Global Value Chains:
The Economics of Spiders and Snakes

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Three Major Developments

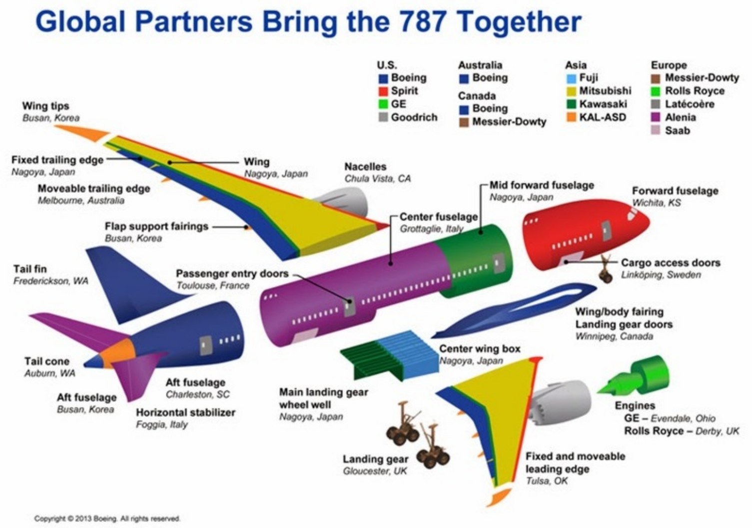
- Three major developments in the world economy in the last 30 years:

1. Information and communication technology (ICT) revolution
2. Deepening of trade liberalization and continuing transportation cost reduction
3. Political developments expanding the reach of globalization

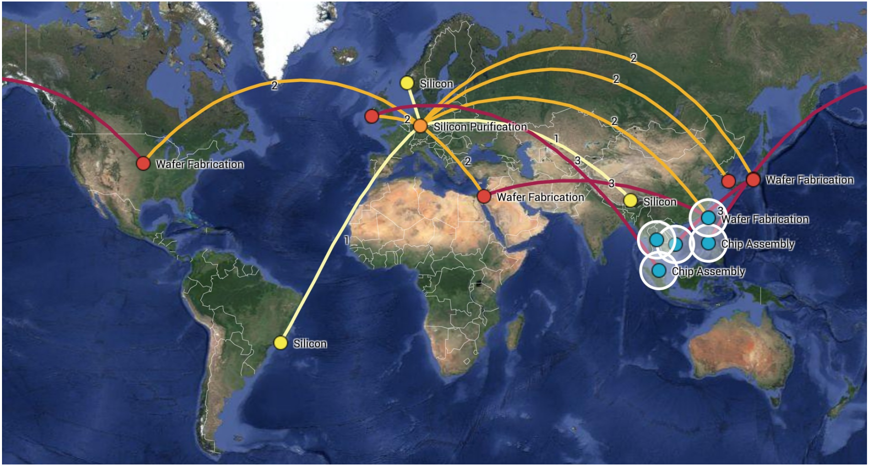
- An implication: Gradual disintegration of production across borders
    - Spiders and Snakes (Baldwin and Venables, 2013)

Spiders and Snakes

A Spider: Boeing's Dreamliner



A Snake: Manufacturing a Chip

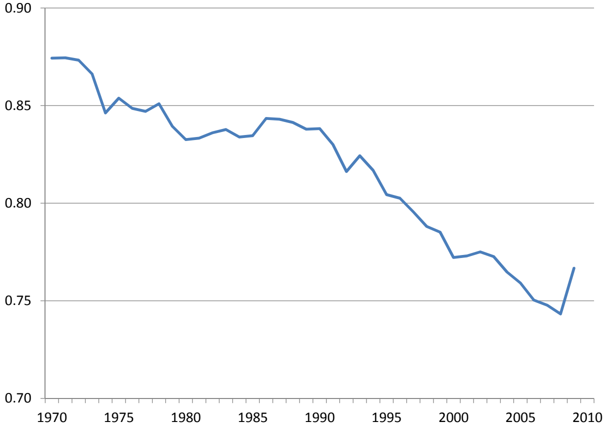


A Hybrid ("Sniker"): Ford Fiesta

Broader Evidence

Broader Phenomenon: A Smoking Gun

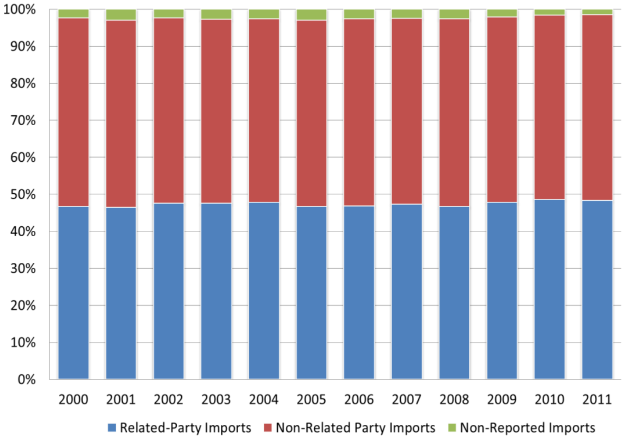
- Declining valued-added share in exports demonstrates rise of GVCs



Source: Johnson and Noguera (2012b)

Another Striking Related Fact

- Intrafirm transactions are remarkably **prevalent** in U.S. trade (close to 50% of imports and around 30% of exports)



Source: U.S. Census Related-Party Trade Database

Conceptual Issues

Taking Stock: Distinctive Features of GVCs

- Prevalence of intermediate input trade in the data (roughly 2/3 of world trade)
- Trade relationships often initiated by importers or lead firms seeking to procure inputs from foreign suppliers
- Parts and components are frequently customized to the needs of their intended buyers
- Due to search and matching frictions, setting up GVCs often entail significant upfront costs
- Trade within GVCs is often sequential in nature
- GVCs entail intensive contracting between parties subject to distinct legal systems

Road Map

Road Map

- Today and next time, I want to highlight a number of **novel** lessons learned when analyzing, structurally estimating and quantifying multi-country models of global value chains

1. **Spiders:** Overview of Antràs, Fort and Tintelnot (2017)
2. **Snakes:** Overview of Antràs and de Gortari (2020)
3. **"Snikers":** A Taste of On-Going Work
4. In the process, I will suggest possible avenues for future research

Building Blocks

1. Neoclassical Trade Theory (technology, factor costs, trade costs)
2. New Trade Theory (product differentiation, scale economies, market power)
3. Firm-Level or "New-New" Trade Theory (heterogeneity, selection into exporting, global sourcing, and MNE activity)
4. Incomplete-Contracting Trade Theories (contractual insecurity and bargaining power)
5. Quantitative Trade Theory (tools for estimating and quantifying trade models)
6. Structural Estimation Techniques (particularly, estimation of multi-market entry models)

Why Should You Care?

- These lectures are not just about making models more “realistic”
- These lectures is not just about developing tools
- There is huge demand for trade counterfactuals these days...
- ... and current workhorse models sometimes give incomplete answers
- Future work: implications for trade policy

Spiders: Antràs, Fort and Tintelnot (2017)

The Margins of Trade

- Suppose you interpret world trade flows (or U.S. imports more narrowly) as the legs of spiders
- Lead firms make decisions of where (extensive margin) to source inputs from and how much (intensive margin) to buy of each input
- **Fact #1:** Extensive margin accounts for most of the cross-country variation in U.S. imports
- **Fact #2:** Superior performance (size, labor productivity, TFP) of firms with more complex sourcing strategies (importing from more countries)
- Similar facts on the export side motivated today's workhorse models of trade (c.f., Melitz, 2003)

Challenges for a Multi-Country Global Sourcing Model

- In canonical models of exporting, firms assumed to have constant marginal costs unaffected by trade decisions
  - Easy to handle various margins of trade
- But importing inputs naturally affects the marginal cost of the firm!
- Import entry decisions are thus interdependent across markets
- Interdependencies across markets complicate the firm's decision
  - Which countries should a firm invest in importing from?
  - From which particular country should each input be bought?
  - How much of each input should be purchased?

Main Contributions of Antràs, Fort and Tintelnot (2017)

- Develop a quantifiable multi-country sourcing model
  - Characterization of intensive and extensive margins of global sourcing
  - Eaton-Kortum (2002) and multi-country Melitz (2003) are special cases
- Develop methodology to solve firm's problem with interdependencies
  - Apply theoretical insights and IO algorithm to estimate model
  - Estimate model with universe of U.S. manufacturing importers in 2007
  - Counterfactual analysis of shock to China's sourcing potential
- Study effects of shocks to global sourcing
  - Distinguish net vs. gross changes in sourcing / employment
  - Reduced-form evidence consistent with these predictions

A Model of Spiders

Environment

- J countries (index i or j), each with measure L_i of individuals
- **Preferences**: Dixit-Stiglitz over manufacturing varieties ($\sigma > 1$)
- **Final good** sector produces these varieties:
  - Measure N_i of heterogeneous firms (pinned down by free entry)
  - Firms characterized by core productivity φ
  - Monopolistic competition
  - Non-tradable final output
- **Intermediate good** sector
  - Each firm uses a unit measure of intermediate inputs (next slide)
  - Each firm in i needs to pay fixed cost $w_i f_{ij}$ to activate source market j
  - Sourcing strategy: $\mathcal{J}_i(\varphi) \subseteq \{1, ..., J\}$
  - Iceberg trade cost τ_{ij} for firms in i to import from j
  - Perfect competition $\Longrightarrow$ Marginal-cost pricing of inputs

Production Technology

- Marginal cost of final good producer φ based in i is:

$$c_i\left(\{j(v)\}_{v=0}^{1}, \varphi\right) = \frac{1}{\varphi}\left(\int_0^1 (p_i(v, j(v)))^{1-\rho}\, dv\right)^{1/(1-\rho)}$$

Production Technology

- Marginal cost of final good producer φ based in i is:

$$c_i\left(\{j(v)\}_{v=0}^{1}, \varphi\right) = \frac{1}{\varphi}\left(\int_0^1 \left(\tau_{ij(v)} a_{j(v)}(v) w_{j(v)}\right)^{1-\rho} dv\right)^{1/(1-\rho)}$$

- Tricky to characterize equilibrium in terms of a_j's
- Instead assume that productivity $1/a_j(v)$ for a given location j is drawn from Fréchet distribution:

$$\Pr(a_j(v) \geq a) = e^{-T_j a^{\theta}}, \quad \text{with } T_j > 0.$$

  - Pros and Cons

Firm Behavior Conditional on Sourcing Strategy

- Share of intermediate input purchases sourced from any country j:

$$\chi_{ij}(\varphi) = \frac{T_j \left(\tau_{ij} w_j\right)^{-\theta}}{\Theta_i(\varphi)} \quad \text{if } j \in \mathcal{J}_i(\varphi)$$

- Sourcing potential of country j (for firms in i): $T_j \left(\tau_{ij} w_j\right)^{-\theta}$
- Sourcing capability of firm φ in i:

$$\Theta_i(\varphi) \equiv \sum_{k \in \mathcal{J}_i(\varphi)} T_k \left(\tau_{ik} w_k\right)^{-\theta}$$

- Marginal cost:

$$c_i(\varphi) = \frac{1}{\varphi} \left(\gamma \Theta_i(\varphi)\right)^{-1/\theta}$$

Optimal Sourcing Strategy

- Profit Function:

$$\max_{I_{ij}\in\{0,1\}_{j=1}^{J}} \varphi^{\sigma-1}\left(\gamma\sum_{j=1}^{J} I_{ij}T_j\left(\tau_{ij}w_j\right)^{-\theta}\right)^{(\sigma-1)/\theta} B_i - w_i\sum_{j=1}^{J} I_{ij}f_{ij}$$

- Proposition 1. The solution $I_{ij}(\varphi)\in\{0,1\}_{j=1}^{J}$ to the optimal sourcing problem is such that firm's sourcing capability $\Theta_i(\varphi)=\sum_{j=1}^{J} I_{ij}(\varphi)\,T_j\left(\tau_{ij}w_j\right)^{-\theta}$ is nondecreasing in φ.

- Proposition 2. For all $j\in\{1,...,J\}$, define the mapping $V_{i,j}(\varphi,\mathcal{J})$ to take a value of one whenever including country j in the sourcing strategy $\mathcal{J}$ raises firm-level profits $\pi_i(\varphi,\mathcal{J})$, and to take a value of zero otherwise. Then, whenever $(\sigma-1)/\theta\geq 1$ $V_{i,j}(\varphi,\mathcal{J}')\geq V_{i,j}(\varphi,\mathcal{J})$ for $\mathcal{J}\subseteq\mathcal{J}'$.

Interdependencies in Firm Sourcing Decisions

- Proposition 3. Holding constant the the market demand level B_i, whenever $(\sigma - 1)/\theta \geq 1$, an increase in the sourcing potential $T_j (\tau_{ij} w_j)^{-\theta}$ or a reduction in the fixed cost f_j of any country j, (weakly) increases the input purchases by firms in i not only from j, but also from all other countries.

- Corollary. There may exist complementarities between domestic and foreign sourcing

Structural Estimation

Data

- 2007 data from the U.S. Census Bureau
  - Economic Censuses
  - Import transactions data
- Sample is all manufacturing firms (around 250,000 firms)
  - Include firms with non-manufacturing activity
  - 23% of employment and 38% of sales
  - 65% of (non-mining) imports
  - A quarter of these firms imports
- Structural Estimation
  - Limit analysis to countries with 200+ U.S. importers
  - 66 countries and the U.S.
- Reduced form evidence on interdependencies
  - Balanced panel of manufacturing firms in 1997 and 2007
  - UN Comtrade data; 1997 BEA Input-Output tables

Some Firm-level Import Statistics

- Count of distinct source locations and products imported by a firm

	Mean	Std. Dev.	25th Ptile	Median	95th Ptile
Country Count	3.26	5.09	1	2	11
Product Count	11.91	48.89	1	3	41

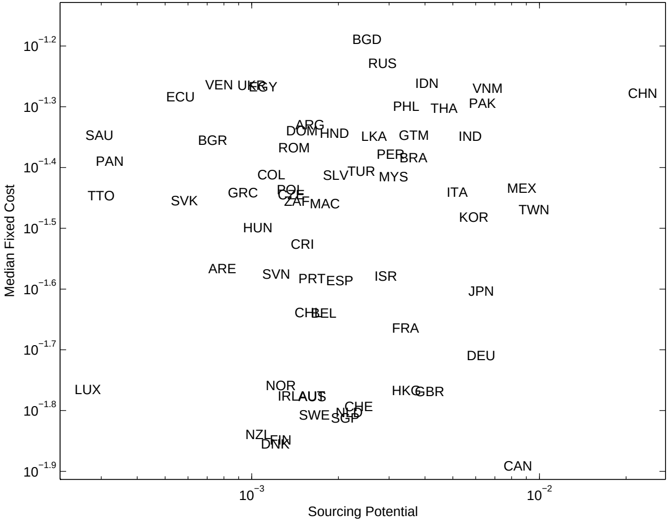
- Although extreme, the continuum of inputs assumption helps a lot

Overview of Estimation

- Step 1: Back out sourcing potential from firm-level input shares
  - Recovered from country fixed effects in normalized share regressions
- Step 2: Estimate demand elasticity and productivity dispersion
  - Project fixed effect on human-capital adjusted labor cost
- Step 3: Estimate fixed costs of sourcing and residual demand
  - Simulated method of moments + Jia's (2008) algorithm

$$\Pi(\mathcal{J},\varphi,f_{ij}^{n}) = \varphi^{\sigma-1}\Bigg(\sum_{j=1}^{j\in\mathcal{J}}\overbrace{T_j(\tau_{ij}w_j)^{-\theta}}^{\text{Step 1}}\Bigg)^{\overbrace{(\sigma-1)/\theta}^{\text{Step 2}}}\overbrace{\widetilde{B}-\sum_{j\in\mathcal{J}}f_{ij}^{n}}^{\text{Step 3}}$$

Sourcing Potential vs. Fixed Cost Estimates



Counterfactual and Reduced-Form Evidence

Counterfactual and Reduced-Form Evidence: China Shock

- Negative shock to China's sourcing potential to match 1997 share of China importers (38% of its 2007 level)
- Resolve for equilibrium price index and mass of new firms
- Calculate impact from going back to 2007 sourcing potential values
- We find evidence of heterogeneous effects
  - Some firms expand sourcing **everywhere**, others contract
- We also provide reduced-form evidence using plausibly exogenous variation in sourcing from China (as in Autor et al., 2013)
  - U.S. firms that started importing from China actually expanded their sourcing from U.S. and also from third countries

Estimates of the China Shock on Firm Sourcing

Dependent variable is change from 1997 to 2007 in firm *n*:

	Domestic inputs	No. of countries	Foreign inputs	Domestic inputs	No. of countries	Foreign inputs
		OLS			IV	
China, DHS	0.084***	0.255***	0.360***	0.934***	0.553***	0.654***
	(0.012)	(0.007)	(0.013)	(0.258)	(0.080)	(0.197)
Constant	0.069***	0.144***	0.315***	-0.064	0.097***	0.269***
	(0.023)	(0.013)	(0.026)	(0.047)	(0.017)	(0.044)
Adj. R^2	0.00	0.11	0.05			
N	127,400	127,400	127,400	127,400	127,400	127,400
First Stage Statistics		Coeff (se) 2.691*** (0.504)			KP Fstat 28.51	

Notes: All variables are changes or growth rates from 1997 to 2007. Standard errors are in parentheses and clustered by 439 NAICS industries. N rounded for disclosure avoidance.

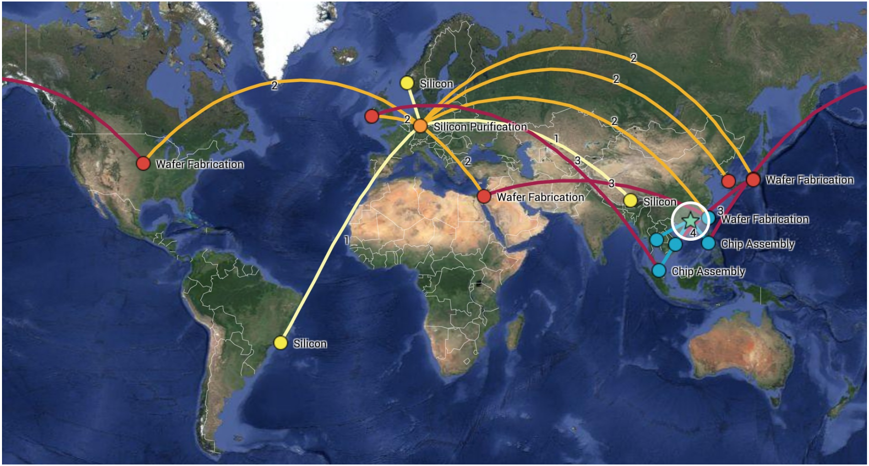
Extensions

Extensions

1. Exporting: allow final-good producers to export
   - In the data, most importers also export; importer-exporters account for over 90% of U.S. trade
2. Endogenous Input Variety: monopolistic competition upstream
   - "Home-market" effect at the firm level
3. Non-CES preferences: variable markups, incomplete pass-through
   - Could the observed rise in markups partly be shaped by rise of GVCs?
4. Variation in institutional quality: T_j is not just technology
   - Study how variation in contracting institutions shapes U.S. sourcing
   - Can build in a choice between foreign outsourcing and FDI

Snakes: Antràs and de Gortari (2020)

A Snake: Manufacturing a Chip



Snakes and Trade Costs: A Challenge

- Consider optimal location of production for the different stages in a sequential GVC
- Without trade frictions ≈ standard multi-country sourcing model (spider)
- With trade frictions, matters become trickier
- Location of a stage takes into account upstream and downstream locations
  - Where is the good coming from? Where is it going to?
  - Need to solve jointly for the optimal path of production
- Connection with logistics literature

Main Contributions of Antràs and de Gortari (2018)

- 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
2. Develop tools to solve the model in high-dimensional environments
3. Show how to map our model to world Input-Output tables
4. Structurally estimate the model and perform counterfactuals

Partial Equilibrium Model

Partial Equilibrium Environment

- Final good demanded in J countries
- Good produced combining N stages that need to be performed sequentially (stage $N =$ assembly)
- Initial stage produced with (equipped) labor
- At each stage $n > 1$, production combines (equipped) labor with good finished up to $n - 1$
- The wage rate w_i varies across countries
- Countries also differ in their geography: $J \times J$ matrix of iceberg trade cost coefficients τ_{ij}
- Technology features constant returns to scale and market structure is perfectly competitive

Partial Equilibrium: Sequential Production Technology

- Optimal path of production $\boldsymbol{\ell}^j = \left\{ \ell^j (1), \ell^j (2), ..., \ell^j (N) \right\}$ for providing the good to consumers in country j dictated by cost minimization

- Assume a Cobb-Douglas-Ricardian cost function

$$p^n_{\ell(n)} (\boldsymbol{\ell}) = \left(a^n_{\ell(n)} w_{\ell(n)} \right)^{\alpha_n} \left(p^{n-1}_{\ell(n-1)} (\boldsymbol{\ell}) \tau_{\ell(n-1)\ell(n)} \right)^{1-\alpha_n}, \text{ for all } n,$$

with $\alpha_1 = 1$

- A good assembled in $\ell (N)$ after following the path $\boldsymbol{\ell}$ is available in any country j at a cost $p^F_j (\boldsymbol{\ell}) = p^N_{\ell(N)} (\boldsymbol{\ell}) \tau_{\ell(N)j}$

Some Results

- Iterating, the cost-minimization problem for a **lead firm** is:

$$\ell^j = \arg\min_{\ell \in \mathcal{J}^N} \left\{ \prod_{n=1}^{N} \left(a^n_{\ell(n)} w_{\ell(n)} \right)^{\alpha_n \beta_n} \times \prod_{n=1}^{N-1} \left(\tau_{\ell(n)\ell(n+1)} \right)^{\beta_n} \times \tau_{\ell(N)j} \right\}$$

where

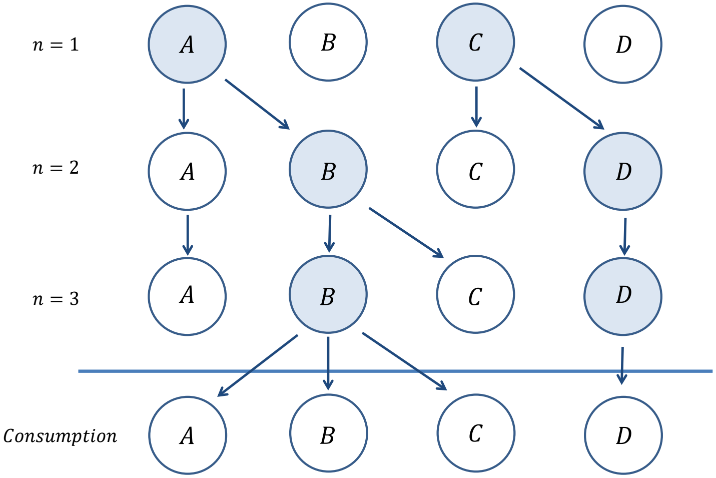
$$\beta_n \equiv \prod_{m=n+1}^{N} (1 - \alpha_m)$$

1. Unless $\tau_{\ell(n-1)\ell(n)} = \tau$, one cannot minimize costs stage-by-stage
   - Turns a problem of dimensionality $N \times J$ into a J^N problem
   - But easy to reduce dimensionality with dynamic programming
2. Trade-cost elasticity of the unit cost of serving consumers in country j increases along the value chain ($\beta_1 < \beta_2 < ... < \beta_N = 1$)
   - Incentive to reduce trade costs increases as one moves downstream

Decentralization

- What if no lead firm coordinates the whole value chain?
- Assume value chain consists of a series of cost-minimizing stage-specific agents (including consumers in each country)
- Stage n producers in $\ell(n)$ pick $\ell(n-1)$ to min $\left\{p^{n-1}_{\ell(n-1)}\tau_{\ell(n-1)\ell(n)}\right\}$, regardless of $w_\ell(n)$, productivity , and future path of the good
- With CRS, identity of the specific firms is immaterial $\Longrightarrow$ as if a lead firm used dynamic programming to solve for the optimal path
- Invoking the principle of optimality, we get the exact same optimal path of production than before
- But much lower dimensionality! ($N \times J$ computations)

Dynamic Programming: An Example



General Equilibrium Model

A Multi-Stage Ricardian Model

- We next embed our framework into a general equilibrium model
- Framework accommodates:
  - Ricardian differences in technology across stages and countries
  - A continuum of final goods
  - Multiple GVCs producing each of these final goods
  - An arbitrary number of countries J and stages N
- Model constitutes a multi-stage extension of the Eaton and Kortum (2002) framework
  - Characterize the relative prevalence of different possible GVCs
  - Study average positioning of countries in GVCs
  - Trace implications for the world distribution of income
- Conceptual innovation: think about (Fréchet) productivity at the chain rather than stage level

Formal Environment

- Preferences are

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

- Technology features CRS and Ricardian technological differences

$$p_{\ell(n)}^n(\boldsymbol{\ell}) = \left(a_{\ell(n)}^n c_{\ell(n)}\right)^{\alpha_n} \left(p_{\ell(n-1)}^{n-1}(\boldsymbol{\ell})\, \tau_{\ell(n-1)\ell(n)}\right)^{1-\alpha_n}, \text{ for all } n$$

Formal Environment

- Preferences are

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

- Technology features CRS and Ricardian technological differences

$$p_j^F(\boldsymbol{\ell}) = \tau_{\ell(N)j} \times \prod_{n=1}^{N-1} \left(\tau_{\ell(n)\ell(n+1)}\right)^{\beta_n} \times \prod_{n=1}^{N} \left(a_{\ell(n)}^n c_{\ell(n)}\right)^{\alpha_n \beta_n}$$

- Bundle of inputs comprises labor and CES aggregator in $u(\cdot)$
  - $c_i = (w_i)^{\gamma_i} (P_i)^{1-\gamma_i}$, where P_i is the ideal consumer price index

Probabilistic Representation of Technology

- In Eaton and Kortum (2002) with $N = 1$, they assume $1/a^j(z)$ is drawn for each good z independently from the Fréchet distribution

$$\Pr(a_n^j(z) \geq a) = e^{-T_j a^\theta}, \text{ with } T_j > 0$$

- **Problem:** The distribution of the product of Fréchet random variables is **not** distributed Fréchet
  - The same would be true with fixed proportions (sum of Fréchets)
- How can one recover the magic of the Eaton and Kortum in a multi-stage setting?

The Challenge: Two Solutions

1. If a production chain follows the path $\{\ell(1), \ell(2), ..., \ell(N)\}$, then

$$\Pr\left(\prod_{n=1}^{N}\left(a^{n}_{\ell j(n)}\right)^{\alpha_n\beta_n} \geq a\right) = \exp\left\{-a^{\theta}\prod_{n=1}^{N}\left(T_{\ell(n)}\right)^{\alpha_n\beta_n}\right\}$$

   - Randomness can be interpreted as uncertainty on compatibility

2. Decentralized equilibrium in which stage-specific producers do not observe realized prices before committing to sourcing decisions
   - Firms observe the productivity levels of their potential direct (or tier-one) suppliers
   - But not of their tier-two, tier-three, etc. suppliers

Some Results

- Percentage of country j's spending produced following a path ℓ:

$$\pi_{\ell j} = \frac{\prod_{n=1}^{N-1} \left(\left(T_{\ell(n)} \right)^{\alpha_n} \left(\left(c_{\ell(n)} \right)^{\alpha_n} \tau_{\ell(n)\ell(n+1)} \right)^{-\theta} \right)^{\beta_n} \times \left(T_{\ell(N)} \right)^{\alpha_N} \left(\left(c_{\ell(N)} \right)^{\alpha_N} \tau_{\ell(N)j} \right)^{-\theta}}{\Theta_j}$$

where Θ_j is the sum of the numerator over all possible paths

- Can compute final-good trade shares and intermediate input shares as explicit functions of T_j's, c_j's, and τ_{ij}'s (conditional probabilities)
- Can also express labor market clearing as a function of transformations of these probabilities
- Costs of going to autarky are a simple function of prevalence of 'purely-domestic' value chain

Estimation

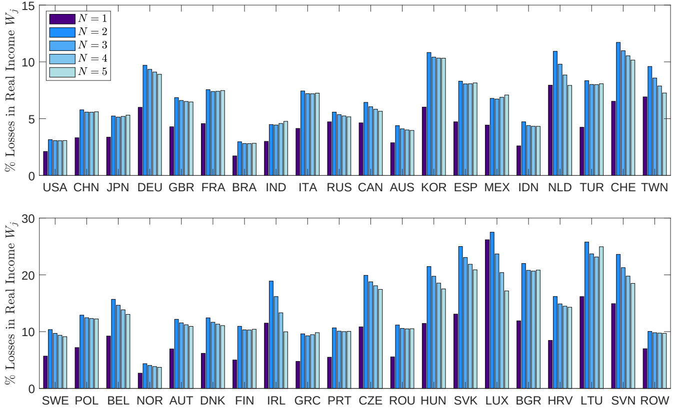
Calibration to World-Input Output Database

- We next map our multi-country Ricardian framework to world Input-Output Tables
- Core dataset: World Input Output Database (2016 release)
    - 43 countries (86% of world GDP) + ROW; available yearly 2000-2014
    - Provides information on input and final output flows across countries
- Also Eora dataset: 190 countries (but consolidate to 101)

		Input use & value added			**Final use**			**Total use**
		Country 1	$\cdots$	Country J	Country 1	$\cdots$	Country J	
Intermediate inputs supplied	Country 1							
	$\cdots$							
	Country J							
Value added								
Gross output								

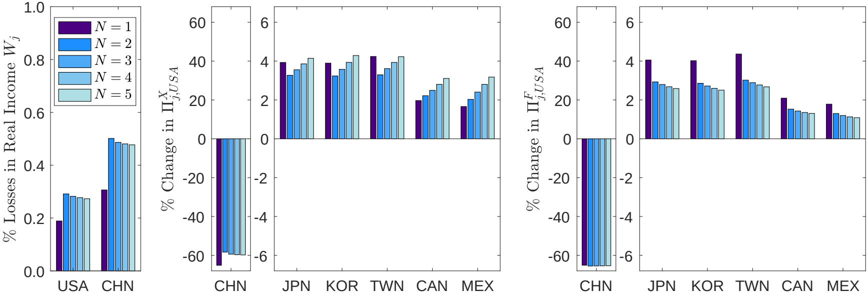
Counterfactuals

Counterfactuals: Real Income Gains Relative to Autarky



- GVC model with $N = 1$, i.e. Eaton-Kortum model, underestimates gains from trade by about 60%

Counterfactuals: U.S.-China Trade War



Extensions

Extensions

1. With CRS and perfect competition, straightforward to add:
   - Further sources of heterogeneity across stages (e.g., raw materials)
   - Multiple sectors with firms buying multiple inputs (spiders)
2. Introducing scale economies is trickier
   - Generates interdependencies across GVCs serving different markets
   - Probably can be solved brute force for low dimensionality
   - See case of "snikers" next
3. An interesting case: external economies of scale with one good and $N = J$ (next, time permitting)
4. Variation in institutional quality: T_j is not just technology
   - Study how variation in contracting institutions shapes location of GVCs
   - Subtle incentive effects working through chains (c.f., Antràs and Chor)

External Economies of Scale

A Particular Case: Pure Snakes with Agglomeration

- We make the following simplifying assumptions

1. There is only one final good
2. Gains from specialization driven purely by external economies of scale

$$a_{\ell(n)}^{n} = \left(L_{\ell(n)}^{n}\right)^{-\phi}$$

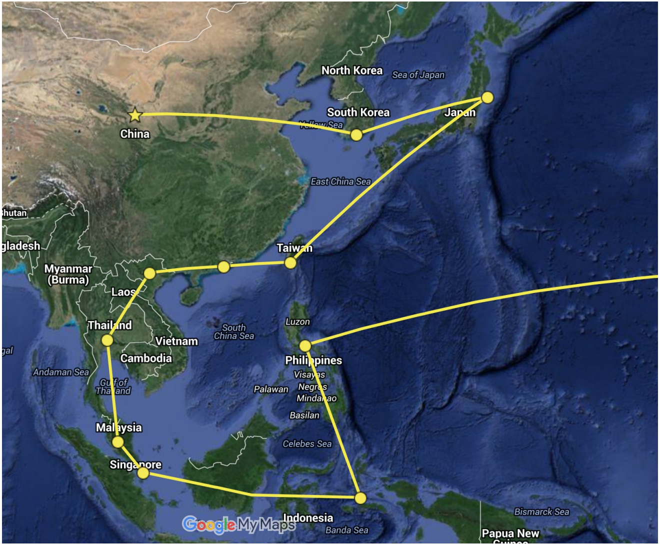
3. GVCs are **pure snakes**
4. There are as many stages as countries $N = J$ and assignment is **injective** (one-to-one)
5. Logarithmic utility: $u\left(c_i^N / L_i\right) = \ln\left(c_i^N / L_i\right)$
6. Solve planner's problem (Pareto weight $\Lambda_i = \lambda_i L_i / \sum_{i=1}^{J} \lambda_i L_i$)

Injective Assignment with $N = J$

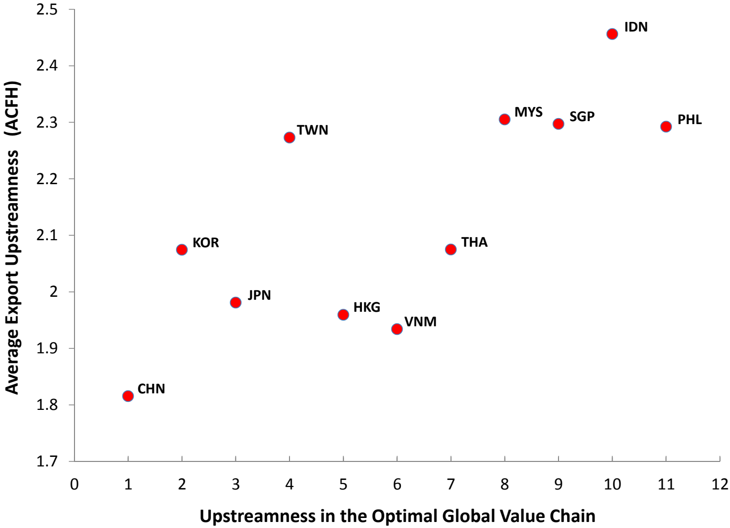
$$\min_{\{\ell(n)\}_{n=1}^{N}} H(\ell(1), ..., \ell(N)) = \sum_{i=1}^{N} \Lambda_i \mathbf{N} \ln \tau_{\ell(N)i} + \sum_{n=1}^{N-1} \mathbf{n} \ln \tau_{\ell(n)\ell(n+1)}$$

- 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 is more beneficial downstream than upstream
- As a result, central locations are more prone to specialize downstream

Optimal Pure Snake in Factory Asia

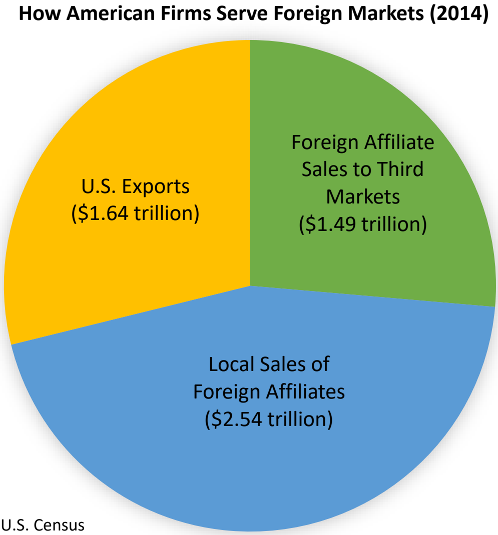


Empirical Fit



"Snikers": Antràs, Fadeev, Fort and Tintelnot

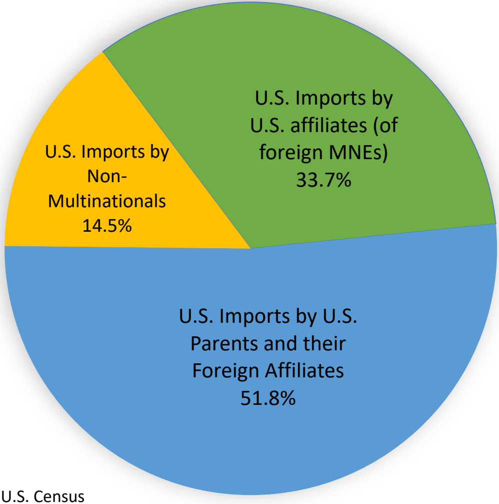
Global Assembly is Important in the Aggregate



Source: BEA and U.S. Census

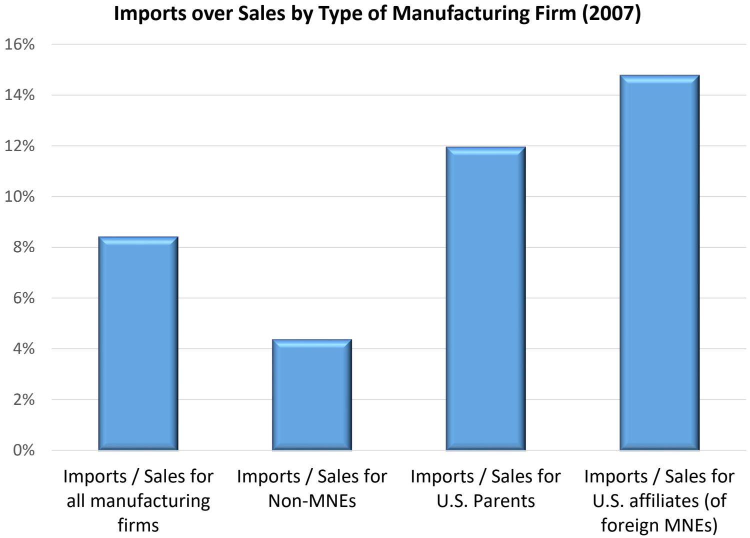
MNEs Dominate U.S. Imports by Manufacturing Firms

U.S. Imports by Type of Manufacturing Firm (2007)



Source: BEA and U.S. Census

MNEs Are Disproportionately Engaged in Global Sourcing



Some Takeaways

- Global Assembly and Global Sourcing are **prominent** features of (U.S.) manufacturing
- These firm strategies appear to be **interdependent**:
  - global sourcing decisions shaped by global assembly strategy
  - global assembly decisions shaped by global sourcing strategy
- These interdependencies are likely to complicate the response of the geography of world manufacturing to increases in trade barriers
  - Tariff-jumping FDI (assembly) versus putting sand in the wheels of GVCs (global sourcing)
- Will Trump tariffs invigorate U.S. manufacturing?

Contributions of Our Project

Our Contributions

- Develop a multi-country model of global assembly **and** global sourcing
  - Model is parsimonious but allows for multiple layers of heterogeneity (permits informative quantification)
- Illustrate how unilateral import tariffs may backfire (revisit Venables-Ossa)
- Develop tools to solve for and estimate the extensive margin of assembly and global sourcing (Jia' 08)
- **Future:** Estimate the model with merged U.S. Census + U.S. Customs + U.S. BEA data on MNEs
- **Today:** Outline estimation strategy and show some preliminary quantitative results
- Explore counterfactuals associated with increases in trade costs

Theoretical Framework

Theoretical Framework: Non-Technical Overview

- Marriage of the global assembly framework in Tintelnot (2017) with the global sourcing framework in Antràs, Fort and Tintelnot (2017)
- Single manufacturing sector: J countries, CES preferences, scale economies, trade costs, monopolistic competition, and free entry
  - Krugman' 80, Melitz '03, and Eaton-Kortum '02 are all special cases
- Final-good producers in the model:
  1. Decide whether and where to pay a fixed cost of entry
  2. Learn their *core* productivity level and obtain blueprint to produce a unit measure of consumer goods
  3. Decide where to set up assembly plants and where to 'search' for potential suppliers (use a unit measure of inputs)
  4. Learn their marginal cost for each input and for each final good
  5. Assembly plants buy inputs from cheapest source; consumers buy final goods from cheapest source

Theoretical Framework: Endowments and Preferences

- J countries indexed by i when consuming, by k when assemblying, by j when providing inputs, and by h when hosting headquarters (entry)
- Fixed (equipped) labor force L_j for $j \in \{1, ..., J\}$, wage w_j
- Endogenous measure Ω_i of manufacturing firms (index φ) selling final goods in country i
- Each firm sells a unit measure of varities (index ω)
- Consumers worldwide spend a share η of income on manufacturing goods
- Preferences over manufacturing are symmetric CES aggregator over goods and varieties

$$U_{Mi} = \left(\int_{\varphi \in \Omega_i} \int_0^1 q_i \left(\varphi, \omega\right)^{(\sigma-1)/\sigma} \mathrm{d}\omega \mathrm{d}\varphi \right)^{\sigma/(\sigma-1)}, \quad \sigma > 1$$

Technology and Market Structure

- Non-manufacturing sector is perfectly competitive and operates under a constant-returns-to scale technology in labor
- Manufacturing sector is monopolistically competitive; free entry
- Manufacturing varieties are produced under increasing returns to scale due to various fixed costs
  - fixed cost of entry: $w_h f_h^e$ to open headquarters in h
  - fixed cost of assembly: $w_h f_{hk}^a$ to assemble in country k
  - fixed cost of sourcing: $w_h f_{hj}^s$ to be able to buy inputs from j
- **Global Assembly Strategy** $\mathcal{K}_h(\varphi)$**:** set of countries k for which a firm headquartered in h has paid $w_h f_{hk}^a$
- **Global Sourcing Strategy** $\mathcal{J}_h(\varphi)$**:** set of countries j for which a firm headquartered in h has paid $w_h f_{hj}^s$
  - Note: *any* assembly plant $k \in \mathcal{K}_h(\varphi)$ can use inputs from $j \in \mathcal{J}_h(\varphi)$

Technology and Market Structure

- Marginal cost in assembly plant k is constant and given by:

$$c_k(\varphi,\omega) = \underbrace{\frac{1}{\varphi}}_{\text{Core productivity}} \times \underbrace{\frac{1}{z_k(\varphi,\omega)}}_{\text{Assembly productivity}} \times \underbrace{(w_k)^{1-\alpha}}_{\text{Assembly labor costs}} \times \left(\int_0^1 \underbrace{\left(\tau^s_{j(v)k} a_{j(v)}(v,\varphi)\, w_{j(v)}\right)}_{\text{Marginal cost of input v}}^{1-\rho} dv \right)^{\alpha/(1-\rho)}$$

- Iceberg trade costs τ^s_{jk} and τ^a_{ki}
- Probabilistic formulation of assembly and input productivities:

$$\Pr(a_j(v,\varphi) \geq a) = e^{-T^s_j a^{\theta^s}}, \quad \text{with } T^s_j > 0$$
$$\Pr(1/z_k(\varphi,\omega) \geq a) = e^{-T^a_k a^{\theta^a}}, \quad \text{with } T^a_k > 0$$

Timing of Events

- Firms worldwide decide whether to pay the fixed cost of setting up headquarters in any country $h \in J$
- Upon entry, they observe their core productivity, drawn from pdf $g_h(\varphi)$ with support in $[\underline{\varphi}_h, \infty)$
- Firms decide on their assembly strategy $\mathcal{K}_h(\varphi)$ and their sourcing strategy $\mathcal{J}_h(\varphi)$
- Firms observe the realization of the productivity levels $a_j(v, \varphi)$ and $z_k(\varphi, \omega)$ for all $j \in \mathcal{J}_h(\varphi)$ and all $k \in \mathcal{K}_h(\varphi)$
- Active assembly plants source inputs from their cheapest location and consumers purchase manufacturing good varieties from the assembly plants that offer the minimum price for those varieties
- Production and consumption takes place

Equilibrium

Firm Behavior for Fixed Assembly and Sourcing Strategies

- Share of intermediate input purchases sourced by an assembly plant in $k \in \mathcal{K}_h(\varphi)$ from any country j is

$$\chi_{hjk}(\varphi) = \frac{T_j^s \left(\tau_{jk}^s w_j\right)^{-\theta^s}}{\Theta_{hk}(\varphi)} \quad \text{if } j \in \mathcal{J}_h(\varphi) \tag{1}$$

and $\chi_{hjk}(\varphi) = 0$ otherwise, where

$$\Theta_{hk}(\varphi) \equiv \sum_{j' \in \mathcal{J}_h(\varphi)} T_{j'}^s \left(\tau_{j'k}^s w_{j'}\right)^{-\theta^s}. \tag{2}$$

- $T_j^s \left(\tau_{jk}^s w_j\right)^{-\theta^s}$ captures the sourcing potential of country j from the point of view of assembly plants in k
- $\Theta_{hk}(\varphi)$ summarizes the sourcing capability of an assembly plant in k producing goods for a firm φ headquartered in h

Firm Behavior for Fixed Assembly and Sourcing Strategies

- Share of firm φ's sales in market i originating from assembly plants in k is given by:

$$\mu_{hki} = \frac{T_k^a \left(\tau_{ki}^a\right)^{-\theta^a} \left(w_k\right)^{-(1-\alpha)\theta^a} \left(\Theta_{hk}\left(\varphi\right)\right)^{\alpha\theta^a/\theta^s}}{\Psi_{hi}}$$

with

$$\Psi_{hi}\left(\varphi\right) = \sum_{k' \in \mathcal{K}_h(\varphi)} T_{k'}^a \left(\tau_{k'i}^a\right)^{-\theta^a} \left(w_{k'}\right)^{-(1-\alpha)\theta^a} \left(\Theta_{hk'}\left(\varphi\right)\right)^{\alpha\theta^a/\theta^s}.$$

- $T_k^a \left(\tau_{ki}^a\right)^{-\theta^a} \left(w_k\right)^{-(1-\alpha)\theta^a}$ captures assembly cost potential of country k when selling to country i
- $\Psi_{hi}\left(\varphi\right)$ summarizes the global production capability of a firm φ headquartered in country h when selling in i.

Firm Behavior for Fixed Assembly and Sourcing Strategies

- Price index at which firm φ based in h sells its unit measure of varieties in market i:

$$p_{hi}(\varphi) = \frac{\sigma}{\sigma - 1}\frac{1}{\varphi}\left(\zeta\Psi_{hi}(\varphi)\right)^{-1/\theta^a},$$

  and firm sales in i are $\left(p_{hi}(\varphi)\right)^{1-\sigma} E_i P_i^{\sigma-1}$
  - Need $\sigma - 1 < \theta^a$ for bounded sales (cannibalization effect dominates)
- Assembly plant k overall sales are

$$s_{hk}(\varphi) = \widetilde{\zeta}\varphi^{\sigma-1}\sum_{i\in J}\mu_{hki} \times \left(\Psi_{hi}(\varphi)\right)^{(\sigma-1)/\theta^a} E_i P_i^{\sigma-1}$$

- Firm's operating profits conditional on $\mathcal{J}_h(\varphi)$ and $\mathcal{K}_h(\varphi)$ are

$$\pi_h(\varphi) = \frac{1}{\sigma}\widetilde{\zeta}\varphi^{\sigma-1}\sum_{i\in J}\left(\Psi_{hi}(\varphi)\right)^{(\sigma-1)/\theta^a} E_i P_i^{\sigma-1}$$

Optimal Assembly and Sourcing Strategies

- Define $\xi^a_{ki} = T^a_k \left(\tau^a_{ki}\right)^{-\theta^a} \left(w_k\right)^{-(1-\alpha)\theta^a}$ and $\xi^s_{jk} = T^s_j \left(\tau^s_{jk} w_j\right)^{-\theta^s}$
- Firm chooses $\mathcal{I}^a_k \in \{0,1\}^J$ and $\mathcal{I}^s_j \in \{0,1\}^J$ to solve

$$\max \ \pi_h(\varphi) = \kappa \varphi^{\sigma-1} \sum_{i \in J} E_i P_i^{\sigma-1} \left(\sum_{k \in J} \mathcal{I}^a_k \cdot \xi^a_{ki} \left(\sum_{j \in J} \mathcal{I}^s_j \cdot \xi^s_{jk} \right)^{\frac{\alpha\theta^a}{\theta^s}} \right)^{\frac{(\sigma-1)}{\theta^a}} - \sum_{j \in J} \mathcal{I}^s_j \cdot w_h f^s_{hj} - \sum_{k \in J} \mathcal{I}^a_k \cdot w_h f^a_{hk},$$

- This is a $2^{J \times 2}$ problem; even for $J = 20$, this is roughly 10^{12}
- Can we exploit some properties of the profit function? (as in Antràs, Fort and Tintelnot, 2017)

Some Properties of the Profit Function

Lemma

The profit function $\pi_h(\varphi)$ *features:*
(a) decreasing differences in $\left(\mathcal{J}^a_k, \mathcal{J}^a_{k'}\right)$ *for* $k, k' \in \{1, ..., J\}$ *and* $k \neq k'$.
(b) decreasing differences in $\left(\mathcal{J}^s_j, \mathcal{J}^s_{j'}\right)$ *for* $j, j' \in \{1, ..., J\}$ *when* $\alpha(\sigma - 1) < \theta^s$.

- In words:
  - extensive margin of assembly features substitutability
  - extensive margin of sourcing may feature subst. or complementarity
- Extensive margins of assembly and sourcing *not* always complements
- Profit function does **not** feature 'single crossing' property

Closing the Model: Industry and General Equilibrium

- Free entry implies $E_i = w_i L_i$
- Consumers spend constant share η on manufacturing sector
- Assume non-manufacturing sector pins down wages and (for now) assume that wage is independent of manufacturing equilibrium
  - e.g., non-manufacturing goods are freely traded and produced in i
  - all general equilibrium action is on allocation of labor to manufacturing and on price index, rather than on nominal wages (Autor, Dorn and Hanson' 13)
- Industry Equilibrium is characterized by:
  - fixed point for vector of price indices P_i
  - free entry condition
- Assume balanced trade (can easily accommodate trade imbalances)

Special Cases

- Symmetric Input Trade Costs ▸ Details
  - (Log) separability (complementarity) of optimal assembly and sourcing strategies
  - Sharp results for sourcing strategies
- Negligible Cannibalization Effects
  - Leads to comparative statics diametrically different from Trump's *mantra* (protection shrinks domestic firms for fixed $E_i P_i^{\sigma-1}$)
- Ossa-Venables model with symmetric firms

Towards an Empirical Model

Towards an Empirical Model

- Adding additional sources of heterogeneity
- Solving extensive margin problem for estimation purposes
  - No "single-crossing" property $\Longrightarrow$ no simple iterative algorithm as in Jia' 08 (or AFT' 17)
  - Brute force method would constrain us to low number of countries J
  - We face data confidentiality constraints, but ideally, we would like to run estimation with $J = 30$ or $J = 40$
- What to do?
  - Iterative Algorithm à la Jia' 08 unlikeky to work
  - Search/Probabilistic Approach

Solving the Extensive Margin: Search Approach

- Reinterpretation of Extensive Margin Problem:
  - firms do not "activate" market ($0-1$ decision) at constant fixed cost
  - rather spend resources to increase the probability of finding suppliers in j or assemblers in k
- Firm chooses search intensities $x_k^a \in [0, \infty)$ and $x_j^s \in [0, \infty)$ at costs $f_{hk}^a(x_k^a)$ and $f_{hj}^s(x_j^s)$
- These expenditures affect the probability of successfully assemblying in country k, $p_k^a(x_k^a) = \mathbb{P}\left(\mathcal{I}_k^a = 1 | x_k^a\right)$, and of successfully sourcing from country j, $p_j^s(x_j^s) = \mathbb{P}\left(\mathcal{I}_j^s = 1 | x_j^s\right)$
- We assume that $p_k^a(x_k^a)$ and $p_j^s(x_j^s)$ are increasing and strictly concave, while $f_{hk}^a(x_k^a)$ and $f_{hj}^s(x_j^s)$ are increasing and strictly convex
- We can of course set $p_k^a(x_k^a) = x_k^a$ and $p_j^s(x_j^s) = x_j^s$ (i.e., firms choose their success probabilities)

Search Approach: Formulation of the Problem

- Denote by $x = (x^a, x^s)$ the vector of search intensities with $x^a \in \mathbb{R}_+^J$ and $x^s \in \mathbb{R}_+^J$. Then, given x the probability of a bundle $\mathcal{J} = (\mathcal{J}^a, \mathcal{J}^s) \in \{0,1\}^{2J}$ with $\mathcal{J}_k^a = 1$ and $\mathcal{J}_j^s = 1$ is

$$\mathbb{P}(\mathcal{J}|x) = \prod_{k \in \mathcal{K}_\mathcal{J}} \prod_{j \in \mathcal{J}_\mathcal{J}} \prod_{k' \notin \mathcal{K}_\mathcal{J}} \prod_{j' \notin \mathcal{J}_\mathcal{J}} p_k^a(x_k^a) \cdot p_j^s(x_j^s) \cdot (1 - p_{k'}^a(x_{k'}^a)) \cdot \left(1 - p_{j'}^s(x_{j'}^s)\right)$$

- Expected operating profits can be written as

$$\mathbb{E}[\pi_h^{op}(\varphi)|x] = \sum_{\mathcal{J} \in \{0,1\}^{2J}} \pi_h^{op}(\varphi, \mathcal{J}) \times \mathbb{P}(\mathcal{J}|x)$$

- Note that the expectation $\mathbb{E}[\pi_h^{op}(\varphi)|x]$ is of dimension 2^{2J}... so what have we gained?

- Key: This probabilistic approach allows us to use Monte-Carlo simulations to compute specific conditional expectations

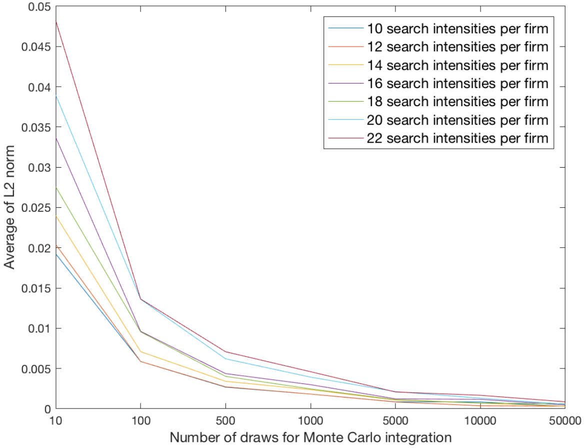
Search Approach: Computational Approach

- **Idea:** compute first-order condition for the choice of each $x \in (x^a, x^s)$ holding the other x's constant (conditional expectation)
- Problem of finding optimal vector of search intensities x^* for firm φ can be written as fixed point of system of first-order conditions
- First-Order Condition for assembly location k

$$\frac{\mathrm{d}}{\mathrm{d}x_k^a} p_k^a(x_k^a) \cdot \Big(\mathbb{E}[\pi_h^{op}(\varphi) \,|\mathcal{I}_k^a = 1, (x^s, x_{-k}^a)] - \\ - \mathbb{E}[\pi_h^{op}(\varphi) \,|\mathcal{I}_k^a = 0, (x^s, x_{-k}^a)] \Big) = \frac{\mathrm{d}}{\mathrm{d}x_k^a} f_k^a(x_k^a)$$

- Use Monte-Carlo simulations to approximate the conditional expectations when solving the model with a large number of countries
- **Issue:** Second-Order-Conditions (can check locally)

A Preview



- Can use Chernoff bounds to evaluate errors in simulations for larger number of countries

Data

A New Linked U.S. Census-BEA Dataset

- 2007 Census data
  - Longitudinal Business Database: private non-farm employer establishments
  - Economic Censuses: Sales and inputs Import and Export transactions of merchandise goods (LFTTD)
  - Company Organization Survey (COS): ownership information
- 2007 BEA data on Direct Investment and Multinational Enterprises:
  - BEA U.S. Direct Investment Abroad Dataset: foreign affiliate activities of firms headquartered in US
  - BEA Foreign Direct Investment in the United States Dataset: U.S. affiliate activities of firms headquartered abroad
- Combine datasets using EINs and name and address matching
  - Census generally maps more EINs and activity to a unique firm
  - Use COS to distinguish US versus majority-owned foreign firms

Sample Selection

- Limit the analysis to firms with manufacturing in the US
- US import data give us these firms' global sourcing strategy
  - can distinguish between input and final-good purchases using the US Census material trailers files and Input-Output tables
  - Foreign sourcing is limited to imports of HS6 goods that are in the same broad NAICS 6 categories that the firms' manufacturing plants use as inputs
- Focus on foreign affiliates with manufacturing activity
  - Goal is to identify foreign assembly locations
  - Eliminate foreign affiliates overwhelmingly selling intermediate inputs to the U.S.
  - Refine sales of foreign affiliates back to US with Customs data

Estimation

Broad Overview

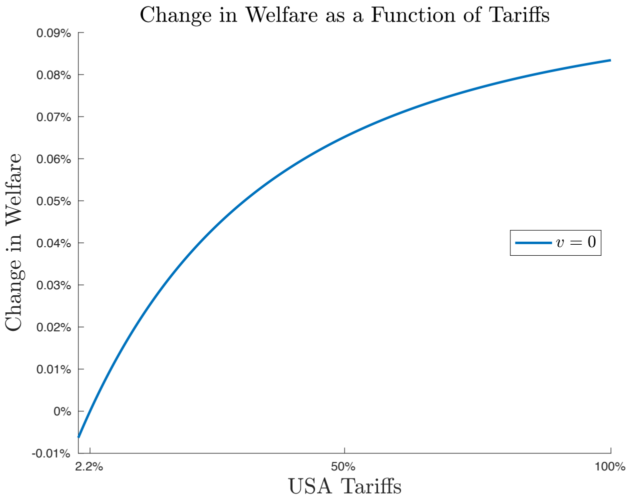
1. Back out sourcing potential from U.S. firm-level input shares
   - Recovered from country fixed effects in normalized share regressions
2. Estimate demand elasticity (σ) and input productivity dispersion (θ^s)
   - Project fixed effects on cost-shifters (wages, tariffs)
3. Use affiliate sale data of foreign affiliates of U.S. firms to back out assembly potentials
   - Solve system of equations with auxiliary estimates for trade costs and market potential
   - May also try to estimate assembly productivity dispersion (θ^a)
4. Estimate fixed costs of sourcing and assembly
   - Simulated method of moments + Algorithm for solving extensive margin

Preliminary Exercise

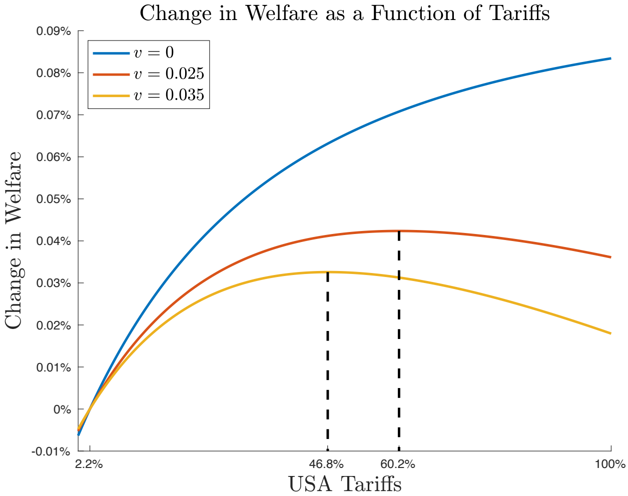
A Rough Exercise

- Consider our modified Ossa-Venables example with homogeneous firms
- We can extend it to include transport costs, asymmetric wages and asymmetric technologies
- Easy to perform counterfactuals with simple trade and affiliate sales shares (available from public sources), relative wages, tariff levels and estimates of key elasticities (σ, θ^s, θ^a)
    - related to hat algebra approach in Dekle, Eaton and Kortum' 07 or Ossa' 11
- Can evaluate the quantitative importance of input tariff incidence for welfare implications of rising tariffs?

Effects of Tariffs on Welfare



Effects of Tariffs on Welfare



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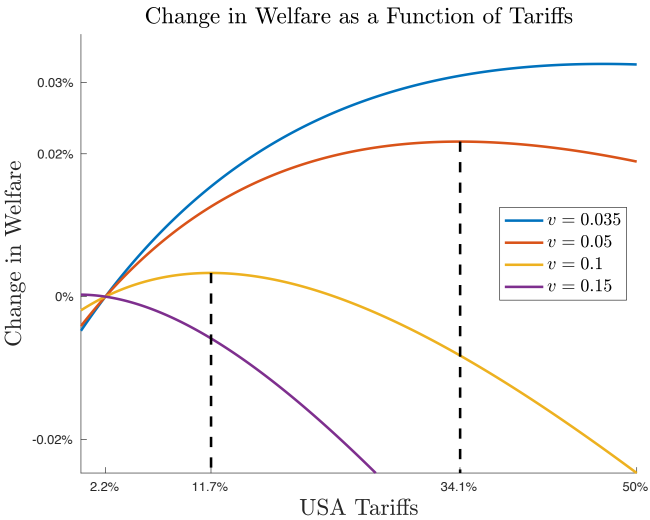

Effects of Tariffs and Tariff Wars on Welfare

TABLE 1
WELFARE ESTIMATES

Incidence	20% unilateral	20% trade war	50% unilateral	50% trade war
$v = 0$	0.036%	0.015%	0.065%	0.000%
$v = 0.05$	0.019%	−0.003%	0.019%	−0.045%
$v = 0.10$	0.001%	−0.020%	−0.025%	−0.089%
$v = 0.15$	−0.015%	−0.036%	−0.066%	−0.129%
$v = 1$	−0.249%	−0.268%	−0.516%	−0.572%

Conclusions

Conclusions

- We have developed frameworks to study how technology, geography, and institutional quality shape the location of production along GVCs
- Both for Spiders and for Snakes, and for hybrids of the two
- Frameworks deliver novel qualitative insights, but can also be used to quantitatively assess the implications of the rise of GVCs
- I view this 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?