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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- What is role of GVCs in increased inequality?
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**

- **Roy-like assignment framework**
  - Theory: Costinot and Vogel (2010)

- **Sectoral linkage of production**: Caliendo and Parro (2015)

- **Offshoring and the skill premium**: Feenstra and Hanson (1996), Zhu and Trefler (2005), Krugman (2008), Costinot and Vogel (2010)
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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
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 $\omega$ on the unit interval in each sector

- Production function for each stage:

$$f_{i}^{s,1}(\omega) = z_{i}^{s,1}(\omega)(x_{i}^{s,1})^{1-\alpha_{i}^{s}}((L_{i}^{s,1,H}(\omega)))^{\beta_{1,H}^{s}}(L_{i}^{s,1,L}(\omega))^{\beta_{1,L}^{s}}\alpha_{i}^{s}$$

$$f_{i}^{s,2}(\omega) = z_{i}^{s,2}(\omega)[(x_{i}^{s,2})^{1-\alpha_{i}^{s}}((L_{i}^{s,2,H}(\omega)))^{\beta_{2,H}^{s}}(L_{i}^{s,2,L}(\omega))^{\beta_{2,L}^{s}}\alpha_{i}^{s}]^{\gamma_{s}}(m_{i}^{s,1}(\omega))^{1-\gamma_{s}}$$

- $z_{i}^{s,j}$: 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)
- $\beta_{j,o}^{s} \in [0, 1]$: occupation intensity for occupation $o$
  - $\beta_{j,H}^{s} + \beta_{j,L}^{s} = 1$ 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)

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

  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

- 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:
    
    \[ G^{s,o}_t(\epsilon) = \exp(-T^{s,o}_t \epsilon^{-\theta_t}) \]

  - Interpretation: efficiency units of labor
  - $\theta_{\tau}$: Within-type dispersion of productivity, labor supply elasticity
  - $T^{s,o}_t$: Level of labor productivity
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Worker’s problem characterizes the Roy mechanism:

$$\max_{s,o} w_{i}^{s,o} e^{s,o}$$

Equilibrium labor supply:

$$\pi^{s,o}_{i,t} = \frac{T^{s,o}_{t}(w_{i}^{s,o})^{\theta_{t}}}{\sum_{s'},o' T^{s',o'}_{t}(w_{i}^{s',o'})^{\theta_{t}}}$$

Equilibrium type-level average wage:

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

Skill premium: ratio of $\bar{w}_{i,H}$ to $\bar{w}_{i,L}$
Worker’s problem characterizes the Roy mechanism:

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Equilibrium labor supply:

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\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}}
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Skill premium: ratio of \(\bar{w}_{i, H}\) to \(\bar{w}_{i, L}\)
**Model: Equilibrium**

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

$$\lambda_{l,i}^s = \frac{A_{l_1}^s (c_{l_1}^{s,1} \tau_{l_1}^{s,1})^{-\nu (1-\gamma^s)} \times A_{l_2}^s [(c_{l_2}^{s,2})^{s} \tau_{l_2}^{s,2}]}{\sum_{l'' \in N} A_{l''_1}^s (c_{l''_1}^{s,1} \tau_{l''_1}^{s,1})^{-\nu (1-\gamma^s)} \times A_{l''_2}^s [(c_{l''_2}^{s,2})^{s} \tau_{l''_2}^{s,2}]}^{-\nu}$$

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

- Labor market clearing:

$$\frac{1}{\alpha_i^s} \sum_t \bar{w}_{i,t} \pi_{i,t}^{s,o} \bar{L}_{i,t} = (1-\gamma^s) \beta^{1,o} \sum_{n=1}^N \sum_{l \in \Lambda_i^1} \lambda_{l,n}^s X_n^s + \gamma^s \beta^{2,o} \sum_{n=1}^N \sum_{l \in \Lambda_i^2} \lambda_{l,n}^s X_n^s$$

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

- Extreme GVC intensities imply stage specialization is irrelevant for skill premium
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where \( X_n^s \equiv b^s \left[ \sum_t \bar{w}_{n,t} \bar{L}_{n,t} + \sum_{s'} \left( \frac{1 - \alpha_n^{s'}}{\alpha_n^{s'}} \right) \sum_t \bar{w}_{n,t} \bar{\pi}_{n,t}^{s',0} \bar{L}_{n,t} \right] \)

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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 $A^s_i$ 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 $T^{s,o}_i$
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3. Numerical Exercises with $2^5$ Model
4. Calibration and Estimation of Baseline Model
5. Counterfactuals

Lee and Yi
GVG and Inequality
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2 $2^5$ Version of Model
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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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    ▶ Stolper-Samuelson effects

Workers switch sectors AND occupations
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 $\gamma^1$ (and $\gamma^2$)
- 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 $\gamma^s$; monotonic magnification effects
Non-monotonic effects of the GVC intensity on the skill premium

With extreme GVC intensities, skill premium affected only by sector specialization – therefore, smaller changes
Model: Sectoral Variation in GVC Intensity

Exercise:
- Move $\gamma^1$ and $\gamma^2$ 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

(b) Country 2

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

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<td><strong>5 Occupations</strong></td>
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- Data: WIOD 2000 and ACS 2000
Roadmap

<table>
<thead>
<tr>
<th>3 Countries</th>
<th>China, US, ROW</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 Worker Types</td>
<td>Based on Education</td>
</tr>
<tr>
<td>4 Sectors</td>
<td>Agr, Min, Mfg, Svc</td>
</tr>
<tr>
<td>2 Production stages</td>
<td>Stage 1, stage 2</td>
</tr>
<tr>
<td>5 Occupations</td>
<td>Based on required skill level</td>
</tr>
</tbody>
</table>

- **Data:** WIOD 2000 and ACS 2000

- **Parameters**
  - Assigned: $\sigma$ (2) and $\nu$ (4)
  - Calibrated from data: $b^s$, $\bar{L}_{i,t}$, and $\tau^s_{in}$
  - Estimated from data: $T^s_{t,o}$ and $\theta_t$ (Roy parameters)
  - Calibrated by matching moments of model: $A^s_i$, $\gamma^{s,j}$, $\alpha^s_i$, 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 \( \tau_{in}^s \) conditional on \( \nu \)
Estimation of Roy Parameters

- Assume that Roy parameters ($T^s_o$ and $\theta_t$) 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 $\sum_{s,o} T^s_o (w^s_o)^{\theta_t}$ and $\theta_t$ for each type $t$ using MLE

- Use $\pi^s_o_{US,t}$ in 2000 to back out $T^s_o$ 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
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Main Calibration

- Need to calibrate:
  - $\gamma^s$: share of stage 2 value-added (1 - GVC intensity)
  - $\alpha^s_i$: value-added share
  - $A^s_i$: sector- and country-level average productivity level
  - $\beta^j_i$: 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: $\nu$, $\sigma$, $b^s$, $\bar{L}_{i,t}$, $\theta_t$, $T_{t,o}^s$, and $\tau_{in}^s$
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- Conditional on parameters already calibrated/estimated: $\nu$, $\sigma$, $b^s$, $\bar{L}_{i,t}$, $\theta_t$, $T^s_{i,o}$, and $\tau^s_{in}$
Main Calibration: Results

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

<table>
<thead>
<tr>
<th>Stage 1</th>
<th>Stage 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>US high-skilled</td>
<td>low-skilled</td>
</tr>
<tr>
<td>low-skilled intensive</td>
<td>low-skilled intensive</td>
</tr>
<tr>
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- $\gamma^s$: 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)

- $\alpha^s_i$: also varies significantly by country and sector (avg 0.50; std dev 0.22)

- $A^s_i$: 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
Aggregate Effect of China Shock

- Main counterfactual scenario: decline in trade costs with China by 50%
Aggregate Effect of China Shock

- Main counterfactual scenario: decline in trade costs with China by 50%
- 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
3. Through Roy channel, higher educated workers have CA in high-skilled occupations

- Three outcomes lead to increase in skill premium both in the U.S. and China

[Graph]
Specialization and the Skill Premium

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[Graph]
**Distributional Effect of China Shock**

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

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- 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
Distributional Effect of China Shock

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Alternative Counterfactuals

- **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 $\beta_{j,0}^i$; set $\gamma^{MFG} = 1$ and $\gamma^{SVC} = 0$
  - Puts the maximum weights on each country’s CA (stage,sector)
  - The skill premium **increases** in the U.S. (in China) by **1.47%** (**0.58%**)
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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

(b) Advanced degrees
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:

\[ f_{i}^{s,j}(x_i^{s,j}, L_i^{s,j,1}(\omega), \ldots, L_i^{s,j,O}(\omega), m_i^{s,j-1}(\omega)) = \]

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

- \((1 - \gamma_i^{s,j}) \in [0, 1]\): share of stage \((j - 1)\) materials in stage \(j\) production
  - GVC intensity
  - Note \(\gamma_i^{s,1} \equiv 1\) 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 \(j\)
Sourcing Decision: Equilibrium

- Probability of the entire GVC path

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

where \( N^J \) 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 and Price Index

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

$$c^s_{i,j} = \phi^s_{i,j} (P_i)^{1 - \alpha^s_i} \prod_{o} (w^{s,o}_i)^{\alpha^s_i \beta^j_{i,o}}$$

for some constant $\phi^s_{i,j}$

- Sector-level exact price index

$$P^s_i = \left[ \Gamma \left( \frac{\nu + 1 - \sigma}{\nu} \right) \right]^{1/(1 - \sigma)} \left( \sum_{l' \in N^J} \prod_{j=1}^J A^{s}_{l'j} \left[ (c^{s}_{l'j})^{\gamma^s_{j}} (\tau^{s}_{l'j/l'j+1})^{-\nu \gamma^s_{j}} \right]^{-1/\nu} \right)$$
Sourcing Equilibrium: Details

- **Stage 1:**

\[ l^{s,1}_i(\omega) = \arg \min \left[ \left( \frac{C^{s,1}_i}{Z^{s,1}_i(\omega)} \right)^{1 - \gamma^{s,2}} \right] = \arg \min \left[ \left( \frac{C^{s,1}_i}{Z^{s,1}_i(\omega)} \right)^{1 - \gamma^{s,2}} \right] \]

- **Stage j:**

\[ l^{s,j}_i(\omega) = \arg \min \left\{ \left( \frac{C^{s,j}_i}{Z^{s,j}_i(\omega)} \right)^{1 - \gamma^{s,j+1}} \times \Theta^{s,j-1}_i \left( \left( 1 - \gamma^{s,j+1} \right) \left( 1 - \gamma^{s,j} \right) \right) \times \left( \tau^{s}_i \right)^{1 - \gamma^{s,j+1}} \right\} \]

where \( \Theta^{s,j}_i(x) \equiv E_j \left[ (p^{s,j}_i(\omega) \tau^{s}_{i}(\omega))^{x} \right] \)

- **Equilibrium probability of stage j sourcing**

\[ \Pr(l^{s,j}_i(\omega) = n) = \frac{A^{s,j}_n (B^{s,j}_{ni})^{-\nu \gamma^{s,j}} / (1 - \gamma^{s,j+1})}{\sum_{n'} A^{s,j}_{n'} (B^{s,j}_{n'i})^{-\nu \gamma^{s,j}} / (1 - \gamma^{s,j+1})} \]

where \( B^{s,j}_{ni} \equiv (c^{s,j}_n)^{\gamma^{s,j}(1 - \gamma^{s,j+1})} \times \Theta^{s,j-1}_n \left( \left( 1 - \gamma^{s,j+1} \right) \left( 1 - \gamma^{s,j} \right) \right) \times \left( \tau^{s}_n \right)^{1 - \gamma^{s,j+1}} \)
Details of the Simple $2^5$ Case

- Production function for each stage:

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

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

- Stage 1 sourcing decision:

$$l_i^{s,1}(\omega) = \arg\min_l [(p_i^{s,1}(\omega) \tau_{li})^{1-\gamma^s}] = \arg\min_l [(\frac{C_i^{s,1}}{Z_i^{s,1}(\omega)})^{1-\gamma^s}]$$

- Stage 2 sourcing decision:

$$l_i^{s,2}(\omega) = \arg\min_l [(\frac{C_i^{s,2}}{Z_i^{s,2}(\omega)})^{\gamma^s} \times \Theta_i^s \times \tau_{li}^s]$$
Equilibrium $w^{s,o}_i$ solves the following set of $(N \times S \times O)$ labor market clearing conditions

$$\frac{1}{\alpha^s_i} \sum_t \bar{w}_{i,t} \pi^{s,o}_{i,t} \bar{L}_{i,t} = \sum_j \gamma^{s,j}_s \gamma^{s,j}_s \beta^j_o \sum_{n=1}^N \sum_{l \in \Lambda^j_i} \lambda^{s,n}_l X^{s}_n$$

where \( \Lambda^j_i \equiv \{ l = (l^1, \ldots, l^J) \in N^J | l^j = i \} \), up to a normalization.

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

where $\Lambda^j_i \equiv \{ l = (l^1, \ldots, l^J) \in N^J | l^j = i \}$, up to a normalization.
Estimation of the Roy Parameters: Result

<table>
<thead>
<tr>
<th>Worker type</th>
<th>$t_1$</th>
<th>$t_2$</th>
<th>$t_3$</th>
<th>$t_4$</th>
<th>$t_5$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated $\theta_t$</td>
<td>1.97</td>
<td>1.86</td>
<td>1.74</td>
<td>1.60</td>
<td>1.48</td>
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- Compare the estimates of $T_t^{S,O}$ for
Aggregate Effect of China Shock: Specialization

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

![Bar chart showing changes in the share of stage 1 output within each sector for China, USA, and ROW. The chart includes categories for Agriculture, Mining, Manufacturing, and Services.]
Within-type Labor Reallocation

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

(a) High school dropouts

(b) Advanced degrees
Graphical Illustration of the Model: Production

Sector 1

Stage 1
- labor
- composite intermediates

Stage 2
- labor
- stage 1 materials
- composite intermediates

Sector 2

Stage 1
- labor
- composite intermediates

Stage 2
- labor
- stage 1 materials
- composite intermediates
Graphical Illustration of the Model: Production
Graphical Illustration of the Model: Production

Sector 1

Stage 1
- Labor
- Composite intermediates

Stage 2
- Labor
- Stage 1 materials
- Composite intermediates

Stage 1 materials flow to sector 1 final goods

Imports flow from sector 1 to sector 2

Sector 2

Stage 1
- Labor
- Composite intermediates

Stage 2
- Labor
- Stage 1 materials
- Composite intermediates

Stage 1 materials flow to sector 2 final goods

Imports flow from sector 2 to sector 1

Lee and Yi
GV C and Inequality
January 13, 2018 29 / 30
Graphical Illustration of the Model: Production

Sector 1
- Stage 1
  - Labor
  - Composite intermediates
  - Stage 1 materials

Sector 2
- Stage 1
  - Labor
  - Composite intermediates

Imports

Sector 1 final goods

Domestic consumers

Foreign consumers

Sector 2
- Stage 1
  - Labor
  - Composite intermediates

Imports

Sector 2 final goods
Graphical Illustration of the Model: Production

Sector 1

Stage 1
- labor
- composite intermediates

Stage 2
- labor
- stage 1 materials
- composite intermediates

Sector 2

Stage 1
- labor
- composite intermediates

Stage 2
- labor
- stage 1 materials
- composite intermediates

Sectors 1 and 2 produce final goods, which are consumed by domestic and foreign consumers.
Graphical Illustration of the Model: Workers

Sector 1

Stage 1
- occupation $H$
- labor

Stage 2
- occupation $L$
- labor

Sector 2

Stage 1
- occupation $H$
- labor

Stage 2
- occupation $L$
- labor

Type $H$ workers (#: $L_{i,H}$)

Type $L$ workers (#: $L_{i,L}$)
Graphical Illustration of the Model: Workers

- **Type H workers** (#: $L_{i,H}$)
- **Type L workers** (#: $L_{i,L}$)

**Sector 1**
- **Stage 1**
  - Occupation $H$
  - Labor

- **Stage 2**
  - Occupation $L$
  - Labor

**Sector 2**
- **Stage 1**
  - Occupation $H$
  - Labor

- **Stage 2**
  - Occupation $L$
  - Labor
Graphical Illustration of the Model: Workers

Type $H$ workers (# : $L_{i,H}$)

Type $L$ workers (# : $L_{i,L}$)

Sector 1

Stage 1

Stage 2

Sector 2

Stage 1

Stage 2