Plan for Today’s Lecture

1. How do we measure the international fragmentation of production?
2. What are some of its consequences for the study of trade flows?
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1. How do we measure the international fragmentation of production?

2. What are some of its consequences for the study of trade flows?
Estimates suggest that a large share (eg 2/3rds) of world trade is in intermediate goods.

This suggests that a lot of production activity is being internationally fragmented. Or equivalently that the modern global economy features lots of what gets variously called:

- “Offshoring.”
- “Slicing up of the value chain (internationally).”
- “Vertical specialization.”
- “Outsourcing.”
- “Disintegration of production.”
- “Multi-stage production.”
- “Intra-product specialization.”
- “Great Unbundling.”
- ...!
Measuring International Fragmentation

Why is fragmentation hard to measure?
- Trade flows are classified into ‘products’.
- Trade flows are measured as the amount of value added that is crossing the border, not the amount of value added that was added to the shipment while it was inside the exporting country.
- Whether these are intermediate products or not is surprisingly hard to judge based on their descriptions (the state of the art, to my knowledge, is to call a product an intermediate if the word ‘part’ or ‘component’ etc appears in the description.)
- And of course, many goods can be both intermediates and final goods (both within and across countries).

**Idea:** Use Input-Output tables (which of course declare which goods are used as inputs and which are final outputs) to shed light on this.
- Hummels, Ishii and Yi (JIE 2001)
- Johnson and Noguera (JIE 2012)
FIGURE 1. The U.S. Input-Output Matrix, 1997 (480 Industries)

Note: The plot shows the matrix $[\sigma_{ij} + \lambda_{ij}]$, that is, the matrix of intermediate good shares for 480 industries. A contour plot method is used, showing only those shares greater than 2%, 4%, and 8%.

Source: BEA 1997 Input-Output Benchmark data.
FIGURE 2. The U.S. Input-Output Matrix, 2000 (48 Industries)

Note: See notes to Figure 1. Source: OECD 2006 database.
FIGURE 3. Input-Output Matrix in Japan and China (48 Industries)
Domestic I-O Tables
Coarser level (Jones 2013)

FIGURE 3. Input-Output Matrix in Japan and China (48 Industries)

Industry Using the Input

The Good Being Used

(b) China

Electricity (26)
Metals (13–15)
From Domestic to Global I-O Tables

Global I-O tables are constructed from domestic I-O tables and bilateral trade data. Many possible sources, but sector classification always fairly coarse (Johnson, JEP 2013)

<table>
<thead>
<tr>
<th>Name of dataset</th>
<th>Key features</th>
<th>Selected research using this data</th>
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</table>
HIY (2001) focus on one particular type of international fragmentation, which they refer to as "vertical specialization":

- When an intermediate good is imported, transformed into a final good, and then exported.
- Example: Japan exports raw steel to Mexico, where the steel is stamped and pressed, and exported to the U.S.

Clearly this will be an underestimate of international fragmentation (because imported intermediates, without subsequent exporting, are a simpler form of fragmentation).

HIY use domestic I-O tables:

- These contain industry-wise input purchases from both home and 'foreign' (never bilaterally foreign).
- Also include total output and exports (again, not bilateral).
HIY (2001): Method

Define Vertical Specialization (here), in sector $k$, as imported input content of exports: $VS^k_2 = \left( \frac{A}{D+E} \right) E$.

Figure 1. Vertical specialization.

Country 1 produces an intermediate good and exports it to Country 2. Country 2 combines the imported intermediates with capital and labor (value-added), and domestically produced intermediate inputs to produce a final good (gross output). Finally, Country 2 exports some of the final good to Country 3.
HIY (2001): Results
Many OECD countries are considerably engaged in fragmentation, even by this narrow measure.

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

Source: Authors' calculations, based on the Organization for Economic Cooperation and Development's Input-Output Database. Italy is not shown because data were available only for 1995.
HIY (2011) focus on imported input embodied exports, but if imported and domestic inputs themselves use inputs, this may be different from the foreign value added embodied in exports.

JN (2012) propose to address that question:

- How much of a country’s exports (which, recall, are ‘gross output’) are value added by that country?

**Method:**

- Same basic idea as in factor content calculation in the HOV literature.
- Goal is to compute factors embodied in consumption at a destination (e.g. U.S. consumption)
- But compared to the HOV literature:
  - The (composite) factor of interest is not on labor, physical capital or land, it is "Value Added in an origin country" (e.g. Chinese VA)
  - We need to take into account all the direct and indirect ways, because of I-O linkages, through which value added from that origin may have been used to produce final consumption in that destination.
JN (2012): Input-Output Accounting

- Start with the global I-O matrix, $A ≡ A_{ij}(s, t)$, recording spending share in sector $t$ from country $j$ on inputs from sector $s$ in country $i$
- JN (2012) construct it by making proportionality assumptions
- Good market clearing (expressed in values) requires:
  
  $y_i(s) = \sum_j c_{ij}(s) + \sum_{j,t} A_{ij}(s, t)y_j(t)$

  with $y_i(s) =$ gross output in sector $s$ and country $i$ and $c_{ij}(s) =$ final consumption of good $s$ from country $i$ in country $j$ (also in values)
- In vector notation, gross output therefore satisfies:
  
  $y = (Id - A)^{-1} \sum_j c_j$

  $(Id - A)^{-1} = \sum_{k=0} A^k$ is the “Leontief inverse”
  
  “$k = 0$” corresponds to gross output used as final good, “$k = 1$” corresponds to gross output used as inputs to produce final goods etc.
\( y_{ij}(s) = \) gross output of good \( s \) from country \( i \) used for final consumption in country \( j \) is given by the \((i, s)\) entry of \( y_j \) such that

\[
y_j = (ld - A)^{-1} c_j
\]

\( va_{ij}(s) = \) value added from country \( i \) and sector \( s \) used for final consumption in country \( j \) is then given by the zero-profit condition,

\[
va_{ij}(s) = (1 - \sum_{j, t} A_{ji}(t, s)) y_{ij}(s)
\]

VAX Ratio = \( va_{ij}(s) / x_{ij}(s) \) with \( x_{ij}(s) = \) gross exports

- Given disaggregated VAX ratios, one can compute sector-level (summing across countries), country-level (summing across sectors) etc.
JN (2012): Sector-Level Results

Sector Shares in Total World Value-Added and Gross Exports

Sources: World Input-Output Database (WIOD) and author’s calculations.
Notes: Data are for 2008. Agriculture includes Forestry, Hunting, and Fishing. Non-Manufacturing Industrial Production includes Mining and Quarrying, Electricity/Gas/Water Supply, and Construction. Manufacturing is the remainder of Industrial Production.
The Ratio of Value-Added to Gross Exports for the Top 20 Exporting Countries

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<thead>
<tr>
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<tbody>
<tr>
<td>Germany</td>
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<td>-0.10</td>
<td>-0.16</td>
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<tr>
<td>United States</td>
<td>0.78</td>
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<td>Austria</td>
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<tr>
<td>Minimum</td>
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<tr>
<td>Median</td>
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<tr>
<td>Maximum</td>
<td>0.92</td>
<td>0.02</td>
<td>-0.04</td>
</tr>
</tbody>
</table>

Sources: World Input-Output Database (WIOD) and author’s calculations, Johnson and Noguera (2014).
Notes: The column “WIOD 2008” is the ratio of value-added exports to gross exports for each country in 2008 from the World Input-Output Database. The column “WIOD change 1995–2008” is the change in this ratio from 1995 to 2008. The column “Johnson–Noguera change 1970–2008” is the change in the ratio of value-added exports to gross exports for each country from 1970 to 2008, from Johnson and
Aside on Re-Exporting

- Re-exporting is the phenomenon by which a country (typically Belgium, Hong Kong and Singapore) acts as a sort of international ‘distribution hub’.
  - So lots of goods get imported by these hub countries, and then subsequently exported.
  - Some of these hubs (eg Hong Kong) keep separate trade statistics for re-exported goods (goods that ‘are not sufficiently transformed in HK for their country of origin to plausibly be taken as HK’), but most don’t.
  - So there is always a risk that re-exporting looks like fragmentation.

- Young (1999) studies Hong Kong’s re-export data in detail and attempts to understand why this phenomenon is so prevalent (IRTS in transportation vs IRTS in ‘processing’ vs IRTS in matching buyers to sellers).
Lots of re-exporting is acute. Eg, 15% of goods that come from US get sent back to the US. This is 65% for Israel.
Plan for Today’s Lecture

1. How do we measure the international fragmentation of production?
2. What are some of its consequences for the study of trade flows?
We now discuss some of the consequences of international fragmentation for the study of trade flows.

1. Yi (JPE 2003): The possibility of international fragmentation raises the trade-to-tariff elasticity.

Yi (2003) motivates his paper with 2 puzzles:

- The trade flow-to-tariff elasticity in the data is way higher than what our models predict.
- The trade flow-to-tariff elasticity in the data appears to have changed (become much higher) non-linearly around the 1980s. Why?

Yi (2003) formulates and calibrates a pre-EK/2-country DFS (1977)-style model with and without ‘vertical specialization’ (i.e. intermediate inputs are required for production, and these are tradable).

- The model without VS fails to match puzzles 1 or 2.
- The calibrated model with VS gets much closer.

**Intuition:**

- Puzzle 1: if goods are crossing borders $N$ times then it is not the tariff $(1 + \tau)$ that matters, but $(1 + \tau)^N$ instead.
- Puzzle 2: if tariffs are very high then countries won’t trade inputs at all. So elasticity will be initially low ($N = 1$) and then suddenly higher ($N > 1$).
Yi (2003): Simplified Version of Model

- Production takes 3 stages:
  1. \( y_1^i(z) = A_1^i(z)l_1^i(z) \) with \( i = H, F \). Inputs produced.
  2. \( y_2^i(z) = x_1^i(z)^\theta [A_2^i(x)l_2^i(z)]^{1-\theta} \) with \( i = H, F \). Sector uses inputs to produce final goods.
  3. \( Y = \exp \left[ \int_0^1 \ln [x_2(z)] \, dz \right] \). Final (non-tradable) consumption good is Cobb-Douglas aggregate of Stage 2 goods.

- Home has comparative advantage in:
  - low-z goods: \( A_s(z) \equiv A_s^H(z)/A_s^F(z) \) is decreasing for \( s = 1, 2 \)
  - stage 1: \( A_1(z) > A_2(z) \) for all \( z \)
Yi (2003): Pattern of International Specialization
Without trade costs

Fig. 5.—Vertical model: free trade. HF denotes that Home produces the first stage and Foreign produces the second stage.
Yi (2003): Pattern of International Specialization
With trade costs

**Fig. 6.**—Vertical model: tariffs (home consumer’s perspective)
If VS is occurring (ie $\tau$ is sufficiently low) then let $z_l$ be the cut-off that makes a Stage 3 firm indifferent between using a “HH” and a “HF” upstream organization of production.

This requires that: 
$$\frac{w^H}{w^F} = (1 + \tau)^{(1+\theta)/(1-\theta)} \frac{A^H_2(z_l)}{A^F_2(z_l)}.$$ 

Differentiating and ignoring changes in the relative wage:

$$\hat{1} - z_l = \left( \frac{1 + \theta}{1 - \theta} \right) \left[ \frac{z_l}{(1 - z_l)\eta_{A_2}} \right] \hat{1} + \tau$$

However, if VS is not occurring (ie $\tau$ is high) then:

This requires that 
$$\frac{w^H}{w^F} = (1 + \tau)A^H(z_l)/A^F(z_l)$$ 

So the equivalent derivative is:

$$\hat{1} - z_l = \left[ \frac{z_l}{(1 - z_l)\eta_{A}} \right] \hat{1} + \tau$$

For $\theta < 1$ (eg $\theta = \frac{2}{3}$) the multiplier in the VS can be quite big (eg 5).
Yi (2003): The Model and the 2 Puzzles

Fig. 10.—Narrow case: vertical model vs. one-stage model

The model cannot generate any nonlinear effects. Table 3 indicates that the model can explain only about 13 percent of export growth between 1962 and 1999; this is only one-third of what the vertical model explains.

The standard model performs well relative to the vertical model in the earlier subperiods but considerably worse in the later subperiods. For example, between 1962 and 1976, the standard model explains about the same export growth as the vertical model, because vertical specialization is insignificant in this subperiod. However, between 1989 and 1999, the standard model implies export growth of just 3 percent, as opposed to 27 percent in the vertical model and 80 percent in the data.

Moreover, the standard model implies elasticities of trade with respect to tariffs that are larger in the earlier subperiods than in the later subperiods, which is counterfactual.

Finally, the RMSE is 1.2 percentage points higher than in the vertical model. The results for the broad benchmark case are similar. In every dimension, then, the one-stage model performs more poorly than the vertical model.

I can assess the welfare gains to vertical specialization by comparing the previously computed welfare gains with the welfare gains in the standard model. The gain in steady-state consumption from lower tariffs is 0.95 and 2.2 percentage points higher in the vertical model relative to the standard model in the narrow and broad cases, respectively. These gains are significant.
Yi (2010) points out that the Yi (2003) VS argument also has implications for cross-sectional variation in the trade elasticities.

Recall that estimates of the gravity equation (eg Anderson and van Wincoop, 2003) within the US and Canada find that there appears to be a significant additional trade cost involved in crossing the US-Canada border. The tariff equivalent of this border effect is much bigger than US-Canada tariffs.

This is called the ‘border effect’ or the ‘home bias of trade’ puzzle.

Yi (2010) argues that if production can be fragmented internationally then the (gravity equation-) estimated border-crossing trade cost will be higher than the true border-crossing trade cost.

This is because (in such a model) the true trade flow-to-border cost elasticity will be larger than that in a standard model (without multi-stage production).
Yi (2010): Results

- Yi (2010) uses data on tariffs, NTBs, freight rates and wholesale distribution costs to claim that the ‘true’ Canada-US border trade costs are 14.8%.
- He then simulates (a calibrated version of) his model based on this ‘true’ border cost.
- He then compares the border dummy coefficient in 2 regressions:
  - A gravity regression based on his model’s predicted trade data.
  - And the gravity regression based on actual trade data.
- The coefficient on the model regression is about 2/3 of the data regression. A trade cost of 26.1% would be needed for the coefficients to match.
  - By contrast, a standard Eaton and Kortum (2002) model equivalent (without multi-stage production) would give much smaller coherence between model and data.