Global Value Chains: The Economics of Spiders and Snakes

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Three Major Developments

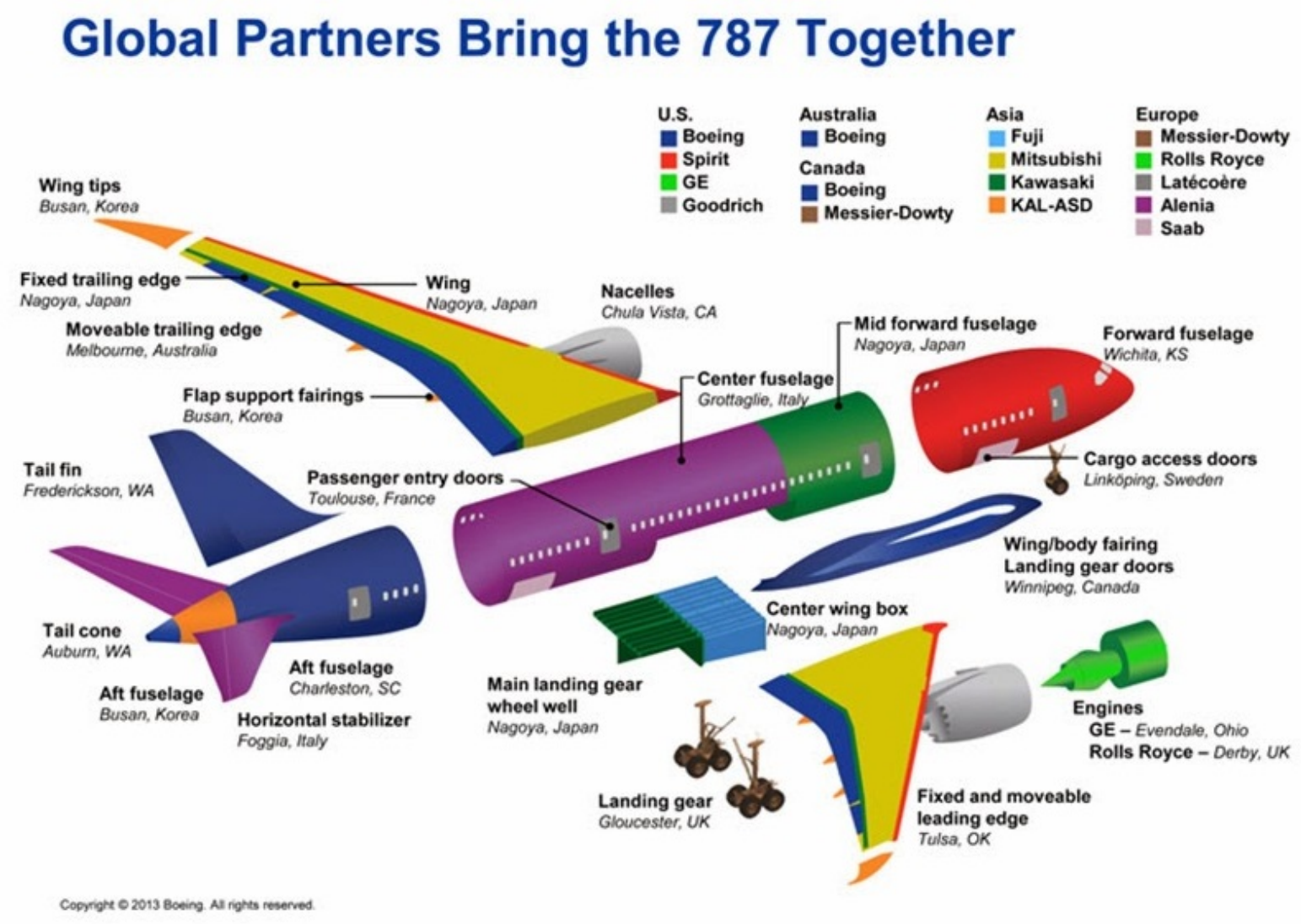
- Three major developments in the world economy in the last 30 years:

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

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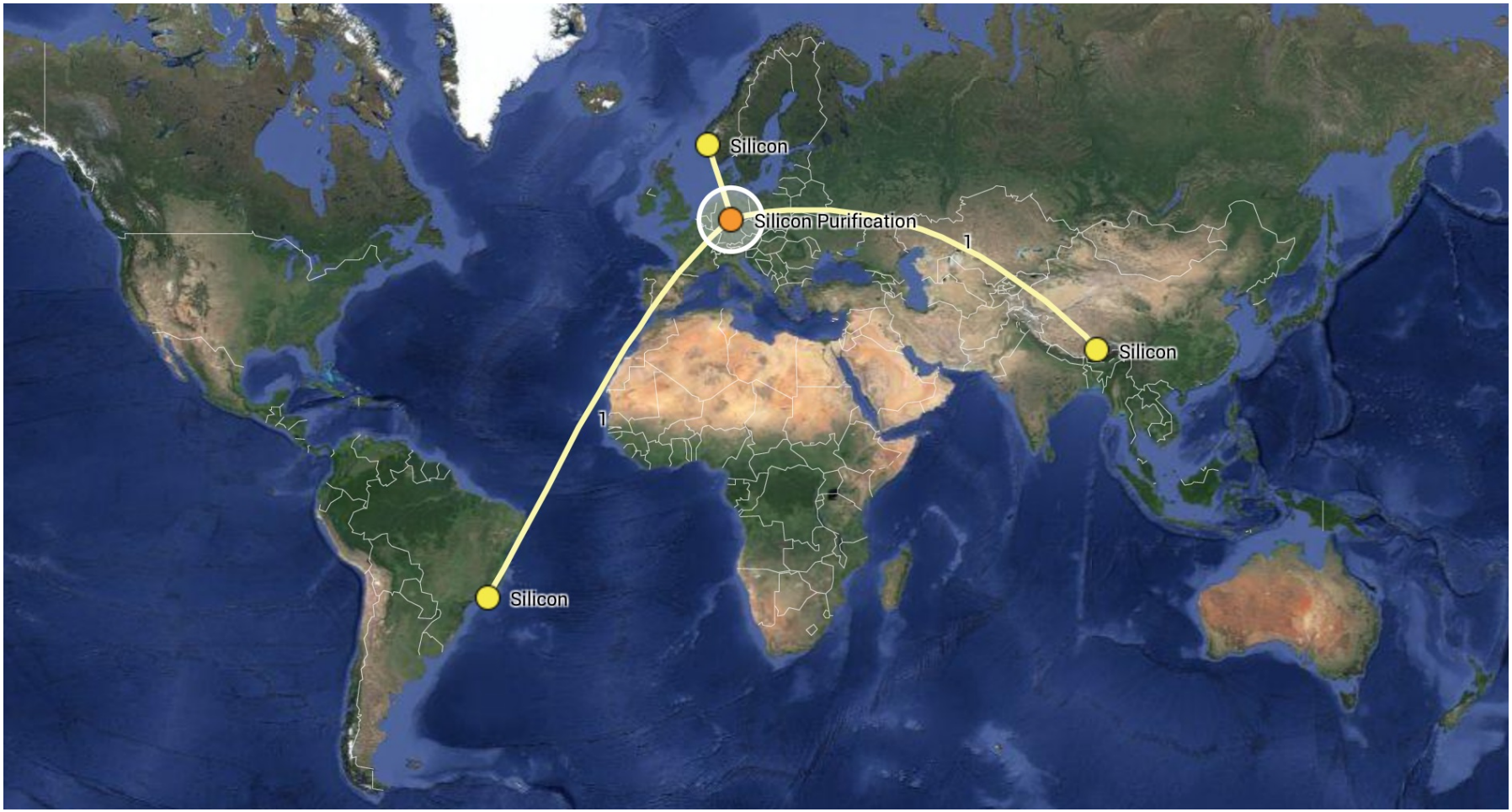

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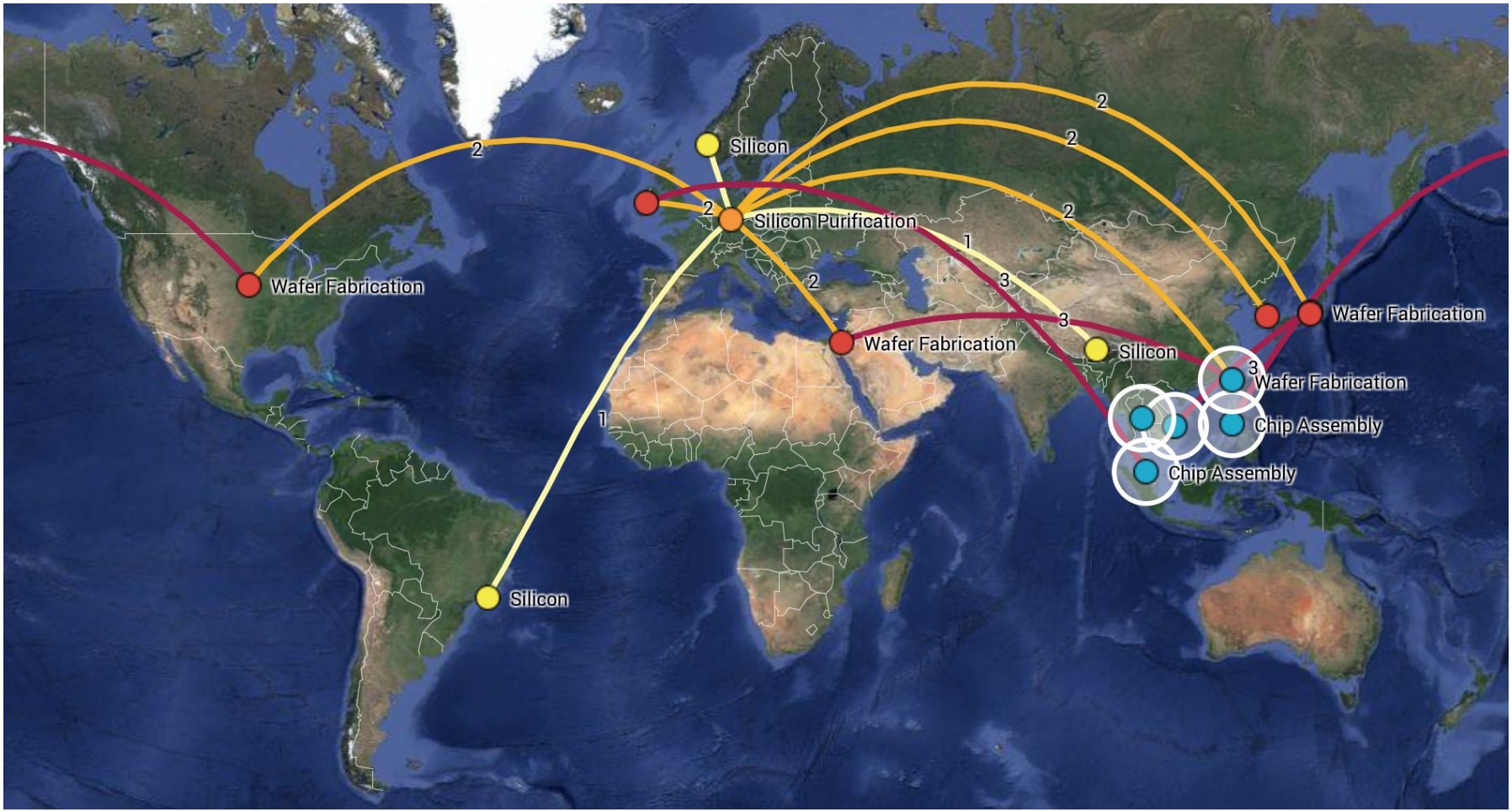
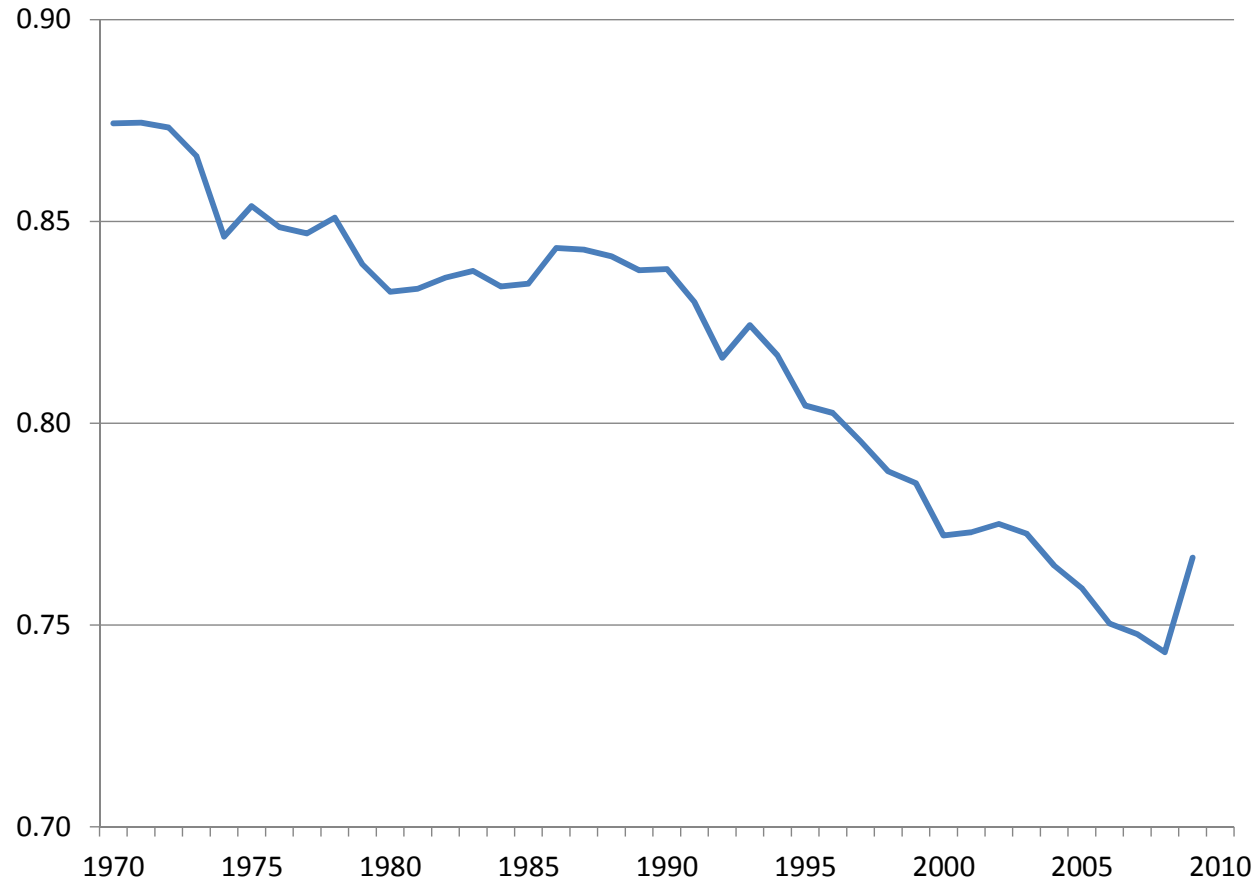


A Hybrid ("Sniker"): Ford Fiesta

Broader Evidence

Broader Phenomenon: A Smoking Gun

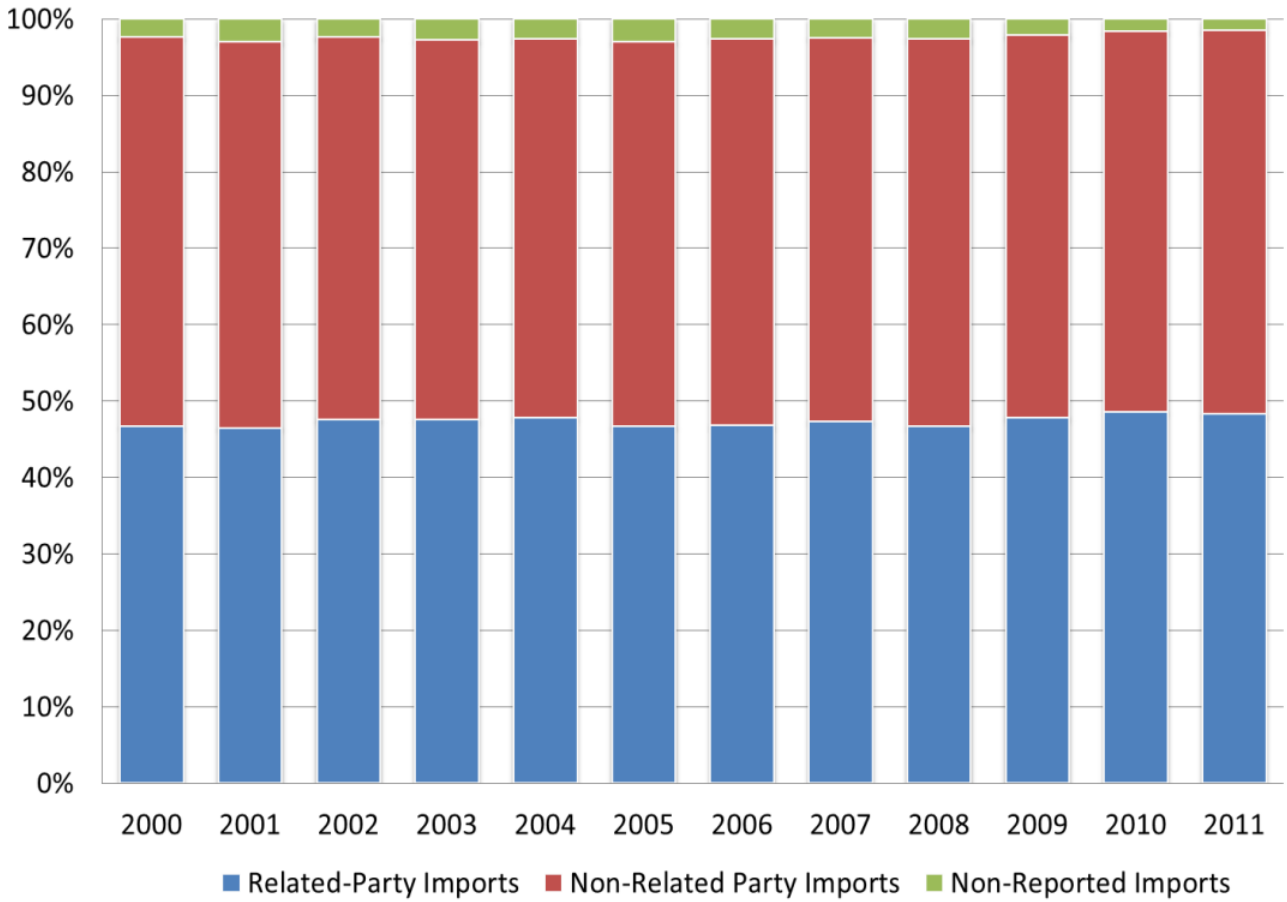
- Declining valued-added share in exports demonstrates rise of GVCs



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 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 (2018)
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?

- This lecture is not just about making models more "realistic"
- This lecture 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:

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

Production Technology

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

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

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

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

  - Pros and Cons

Firm Behavior Conditional on Sourcing Strategy

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

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

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

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

- Marginal cost:

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

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

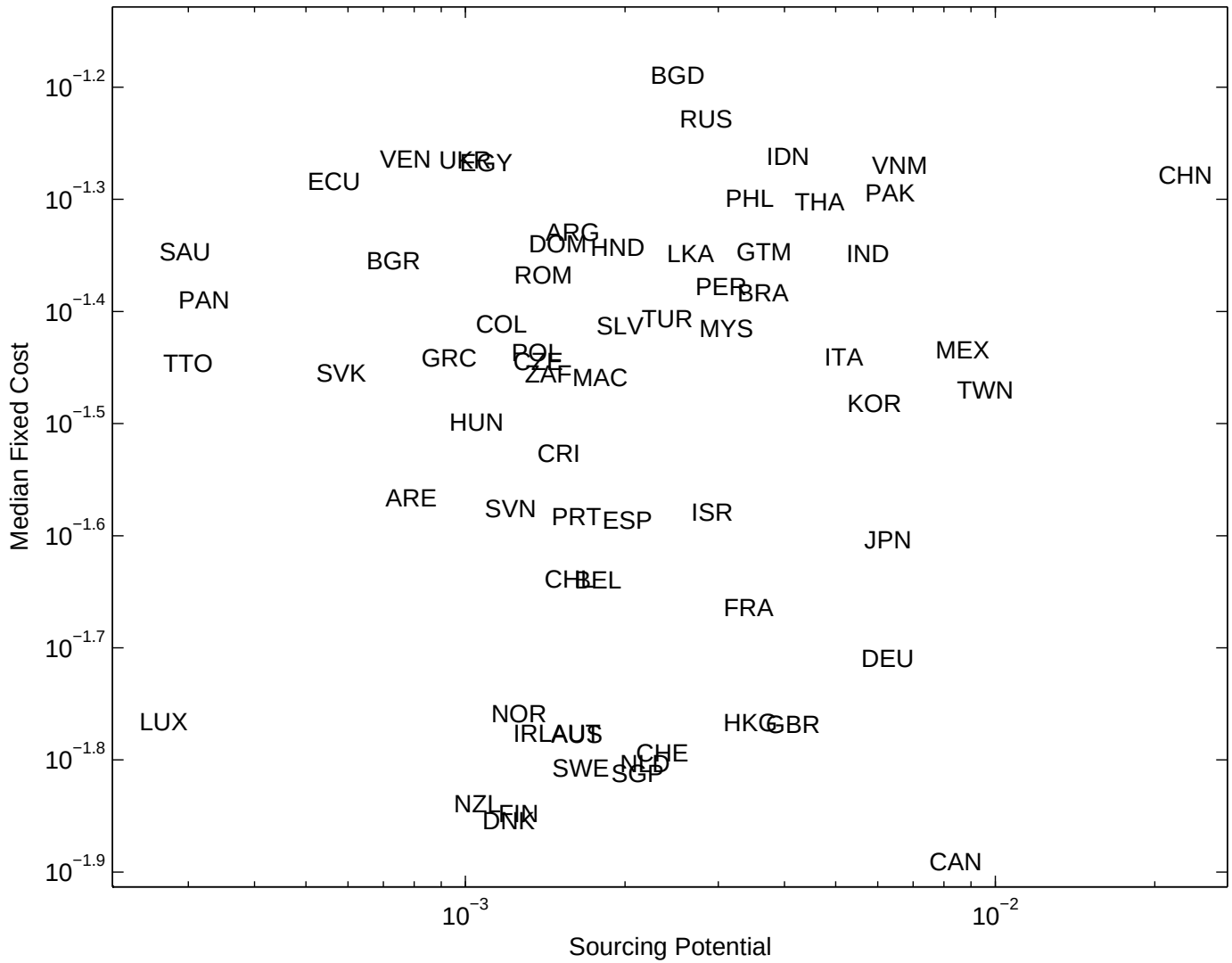
Overview of Estimation

- 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

$$\Pi(\mathcal{J},\varphi,f_{ij}^n) = \varphi^{\sigma-1}\left(\sum_{j=1}^{j\in\mathcal{J}} T_j(\tau_{ij}w_j)^{-\theta}\right)^{(\sigma-1)/\theta} \widetilde{B} - \sum_{j\in\mathcal{J}} f_{ij}^n$$

Step 1 Step 2 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.

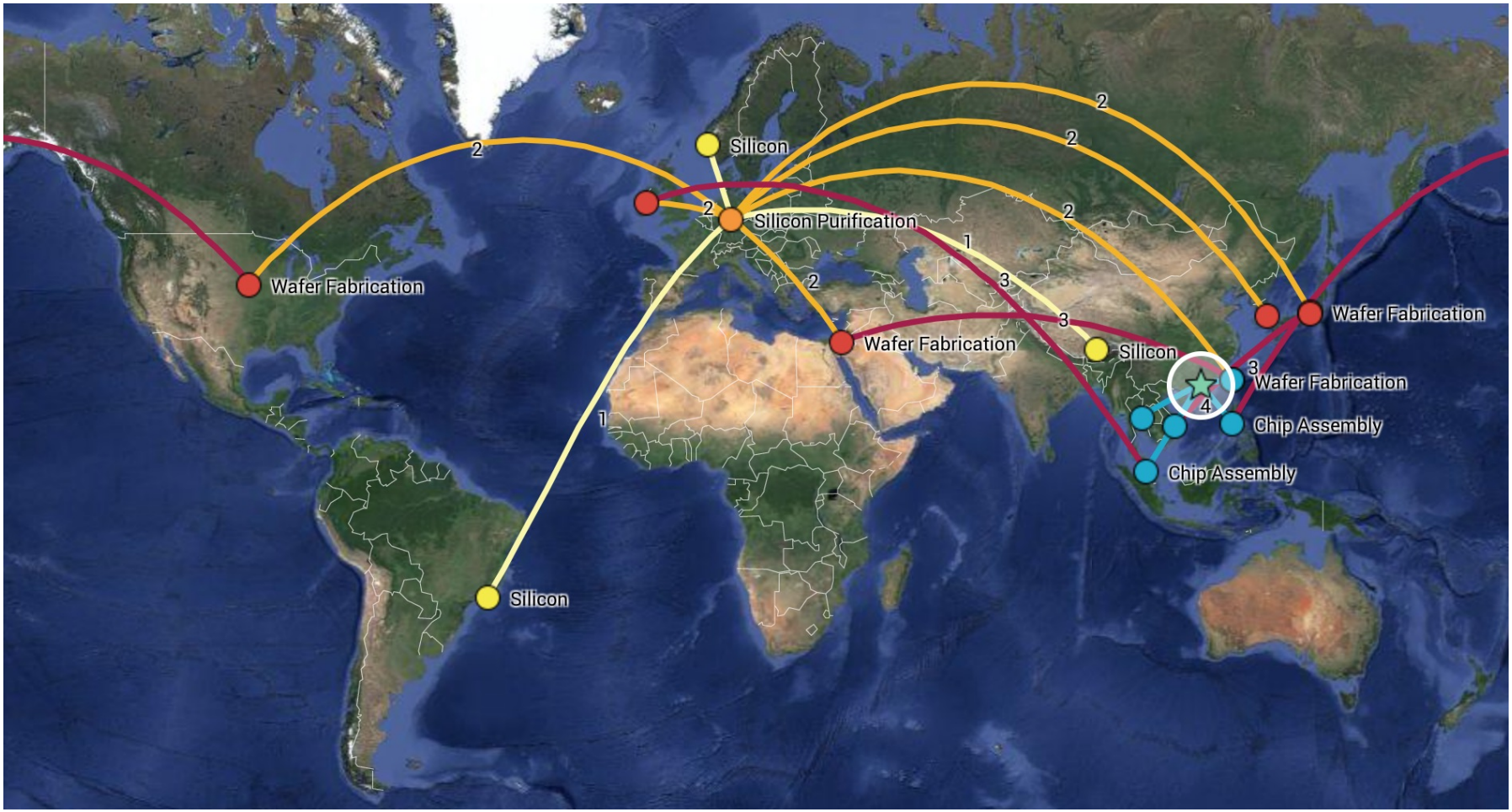
Extensions

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 (2018)

A Snake: Manufacturing a Chip



Snakes

"As a matter of fact, production is in many cases divided not into two stages - raw materials and finished goods - but into many, [...] of which each acts as a market for the preceding one."

Bertil Ohlin (1933), *Interregional and International Trade*

Snakes and Trade Costs: A Challenge

- Consider optimal location of production for the different stages in a sequential GVC
- Without trade frictions $\approx$ 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 $\left\{ p_{\ell(n-1)}^{n-1} \tau_{\ell(n-1)\ell(n)} \right\}$, 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)

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

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								

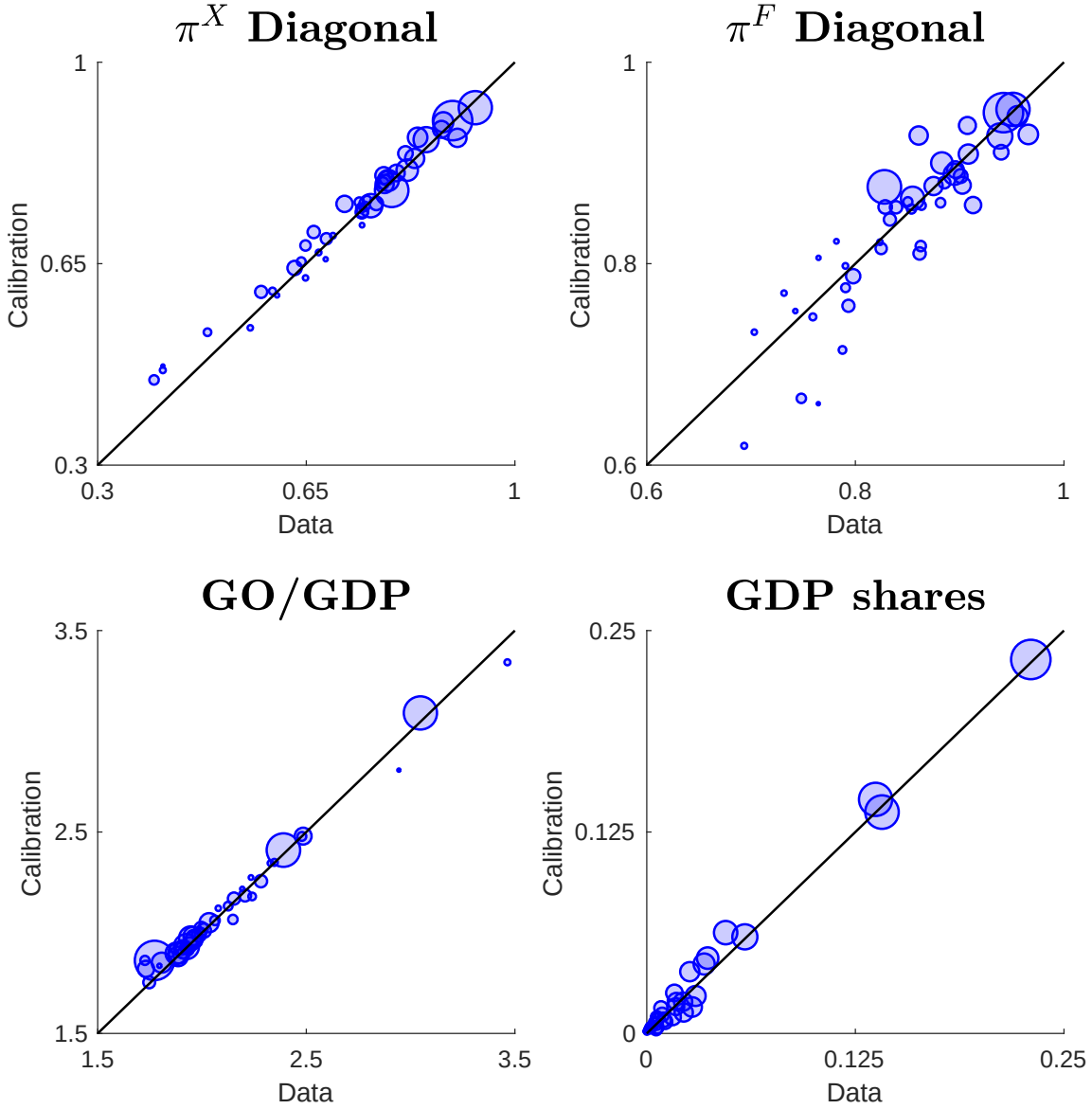
Empirical Strategy

- Normalizing $\tau_{ii} = 1$, it turns out that

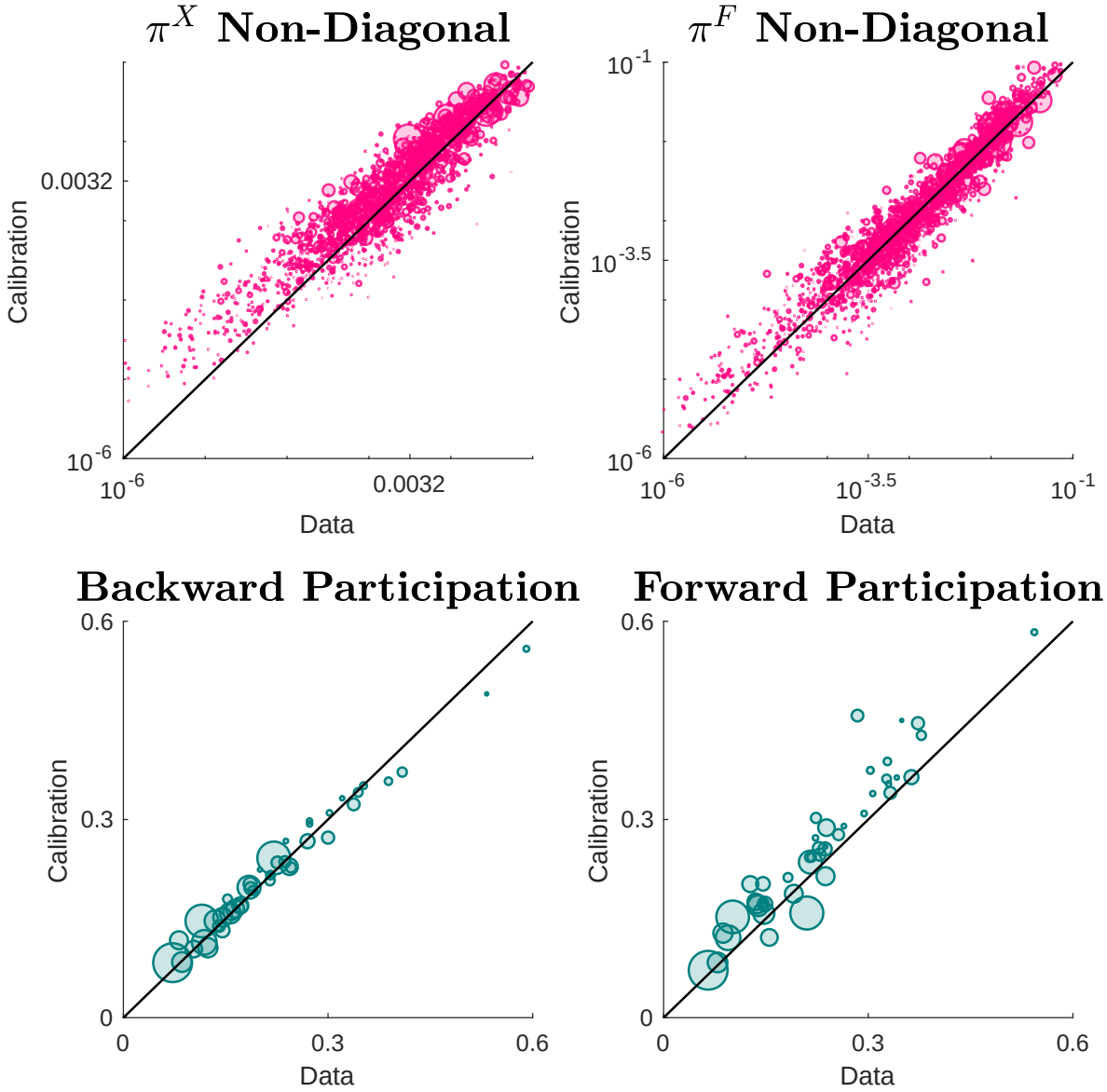
$$(\tau_{ij})^{-\theta} = \sqrt{\frac{\pi_{ij}^F}{\pi_{ii}^F}\frac{\pi_{ji}^F}{\pi_{jj}^F}}$$

- Estimate (T_j, γ_j) for all j, α_n for all n, and θ targeting:
  - Diagonal of intermediate input and final-good share matrices
  - Ratio of value added to gross output by country
  - GDP shares by country (also take into account trade deficits)
- We set $N = 2$ (so far data is 'rejecting' $N > 2$)
- We find $\theta = 4.95$, $\alpha_2 = 0.16$ (remember $\alpha_1 = 1$ by assumption)
  - Hence, data rejects a standard roundabout model ($\alpha_2 = 1$)

Fit of the Model: Targeted Moments

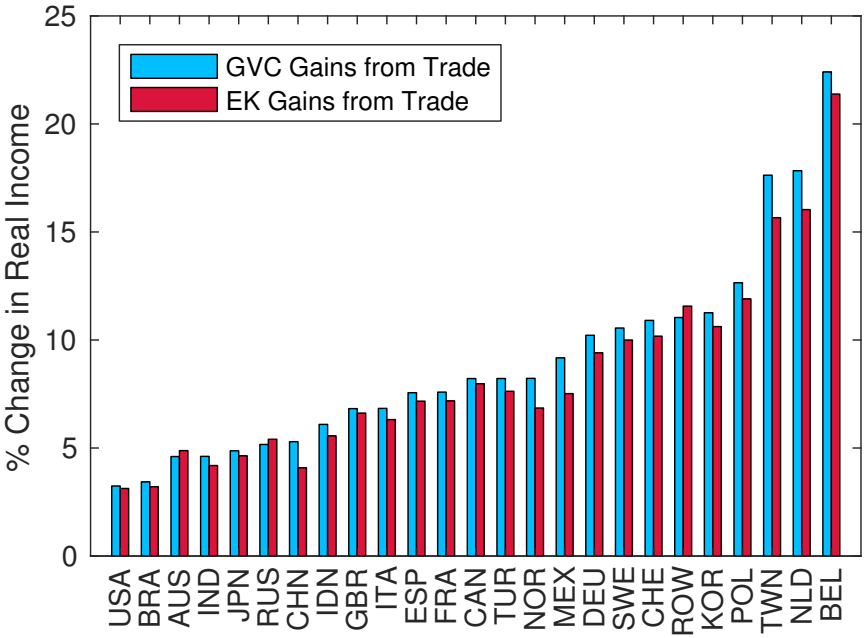


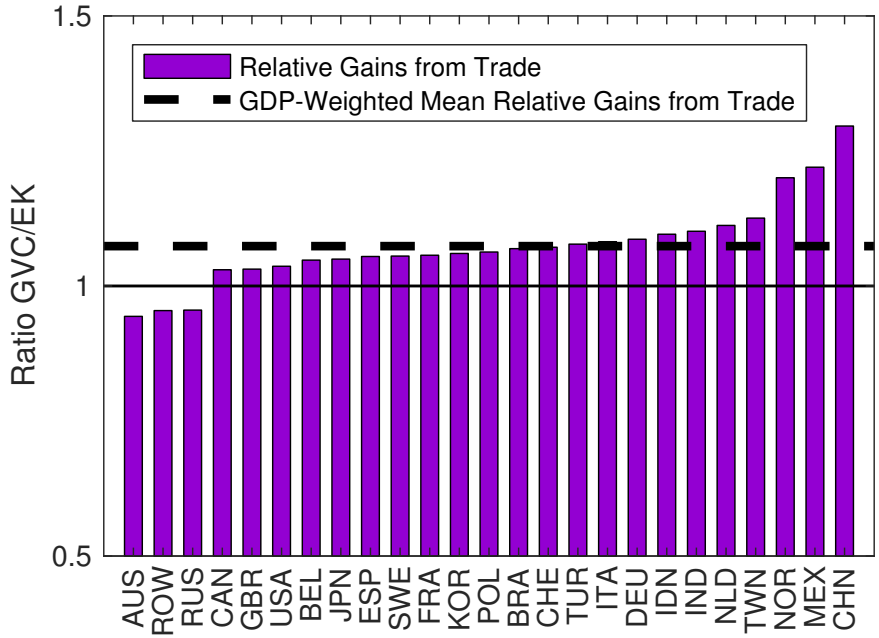
Fit of the Model: Untargeted Moments



Counterfactuals

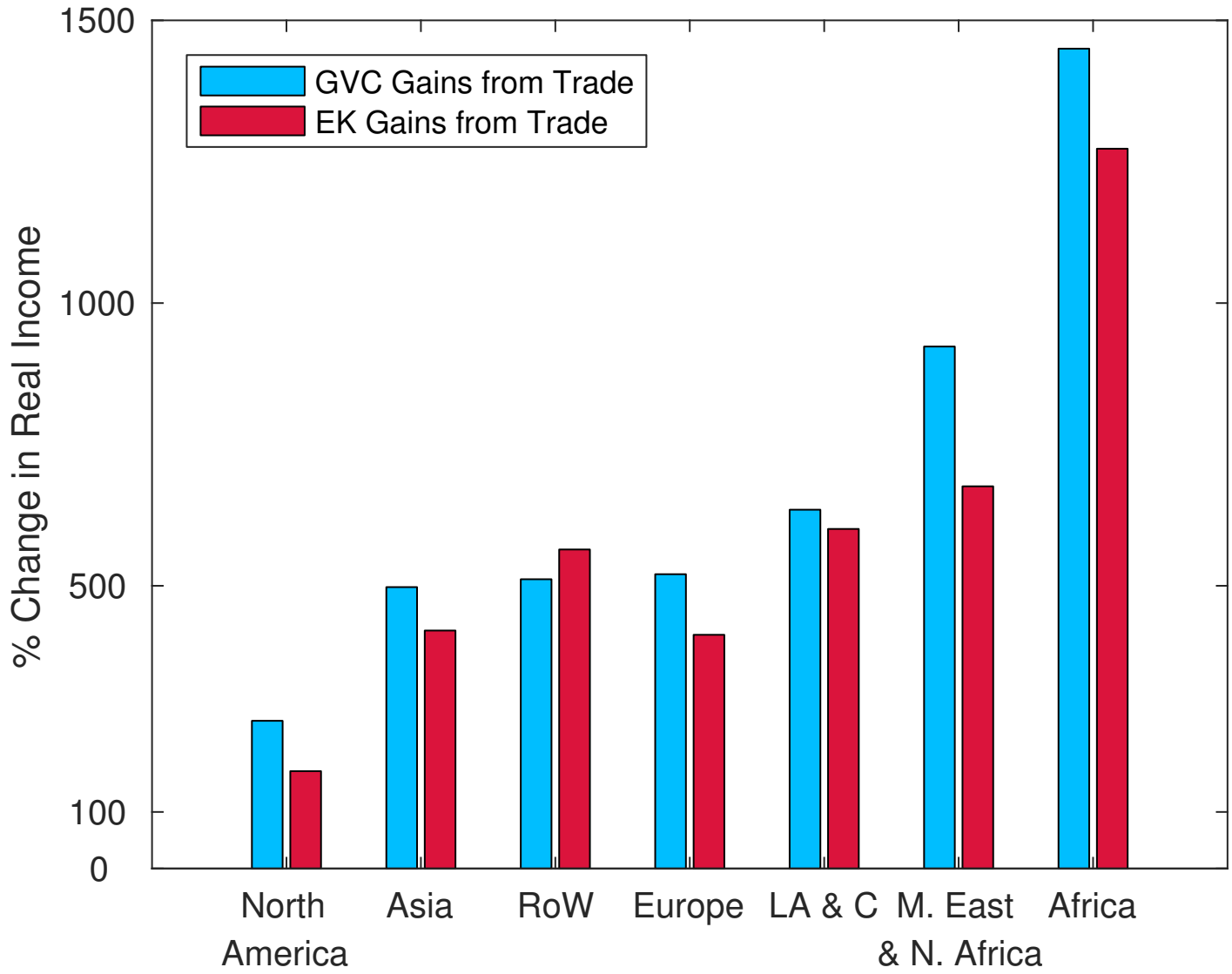
Counterfactuals: Real Income Gains Relative to Autarky





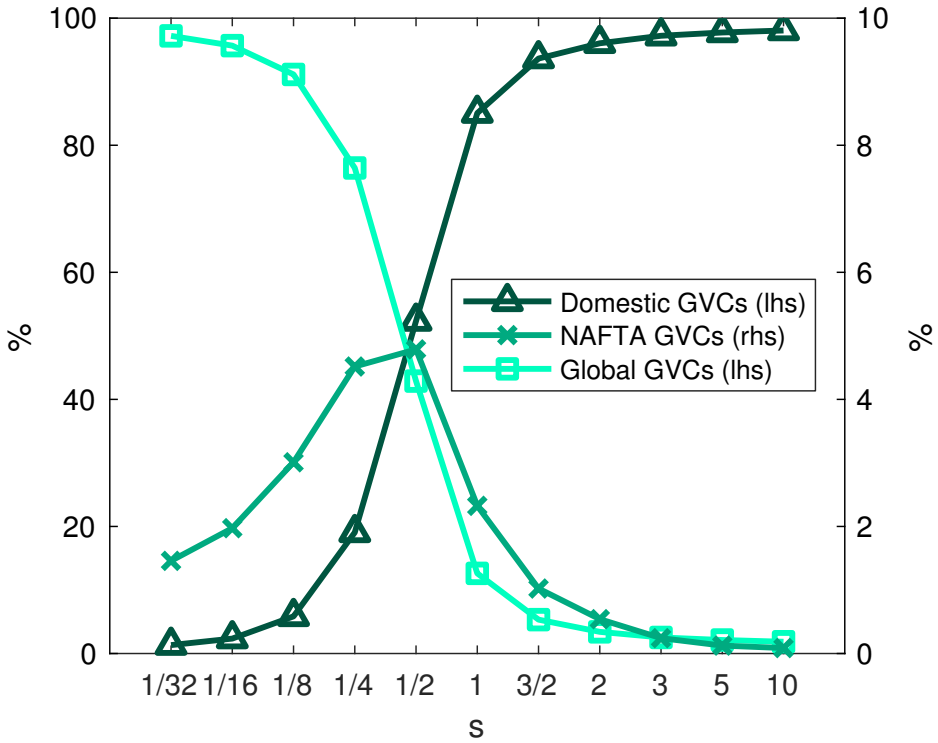
- GVC model with $N = 1$, i.e. EK model, underestimates gains from trade by 8% on average (11% in EORA)

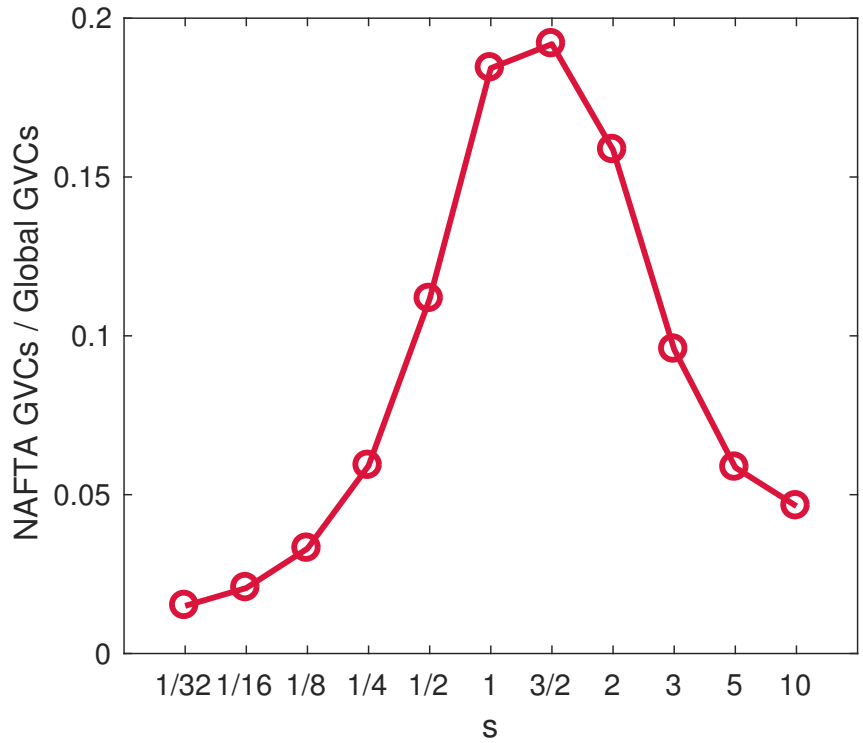
Counterfactuals: Free Trade Real Income Gains



Counterfactuals: Local vs. Regional vs. Global Chains

- Consider $\tau'_{ij} = 1 + s(\tau_{ij} - 1)$ for $s > 0$





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

$$a^n_{\ell(n)} = \left(L^n_{\ell(n)}\right)^{-\phi}$$

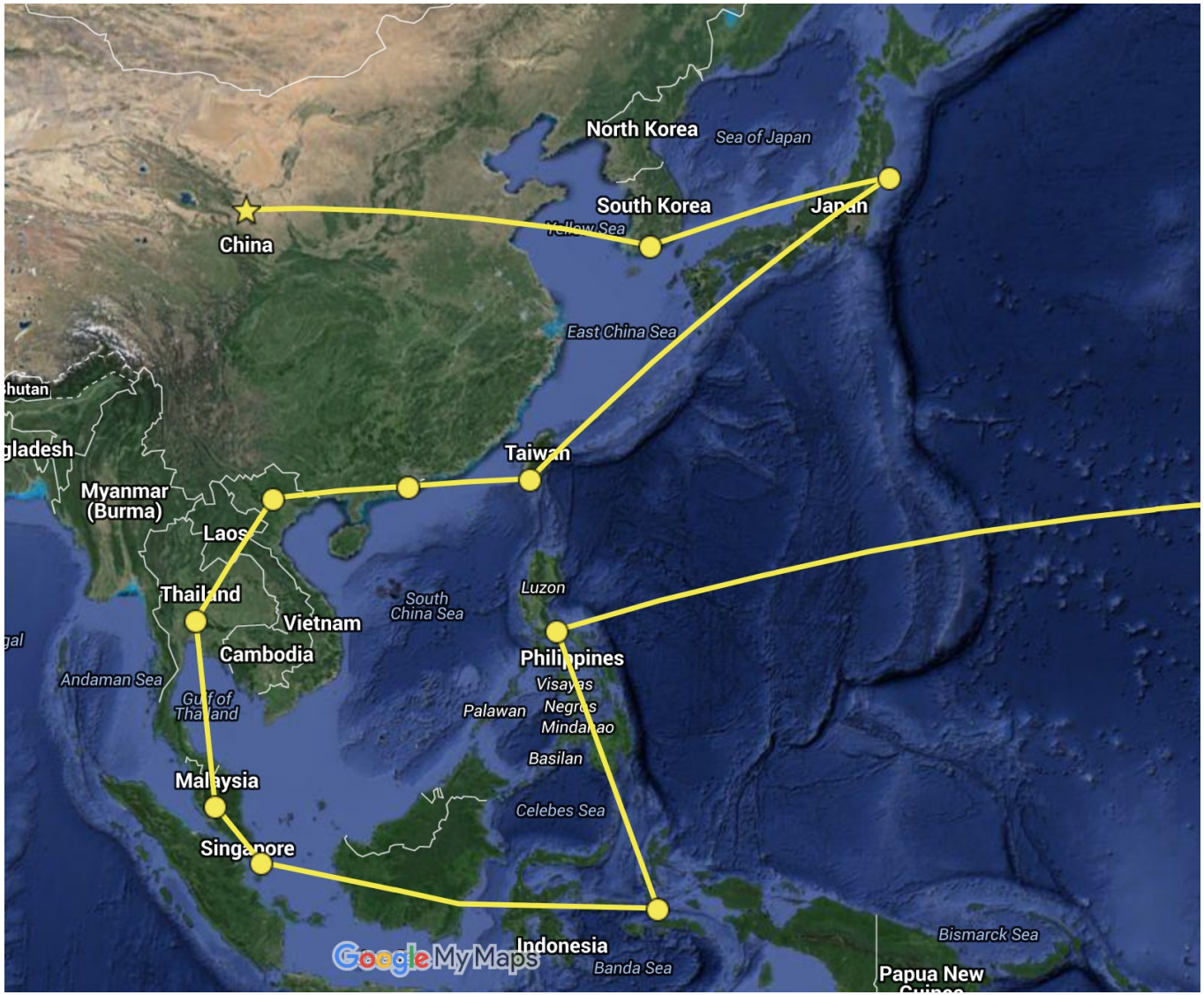
3. GVCs are **pure snakes**
4. There are as many stages as countries $N = J$ and assignment is **injective** (one-to-one)
5. Logarithmic utility: $u\left(c_i^N / L_i\right) = \ln\left(c_i^N / L_i\right)$
6. Solve planner's problem (Pareto weight $\Lambda_i = \lambda_i L_i / \sum_{i=1}^{J} \lambda_i L_i$)

Injective Assignment with $N = J$

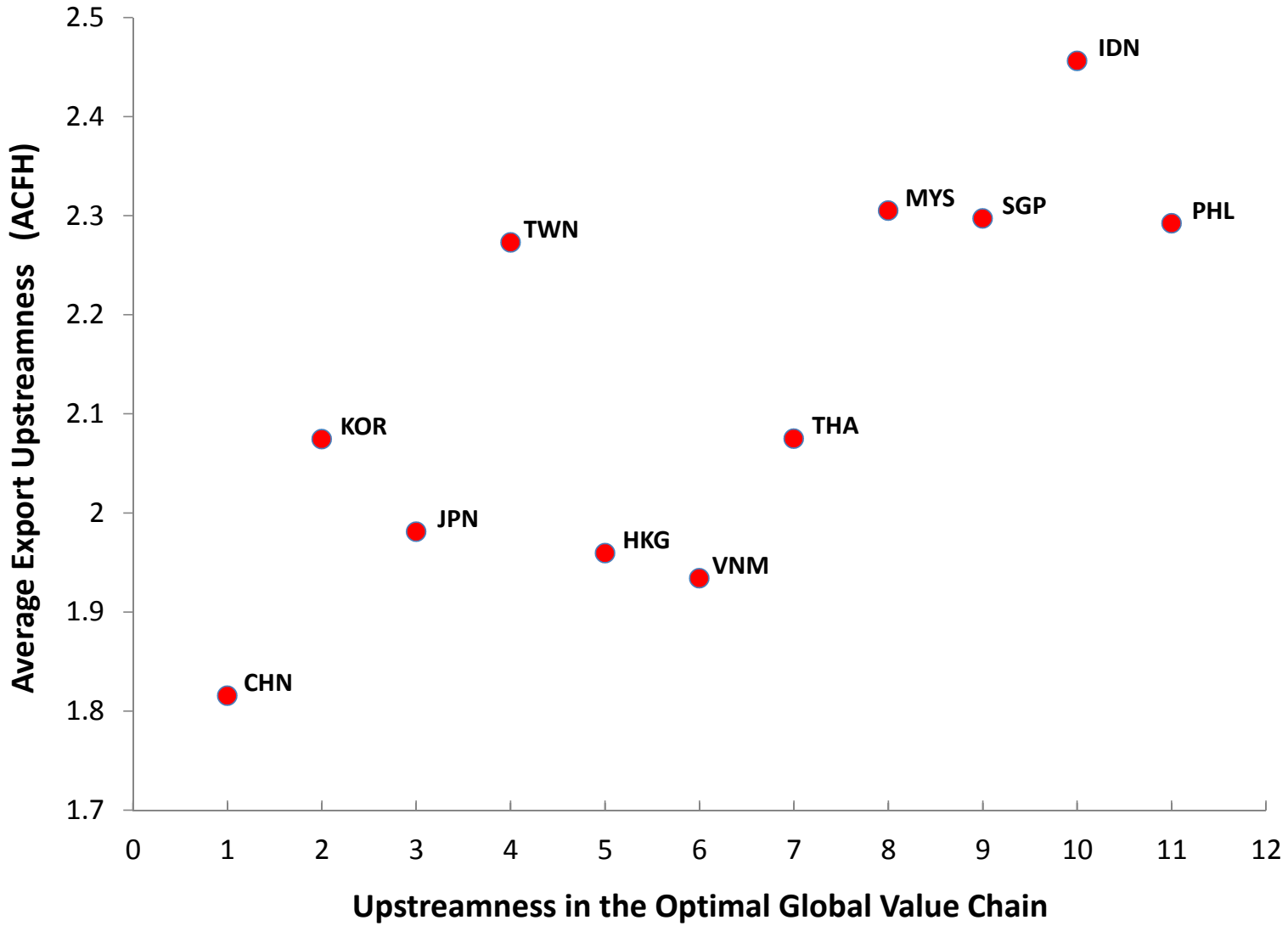
$$\min_{\{\ell(n)\}_{n=1}^{N}} H\left(\ell\left(1\right),...,\ell\left(N\right)\right) = \sum_{i=1}^{N} \Lambda_i \boldsymbol{N} \ln \tau_{\ell(N)i} + \sum_{n=1}^{N-1} \boldsymbol{n} \ln \tau_{\ell(n)\ell(n+1)}$$

- 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

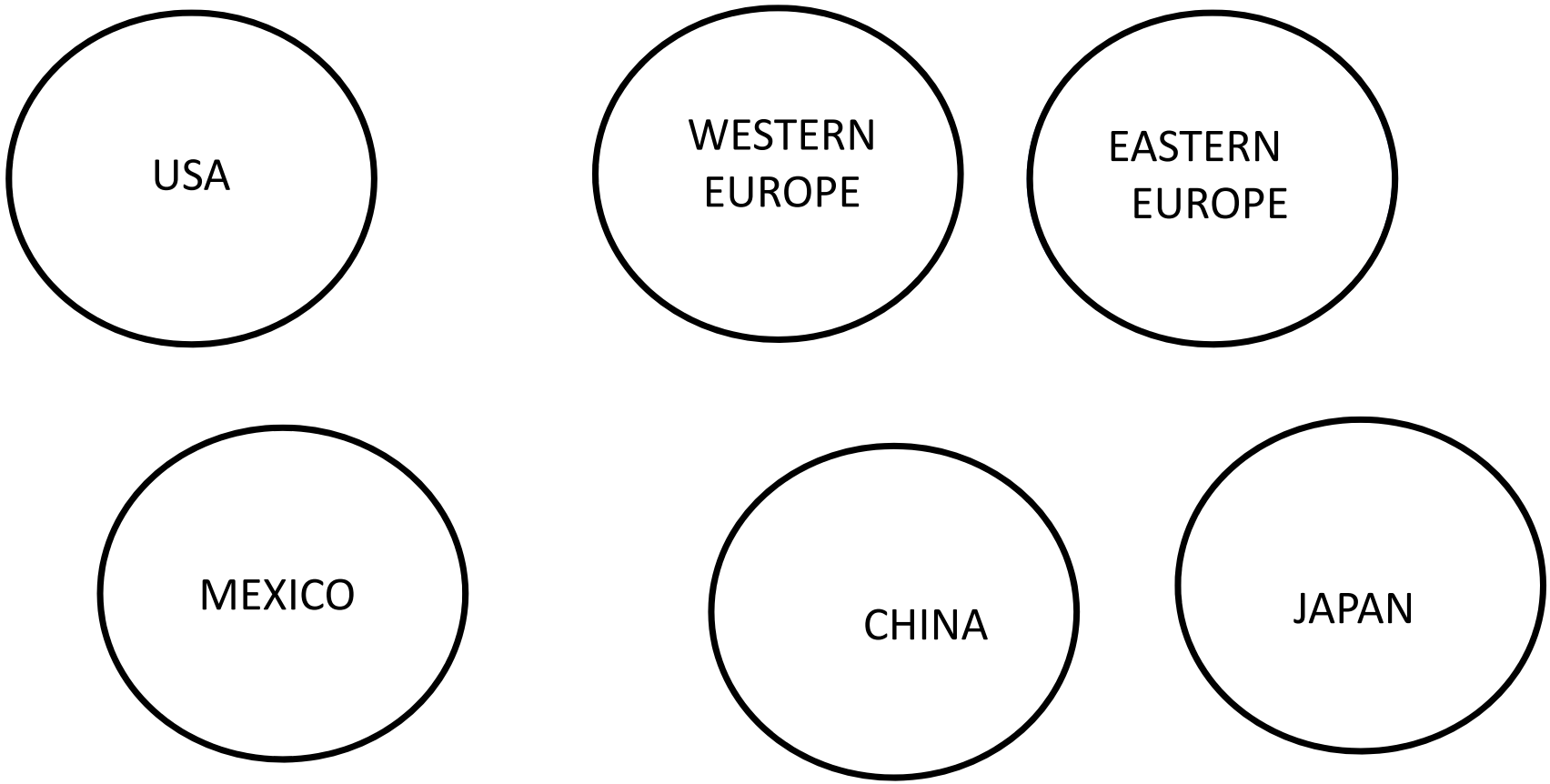


"Snikers": Antràs, Fadeev, Fort and Tintelnot

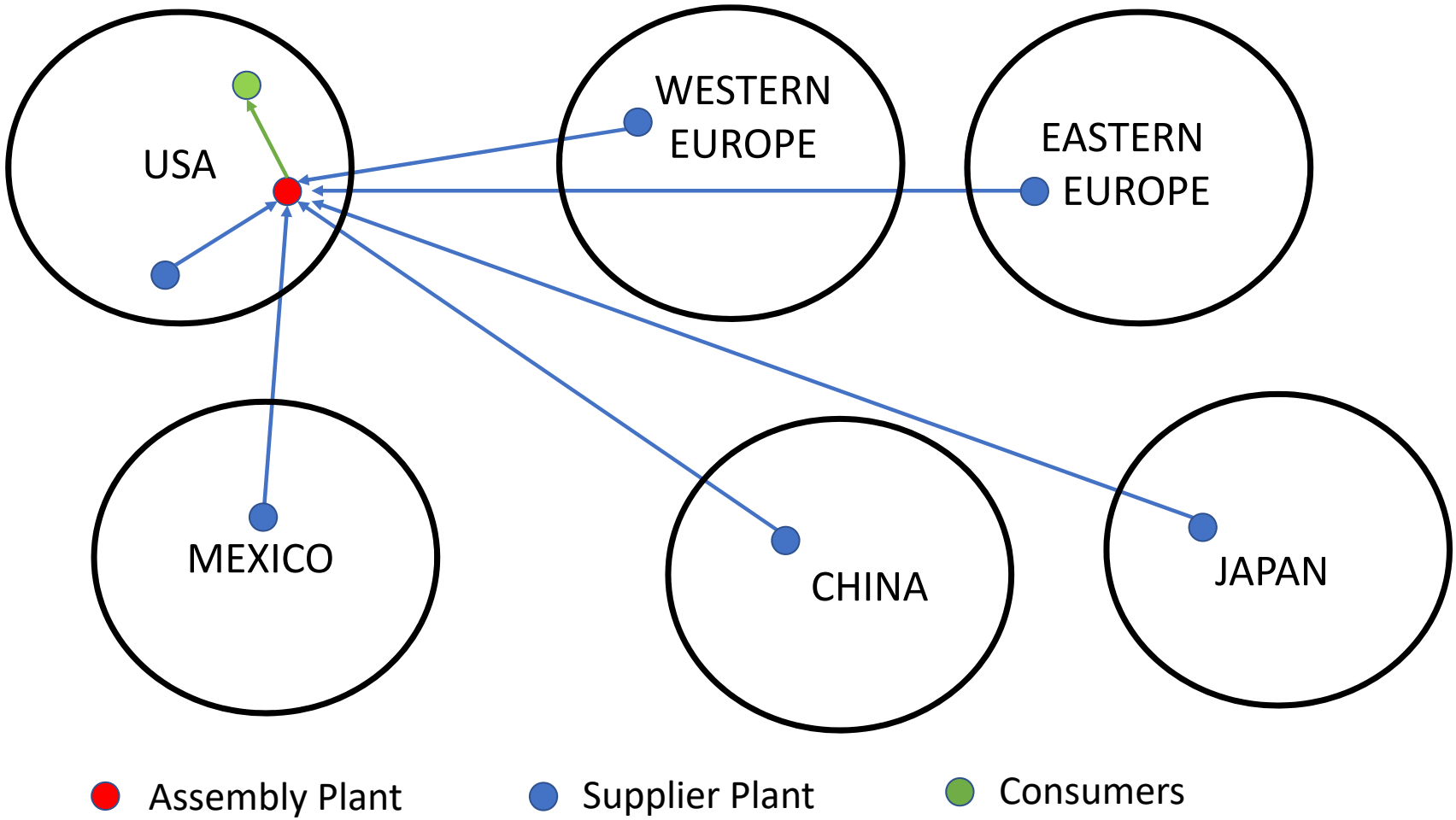
Overview

- In Antràs, Fort and Tintelnot (2017) firms choose a sourcing strategy conditional on an assembly location, and maybe export the final good
- In Antràs and de Gortari (2018), firms choose a path of production for each location of consumption (but CRS and no spiders)
- In Antràs, Fadeev, Fort and Tintelot (in progress) we jointly study assembly strategy and sourcing strategy with scale economies
  - Allow for export platform FDI as well as multi-product firms (e.g., car models)
  - Allow for multiple inputs
- This is best illustrated via some examples

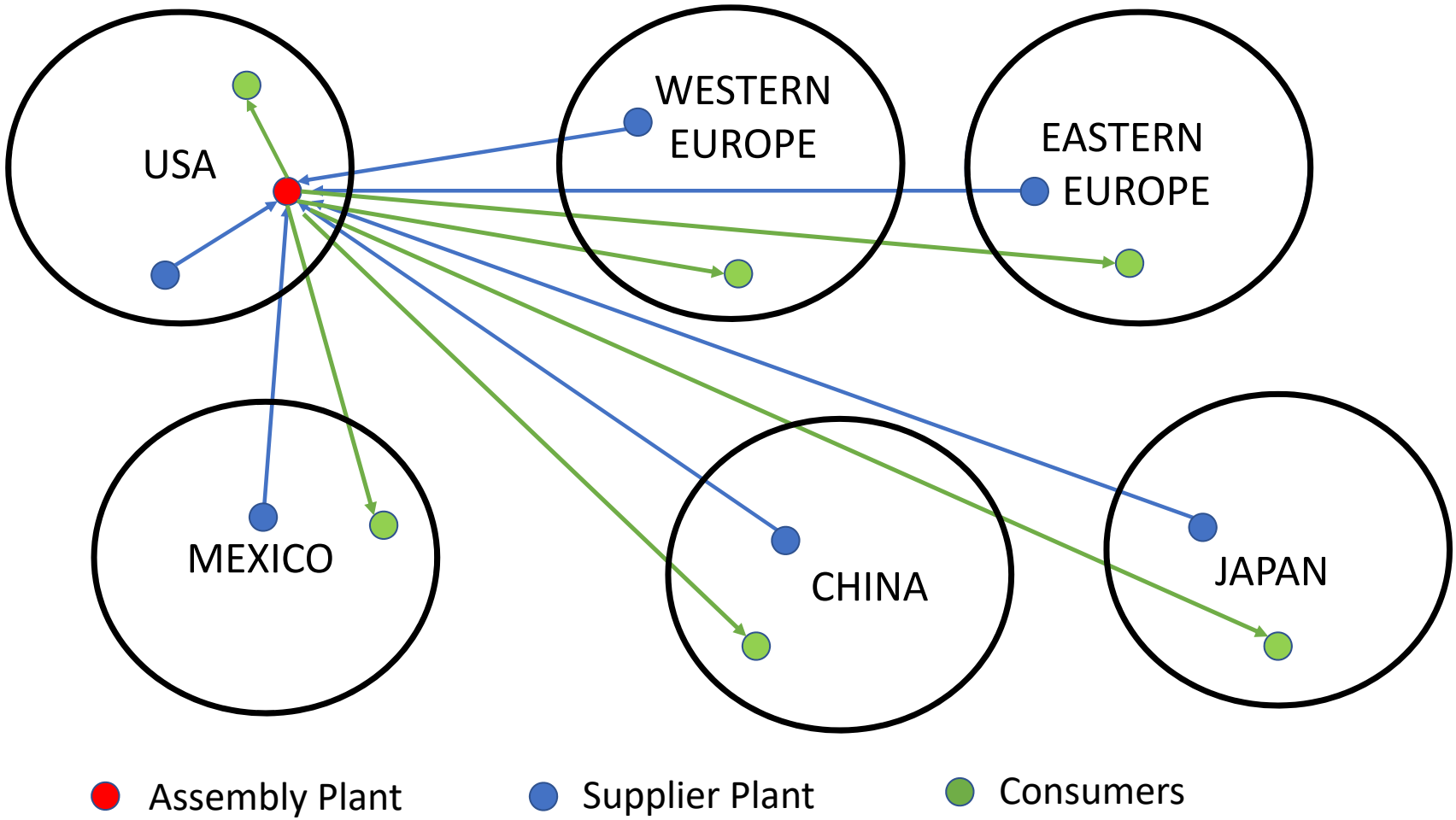
Patterns of Global Production



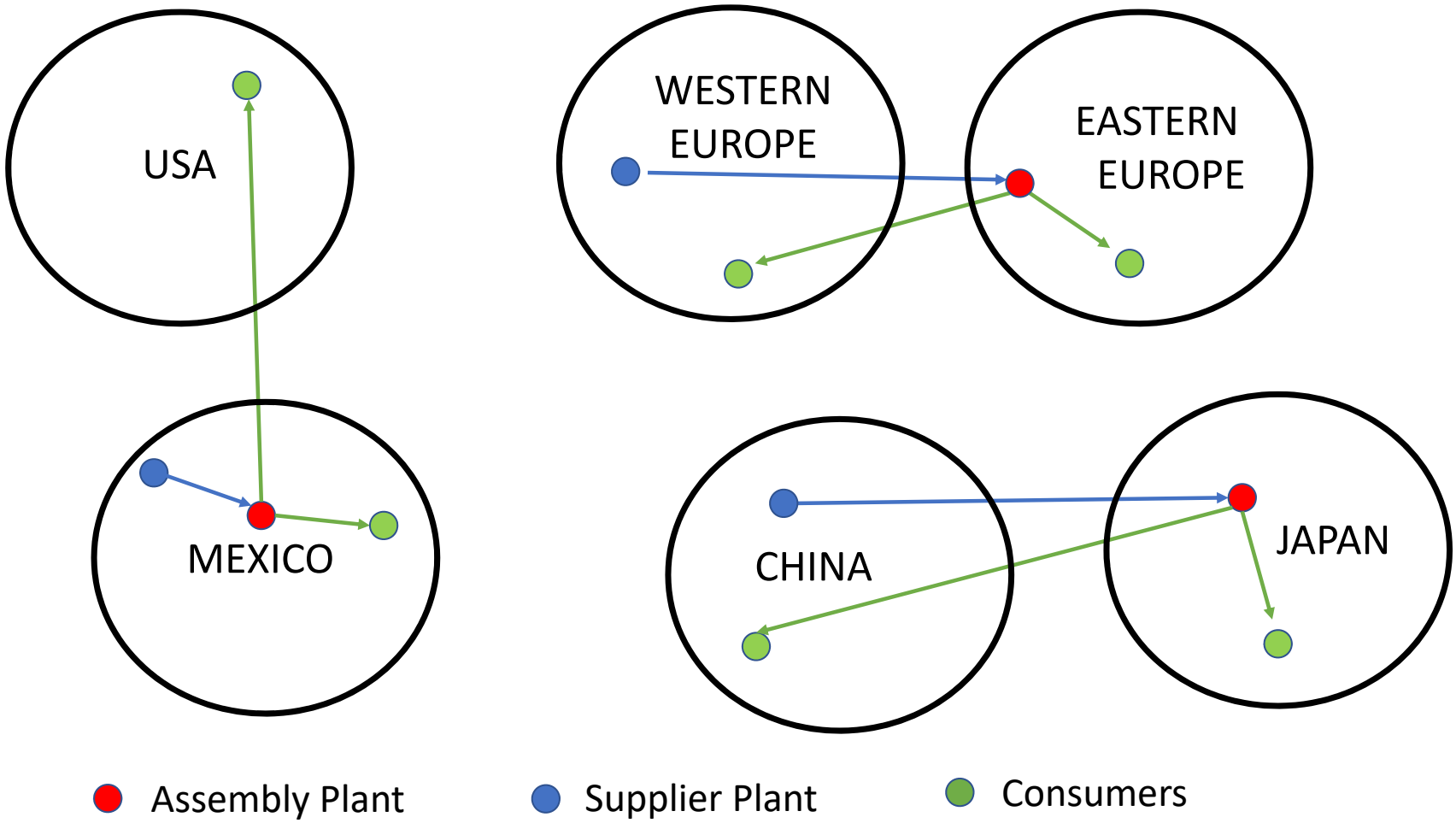
Patterns of Global Production: AFT



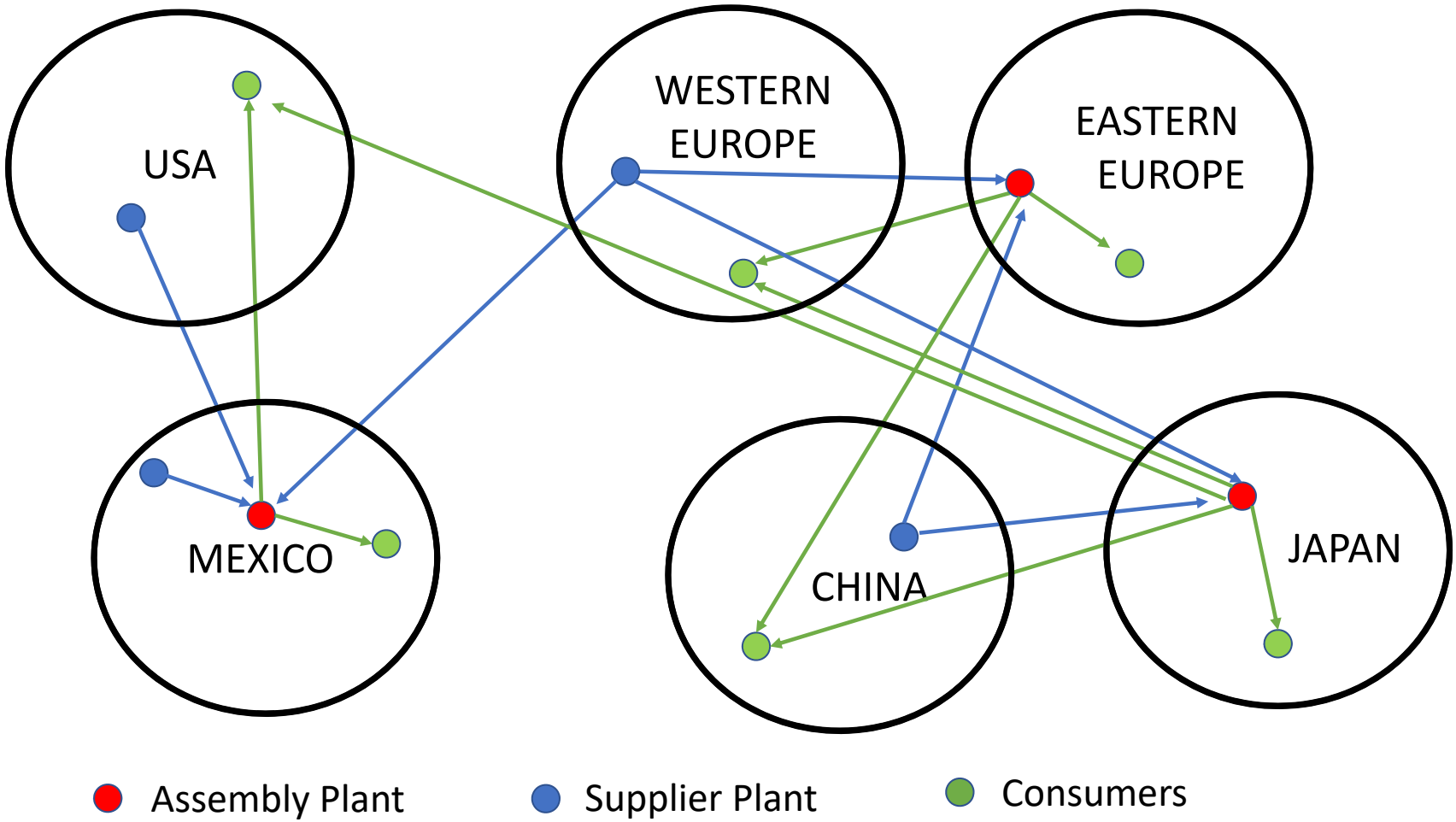
Patterns of Global Production: AFT with exporting



Patterns of Global Production: AdG



Patterns of Global Production: AFFT



Some Preliminary Results

- Tractable marriage of Antràs, Fort and Tintelnot (2017), Antràs and de Gortari (2018) and Tintelnot (2017)
- Complementarity between assembly strategy and sourcing strategy
  - Again, potentially relevant for counterfactuals
- Other results depend on finer details:
  - Productivity heterogeneity among inputs vs final goods
  - Sourcing strategies at the firm or at the plant level
- But confident we can devise iterative algorithms to reduce the dimensionality of the firm-level problem
- **To do:** estimate model by merging U.S. Census data and BEA data on inward and outward MNE operations

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?