A Coasian model of international production chains

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Motivation

- Production processes seem increasingly complex
  - Many suppliers involved (e.g. car and aircraft industries)
  - Many examples: barbie doll, ipod, Airbus, etc.
- Growth of trade in intermediate goods and reduction in value-added content in trade (Johnson and Noguera 2012):
  - “vertical specialization”
  - “Great unbundling”
  - “Fragmentation of production”
  - “Slicing up the value chain”
  - “Disintegration of production”
  - “Delocalization”
  - “Global production sharing”
  - “Flattening of the world” ...
An extensive literature

Focusing on vertical specialization / sequential fragmentation:

- Yi (2003, 2010): fragmentation magnifies the effect of trade costs on trade
- Costinot and R-C (2013): fragmentation magnifies the gains from trade
- Antras and Chor (2013): integration of supplier along the chain
- Costinot, Vogel and Wang (2011): O-ring theory and specialization along production chains

... Yet, models of trade and production chains often assume:

- Exogenous **length** of production chains: often 1 or 2 stages (or no within-country fragmentation)
- Exogenous or random **position** of countries on production chains
- With a few exceptions: muted effects of trade costs
This paper

Part 1. A model of production staging and vertical specialization:

Ingredients: within-firm coordination costs vs. transaction costs (these cost parameters vary across countries)

⇒ Predictions on production staging within and across countries:
  - Endogenous fragmentation and number of production stages
  - Endogenous sorting of countries along production chains
  - Endogenous allocation of tasks across firms, across/within countries

Part 2. Quantitative analysis:

  - Indexes of fragmentation (Fally, 2012)
  - Calibration of 10-country model based on Asian input-output tables
  - Counterfactuals: trade costs decrease, with and without China, etc.
Take-aways

1. **Fragmentation** and allocation of tasks along the chain:
   - Firm scope (range of tasks performed) tends to be smaller upstream
   - Trade Lib. leads to more fragmentation across and within countries

2. **Comparative advantage** along and across chains:
   - Countries with smaller firm scope specialize upstream

3. **Link** to the data
   - Key parameters reflected in the gross-output-to-VA ratio
   - Calibration + more testable predictions than existing models

Other points:

4. Magnifies **elasticity of trade** to trade costs (as in Yi 2010)
   - Smaller elasticity for trade in VA than gross trade

5. **Gains from trade** depend on value-added content of trade
   - final goods ACR: understate GT downstream, overstate GT upstream
A Coasian Model of GVC's

Introduction

VA/GO ratio along the chain

- Motivating fact: VA/GO is lower for upstream industries/countries
Model

Final goods:

- Indexed by $\omega$

- Cobb-Douglas preferences: $U = \int_{\omega} \log q^F(\omega) \, d\omega$

- Labor productivity $a_i(\omega)$ varies across varieties as in EK (2002) to generate specialization across varieties.

- Perfect competition (and CRS)

- Each final good variety $\omega$ involves a different production chain $\omega$:
  $\Rightarrow$ Focus of the model: behavior and outcomes within chains.
Modeling a chain $\omega$

Borrows from Kikuchi et al (’12), Chaney Ossa (’14), Costinot et al (’12):

- Range $[0, 1]$ of (ordered) tasks to be performed sequentially.

- Firm $f$ completing range $s_{if}$ of tasks in country $i$ incurs convex costs:

$$w_i c_i(\omega, s) df = w_i a_i(\omega) \frac{s_{if}}{\theta_i(\omega) + 1}$$

$\Rightarrow$ Diseconomies of scope ($\theta_i$) limits size of a given firm

- Transactions between firm $f$ and $f + df$ (within borders) induce losing a fraction $\gamma_i df$ of the value of the transaction

$\Rightarrow$ Transaction costs $\gamma_i$ give firms incentives to internalize activities

+ Ad valorem trade costs $\tau > 1$ also limits expansion across countries
Along a specific chain $\omega$

- Indexing countries by $i$ from 1 (downstream) to $N$ (upstream) and firms from 0 to $F_i$ within each country.

- Completing all tasks requires: $\sum_i \int_{f=0}^{F_i} s_{if} df = 1$

- **Quantities** grow exponentially. For domestic transactions:
  
  $$q_{i,f+df} = q_{i,f} (1 + \gamma_i df) \quad \Rightarrow q_{i,f} = q_{i,0} e^{\gamma_f}$$

  and for international transactions:

  $$q_{i,F_i} = \tau q_{i+1,0}$$

- **Price** of good sold at stage $f−df$ in country $i$:

  $$p_{i,f−df} = p_{i,f} + \gamma_i p_{i,f} df + w_i c_i(s_{i,f}) df$$
If firms are in different countries:
• Further multiplies price by $\tau > 1$

---

Firm f:
• Buys input from firm $f+df$
• Sells output to firm $f-df$
• Adds value $wc(s_f)\, df$

\[
p(f) = wc(s(f)) \, df + (1+\gamma df) \, p(f+df)
\]

Price at stage $f$

Cost of activities performed by firm $f$

Price of intermediate goods from firm $f+df$
Gross output and VA

Gross output at $f$: $Q \cdot p(f) = \int wc(f') df'$

VA: $Q \cdot wc(s(f)) df$
Along a chain $\omega$

For each chain $\omega$, we need to solve for:

- Which countries participate
- Sorting of countries (i.e. which is $i = 1, 2, ...$ as we go upstream)
- Range of tasks $S_i$ performed in country $i$
- Range of firms $F_i$ within each countries
- Firm scope $s_{if}$ for firm $f$ in country $i$
- Quantities $q_{if} = q_{i,0} e^{\gamma_{if}}$
- Prices $p_{if}$ and costs $c_{if}$ along the chain
Main questions to explore in this setup:

- Extent of fragmentation across and within countries?

- Patterns of specialization and sorting of countries along the chain? How are they affected by the Coasian parameters $\theta_i$ and $\gamma_i$?

- What are the gains from domestic and international fragmentation?

- What are the effect of trade costs on trade and VA content of trade?

- What determines firm scope and allocation of value-added?
Within-country fragmentation

- CRS + Perfect comp: economy at its first best
- Objective: minimize final good price for each chain
- First step: Minimize the price given the range of tasks $S$ and the price of imported intermediate goods $P^M$:

$$P(S, P^M) = \min_{s_f, F} \left[ \int_{f=0}^{F} e^{\gamma f} \omega c(s_f) df + e^{\gamma F} P^M \right]$$

under the constraint:

$$\int_{f=0}^{F} s_f df = S$$

associated with Lagrangian $\lambda$ (shadow cost of fragmentation).
A Coasian Model of GVC's Model

Firm scope along the chain

**Result #1:** Firm scope decreases with upstreamness

- FOC in **firm scope**:
  \[ wc'(s_f) = \lambda e^{-\gamma_f} \]

\[ \Rightarrow \] Firm scope decreases with upstreamness (within a country):
  - Transactions are more costly when products are more valuable
  - Downstream goods are more valuable (value builds up)
  - Hence transactions are more costly downstream
Market for tasks

- Equilibrium allocation: as if tasks were traded
  - Price summarized by shadow cost $\lambda$

- Perfect competition and free entry along the chain:

  $P = MC = AC$ in terms of tasks:

  $$\lambda e^{-\gamma_f} = wc'(s_f) = \frac{wc(s_f) + \gamma p_f}{s_f} = AC$$

- As we go downstream (smaller $f$), AC increases:
  - Value of inputs $p_f$ increases (similar to Costinot et al 2012)
  - Firm scope $s_f$ expands (new margin)
Within-country fragmentation

**Result #2**: More fragmentation when $\theta_i$ is high or $\gamma_i$ is low

- Explicit solution for extent of **fragmentation** $F$ and shadow cost of fragmentation $\lambda$

**Result #3**: $\frac{GO}{VA}$ equals ratio of Coasian parameters $\theta_i$ and $\gamma_i$

- **VA/GO** ratio at the firm level:

  $$\frac{VA}{GO} = \frac{wc(s_f)}{p_f} = \frac{\gamma}{\theta}$$

  remains constant across firms within a country/chain

- Same **VA/GO** ratio on aggregate:

  $$\frac{VA}{GO} = \frac{\int_0^F e^{\gamma f} wc(s_f) df}{\int_0^F e^{\gamma f} p_f df} = \frac{\gamma}{\theta}$$
Within-country fragmentation

**Result #4:** Productivity is log-supermodular in $\theta$ and $\gamma$

- Productivity term: $A \equiv a \left( \frac{\gamma(\theta+1)}{\theta} \right)^\theta$

- **Price** at the downstream stage within the country:
  
  $$P = \left[ \left( \frac{S}{\theta+1} \right) (wA)^{\frac{1}{\theta+1}} + \left( P^M \right)^{\frac{1}{\theta+1}} \right]^{\theta+1}$$

- Share of imported intermediate goods in total costs:
  
  $$\frac{Q^M P^M}{QP} = \frac{(P^M)^{\frac{1}{\theta+1}}}{\left( \frac{S}{\theta+1} \right) (wA)^{\frac{1}{\theta+1}} + (P^M)^{\frac{1}{\theta+1}}}$$
Global value chains

- **Choice variables (endogenous):**
  - Price $P_i$ at the end of the portion of the chain located in $i$
  - Range of tasks $S_i$ performed by each country
  - Number of countries involved in the chain
  - Country rank (index $i$)

- **Cost minimization:** $\min P_1$ under the constraints:

  $$P_i = \left[ \left( \frac{S_i}{\theta_i + 1} \right) \left( w_i A_i \right)^{\frac{1}{\theta_i+1}} + \left( \tau P_{i+1} \right)^{\frac{1}{\theta_i+1}} \right]^{\theta_i+1}$$

  \[ \sum_{i=1}^{N} S_i = 1 \]

  where $N$ is the number of countries involved in the chain ($P_{N+1} = 0$).
Global optimum: Sorting along the chain

Result #5: High-θ_i countries specialize upstream

- More precisely: θ_i must increase along the chain

\[ θ_1 < θ_2 < ... < θ_N \]

⇒ Countries with smaller firms specialize upstream

Result #6: High-γ_i countries tend to produce downstream

- Recall that productivity is LSM in γ_i and θ_i
  Hence, high-γ countries are more likely to participate in chains where they have low θ’s.
**Sorting along the chain: more intuition**

- For intermediate good price $p$, suppose:

\[
AC_1 = \frac{w_1 c_1(s_1) + \gamma_1 p}{s_1} = \frac{w_2 c_2(s_2) + \gamma_2 p}{s_2} = AC_2
\]

- Going downstream, we now have $p' > p$ (value builds up):

  **case 1.** If $s_1 = s_2 = \bar{s}$ fixed and exogenous (as in Costinot et al 2012)

  \[
  AC_1' < AC_2' \iff \gamma_1 < \gamma_2
  \]

  **case 2.** If $s_1$ and $s_2$ are endogenous (new margin), with $w_i c_i(s_i) = \frac{\gamma_i p}{\theta_i}$ and $\frac{\gamma_i p}{AC_i} = \frac{\theta_i}{\theta_i+1}$, we get instead:

  \[
  AC_1' < AC_2' \iff \theta_1 < \theta_2
  \]

  $\Rightarrow$ **Log-supermodularity** in $\{p, \theta\}$ determines sorting of countries
Global solution

**Result #7**: Reductions in trade costs lead to lower final goods prices and more fragmentation, within and across countries.

Analytical results using $\Theta(wA, \tau)$, capturing gains from fragmentation:

$$
\Theta(wA, \tau) = \left[1 - \sum_{n=1}^{N-1} (\theta_{n+1} - \theta_n) \left(\frac{w_n A_n}{\tau w_{n+1} A_{n+1}}\right)^{\frac{1}{\theta_{n+1} - \theta_n}}\right]^{\theta_{n+1}} < 1
$$

- Price of final goods: $P_1 = \frac{A_1 w_1}{(\theta_1+1)^{\frac{\theta_1}{\theta_1+1}}} \Theta(wA, \tau)$
- Share of country $i$ in total costs $P_1$ of producing final good: $\frac{d \log \Theta}{d \log w_i}$
- Shadow cost of fragmentation: $\lambda_G = \frac{A_1 w_1}{(\theta_1+1)^{\frac{\theta_1}{\theta_1+1}}} \Theta(wA, \tau)^{\frac{\theta_1}{\theta_1+1}}$
- Firm scope for the most downstream firm: $s_{1,f=0} = \frac{\gamma_1}{\theta_1} \Theta(wA, \tau)^{\frac{1}{\theta_1+1}}$
General equilibrium in a two-country case:

Additional analytical results:

- Two countries: $D$ and $U$ (“D” and “Up”) with $\theta_D < \theta_U$
- Frechet-distributed productivity across chains, dispersion parameter $\xi$

**Result #8**: Fragmentation magnifies elasticity of trade to $\tau$, Effect depends on foreign VA content for marginal variety

$\Rightarrow$ Can be potentially very large

**Result #9**: Lower VAX ratio with lower trade costs $\tau$

**Result #10**: Larger gains from trade for downstream country than upstream compared to Arkolakis et al (2012) formula
Some extensions

- **Assembly**: Production function for assembly:

  \[ p^F = w^\gamma \left( \prod_k \log p(1, k)^{\beta_k} \right)^{1-\gamma} \]

- Generates the following results:
  - Assembly in low-wage countries (mostly China)
  - Low-wage countries end up doing more downstream tasks (besides assembly) to save on transport costs: **overshooting** effect

- Add **sectoral** dimension:
  - Introduce both sectors and **spiders**
  - Combine at assembly stage
  - Adding other sources of CA along chain: differences in factor intensity?
Asian International Input-Output Tables

- Developed by IDE-JETRO (Japan Ministry of Commerce)
- Cover: USA, JPN, SGP, CHN, TWN, KOR, MYL, THA, IDN, PHL
- 1975, 1990, 2000 Tables with 45 industries in panel
  (76+ industries in 1990 and 2000)
- 4-D Input-output matrix with coefficients $\mu_{ijcs}$ depending on:
  ◦ Output industry $i$
  ◦ Input industry $j$
  ◦ Destination country $c$
  ◦ Input country source $s$
    (deviates from proportionality assumption: see Puzello 2012)

NB: More aggregated than BEA tables for the US (430 industries for 2002)
Global I-O matrix to inform on key moments

- Gross-output-to-VA ratios

- **Upstreamness** index $D$ to capture $f$ and $F$
  - Average number of stages before reaching final consumers (see Fally 2012, Antras et al 2012)
  - $D_i$: average weighted by value-added
  - $DX_i$: average weighted by exports

- Index $N$ to reflect embodied upstream stages
  - Aggregate $N_i$: weighted by final output (see Fally 2012)

- To capture the border crossings instead of plant crossings:
  - Index $D^*$: border crossings before reaching final consumers
  - Index $N^*$: border crossings embodied in production
Illustration:

- **D=2**: 100% → 100%
- **D=1.5**: 50% → 50% → 50% → 100%
- **D=1**: 100%
VA/GO ratio along the chain

- Motivating fact: VA/GO is lower for upstream industries/countries

Recall: $\frac{\gamma_i}{\theta_i}$

Variations in $\gamma_i$ and $\theta_i$ can generate this pattern

- High-$\theta$ countries/industries more likely to be upstream
- High-$\gamma$ countries more likely to specialize downstream
### VA/GO ratio along the chain

**Table:** Simple means of staging statistics

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependent var.:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VA/GO</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upstreamness</td>
<td>-0.025</td>
<td>-0.060</td>
<td>-0.019</td>
<td>-0.028</td>
</tr>
<tr>
<td></td>
<td>[0.012]**</td>
<td>[0.008]**</td>
<td>[0.008]*</td>
<td>[0.008]*</td>
</tr>
<tr>
<td>Industry FE</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Country FE</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>R2</td>
<td>0.106</td>
<td>0.429</td>
<td>0.152</td>
<td>0.542</td>
</tr>
<tr>
<td>N Obs.</td>
<td>478</td>
<td>478</td>
<td>478</td>
<td>478</td>
</tr>
</tbody>
</table>

**Notes:** OLS regression with robust s.e.; manufacturing industries, trimming observations with upstreamness above 4; * significant at 5%; ** significant at 1%.
Calibration (model in general equilibrium)

- 10-country GE with both heterogeneous $A$’s and heterogeneous $\theta$’s (all countries export some final goods and some intermediate goods)

- Using analytical results above, we reduce the optimization problem for each chain to a linear programming problem (solving in GAMS).

- Exploit simple comparative statics in GE for $A$’s, $\theta$’s and $\gamma$’s

- Now: simulations for 10,000 product varieties
  Can be scaled up to at least 100,000 varieties
Calibration (model in general equilibrium)

Parameters:

- Efficiency parameter $A_i$ calibrated to clear labor markets given:
  - wages $w_i$ from the PWT (GDP per capita)
  - Labor supply to match observed value added by country

- Calibrating $\theta_i$ to match $DX_i$ for each country

- GO/VA ratios from input-output tables to calibrate $\gamma_i$

- Trade costs $\tau$ calibrated to match Trade/GDP ratios for Asia

Calibration: country-specific parameters

<table>
<thead>
<tr>
<th>Country</th>
<th>Targeted moments</th>
<th>Fitted parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>log(w)</td>
<td>DX</td>
</tr>
<tr>
<td>US</td>
<td>0</td>
<td>2.555</td>
</tr>
<tr>
<td>Singapore</td>
<td>-0.067</td>
<td>2.659</td>
</tr>
<tr>
<td>Japan</td>
<td>-0.272</td>
<td>2.375</td>
</tr>
<tr>
<td>Taiwan</td>
<td>-0.472</td>
<td>2.613</td>
</tr>
<tr>
<td>Korea</td>
<td>-0.712</td>
<td>2.637</td>
</tr>
<tr>
<td>Malaysia</td>
<td>-1.489</td>
<td>2.590</td>
</tr>
<tr>
<td>Thailand</td>
<td>-1.913</td>
<td>2.360</td>
</tr>
<tr>
<td>Indonesia</td>
<td>-2.622</td>
<td>3.002</td>
</tr>
<tr>
<td>China</td>
<td>-2.665</td>
<td>1.973</td>
</tr>
<tr>
<td>Philippines</td>
<td>-2.765</td>
<td>2.508</td>
</tr>
</tbody>
</table>
Calibration: country-specific parameters

A simple smell test:

$\gamma_i$ is positively correlated with Doing Business indexes (World bank)

**Table: Simple correlations with DB indicators**

<table>
<thead>
<tr>
<th>Correlation with:</th>
<th>gamma</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of starting a business (% of income)</td>
<td>0.805</td>
</tr>
<tr>
<td>Cost of enforcing contract (% of claim)</td>
<td>0.841</td>
</tr>
<tr>
<td>Time to enforce contracts</td>
<td>0.188</td>
</tr>
<tr>
<td>Resolving insolvency (recovery rate)</td>
<td>-0.435</td>
</tr>
</tbody>
</table>
## Fragmentation indexes: model vs. data

Table: Averages of indexes $D$ and $N$ by country

<table>
<thead>
<tr>
<th>Index</th>
<th>$D$</th>
<th>$D^*$</th>
<th>$N$</th>
<th>M share</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Data</td>
<td>Model</td>
<td>Data</td>
<td>Model</td>
</tr>
<tr>
<td>USA</td>
<td>2.252</td>
<td>2.706</td>
<td>0.208</td>
<td>0.171</td>
</tr>
<tr>
<td>SGP</td>
<td>2.558</td>
<td>4.112</td>
<td>1.062</td>
<td>0.274</td>
</tr>
<tr>
<td>JPN</td>
<td>2.370</td>
<td>2.699</td>
<td>0.278</td>
<td>0.187</td>
</tr>
<tr>
<td>TWN</td>
<td>2.567</td>
<td>3.652</td>
<td>0.699</td>
<td>0.276</td>
</tr>
<tr>
<td>KOR</td>
<td>2.537</td>
<td>3.159</td>
<td>0.503</td>
<td>0.286</td>
</tr>
<tr>
<td>MYS</td>
<td>2.755</td>
<td>3.305</td>
<td>0.912</td>
<td>0.320</td>
</tr>
<tr>
<td>THA</td>
<td>2.373</td>
<td>2.823</td>
<td>0.591</td>
<td>0.282</td>
</tr>
<tr>
<td>IDN</td>
<td>2.509</td>
<td>2.997</td>
<td>0.521</td>
<td>0.592</td>
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<td>CHN</td>
<td>2.707</td>
<td>2.746</td>
<td>0.278</td>
<td>0.139</td>
</tr>
<tr>
<td>PHL</td>
<td>2.006</td>
<td>2.718</td>
<td>0.483</td>
<td>0.363</td>
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<tr>
<td>Corr. w. data</td>
<td>0.469</td>
<td>0.305</td>
<td>0.844</td>
<td>0.801</td>
</tr>
</tbody>
</table>

*D*: upstreamness; *N*: embodied stages

“M share”: export share of intermediate goods
Counterfactual exercises:

1) 10% Decrease in multi-lateral border trade costs $\tau$
2) 10% Increase in labor productivity in China
3) 10% Decrease in transaction costs $\gamma_{CHN}$ in China
4) 10% Decrease in trade costs between China and the US

Other possible interesting counter-factual exercises:

- Decrease in coordination costs in China
- Removing China
- Increase in overall range of tasks
- Unilateral trade liberalization
- Productivity shocks in other countries
Counterfactual exercise 1)

Table: 10% decrease in border trade costs: \( \tau' - 1 = (\tau - 1)/1.1 \)

<table>
<thead>
<tr>
<th>10x Δ</th>
<th>Welfare gains</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>10x Frag</td>
<td>No frag</td>
<td>DX</td>
<td>D</td>
<td>D*</td>
<td>N</td>
<td>N*</td>
<td>VAX</td>
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</tr>
<tr>
<td>USA</td>
<td>0.080</td>
<td>0.064</td>
<td>-0.304</td>
<td>-0.062</td>
<td>0.066</td>
<td>-0.043</td>
<td>0.036</td>
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<tr>
<td>SGP</td>
<td>0.241</td>
<td>0.225</td>
<td>0.221</td>
<td>-0.285</td>
<td>0.143</td>
<td>-0.452</td>
<td>0.076</td>
<td>-0.135</td>
<td></td>
</tr>
<tr>
<td>JPN</td>
<td>0.124</td>
<td>0.100</td>
<td>-0.362</td>
<td>-0.116</td>
<td>0.055</td>
<td>-0.049</td>
<td>0.048</td>
<td>-0.087</td>
<td></td>
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<tr>
<td>TWN</td>
<td>0.228</td>
<td>0.198</td>
<td>-0.356</td>
<td>-0.110</td>
<td>0.053</td>
<td>-0.023</td>
<td>0.018</td>
<td>-0.111</td>
<td></td>
</tr>
<tr>
<td>KOR</td>
<td>0.203</td>
<td>0.178</td>
<td>-0.541</td>
<td>-0.178</td>
<td>0.043</td>
<td>-0.178</td>
<td>0.056</td>
<td>-0.112</td>
<td></td>
</tr>
<tr>
<td>MYS</td>
<td>0.246</td>
<td>0.222</td>
<td>-0.445</td>
<td>-0.064</td>
<td>0.052</td>
<td>0.006</td>
<td>0.034</td>
<td>-0.113</td>
<td></td>
</tr>
<tr>
<td>THA</td>
<td>0.248</td>
<td>0.210</td>
<td>-0.564</td>
<td>-0.156</td>
<td>-0.001</td>
<td>-0.036</td>
<td>0.078</td>
<td>-0.144</td>
<td></td>
</tr>
<tr>
<td>IDN</td>
<td>0.256</td>
<td>0.198</td>
<td>-0.279</td>
<td>0.060</td>
<td>0.093</td>
<td>-0.047</td>
<td>0.049</td>
<td>-0.075</td>
<td></td>
</tr>
<tr>
<td>CHN</td>
<td>0.146</td>
<td>0.127</td>
<td>-0.264</td>
<td>-0.113</td>
<td>0.047</td>
<td>0.138</td>
<td>0.052</td>
<td>-0.098</td>
<td></td>
</tr>
<tr>
<td>PHL</td>
<td>0.242</td>
<td>0.219</td>
<td>-0.306</td>
<td>-0.059</td>
<td>0.083</td>
<td>-0.054</td>
<td>0.052</td>
<td>-0.117</td>
<td></td>
</tr>
</tbody>
</table>
Counterfactual exercise 2)

Table: 10% increase in labor productivity in China

<table>
<thead>
<tr>
<th>10x Δ</th>
<th>Frag</th>
<th>No frag</th>
<th>DX</th>
<th>D</th>
<th>D*</th>
<th>N</th>
<th>N*</th>
<th>VAX</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHN</td>
<td>0.975</td>
<td>0.975</td>
<td>-0.377</td>
<td>-0.221</td>
<td>-0.078</td>
<td>-1.165</td>
<td>-0.013</td>
<td>0.010</td>
</tr>
<tr>
<td>USA</td>
<td>0.016</td>
<td>0.016</td>
<td>0.127</td>
<td>0.050</td>
<td>0.035</td>
<td>-0.812</td>
<td>0.003</td>
<td>0.002</td>
</tr>
<tr>
<td>SGP</td>
<td>0.001</td>
<td>0.020</td>
<td>0.430</td>
<td>0.554</td>
<td>0.067</td>
<td>-1.097</td>
<td>-0.020</td>
<td>0.019</td>
</tr>
<tr>
<td>JPN</td>
<td>0.017</td>
<td>0.015</td>
<td>0.205</td>
<td>0.084</td>
<td>0.038</td>
<td>-1.089</td>
<td>0.005</td>
<td>-0.001</td>
</tr>
<tr>
<td>TWN</td>
<td>0.019</td>
<td>0.012</td>
<td>0.243</td>
<td>0.110</td>
<td>0.050</td>
<td>-0.932</td>
<td>-0.006</td>
<td>0.001</td>
</tr>
<tr>
<td>KOR</td>
<td>0.009</td>
<td>0.019</td>
<td>0.285</td>
<td>0.205</td>
<td>0.052</td>
<td>-1.346</td>
<td>-0.007</td>
<td>0.003</td>
</tr>
<tr>
<td>MYS</td>
<td>0.022</td>
<td>0.021</td>
<td>0.110</td>
<td>0.148</td>
<td>0.030</td>
<td>-1.503</td>
<td>-0.012</td>
<td>-0.001</td>
</tr>
<tr>
<td>THA</td>
<td>0.001</td>
<td>0.021</td>
<td>0.231</td>
<td>0.239</td>
<td>0.045</td>
<td>-1.624</td>
<td>-0.011</td>
<td>0.014</td>
</tr>
<tr>
<td>IDN</td>
<td>0.017</td>
<td>0.006</td>
<td>0.364</td>
<td>0.334</td>
<td>0.107</td>
<td>-0.985</td>
<td>-0.022</td>
<td>0.024</td>
</tr>
<tr>
<td>PHL</td>
<td>0.017</td>
<td>0.024</td>
<td>0.163</td>
<td>0.195</td>
<td>0.053</td>
<td>-1.584</td>
<td>-0.027</td>
<td>0.014</td>
</tr>
</tbody>
</table>
Counterfactual exercise 3)

**Table:** 10% decrease in transaction costs $\gamma_i$ in China

<table>
<thead>
<tr>
<th>10x $\Delta$</th>
<th>welfare</th>
<th>DX</th>
<th>$D^*$</th>
<th>$D$</th>
<th>$N^*$</th>
<th>$N$</th>
<th>VAX</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHN</td>
<td>0.953</td>
<td>1.661</td>
<td>0.042</td>
<td>4.513</td>
<td>-0.082</td>
<td>3.876</td>
<td>0.142</td>
</tr>
<tr>
<td>USA</td>
<td>0.031</td>
<td>0.301</td>
<td>0.022</td>
<td>0.116</td>
<td>0.024</td>
<td>0.183</td>
<td>0.015</td>
</tr>
<tr>
<td>SGP</td>
<td>0.025</td>
<td>-0.003</td>
<td>0.014</td>
<td>-0.169</td>
<td>0.027</td>
<td>-0.498</td>
<td>-0.011</td>
</tr>
<tr>
<td>JPN</td>
<td>0.029</td>
<td>0.251</td>
<td>0.023</td>
<td>0.106</td>
<td>0.029</td>
<td>0.173</td>
<td>0.002</td>
</tr>
<tr>
<td>TWN</td>
<td>0.031</td>
<td>0.197</td>
<td>0.014</td>
<td>0.048</td>
<td>0.013</td>
<td>0.095</td>
<td>0.001</td>
</tr>
<tr>
<td>KOR</td>
<td>0.035</td>
<td>0.282</td>
<td>0.037</td>
<td>0.269</td>
<td>0.016</td>
<td>0.194</td>
<td>0.003</td>
</tr>
<tr>
<td>MYS</td>
<td>0.025</td>
<td>0.182</td>
<td>-0.001</td>
<td>0.228</td>
<td>-0.007</td>
<td>0.080</td>
<td>0.017</td>
</tr>
<tr>
<td>THA</td>
<td>0.031</td>
<td>-0.032</td>
<td>-0.017</td>
<td>-0.001</td>
<td>0.024</td>
<td>0.031</td>
<td>-0.010</td>
</tr>
<tr>
<td>IDN</td>
<td>0.035</td>
<td>0.429</td>
<td>0.038</td>
<td>0.440</td>
<td>0.003</td>
<td>0.122</td>
<td>0.014</td>
</tr>
<tr>
<td>PHL</td>
<td>0.030</td>
<td>0.376</td>
<td>0.055</td>
<td>0.396</td>
<td>-0.024</td>
<td>0.130</td>
<td>0.043</td>
</tr>
</tbody>
</table>
Counterfactual exercise 4)

Table: 10% Reciprocal decrease in trade costs between China and the US

<table>
<thead>
<tr>
<th>Model:</th>
<th>With Fragmentation</th>
<th>No Frag</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Δlog</td>
<td>Gross trade</td>
</tr>
<tr>
<td>USA-CHN</td>
<td>0.449</td>
<td>0.506</td>
</tr>
<tr>
<td>CHN-USA</td>
<td>0.387</td>
<td>0.441</td>
</tr>
</tbody>
</table>
Summary and concluding remarks

- We develop a new theoretical framework
  - A model of Foreign and Domestic fragmentation
  - Trade leads to more fragmentation across firms
  - Endogenous sorting of countries and firms w.r.t firm scope
  - Fragmentation magnifies trade elasticities and gains from trade
  - Parsimonious framework, allowing for calibration in GE.

- Quantitative analysis based on input-output data on Asia
  - Calibration and various counter-factual exercises
  - Generalizing indexes from Fally (2012) and Antras et al. (2012) that can be computed with multi-country Input-Output Tables.
  - Negative correlation between Upstreamness and VA/GO
  - Future work: assembly stage (+ maybe spiders), calibration by sector