: efficiency units of labor
  - θ_τ: Within-type dispersion of productivity, **labor supply elasticity**
  - $T_t^{s,o}$: Level of labor productivity

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Equilibrium Labor Supply and Wages

- Worker's problem characterizes the Roy mechanism:

$$\max_{s,o} w_i^{s,o} \epsilon^{s,o}$$

- Equilibrium labor supply:

$$\pi_{i,t}^{s,o} = \frac{T_t^{s,o}(w_i^{s,o})^{\theta_t}}{\sum_{s',o'} T_t^{s',o'}(w_i^{s',o'})^{\theta_t}}$$

- Equilibrium type-level average wage:

$$\bar{w}_{i,t} = [\sum_{s',o'} T_t^{s',o'}(w_i^{s',o'})^{\theta_t}]^{1/\theta_t}\Gamma(1 - \frac{1}{\theta_t})$$

  - Skill premium: ratio of $\bar{w}_{i,H}$ to $\bar{w}_{i,L}$

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2^5 Model: Equilibrium

- Equilibrium probability of a GVC path $l = (l^1, l^2)$ Details

$$\lambda^s_{l,i} = \frac{A^s_{l^1}(c^{s,1}_{l^1}\tau^s_{l^1 l^2})^{-\nu(1-\gamma^s)} \times A^s_{l^2}[(c^{s,2}_{l^2})^{\gamma^s}\tau^s_{l^2 i}]^{-\nu}}{\sum_{l'\in \mathbf{N}^2} A^s_{l'^1}(c^{s,1}_{l'^1}\tau^s_{l'^1 l'^2})^{-\nu(1-\gamma^s)} \times A^s_{l'^2}[(c^{s,2}_{l'^2})^{\gamma^s}\tau^s_{l'^2 i}]^{-\nu}}$$

  - Effect of changes in trade costs on aggregate trade flows can be multiplied

- Labor market clearing:

$$\frac{1}{\alpha^s_i}\sum_t \bar{w}_{i,t}\pi^{s,o}_{i,t}\bar{L}_{i,t} = \underbrace{(1-\gamma^s)\beta^{1,o}\sum_{n=1}^{N}\sum_{l\in\Lambda^1_i}\lambda^s_{l,n}X^s_n}_{\text{stage 1's contribution}} + \underbrace{\gamma^s\beta^{2,o}\sum_{n=1}^{N}\sum_{l\in\Lambda^2_i}\lambda^s_{l,n}X^s_n}_{\text{stage 2's contribution}}$$

where $X^s_n \equiv b^s[\sum_t \bar{w}_{n,t}\bar{L}_{n,t} + \sum_{s'}\frac{(1-\alpha^{s'}_n)}{\alpha^{s'}_n}\sum_o\sum_t \bar{w}_{n,t}\pi^{s',o}_{n,t}\bar{L}_{n,t}]$

  - Extreme GVC intensities imply stage specialization is irrelevant for skill premium

General Version

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General Version

Transmission channels

- Four main channels:
  1. Country-level comparative advantage: HO and Ricardian
  2. "Roundabout" production structure
  3. "Snake" production structure $\Rightarrow$ global value chain (GVC)
  4. Worker-level comparative advantage: "Roy" channel
- Our model builds bridges between these channels

Interaction of Comparative Advantages and Skill Premia

- HO comparative advantage
  - Across **production stages** via relative endowments of labor and $\beta^{j,o}$.
  - Across **sectors** if $1-\alpha^s$ or $1-\gamma^s$ vary across sectors
- Ricardian comparative advantage (CA)
  - Across **sectors** via relative A_i^s in conjunction with Roy worker sorting into CA sector and the occupation for which workers have relatively high productivity
    - $1-\gamma^s$ plays a role, because it determines how much sector specialization feeds into demand for occupations
- Roy (worker-level) comparative advantage
  - Across **sectors** and **occupations**: based on $T_i^{s,o}$

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2^5 Model: Numerical Example

- Focus on how HO and the Roy mechanisms operate through GVC
- We set parameter values so that **country 1** has a HO comparative advantage in **stage 1** and **sector 1**
  - Stage 1 uses **low-skilled occupations** more intensively
- Two counterfactual trade costs: $\tau_{in}^{s} = 2$ and $\tau_{in}^{s} = 1$ for all i, n, and s
- Results (when trade costs fall)
  - Aggregate effect: **greater specialization in stages of production**
    - Domestic sourcing becomes less likely (e.g., falls from 83.7% to 26.4% in sector 1)
    - Most prevalent GVC is $l = (1, 2)$
  - Skill premium ($\bar{w}_{i,H}/\bar{w}_{i,L}$) **decreases (-1.11%) in country 1 and increases (+1.08%) in country 2**
    - Stolper-Samuelson effects
- Workers switch sectors AND occupations

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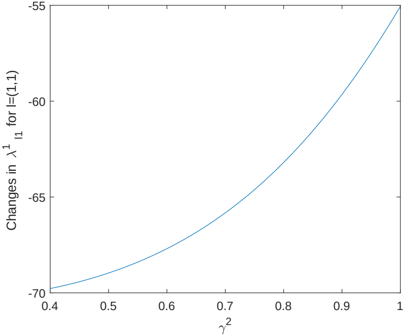
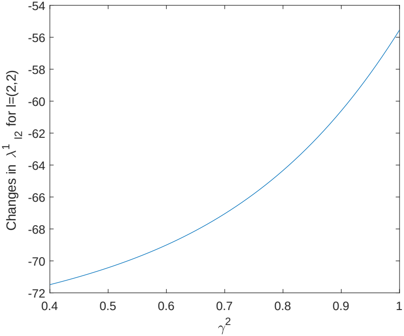
2^5 Model: GVC Intensity and Domestic Sourcing

- **GVC magnifies effect of decline in trade costs on trade flows**
- Exercise:
  - keep $\gamma^1 - \gamma^2 < 0$ fixed; raise or lower γ^1 (and γ^2)
  - Plot changes in domestic sourcing probability $\lambda^s_{(i,i),i}$

(a) Country 1, sector 1



(b) Country 2, sector 1

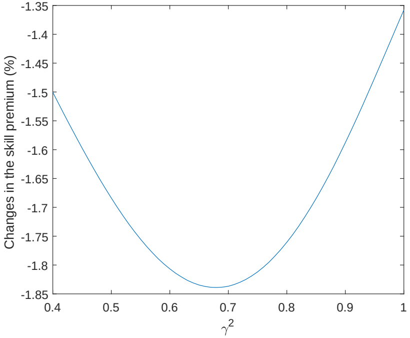


- Larger magnification effects with lower γ^s; monotonic magnification effects

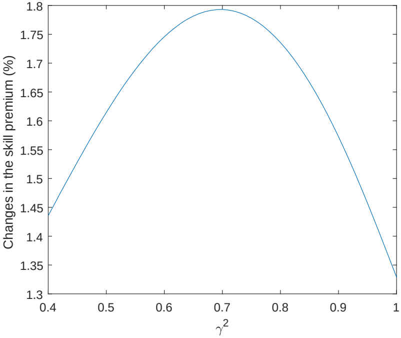
2⁵ Model: GVC Intensity and the Skill Premium

- **Non-monotonic effects of the GVC intensity on the skill premium**

(a) Country 1



(b) Country 2



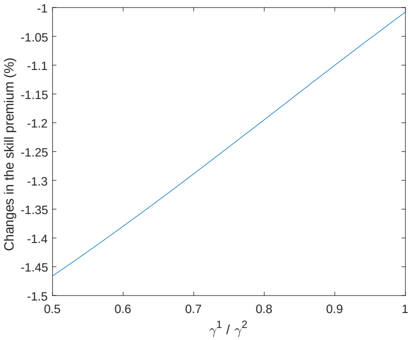
- With extreme GVC intensities, skill premium affected only by sector specialization – therefore, smaller changes

2^5 Model: Sectoral Variation in GVC Intensity

Exercise:

- Move γ^1 and γ^2 in opposite directions in order to reinforce HO CA
  - Make stage 1 (stage 2) more important for sector 1 (sector 2)
  - Implies that each country's CA (stage,sector) becomes more important
- Plot changes in the skill premium from decline in trade costs

(a) Country 1



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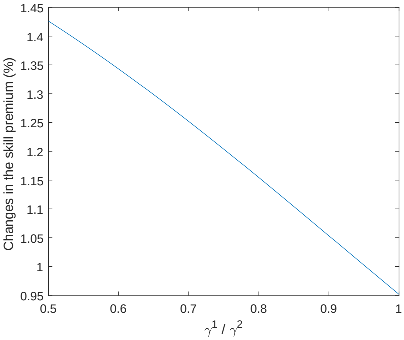

Larger skill premium effects if higher weights on CA stage and CA sector

Outline

Outline

Roadmap

3 Countries	China, US, ROW
5 Worker Types	Based on Education
4 Sectors	Agr, Min, Mfg, Svc
2 Production stages	Stage 1, stage 2
5 Occupations	Based on required skill level

- Data: WIOD 2000 and ACS 2000

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- Data: WIOD 2000 and ACS 2000
- Parameters
  - Assigned: σ (2) and ν (4)
  - Calibrated from data: b^s, $\bar{L}_{i,t}$, and τ^s_{in}
  - Estimated from data: $T^{s,o}_t$ and θ_t (Roy parameters)
  - Calibrated by matching moments of model: A^s_i, $\gamma^{s,j}$, α^s_i, and $\beta^{j,o}_i$

Calibration of Bilateral Trade Costs

- Use WIOD IO tables for data counterpart of bilateral final goods trade flows:

$$\tilde{\lambda}_{in}^{F,s} = \sum_{l \in \Lambda_i^J} \lambda_{l,n}^s$$

- Assume symmetry of bilateral trade costs, then use Head-Ries index to back out τ_{in}^s conditional on ν

Estimation of Roy Parameters

- Assume that Roy parameters ($T_t^{s,o}$ and θ_t) do not vary by country
  - Parameters govern complementarity between skill and (sector,occupation)-specific task

- Use within-type wage distribution in U.S. in 2000 to jointly estimate $\sum_{s,o} T_t^{s,o}(w_{US}^{s,o})^{\theta_t}$ and θ_t for each type t using MLE

- Use $\pi_{US,t}^{s,o}$ in 2000 to back out $T_t^{s,o}$ up to normalization (cf. Hsieh et al. (2013))

- Results
  - More within-type heterogeneity for higher skilled workers
  - Better educated workers have CA in the service sector and high-skilled occupations

Graph on T

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Main Calibration

- Need to calibrate:
  - γ^s: share of stage 2 value-added ($1-$ GVC intensity)
  - α_i^s: value-added share
  - A_i^s: sector- and country-level average productivity level
  - $\beta_i^{j,o}$: occupation intensity in each stage and each country

- Calibrate by targeting moments:
  - Domestic absorption of final/intermediate goods for each sector and each country
  - Ratio of value added to gross output for each sector and each country
  - Share of each country's GDP in each sector
  - Share of labor payment to each occupation group in each sector in each country

- Conditional on parameters already calibrated/estimated: ν, σ, b^s, $\bar{L}_{i,t}$, θ_t, $T_t^{s,o}$, and τ_{in}^s

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Main Calibration: Results

- $\beta_i^{j,o}$: Occupation intensities vary a lot by stage and country. For example,

	Stage 1	Stage 2
US	high-skilled o intensive	low-skilled o intensive
China	low-skilled o intensive	high-skilled o intensive

- γ^s: GVC intensities vary by sector
  - Relatively lower in agriculture (0.12) and manufacturing (0.39)
  - Relatively higher in mining (0.50) and services (0.44)

- α_i^s: also varies significantly by country and sector (avg 0.50; std dev 0.22)

- A_i^s: China (US) has a Ricardian comparative advantage in manufacturing (in service)

Outline

1. Introduction
2. 2^5 Version of Model
3. Numerical Exercises with 2^5 Model
4. Calibration and Estimation of Baseline Model
5. Counterfactuals

Outline

Aggregate Effect of China Shock

- Main counterfactual scenario: decline in trade costs with China by 50%

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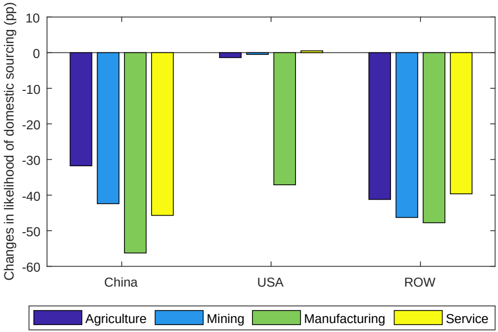
- Changes in prevalence of domestic sourcing: $\lambda^{s}_{(i,i),i}$
  - **Domestic sourcing becomes less likely everywhere**



Specialization and the Skill Premium

- **Sector specialization**: US specializes in services, China specializes in manufacturing
  - Through Roy channel, higher educated workers have CA in services
  - Leads to **increase (decrease)** in skill premium **in the U.S. (in China)**

- **Stage specialization**: Three key outcomes drive results.
  1. Within sectors, US specializes in stage 1, China specializes in stage 2
  2. Stage 1 (stage 2) is more high-skilled-occupation-intensive in the U.S. (in China); hence, both countries specialize in high-skilled-occupation-intensive stage
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  - Three outcomes lead to **increase** in skill premium **both in the U.S. and China**

  Graph

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Distributional Effect of China Shock

- Changes in the skill premium: $\bar{w}_{i,H}/\bar{w}_{i,L}$

	China	USA	ROW
% Baseline	0.25	0.94	1.09
% No GVC (no recalib)	-1.16	0.17	1.04
% No GVC (recalib)	-0.39	0.02	0.50

- The GVC channel is more important than sector specialization

- **U.S.** has CA in, and specializes in, **stage 1** and **service** sector
  - Both sector and stage specializations **increase** U.S. skill premium

- **China** has CA in, and specializes in **stage 2** and **manufacturing** sector
  - Low-skilled workers have CA in **manufacturing**, which leads to **lower** skill premium
  - **Stage 2** is relatively high-skilled-occupation-intensive in China
  - High-skilled workers have CA in high-skilled occupations, which leads to **higher** skill premium
  - On net, stage specialization dominates sector specialization

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- Two alternative counterfactuals
- Alternative 1: Shut down the GVC channel by setting $\gamma^s = 1$. Do not recalibrate other parameters.
  - Only sector specialization affects the skill premium
  - The skill premium **increases** in the **U.S.** by **0.17%**
  - The skill premium **decreases** in **China** by **1.16%**
- Alternative 2: Fix $\beta_i^{j,o}$; set $\gamma^{MFG} = 1$ and $\gamma^{SVC} = 0$
  - Puts the maximum weights on each country's CA (stage,sector)
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Role of GVC Mechanism

GVC channel:

- **Magnifies aggregate** effects of China trade shock
- **Delivers skill upgrading story** through stage specialization
  - **Direction** of changes in the skill premium
- **Increases distributional effects of the China trade shock**, but, because of lower weights on each country's CA (stage,sector)
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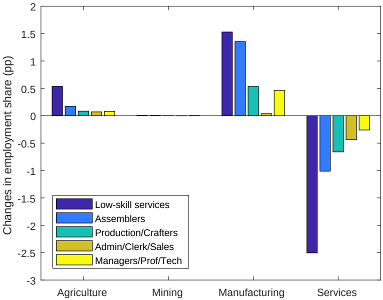
Within-type Labor Reallocation

- Different labor reallocation patterns across different worker types
- For example, in China,

(a) High school dropouts



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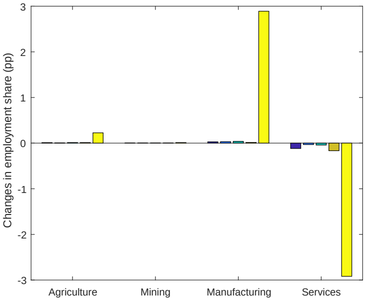


USA

Conclusion

- Develop multi-sector GVC model with endogenous labor supply that builds bridges between country-level CA, worker-level CA, and two types of GVCs (snake and roundabout)
- Quantitatively assess the role of GVCs in transmitting trade shocks to aggregate and distributional outcomes
- Quantitative results suggest that:
  - GVCs magnify aggregate effects, and increase distributional effects, of trade liberalization on China and U.S.
  - A skill upgrading story can occur via the GVC channel
  - Effect of GVC (stage specialization) on the skill premium is larger than that of sector specialization
  - Sectoral variation in GVC intensity is important in determining magnitude of effect

Multi-stage Production

- Production function:

$$f_i^{s,j}(x_i^{s,j}, L_i^{s,j,1}(\omega), \ldots, L_i^{s,j,O}(\omega), m_i^{s,j-1}(\omega)) =$$

$$z_i^{s,j}(\omega)((x_i^{s,j})^{1-\alpha_i^s}\prod_o (L_i^{s,j,o}(\omega))^{\beta_i^{j,o}\alpha_i^s})^{\gamma^{s,j}}(m_i^{s,j-1}(\omega))^{1-\gamma^{s,j}}$$

- $(1-\gamma^{s,j}) \in [0,1]$: share of stage $(j-1)$ materials in stage j production
  - GVC intensity
  - Note $\gamma^{s,1} \equiv 1$ for every s
- $\alpha_i^s \in [0,1]$: value-added share
- $\beta_i^{j,o} \in [0,1]$: occupation intensity at stage j in country i
  - $\sum_o \beta_i^{j,o} = 1$ for every i and j

Back:Production

Sourcing Decision: Equilibrium

- Probability of the entire GVC path

$$\lambda_{l,i}^{s} = \frac{\prod_{j=1}^{J} A_{l^j}^{s,j} [(c_{l^j}^{s,j})^{\gamma^{s,j}} (\tau_{l^j l^{j+1}}^{s})]^{-\nu \tilde{\gamma}^{s,j}}}{\sum_{l' \in \mathbf{N}^J} \prod_{j=1}^{J} A_{l'^j}^{s,j} [(c_{l'^j}^{s,j})^{\gamma^{s,j}} (\tau_{l'^j l'^{j+1}}^{s})]^{-\nu \tilde{\gamma}^{s,j}}}$$

where $\mathbf{N}^J$ is a set of all J-dim permutations of N countries

- Overall effective trade elasticity is larger if GVC intensity is larger

- Effective trade elasticity is larger in downstream stages

Unit cost equation | Exact price index | Sourcing Problem: Detail | Back:Main

Unit Cost and Price Index

- Unit cost of input bundle excluding stage $j-1$ materials

$$c_i^{s,j} \equiv \varphi_i^{s,j}(P_i)^{1-\alpha_i^s} \prod_o (w_i^{s,o})^{\alpha_i^s \beta_i^{j,o}}$$

for some constant $\varphi_i^{s,j}$

- Sector-level exact price index

$$P_i^s = [\Gamma(\frac{\nu+1-\sigma}{\nu})]^{1/(1-\sigma)} (\sum_{l' \in \mathbf{N}^J} \prod_{j=1}^{J} A_{l'j}^{s,j} [(c_{l'j}^{s,j})^{\gamma^{s,j}} (\tau_{l'j\,l'j+1}^{s})]^{-\nu \tilde{\gamma}^{s,j}})^{-1/\nu}$$

Back:Sourcing1

Sourcing Equilibrium: Details

- Stage 1:

$$l_i^{s,1}(\omega) = \arg\min_l [(p_l^{s,1}(\omega)\tau_{li}^s)^{1-\gamma^{s,2}}] = \arg\min_l [(\frac{c_l^{s,1}}{z_l^{s,1}(\omega)}\tau_{li}^s)^{1-\gamma^{s,2}}]$$

- Stage j:

$$l_i^{s,j}(\omega) = \arg\min_l \{(\frac{(c_l^{s,j})^{\gamma^{s,j}}}{z_l^{s,j}(\omega)})^{1-\gamma^{s,j+1}} \times \Theta_l^{s,j-1}((1-\gamma^{s,j+1})(1-\gamma^{s,j})) \times (\tau_{li}^s)^{1-\gamma^{s,j+1}}\}$$

where $\Theta_i^{s,j}(x) \equiv E_j[(p^{s,j}_{l_i^{s,j}(\omega)}(\omega)\tau^s_{l_i^{s,j}(\omega)i})^x]$

- Equilibrium probability of stage j sourcing

$$\Pr(l_i^{s,j}(\omega) = n) = \frac{A_n^{s,j}(B_{ni}^{s,j})^{-\nu\tilde{\gamma}^{s,j}/(1-\gamma^{s,j+1})}}{\sum_{n'} A_{n'}^{s,j}(B_{n'i}^{s,j})^{-\nu\tilde{\gamma}^{s,j}/(1-\gamma^{s,j+1})}}$$

where $B_{ni}^{s,j} \equiv (c_n^{s,j})^{\gamma^{s,j}(1-\gamma^{s,j+1})} \times \Theta_n^{s,j-1}((1-\gamma^{s,j+1})(1-\gamma^{s,j})) \times (\tau_{ni}^s)^{1-\gamma^{s,j+1}}$

Back:Sourcing1

Details of the Simple 2^5 Case

- Production function for each stage:

$$z_i^{s,1}(\omega)(x_i^{s,1})^{1-\alpha_i^s}((L_i^{s,1,H}(\omega))^{\beta^{1,H}}(L_i^{s,1,L}(\omega))^{\beta^{1,L}})^{\alpha_i^s}$$

$$z_i^2(\omega)[(x_i^{s,2})^{1-\alpha_i^s}((L_i^{s,2,H}(\omega))^{\beta^{2,H}}(L_i^{s,2,L}(\omega))^{\beta^{2,L}})^{\alpha_i^s}]^{\gamma^s}(m_i^{s,1}(\omega))^{1-\gamma^s}$$

- Stage 1 sourcing decision:

$$l_i^{s,1}(\omega) = \arg\min_l[(p_l^{s,1}(\omega)\tau_{li}^s)^{1-\gamma^s}] = \arg\min_l[(\frac{c_l^{s,1}}{z_l^{s,1}(\omega)}\tau_{li}^s)^{1-\gamma^s}]$$

- Stage 2 sourcing decision:

$$l_i^{s,2}(\omega) = \arg\min_l[\frac{(c_l^{s,2})^{\gamma^s}}{z_l^{s,2}(\omega)} \times \Theta_l^s \times \tau_{li}^s]$$

Back:Equilibrium of the simple version

Labor Market Clearing Conditions

- Equilibrium $w_i^{s,o}$ solves the following set of $(N \times S \times O)$ labor market clearing conditions

$$\underbrace{\frac{1}{\alpha_i^s}\sum_t \bar{w}_{i,t}\pi_{i,t}^{s,o}\bar{L}_{i,t}}_{\text{labor supply}} = \underbrace{\sum_j \gamma^{s,j}\tilde{\gamma}^{s,j}\beta_i^{j,o}\sum_{n=1}^{N}\sum_{l\in\Lambda_i^j}\lambda_{l,n}^s X_n^s}_{\text{labor demand}}$$

$$X_n^s \equiv b^s[\sum_t \bar{w}_{n,t}\bar{L}_{n,t} + \sum_{s'}\frac{(1-\alpha_n^{s'})}{\alpha_n^{s'}}\sum_o\sum_t \bar{w}_{n,t}\pi_{n,t}^{s',o}\bar{L}_{n,t}]$$

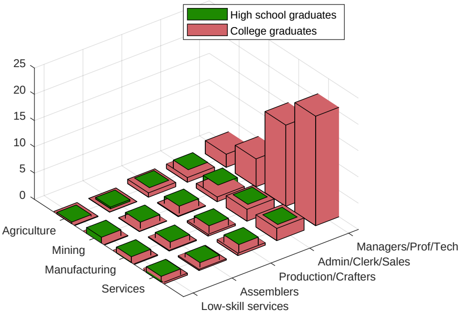
where $\Lambda_i^j \equiv \{l = (l^1, \ldots, l^J) \in \mathbf{N}^J | l^j = i\}$, up to a normalization

Back:2^5 case

Estimation of the Roy Parameters: Result

Worker type	t_1	t_2	t_3	t_4	t_5
Estimated θ_t	1.97	1.86	1.74	1.60	1.48

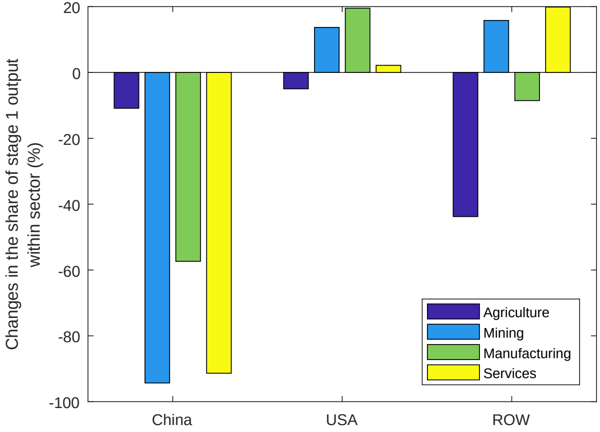
- Compare the estimates of $T_t^{s,o}$ for



Back:Roy Estimation

Aggregate Effect of China Shock: Specialization

- Changes in the share of stage 1 output within each sector



Back: Aggregate Effects

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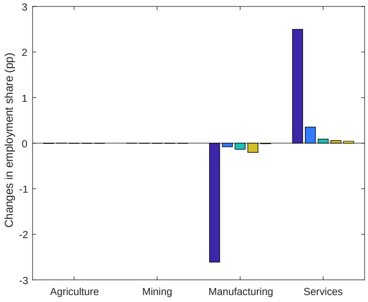

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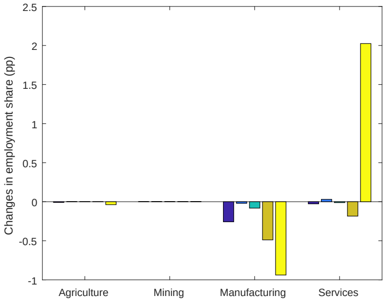
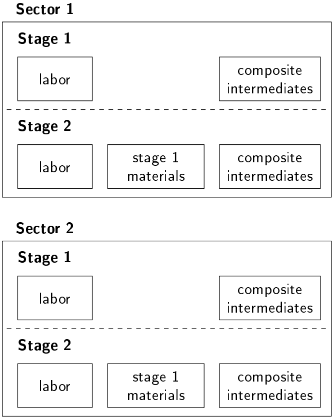


Back:China

Graphical Illustration of the Model: Production



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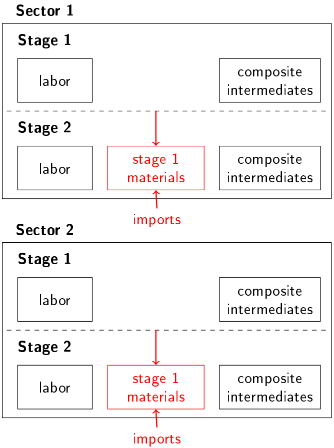

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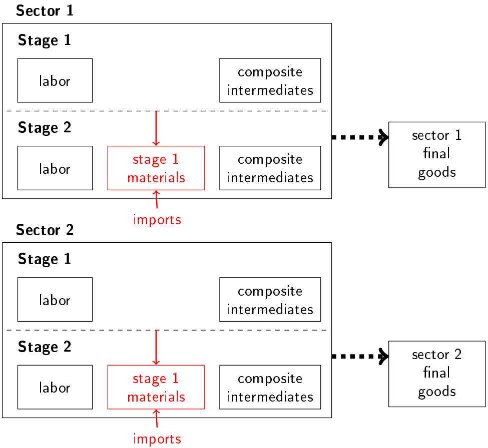

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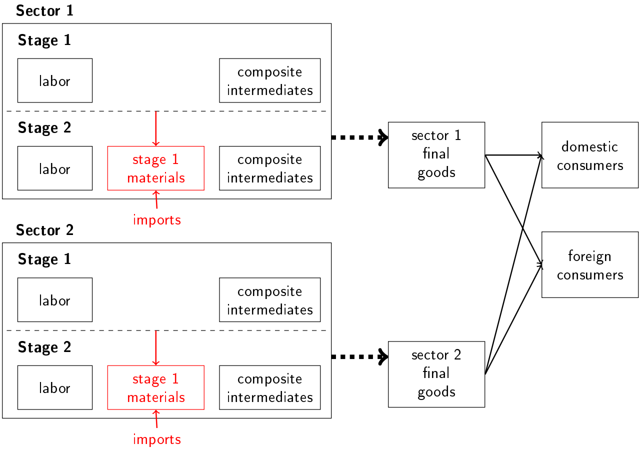

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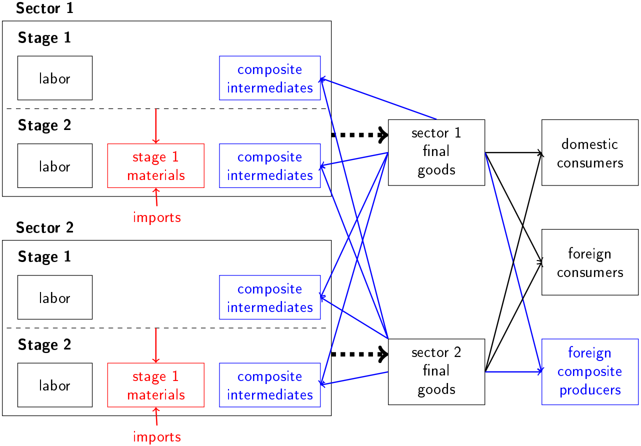

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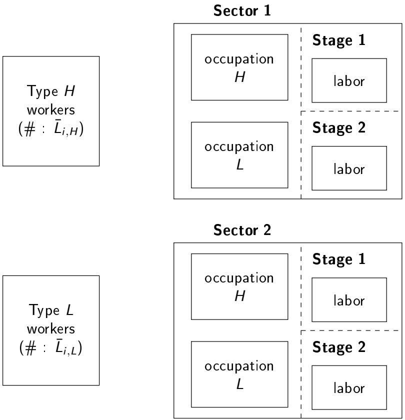

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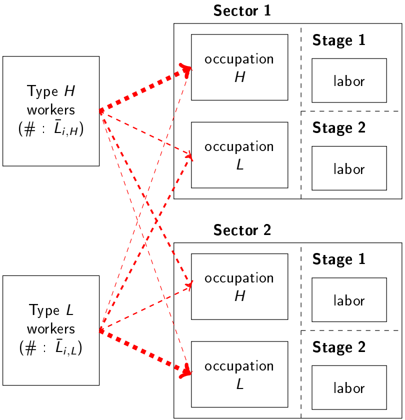

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