Structural Change in Global Value Chains

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World Input-Output Table

- S sectors in J countries
- Row: sell intermediate input (I.I) to country-sector; sell final good to countries.
- Column: buy I.I from country-sector; make value added (VA) from primary factor
- Global Value Chains (GVC): the value of all activities such as sourcing of I.I and primary factor, that are directly and indirectly needed to produce final goods.

			Input use & value added							**Final use**			**Total use**
			Country 1			...	Country J			Country 1	...	Country J	
			Sector 1	...	Sector S	...	Sector 1	...	Sector S				
Inputs Supplied	Country 1	Sector 1	X_{11}^{11}	...	X_{11}^{1S}	...	X_{1J}^{11}	...	X_{1J}^{1S}	F_{11}^{1}	...	F_{1J}^{1}	GO_1^1
		...	...	X_{11}^{rs}	...	...	...	X_{1J}^{rs}	...	...	...	...	...
		Sector S	X_{11}^{S1}	...	X_{11}^{SS}	...	X_{1J}^{S1}	...	X_{1J}^{SS}	F_{11}^{S}	...	F_{1J}^{S}	GO_1^S
	...	...	...	...	...	X_{ij}^{rs}	...	...	...	...	F_{ij}^{r}	...	GO_i^r
	Country J	Sector 1	X_{J1}^{11}	...	X_{J1}^{1S}	...	X_{JJ}^{11}	...	X_{JJ}^{1S}	F_{J1}^{1}	...	F_{JJ}^{1}	GO_J^1
		...	...	X_{J1}^{rs}	...	...	...	X_{JJ}^{rs}	...	...	...	...	...
		Sector S	X_{J1}^{S1}	...	X_{J1}^{SS}	...	X_{JJ}^{S1}	...	X_{JJ}^{SS}	F_{J1}^{S}	...	F_{JJ}^{S}	GO_J^S
Value added			VA_1^1	...	VA_1^S	VA_j^s	VA_J^1	...	VA_J^S				
Gross output			GO_1^1	...	GO_1^S	GO_j^s	GO_J^1	...	GO_J^S				

Motivation

Definition

Let B denotes the global input-output matrix: $b_{ij}^{rs} = \frac{X_{ij}^{rs}}{GO_j^s}$, the vector of sectoral centrality E is defined as

$$E = (I - B)^{-1} \mathbb{1}$$

- In chapter 2, this centrality is called supply multiplier.
- In network, this is Bonacich centrality. Here it is a measure of direct and indirect supply connection from this sector to all other sectors.

Motivated Question

Chapter 2 suggests an important role of domestic centrality in structural change. Does this global centrality matters for structural change?

Fact

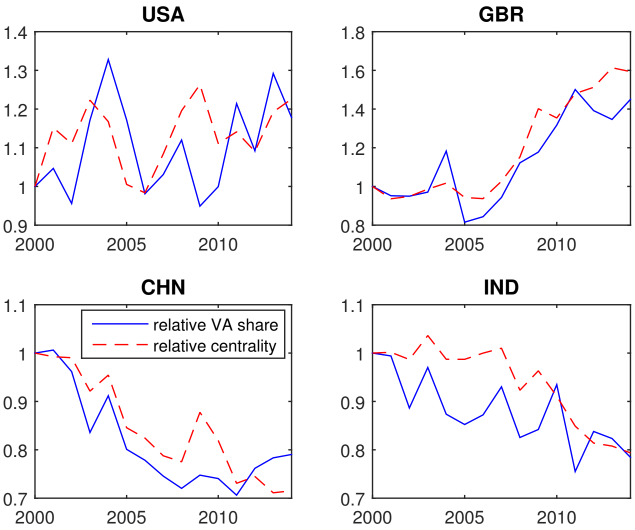

Figure: Crop and animal production, hunting and related service activities

Fact

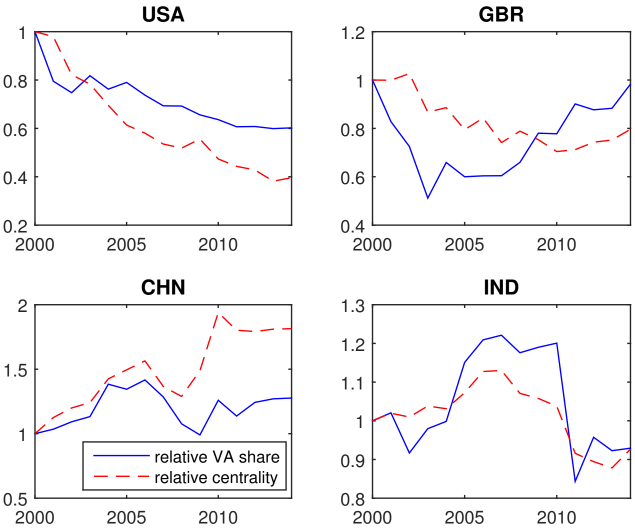

Figure: Manufacture of computer, electronic and optical products

Fact

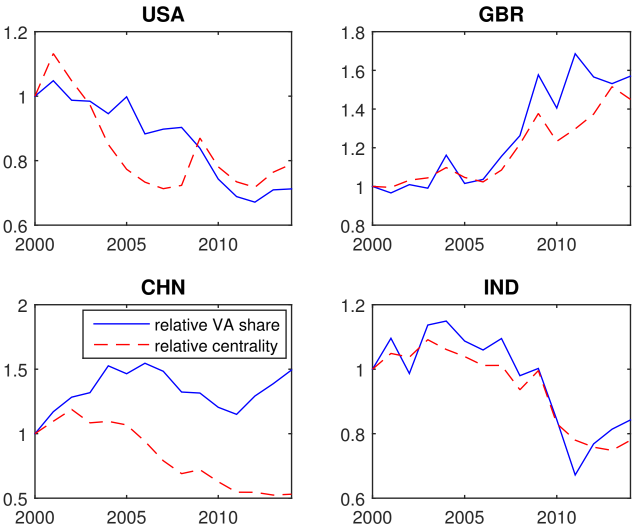

Figure: Telecommunications

Question

Question 1

How does trade of I.I and final output affect structural change?

- Domestic VA share based structural change
- Accounting mechanism
- Multi-country, multi-sector and multi-stage trade model

Question 2

If trade matters, which type of trade?

- International I.I trade vs. international final output trade
- International I.I trade vs. domestic I.I trade

Mechanism

Accounting Entity in GVC

In the supply side, trade flow is

$$P_i^r Q_i^r = \sum_{s=1}^{S} \sum_{j=1}^{J} b_{ij}^{rs} P_j^s Q_j^s + P_i^{rC} C_i^r$$

$$\gamma_i^r \equiv \frac{P_i^r Q_i^r}{GDP} = \sum_{s=1}^{S} \sum_{j=1}^{J} b_{ij}^{rs} \frac{P_j^s Q_j^s}{GDP} + \frac{P_i^{rC} C_i^r}{GDP}$$

- GDP is world GDP
- γ_i^r is Domar weight in terms of world GDP

Domar weight vector is solved as following:

$$\gamma = (I - B)^{-1} \lambda \tag{1}$$

- λ is vector of consumption share in terms of world GDP

Structural Term

VA share is constructed by

$$\begin{aligned}\eta_i^r &= \frac{VA_i^r}{VA_i} \\ &= \frac{VA_i^r}{GO_i^r}\frac{GO_i^r}{GDP}\frac{GDP}{VA_i} \\ &= (1-\sigma_i^r)\gamma_i^r\frac{GDP}{VA_i}\end{aligned}$$

- $\sigma_i^r = \sum_{t=1}^{S}\sum_{k=1}^{J} b_{ki}^{tr}$

Relative VA share is given by

$$\frac{\eta_i^r}{\eta_i^s} = \frac{1-\sigma_i^r}{1-\sigma_i^s}\frac{\gamma_i^r}{\gamma_i^s} \tag{2}$$

Empirical Evidence

Data

The latest World Input-Output Database contains

- $J = 44$ countries (43 major economies + rest of world)
- $S = 56$ sectors: 2-digit ISIC revision 4 level
- $T = 15$ years: 2000-2014

Perfect database to study effect of trade on structural change

- At any year, we have $44 \times 56 = 2464$ nodes, a big trade network.
- At any sector, we have country year panel $J \times T$.
- At any country, we have sector year panel $S \times T$.

Balanced dataset contains 30 sectors.

Country Year Panel

At every sector, we run the following regression

$$\hat{\eta}_{it} = \alpha + \beta \hat{e}_{it} + \hat{x}' \tau + f_i + f_t + u_{it}$$

- $\hat{\eta}_{it}$ is VA share relative to the benchmark sector.
- $\hat{e}_{it}$ is centrality relative to the benchmark sector.
- Benchmark sector: manufacture of chemicals and chemical products.
- $\hat{x}$ are control variables: Upstreamness and downstreamness (Antras and Chor 2018).

Result

- Centrality: Positive and significant at 1 percent for all 29 sectors.
- Upstream and downstream sectors tend to lose VA share, but the relationships are not as robust as in centrality.

Sector Year Panel

At every country, we run the following regression

$$\hat{\eta}_t^r = \alpha + \beta \hat{e}_t^r + \hat{x}' \tau + f_r + f_t + u_{rt}$$

- The panel here is sector, otherwise same as the last slide.

Result

- Centrality: Positive and significant at 1 percent for 40 out of 44 countries.
- Upstream and downstream sectors tend to lose VA share, but the relationships are not as robust as in centrality.

One Stage Model

Model Setup

- This model follows Lorenzo and Parro (2015); and Antras and Chor (2018).
- J countries: i and j denote country
- ij in subscript: international trade from i to j
- S sectors: r and s denote sector
- rs in superscript: inter-sectoral trade from r to s
- Continuum of firms: $\omega^r \in [0, 1]$; for every r=1,...,S.
- For intermediate good, trade costs are sector pair specific.
- For final good, trade costs are sector specific.
- All markets are competitive.

Preference

Utility of representative consumer is Cobb-Douglas sum of sectoral consumption

$$u(C_j) = \prod_{s=1}^{S} (C_j^s)^{\varepsilon_j^s} \tag{3}$$

- For any country j: $\sum_{s=1}^{S} \varepsilon_j^s = 1$

Firm Level Production

Constant return to scale Cobb-Douglas function

$$y_j^s(\omega^s) = z_j^s(\omega^s)\left(l_j^s(\omega^s)\right)^{1-\sum_{r=1}^S \beta_j^{rs}} \prod_{r=1}^{S} \left(M_j^{rs}(\omega^s)\right)^{\beta_j^{rs}} \tag{4}$$

- Sector pair specific intermediate input
- Assume $z_j^s(\omega^s)$ is an i.i.d draw from Fréchet distribution: $\exp\{-T_j^s z^{-\theta^s}\}$
- Marginal cost: $c_j^s = \Upsilon_j^s w_j^{1-\sum_{r=1}^S} \prod_{r=1}^S (P_j^{rs})^{\beta_j^{rs}}$
- Price: $P_j^s(\omega^s) = \frac{c_j^s}{z_j^s(\omega^s)}$

Intermediate Input Demand

Buy sector pair specific intermediate input from the lowest price producer

$$P_j^{rs}(\omega^r) = \min_i \left\{ \frac{c_i^r \tau_{ij}^{rs}}{z_i^r(\omega^r)} \right\}$$

Sector pair intermediate input

$$M_j^{rs} = \left(\int_0^1 q_j^{rs}(\omega^r)^{\frac{\sigma^r - 1}{\sigma^r}} d\omega^r \right)^{\frac{\sigma^r}{\sigma^r - 1}}$$

Final Good Demand

Buy sector specific final good from the lowest price producer

$$P_j^{rF}(\omega^r) = \min_i \left\{ \frac{c_i^r \tau_{ij}^{rF}}{z_i^r(\omega^r)} \right\}$$

Sector final good

$$C_j^r = \left(\int_0^1 q_j^{rF}(\omega^r)^{\frac{\sigma^r - 1}{\sigma^r}} d\omega^r \right)^{\frac{\sigma^r}{\sigma^r - 1}}$$

Key Equations Following Eaton and Kortum (2002)

Expenditure Share

$$\pi_{ij}^{rs} = \frac{T_i^r (c_i^r \tau_{ij}^{rs})^{-\theta^r}}{\sum_{k=1}^{J} T_k^r (c_k^r \tau_{kj}^{rs})^{-\theta^r}} \tag{5}$$

$$\pi_{ij}^{rF} = \frac{T_i^r (c_i^r \tau_{ij}^{rF})^{-\theta^r}}{\sum_{k=1}^{J} T_k^r (c_k^r \tau_{kj}^{rF})^{-\theta^r}} \tag{6}$$

Price

$$P_j^{rs} = A^r \left(\sum_{k=1}^{J} T_k^r (c_k^r \tau_{kj}^{rs})^{-\theta^r} \right)^{-\frac{1}{\theta^r}} \tag{7}$$

$$P_j^{rF} = A^r \left(\sum_{k=1}^{J} T_k^r (c_k^r \tau_{kj}^{rF})^{-\theta^r} \right)^{-\frac{1}{\theta^r}} \tag{8}$$

Multiple Stage Model

Why Multiple Stage Matters?

1. Multiple stage emphasize the fact of vertical specialized production.
   - iphone: design & processor in Apple $\Longrightarrow$ display & memory in Toshiba and Samsung $\Longrightarrow$ assembling & test in Foxconn
2. This vertical fragmentation deepens over time (Hummels et al. 2001).
3. Global vertical fragmentation heterogeneously distribute VA across countries and across sectors (Timmer et al. 2014).
   - Countries and sectors are in different position of GVC.
   - iphone: US (50%); Japan and Korea (20%); China (2%) approx.
   - Their position change over time.
4. Multiple stage has different implication on trade elasticity.
   - Multiple stage production implies I.I pass multiple borders.
   - Small reduction in tariff can generate large trade rise (Yi 2003).
   - In one stage model we need large tariff reduction or large elasticity.

Model Setup

- This model extends the one sector multiple stage model (Antras and de Gortari 2017) to multiple sector multiple stage model.
- J countries: i and j denote country; $\mathcal{J} = \{1, ..., J\}$
- S sectors: r and s denote sector
- Continuum of firms: $\omega^r \in [0, 1]$; for every r=1,...,S.
- N production stages: n denotes stage; $l(n)$ denotes location at stage n; $N + 1$ denotes final consumption
- rs in superscript: inter-sectoral trade from r to s
- $l(n-1)l(n)$ in subscript: trade flow from $l(n-1)$ to $l(n)$

Model Setup

- Every good takes N stages to produce.
- At stage 1, production uses labour and finished input from other sectors at the same country (horizontal integration).
- At stage $n > 1$, production combines labour, finished input, with unfinished good from stage n-1 (horizontal integration + vertical integration).
- At every stage, location choice is endogenous.
- When a good (finished or unfinished) crosses border, the sector and country pair specific trade cost (τ_{ij}^{s}) is incurred.
- All markets are competitive.

Technology

Firm level price relation

$$P^s_{l(n)}(\omega^s) = \left(\frac{c^s_{l(n)}}{z^s_{l(n)}(\omega^s)}\right)^{\alpha_n} \left(P^s_{l(n-1)}(\omega^s)\tau^s_{l(n-1)l(n)}\right)^{1-\alpha_n} \tag{9}$$

- Horizontal marginal cost: $c^s_{l(n)} = \Upsilon^s_{l(n)} w_{l(n)}^{1-\sum_{r=1}^{S}} \prod_{r=1}^{S} \left(P^r_{l(n)}\right)^{\beta^{rs}_{l(n)}}$
- Vertical marginal cost conditional on endogenous location
- When $n = 1$, $P^s_{l(1)}(\omega^s) = \frac{c^s_{l(1)}}{z^s_{l(1)}(\omega^s)}$
- Final good price at j: $P^s_j(\omega^s) = P^s_{l(N)}(\omega^s)\tau^s_{l(N)j}$

Optimal Location Problem

Final good producer minimizes final good price by solving optimal production path $l_j^s(\omega^s) = \{l_{1j}^s(\omega^s), ..., l_{Nj}^s(\omega^s)\}$.

$$l_j^s(\omega^s) = \arg\min_{l \in \mathcal{J}^{\mathcal{N}}} \left\{ \prod_{n=1}^{N} \left(\frac{c_{l(n)}^s}{z_{l(n)}^s(\omega^s)} \right)^{\alpha_n \delta_n} \prod_{n=1}^{N-1} \left(\tau_{l(n)l(n+1)}^s \right)^{\delta_n} \tau_{l(N)j}^s \right\}$$

- $\delta_n \equiv \prod_{m=n+1}^{N}(1-\alpha_m)$
- Optimal path is determined by upstream and downstream marginal cost and efficiency (vertical cost); and other sectoral input cost at each stage (horizontal cost).

Eaton and Kortum (2002) Framework

Assume $\prod_{n=1}^{N} \left[z_{l(n)}^{s}(\omega^s)\right]^{\alpha_n \delta_n}$ is an i.i.d draw from Fréchet distribution: $\exp\{-\prod_{n=1}^{N} \left[T_{l(n)}^{s}\right]^{\alpha_n \delta_n} z^{-\theta^s}\}$.

- As suggested by Antras and de Gortari (2017), this is equivalent to assume under a decentralized approach, $\left[z_{l(n)}^{s}(\omega^s)\right]^{\alpha_n \delta_n}$ is an iid draw from Fréchet distribution: $\exp\{-\left[T_{l(n)}^{s}\right]^{\alpha_n \delta_n} z^{-\theta^s}\}$

Solution

Probability or expenditure share on a particular path ending in country j

$$\pi_{lj}^{s} = \frac{\prod_{n=1}^{N}\left(\left[T_{l(n)}^{s}\right]^{\alpha_n}\left[(c_{l(n)}^{s})^{\alpha_n}\tau_{l(n)l(n+1)}^{s}\right]^{-\theta}\right)^{\beta_n}}{\sum_{l\in\mathcal{J}^{\mathcal{N}}}\prod_{n=1}^{N}\left(\left[T_{l(n)}^{s}\right]^{\alpha_n}\left[(c_{l(n)}^{s})^{\alpha_n}\tau_{l(n)l(n+1)}^{s}\right]^{-\theta}\right)^{\beta_n}} \tag{10}$$

- $l_{N+1} = j$
- If N=1, $\pi_{l(N)j}^{s} = \frac{T_{l(N)}^{s}\left[c_{l(n)}^{s}\tau_{l(N)j}^{s}\right]^{-\theta}}{\sum_{l\in\mathcal{J}} T_{l(N)}^{s}\left[c_{l(n)}^{s}\tau_{l(N)j}^{s}\right]^{-\theta}}$, consistent with one stage model.
- If only one sector, consistent with Antras and de Gortari (2017).