14.581: International Trade
— Lecture 16—
International Fragmentation (Empirics)

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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Introduction

- 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

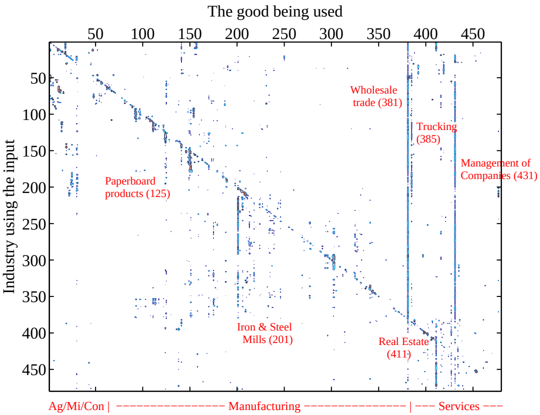
- Why is fragmentation hard to measure?
  - Trade flows are classified into 'products'.
  - Trade flows are measured as the amount of value added that is crossing the border, not the amount of value added that was added to the shipment while it was inside the exporting country.
  - Whether these are 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)

Domestic I-O Tables

Finer level (Jones 2013)

FIGURE 1. The U.S. Input-Output Matrix, 1997 (480 Industries)

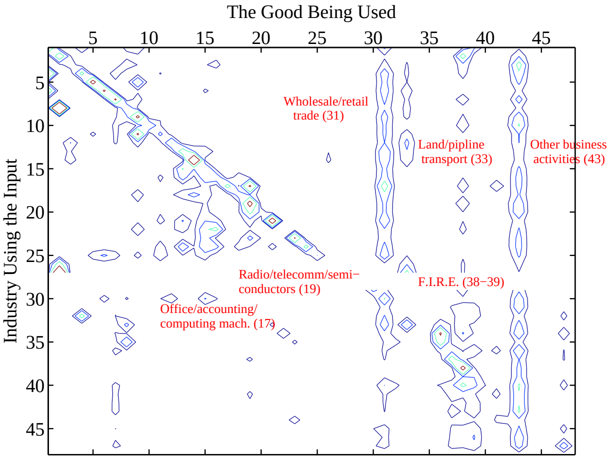


Note: The plot shows the matrix $[\sigma_{ij} + \lambda_{ij}]$, that is, the matrix of intermediate good shares for 480 industries. A contour plot method is used, showing only those shares greater than 2%, 4%, and 8%. Source: BEA 1997 Input-Output Benchmark data.

Domestic I-O Tables

Coarser level (Jones 2013)

FIGURE 2. The U.S. Input-Output Matrix, 2000 (48 Industries)

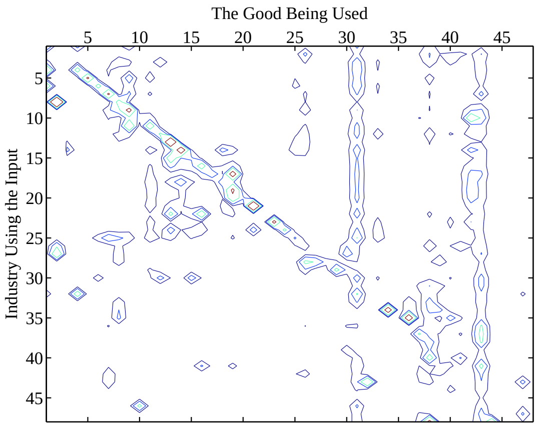


Note: See notes to Figure 1. Source: OECD 2006 database.

Domestic I-O Tables

Coarser level (Jones 2013)

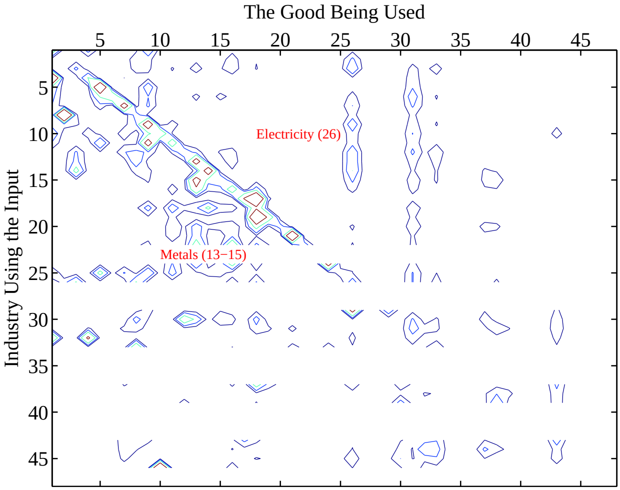
FIGURE 3. Input-Output Matrix in Japan and China (48 Industries)



(a) Japan

Domestic I-O Tables

Coarser level (Jones 2013)



(b) China

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 1
Public Datasets for Research on Value-Added Exports

Name of dataset	*Key features*	*Selected research using this data*
Global Trade Analyis Project Database	Input-output tables for over 100 countries for various benchmark years, mostly after 2000. https://www.gtap.agecon.purdue.edu	Trefler and Zhu (2010), Daudin, Rifflart, and Schweisguth (2011), Johnson and Noguera (2012a), and Koopman, Wang, and Wei (2014)
World Input-Output Database	Global tables covering OECD countries and major emerging markets from 1995–2011. http://www.wiod.org	Baldwin and Lopez-Gonzales (2013), Costinot and Rodríguez-Clare (2013), Timmer, Los, Stehrer, and de Vries (2013)
IDE-JETRO Asian Input-Output Tables	Regional tables covering 8 East Asian countries at five-year intervals between 1985 and 2000. http://www.ide.go.jp	Various chapters in Hiratsuka and Uchida (2010), IDE-JETRO and WTO (2011), Puzzello (2012)
WTO-OECD TiVA Database (Trade in Value Added)	Value-added exports and other measures of global supply chain activity for 57 countries in 1995, 2000, 2005, 2008 and 2009. http://stats.oecd.org	De Backer and Miroudot (2013)
OECD Input-Output Tables	Input-output tables for OECD countries and major emerging markets, available various years from 1970–2005. http://www.oecd.org/trade/input-outputtables.htm	Hummels, Ishii, and Yi (2001), Johnson and Noguera (2012b, 2014)

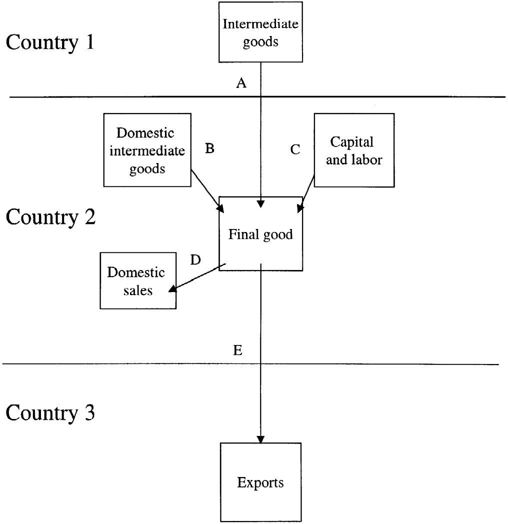
Hummels, Ishii and Yi (JIE 2001)

Fragmentation = Vertical Specialization (VS)

- HIY (2001) focus one 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).

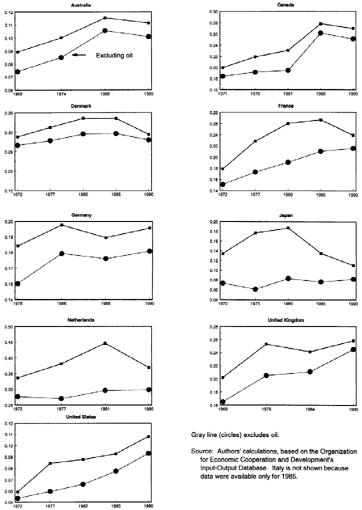
HIY (2001): Method

Define Vertical Specialization (here), in sector k, as imported input content of exports: $VS_2^k = \left(\frac{A}{D+E}\right) E$.



HIY (2001): Results

Many OECD countries are considerably engaged in fragmentation, even by this narrow measure



Gray line (circles) excludes oil.

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 1985.

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

Johnson and Noguera (JIE 2012)

Fragmentation = Value Added to Gross Exports Ratio (VAX Ratio)

- 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, $A \equiv A_{ij}(s,t)$, 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.

JN (2012): Input-Output Accounting

- $y_{ij}(s)$ = 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

$$y_j = (Id - A)^{-1} c_j$$

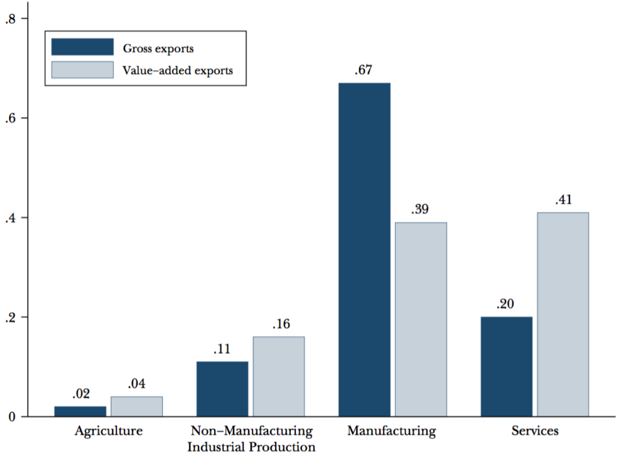
- $va_{ij}(s)$ = value added from country i and sector s used for final consumption in country j is then given by the zero-profit condition,

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

- 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.

JN (2012): Country-Level Results

The Ratio of Value-Added to Gross Exports for the Top 20 Exporting Countries

	WIOD 2008	*WIOD Change 1995–2008*	*Johnson–Noguera Change 1970–2008*
Germany	0.69	−0.10	−0.16
United States	0.78	−0.05	−0.14
China	0.75	−0.09	−0.20
Japan	0.80	−0.12	−0.09
United Kingdom	0.78	−0.01	−0.04
France	0.71	−0.08	−0.13
Italy	0.73	−0.07	−0.12
Netherlands	0.62	−0.06	−0.11
Canada	0.76	0.02	−0.11
South Korea	0.58	−0.18	−0.18
Russia	0.92	0.00	
Belgium	0.53	−0.07	−0.15
Spain	0.69	−0.09	−0.17
Taiwan	0.51	−0.16	
Mexico	0.70	−0.03	−0.21
India	0.78	−0.12	−0.20
Sweden	0.66	−0.08	−0.13
Australia	0.84	−0.04	−0.06
Brazil	0.86	−0.05	−0.10
Austria	0.65	−0.10	−0.17
Minimum	0.51	−0.18	−0.21
Median	0.72	−0.08	−0.14
Maximum	0.92	0.02	−0.04

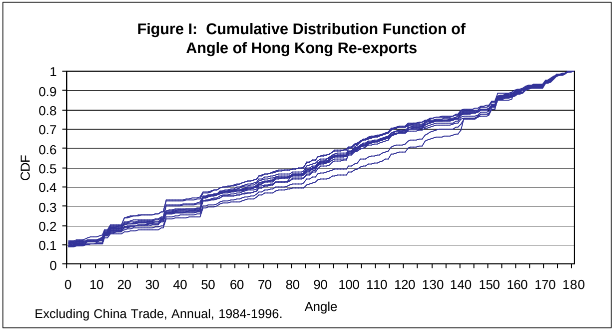
Sources: World Input-Output Database (WIOD) and author's calculations, Johnson and Noguera (2014).
Notes: The column "WIOD 2008" is the ratio of value-added exports to gross exports for each country in 2008 from the World Input-Output Database. The column "WIOD change 1995–2008" is the change in this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

Young (1999): Hong Kong's Re-exporting 'angle' of diversion

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?**

Fragmentation and the Trade Elasticity

- 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.
  2. Yi (AER, 2010): Similar consequences for estimation of the 'border effect'.

Yi (2003)

- 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): Puzzles 1 and 2

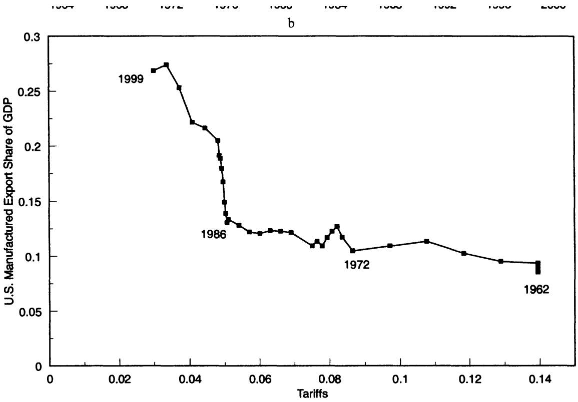


FIG. 1.—Manufacturing export share of GDP and manufacturing tariff rates. Source: World Trade Organization (2002) and author's calculations (see App. A and Sec. V).

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. $y_2^i(z) = x_1^i(z)^\theta \left[A_2^i(x) l_2^i(z)\right]^{1-\theta}$ with $i = H, F$. Sector uses inputs to produce final goods.
  3. $Y = exp\left[\int_0^1 \ln\left[x_2(z)\right] dz\right]$. 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

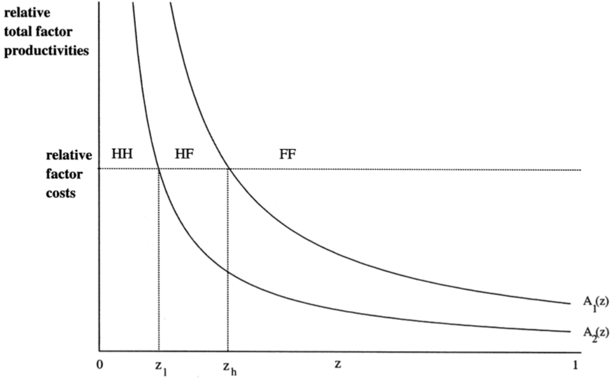


FIG. 5.—Vertical model: free trade. *HF* denotes that Home produces the first stage and Foreign produces the second stage.

With trade costs

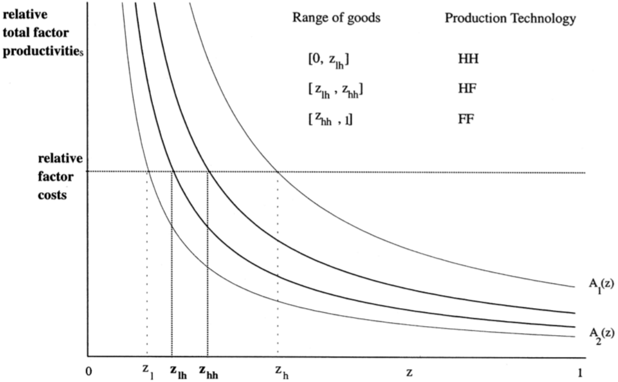


FIG. 6.—Vertical model: tariffs (home consumer's perspective)

Yi (2003): Simplified Version of Model

- If VS is occurring (ie τ 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: $\frac{w^H}{w^F} = (1+\tau)^{(1+\theta)/(1-\theta)} A_2^H(z_l)/A_2^F(z_l)$.
  - Differentiating and ignoring changes in the relative wage:

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

- However, if VS is not occurring (ie τ is high) then:
  - This requires that $\frac{w^H}{w^F} = (1+\tau) A^H(z_l)/A^F(z_l)$ where $A^i(z) = (A_1^i(z))^\theta (A_2^i(z))^{1-\theta}$.
  - So the equivalent derivative is:

$$\widehat{1 - z_l} = \left[\frac{z_l}{(1-z_l)\eta_A}\right] \widehat{1+\tau}$$

- 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

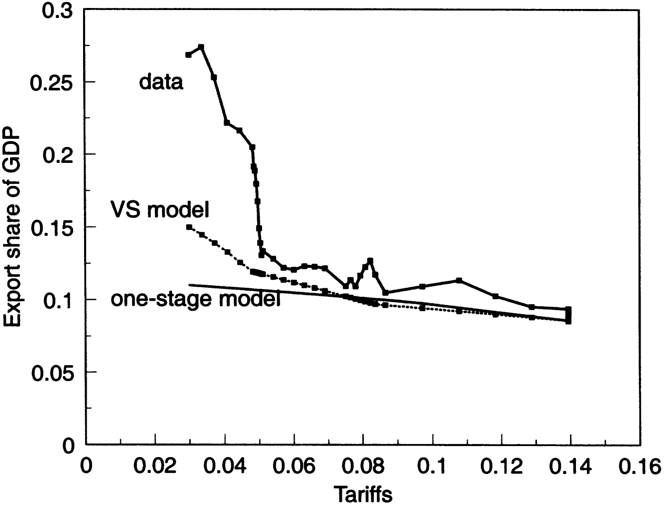


FIG. 10.—Narrow case: vertical model vs. one-stage model

Yi (AER, 2010)

- 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.