An Anatomy of U.S. Establishments' Trade Linkages in Global Value Chains

Aaron Flaaen[1] Fariha Kamal[2] Eunhee Lee[3] Kei-Mu Yi[4]

[1]Federal Reserve Board

[2]U.S. Census Bureau

[3]Seoul National University

[4]University of Houston, Federal Reserve Bank of Dallas, and NBER

3rd Banca d'Italia, European Central Bank and World Bank Conference on "Trade, value chains and financial linkages in the global economy"
November 14, 2024

Disclaimer

Any opinions and conclusions expressed herein are those of the authors and do not represent the views of the U.S. Census Bureau, the Federal Reserve Bank of Dallas, the Board of Governors of the Federal Reserve System, or their research staff. The Census Bureau has reviewed this data product to ensure appropriate access, use, and disclosure avoidance protection of the confidential source data used to produce this product. This research was performed at a Federal Statistical Research Data Center under FSRDC Project Number 2631 (CBDRB-FY23-0248, CBDRB-FY24-P2631-R11288, CBDRB-FY24-P2631-R11530).

Motivation

- Recent global shocks confirm central importance of **global value chains (GVCs)** for evaluating economic outcomes and assessing appropriate policy responses

Motivation

- Recent global shocks confirm central importance of **global value chains (GVCs)** for evaluating economic outcomes and assessing appropriate policy responses

- Existing research quantifies spillovers and indirect exposure from GVCs with global input-output tables (e.g., WIOD, OECD-ICIO)
  - U.S. direct exposure to Chinese imports has declined, but what about indirect exposure (i.e. through Vietnam)?
  - Such IO tables are invaluable, but underlying assumptions are not well understood

Motivation

- Recent global shocks confirm central importance of **global value chains (GVCs)** for evaluating economic outcomes and assessing appropriate policy responses
- Existing research quantifies spillovers and indirect exposure from GVCs with global input-output tables (e.g., WIOD, OECD-ICIO)
  - U.S. direct exposure to Chinese imports has declined, but what about indirect exposure (i.e. through Vietnam)?
  - Such IO tables are invaluable, but underlying assumptions are not well understood
- **Our thesis:** Progress in evaluating outcomes and policies requires granular data:
  - By definition, GVCs exist and evolve at the firm or establishment level
  - Such micro-level heterogeneity matters for aggregate outcomes

What We Do

- Construct novel granular estimates of GVCs moving through the United States
  - Classify imports by intended use and link exports to production for individual plants
  - Measure GVCs over time in the U.S. manufacturing sector

What We Do

- Construct novel granular estimates of GVCs moving through the United States
  - Classify imports by intended use and link exports to production for individual plants
  - Measure GVCs over time in the U.S. manufacturing sector
- New Lessons from Micro-Level Perspective
  - Imported content of U.S. exports has grown more rapidly than aggregate data suggest

What We Do

- Construct novel granular estimates of GVCs moving through the United States
  - Classify imports by intended use and link exports to production for individual plants
  - Measure GVCs over time in the U.S. manufacturing sector
- New Lessons from Micro-Level Perspective
  - Imported content of U.S. exports has grown more rapidly than aggregate data suggest
  - New understanding of determinants of multi-country supply chains
    - Complementarities between input and output markets (Round-trip linkages)
    - Evidence for interaction of regional trade agreements (RTA) between input and output markets
  - Proportionality assumptions limit visibility of these patterns in multi-country I-O tables

What We Do

- Construct novel granular estimates of GVCs moving through the United States
  - Classify imports by intended use and link exports to production for individual plants
  - Measure GVCs over time in the U.S. manufacturing sector
- New Lessons from Micro-Level Perspective
  - Imported content of U.S. exports has grown more rapidly than aggregate data suggest
  - New understanding of determinants of multi-country supply chains
    - Complementarities between input and output markets (Round-trip linkages)
    - Evidence for interaction of regional trade agreements (RTA) between input and output markets
  - Proportionality assumptions limit visibility of these patterns in multi-country I-O tables
- Account (partially) for new micro-level patterns with off-the-shelf model of sourcing and exporting

Literature Review

- **Input-Output Table-Based GVC**: Hummels, Ishii, and Yi (2001); Johnson and Noguera (2011, 2017); Koopman, Wang, and Wei (2014); Timmer *et al.* (2014, 2016); Antràs and de Gortari (2020)
  - Contribution: Establishment-level GVC measures for the U.S. manufacturing sector, trilateral impacts of RTA on GVCs
- **Firm-Level GVC**: Kee and Tang (2016); Bems and Kikkawa (2021)
  - Contribution: Establishment-level GVC, multi-industry firms
- **Global Supply Chains and U.S Manufacturing**: Bernard and Fort (2015); Boehm, Flaaen, and Pandalai-Nayar (2019); Handley, Kamal and Monarch (forthcoming); Ding, Fort, Redding, and Schott (2022); Feenstra and Jensen (2012); Fort (2017, 2023)
  - Contribution: Document and characterize changes in the imported content of U.S. manufactured exports by sector and country

Outline

Measuring Disaggregated GVC

GVC: use of imported inputs in producing goods that are exported

$$GVC_{esmnt} = \frac{\sum_r IMP^I_{emrt}}{GO_{est}} \sum_p EXP_{enpt}$$

- establishment e; product p; producing industry s; input commodity r; destination country n; source country m; year t
- IMP^I: **direct** imports of goods used in further production (inputs)
- EXP: **direct** exports of goods produced in U.S.
- GO: gross output

Conceptual Example

	Imports		Exports		Gross
	Mexico	China	U.K.	Germany	**Output**
Firm 1	$100	$0	$150	$0	$500
Firm 2	$0	$100	$0	$300	$1000

Conceptual Example

	Imports		Exports		Gross
	Mexico	China	U.K.	Germany	**Output**
Firm 1	\$100	\$0	\$150	\$0	\$500
Firm 2	\$0	\$100	\$0	\$300	\$1000

Bilateral GVC: Reality

	U.K.	Germany
Mexico	\$30	\$0
China	\$0	\$30

Conceptual Example

	Imports		Exports		Gross
	Mexico	China	U.K.	Germany	**Output**
Firm 1	\$100	\$0	\$150	\$0	\$500
Firm 2	\$0	\$100	\$0	\$300	\$1000
Total	**\$100**	**\$100**	**\$150**	**\$300**	**\$1500**

Bilateral GVC: Reality

	U.K.	Germany
Mexico	\$30	\$0
China	\$0	\$30

Conceptual Example

	Imports		Exports		Gross
	Mexico	China	U.K.	Germany	**Output**
Firm 1	\$100	\$0	\$150	\$0	\$500
Firm 2	\$0	\$100	\$0	\$300	\$1000
Total	**\$100**	**\$100**	**\$150**	**\$300**	**\$1500**

Bilateral GVC: Reality

	U.K.	Germany
Mexico	\$30	\$0
China	\$0	\$30

Bilateral GVC: Aggregated

	U.K.	Germany
Mexico	\$10	\$20
China	\$10	\$20

Data and Measurement Challenges

- **Gross Output** GO_{est}
  - Source: CMF (2002, 2007, 2012, 2017)

Data and Measurement Challenges

- **Gross Output** GO_{est}
  - Source: CMF (2002, 2007, 2012, 2017)

- **Imports** IMP^{I}_{emrt}
  - Source: LFTTD (2002, 2007, 2012, 2017)
  - Challenges
    1. only firm-level identifiers
    2. identify **inputs** imported by establishments/firms

Data and Measurement Challenges

- **Gross Output** GO_{est}
  - Source: CMF (2002, 2007, 2012, 2017)

- **Imports** IMP^{I}_{emrt}
  - Source: LFTTD (2002, 2007, 2012, 2017)
  - Challenges
    1. only firm-level identifiers
    2. identify **inputs** imported by establishments/firms

- **Exports** EXP_{enpt}
  - Source: LFTTD (2002, 2007, 2012, 2017)
  - Challenges
    1. only firm-level identifiers
    2. identify **manufactured** exports

Imported Input Classification

Details

Challenge: Separate inputs from final goods imports, AND connect imported inputs to individual plants

Solution: Match imports to *establishment-level* input usage from CMF Material Trailer

Imported Input Classification

Details

Challenge: Separate inputs from final goods imports, AND connect imported inputs to individual plants

Solution: Match imports to *establishment-level* input usage from CMF Material Trailer

	Intermediate Share of Firm Imports	Import Cost Share
2002	56.9	14.0
2007	60.9	17.6
2012	62.9	16.9
2017	58.5	18.4

- About 40% of firms' imports are sold without further processing (final goods)
- In 2017, imported inputs represent about 18% of material costs for the representative (sales-weighted) plant

Separating Inputs from Output

Produced Export Classification

Challenge: Match exports to establishment-level production

Solution: Link exports to products produced in CMF Product Trailer

Produced Export Classification

Challenge: Match exports to establishment-level production

Solution: Link exports to products produced in CMF Product Trailer

	"Produced" Export Share of Total	Export Share of Shipments
2002	69.8	7.7
2007	70.6	9.1
2012	69.8	10.3
2017	68.9	10.4

- About 30% of firms' exports are not produced by its manufacturing plants
- In 2017, produced exports represent about 10% of the total shipments for the representative (sales-weighted) plant Separating Inputs from Output

Sectoral GVC

Start with...

$$GVC_{est} = \frac{\sum_{m,r} IMP^{l}_{emrt}}{GO_{est}} \sum_{n} EXP_{enst}$$

Sectoral GVC

Start with...

$$GVC_{est} = \frac{\sum_{m,r} IMP^{I}_{emrt}}{GO_{est}} \sum_{n} EXP_{enst}$$

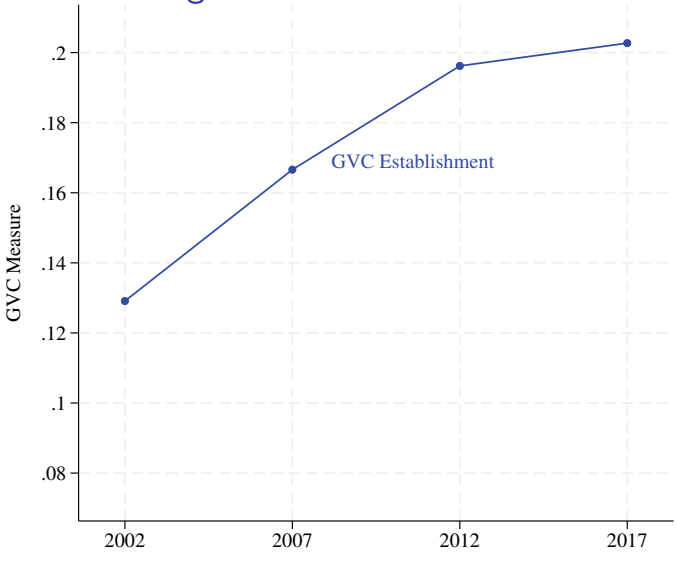
For sectoral measures, we aggregate and scale by overall exports:

$$gvc^{E}_{st} = \frac{\left[\sum_{e \in E_{st}} GVC_{est}\right]}{\sum_{e \in E_{st}} EXP_{est}}$$

Generate our own industry-level analogues:

$$gvc^{I}_{st} = \frac{\left[\left(\sum_{e \in E_{st}} EXP_{est}\right) \frac{\sum_{e \in E_{st}} IMP^{I}_{est}}{\sum_{e \in E_{st}} GO_{est}}\right]}{\sum_{e \in E_{st}} EXP_{est}}$$

GVC: Manufacturing



Industry Estimates Input Cost Share

Industry Aggregation Bias; Worsens Over Time

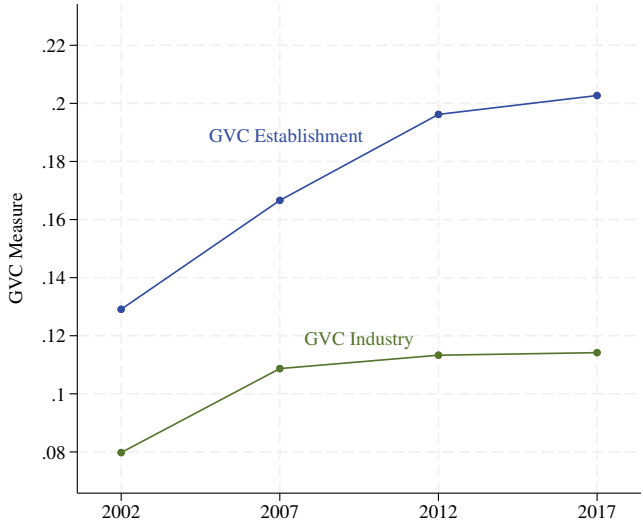
Establishment vs. Industry:

- higher levels
- gap widens over time

Simple Illustration

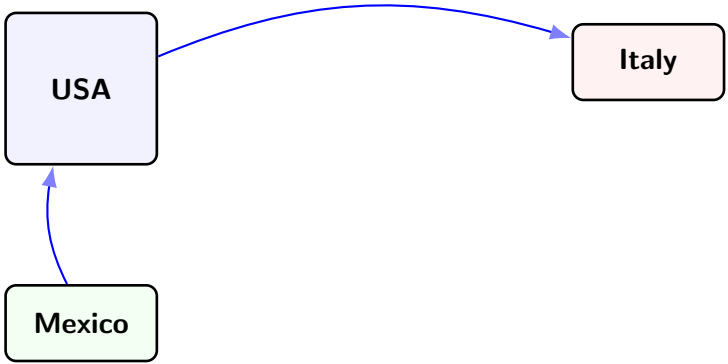
Industry-Level Bias Measures

More Details on Aggregation Bias



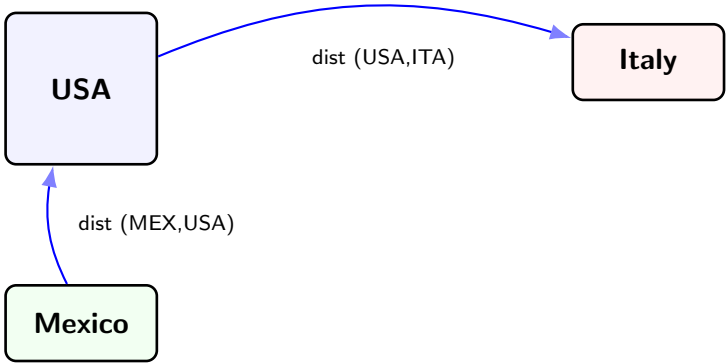
Outline

New Patterns in Multi-Country GVC Chains



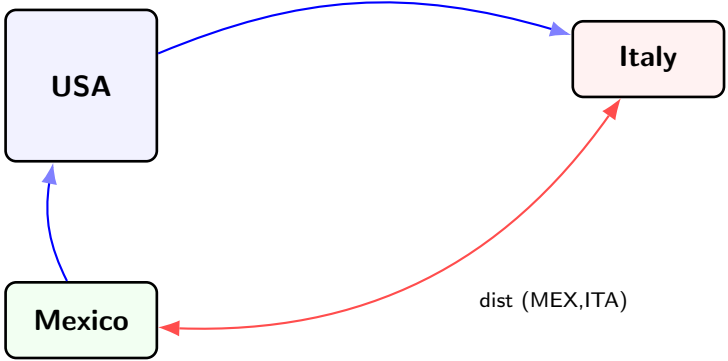
- Our data provide a unique environment to explore patterns of multi-country supply chains.
- We adapt the well-known Gravity framework to model determinants of GVCs

Gravity in Three Country GVC Relationships



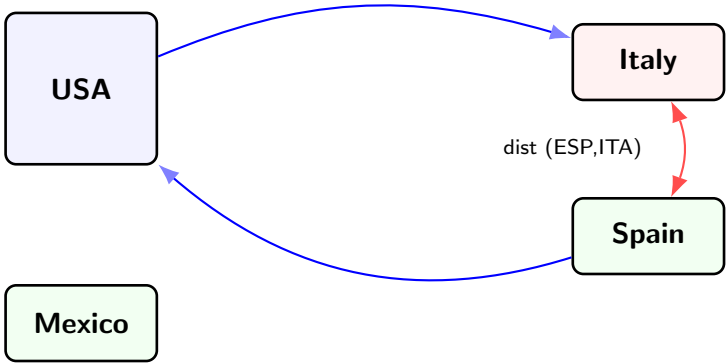
- Distance is typically used to proxy for trade frictions
- **Combined** distance from country m to US to country n : $d_{m,US,n} = d_{m,US} + d_{US,n}$

Gravity in Three Country GVC Relationships



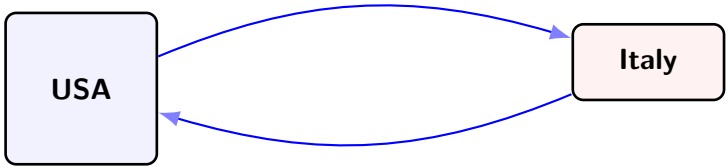
- New: How are input and output markets linked?
- **Direct** distance from country m to n : $d_{m,n}$

Gravity in Three Country GVC Relationships



- Does proximity support or detract from GVC flows?
- Detract (positive coeff): Greater relative cost moving goods through middle country
- Support (negative coeff): Complementarities between input and output markets.

Gravity in Three Country GVC Relationships



- Extreme example of potential complementarities between input and output markets is **Round-trip** behavior ($m = n$)

Analysis of Three-Country Pairs

Formally, we evaluate gravity regressions of the form:

$$log(GVC_{mnt}) = \delta_{m,t} + \eta_{n,t} + \beta \mathbb{I}(m = n) + \gamma d_{m,US,n} + \lambda d_{m,n} + \varepsilon_{mnt},$$

Analysis of Three-Country Pairs

Formally, we evaluate gravity regressions of the form:

$$log(GVC_{mnt}) = \delta_{m,t} + \eta_{n,t} + \beta \mathbb{I}(m = n) + \gamma d_{m,US,n} + \lambda d_{m,n} + \varepsilon_{mnt},$$

In this environment, we can also explore the role of **regional trade agreements**

- **RTA(m,n)**: Countries *m* and *n* have an RTA
- **RTA (m & US, n & US)**: Both countries have RTAs with U.S.
- **RTA (m, n, US)**: All three countries have RTA

Basic Gravity: Pooled Results for 2002–2017

Variable	Dependent Variable: Log Bilateral GVC (1)	(2)	(3)	(4)
Log Distance ($m \rightarrow$US$\rightarrow n$)	-1.64***			-0.414***
	(0.106)			(0.118)
Log Distance (m to n)		-0.26***		-0.175***
		(0.009)		(0.011)
Round-trip (m=n)			2.33***	1.38***
			(0.112)	(0.121)
Exporter-Year F.E.	yes	yes	yes	yes
Importer-Year F.E.	yes	yes	yes	yes
Observations	117,000	117,000	117,000	117,000
R^2	0.861	0.861	0.861	0.861

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

- Distance detracts from GVC flows (combined distance more important)
- Strong links between input and output markets
- Large round-trip effects (even after controlling for distance)

RTAs and GVCs: Pooled Results for 2002–2017

Variable	Dependent Variable: Log Bilateral GVC (1)	(2)	(3)
Log Distance ($m \rightarrow$US$\rightarrow n$)	-1.38***	-1.39***	-1.35***
	(0.105)	(0.104)	(0.104)
Round-trip (m=n)	2.20***	2.23***	2.21***
	(0.112)	(0.111)	(0.112)
RTA (m & n)	0.044**		
	(0.020)		
RTA (m & US, n & US)		0.198***	
		(0.059)	
RTA (m, n, US)			0.438***
			(0.112)

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Includes Exporter-Year F.E. and Importer-Year F.E. More Evidence

- Unsurprisingly, an RTA that does NOT include the U.S. has little impact on GVC flows
- Bilateral RTAs have important effects on multi-country GVC activity
- Effect is magnified when all three countries are in an RTA

Outline

Existing Data Problematic for this Type of Analysis

	Dep. Variable: Log Bilateral GVC	
Variable	CENSUS	WIOD
Log Distance ($m \rightarrow$US$\rightarrow n$)	-1.36***	-0.03
	(0.104)	(0.061)
Round-trip (m=n)	2.21***	0.08***
	(0.112)	(0.015)
RTA (m, n, US)	0.44***	-0.04
	(0.112)	(0.064)
Data	Census	WIOD
Basis	Estab	Agg.
Country Sample	All–Data	WIOD-43
Observations	117,000	7,056
R-Squared	0.86	0.99

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1.

Includes Exporter-Year F.E. and Importer-Year F.E.

- Use multi-country input-output data (WIOD) to conduct similar analysis...
- ...But these patterns are not evident
- Visibility limited due to sample coverage and aggregation: both pairwise proportionality and traditional import proportionality

Proportionality Assumptions

Pairwise Proportionality Assumption: Connects source and destination countries from aggregate data.

Import Proportionality Assumption: Allocates commodity imports to using industries, based on aggregate ratios A quick refresher

- While issues are discussed in de Gortari (2019) and Antràs and Chor (2022), there are few systematic assessments of this assumption

Proportionality Assumptions

Pairwise Proportionality Assumption: Connects source and destination countries from aggregate data.

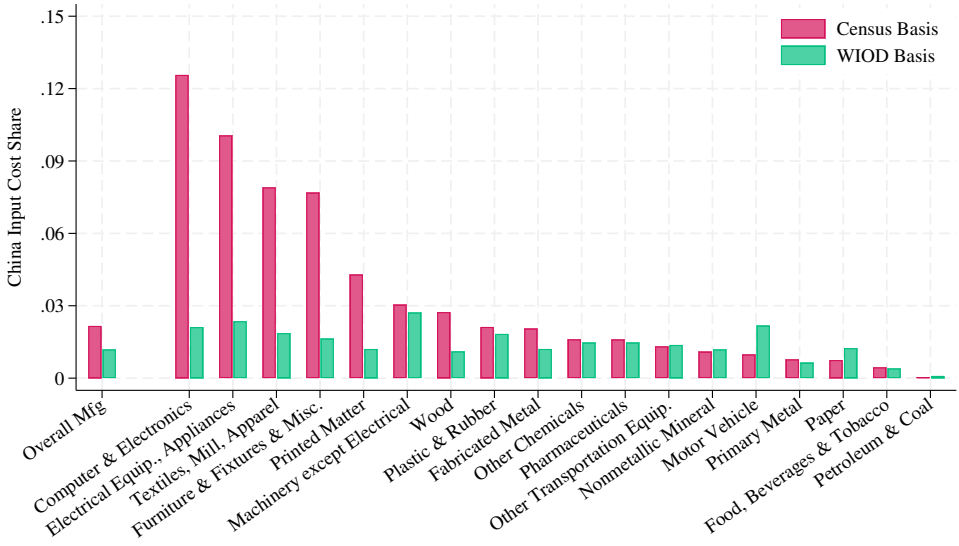
Import Proportionality Assumption: Allocates commodity imports to using industries, based on aggregate ratios A quick refresher

- While issues are discussed in de Gortari (2019) and Antràs and Chor (2022), there are few systematic assessments of this assumption

For benchmarking, we aggregate our data to the level of detail given in WIOD

- 18 manufacturing industries
- 42 countries plus ROW aggregate

Chinese Input Cost Share in U.S. Manufacturing, 2012



Benchmarking Proportionality Assumptions Against Reality

Summary of Additional Results:

- Country Cost Shares Across Industries Details
  - WIOD reflects import proportionality
  - Correlation of Census/WIOD country cost shares across industries: 0.64

Benchmarking Proportionality Assumptions Against Reality

Summary of Additional Results:

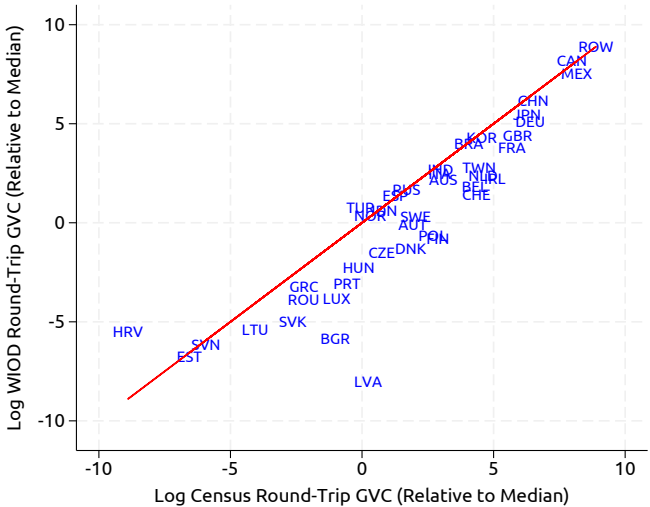
- Country Cost Shares Across Industries Details
  - WIOD reflects import proportionality
  - Correlation of Census/WIOD country cost shares across industries: 0.64
- Country-Pair GVC Values Details
  - WIOD reflects import proportionality *and* pairwise proportionality
  - Correlation of Census/WIOD GVC bilateral pairs across industries: 0.42

Benchmarking Proportionality Assumptions Against Reality

Summary of Additional Results:

- Country Cost Shares Across Industries Details
  - WIOD reflects import proportionality
  - Correlation of Census/WIOD country cost shares across industries: 0.64
- Country-Pair GVC Values Details
  - WIOD reflects import proportionality *and* pairwise proportionality
  - Correlation of Census/WIOD GVC bilateral pairs across industries: 0.42
- Excess Smoothing of GVC Linkages from pairwise proportionality Details
  - Unlike in WIOD, common to see zero GVC flows between bilateral country-pairs in data
- Pairwise proportionality appears to systematically under-estimate extent of round-trip linkages

WIOD under-estimates "Round-Trip" GVC



- **Round-Trip GVC:** where input market=output market
- Proportionality appears to systematically under-estimate this form of GVC

Disentangling Country Sample, Proportionality, Aggregation

Variable	Dependent Variable: Log Bilateral GVC (1)	(2)	(3)	(4)	(5)	(6)
Log Distance ($m \rightarrow$US$\rightarrow n$)	-1.36***					-0.02
	(0.104)					(0.045)
Round-trip (m=n)	2.21***					0.08***
	(0.112)					(0.008)
RTA (m, n, US)	0.44***					-0.02
	(0.112)					(0.034)
Data	Census					WIOD
Basis	Estab					Agg.
Country Sample	All–Data					WIOD-43
Observations	117,000					7,056
R-Squared	0.86					0.99

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Includes Exporter-Year F.E. and Importer-Year F.E.

- Our findings do not replicate in the WIOD

Disentangling Country Sample, Proportionality, Aggregation

Variable	Dependent Variable: Log Bilateral GVC (1)	(2)	(3)	(4)	(5)	(6)
Log Distance ($m \rightarrow$US$\rightarrow n$)	-1.36***	0.26				-0.02
	(0.104)	(0.280)				(0.045)
Round-trip (m=n)	2.21***	1.71***				0.08***
	(0.112)	(0.119)				(0.008)
RTA (m, n, US)	0.44***	-0.13				-0.02
	(0.112)	(0.220)				(0.034)
Data	Census	Census				WIOD
Basis	Estab	Estab				Agg.
Country Sample	All–Data	WIOD-43				WIOD-43
Observations	117,000	7,100				7,100
R-Squared	0.86	0.94				0.99

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Includes Exporter-Year F.E. and Importer-Year F.E.

- Importance of Round-Trip still evident with reduced sample ....

Disentangling Country Sample, Proportionality, Aggregation

Variable	Dependent Variable: Log Bilateral GVC (1)	(2)	(3)	(4)	(5)	(6)
Log Distance ($m \rightarrow$US$\rightarrow n$)	-1.36***	0.26	0.11**	-0.011		-0.02
	(0.104)	(0.280)	(0.049)	(0.045)		(0.045)
Round-trip (m=n)	2.21***	1.71***	0.17***	0.21***		0.08***
	(0.112)	(0.119)	(0.0426)	(0.0396)		(0.008)
RTA (m, n, US)	0.44***	-0.13	0.16***	0.17***		-0.02
	(0.112)	(0.220)	(0.046)	(0.045)		(0.034)
Data	Census	Census	Census	Census		WIOD
Basis	Estab	Estab	Agg.	Agg.		Agg.
Country Sample	All–Data	WIOD-43	All–Poss	All–Data		WIOD-43
Observations	117,000	7,100	139,000	117,000		7,100
R-Squared	0.86	0.94	0.96	0.96		0.99

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Includes Exporter-Year F.E. and Importer-Year F.E.

- ... but nearly disappears with aggregation and pairwise proportionality

Disentangling Country Sample, Proportionality, Aggregation

Variable	Dependent Variable: Log Bilateral GVC (1)	(2)	(3)	(4)	(5)	(6)
Log Distance ($m \rightarrow$US$\rightarrow n$)	-1.36***	0.26	0.11**	-0.011	-0.28**	-0.02
	(0.104)	(0.280)	(0.049)	(0.045)	(0.114)	(0.045)
Round-trip (m=n)	2.21***	1.71***	0.17***	0.21***	0.18***	0.08***
	(0.112)	(0.119)	(0.0426)	(0.0396)	(0.0282)	(0.008)
RTA (m, n, US)	0.44***	-0.13	0.16***	0.17***	0.06	-0.02
	(0.112)	(0.220)	(0.046)	(0.045)	(0.087)	(0.034)
Data	Census	Census	Census	Census	Census	WIOD
Basis	Estab	Estab	Agg.	Agg.	Agg.	Agg.
Country Sample	All–Data	WIOD-43	All–Poss /	All–Data	WIOD-43	WIOD-43
Observations	117,000	7,100	139,000	117,000	7,100	7,100
R-Squared	0.86	0.94	0.96	0.96	0.99	0.99

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Includes Exporter-Year F.E. and Importer-Year F.E.

- ... and is not about sample coverage

Outline

Summary of Model Features

How to incorporate these features to model with joint sourcing and exporting decisions?

Model Features

- Starting point is "Global Firms" model (cf. Bernard, Redding, Schott (JEL, 2018))
- Multi-country firm-level model: Eaton-Kortum on import sourcing side and Melitz on export side
  - Firms can lower variable unit cost function via increased sourcing of inputs
  - Firms can increase sales via exporting to other markets
  - Importing and exporting are subject to fixed and variable costs

Fixed Costs and Firm Profits

- Firm-specific fixed costs of exporting and sourcing: F^X_{ifn} and F^I_{ifm}
  - Fixed cost of production $= 0$
- Final goods from f in i chooses Ω^{NX}_{if}, $\Omega^{N_I}_{if}$, and prices, labor, and inputs to maximize:

$$\Pi^F_{if} = \sum_{n \in \Omega^{NX}_{if}} \left(\frac{1}{\sigma}\right) E^F_{ifn} - \sum_{n \in \Omega^{NX}_{if}} w_i F^X_{ifn} - \sum_{m \in \Omega^{NI}_{if}} w_i F^I_{ifm},$$

where $E^F_{ifn} = S^F_{ifn} w_n L_n$ is total sales of firm f in market n

More Model Details

Model Counterparts to Bilateral GVC Measures

- Firm-level GVC (country i, firm f's imports from m embodied in its exports to n):

$$\begin{aligned} GVC^{M}_{ifmn} &= \frac{IMP^{M}_{ifm}}{GO^{M}_{if}} EXP^{M}_{ifn} \\ &= \mu_{ifm}(\Omega^{NI}_{if})(1-\alpha)E^{F}_{ifn}. \end{aligned}$$

  - where μ_{ifm} is share of inputs sourced from m, and $1-\alpha$ is share of intermediates in production

- Total GVC (imported inputs from m embodied in i's exports to n):

$$GVC^{M}_{imn} = \sum_{f \in F_{imn}} \mu_{ifm}(\Omega^{NI}_{if})(1-\alpha)E^{F}_{ifn},$$

Model: Numerical Exercise

- Partial equilibrium (wages constant in each country)
- 14 symmetric countries plus "U.S.", which has higher wage, labor endowment and average productivity
- 1000 heterogeneous firms per country, productivities drawn from Pareto distribution (shape parameter $= 4$)
- Other parameters:
  1. $\theta = \sigma = 4$
  2. Variable trade costs range from 1 to 1.4; intermediate goods and final goods have same trade cost
- RTA indicator: Randomly choose 30 percent of country-pairs as having RTA. If chosen, then country pair's export and import variable costs set to 1.

Fixed Costs for Numerical Exercise

Three Potential Features of Fixed Costs:

1. **Symmetry:** Sourcing and export fixed costs are symmetric $F^X_{ifn} = F^I_{ifn}$
2. **Idiosyncratic:** Export and import fixed costs are firm-specific with both idiosyncratic and common components

$$F^X_{ifn} = F^X_{in}\varepsilon^X_{ifn}(\Omega^{NI}_{if})$$

3. **Round-trip adjustment:** If paying either source or destination fixed cost, the idiosyncratic component of the fixed cost in opposite direction is reduced by ξ_f

$$\varepsilon^X_{ifn}(\Omega^{NI}_{if}) \equiv \bar{\varepsilon}^X_{ifn} \times \left(1 - \xi_f 1(n \in \Omega^{NI}_{if})\right)$$

Gravity Regressions on Simulated Data

Variable	Dependent Variable: Log Simulated Bilateral GVC			
	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Round-trip (m=n)	0.19***	0.06***	0.05**	0.03
	(0.011)	(0.021)	(0.022)	(0.021)
Log Distance (m →US→ n)	-0.51*	-0.91*	-0.76	-1.35***
	(0.262)	(0.512)	(0.524)	(0.503)
RTA (m, n, US)	0.05**	0.10**	0.10**	0.08*
	(0.022)	(0.043)	(0.044)	(0.042)
Exporter F.E., Importer F.E.	yes	yes	yes	yes
Observations	196	196	196	196
R-squared	0.99	0.99	0.99	0.99
Symmetric Sourcing and Export Fixed Costs	yes	yes	yes	no
Idiosyncratic Fixed Costs	yes	yes	no	no
Round-trip Adjustment	yes	no	no	no

Summary and Future Work

Summary

- Novel supply chain measurement for the U.S. manufacturing sector
- New evidence on complementarities in input and output markets
- Strong role for roundtrip GVC linkages and for RTAs to promote GVC relationships
- Unpack effects from proportionality assumptions
- Model broadly consistent with empirical results

Summary and Future Work

Summary

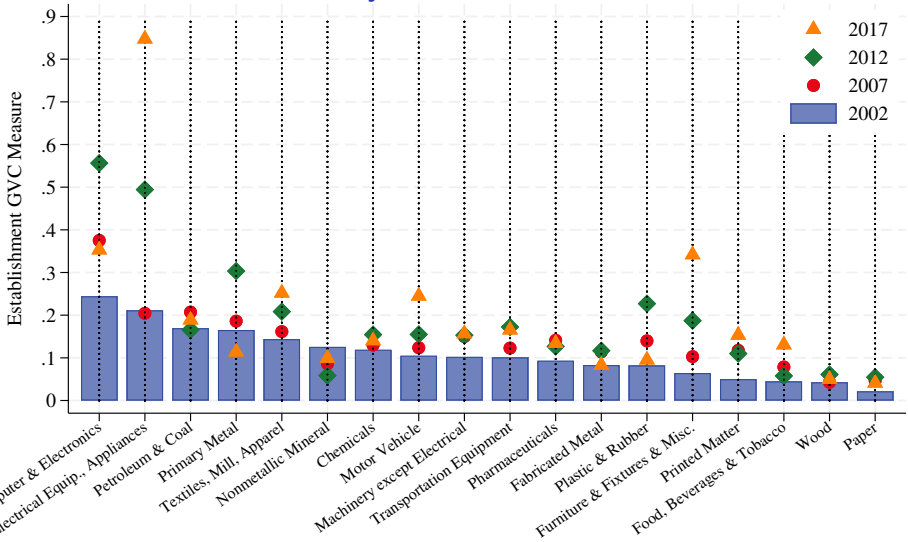
- Novel supply chain measurement for the U.S. manufacturing sector
- New evidence on complementarities in input and output markets
- Strong role for roundtrip GVC linkages and for RTAs to promote GVC relationships
- Unpack effects from proportionality assumptions
- Model broadly consistent with empirical results

Ongoing and Future Work

- Refine measurement – add in indirect imports and exports through extended GVC framework.
- Pair model with detailed Census data that matches these empirical features

Appendix Slides

Trends in Establishment GVC by Sector



Back

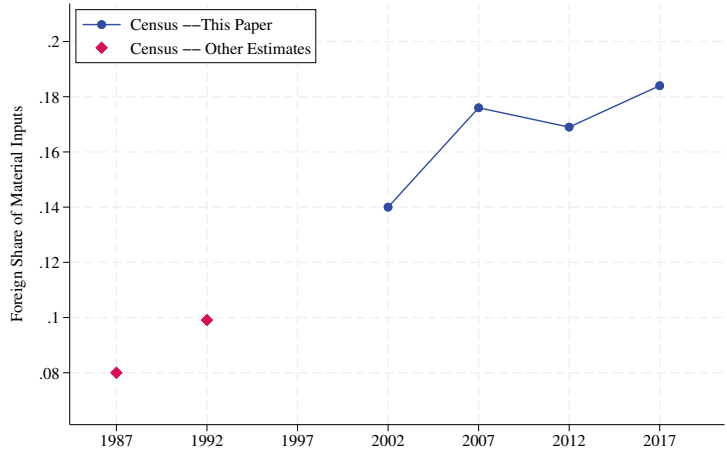
Input-Output Overlap: How Big is the Diagonal?

Overlap Between Input Products and Output Products

	Share of Input Codes Matching Product Codes (by value)			
	2002	**2007**	**2012**	**2017**
6-digit	14.5%	16.0%	14.5%	19.4%
4-digit	25.8%	28.7%	29.6%	29.0%
3-digit	44.5%	46.8%	45.0%	44.2%

Back

Figure: The Foreign Input Cost Share in U.S. Manufacturing

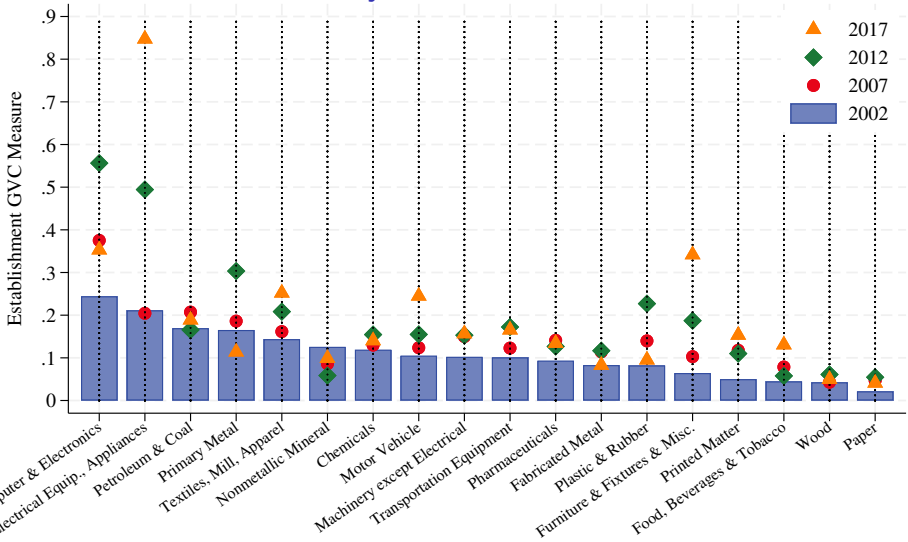


Notes: This figure plots estimates of the foreign input cost share for U.S. manufacturing.

Source: Author's calculations using CMF and LFTTD (blue line) and Berman, Bound, and Griliches (1993) and Kurz (2006) (red diamonds).

Back

Trends in Establishment GVC by Sector



Back

Downward Aggregation Bias: Establishment to Industry

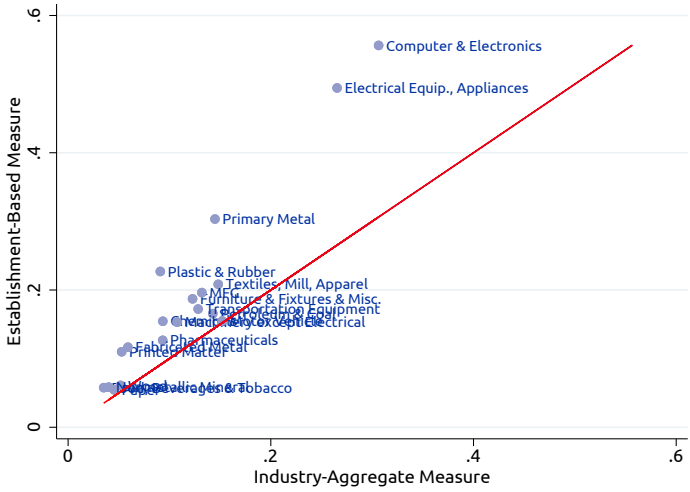
	Imports	Gross Output	Exports	GVC	GVC/Exports
Estab 1	50	100	50	25	
Estab 2	10	100	10	1	
Industry true			60	26	0.43
Industry biased	60	200	60	18	0.3

Note: Adapted from Bems & Kikkawa (2021). Back

Industry Aggregation Bias by Sector (2012)

- Downward aggregation bias present for all industries
- Worse bias for higher GVC industries

Back



Establishment or Firm as Relevant Unit?

Appropriate level of aggregation is not obvious!

Establishment or Firm as Relevant Unit?

Appropriate level of aggregation is not obvious!

Benefits of Firm-Level

- Level at which sourcing decisions are made?
- Would capture inter-plant transfers

Establishment or Firm as Relevant Unit?

Appropriate level of aggregation is not obvious!

Benefits of Firm-Level

- Level at which sourcing decisions are made?
- Would capture inter-plant transfers

Benefits of Establishment-Level

- Firm-level aggregation bias?
- Firm-level industry is not a well-defined concept

Aggregation Bias: Establishment to Firm

Downward bias

	Imports	Output	Exports	GVC	GVC/Exports
Estab 1	20	80	20	5	
Estab 2	0	80	0	0	
Estab basis			20	5	0.25
Firm basis	20	160	20	2.5	0.125

Aggregation Bias: Establishment to Firm

Downward bias

	Imports	Output	Exports	GVC	GVC/Exports
Estab 1	20	80	20	5	
Estab 2	0	80	0	0	
Estab basis			20	5	0.25
Firm basis	20	160	20	2.5	0.125

Upward bias

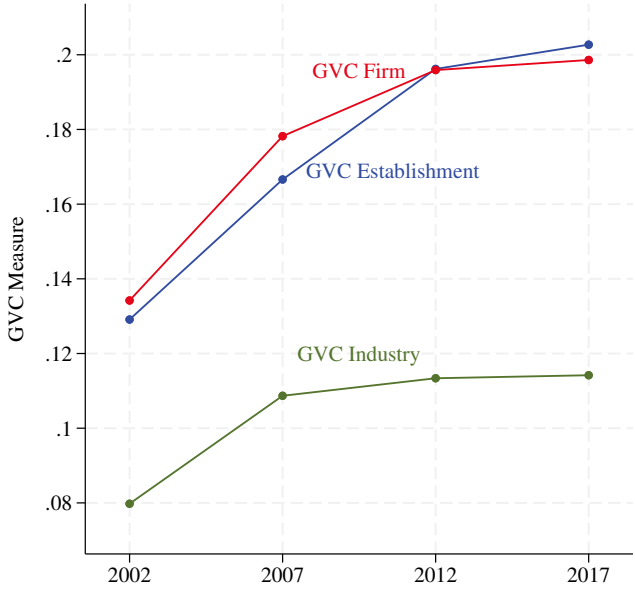
	Imports	Output	Exports	GVC	GVC/Exports
Estab 1	20	80	0	0	
Estab 2	0	80	20	0	
Estab basis			20	0	0
Firm basis	20	160	20	2.5	0.125

Back

GVC: Manufacturing

- On net, slight upward bias in firm aggregation
- Despite small net bias, *gross* biases (both upward/downward) could be large!

Back



Multi-Industry Firms Affect GVC Measurement

- Industry-level estimates based on firm-level data will include bias!
- Trading firms typically span many industries

Average Number of Industries per firm

Year	4-digit Industry	6-digit Industry
2002	5.7	9.5
2007	4.9	8.2
2012	4.7	7.6
2017	4.8	7.4

Notes: Exporter-Importer Firms. By Trader Type.

Multi-Industry Firms Affect GVC Measurement

- Industry-level estimates based on firm-level data will include bias!
- Trading firms typically span many industries

Average Number of Industries per firm

Year	4-digit Industry	6-digit Industry
2002	5.7	9.5
2007	4.9	8.2
2012	4.7	7.6
2017	4.8	7.4

Notes: Exporter-Importer Firms. By Trader Type.

- Bias from this dimension is modest (at 3-digit NAICS aggregation).

GVC: Alternate Industry Definition

$$gvc^{F'}_{s^*t} = \frac{\sum_{f \in F_{s^*}} \left[EXP_{ft} \left(\frac{IMP^I_{ft}}{GO_{ft}} \right) \right]}{\sum_{f \in F_{s^*}} EXP_{ft}}$$

$$gvc^{I'}_{s^*t} = \frac{\left(\sum_{f \in F_{s^*}} EXP_{ft} \right) \left(\frac{\sum_{f \in F_{s^*}} IMP^I_{ft}}{\sum_{f \in F_{s^*}} GO_{ft}} \right)}{\sum_{f \in F_{s^*}} EXP_{ft}}$$

F_{s^*t} set of firms reporting s^* as their primary industry in time t

- *à la* Bems and Kikkawa (2021)
- Issue: *EXP*, *IMP*, and *GO* include values not belonging to sector s^* in case of *multi-industry* firms

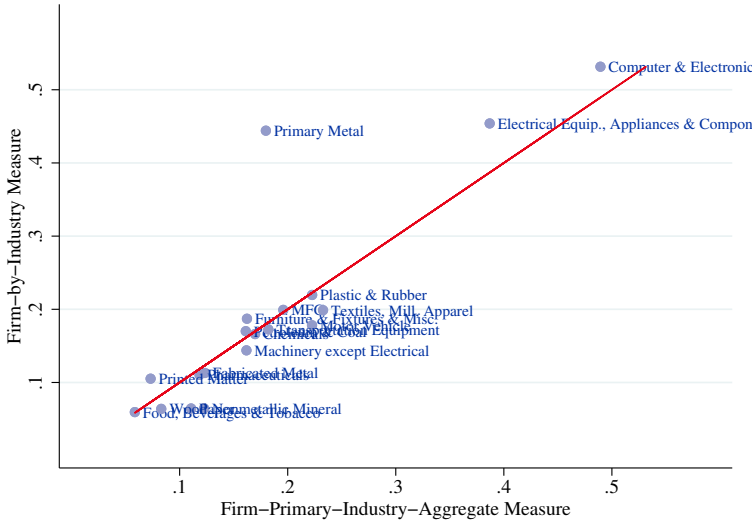
Why is There Aggregation Bias and Why is it Worsening?

- We answer this question in recent short note (Flaaen et al (2024))
- Arises from aggregating out firm and/or establishment level heterogeneity in export and import intensities
  - U.S. firm's export and import intensities positively correlated (Bernard *et al*, 2012)
- Conduct decomposition along the lines of Bems and Kikkawa (2021)
- **Main takeaway:** increased correlation of export and import intensities by U.S. manufacturers

Back

Firm GVC Comparisons by Sector, 2012

- At WIOD industry basis (roughly 3-digit NAICS) this bias is relatively small (correlation is 0.87)
- Interpretation: Primary Metal estabs whose firm is NOT in primary metals have much higher GVC



Back

Proportionality Assumption: An Example

Reality: Input Usage of Given Commodity

	Domestic	Germany	Ireland
Chemicals	\$800	\$200	\$0
Pharma	\$120	\$0	\$480

- Two industries (chemicals, pharmaceuticals) source the same commodity from different locations

Proportionality Assumption: An Example

Reality: Input Usage of Given Commodity

	Domestic	Germany	Ireland
Chemicals	\$800	\$200	\$0
Pharma	\$120	\$0	\$480

- Two industries (chemicals, pharmaceuticals) source the same commodity from different locations
- But, I-O tables do not have source detail!

Proportionality Assumption: An Example

Reality: Input Usage of Given Commodity

	Domestic	Germany	Ireland	**Data**
Chemicals	\$800	\$200	\$0	**\$1000**
Pharma	\$120	\$0	\$480	**\$600**
Data	**\$920**	**\$200**	**\$480**	

- Instead, I-O Tables have aggregate commodity usage, by industry...

Proportionality Assumption: An Example

Reality: Input Usage of Given Commodity

	Domestic	Germany	Ireland	**Data**
Chemicals	\$800	\$200	\$0	**\$1000**
Pharma	\$120	\$0	\$480	**\$600**
Data	**\$920**	**\$200**	**\$480**	

- ... which are combined with aggregate commodity usage by source (but not industry!) from i.e. import data

Proportionality Assumption: An Example

Reality: Input Usage of Given Commodity

	Domestic	Germany	Ireland	**Data**
Chemicals	\$800	\$200	\$0	**\$1000**
Pharma	\$120	\$0	\$480	**\$600**
Data	**\$920**	**\$200**	**\$480**	

- Hence, the *Proportionality Assumption* is applying the industry-level commodity proportions to all aggregate sources

Proportionality Assumption: An Example

Back

Reality: Input Usage of Given Commodity

	Domestic	Germany	Ireland
Chemicals	\$800	\$200	\$0
Pharma	\$120	\$0	\$480

Proportionality: Input Usage of Given Commodity

	Domestic	Germany	Ireland
Chemicals	\$575	\$125	\$300
Pharma	\$345	\$75	\$180

Census-WIOD Input Cost Share Correlations, 2012

NAICS	Input Costs
Food, Beverage, and Tobacco	0.83
Textiles, Apparel, Leather	0.67
Wood and Wood Products	0.87
Paper and Paper Products	0.81
Printing	0.73
Coke and Petroleum Products	0.68
Pharmaceutical	0.30
Chemicals and Chemical Products	0.62
Rubber and Plastics	0.67
Non-metallic Mineral Products	0.86
Basic Metals	0.94
Fabricated Metal Products	0.79
Machinery and Equipment	0.87
Computer, Electronic and Optical	0.62
Electrical Equipment	0.75
Motor Vehicles and Trailers	0.90
Other Transport Equipment	0.85
Furniture and Other Mfg	0.58
Overall Manufacturing	**0.64**

- Overall correlation of cost shares is positive, but well below one
- Proportionality works well in motor vehicles, basic metals, but less so in pharmaceuticals

Census-WIOD Bilateral GVC Country Correlations, 2012

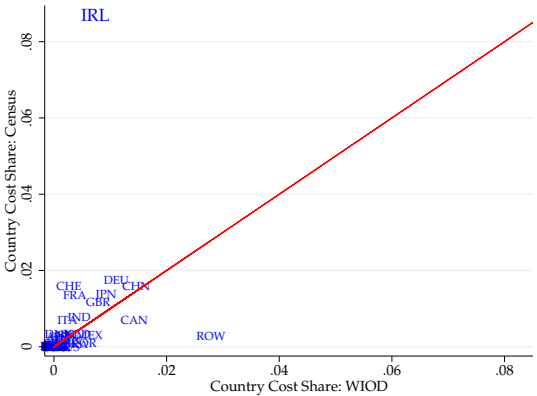
Back

NAICS	Bilateral Pair GVC
Food, Beverage, and Tobacco	0.92
Textiles, Apparel, Leather	0.56
Wood and Wood Products	0.63
Paper and Paper Products	0.76
Printing	0.64
Coke and Petroleum Products	0.94
Pharmaceutical	0.26
Chemicals and Chemical Products	0.81
Rubber and Plastics	0.49
Non-metallic Mineral Products	0.66
Basic Metals	0.69
Fabricated Metal Products	0.77
Machinery and Equipment	0.85
Computer, Electronic and Optical	0.83
Electrical Equipment	0.69
Motor Vehicles and Trailers	0.86
Other Transport Equipment	0.81
Furniture and Other Mfg	0.48
Overall Manufacturing	**0.42**

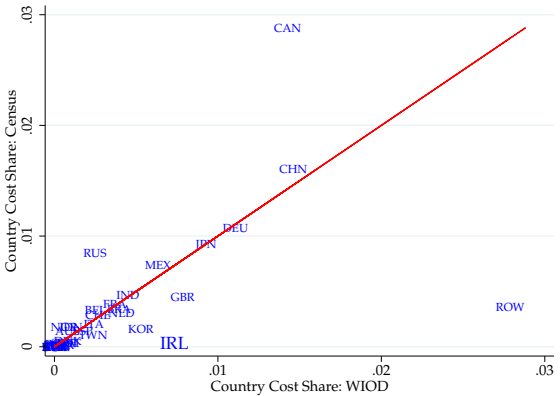
- Correlation of bilateral country pairs is generally lower
- Proportionality works well in coke and petroleum products and food, beverage, and tobacco

Where Import Proportionality Performs Less Well

Pharmaceutical (NAICS 3254)



Basic Chemicals (NAICS 325X)



Proportionality Makes GVC Linkages Too Diffuse

Back

- Proportionality implies positive values for ALL bilateral input-output linkages
- Even within set of WIOD countries, zero input-output flows are common

Fraction of Zero Bilateral Pair Linkages, by Sector, 2012

NAICS	Percent	NAICS	Percent
Food, Beverage, and Tobacco	14%	Wood and Wood Products	37%
Textiles, Apparel, Leather	11%	Non-metallic Mineral Products	13%
Paper and Paper Products	14%	Basic Metals	6%
Printing	28%	Fabricated Metal Products	1%
Coke and Petroleum Products	20%	Machinery and Equipment	0%
Pharmaceutical	4%	Computer, Electronic and Optical	0%
Chemicals and Chemical Products	2%	Electrical Equipment	0%
Rubber and Plastics	3%	Motor Vehicles and Trailers	1.6%
		Other Transport Equipment	0.2%
		Furniture and Other Mfg	0.1%

Top GVC Country Pairs, Overall Manufacturing 2012

Source	Destination	GVC ($bill)	GVC/Exports
Mexico	Canada	5.2	1.98%
China	Canada	4.6	1.72%
Mexico	Mexico	4.3	2.23%
Canada	Canada	3.6	1.36%
Canada	Mexico	2.7	1.37%
Japan	Canada	1.9	0.73%
China	Mexico	1.5	0.79%
Singapore	Canada	1.2	0.44%
Germany	Canada	1.1	0.43%

Top GVC Country Pairs, Selected Sectors 2012

Source Country	Destination Country	GVC/Exports
Motor Vehicles and Trailer		
Mexico	Canada	2.73%
Mexico	Mexico	5.95%
Canada	Canada	1.73%
Japan	Canada	1.54%
Germany	Mexico	1.78%
Canada	Mexico	1.74%
Japan	Mexico	1.13%
Germany	Canada	0.50%
Germany	Germany	3.09%
South Korea	Canada	0.37%

Top GVC Country Pairs, Selected Sectors 2012

Source Country	Destination Country	GVC/Exports
Other Transport Equipment		
France	France	3.29%
Japan	Japan	2.88%
Japan	United Arab Emirates	2.90%
Japan	China	2.68%
Japan	France	2.28%
Canada	France	2.04%
United Kingdom	France	2.00%
France	Brazil	2.27%
United Kingdom	United Arab Emirates	1.70%
France	Japan	1.46%

Top GVC Country Pairs, Selected Sectors 2012

Source Country	Destination Country	GVC/Exports
Machinery and Equipment		
Mexico	Canada	0.91%
Canada	Canada	0.82%
Germany	Canada	0.75%
Japan	Canada	0.68%
China	Canada	0.54%
Mexico	Mexico	1.00%
United Kingdom	Canada	0.48%
Mexico	Australia	0.72%
Mexico	Germany	3.17%
Canada	Australia	1.56%

Top GVC Country Pairs, Selected Sectors 2012

Source Country	Destination Country	GVC Share
	Pharmaceuticals	
Ireland	Italy	11.04%
Ireland	Japan	4.61%
Ireland	Belgium	4.96%
Ireland	South Korea	16.07%
Ireland	France	5.05%
Ireland	Ireland	9.74%
Ireland	Canada	2.69%
Ireland	Brazil	5.69%
Ireland	Mexico	3.89%

Trailer Files: Match Details

Not Elsewhere Specified (NESOI) Products

Share of Costs/Shipments

Material Trailer File	
2002	30.9%
2007	28.1%
2012	21.6%
2017	33.3%
Product Trailer File	
2002	0.4%
2007	0.3%
2012	0.3%
2017	0.5%

Source: Authors' calculations using Economic Census, U.S. Census Bureau.

Back

Fraction of Indirect (NESOI) Imported Inputs

	Indirect Imported Inputs *Share of Total*
2002	43.5%
2007	42.3%
2012	42.4%
2017	56.8%

Source: Authors' calculations using Economic Census, U.S. Census Bureau.

Back

Additional Results on RTAs and GVCs: 2002–2017

Variable	Dependent Variable: Log Bilateral GVC (1)	(2)	(3)
RTA (m & n)	-0.08**		
	(0.037)		
RTA (m & US, n & US)		0.135*	
		(0.075)	
RTA (m, n, US)			0.196**
			(0.099)
Exporter-Importer F.E.	Yes	Yes	Yes
Observations	112,000	112,000	112,000
R^2	0.92	0.92	0.92

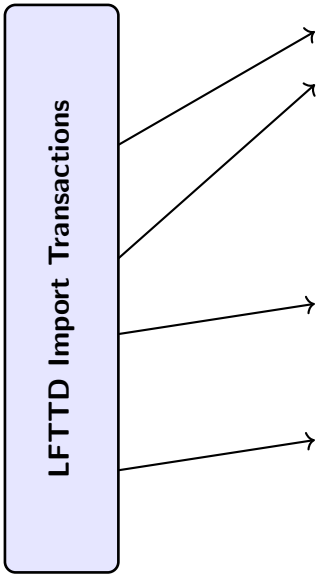
Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

- Results support findings in Johnson and Noguera (2019)

Back

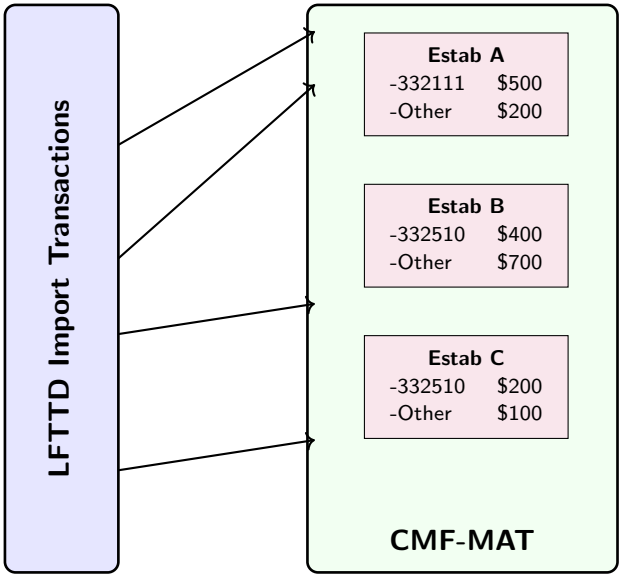
Imported Input Classification Details

1. Harmonize product classifications
   - Use Pierce/Schott Concordances for common NAICS product basis
2. Match imports and material product codes (NAICS-basis)
   - Direct: Import products match CMF-MT product
   - Indirect: Import products that *do not* match to any CMF-PT product
     - Concern: Significant "Not elsewhere specified or indicated" (NESOI) in CMF-MT
3. Allocate imported inputs to individual establishments
   - Matches to one establishment $\rightarrow$ straightforward
   - Matches to > 1 establishment $\rightarrow$ split value by material usage share



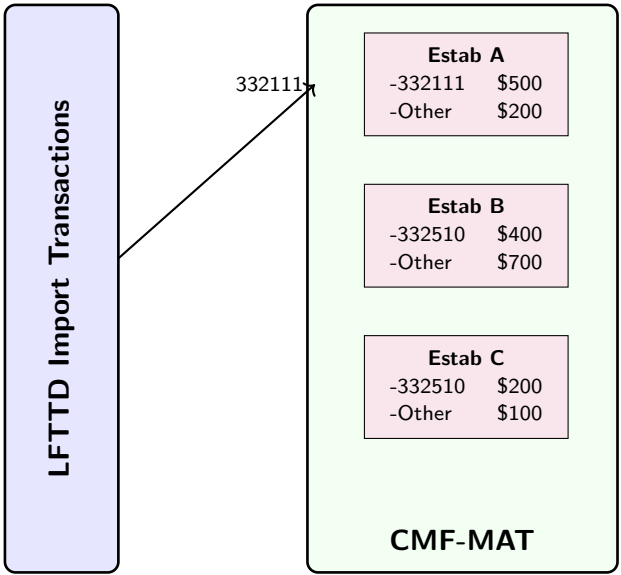
Allocation of Imports

- Begin with set of imports of a particular firm...



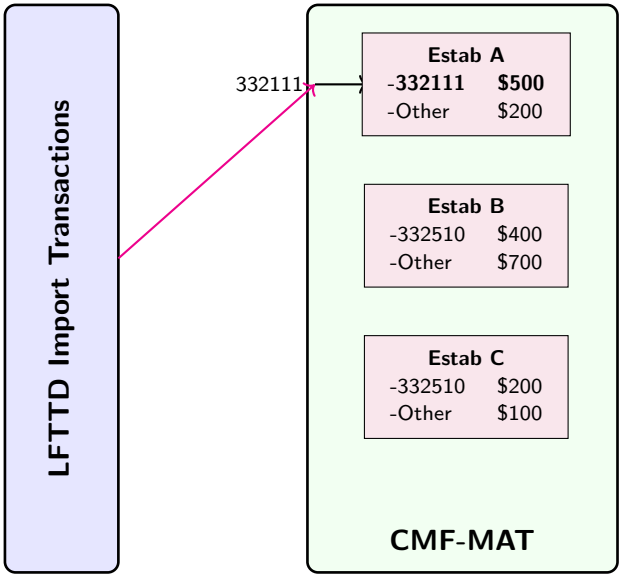
Allocation of Imports

- First step: use material trailer files for all establishments...



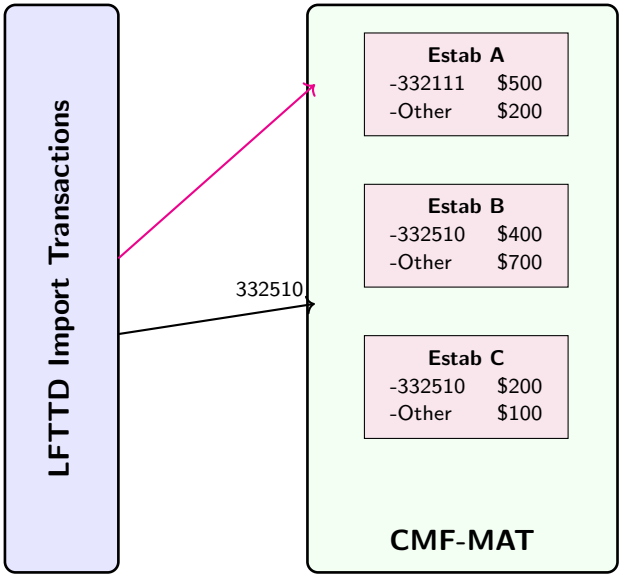
Allocation of Imports

- First step: use material trailer files for all establishments...
- ...to identify imports that match to material input usage...



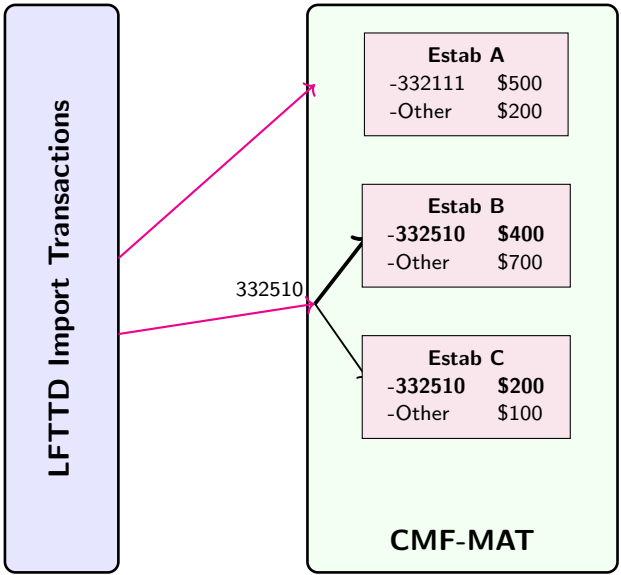
Allocation of Imports

- First step: use material trailer files for all establishments...
- ...to identify imports that match to material inputs of establishments...
- ... and allocate import value as input to that establishment.



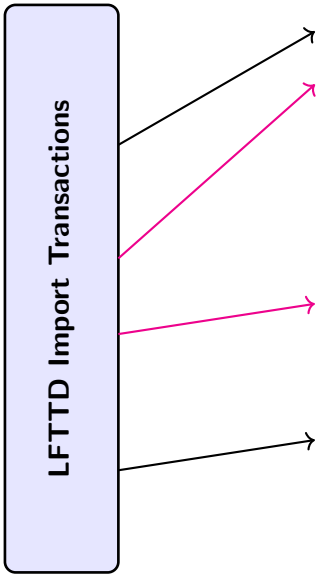
Allocation of Imports

- If import product matches to multiple establishments...



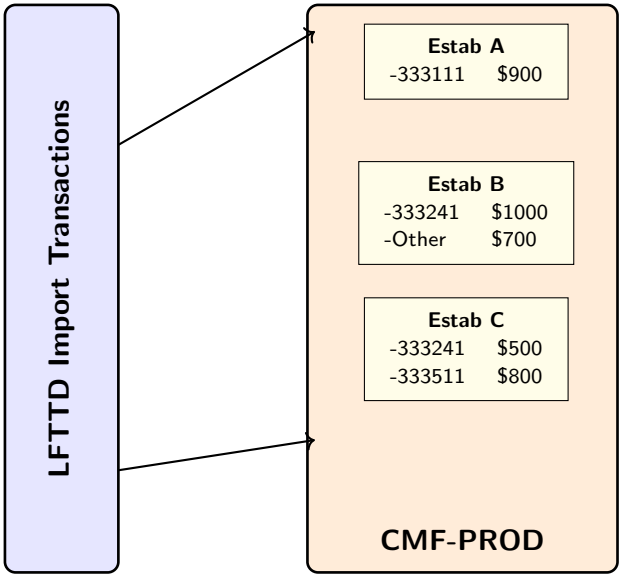
Allocation of Imports

- If import product matches to multiple establishments...
- Split value of imported input according to ratio of material input usage



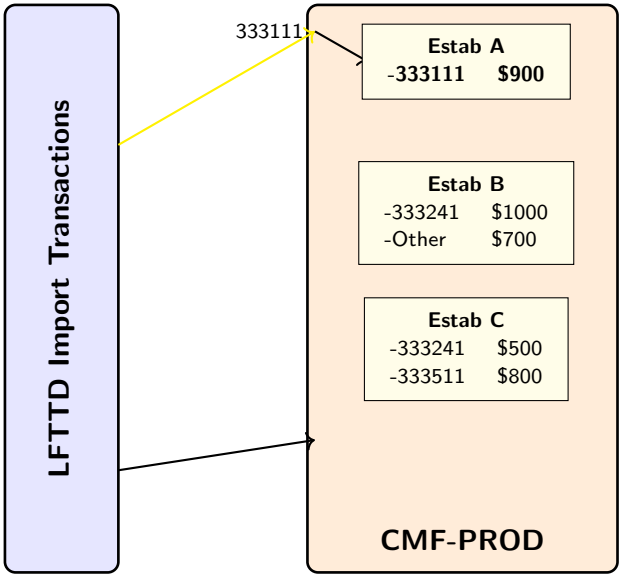
Allocation of Imports

- Remaining imports could be:
  - final goods, or
  - input, but not identified explicitly by CMF-MAT (NESOI)



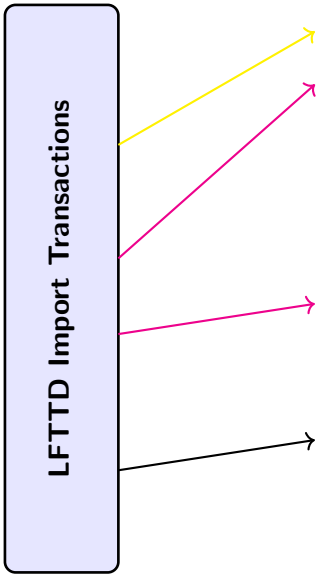
Allocation of Imports

- For remaining imported products, check to see whether products align with produced output according to CMF-PROD file



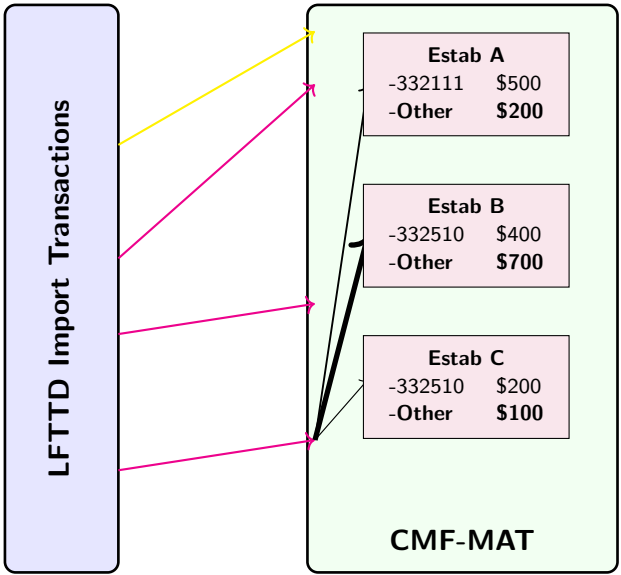
Allocation of Imports

- For remaining imported products, check to see whether products align with produced output according to CMF-PROD file
- If so, then define as final good and remove those imports.



Allocation of Imports

- For all remaining imported products, we assume they represent the “Other” material usage categories in the CM-MAT.



Allocation of Imports

- For all remaining imported products, we assume they represent the "Other" material usage categories in the CM-MAT.
- We split the value of imported inputs according to share of total "Other" material usage for the firm as a whole...

Back

Firm and Establishment Counts by Trader Type

Firm Trade Status	Year	Firms	Establishments
Non-Trader	2002	118,000	126,000
Non-Trader	2007	98,000	103,000
Non-Trader	2012	86,000	91,000
Exporter-Only	2002	11,000	14,000
Exporter-Only	2007	24,000	29,000
Exporter-Only	2012	21,000	25,000
Importer-Only	2002	13,000	18,000
Importer-Only	2007	10,000	11,000
Importer-Only	2012	10,000	12,000
Exporter-Importer	2002	11,000	43,000
Exporter-Importer	2007	20,000	55,000
Exporter-Importer	2012	20,000	51,000

Industries per Firm by Trader Type

- Point 1

Back

Firm Trade Status	Year	4-digit Industry	6-digit Industry
Non-Trader	2002	1.08	1.12
Non-Trader	2007	1.04	1.06
Non-Trader	2012	1.03	1.04
Exporter-Only	2002	1.13	1.26
Exporter-Only	2007	1.12	1.24
Exporter-Only	2012	1.11	1.18
Importer-Only	2002	1.32	1.52
Importer-Only	2007	1.28	1.42
Importer-Only	2012	1.26	1.35
Exporter-Importer	2002	5.68	9.54
Exporter-Importer	2007	4.91	8.21
Exporter-Importer	2012	4.74	7.56

No Aggregation Bias: Establishment to Firm

	Imports	Gross Output	Exports	GVC	GVC/Exports
Firm 3					
Estab 1	20	80	20	5	0.25
Estab 2	20	80	0	0	0
Firm true			20	5	0.25
Firm biased	40	160	20	5	0.25

Concording Product Classification Systems

Implement common product-level basis for trade, material use, and production (Pierce and Schott , 2012):

1. Goods Trade
   - Source: LFTTD
   - Native codes: Schedule B HS (exports), HTS (imports)
2. Material Inputs
   - Source: CM Materials Trailer File
   - Native codes: MNAICS
3. Production
   - Source: CM Products Trailer File
   - Native codes: NAICSPC

Goal: Concord each to common 6-digit NAICS (baseroot)

Examples

- **HTS-NAICS**

HS	NAICS
8419895040 Electrical Actuators	333999 General Purpose Machinery

- **HS-NAICS**

HS	NAICS
6902205020 Refractory bricks	327125 Nonclay Refractory

- **Census Product-NAICS**

Census Product	NAICS
3261121 Single-web film/rolls/sheets for flexible packaging uses	326112 Plastics Packaging

Unmatched Imported Products

- Not all imported products of the firm match directly to a reported material code
  - Firms find it difficult to report material usage at establishment level
  - Consolidation of MNAICS
  - Prioritizing most important MNAICS to be pre-populated on forms
- For the imported products that do not match directly, we first ensure that they are not on the list of produced product codes for any of the firm's establishments
- Of the remaining unmatched imported products, apportion the value per the establishment's share of NESOI in the firm's total imports

Fixed Cost Specification in Numerical Exercise

$$
\begin{aligned}
F^X_{ifn} &= F^X_{in}\varepsilon^X_{ifn}(\Omega^{NI}_{if}) \\
F^I_{ifm} &= F^I_{mi}\varepsilon^I_{ifm}(\Omega^{NX}_{if}),
\end{aligned}
$$

$$
\begin{aligned}
\varepsilon^X_{ifn}(\Omega^{NI}_{if}) &\equiv \bar{\varepsilon}^X_{ifn} \times \left(1 - \xi_f 1(n \in \Omega^{NI}_{if})\right) \\
\varepsilon^I_{ifm}(\Omega^{NX}_{if}) &\equiv \bar{\varepsilon}^I_{ifm} \times \left(1 - \xi_f 1(m \in \Omega^{NX}_{if})\right)
\end{aligned}
$$

Example of Import → Export Proportionality

	Imports		**Exports**		Gross
	Mexico	China	U.K.	Germany	Output
Firm A	100	0	300	0	500
Firm B	0	200	0	500	1000
Total	**100**	**200**	**300**	**500**	**1500**

Preferences, Expenditure Shares, and Final Goods Production

Back

- Preferences of consumer in country n are CES (with elasticity σ) over varieties produced by firms-countries that sell to n
- Expenditure share by consumer in n on good sold by country i firm f is:

$$S_{ifn}^{F} = \frac{(P_{ifn}^{F})^{1-\sigma}}{\sum_{i' \in \Omega_n^N} \sum_{f' \in \Omega_{i'n}^F} (P_{i'f'n}^{F})^{1-\sigma}}, \tag{1}$$

where P_{ifn}^{F} is the price paid by consumer in n for good produced by country i firm f

- Firm f from country i produces final good from labor and intermediate composite:

$$Q_{if}^{F} = \varphi_{if} \left(\frac{L_{if}^{F}}{\alpha} \right)^{\alpha} \left(\frac{Y_{if}^{F}}{1-\alpha} \right)^{1-\alpha}, \tag{2}$$

where Y_{if}^{F} is CES over intermediate goods with elasticity η.

Sourcing of Intermediate Inputs

Back

- Intermediate goods are produced by labor with constant returns to scale and productivity drawn from Fréchet distribution with productivity and shape parameters T and θ
- Probability that firm f in i sources intermediate inputs from country $m \in \Omega_{if}^{NI}$:

$$\mu_{ifm}(\Omega_{if}^{NI}) = \frac{T_m(w_m d_{mi}^I)^{-\theta}}{\sum_{m' \in \Omega_{if}^{NI}} T_{m'}(w_{m'} d_{m'i}^I)^{-\theta}}, \tag{3}$$

where w and d_{mi}^I are the wage and the variable trade cost for inputs sourced from m

- If f in i exports to n, consumer in n pays:

$$P_{ifn}^F = \left(\frac{\sigma}{\sigma - 1}\right) d_{in}^X \delta_{if}(\varphi_{if}, \Omega_{if}^{NI}), \tag{4}$$

where d_{in}^X and δ_{if} are variable trade cost for final goods from i to n and variable unit cost for f in i