On the Geography of Global Value Chains

Pol Antràs and Alonso de Gortari

Harvard University

May 5, 2016
Sequential Global Value Chains

- Production processes are **sequential** in nature: Raw materials $\rightarrow$ Basic components $\rightarrow$ Complex components $\rightarrow$ Assembly
Sequential Global Value Chains

- Production processes are **sequential** in nature: Raw materials $\rightarrow$ Basic components $\rightarrow$ Complex components $\rightarrow$ Assembly
Sequential Global Value Chains

- Production processes are **sequential** in nature: Raw materials → Basic components → Complex components → Assembly
Sequential Global Value Chains

- Production processes are sequential in nature: Raw materials $\rightarrow$ Basic components $\rightarrow$ Complex components $\rightarrow$ Assembly
Sequential Global Value Chains

- Production processes are **sequential** in nature: Raw materials $\rightarrow$ Basic components $\rightarrow$ Complex components $\rightarrow$ Assembly
Cool Pictures... But Why Do We Care?

- What are the implications of sequential GVCs for the workings of general-equilibrium models?
  - **Location**: Harms, Lorz, and Urban (2012), Baldwin and Venables (2013), Costinot et al. (2013)
  - **Organization**: Antràs and Chor (2013), Alfaro et al. (2015), Kikuchi et al. (2014)
  - **Both**: Fally and Hillberry (2014)

- What are the implications of sequential GVCs for the quantitative consequences of trade cost reductions?
  - Yi (2003), Johnson et al. (2014), Fally and Hillberry (2014)

- **Past work**: very stylized or non-existent trade costs
Consider optimal location of production for the different stages in a sequential global (multi-country) value chain.

Without trade frictions, not much different from standard multi-country sourcing models.

With trade frictions, matters become trickier.

Location of a stage takes into account geography of upstream and downstream locations.

Where is the good coming from? Where is it going to?

Connection with logistics literature (Travelling Salesman Problem).

NP-complex problem: curse of dimensionality.
Contributions of This Paper

- Develop a general-equilibrium model of GVCs with a general geography of trade costs across countries

1. Characterize the optimality of a centrality-downstreamness nexus
   - Consistent with evidence from *Factory Asia*
Contributions of This Paper

![Graph showing the relationship between Average Export Upstreamness (ACFH) and Log GDP-Weighted Distance (km) to Other Countries in the World for various countries: CHN, HKG, IDN, JPN, KOR, MYS, SGP, THA, TWN, VNM. Points are scattered across the graph, indicating different levels of upstreamness and distance.]
Contributions of This Paper

1. Develop a general-equilibrium model of GVCs with a general geography of trade costs across countries
   - Characterize the optimality of a centrality-downstreamness nexus
     - Consistent with evidence from *Factory Asia*

2. Present tools to solve the problem in high-dimensional environments
   - Reformulate problem so it is solvable with LP techniques
   - Useful for illustrating the role of trade frictions in shaping the global versus regional versus local nature of GVCs

3. Develop a tractable multi-stage variant of the Eaton-Kortum (2002) framework for an arbitrary number of sequential stages
   - Opens the door for quantitative analysis using world I-O tables
Road Map

1. Theoretical Preliminaries: An illustrative example
2. General formulation of the problem
3. Special case that isolates the role of trade costs
   - Proximity-concentration tradeoff
   - Application to Factory Asia
4. A still special, but less special case
5. A multi-stage Ricardian Model
Theoretical Preliminaries
Theoretical Preliminaries: An Illustrative Example

- Suppose a firm is deciding on the location $\ell(n)$ of the different stages in a sequential value chain of length $N$

$$y^n_{\ell(n)} = f^n_{\ell(n)} \left( L^n_{\ell(n)}, c^{n-1}_{\ell(n)} \right) \text{ for all } n \in \{1, \ldots, N\}$$

where

$$c^{n-1}_{\ell(n)} = \frac{y^{n-1}_{\ell(n-1)}}{\tau_{\ell(n-1)\ell(n)}}, \text{ for all } n \in \{2, \ldots, N\}$$

with some initial $c^0_{\ell(1)}$.

- Assume further:

$$y^n_{\ell(n)} = \left( \frac{L^n_{\ell(n)}}{a^n_{\ell(n)}} \right)^{1/n} \left( c^{n-1}_{\ell(n)} \right)^{1-1/n}$$
An Illustrative Example: No Trade Costs

- Without trade frictions, this reduces to:

\[ y_{\ell(N)}^N = \prod_{i=1}^{N} \left( \frac{L_{\ell(n)}^n}{a_{\ell(n)}^n} \right)^{1/N} \]

so you want to minimize \( a_{\ell(n)}^n w_{\ell(n)} \) stage by stage (c.f. AFT, 2015)

- Perhaps different locations have comparative advantage at different parts of the value chain

- Example: \( a_{\ell(n)}^n = \left( T_{\ell(n)} \right)^n \), so \( y_{\ell(n)}^n = T_{\ell(n)} \left( L_{\ell(n)}^n \right)^{1/n} \left( c_{\ell(n)}^{n-1} \right)^{1-1/n} \)

- As in CVW (2013), high TFP countries have comparative advantage downstream
An Illustrative Example: Trade Costs

- With trade frictions, one instead gets

\[ y_{\ell(n)}^N = \prod_{i=1}^{N} \left( \frac{L_{\ell(n)}}{a_{\ell(n)}} \frac{1}{\left( \tau_{\ell(n-1)\ell(n)} \right)^{n-1}} \right)^{1/N} \]

- Two complications
  - Can no longer minimize costs stage-by-stage
  - Location of assembly is no longer detached from where consumption takes place

- Notice that the incentive to reduce trade costs increases as one moves down the value chain
An Illustrative Example: Road Map

- We will first develop a fairly general model of the (Pareto) optimal location of GVCs
- First we will seek to isolate the role of trade costs

$$y_{\ell(n)}^N = \prod_{i=1}^{N} \left( \frac{L_{\ell(n)}}{a_{\ell(n)}} \right)^{1/N} \times \left( \tau_{\ell(n-1)\ell(n)} \right)^{-\frac{n-1}{N}}$$

as well as of trade costs of distributing the final good

**Key:** productivity differences coming from external economies of scale + one-to-one mapping between countries and stages

- Later we will bring back Ricardian productivity differences as in E-K
  - pros: tractable and quantifiable
  - cons: path of a GVC is a random variable
Formal Model: General Environment
Formal Environment

- There are $J$ countries where consumers derive utility from consuming a set of final-good varieties.
- Consumer goods are produced combining $N$ stages that need to be performed sequentially using a unique composite factor (labor).
- The last stage of each production process can be interpreted as assembly and is indexed by $N$.
- Countries differ in their geography, as captured by a $J \times J$ matrix of iceberg trade coefficients $\tau_{ij}$.
- We also let countries vary in their size: each country $i$ is populated by $L_i$ workers (can also model this as variation in efficiency units of labor).
Some Notation

- $c_i^N(z) = \text{consumption of (assembled) final-good variety } z \text{ in country } i$

- $c_i^n(z) = \text{quantity of intermediate good } z \text{ completed up to stage } n < N \text{ available in country } i$

- $L_i^n(z) = \text{allocation of country } i\text{'s labor to the production of stage } n \text{ of good } z$

- $y_i^n(z) = \text{quantity of good } z \text{ up to stage } n \text{ produced in country } i$

- $\delta_{ij}^n(z) = \text{share of production } y_i^n(z) \text{ shipped to country } j$
Graphical Illustration

Stage n

Stage n+1

A

B

C

A

B

C

Formal Model

General Environment

Antràs & de Gortari (Harvard University)

On the Geography of GVCs

May 5, 2016
Graphical Illustration

Stage $n$

- $A$: $c_A^{n-1} \rightarrow L_A^n \rightarrow \delta^n_{AA} \times y^n_A / \tau_{AA}$
- $B$: $c_B^{n-1} \rightarrow L_B^n \rightarrow (1 - \delta^n_{AA}) \times y^n_A / \tau_{AB}$
- $C$: $y^n_B / \tau_{BC}$

Stage $n+1$

- $A$: $c_A^n \rightarrow L_A^{n+1}$
- $B$: $c_B^n \rightarrow L_B^{n+1}$
- $C$: $c_C^n \rightarrow L_C^{n+1}$
Formulation of the Pareto Problem

- Rather than specify market structure, focus on planner's problem
- Pareto optimal allocations are the allocations of labor $L_n^i(z)$ and the distribution shares $\delta_{ji}^n(z)$ that solve:

$$
\begin{align*}
\text{max} & \quad W = \sum_{i=1}^J \lambda_i L_i u \left( \left\{ \frac{c_i^N(z)}{L_i} \right\} \right)_{z=0} \\
\text{subject to} & \quad y_i^n(z) = f_{i,z} \left( L_i^n(z), c_i^{n-1}(z) \right), \text{ for all } n, i, z, \\
& \quad c_i^n(z) = \sum_{j=1}^J \frac{\delta_{ji}^n(z) y_j^n(z)}{\tau_{ji}}, \text{ for all } n, i, z; \quad c_i^0(z) = c, \\
& \quad \sum_{i=1}^J \delta_{ji}^n(z) = 1, \text{ for all } n, j, z, \\
& \quad \int_0^1 \sum_{n=1}^N L_i^n(z) \, dz = L_i, \text{ for all } n.
\end{align*}
$$
Isolating the Role of Trade Costs
A Particular Case: Pure Snakes with Agglomeration

- Let us begin by making the following simplifying assumptions
  1. There is only one final good
  2. Gains from specialization driven purely by external economies of scale

\[
f^n (L_i^n, c_i^{n-1}) = \left( (L_i^n)^\phi L_i^n \right)^{1/n} (c_i^{n-1})^{1-1/n}.
\]

- GVCs are **pure snakes**: no ‘merging’ for \( n \leq N \) and no ‘splitting’ for \( n < N \)

- There are as many stages as countries \( N = J \) and assignment is \textbf{injective} (one-to-one)

- Logarithmic utility: \( u \left( \frac{c_i^N}{L_i} \right) = \ln \left( \frac{c_i^N}{L_i} \right) \)
Injective Assignment with $N = J$

Then, world welfare is given by

$$W = \sum_{i=1}^{N} \lambda_i L_i \ln \left( \frac{\delta^N(N)}{L_i} \left( \frac{\tau_{\ell(N)}i}{\tau_{\ell(N)}i} \right)^{-1} \prod_{n=1}^{N-1} \left( \tau_{\ell(n)}\ell(n+1) \right)^{-n/N} \left( \prod_{n=1}^{N} \left( L_{\ell(n)} \right)^{1/N} \right)^{\phi+1} \right)$$

where $\ell^i(n)$ is the country producing stage $n$ in that chain.

Lemma 1 (Modified TSP)

In the even case $N = J$, the optimal injective assignment of stages to countries with logarithmic utility seeks to solve

$$\min_{\{\ell(n)\}_{n=1}^{N}} H(\ell(1), \ldots, \ell(N)) = \sum_{i=1}^{N} \Lambda_i N \ln \tau_{\ell(N)i} + \sum_{n=1}^{N-1} n \ln \tau_{\ell(n)}\ell(n+1),$$

where $\Lambda_i = \lambda_i L_i / \sum_{i=1}^{J} \lambda_i L_i$. 
Injective Assignment with $N = J$

$$
\min_{\{\ell(n)\}_{n=1}^N} H(\ell(1), \ldots, \ell(N)) = \sum_{i=1}^N \Lambda_i N \ln \tau_{\ell(N)i} + \sum_{n=1}^{N-1} n \ln \tau_{\ell(n)\ell(n+1)}
$$

- Notice that Pareto weights and population matter only in determining location of assembly (market access)

- Connection to Traveling Salesman Problem
  - But ‘traveling salesman’ is getting increasingly tired

- Reducing trade costs downstream is more beneficial than upstream

- As a result, central locations are more prone to specialize downstream
The Centrality-Downstreamness Nexus

- Assume trade costs can be decomposed as follows:

\[ \tau_{ij} = \begin{cases} 
(\rho_i \rho_j)^{-1} & \text{if } i \neq j \\
\zeta (\rho_i \rho_j)^{-1} & \text{if } i = j, \text{ with } \zeta < 1 
\end{cases} \]  

(1)

**Proposition 1 (Centrality-Downstreamness Nexus)**

Let countries be ordered according to their centrality so that \( \rho_1 < \rho_2 < \ldots < \rho_N \). Then, as long as cross-country differences in \( \lambda_i \) and \( L_i \) are sufficiently small, the optimal injective assignment is such that \( \ell(n) = n \), and thus the \( n \)-th most central country is assigned the \( n \)-th most downstream position in the value chain.

- **Corollary:** conditional on \( \ell(N) \), differences in \( \lambda_i \) and \( L_i \) are irrelevant

- What if trade costs are not log-separable? Solve modified TSP
An Application: Factory Asia

Consider a solution to the modified TSP in Lemma 1 with empirical proxies for bilateral trade costs and population sizes (set $\lambda_i = 1$).

Choose $J = 12$: 11 largest East and Southeast Asian economies and the U.S.

Use gravity equation estimates (Head and Mayer, 2014) to back out log trade costs, up to an irrelevant scalar.

- Distance, contiguity, common language, colonial link, RTAs, common currency, domestic trade.

Computing $12! \approx 479$ million permutations by brute force takes time.

Instead we express the problem as a zero-one linear programming problem (defining dummy variables) and use standard algorithms.
Optimal Pure Snake in Factory Asia: Production
Optimal Pure Snake in Factory Asia: Consumption
Empirical Fit

The graph illustrates the relationship between average export upstreamness (ACFH) and upstreamness in the optimal global value chain. Countries such as China (CHN), Hong Kong (HKG), Indonesia (IDN), Japan (JPN), Korea (KOR), Malaysia (MYS), Singapore (SGP), Thailand (THA), Taiwan (TWN), and Vietnam (VNM) are plotted on the graph. The X-axis represents upstreamness in the optimal global value chain, while the Y-axis shows the average export upstreamness (ACFH). The data points indicate the level of upstreamness each country has in the optimal global value chain and its average export upstreamness. The graph suggests a trend where higher upstreamness in the chain correlates with higher average export upstreamness.

Antràs & de Gortari (Harvard University)
On the Geography of GVCs
May 5, 2016
Relaxing Assumptions
The Non-Injective Case

- So far, single GVC with each stage produced in a single country
  - Useful for illustrating role of geography
  - Real world: multiple GVCs, countries participating at various stages

- Simplest departure from even case:
  - Still only one homogenous good (aggregate output)
  - There are now $J$ countries and $N$ stages, with potentially $J \neq N$
  - Each country sources the final good from a single supply chain and the supply chain follows a unique snake path

- Note that countries may now:
  - perform various stages for a given value chain
  - perform different stages for distinct value chains
  - or be in autarky altogether
The Non-Injective Case

- Various GVCs might now coexist: what do they look like?
- Note that consumption in country $i$ will still satisfy:

$$c_i^N = \delta_{\ell i(N)i}^N \left( \tau_{\ell i(N)i} \right)^{-1} \prod_{n=1}^{N-1} \left( \tau_{\ell i(n)\ell i(n+1)} \right)^{-\frac{n}{N}} \left( \prod_{n=1}^{N} \left( L_{\ell i(n)}^n \right)^{\frac{1}{N}} \right)^{1+\phi},$$

- Main new complication is solving for the amount of labor each country devotes to each value chain’s stage (i.e., $L_{\ell i(n)}^n$)
- The lower the trade costs and the higher $\phi$, the more ‘global’ value chains are
- Computationally, can still reduce problem to zero-one LP problem (country-size bins help enhance dimensionality)
Non-Injective Assignment in Factory Asia: \( J = N = 12 \)
Non-Injective Assignment in Factory Asia: $J = N = 12$
A Reduction in Trade Costs: Production
A Reduction in Trade Costs: Assembly and Consumption
A Multi-Stage Ricardian Model
A Multi-Stage Ricardian Extension

- Further generalizations of the previous proximity-concentration framework are very cumbersome.
- We next pursue an alternative approach building on the probabilistic approach of Eaton and Kortum (2002).
- The framework will accommodate multiple final goods and multiple GVCs producing each of these final goods.
- Model will not predict the path of each specific GVC, but will characterize the relative prevalence of different possible GVCs.
- Past work on multi-stage E-K models has focused on low-dimensional environments (namely $N = 2$).
- We propose a new approach that is equally flexible for environments with $N > 2$. 
Formal Environment

- We go back to our initial general environment with a continuum of final goods. Preferences are now

\[ u \left( \left\{ c_i^N (z) \right\}_{z=0}^1 \right) = \left( \int_0^1 \left( c_i^N (z) \right)^{(\sigma-1)/\sigma} dz \right)^{\sigma/(\sigma-1)}, \quad \sigma > 1 \]

- Technology now features CRS and Ricardian technological differences

\[ f_{i,z}^n (L_i^n (z), c_{i-1}^n (z)) = \left( \frac{L_i^n (z)}{a_i^n (z)} \right)^{1/n} \left( c_{i-1}^n (z) \right)^{1-1/n} \]

- Each country \( j \) draws productivity levels \( 1/a_i^n (z) \) for each stage \( n \) and each good \( z \) independently from the Fréchet distribution

\[ \Pr(a_i^n (z) \geq a) = e^{-T_j a^\theta}, \text{ with } T_j > 0 \]
The Challenge: An Illustration

- Take the case $N = 2$
- Consider cost-minimizing way to service consumers in country $i$
- With knowledge of the productivity draws $1/a^k_1 (z)$ and $1/a^j_2 (z)$, firms would choose $k^* (i)$ and $j^* (i)$ that solve

$$ (k^* (i), j^* (i)) = \arg \min_{(k,j)} \left( a^k_1 (z) w_k \tau_{kj} a^j_2 (z) w_j (\tau_{ji})^2 \right)^{1/2}. $$

- Note that downstream trade costs again carry a higher weight
- **Problem:** the distribution of the product $a^k_1 (z) a^j_2 (z)$ is not Fréchet
  - Eaton-Kortum’s magic is gone
  - This is true even when countries draw a common productivity level $1/a_i (z)$ for all stages $n$ in a given value chain
A Feasible Approach

- **E-K:** firms know the precise productivity levels in a value chain for all stages and countries before making any location decision.

- **Alternative:** Assume instead that firms learn the particular realization of $1/a_i^n(z)$ in different countries $i$ only when the location of production of stage $n-1$ has been decided.
  
  - the same results apply under backward rather than forward learning.

- In the $N = 2$ case, second stage location now solves

  $$j^*(i) = \arg \min_{j \in J} \left( c_k^1 \tau_{kj} a_j^2(z) w_j (\tau_{ji})^2 \right)^{1/2}$$

  - The key is that $c_k^1$ is taken as given.

  - Can iterate for any number of stages and use E-K magic at each stage.
Some Results

- Likelihood of a GVC ending in $i$ and flowing through a given sequence of countries is

$$
Pr(\ell(1), \ell(2), ..., \ell(N); i) = \frac{\prod_{n=1}^{N-1} A_{\ell(n)} \left( \tau_{\ell(n)}\ell(n+1) \right)^{-\theta n} \times A_{\ell(N)} \left( \tau_{\ell(N)}i \right)^{-\theta N}}{\Theta_i}
$$

where $A_j = T_j (w_j)^{-\theta}$ and $\Theta_i$ is the sum of the numerator over all possible country permutations.

- Notice that $-\ln Pr(\ell(1), \ell(2), ..., \ell(N); i)$ is

$$
\theta N \ln \tau_{\ell(N)i} + \theta \sum_{n=1}^{N-1} n \ln \tau_{\ell(n)}\ell(n+1) + \ln \Theta_i - \sum_{n=1}^{N} \ln A_{\ell(n)},
$$

and is closely related to $H(\ell(1), ..., \ell(N))$ in Lemma 1.
The Centrality-Downstreamness Revisited

- Define the average upstreamness $U(\ell; i)$ of production of a given country $\ell$ in value chains that seek to serve consumers in country $i$:

  $$U(\ell; i) = \sum_{n=1}^{N} (N-n+1) \times \frac{\Pr(\ell = \ell(n); i)}{\sum_{n'=1}^{N} \Pr(\ell = \ell(n'); i)}$$

- Closely related to the upstreamness measure proposed by Antràs et al. (2012)

- In the log-separable specification of trade costs, we have that:

**Proposition 3 (Centrality-Upstreamness Nexus)**

The average upstreamness $U(\ell)$ of a country in global value chains is decreasing in its centrality $\rho(\ell)$. 
Revisiting the Factory Asia Example

- We can also compute average upstreamness with empirical proxies for bilateral trade costs and $A_j$
- We do this for the same 12 countries as in our Factory Asia TSP
- Set $N = 3$ (to match an aggregate gross-output to value-added ratio of 2)
- Again use gravity equation estimates to back out log trade costs (we set $\theta = 5$)
- We back out $A_j$ from the sourcing potential estimates in Antràs, Fort and Tintelnot (2015)
Empirical Fit

The empirical fit shows a scatter plot of predicted average upstreamness against average upstreamness in ACFH (2012) for various countries. The correlation coefficient is 0.651, indicating a moderate positive relationship between the predicted and observed upstreamness values. The countries included in the analysis are CHN, HKG, IDN, JPN, KOR, MYS, PHL, SGP, THA, TWN, and VNM.
We next show how we can map the WIOD to our multi-country Ricardian framework

World Input Output Database: Released in 2012

35 sectors

40 countries (85% of world GDP) + ROW

Yearly: 1995-2011

Provides information on input and final output flows across countries
### Calibration to World-Input Output Database

#### Figure 1. Schematic Outline of a World Input–Output Table (WIOT)

<table>
<thead>
<tr>
<th>Supply from country-industries</th>
<th>Final use by countries</th>
<th>Total use</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Use by country-industries</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Country 1</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Industry 1</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Industry N</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Country M</td>
<td>Industry 1</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>Industry N</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Value added by labour and capital</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross output</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Figure: Timmer et al. (2015)*
Targeting Final-Good Shares

- Working with probability formulas, we have that

$$\Pr (\ell (N) = \ell^*; i) = \frac{\sum_{\ell(1) \in J} A_{\ell(1)} \sum_{\ell(2) \in J} \rho_{\ell(1)\ell(2)} A_{\ell(2)} \cdots \left(\rho_{\ell(N-1)\ell^*}\right)^{N-1} A_{\ell^*} \left(\rho_{\ell^*i}\right)^N}{\Theta_i}$$

- This also corresponds to final-good trade shares (right part of WIOD)

- Remember that $$A_j = T_j (w_j)^{-\theta}$$ and $$\rho_{ij} = (\tau_{ij})^{-\theta}$$

- Can use $$(J - 1) \times (J - 1)$$ WIOD final-good shares to estimate:

1. $$A_j$$ for $$j = 1, \ldots, J$$; and

2. The exponent $$\theta$$ needed to transition from gravity estimates of trade costs $$\left(\tau_{ij}\right)^{\epsilon}$$ to $$\rho_{ij} = (\tau_{ij})^{-\theta}$$

3. $$N=3$$ to match an aggregate gross-output to value-added ratio of 2
Fit of the Model: Final-Good Shares

Antràs & de Gortari (Harvard University)  
On the Geography of GVCs  
May 5, 2016 35 / 41
Intermediate Input Flows

- Model produces an input flow from some country $k$ to some other country $j$ in value chains in which $k$ immediately precedes $j$

- Furthermore, if $k$ is at stage $n - 1$ and $j$ is at stage $n$, then that flow accounts for a share $(n - 1) / N$ of the value of the chain

- If the chain ends with consumption in country $i$, then the dollar flow occurring between $n - 1$ and $n$ is

$$\Phi_{k,j; i}^{n-1,n} = \frac{n-1}{N} \times \Pr(\ell(1), \ell(2), \ldots, \ell(n-2), k, j, \ell(n+1) \ldots \ell(N); i) \times F_i$$

where $F_i$ is total spending on final goods in $i$

- Finally, aggregate across all permutations in which $k$ immediately precedes $j$ (and across all $i$) to get overall input flows between $k$ and $j$
We can then compute, for instance, the foreign value-added content of each country’s gross exports, both in the data and in the model.
Work in Progress

- Solve for general equilibrium of the model and calibrate additional moments:
  \[ w_j L_j = \sum_{i \in J} \sum_{n \in N} \Pr(j = \ell(n); i) \frac{1}{N} w_i L_i \]

- Bring in moments from the input flow \( J \times J \) matrix (left part of the WIOD) to estimate trade costs more flexibly (rather than using gravity estimates)

- Improve fit of the model by relaxing the assumption of a common \( T_j \) in all stages
  - formulas readily generalize to the case in which \( T_j^n \) varies both across \( j \) and \( n \)
A Rough Counterfactual

- A 50 percent reduction in trade costs (partial equilibrium!)

![Foreign Content of Exports](chart)

**Legend:**
- **Benchmark**
- **50% fall in trade costs**
A Rough Counterfactual

Foreign Content of Exports by Source

- Benchmark
- 50% fall in trade costs

% of Foreign Content of Exports

- Canada
- Mexico
- Europe
- Asia
- RoW
Conclusions

- We have studied how trade frictions shape the location of production along GVCs.
- We have demonstrated a centrality-downstreamness nexus and have offered suggestive evidence for it.
- Our framework can be used to understand the evolution of value chains from local value chains to regional value chains to truly global value chains.
- We view our work as a stepping stone for a future analysis of the role of man-made trade barriers in GVCs.
  - Should countries use policies to place themselves in particularly appealing segments of global value chains?
  - What is the optimal shape of those policies?