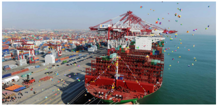

Trade From Space: Shipping Networks and The Global Implications of Local Shocks

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ERWIT, October 2020

Motivation

Large share of global trade takes place through container shipping ($\approx$50%)

- in 2016: 60% of all seaborne trade (Rajkovic et al., 2014), which accounts for 80% of global trade (UNCTAD, 2016)
- containerization has been the dominant innovation in international trade in the past 50 years (Bernhofen et al., 2016)
- nearly all countries have container ports by now, constituting the nodes of the global shipping network

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- essential for our understanding of bilateral shipping cost
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Does the container shipping network matter for global trade?

Contributions

i) document salient features of the global shipping network using satellite data

ii) use shipping routes to analyze global implications of a local shock

- Panama Canal expansion 2016

iii) quantify general equilibrium trade and welfare effects of PC expansion

Preview

i) use satellite data to find

- direct routes
- travel time on direct routes

and graph theory to find

- fastest indirect routes

to describe the global shipping network

Preview, cont'd

ii) application: Panama canal expansion

- **local effects**: how did the expansion affect shipping through the canal?
  - event-study regression with satellite data

- **global effects**: impact on global bilateral trade?

$\Rightarrow$ DiD with quarterly (standard) trade data
  - 1st difference: pre/post expansion in Jun 2016
  - 2nd difference: fastest route passes PC (0/1)

- counterfactual analysis in canonical EK model: **GE effects** on trade and welfare

Preview of results

The shipping network matters:

- **Data**: Shipping network is very sparse, most routes involve two or three stops in other countries
- **DID**: PC expansion $\longrightarrow$ trade $\uparrow$ 9% for country pairs that ship through the canal
- **Counterfactual**: The canal expansion increased world trade by 1.3% and world real income by 20 bill USD (0.02%)
  - Gains are widespread, whereas cost were borne by Panama

Literature

- **Satellite data in economics**
  - Henderson et al. (2012): Night lights
  - Costinot et al. (2016): Soil, topography, crucially, climatic conditions
  - Review of the literature: Donaldson & Storeygard (2016)
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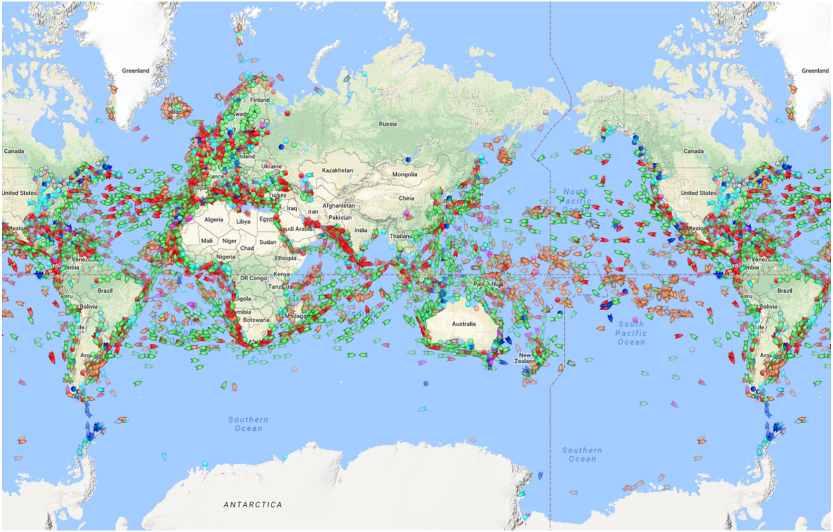
Data: AIS

- AIS: Automatic Identification System
  - technology to track the movements of ships
  - ships have a transceiver that both transmit and receive AIS signals
- Objectives:
  - safe navigation of ships: To see other ships and to be seen
  - allow authorities to monitor vessel movements (monitor fishing fleet, security, search & rescue, etc.)
- Near universal coverage of container ships:
  - the International Maritime Organization requires AIS to be fitted aboard international voyaging ships with 300 or more gross tonnage

Data: AIS


Greenland
Canada
United States
Mexico
Brazil
Bolivia
Russia
Finland
Ukraine
Kazakhstan
Mongolia
China
Turkey
Iraq
Iran
Afghanistan
Pakistan
India
Thailand
Algeria
Libya
Egypt
Mali
Niger
Chad
Sudan
Nigeria
Ethiopia
DR Congo
Kenya
Botswana
Australia
New Zealand
North Pacific Ocean
South Pacific Ocean
Southern Ocean
ANTARCTICA

Data

- AIS data from Marine Traffic on Port Calls
  - all port calls globally by container ships in 2016
  - ship ID, time stamp, arrival/departure port, current draught

- Clarkson World Fleet Register
  - ship ID, Scantling draught (draught when fully loaded), deadweight tons (dwt, weight carrying capacity)
  - info on draught + dwt $\longrightarrow$ Calculate ship cargo (tons)

- Reduced form: Quarterly Comtrade 2015-2017 trade data

- Counterfactual: Eora MRIO global supply chain database (domestic absorption ++)

Descriptives

Table 1: Ships and Ports

Variable:	Obs	Median	Mean	Sd	Min	Max
Ships:						
# ports passed	4,908	64	68	40	1	312
# distinct ports passed	4,908	11	12	7	1	46
Ports:						
# incoming ships	515	203	647	1,451	5	14,473
# outgoing ships	515	199	647	1,447	5	14,407
Port pairs:						
# ships	4160	38	80	168	5	2775
deadweight tonnes (in mio)	4160	1	4	9	.1	210

Note: Summary statistics are based on the port calls made by container ships in 2016. Only ships with deadweight tonnes>15,800 and trips with non-zero duration are used. Summary statistics include only routes taken by at least 5 ships and only routes between ports that appear both as arrival and departure ports.

Fact 1: Container ships typically operate on fixed routes

Table 2: Ships and Ports

Variable:	Obs	Median	Mean	Sd	Min	Max
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Fact 2: Shipping is highly concentrated in space

Table 3: Ships and Ports

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Fact 3: Few direct connections ⇒ Network is sparse

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Fact 3: Few direct connections ⇒ Network is sparse

The 515 ports are allocated across 151 countries

- 6 % of all country pairs have direct port-to-port connections

⇒ a large share of trade travels on indirect routes

Indirect routes

With AIS data we identify *fastest* indirect route between any two ports using

- observed travel time on all direct connections
    - median time between departure and arrival across all container ships observed on a direct route
- shortest-path algorithm to find fastest multistop connection between any two ports

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Fastest route $\neq$ cheapest?

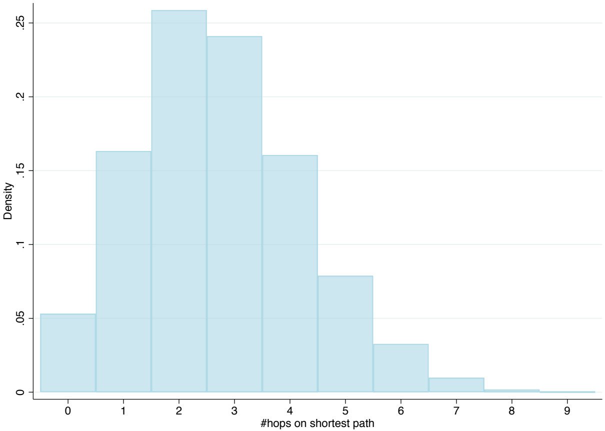
- important cost factors (fuel, labor, capital) highly correlated with time
- our routes are (a good) approximation to actual routes

Descriptives: Indirect routes

more

Note: Figure plots fastest route from Auckland and from Hong Kong to Kiel. All computations are based on observed travel times between all regular (non-anchorage) ports in the AiS. Routes with less than 5 ships are dropped. Indirect travel time computed as shortest path in port network where edges, reflecting direct connections, are weighted by direct travel times.

Descriptives: Density of number of hops



Note: Figure shows the distribution of the number of hops along the fastest route between all country pairs in the sample. Average (median) is 2.7 (3). Computations are based on port-to-port shipments from the AIS data and a shortest-path algorithm using travel-time-weighted edges. For countries with multiple ports #hop on shortest path refers to the connection with smallest #hops.

$\Rightarrow$ Most country pairs have a route that involves two or three other countries

Summary: The shipping network

1. Container ships operate on fixed routes & serve a stable set of ports
2. Shipping activity is highly concentrated in space
3. Few direct connections $\Rightarrow$ network is sparse

Application: Local shock and global implications

Panama Canal Expansion:

- a new, bigger and wider, lane of traffic was added $\rightarrow$ more and **bigger** ships
- expanded canal opened on 26 June 2016 (capacity $\uparrow$ 100%) ▸ event study

Application: Local shock and global implications

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event study

Image Credit: US Energy Information Administration

Application: Local shock and global implications

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Image Credit: US Energy Information Administration

Local shock to shipping infrastructure ⟶ effects on global trade ?

Effects on global bilateral trade

DiD: $$\ln Exp_{ijt} = \beta Post_t * PanExposure_{ij0} + \delta \cdot Z_{ijt} + \delta_{ij} + \delta_{it} + \delta_{jt} + \varepsilon_{ijt}$$

- Exp_{ijt}: value of exports from country i to j in quarter $t \in$ 2015Q3-2017Q2 (Comtrade).
- $Post_t = 1$ if date $>$ Jun 2016
- $PanExposure_{ij0} \in [0, 1]$ ▸ Facts
- Controls Z_{ijt}
  - FTA_{ijt}
  - $\ln Dist_{ij}$, $Contig_{ij}$, $ComLang_{ij}$ interacted with $Post_t$.

Results

Robustness Placebo Event study

The impact of the Panama Canal expansion on trade

Dep. Var.: ln $EXP_{ij,t}$		
$Post_t \times PanExposure_{ij0}$	0.089^{**}	0.090^{**}
	(0.042)	(0.043)
Controls	No	Yes
Fixed effects: *ij*, *it*, *jt*	Yes	Yes
Observations	68,112	68,112
Exporters/Importers	209/90	209/90
R^2	0.964	0.964

Note: The time period is 2015Q3 to 2017Q2. $Post_t = 1$ if $t > 2016Q2$. The control variables are: an *FTA* indicator and geographical variables (distance, contiguity and common language) interacted with $Post_t$. S.e. in parentheses clustered by exporter and importer. The three first columns include all country-pairs, while the three last columns only include country-pairs with positive trade in all quarters. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

GE effects

Eaton-Kortum Model ▸ details

- perfect competition, CRS, multiple countries/sectors

+ constant share α spent on manufacturing; constant trade deficit/GDP

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- we match manufacturing trade and output of 189 countries in 2015 (MRIO)

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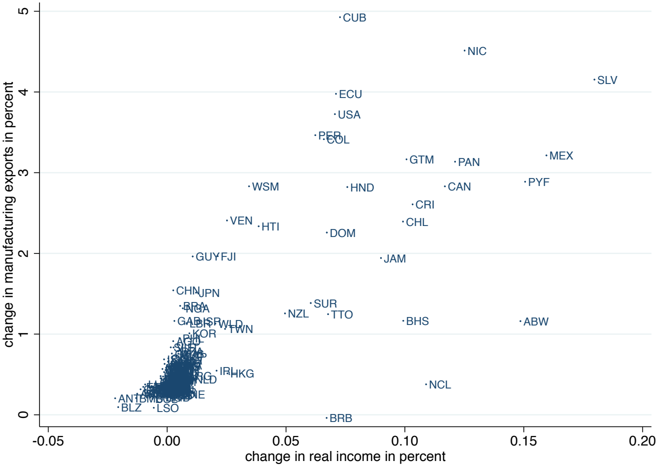
Calibration

- we match manufacturing trade and output of 189 countries in 2015 (MRIO)
- for $\theta = 5$, $\beta = .09 \Rightarrow \widehat{d}_{ij} = -2\%$ for (i, j) with $PanExposure_{ij0} = 1$

GE results: Change in exports and domestic trade share



Global trade ↑ 1.3%, global real income ↑ .02% (20 bill. USD)

Conclusions

Novel data $\longrightarrow$ new insights about the shipping network

- few direct connections, large concentration
- **routes** are key for understanding shipping costs and exposure to shocks

Application:

- heterogeneous effects of PC expansion on global bilateral trade

Model-based quantification combined with sat data:

- expansion increased world trade by 1.3% and world real income by USD 20 billion
- Gains per capita concentrated among North and Central American countries which use the canal intensively

Computing container ship cargo

back

- From draught and dwt to cargo (tonnes/boxes): We need
  - 3 ship characteristics: maximum (scantling) draught H_s, minimum (ballast) draught H_B, deadweight tonnes DWT
  - current draught H_A
- To calculate effective tonnes of cargo (B) on a given trip
  - if actual draught $H_A < H_B \Longrightarrow$ assume ship in ballast and zero boxes ($B = 0$)
  - if actual draught $H_A \geq H_B$ assume laden ship and calculate tonnes of cargo as:

$$B = DWT * \left(\frac{H_A - H_B}{H_S - H_B} \right)$$

Top 10 port-to-port connections

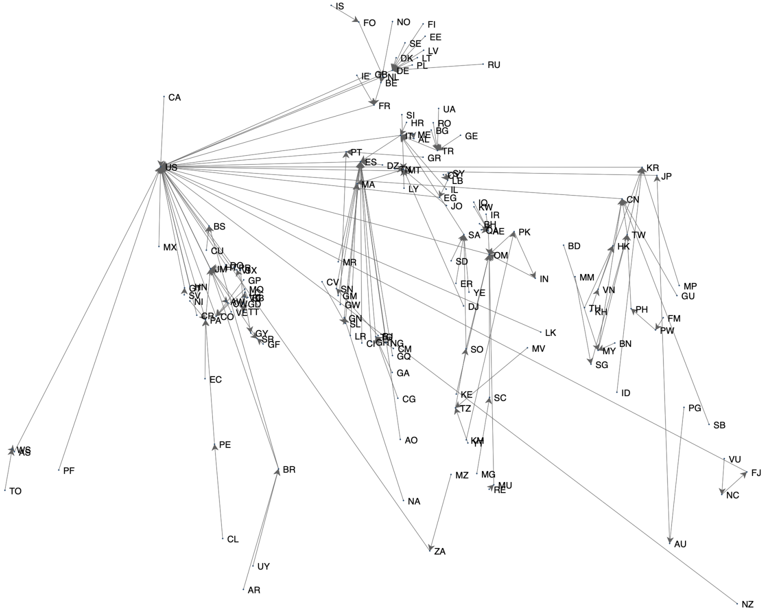
Table 5: Top 10 port-to-port connections

Departure Port/Country		Arrival Port/Country		# ships	DWT (in mio)
Port Klang	MY	Singapore	SG	2775	127
Singapore	SG	Port Klang	MY	2712	116
Shanghai	CN	Ningbo	CN	2600	210
Hong Kong	HK	Shekou	CN	2556	107
Busan New Port	KR	Shanghai	CN	2427	162
Yokohama	JP	Nagoya	JP	2020	57
Shekou	CN	Hong Kong	HK	1916	115
Ningbo	CN	Shanghai	CN	1788	122
Shanghai	CN	Busan New Port	KR	1762	109
Bangkok	TH	Laem Chabang	TH	1558	32

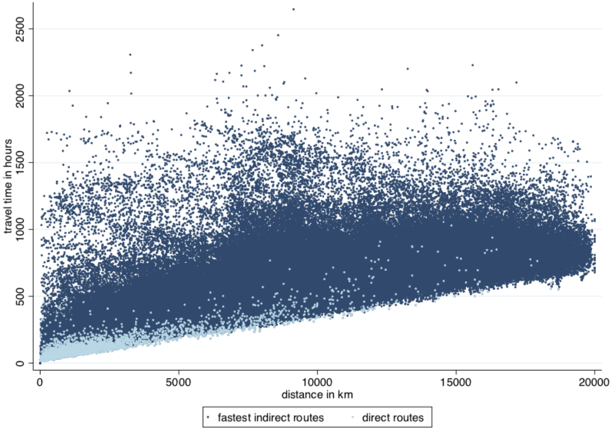
Note: Summary statistics are based on the port calls made by container ships in 2016. Only ships with deadweight tonnes>15800 and trips with non-zero duration are used. Summary statistics include only routes taken by at least 5 ships and only routes between ports that appear both as arrival and departure ports.

Descriptives: U.S. import routes

back



Results: Shortest travel time versus distance



Note: Figure plots travel times between two ports against their geodetic distance. All computations are based on observed travel times between all regular (non-anchorage) ports in the AiS. Routes with less than 5 ships are dropped. Indirect travel time computed as shortest path in port network where edges, reflecting direct connections, are weighted by direct travel times.

- Distance $\propto$ to travel time for direct routes.. not so for indirect ones

PC Exposure

back

Define $PanExposure_{ij0} \in [0,1]$

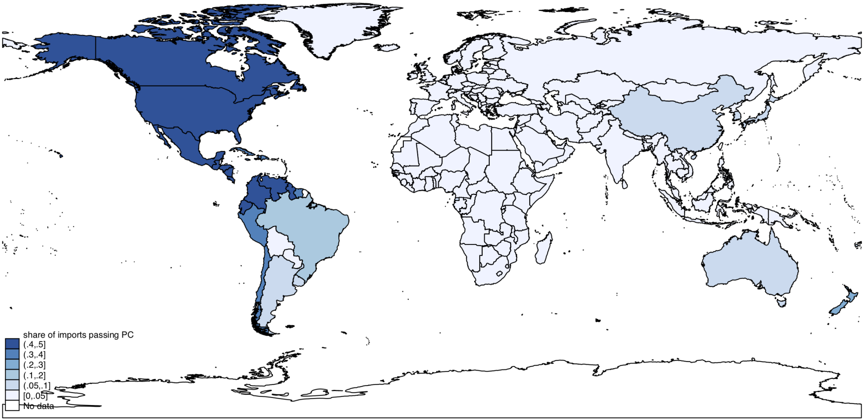
- port-to-port level: $PanExposure_{ij0} = 1$ if fastest route between two ports passes PC in pre-period
- aggregation to country-pair level: port-size-weighted average if multiple port-to-port connections

Country pairs with exposure		Global trade exposed		Importers with exposure	
(1) # pairs	(2) % of total	(3) value in trn $	(4) % of total	(5) # importers	(6) % of total
3,085	12 %	1.8	12 %	141	65 %

Data sources: AIS, BACI

PC Exposure, cont'd

back



Note: The figure shows the share of imports passing through the Panama Canal in total imports by country

Robustness

back

Sample:	Unbalanced			Balanced		
	(1)	(2)	(3)	(4)	(5)	(6)
$Post_t \times PanExposure_{ik}$	0.089**	0.090**		0.084**	0.090**	
	(0.042)	(0.043)		(0.037)	(0.038)	
$\times 1[\#hops \leq med]$			0.216**			0.237**
			(0.087)			(0.092)
$\times 1[\#hops > med]$			0.078*			0.074*
			(0.042)			(0.038)
Controls	No	Yes	Yes	No	Yes	Yes
Fixed effects: *ik*, *it*, *kt*	Yes	Yes	Yes	Yes	Yes	Yes
Observations	68,112	68,112	68,112	49,978	49,978	49,978
Exporters/Importers	209/90	209/90	209/90	200/61	200/61	200/61
R^2	0.964	0.964	0.964	0.968	0.968	0.968

Note: The time period is 2015Q3 to 2017Q2. $Post_t = 1$ if $t > 2016Q2$. The control variables are: an *FTA* indicator and geographical variables (distance, contiguity and common language) interacted with $Post_t$.S.e. in parentheses clustered by exporter and importer. The three first columns include all country-pairs, while the three last columns only include country-pairs with positive trade in all quarters. The triple interaction term in columns (3) and (6) is an indicator variable for whether the number of hops between *i* and *j* is below of above the median number of hops. Significance levels: $^{*}\ p < 0.1$, $^{**}\ p < 0.05$, $^{***}\ p < 0.01$.

Placebo tests

back

Placebo treatments end of June 2015/2017

Time period:	2015Q1-2015Q4	2017Q1-2017Q4
Dep.Var.:	ln *Value*	ln *Value*
post × PanExposure	-0.035	0.010
	(0.045)	(0.044)
Observations	39449	39748
Exporters/Importers	208/90	209/88
R^2	0.971	0.971

Note: Column 1 (2): Placebo treatment is $post = 1$ if $time > 2015Q2$ ($post = 1$ if $time > 2017Q2$). Regressions include *importer* × *time*, *exporter* × *time*, and *pair* fixed effects, an *FTA* indicator, and gravity variables interacted with *post*. S.e. in parenthesis clustered by exporter and importer. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Through what channel did the expansion increase trade?

Event-study regression using AIS data

computing tonnes back

$$x_{ipt} = \sum_t \gamma_t I_t \cdot I_p + I_p + I_i + I_t + \epsilon_{ipt}$$

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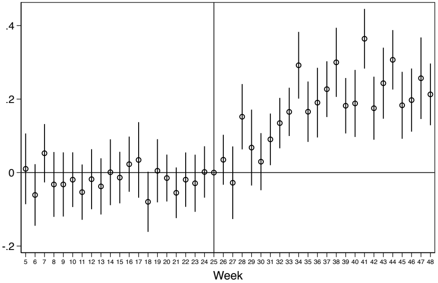
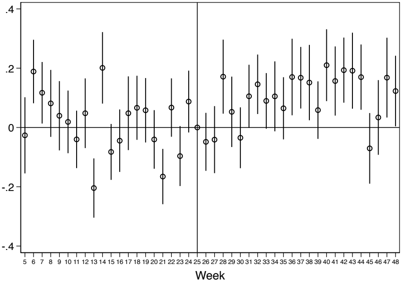


avg. shipments per ship



total shipments

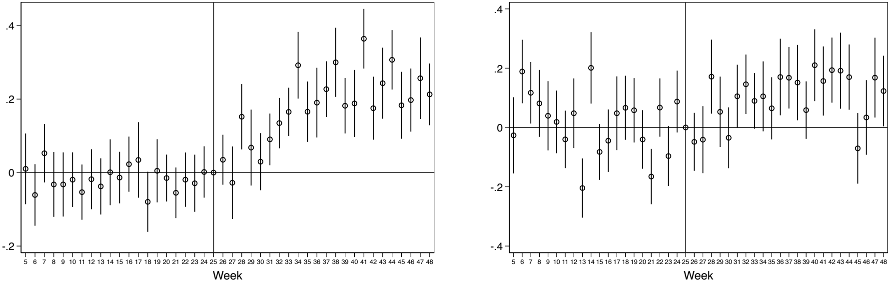
Note: The figure reports the coefficient estimate and standard error of γ_t from the estimating equation above. In the left panel, the dependent variable is log average shipments (in tonnes) per ship. In the right panel, the dependent variable is the log total shipments. Standard errors are clustered by country.

Through what channel did the expansion increase trade?

Event-study regression using AIS data

computing tonnes | back

$$x_{ipt} = \sum_t \gamma_t I_t \cdot I_p + I_p + I_i + I_t + \epsilon_{ipt}$$



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bigger ships $\rightarrow$ lower average cost per container

The Model

- Eaton-Kortum model
- Gravity equation for manufacturing (M)

$$\chi_{ij} = \frac{T_i w_i^{-\theta} d_{ij}^{-\theta}}{\Phi_j},$$

where $\Phi_j = \sum_{i \in N} T_i w_i^{-\theta} d_{ij}^{-\theta}$

- Non-manufacturing (N) non-traded
- Sales of $M =$ worldwide spending on goods from i:

$$Y_i^M = \sum_{j=1}^{N} \chi_{ij} X_j^M,$$

where X_i^M is manufacturing spending in country i

The Model

▸ back

- Trade deficit $D_i^M = X_i^M - Y_i^M$
- Constant share α spent on M: $X_i^M = \alpha X_i = \alpha \left(Y_i + D_i^M\right)$
- GDP equals labor income $Y_i = w_i L_i$
- Goods market clearing condition becomes:

$$w_i L_i \left(1 - \frac{1-\alpha}{\alpha} \frac{D_i^M}{Y_i}\right) = \sum_j \chi_{ij} w_j L_j \left(1 + \frac{D_j^M}{Y_j}\right)$$

Counterfactual

- Consider a change in trade costs d_{ij}
- Assume D_i^M / Y_i constant
- Exact hat algebra yields

$$\hat{\chi}_{ij} = \frac{\hat{w}_i^{-\theta} \hat{d}_{ij}^{-\theta}}{\hat{\Phi}_j}$$

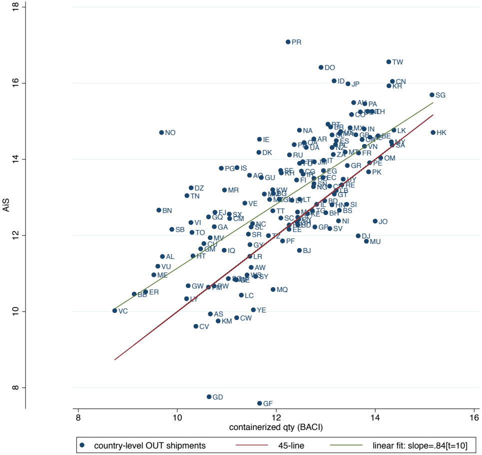
$$\hat{\Phi}_j = \sum_{i \in N} \chi_{ij} \hat{w}_i^{-\theta} \hat{d}_{ij}^{-\theta}$$

$$\hat{w}_i = \sum_j \frac{\chi_{ij} X_j^M}{Y_i^M} \hat{w}_j \hat{\chi}_{ij}$$

- Change in real income

$$\frac{\hat{w}_i}{\hat{P}_i} = \hat{\chi}_{ii}^{-\alpha/\theta}$$

AIS flows vs Comtrade flows distributed over shortest paths



plot of AiS flows (OUT) at the country level against country-level outflows implied by sending all countries bilateral containerized trade along shortest routes