Lecture 12: Fragmentation

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Outline of Lecture 12

1. Introduction
2. Measuring fragmentation
3. A theory of offshoring
4. Upstreamness

References:

- R. Johnson and G. Noguera (2012), "Accounting for Intermediates: Production Sharing and Trade in Value Added," Journal of International Economics, 86(2).
- G. M. Grossman and E. Rossi-Hansberg (2008), "Trading Tasks: A Simple Theory of Offshoring," American Economic Review, 98(5).
- P. Antras, D. Chor, T. Fally and R. Hillberry (2012), "A measure of upstreamness of production and trade flows", American Economic Review P&P 102 (3).

Definitions

- **Fragmentation**: specialization of different countries into different stages of the same production process (a.k.a. vertical specialization)
- **Offshoring**: relocation of production stages to a foreign country
- **Upstreamness**: distance between a production stage and final demand
- **Outsourcing**: contracting out production stages to independent suppliers

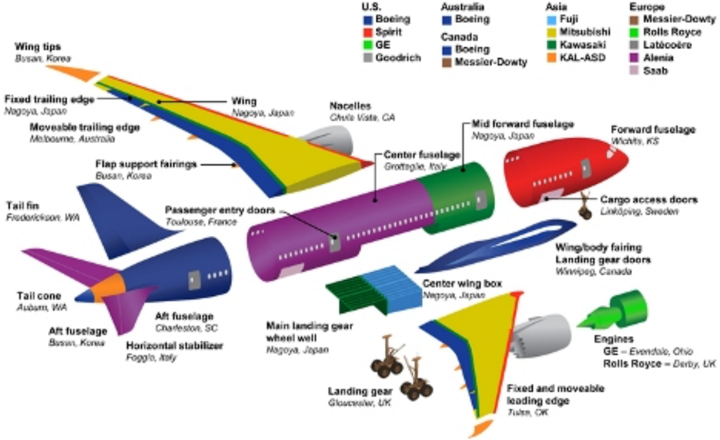
Value-added trade

- GDP measures *value-added* created in a country.
- Conventional measures of trade flows represent sales, not value-added. Ex: HK, Singapore, Ireland have exports/GDP ratios over 100%. Their exports embody value-added from different countries.
- **Value-added exports** measures the local value-added embodied in a country's exports.

Why does fragmentation matter?

- 2/3 of world trade is in intermediates, with anecdotal evidence of increased fragmentation since the 1990's.
- Trade theories apply to value added trade, not gross trade flows.
- Gross trade flows misrepresent trade imbalances.
- Increased fragmentation contributes to the international transmission of shocks.

Global Partners Bring the 787 Together



Hummels, Ishii and Yi (JIE 2001)

- Hummels et al. (2001) build a measure of 'vertical specialization'.
- The measure captures the imported input content of exports:

$$\frac{vs_c}{X_c} = \frac{\sum_s^S \left(\frac{M_{cs}}{Y_{cs}} X_{cs} \right)}{X_c}$$

X: exports; Y: gross output; M: imported intermediates; s: sector; c: country; S number of sectors.

- $\frac{M_{cs}}{Y_{cs}}$ is approximated using input-output matrices.
- Let A^m and A^d be $S \times S$ input-output matrices with
  - a^d_{st}: value of domestic inputs from s used in 1 euro of t's sales
  - a^m_{st}: value of imported inputs from s used in 1 euro of t's sales

  then

$$\frac{vs_c}{X_c} = \frac{1}{X_c} \mathbf{e} A^m \mathbf{X}$$

$\mathbf{e}_{(1,S)}$: all-ones vector. $\mathbf{X}_{(S,1)}$ vector of exports in all sectors.

- $\frac{vs_c}{X_c}$ omits the foreign inputs used *indirectly* in c's exports...
- Let $\mathbf{Q^x}_{(S,1)}$ be exported output plus all inputs used in that output:

$$\mathbf{Q^x} = \mathbf{X} + \sum_{k=1}^{+\infty}(A^d)^k\mathbf{X} = (I - A^d)^{-1}\mathbf{X}$$

- Hummels et al. (2001) compute

$$\frac{VS_c}{X_c} = \frac{1}{X_c}\mathbf{e}A^m(I - A^d)^{-1}\mathbf{X}$$

  using data on A^d and A^m in 10 OECD countries, 1968-1990.
- Results:
  - $\frac{VS_c}{X_c}$ increased from 0.165 in 1970 to 0.2 in 1990.
  - growth in $\frac{VS_c}{X_c}$ contributed to 30% of export/GDP ratio growth

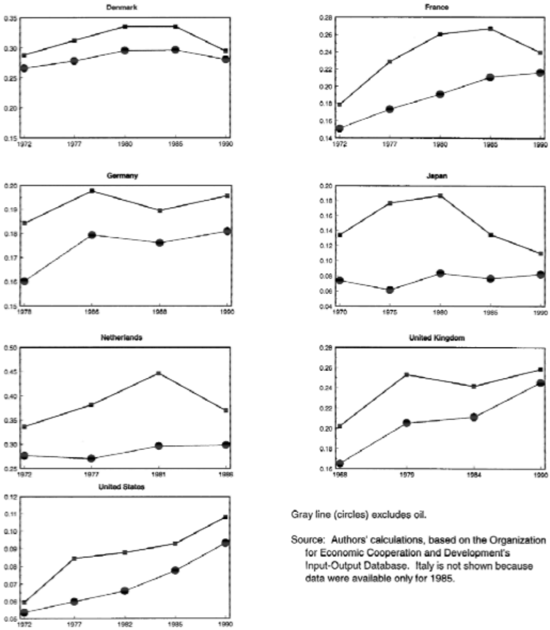


Fig. 2. VS exports as a share of total merchandise exports: OECD countries.

Johnson and Noguera (JIE 2012)

- Extension of HIY allowing for exports of inputs that are imported back or redirected further down the value chain.
- S sectors (s, t), N countries (i, j). Armington assumption.
  - $y_i(s)$: value of output of variety is.
  - $x_{ij}(s)$: exports of is to j.
  - $f_{ij}(s)$: final consumption of is in j.
  - $m_{ij}(s,t)$: intermediate consumption of is by sector t in j
- Market clearing, assuming equal foreign and domestic prices:

$$\forall s, \forall i, x_{ij}(s) = f_{ij}(s) + \sum_{t}^{S} m_{ij}(s,t)$$

$$\forall s, \forall i, y_i(s) = \sum_{j}^{N} f_{ij}(s) + \sum_{j}^{N} \sum_{t}^{S} m_{ij}(s,t)$$

- Denote by A_{ij} the $S \times S$ matrix with element $a_{ij}(s,t) \equiv \frac{m_{ij(s,t)}}{y_j(t)}$. Denote by y_i and f_{ij} the $S \times 1$ vectors of $y_i(s)$ and $f_{ij}(s)$.
- Then

$$y_i = \sum_j^N f_{ij} + \sum_j^N A_{ij} y_j$$

- Consider now A, the $N \times N$ matrix of bilateral matrices A_{ij}:

$$A = \begin{pmatrix} A_{11} & \dots & A_{1N} \\ \dots & \dots & \dots \\ A_{N1} & \dots & A_{NN} \end{pmatrix} \quad y = \begin{pmatrix} y_1 \\ y_2 \\ \dots \\ y_N \end{pmatrix} \quad f = \begin{pmatrix} \sum_j f_{1j} \\ \sum_j f_{2j} \\ \dots \\ \sum_j f_{Nj} \end{pmatrix}$$

- The $S \times N$ market-clearing conditions are written

$$y = Ay + \sum_j f_j \Leftrightarrow y = (I - A)^{-1} \sum_j f_j$$

- Gross output y includes final goods and all intermediates used in successive rounds of production in all countries.

- Define gross output absorbed by each country j as y_{ij}:

$$\begin{pmatrix} y_{1j} \\ y_{2j} \\ \dots \\ y_{Nj} \end{pmatrix} \equiv (I-A)^{-1} \begin{pmatrix} f_{1j} \\ f_{2j} \\ \dots \\ f_{Nj} \end{pmatrix}$$

- In each sector of country i, compute the VA/output ratio

$$r_i(t) = \frac{y_i(t) - \sum_j \sum_s m_{ji}(s,t)}{y_i(t)} = 1 - \sum_j \sum_s a_{ji}(s,t)$$

- Value added from i absorbed in j ('value-added exports'):

$$VA_{ij} \equiv \sum_s va_{ij}(s) = \sum_s r_i(s) y_{ij}(s)$$

- Value added to exports (VAX) ratio:

$$VAX_{ij} = \frac{VA_{ij}}{X_{ij}}$$

where $X_{ij} = \sum_s x_{ij}(s)$.

Example: 3 countries (US, China, Japan), one sector.

- 2 only exports a final good to 1. 1 and 3 only export inputs to 2. All countries produce inputs and final goods for the domestic market.

$$\begin{pmatrix} y_1 \\ y_2 \\ y_3 \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} & 0 \\ 0 & a_{22} & 0 \\ 0 & a_{32} & a_{33} \end{pmatrix} \begin{pmatrix} y_1 \\ y_2 \\ y_3 \end{pmatrix} + \begin{pmatrix} f_{11} \\ f_{21} + f_{22} \\ f_{33} \end{pmatrix}$$

- This can be solved as:

$$\begin{pmatrix} y_1 \\ y_2 \\ y_3 \end{pmatrix} = \begin{pmatrix} \frac{1}{1-a_{11}} & \frac{a_{12}}{(1-a_{11})(1-a_{22})} & 0 \\ 0 & \frac{1}{1-a_{22}} & 0 \\ 0 & \frac{a_{32}}{(1-a_{33})(1-a_{22})} & \frac{1}{1-a_{33}} \end{pmatrix} \begin{pmatrix} f_{11} \\ f_{21} + f_{22} \\ f_{33} \end{pmatrix}$$

- Chinese exports to US include US content, hence $VAX_{21} < 1$. Gross trade statistics overstate Chinese exports to US.
- Chinese exports to US include Japanese content. Gross trade statistics understate Japanese exports to US.

Johnson and Noguera (JIE 2012, NBERwp 2012)

- GTAP data on y, f, A, x in 94 countries and 57 sectors in 2004.
- 3 results:
  - decomposition of bilateral exports

$$\mathbf{e}x_{ij} = \underbrace{\mathbf{e}(f_{ij} + A_{ij}y_{jj})}_{\text{Absorption}} + \underbrace{\mathbf{e}A_{ij}y_{ji}}_{\text{Reflection}} + \underbrace{\sum_{k \neq j,i} \mathbf{e}A_{ij}y_{jk}}_{\text{Redirection}}$$

    $\mathbf{e}_{(1,S)}$: all-ones vector.
  - bilateral VA trade balances
  - changes in VAX and vertical specialization over time

Table 4: Decomposing Trade: Absorption, Reflection, and Redirection

Japan exports to:				U.S. exports to:			
China		U.S.		Mexico		Canada	
China	64.5%	U.S.	92.7%	Mexico	72.3%	Canada	68.9%
U.S.	11.1%	Canada	1.4%	U.S.	22.1%	U.S.	24.1%
Japan	4.3%	Mexico	0.7%	Canada	0.9%	U.K.	0.7%
Germany	2.5%	Japan	0.6%	Germany	0.4%	Japan	0.7%

Germany exports to:				Korea exports to:			
France		Czech Rep.		China		Japan	
France	74.8%	Czech Republic	57.7%	China	61.3%	Japan	83.1%
Germany	3.6%	Germany	11.7%	U.S.	12.1%	U.S.	4.7%
U.K.	2.8%	U.K.	3.0%	Japan	4.7%	China	2.3%
U.S.	2.6%	U.S.	2.6%	Germany	2.7%	Germany	1.0%

See the text for details regarding the decomposition. The entries in the table describe the approximate share of bilateral exports to each destination that are ultimately consumed in that destination. Shares do not sum to one because we include only the top four destinations for each bilateral pair. Data is for 2004.

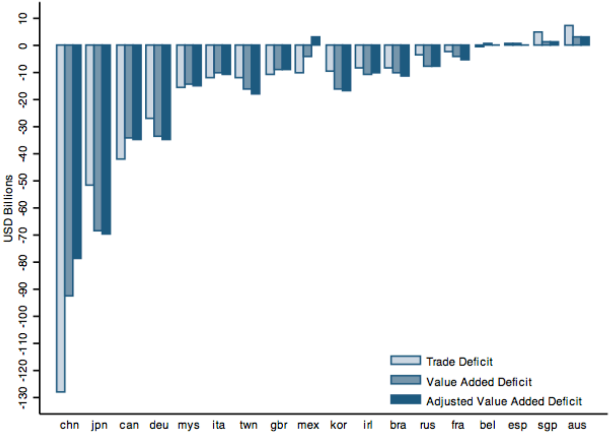
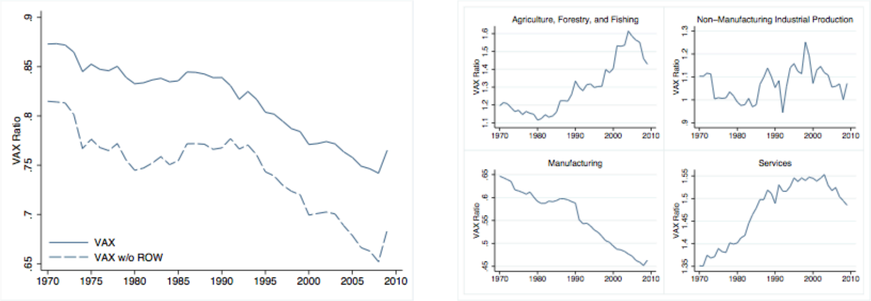


Figure: Gross and VA bilateral trade balances of the US, by partner, in 2004. 'Adjusted' refers to a correction for processing trade.

Figure 1: World Value Added to Export Ratios



(a) Aggregate (b) By Sector

Note: VAX ratios may be greater than one when indirect exports (exports from *i* to *k* but ultimately absorbed by *j*), that belong to VA_{ij} but not X_{ij}, are large.

Grossman and Rossi-Hansberg (AER 2008)

- Fragmentation means countries can specialize in 'tasks' or stages.
- Grossman and Rossi-Hansberg (2008) build a 2x2x2 HOS model of 'trade in tasks':
  - 2 countries, Home and Foreign
  - 2 goods, $i = 1, 2$
  - 2 factors of production, L and H
- L use is composed of a continuum of tasks $j \in [0, 1]$, some of which can be offshored. H tasks cannot be offshored.
- Suppose Home is H-abundant.

Grossman and Rossi-Hansberg (AER 2008)

- L tasks can be offshored at cost $\beta t(j) \geq 1$ units of labor, $t'(j) > 0$.
    - $t(j)$ captures the idea that some tasks are more codified or routine-like and easier to offshore
    - β captures the extra monitoring costs of offshoring
- Home firms offshore task j iff

$$\beta t(j) w_L^* < w_L$$

- Define cutoff task J such as tasks $[0, J]$ are offshored:

$$\beta t(J) w_L^* = w_L \Leftrightarrow J = t^{-1}(\beta \frac{w_L}{w_L^*})$$

Grossman and Rossi-Hansberg (AER 2008)

- Producing one unit of good costs:

$$c_i = a_{Li}\left(w_L(1-J) + w_L^* \beta T(J)\right) + a_{Hi} w_H, i = 1,2$$

where $T(J) = \int_0^J t(j)dj$

- Using the task cutoff condition this can be rewritten as:

$$c_i = a_{Li} w_L \Omega + a_{Hi} w_H, i = 1,2$$

where $\Omega = 1 - J + \frac{T(J)}{t(J)} \leq 1$.

- A fall in Ω is qualitatively equivalent to labor-augmenting technological progress (fall in a_{Li}) in a standard HO model.

Grossman and Rossi-Hansberg (AER 2008)

What is the effect of an exogenous fall in β?

Simple case: Small Open Economy, fixed a_{vi} coefficients (Leontief).

- The equilibrium is found by solving for y_1, y_2, w_L, w_H in

$$(1-J)\left[a_{L1}y_1 + a_{L2}y_2\right] = L \qquad \text{(FE-L)}$$
$$a_{H1}y_1 + a_{H2}y_2 = H \qquad \text{(FE-H)}$$
$$a_{Li}w_L\Omega + a_{Hi}w_H = p_i \qquad i = 1,2 \qquad \text{(ZP)}$$

- (ZP) pins down $\Omega(J)w_L$ and w_H, therefore $\hat{w}_L = -\hat{\Omega}(J)$. The definition of J implies $\hat{w}_L = \hat{\beta} + \hat{t}(J)$.
- Combining both equations:

$$\hat{w}_L = -\frac{T(J)}{(1-J)t(J)}\hat{\beta}$$

Grossman and Rossi-Hansberg (AER 2008)

How does an exogenous fall in offshoring cost β affect unskilled wage w_L?

- In the simple case: positive 'productivity effect'
  - firms in both industries save on the inframarginal offshored tasks
  - thanks to the cost reduction, they all expand and increase their demand for L, but more so in the L-intensive industry
  - labor supply is fixed and w_L rises: *unskilled workers gain!*
  - qualitatively similar to labor-augmenting technological progress
- In general, 3 effects:
  - (+) 'productivity' effect
  - (-) terms of trade effect (large country): the world price of the L-intensive good falls disproportionately, and w_L falls as in Stolper-Samuelson.
  - (-) labor supply effect (when factor prices are *sensitive* to factor endowments): reabsorbing idle unskilled workers reduces w_L.

Upstreamness

- How do countries specialize vertically? How 'upstream' is their production? What are the determinants of 'upstreamness'?
- Two measures of upstreamness:
  1. Antràs and Chor (ECM 2012)
  2. Fally (2012)
- Antràs, Chor, Fally and Hillberry (AER p&p 2012) show they are equivalent and provide empirical determinants.

Upstreamness: measure 1, closed economy

- Consider first a **closed economy**.
- Recall that production in sector s can be written as:

$$y(s) = f(s) + \sum_t a(s,t)f(t) + \sum_u a(s,u) \sum_t a(s,t)f(t) + ...$$

- Antràs and Chor (2012) weigh each term of the sequence by 1 plus the number of stages before final consumption.

$$U_1(s) = 1 \times f(s) + 2 \times \sum_t a(s,t)f(t) + 3 \times \sum_u a(s,u) \sum_t a(s,t)f(t) ....$$

- A greater number indicates greater 'upstreamness'.

Upstreamness: measure 2, closed economy

- Each industry t consumes a share $d(s,t) \equiv \frac{a(s,t)y(t)}{y(s)}$ of the production of s.
- Denote by Δ the matrix with representative element $d(s,t)$.
- Measure 2 is defined by

$$U_2(s) = 1 + \sum_t d(s,t)U_2(t)$$

- The more upstream your customers' industries, the more upstream you are.
- This implies

$$U_2 = (I - \Delta)^{-1}\mathbf{e}$$

- Antràs et al. (2012) show that U_1 and U_2 are equivalent.

Upstreamness: open economy

- In a open economy

$$y(s) = f(s) + \sum_t a(s,t)y(t) + x_s - m_s$$

- We would like to measure $\alpha_{st} = \frac{a_{st}y(t) - x(s,t) + m(s,t)}{y(s)}$, but data on $m(s,t), x(s,t)$ are usually not available.
- If we assume that domestic, import and export content are identical, then we can use

$$\hat{a}(s,t) = \frac{y(s)}{y(s) + x(s) - m(s)} a(s,t)$$

instead of $a(s,t)$ in the above definitions of upstreamness.

Upstreamness: Determinants

- Antràs et al. (2012) compute values of both indices using an IO matrix with 426 industries in the US in 2002.
- At the industry level:
  - U ranges from 1 (19 industries) to 4.65 (Petrochemicals), with a mean of 2.09.
  - within manufacturing, capital-intensive industries are more upstream, skill-intensive industries are less upstream
- At the country level, upstreamness is negatively correlated with skill abundance, credit/GDP and Rule of Law.

Table 3. Export Upstreamness and Country Features

	(1)	(2)	(3)	(4)
Log(Y/L)	−0.035	0.146***	0.156**	0.083
	(0.032)	(0.054)	(0.060)	(0.142)
Rule of Law		−0.313***	−0.164*	−0.029
		(0.070)	(0.091)	(0.103)
Credit/Y			−0.404***	−0.437***
			(0.128)	(0.136)
Log(K/L)				0.156
				(0.131)
School				−0.085***
				(0.031)
N	181	181	151	120
R^2	0.01	0.11	0.11	0.15

Notes: Robust standard errors reported. ***, **, and * denote significance at the 1, 5 and 10 percent levels respectively.

Conclusions

- Global increase in vertical specialization, decrease in VAX ratio
- Value-added trade measures shed new light on trade deficits.
- Upstreamness is negatively correlated with skill abundance and strong financial and legal institutions.
- Suggested further reading:
  - responses of trade flows to changes in trade costs and income
    - ★ Yi (JPE 2003): offshoring explains half of postwar trade growth, explaining strong response to trade liberalization
    - ★ Bems, Yi and Johnson (NBER wp 2012): offshoring explains the disproportionate 2008-2009 trade collapse
  - North-North offshoring model, based on scale economies, not wage differences (Grossman and Rossi-Hansberg ECM 2012)
  - theories of global supply chains:
    - ★ Antràs and Chor (ECM 2013): incentives to outsource a task depend on its upstreamness
    - ★ Costinot, Vogel, Wang (RES 2012): countries with lower probability of mistakes specialize downstream