Local Shocks and Global Implications: Using Satellite Data to understand the Panama Canal Expansion

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Motivation

Largest share of global trade is merchandize trade (≈60%)

- most of it takes places through container shipping
- containerization has been the dominant innovation in international trade in the past 50 years (Bernhofen et al, 2015)

But: We know very little about the actual **routes** that a container takes

- essential for understanding bilateral shipping cost
- through indirect routes, bilateral shipping cost depend on local infrastructure in third countries

This paper: Use satellite data (AiS) to find shipping routes

- application: effect of the Panama Canal expansion on global trade

Our approach

i) simple model of trade with shipping routes

ii) use satellite data to find
   - direct routes
   - travel time on direct routes

iii) use shortest-path algorithm to find
   - fastest indirect routes
   - number of stops

iv) combine ii) and iii) to
   - describe the global shipping network
   - for every port/country pair: find the ports/countries where its trade is passing through

v) application: Panama canal expansion

Our approach, continued

v) application: Panama canal expansion

- local effects: how did the expansion affect shipping through the canal?
  - event-study regression for local effects
- global effects: effect on global bilateral trade?

  $\Rightarrow$ DiD with quarterly Comtrade data
  - 1st difference: pre/post expansion in Jun 2016
  - 2nd difference: shortest route passes PC (0/1)
- counterfactual analysis: simulate GE effects

Preview of results

Local effects: PC expansion

- led to 5-8% increase in shipments (tonnes) compared to RoW

DiD effects:

- bilateral trade increased by 8-10% for pairs that ship through the canal

Related Literature

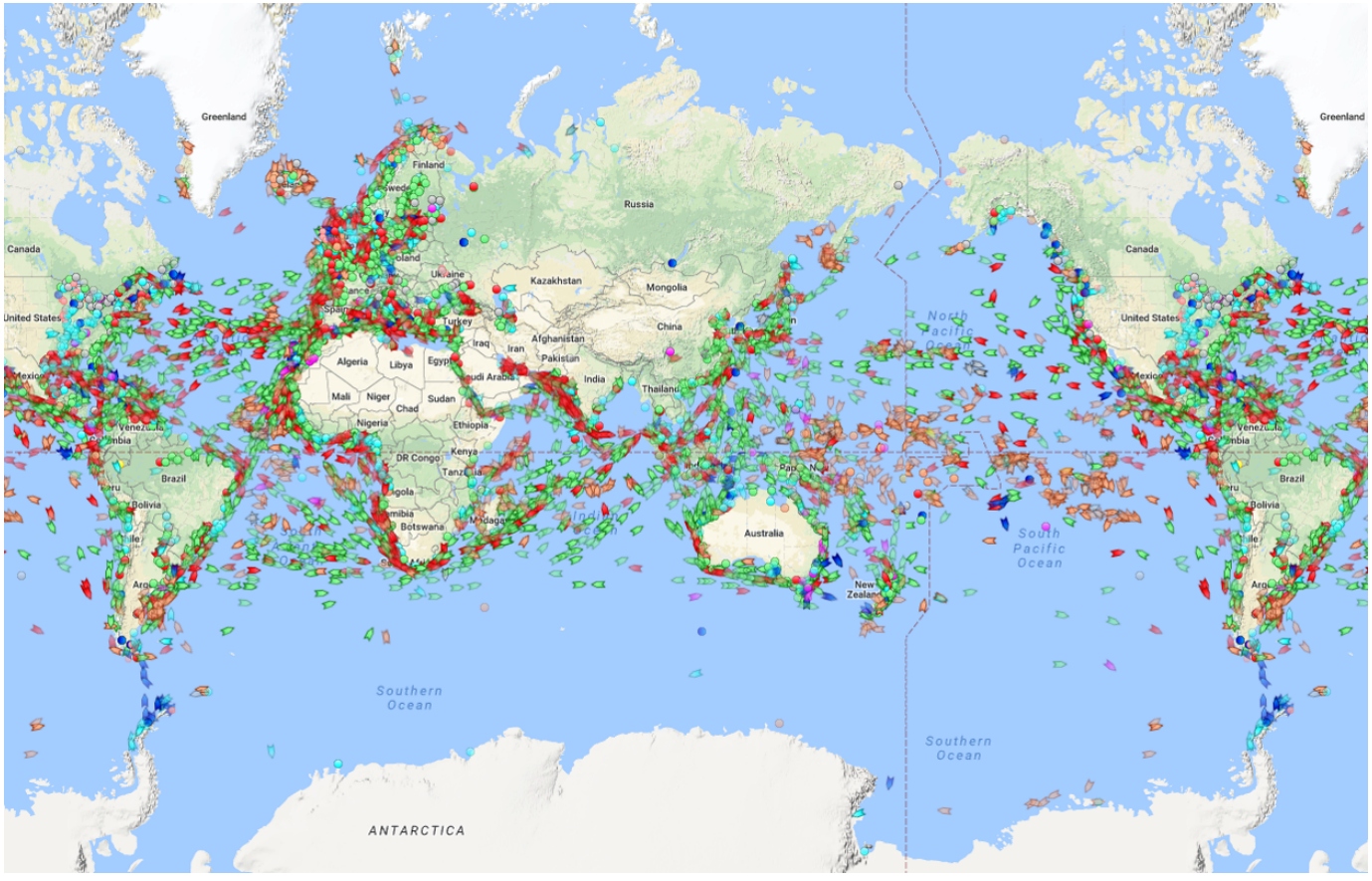
- Satellite data in economics
  - Henderson et al (2012): night lights
  - Costinot, Donaldson and Smith (2016): soil, topography, crucially, climatic conditions
  - Review of the literature: Donaldson and Storeygard (2016)
  - Brancaccio et al (2017): focus on ballast as a driver of trade costs, use satellite to reveal when ships sail without cargo (in ballast)shipping patterns in bulk shipping and endogenous trade costs, build and calibrate a spatial model of transport and trade and analyse the endogeneity of trade costs
- Trade, transport, trade costs and containers (amongst others)
  - Bernhofen et al (2015): the effect of the container revolution on trade
  - Brooks et al (2017): local impact of containerization
  - Behrens & Picard (2011), Wong (2018): freight rate for containers, round trip and endogenous trade costs
- Panama Canal:
  - Maurer & Rauch (2019): effects on economic geography of the U.S.

Data: What is AiS?

- AiS: automatic identification system; is an automatic tracking system used on ships and by vessel traffic services (VTS).
- AiS is intended to assist a vessel's watchstanding officers and allow maritime authorities to track and monitor vessel movements. AIS information supplements marine radar.
- The International Maritime Organization's International Convention for the Safety of Life at Sea requires AiS to be fitted aboard international voyaging ships with 300 or more gross tonnage (GT), and all passenger ships regardless of size.

Ships from Space

Figure: Tracking Ships from Space



Data description

- AiS (Automatic Identification System) Data from Marine Traffic on Port Calls
  - All port calls globally by container ships in 2016
  - Call information: Ship ID, Time stamp, arrival/departure, current draught
- Clarkson World Fleet Register
  - Ship information: Ship ID, Scantling draught and additional information on technical features, owner and management
- monthly/quarterly Comtrade 2015-2017

Ships & Ports

Table: Ships and Ports

Variable:	Obs	Mean	Sd	Min	Max
Ships:					
# ports passed	4,908	68	40	1	312
# distinct ports passed	4,908	12	7	1	46
Ports:					
# incoming ships	515	647	1,451	5	14,473
# outgoing ships	515	647	1,447	5	14,407

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.

Port network: Direct connections

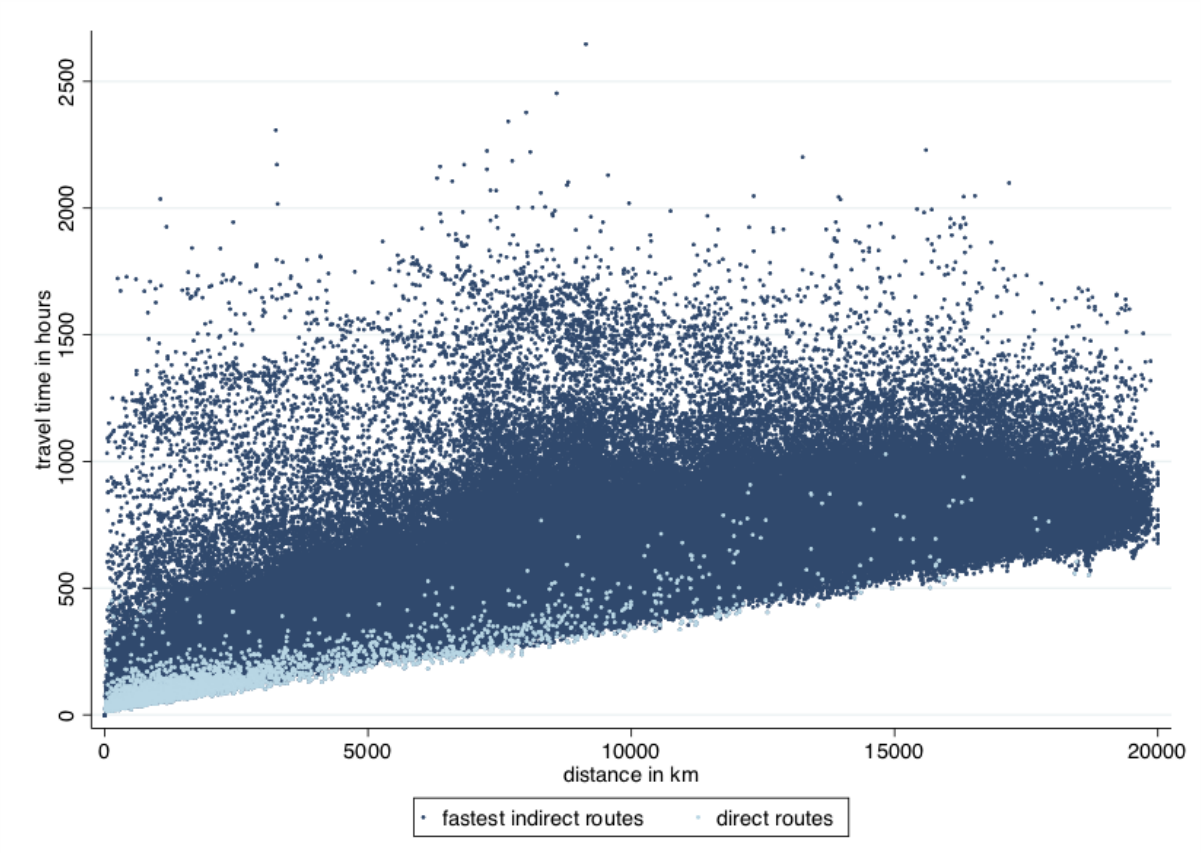
Table: Port Networks

Variable:	Obs	Mean	Sd	Min	Max
All ports:					
Indegree	515	8.08	10.26	1	84
Outdegree	515	8.08	9.84	1	82
Top 10 ports:					
Indegree	10	54.10	12.03	42	84
Outdegree	10	50.10	13.88	37	82

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.

Travel time on direct and indirect routes

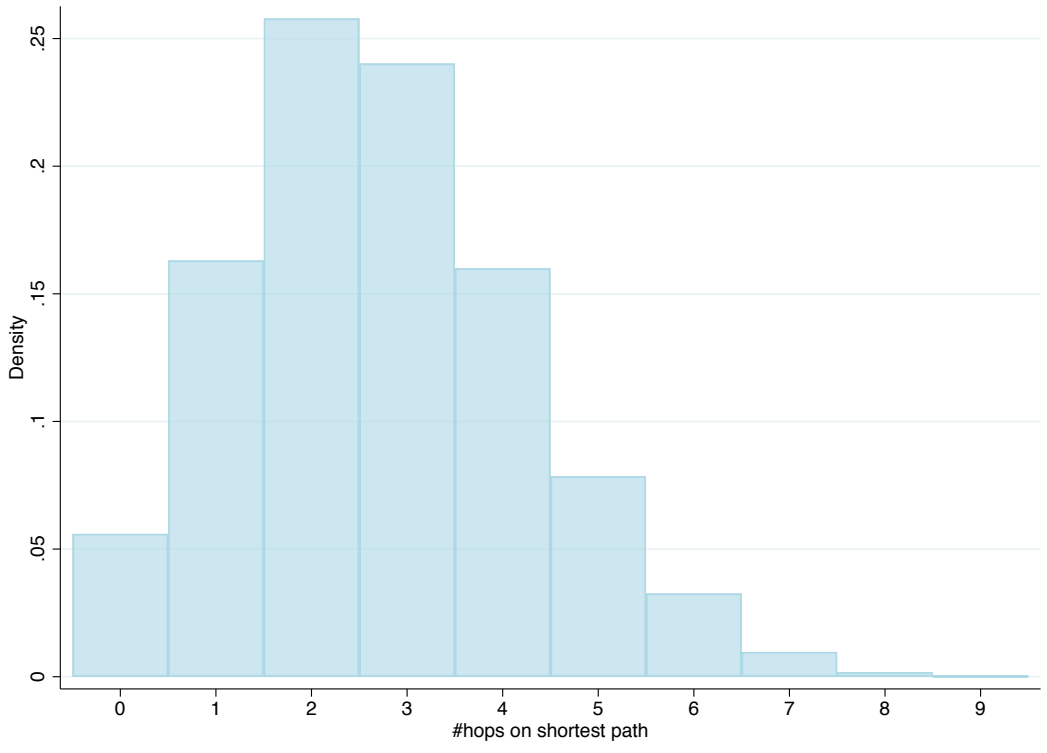
Figure: Travel time



Note: Figure plots travel times between two ports against their geodetic distance. All computions 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.

Shipping network: Direct and indirect connections

Figure: Distribution of number of hops per route



Note: Figure shows the distribution of the number of hops along the fasted route between all country pairs in the sample. 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.

Application: Local Shocks and Global Implications

Panama Canal Expansion

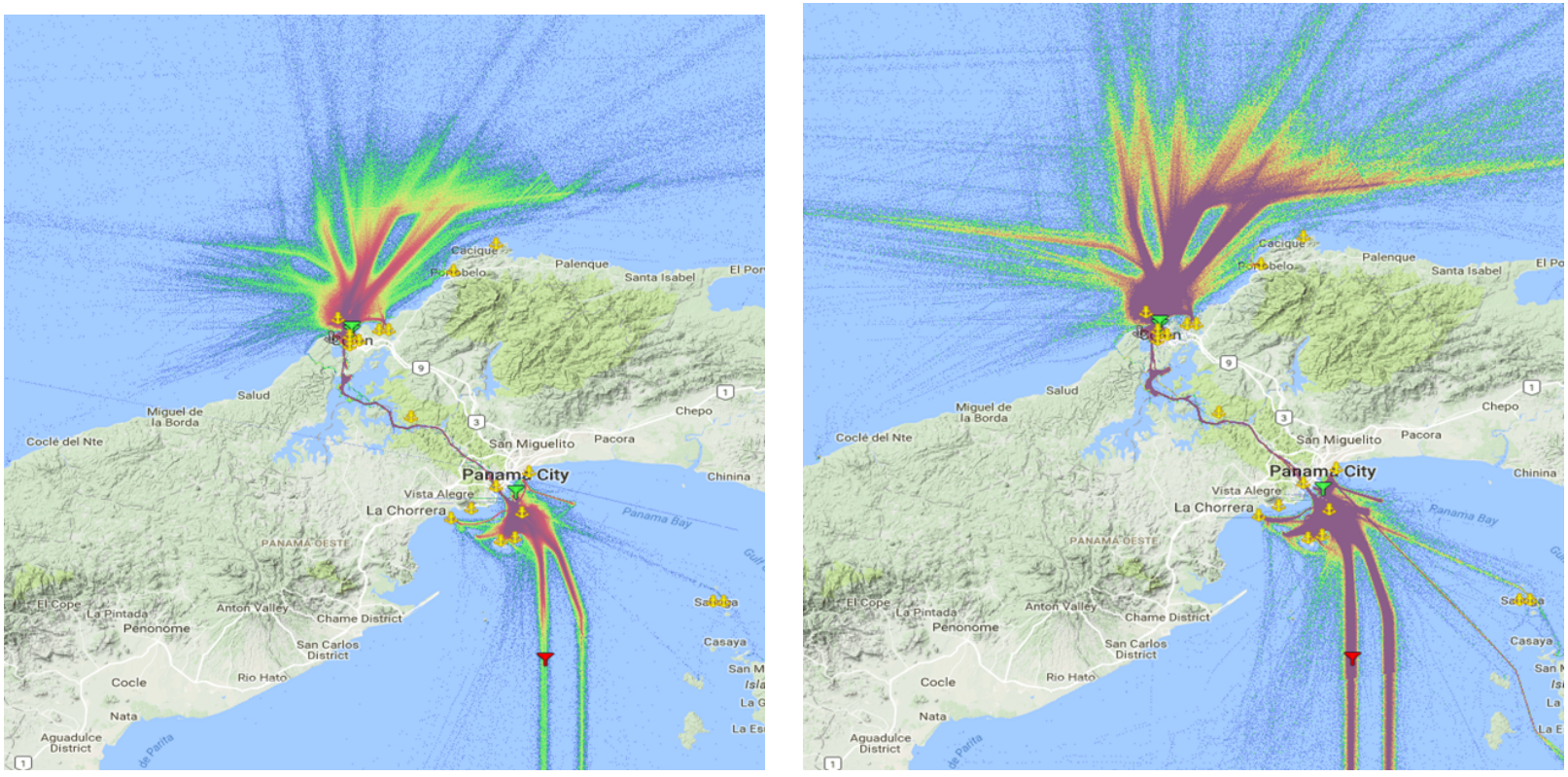
- project was formally proposed on 24 April 2006, and the construction began in 2007. The expanded canal began commercial operation on 26 June 2016.
- It doubled the capacity of the Panama Canal by adding a new lane of traffic allowing for a larger number of ships, and increasing the width and depth of the lanes and locks allowing larger ships to pass (Wikipedia).

How did it affect shipping activity on the canal?
How did it affect global bilateral trade?

Panama Canal Expansion

(commercial operation began on 26 June 2016)

Figure: Density Maps, All Traffic

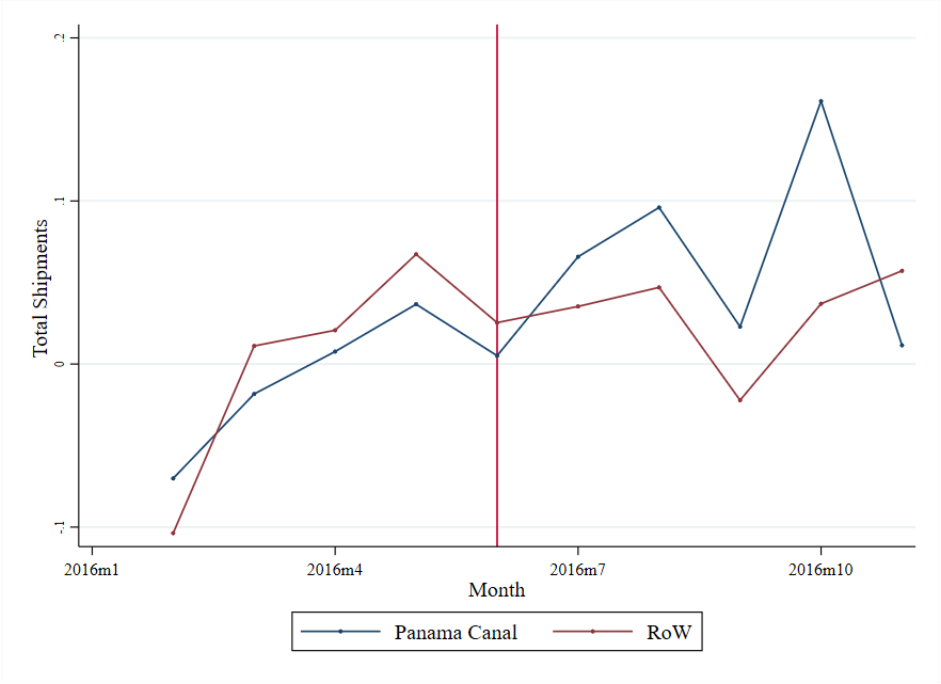


(a) Year 2015 (b) Year 2016

Source: from https://www.marinetraffic.com/en/ais/home/centerx:-123.9/centery:0.0/zoom:2.

Direct Evidence: Shipping Activity on the Canal

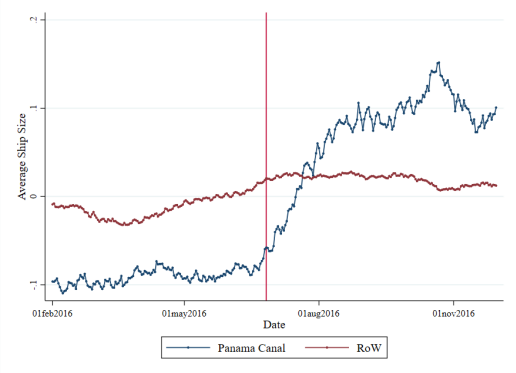
Figure: Container Traffic



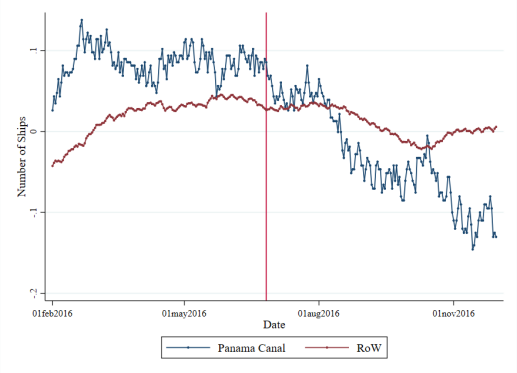
Note: This figure reports the demeaned log tons of goods that passed through the Panama Canal compared to container ship traffic in the rest of the world. The left panel shows the 31-day simple moving average, and the right panel reports the monthly aggregates. January and December are dropped from the analysis.

Direct Evidence: Shipping Activity on the Canal

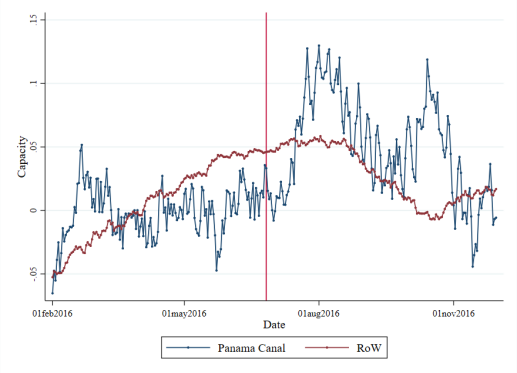
Figure: Capacity, Ships Size, and the Number of Ships



(a) Average Ship Size



(b) Number of Ships



(c) Shipping Capacity

Note: From panel (a) to (c), this figure reports, respectively, average ship size, the total number of ships that depart from Panama (and passed through Panama Canal) and that of the rest of the world and total shipping capacity. The size of a ship is defined as its deadweight tons. All variables are demeaned and smoothed using the 31-day simple moving average. January and December are dropped from the analysis.

Direct Evidence: Shipping Activity through the Canal

Table: Results on Container Traffic

Dependent Variables	Shipments (1)	Ship Size (2)	No. of Ships (3)	Capacity (4)
	(b) Weekly Data			
Pass PA $\times \geq$ Expansion	0.08***	0.13***	-0.11***	0.02*
	(0.02)	(0.01)	(0.01)	(0.01)
Country fixed effects	Yes	Yes	Yes	Yes
Week fixed effects	Yes	Yes	Yes	Yes
Observations	6,838	7,001	7,001	7,001
R-squared	0.95	0.94	0.96	0.97

Note: The dependent variables are log tons of shipments, ship size, the number of ships and shipping capacity leaving from country i at the time t. Each observation is country-time-passPA specific. Robust standard errors in parentheses are clustered at the country level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Effect of the PC Expansion on Bilateral Trade

How did the PC expansion affect bilateral trade between countries ?

DiD estimation:

$$\ln Exp_{ikt} = Post_t * PanExposure_{ik0} + \delta \cdot Z_{ikt} + \delta_{ik} \cdot q + \delta_{it} + \delta_{kt} + \varepsilon_{ikt}$$

- dependent variable $\ln Exp_{ikt}$
  - (tonnes/values exported from country i to k, Comtrade, 2015Q3-2017Q2)
- $PanExposure_{ik}^{SP} = 1$ *if shortest routes between two ports passes PC*
- $Post_t = 1$ if date >Jun 2016
- controls Z_{ikt}
  - FTA_{ikt}; $Post_t * \ln Dist_{ik}$; $Post_t * Contig_{ik}$; $Post_t * ComLang_{ik}$

Regression Results: Comtrade Data, Quarterly

Table: Panama canal exposure and trade flows pre and post opening

Time period:	2016Q1-2016Q4	2015Q3-2017Q2	
Dep.Var.:	ln *Value*	ln *Value*	ln *Value*
post × PanExposure	0.105**	0.078*	0.078*
	(0.047)	(0.044)	(0.041)
Observations	23666	41920	28668
Exporters/Importers	139/65	139/65	137/42
R^2	0.972	0.953	0.983

Note: *post* = 1 if *time* > 2016*Q*2. 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: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Regression Results: Comtrade Data, Quarterly

Table: Placebo treatments end of June 2015/2017

Time period:	2015Q1-2015Q4	2017Q1-2017Q4
Dep.Var.:	ln *Value*	ln *Value*
post × PanExposure	-0.025	0.012
	(0.052)	(0.045)
Observations	24193	24407
Exporters/Importers	67/139	64/139
R^2	0.972	0.953

Note: Column 1 (2): Placebo treatmest is *post* = 1 if *time* > 2015*Q*2 (*post* = 1 if *time* > 2017*Q*2). 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: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Summary, conclusions, outlook

Summary: we use satellite data to find container shipping routes

- describe the container shipping network
- find countries/ports where bilateral trade travels through

Conclusions:

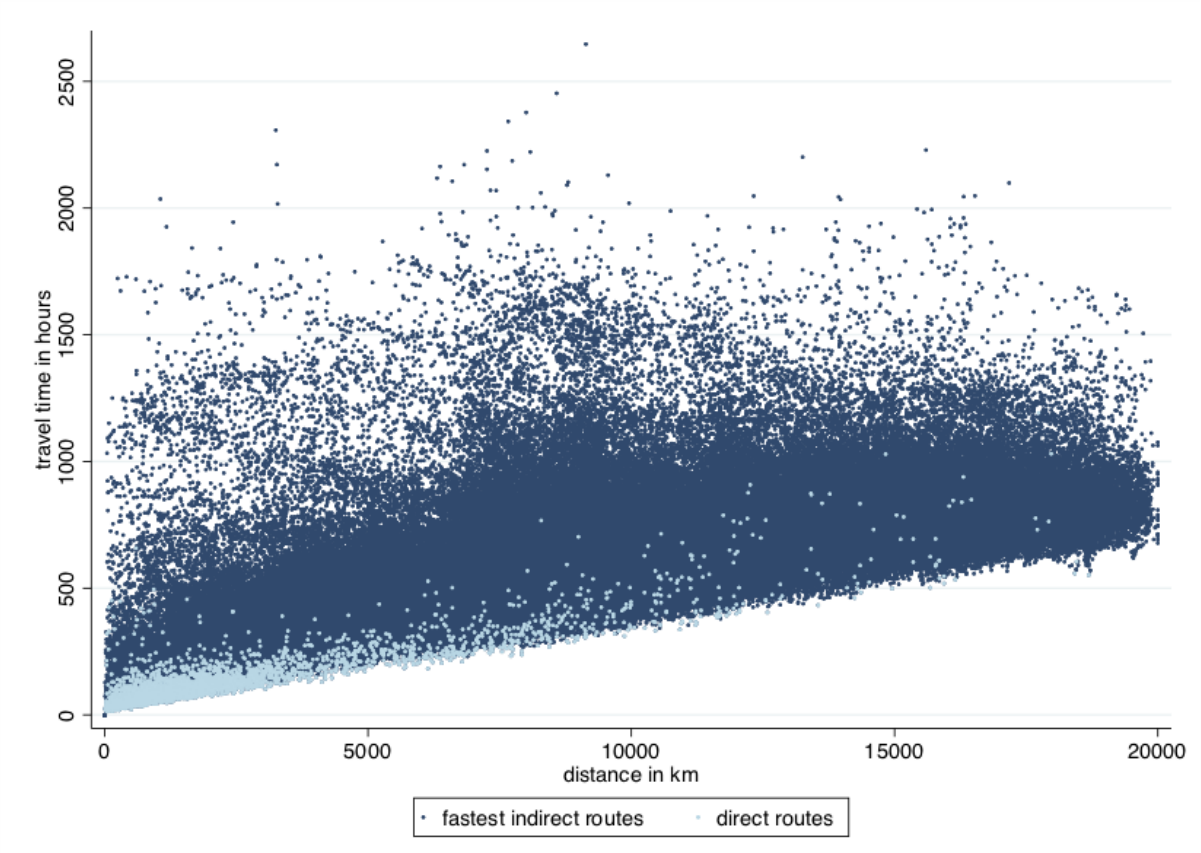
- very few direct connections: indirect routes and exposure to infrastructure of third countries matter
- exemplary application:
  - heterogeneous effects of PC expansion on global bilateral trade

Outlook

- quantify total effect of PC expansion in GE model

Travel time on direct and indirect routes

Figure: Travel time



Note: Figure plots travel times between two ports against their geodetic distance. All computions 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.

Computing Container Ship Cargo

- 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:

$$B = DWT * \left(\frac{H_A - H_B}{H_S - H_B} \right) \tag{1}$$

Direct Evidence: Shipping Activity through the Canal

Table: Results on Container Traffic

Dependent Variables	Shipments (1)	Ship Size (2)	No. of Ships (3)	Capacity (4)
		(a) Daily Data		
Pass PA $\times \geq$ Expansion	0.05***	0.12***	-0.12***	0.00
	(0.01)	(0.01)	(0.01)	(0.01)
Country fixed effects	Yes	Yes	Yes	Yes
Day fixed effects	Yes	Yes	Yes	Yes
Observations	31,885	33,703	33,703	33,703
R-squared	0.81	0.73	0.88	0.87
		(b) Weekly Data		
Pass PA $\times \geq$ Expansion	0.08***	0.13***	-0.11***	0.02*
	(0.02)	(0.01)	(0.01)	(0.01)
Country fixed effects	Yes	Yes	Yes	Yes
Week fixed effects	Yes	Yes	Yes	Yes
Observations	6,838	7,001	7,001	7,001
R-squared	0.95	0.94	0.96	0.97
		(c) Monthly Data		
Pass PA $\times \geq$ Expansion	0.05***	0.11***	-0.11***	-0.01
	(0.02)	(0.01)	(0.01)	(0.02)
Country fixed effects	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes
Observations	1,662	1,683	1,683	1,683
R-squared	0.98	0.98	0.99	0.99

Note: The dependent variables are log tons of shipments, ship size, the number of ships and shipping capacity leaving from country i at the time t. Each observation is country-time-passPA specific. Robust standard errors in parentheses are clustered at the country level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Dynamic Impacts: Shipments

(Weekly Data)