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

November 23, 2024
NBER International Trade and Investment Program Meeting

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

- **Global value chains (GVCs)** are a pervasive feature of modern production and...
- Recent global shocks underscore their importance for evaluating economic outcomes and assessing appropriate policy responses

Motivation

- **Global value chains (GVCs)** are a pervasive feature of modern production and...
- Recent global shocks underscore their importance for evaluating economic outcomes and assessing appropriate policy responses

- Existing research measures and quantifies spillovers from GVCs using global input-output tables (e.g., WIOD, OECD-ICIO)
  - IO tables are invaluable but embedded assumptions generate biases

Motivation

- **Global value chains (GVCs)** are a pervasive feature of modern production and...
- Recent global shocks underscore their importance for evaluating economic outcomes and assessing appropriate policy responses

- Existing research measures and quantifies spillovers from GVCs using global input-output tables (e.g., WIOD, OECD-ICIO)
  - IO tables are invaluable but embedded assumptions generate biases

- **Proposition:** capturing actual GVC linkages require granular data
  - GVCs exist and evolve at the level of the firm/establishment
  - Micro-level heterogeneity shapes aggregate outcomes

What We Do

- Construct novel granular estimates of GVC flows moving through the United States
  - Classify imports by intended use and exports to production for individual plants
  - Measure GVCs in the U.S. manufacturing sector (2002, 2007, 2012, 2017)

What We Do

- Construct novel granular estimates of GVC flows moving through the United States
  - Classify imports by intended use and exports to production for individual plants
  - Measure GVCs in the U.S. manufacturing sector (2002, 2007, 2012, 2017)
- New insights from micro-level perspective
  - Imported content of U.S. exports: 13 to 20 cents/$1 of export from 2002 to 2017
    → Aggregation bias limits visibility of these patterns in aggregate data

What We Do

- Construct novel granular estimates of GVC flows moving through the United States
  - Classify imports by intended use and exports to production for individual plants
  - Measure GVCs in the U.S. manufacturing sector (2002, 2007, 2012, 2017)
- New insights from micro-level perspective
  - Imported content of U.S. exports: 13 to 20 cents/$1 of export from 2002 to 2017
    → Aggregation bias limits visibility of these patterns in aggregate data
  - GVC flows exhibit strong complementarities between input and output markets
    - Round-trip linkages
    - Regional trade agreements (RTA)

    → Proportionality assumptions limit visibility of these patterns in aggregate data

What We Do

- Construct novel granular estimates of GVC flows moving through the United States
  - Classify imports by intended use and exports to production for individual plants
  - Measure GVCs in the U.S. manufacturing sector (2002, 2007, 2012, 2017)
- New insights from micro-level perspective
  - Imported content of U.S. exports: 13 to 20 cents/$1 of export from 2002 to 2017
    → Aggregation bias limits visibility of these patterns in aggregate data
  - GVC flows exhibit strong complementarities between input and output markets
    - Round-trip linkages
    - Regional trade agreements (RTA)

    → Proportionality assumptions limit visibility of these patterns in aggregate data
- Explore fixed cost structures that account for these new micro-level patterns in existing "off-the-shelf" models of sourcing and exporting

Literature Review

- **Input-Output Table-Based GVC**: Hummels, Ishii, & Yi (2001); Johnson & Noguera (2011, 2017); Koopman, Wang, & Wei (2014); Timmer *et al.* (2014, 2016); de Gortari (2019); Antràs & de Gortari (2020)
  - Contribution: Establishment-level GVC measures for the U.S. manufacturing sector, trilateral impacts of RTAs on GVCs
- **Firm-Level GVC**: Kee & Tang (2016); Bems & Kikkawa (2021)
  - Contribution: Export and import allocations for multi-industry firms
- **Global Supply Chains and U.S Manufacturing**: Bernard & Fort (2015); Boehm, Flaaen, & Pandalai-Nayar (2019); Handley, Kamal & Monarch (forthcoming); Ding, Fort, Redding, & Schott (2022); Feenstra & 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
- GO: gross output
- IMP^I: **direct** imports of goods used in further production
- EXP: **direct** sales of goods produced to foreign markets

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. no information on intended use of imports

    → Identify **inputs** imported by establishments

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. no information on intended use of imports

    → Identify **inputs** imported by establishments
- **Exports** EXP_{enpt}
  - Source: LFTTD (2002, 2007, 2012, 2017)
  - Challenges
    1. only firm-level identifiers
    2. no information on products by market

    → Identify **manufactured** exports

Imported Input Classification

Details

Challenge: Separate inputs from final goods imports & connect imported inputs to establishment-level input usage

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

Imported Input Classification

Details

Challenge: Separate inputs from final goods imports & connect imported inputs to establishment-level input usage

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
- In 2017, imported inputs were about 18% of material costs for the representative (sales-weighted) plant Separating Inputs from Output

Produced Export Classification

Challenge: Connect exports to establishment-level production

Solution: Match exports to *establishment-level* shipments in from CMF Product Trailer

Produced Export Classification

Challenge: Connect exports to establishment-level production

Solution: Match exports to *establishment-level* shipments in from 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 were about 10% of total shipment value for the representative (sales-weighted) plant Overall Match

Construct Sectoral GVC

Start with *establishment-level* GVC:

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

Construct Sectoral GVC

Start with *establishment-level* GVC:

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

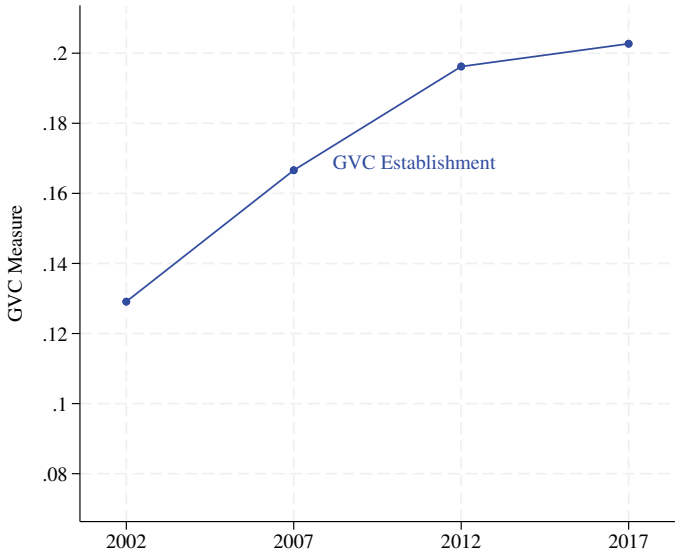
Aggregate and scale by overall exports in industry s:

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

Generate industry-level analogues with our data:

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

GVC in U.S. Manufacturing Growing Over Time



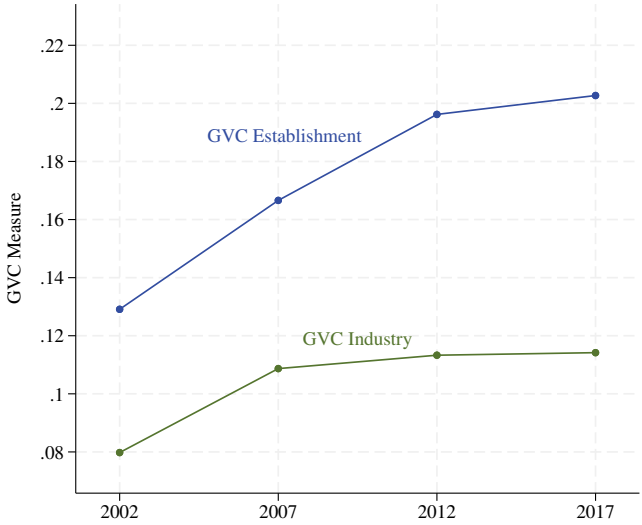
Industry Aggregation Bias Grows Over Time

Establishment vs. Industry:

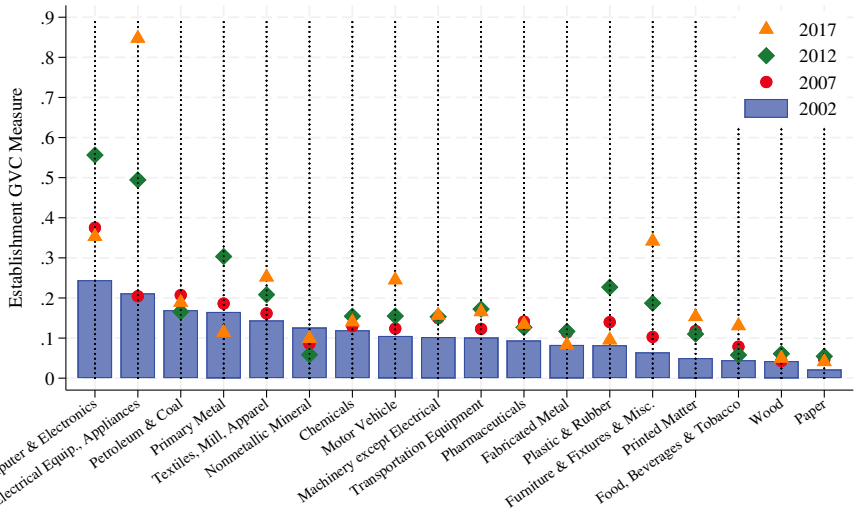
- higher levels
- gap widens over time

Simple Illustration

More Details on Aggregation Bias



Heterogeneous Trends in Establishment GVC Across Sub-Sectors



Outline

Unpacking Multi-Country (m, US, n) Supply Chains

- Construct bilateral GVC
  - Start with *establishment-level* GVC:

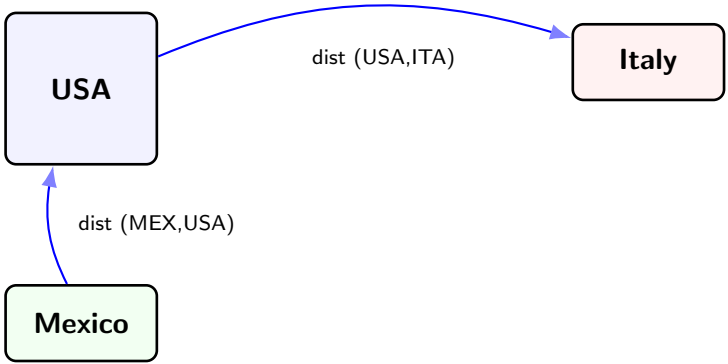
$$GVC_{emnt} = \frac{\sum_r IMP^I_{emrt}}{\sum_s GO_{est}} \sum_p EXP_{enpt}$$

  - Aggregate to source country m and destination country n:

$$GVC^E_{mnt} = \sum_{e \in E_{mnt}} \left(\frac{\sum_r IMP^I_{emrt}}{GO_{est}} \sum_p EXP_{enpt} \right)$$

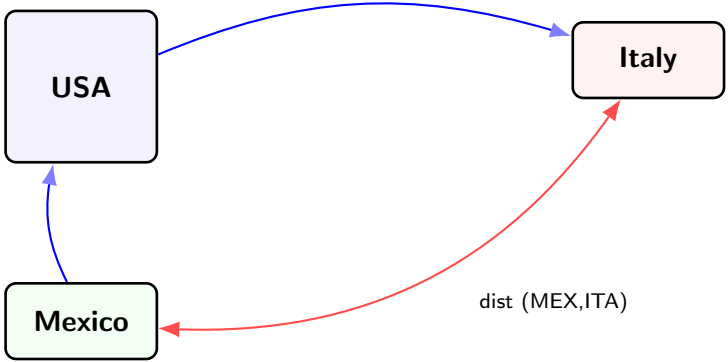
  - Study patterns in multi-country supply chains with newly linked data Summary
  - Adapt the well-known gravity framework to model determinants of GVCs using CEPII (Conte et al., 2022)

Gravity in Three Country GVC Relationships: Combined Distance



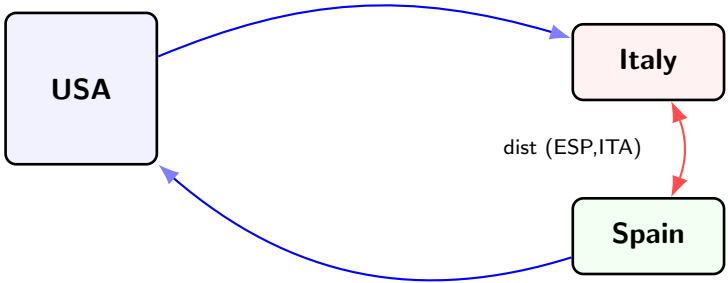
- Distance is typically used to proxy for trade frictions
- **Combined** distance from country m to US to country n : $d_{m,US,n} = d_{m,US} + d_{US,n}$

Gravity in Three Country GVC Relationships: Direct Distance



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

Gravity in Three Country GVC Relationships: Direct Distance



- Does proximity inhibit or support GVC flows?
- Inhibit ($+$ coeff.): higher relative costs of moving goods through USA
- Support ($-$ coeff.): complementarities between input and output markets.

Gravity in Three Country GVC Relationships: Round-trip

- **round-trip** ($m = n$): extreme example of potential complementarities between input and output markets

Examining GVC Flows within Three-Country Pairs

Formally, we evaluate gravity regressions of the form:

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

Examining GVC Flows within Three-Country Pairs

Formally, we evaluate gravity regressions of the form:

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

We 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

GVC Flows and Distance: Pooled Sample, 2002–2017

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)
Observations	117,000	117,000	117,000	117,000
R^2	0.86	0.86	0.86	0.86

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

GVC flows...

- smaller between distant pairs (combined distance more important)
- larger within round-trip (even after controlling for distance)

GVC Flows and RTAs: Pooled Sample, 2002–2017

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)
Observations	117,000	117,000	117,000
R^2	0.86	0.86	0.86

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

More Evidence

GVC flows in RTAs that...

- do NOT include the U.S. are very small
- include the U.S., but not all three countries, are larger
- include ALL three countries are largest

Outline

WIOD and Proportionality Assumptions

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

- 18 manufacturing industries
- 43 countries plus ROW aggregate

Import Proportionality Assumption: Allocate commodity imports to using industries based on economy-wide import shares A quick refresher

Pairwise Proportionality Assumption: Connect source and destination countries through aggregate trade flows

Pairwise Proportionality

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

Pairwise Proportionality

	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

Pairwise Proportionality

	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

Pairwise Proportionality

	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

Construct Bilateral GVC

Start with *establishment-level* GVC:

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

Aggregate to source country m and destination country n:

$$GVC^E_{mnt} = \sum_{e \in E_{mnt}} \left(\frac{\sum_r IMP^I_{emrt}}{GO_{est}} \sum_p EXP_{enpt} \right)$$

WIOD analogue:

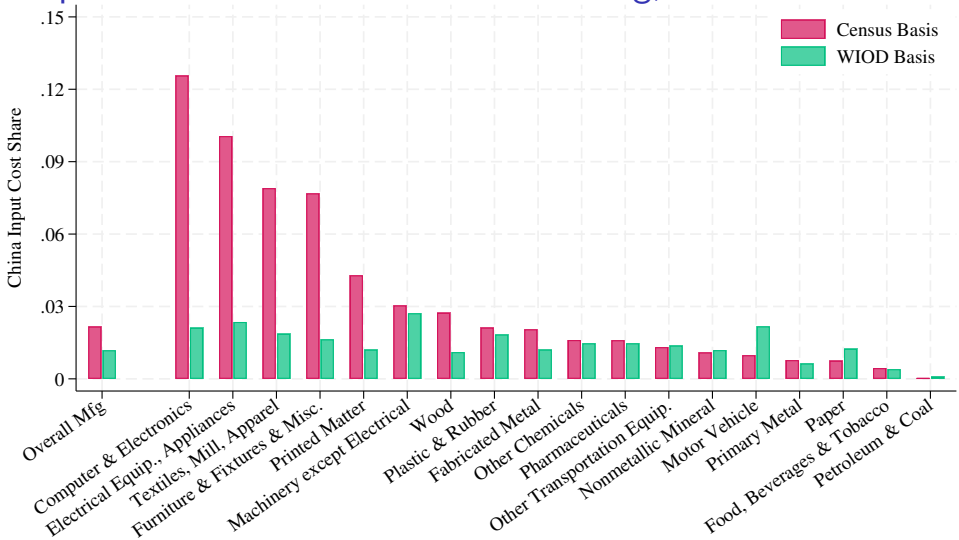
$$GVC^{WIOD}_{mnt} = \sum_s \left(\frac{\sum_{e \in E_{mst}} \sum_r IMP^I_{emrt}}{\sum_{e \in E_{st}} GO_{est}} \sum_{e \in E_{nst}} \sum_p EXP_{enpt} \right)$$

- Excess smoothing of GVC linkages from pairwise proportionality Details

Benchmarking Import Proportionality Assumption Against Reality

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

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



Overall Input Cost Share

Benchmarking Pairwise Proportionality Assumption Against Reality

- Country-Pair GVC Values Details
  - WIOD reflects import proportionality *and* pairwise proportionality
  - Correlation of Census/WIOD GVC bilateral pairs across industries: 0.42

- Pairwise proportionality mismeasures extent of round-trip linkages

Aggregate Data Misses True Import-Export Linkages in U.S. GVCs

Dep. Variable: Log Bilateral GVC		
Data Source	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)
Observation Unit	Estab	Ctry-Ind
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.

- Multi-country input-output data (WIOD) masks patterns evident using microdata
- Visibility limited due to:
  - sample coverage
  - aggregation requiring pairwise and traditional import proportionality

Disentangling Country Sample, Proportionality, Aggregation

	Dependent Variable: Log Bilateral GVC					
	(1)	(2)	(3)	(4)	(5)	(6)
Data Source	Census					WIOD
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)
Observation Unit	Estab					Ctry-Ind
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

	Dependent Variable: Log Bilateral GVC					
	(1)	(2)	(3)	(4)	(5)	(6)
Data Source	Census	Census				WIOD
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)
Observation Unit	Estab	Estab				Ctry-Ind
Country Sample	All–Data	WIOD-43				WIOD-43
Observations	117,000	7,100				7,056
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

	Dependent Variable: Log Bilateral GVC					
	(1)	(2)	(3)	(4)	(5)	(6)
Data Source	Census	Census	Census	Census		WIOD
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)
Observation Unit	Estab	Estab	Ctry-Ind	Ctry-Ind		Ctry-Ind
Country Sample	All–Data	WIOD-43	All–Poss	All–Data		WIOD-43
Observations	117,000	7,100	139,000	117,000		7,056
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

	Dependent Variable: Log Bilateral GVC					
	(1)	(2)	(3)	(4)	(5)	(6)
Data Source	Census	Census	Census	Census	Census	WIOD
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)
Observation Unit	Estab	Estab	Ctry-Ind	Ctry-Ind	Ctry-Ind	Ctry-Ind
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	7,056
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

Bilateral 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 "USA", which has higher wage, labor endowment and average productivity
- 1000 heterogeneous firms per country, productivity 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% 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 various proportionality assumptions
- Identify model features 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 various proportionality assumptions
- Identify model features broadly consistent with empirical results

Ongoing and Future Work

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

Appendix Slides

Multi-Industry Firms Complicate GVC Measurement

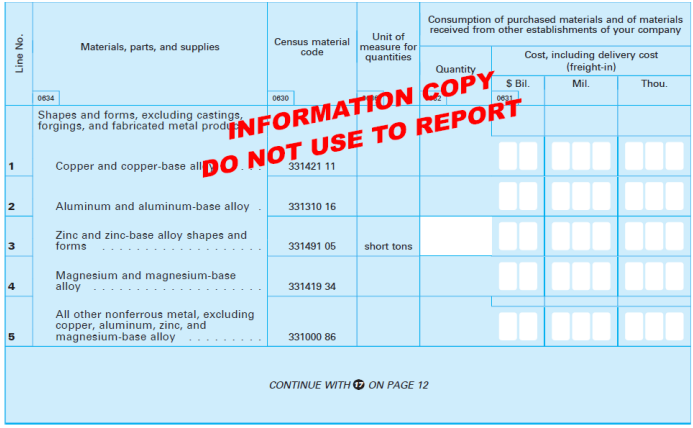
- Trading firms typically span many industries

Average Number of Industries per Exporter-Importer

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

CMF-MAT 2012: Detailed Cost of Materials, Parts, and Supplies

NAICS 331221: Rolled Steel Shape Manufacturing



Line No.	Materials, parts, and supplies	Census material code	Unit of measure for quantities	Consumption of purchased materials and of materials received from other establishments of your company			
				Quantity	Cost, including delivery cost (freight-in)		
	0634	0630			$ Bil. 0631	Mil.	Thou.
	Shapes and forms, excluding castings, forgings, and fabricated metal products						
1	Copper and copper-base alloy	331421 11					
2	Aluminum and aluminum-base alloy	331310 16					
3	Zinc and zinc-base alloy shapes and forms	331491 05	short tons				
4	Magnesium and magnesium-base alloy	331419 34					
5	All other nonferrous metal, excluding copper, aluminum, zinc, and magnesium-base alloy	331000 86					

CONTINUE WITH ON PAGE 12

Imported Input

CMF-PROD 2012: Detail of Sales, Shipments, Receipts, or Revenue

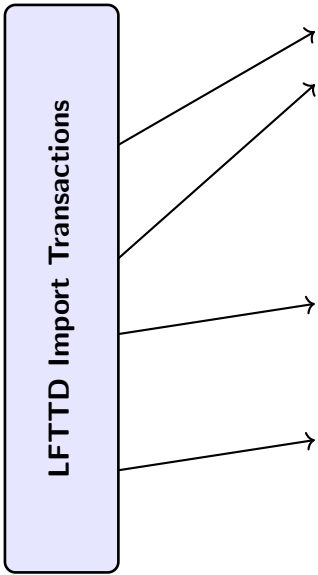
NAICS 331221: Rolled Steel Shape Manufacturing

Line No.	Products and services (0734)	Census product code (0730)	Unit of measure for quantities (0736)	Products shipped and other receipts			
				Quantity (0732)	Value, f.o.b. plant		
					$ Bil. (0731)	Mil.	Thou.
	Nonferrous metal die-casting foundries						
1	Aluminum and aluminum-base alloy	331521 0100					
2	Nonferrous metals and alloys, excluding aluminum	331522 0900					
	Nonferrous metal foundries, excluding die-castings						
	Aluminum and aluminum-base alloy castings						
3	Sand, excluding cast aluminum cooking utensils	331524 0101					
4	Permanent and semi-permanent mold, excluding cast aluminum cooking utensils	331524 0206					
5	Investment, excluding cast aluminum cooking utensils	331524 0311					

Produced Export

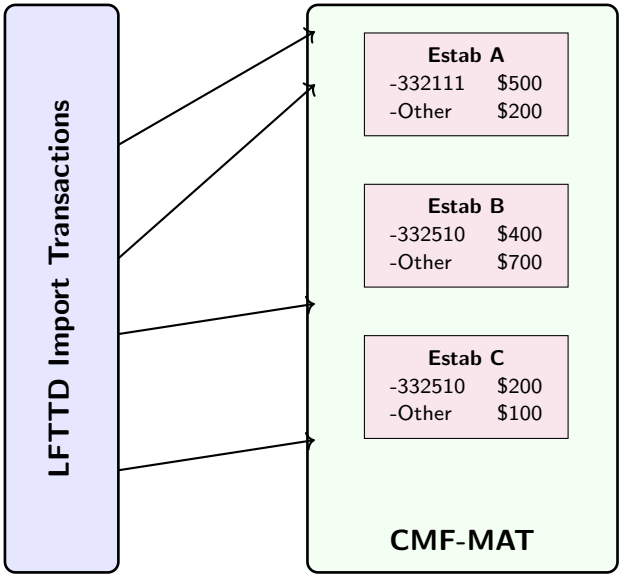
Imported Input Classification Details

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



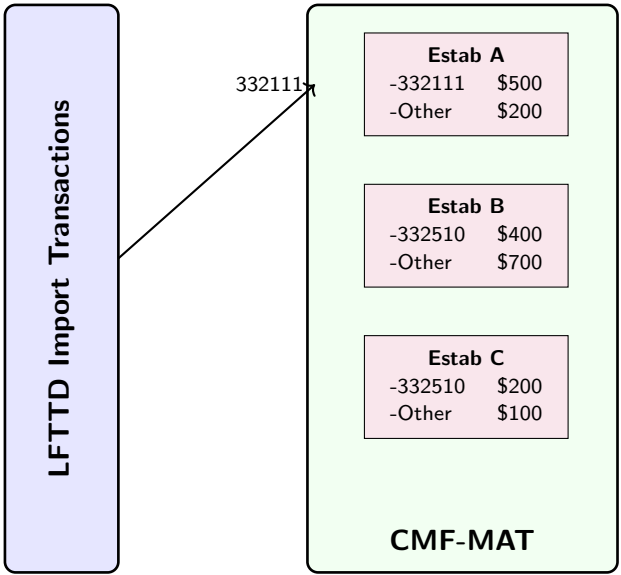
Allocation of Imports

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



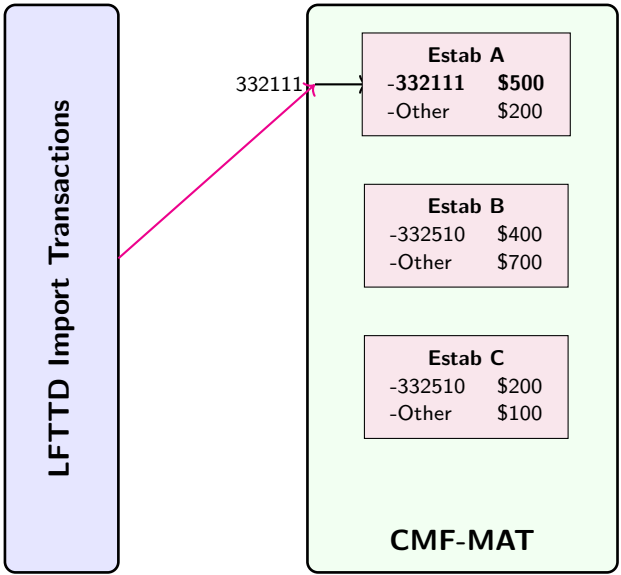
Allocation of Imports

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



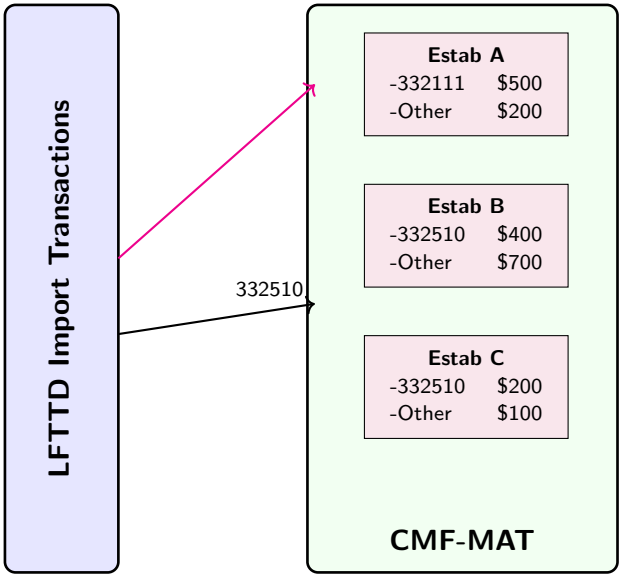
Allocation of Imports

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



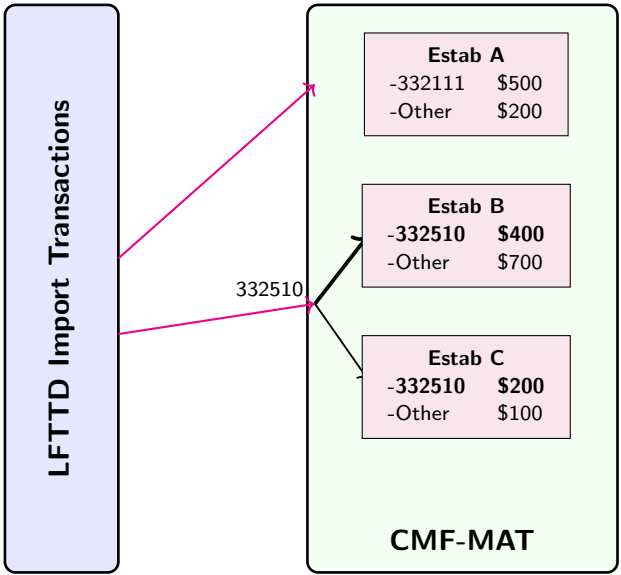
Allocation of Imports

- 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.



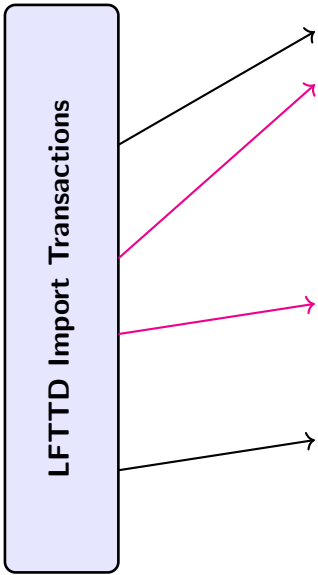
Allocation of Imports

- If import product matches to multiple establishments...



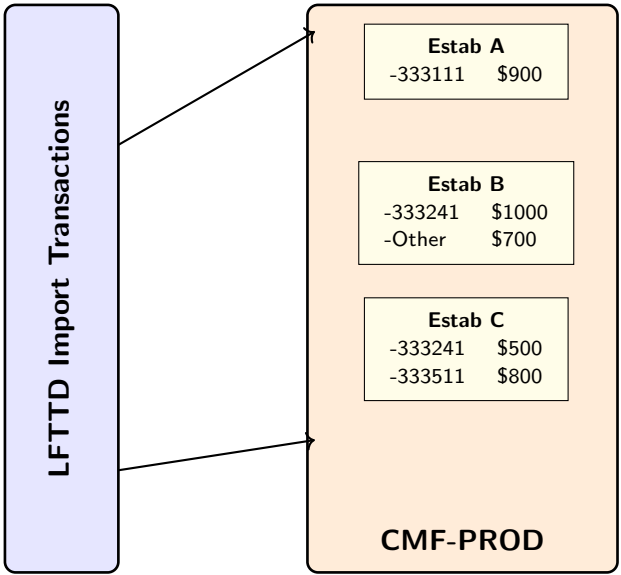
Allocation of Imports

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



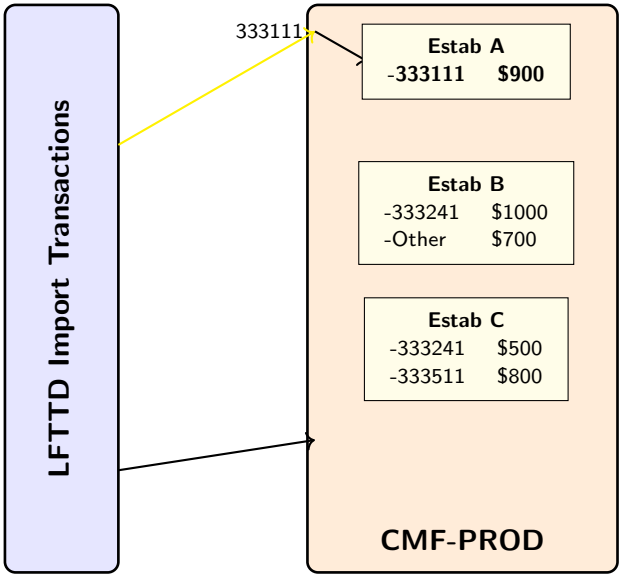
Allocation of Imports

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



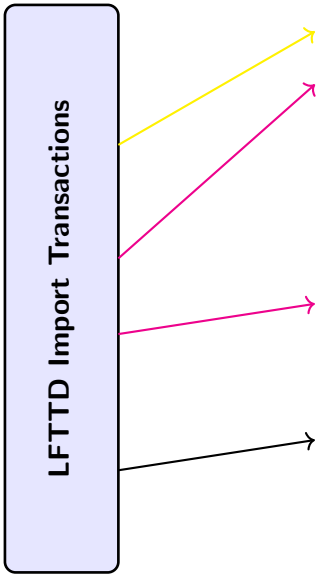
Allocation of Imports

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



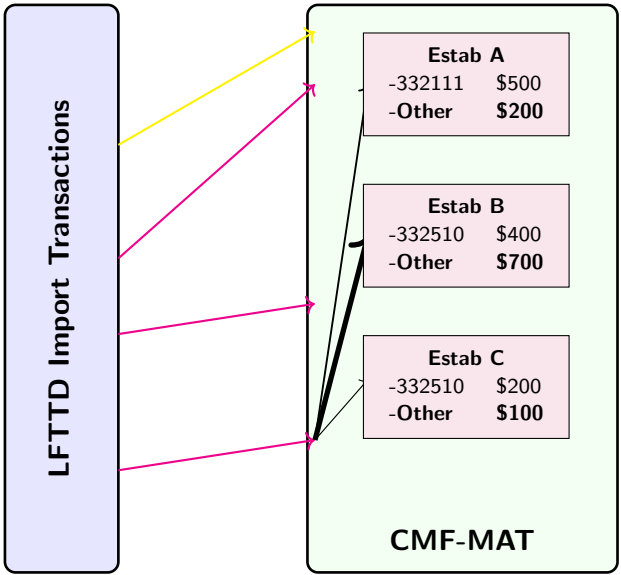
Allocation of Imports

- 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

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

Input-Output Overlap: How Big is the Diagonal?

	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

Sample: Firm and Establishment Counts by Trader Type

Trader Type	Year	Firms	Establishments
Non-Trader	2002	118,000	126,000
Non-Trader	2007	98,000	103,000
Non-Trader	2012	86,000	91,000
Non-Trader	2017	88,500	93,000
Exporter-Only	2002	11,000	14,000
Exporter-Only	2007	24,000	29,000
Exporter-Only	2012	21,000	25,000
Exporter-Only	2017	20,500	25,500
Importer-Only	2002	13,000	18,000
Importer-Only	2007	10,000	11,000
Importer-Only	2012	10,000	12,000
Importer-Only	2017	9,500	12,500
Exporter-Importer	2002	11,000	43,000
Exporter-Importer	2007	20,000	55,000
Exporter-Importer	2012	20,000	51,000
Exporter-Importer	2017	17,500	48,500

What Share of Overall Trade is Represented in Our Sample?

	Share of Overall Trade Linked in Sample (by value)			
	2002	**2007**	**2012**	**2017**
Imports	47.4%	49.0%	46.3%	55.1%
Exports	62.7%	60.4%	55.6%	71.0%

Back

Downward Aggregation Bias: Establishment to Industry

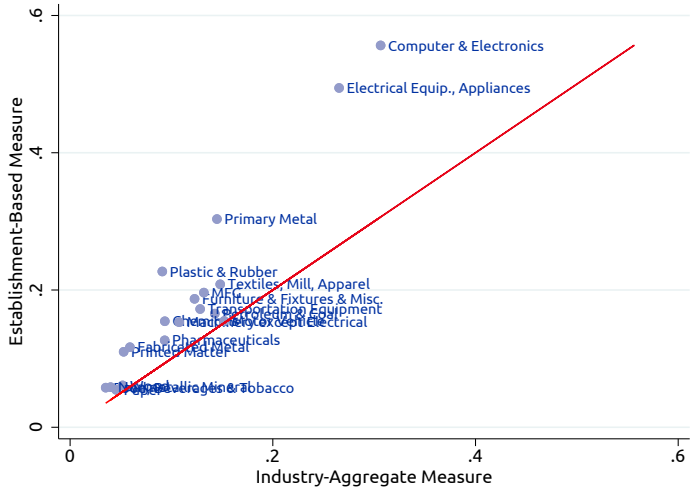
	Imports	Gross Output	Exports	GVC	GVC/Exports
Estab 1	50	100	50	25	
Estab 2	10	100	10	1	
Industry true			60	26	0.43
Industry biased	60	200	60	18	0.3

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

Industry Aggregation Bias by Sector (2012)

- Downward aggregation bias present for all industries
- Bias worsens for higher GVC industries

Back



Why is There Aggregation Bias and Why is it Worsening?

- Flaaen, Kamal, Lee, Yi (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

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

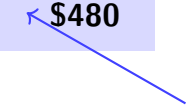
	Domestic	Germany	Ireland	**Data**
Chemicals	\$800	\$200	\$0	**\$1000**
Pharma	\$120	\$0	\$480	**\$600**
Data	**\$920**	**\$200**	**\$480**	

- 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

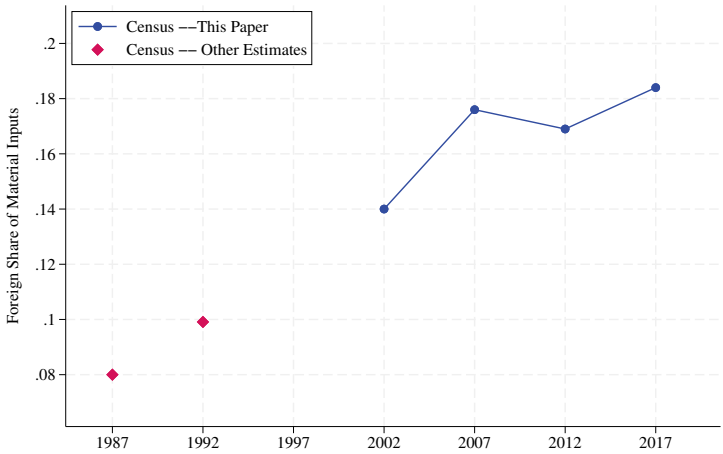
Reality: Input Usage of Given Commodity

	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

Rising Foreign Input Cost Share in U.S. Manufacturing



Source: CMF and LFTTD (blue dots); Berman, Bound, & Griliches (1993); Kurz (2006) (red diamonds).

Back

Census-WIOD Input Cost Share Correlations, 2012

Back

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 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

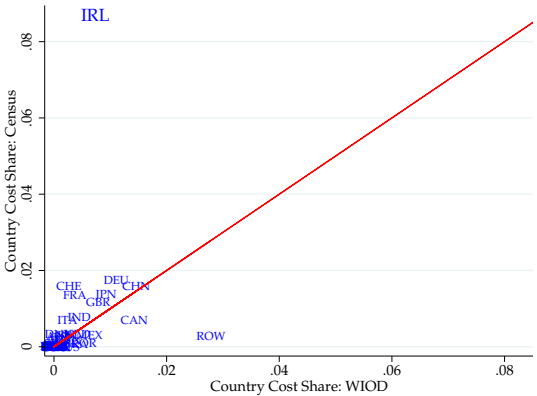
Back

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**

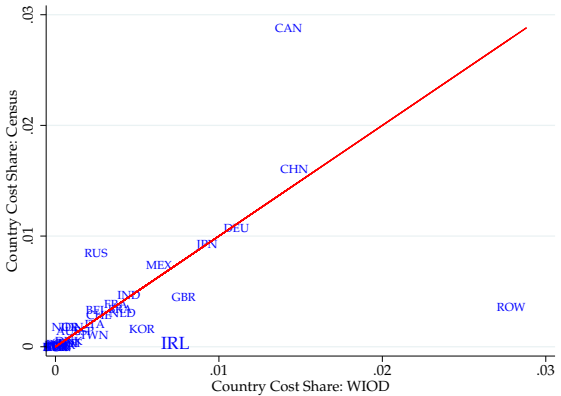
- Correlation of bilateral country pairs is generally lower
- Proportionality works well in coke and petroleum products and food, beverage, and tobacco

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

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%

Back

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%

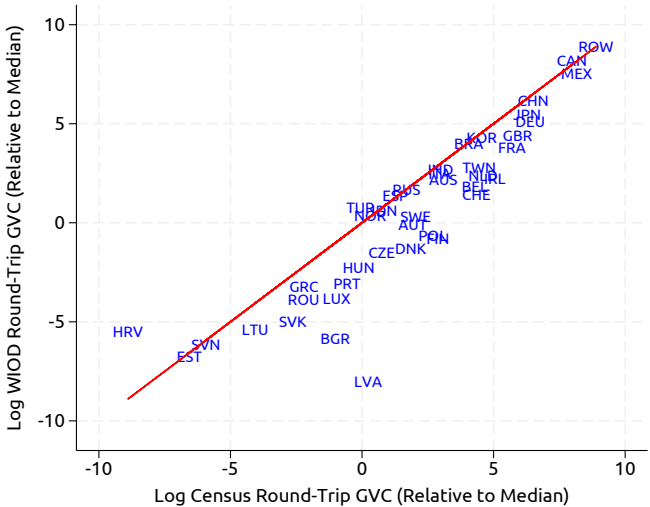
Top GVC Country Pairs, Selected Sectors 2012

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%

WIOD underestimates Round-trip GVC



- Round-trip GVC scaled relative to the median value across all GVC pairs
- WIOD bilateral GVC below the 45-degree line

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

Fixed Cost Specification in Numerical Exercise

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

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

Back

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:

$$S^F_{ifn} = \frac{(P^F_{ifn})^{1-\sigma}}{\sum_{i' \in \Omega^N_n} \sum_{f' \in \Omega^F_{i'n}} (P^F_{i'f'n})^{1-\sigma}}$$

where P^F_{ifn} 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:

$$Q^F_{if} = \varphi_{if} \left(\frac{L^F_{if}}{\alpha} \right)^{\alpha} \left(\frac{Y^F_{if}}{1-\alpha} \right)^{1-\alpha}$$

where Y^F_{if} is CES over intermediate goods with elasticity η.

Intermediate Input Sourcing

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 $m \in \Omega_{if}^{NI}$:

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

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:

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

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