Transportation Bottlenecks and Aggregate Shocks

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Trade Disruptions

Recently a series of trade disruptions related to transportation



Trade Disruptions

Much speculation about the role of transportation sector on macro outcomes, such as trade and prices





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How much do transportation disruptions matter in the aggregate? And how does the transportation sector affect the economy's response to (aggregate) shocks?

This Paper

- Construct tractable model to quantify role of transportation sector and impact of shocks
  - Measure the capacity of the transportation sector and identify its chokepoints
  - Transportation as a sequence of queues
  - Bottlenecks occur as queues get backed up
- Use model to evaluate resilience of transportation during the last 25 years
- Focus on maritime transportation
  - 90% of trade carried by ships
  - main culprit in public discourse

Related Literature

- Trade, Transportation, Infrastructure: Koopmans 1949, Donaldson and Hornbeck 2016, Donaldson 2018, Allen and Arkolakis 2014, 2021, Fajgelbaum and Schaal 2020, Brancaccio, Kalouptsidi, and Papageorgiou 2020, 2025

- Supply chain disruptions, inflation: Alessandria et al. 2023, 2024; Amiti, Itshoki and Weinstein 2024; Bai, Fernandez-Villaverde, Yiliang, Zanetti 2024; Begnignio et al. 2022; Bernanke and Blanchard 2024; Carrier-Swallow et al. 2022; Comin et al., 2023a, 2023b, 2024; Michail et al. 2022

- Supply chains: Carvalho, Nirei, Saito and Tahbaz-Salehi 2021; Alessandria, Khan, Khederlarian, Mix and Ruhl 2022; Grossman, Helpman and Lhuillier 2022; Calvo Lopez and Golub 2023

- Shipping, ports: Asturias 2020; Brancaccio, Kalouptsidi, Papageorgiou, and Rosaia 2022; Brooks, Gendron-Carrier, and Rua 2021; Dunn and Leibovici 2024; Ducruet, Juhasz, Nagy, and Steinwender 2021; Fuchs and Wong 2022; Ganapati, Wong, and Ziv 2021; Heiland, Moxnes, Ulltveit-Moe, and Zi 2021; Hummels 2007; Kalouptsidi 2014; Wong 2020

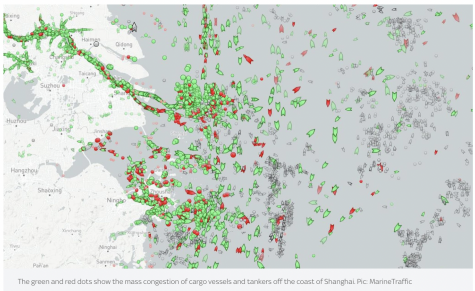
Outline

1. Data and Descriptives
2. A Tractable Model of Transportation
3. Impact of Transportation Bottlenecks

Data and Empirical Patterns

Data

- Focus on raw materials and commodities (bulk carriers) ▸ details
- All port calls, 2013-2023 (timestamp for arrival, loading start/end, commodity; AXS Marine)



The green and red dots show the mass congestion of cargo vessels and tankers off the coast of Shanghai. Pic: MarineTraffic

- Clarksons: total fleet, shipping prices, fuel costs...
- COMTRADE: 6-digit bilateral trade (quantities & prices) for major commodities (coal, grain, ores..)

▸ Importance of Port Congestion

System Capacity and the Ability to Adjust

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- Do these bottlenecks pass through to commodity prices?

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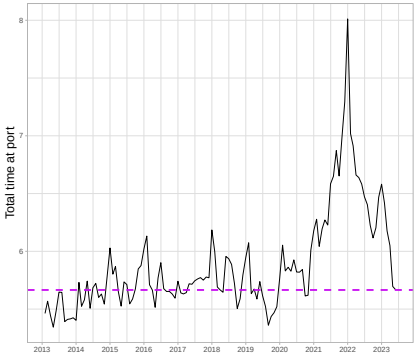

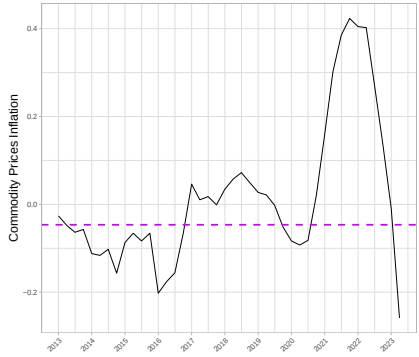

Transportation Disruptions and Commodity Prices

- To get descriptive evidence, would like to run (and much recent research has)

$$\text{commodity prices} = \beta * (\text{time at port}) + \epsilon$$

- But, endogeneity problem, since time at port driven by unobserved demand or supply shocks
- Correct with an instrument capturing unexpected disruptions to port service times Details
- Findings: During COVID, additional 2 days in port in 2022 $\rightarrow$ 3pp (14% of increase)

A Trade Model with Transportation Bottlenecks

Environment: Transport Sector - Ships

2 countries, exporter and importer

- single good to be traded

Transportation Sector: Ships and Ports

Ships:

- S ships in the world
- Expected travel time between countries is d each way
- Cost per trip is $c = c_0 + \underbrace{2c_1 d}_{\text{fuel cost}}$, where $c_{0,} c_1 > 0$

Environment: Transport Sector - Ports

Exporting Ports:

- Ports at exporting country can handle up to K ships at a time
- Expected service time per ship is T

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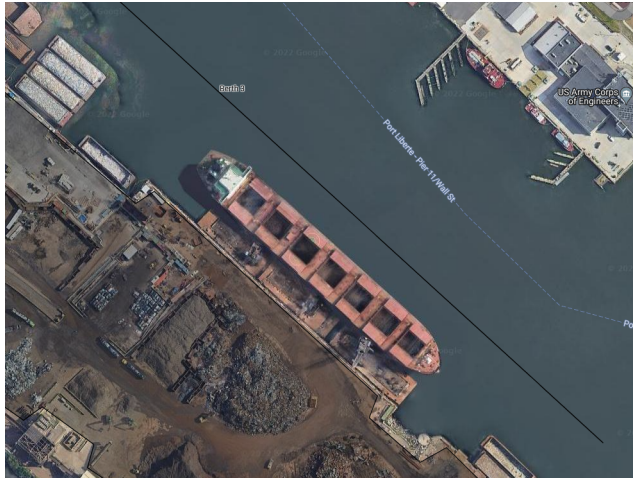
Importing Ports:

- Service time at importing port is zero

Time at Port

Service time



Time at Port

Queueing time (congestion)



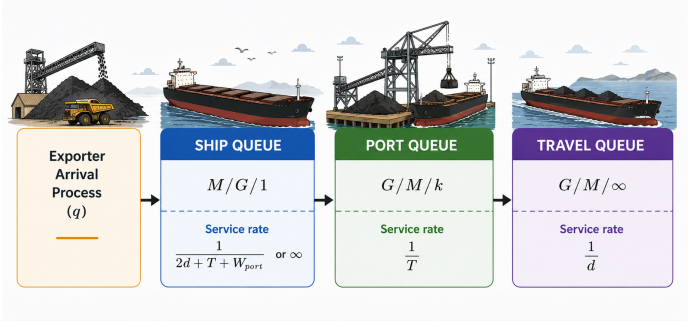
A Sequence of Queues

Cargo needs to go through a sequence of queues:

- Arrive at port at rate q (endogenized later)
- May wait for a ship to arrive (the Ship Queue)
- Once paired with ship, proceed to port (the Port Queue)
    - starts loading immediately if fewer than K ships currently being serviced, or waits for berth to open up
- Travels to the importing port and arrives at rate d (the Travel Queue)

A Sequence of Queues

We use queueing theory



We are after the capacity of this queueing network $=$ min of capacities of *each queue*

Capacity of Queueing Network

- The Travel Queue: never a bottleneck, merely a delay factor

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- The Port Queue: port services up to K ships at rate $1/T$
  - Capacity of this queue $Q_2^{\max}$,

    $$Q_2^{\max} = \frac{K}{T}$$

    and defines the "*port constraint*"

Capacity of Queueing Network

- The Ship Queue
  - "Service rate" is the arrival rate of ships
  - Since ships loop between the two ports, this arrival frequency given by average round-trip duration,

$$2 \times \text{travel time} + \text{time at port}$$

  - Turns out capacity of this queue $Q_1^{\max}$ satisfies

$$Q_1^{max} = \frac{S}{2d + T + W^{port}\left(Q_1^{max}, S, d, K, T\right)}$$

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- **Hence the sequence of queues has max capacity $Q^{\max}$**

$$Q^{\max} = \min\{Q_1^{\max}, Q_2^{\max}\}$$

Environment: Demand & Supply

Demand:

- Consumers' demand given by

$$D(p, Y)$$

where Y demand shifter, and price, $p = \underbrace{p_x}_{\text{exporter price}} + \underbrace{p_T}_{\text{transportation price}}$

Supply:

- Exporters supply is given by

$$q(p_x, A)$$

where A is a supply shifter (can also allow for inventory costs)

How Recent Disruptions Map in this Model

Model captures disruptions of the transportation parameters (T, d, K, S):

- T disruptions:
  - COVID personnel restrictions
  - crane breakdowns, strikes ▸ strike Argentina
- d disruptions:
  - Houthi, Suez blockage, drought at Panama Canal ▸ Houthi
  - extreme weather events (cyclones, hurricanes,..)
- K disruptions:
  - extreme weather events (cyclones, hurricanes,..), other port closures (Baltimore bridge), Strait of Hormuz tensions
- S disruptions:
  - US proposal to impose fees on Chinese-built vessel, Jones Act
- A, Y shocks (often in combination with T, d, K, S):
  - COVID, Ukraine war, 2000s super cycle

Equilibrium

- Two states of the world: unconstrained vs. constrained ▸ formal definition
- Unconstrained case:
  - demand = supply

$$\underbrace{D\left(c + p_x^*, Y\right)}_{\text{demand}} = \underbrace{q\left(p_x^*, A\right)}_{\text{supply}}$$

  - shipping price = c
  - no impact of transportation parameters (other than d)

Equilibrium

- Constrained cases:
  - if port constraint binds

$$\underbrace{D(p^*, Y)}_{\text{demand}} = Q^{\max} = \underbrace{\frac{K}{T}}_{\text{port handling capacity}}$$

port parameters T, K now matter

Equilibrium

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$$\underbrace{D(p^*, Y)}_{\text{demand}} = Q^{\max} = \underbrace{\frac{K}{T}}_{\text{port handling capacity}}$$

    port parameters T, K now matter

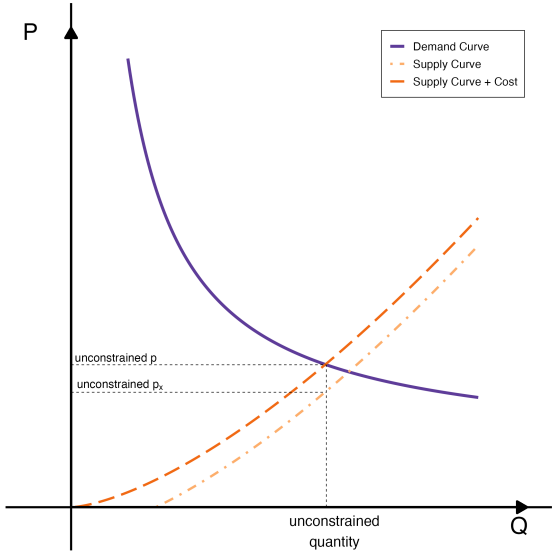
  - if ship constraint binds

$$\underbrace{D(p^*, Y)}_{\text{demand}} = Q^{\max} = \underbrace{\frac{S}{W^{\text{ship}}(Q_2^{\max}, S, d, K, T) + T + d}}_{\text{ship carrying capacity}}$$

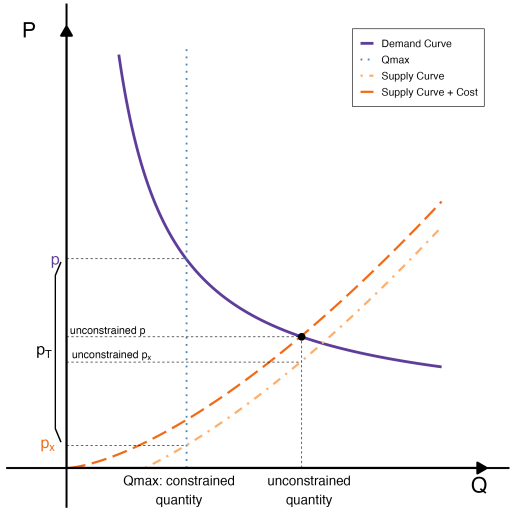
    all transportation parameters T, K, d, S now matter

- In either case, shipping price spike

Case 1: Unconstrained Case

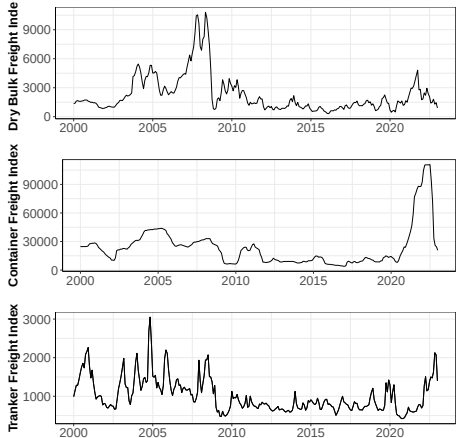


Case 2 & 3: Constrained Cases



Straightforward Implication for Shipping Prices

Shipping prices extremely volatile, experience huge spikes that cannot be explained by fuel cost fluctuations



Impact of Transportation Bottlenecks

Quantification: Functional Forms

Demand:

$$\frac{\sigma - 1}{\sigma} \frac{Y}{p}$$

where:

$$p = p_x + p_T$$

▸ microfoundation

Supply: Exporters arrive at port at rate

$$A p_x^{\beta}$$

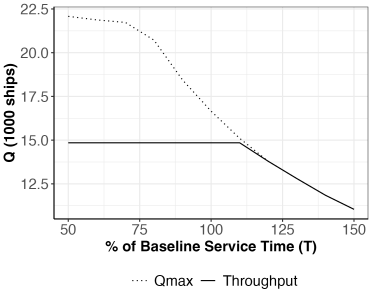
where $A_t, \beta > 0$.

Quantification: Calibration Parameters

Parameter	Target
Total Available Ships S_t	Quarterly, Number of dry bulk ships
Cost of Trip c_t (per Ship)	Quarterly, Fuel cost + fixed operation cost + port dues
Trip Duration Parameter d	Average trip duration (2.9 weeks)
Service Time T_t	Quarterly, Average service time
Port Capacity K_t	Tri-annually, Max number of ships handled simultaneously when congested
Export Supply Slope β	$\beta = 2$, Garcia-Lembergman et al. (2025) and Broda et al. (2008)
Demand Elasticity σ	$\sigma = 4$, Simonovska and Waugh (2014)
Export Supply Intercept A_t	Quarterly, Producer price+quantity
Demand Parameter Y_t	Quarterly, Commodity price+quantity

▸ Y and alpha

Illustration: Service Time Disruptions



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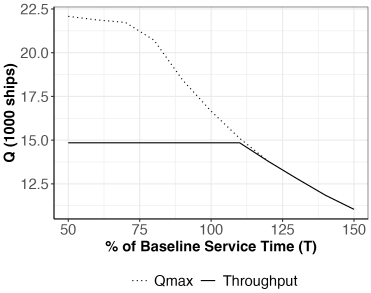

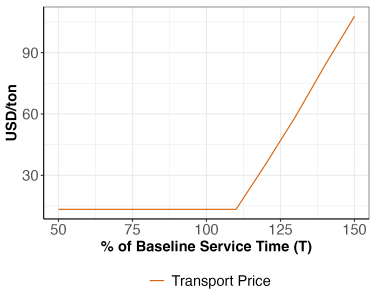

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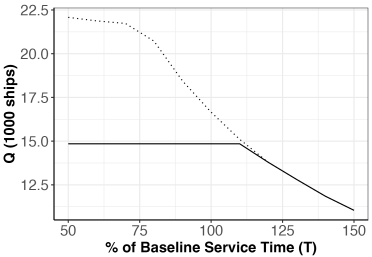
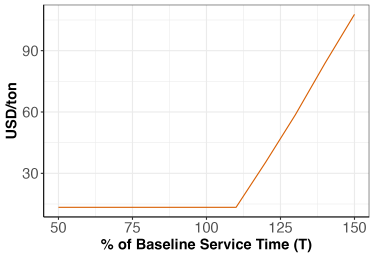
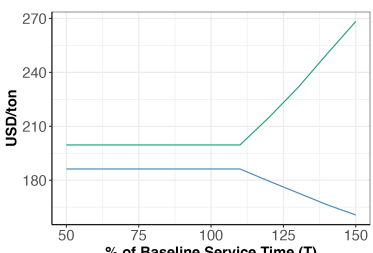
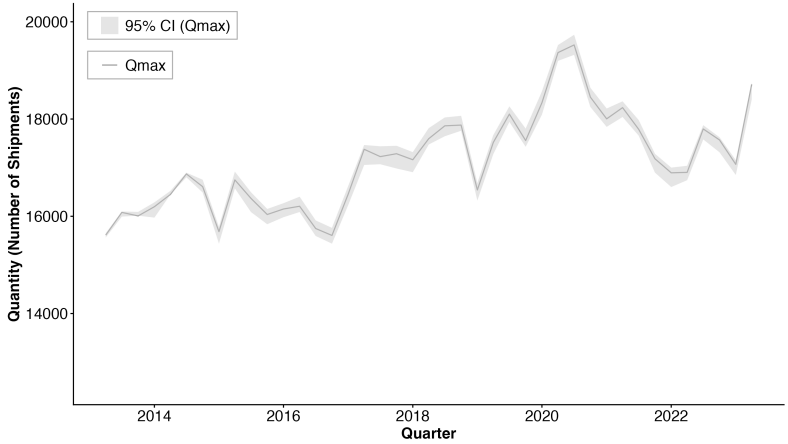




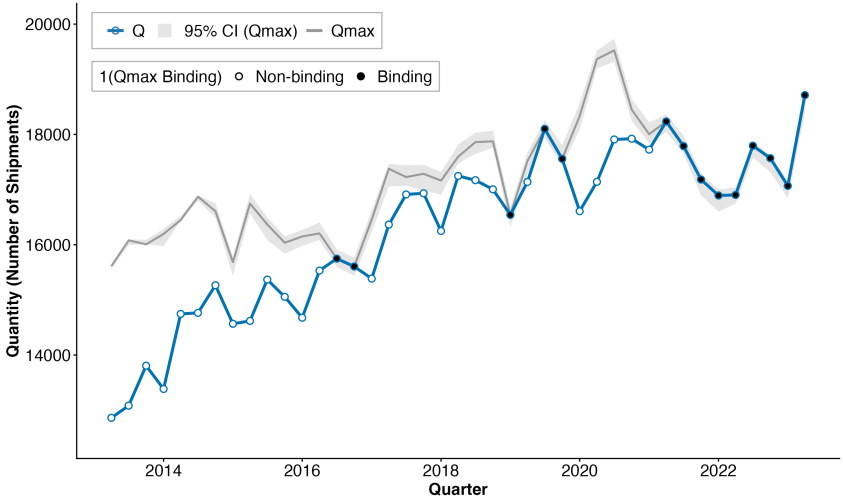


Transportation Sector Capacity



- Service time disruptions during COVID lower Q_{max} service time
- From 2014 it is the port constraint that determines Q_{max}

When Does The System Bind?



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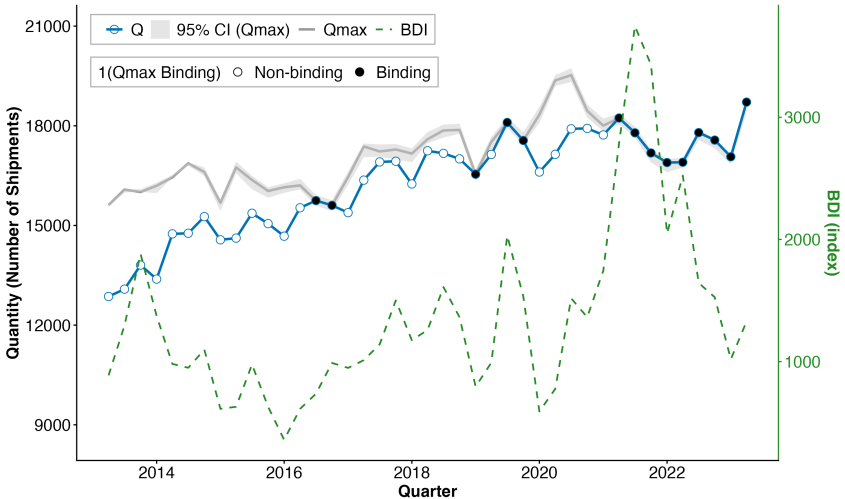
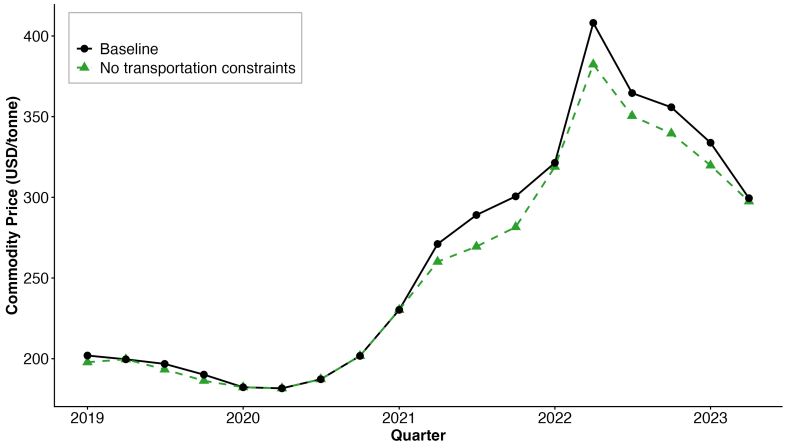


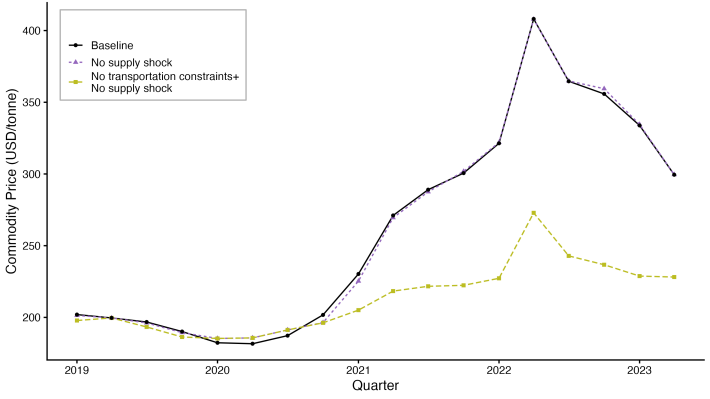
Impact on Commodity Prices

How much of the commodity price increase was due to the transportation bottlenecks?



Impact on Quantity

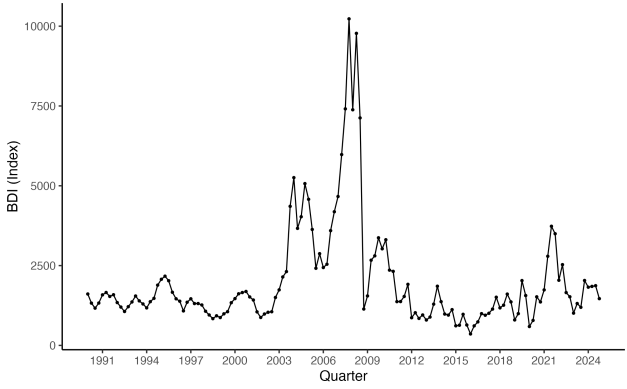
The Role of Supply Shocks



- Contemporaneous supply shock: lockdowns, mine closures, and Ukraine war (big impact on grain trade)
- Mitigates impact of transportation bottleneck
- High commodities prices: either because of supply shock, or if not, because of transportation bottleneck

impact on quantity | with baseline

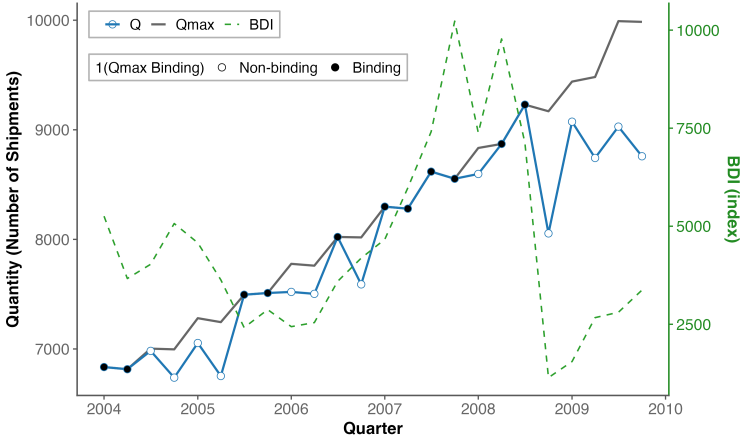
The Super Cycle of 2000s



▸ Commodity Price

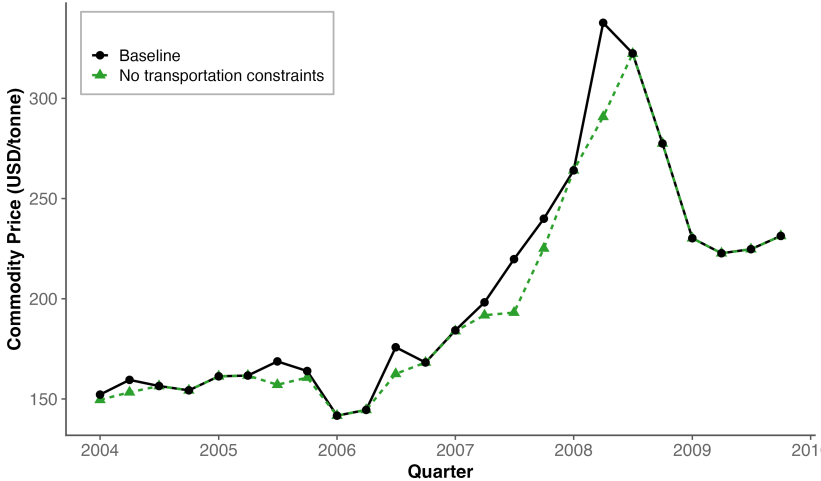
The Super Cycle of 2000s

With coarser data and conservative assumptions, we can go back in time



- It is the ship constraint that binds (fleet more than tripled btw 2002-2023) ▸ Ship Orderbook

The Super Cycle of 2000s



- Much larger impact

Impact on Quantity

Predicting the Impact of Other Disruptions

Red Sea Crisis (Increase in d)

How the Red Sea Shipping Attacks Could Upend Global Trade

Transport costs have soared and energy prices remain volatile as vessels are redirected away from the vital commerce route.

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By Andrew Ross Sorkin, Ravi Mattu, Bernhard Warner, Sarah Kessler, Michael J. de la Merced, Lauren Hirsch and Ephrat Livni
Dec. 19, 2023

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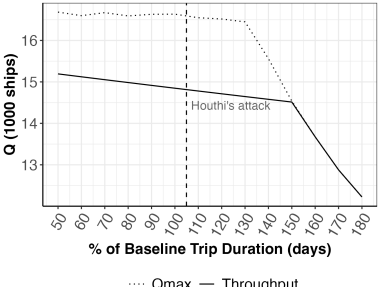
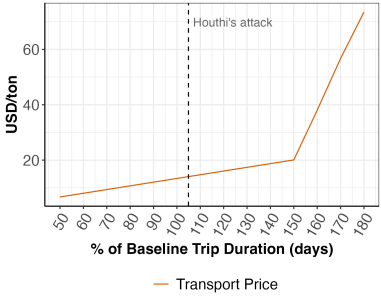
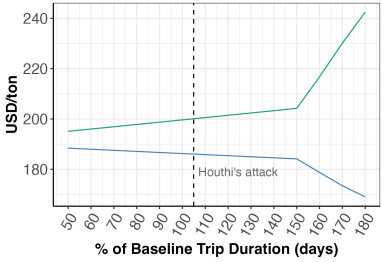
Maersk, the shipping giant, says it will reroute its vessels around Africa and away from the Suez Canal. Suez Canal Authority/via Reuters

Red Sea Crisis (Increase in d)







Conclusion

- Develop tractable framework for transportation, to measure capacity, identify chokepoints and evaluate impact of shocks
- Evaluate resilience of sector during the last 25 years:
  - In post-Covid period, *port constraints* led to sizable increase in commodity prices
    - negative supply shock, mitigated impact of transportation bottleneck
  - For much of the 2000s, *shortage of shipping capacity*, large impact on prices
- Disruptions depend on slack: muted effect of recent Red Sea crisis

Conclusion

- Comments most welcome, thanks!!

Appendix

Ships

Can ships fully respond to demand shocks? Or is fleet capacity fixed?

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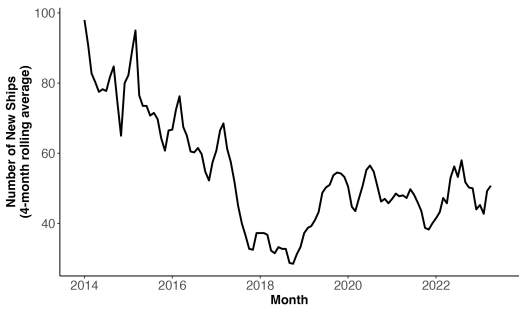
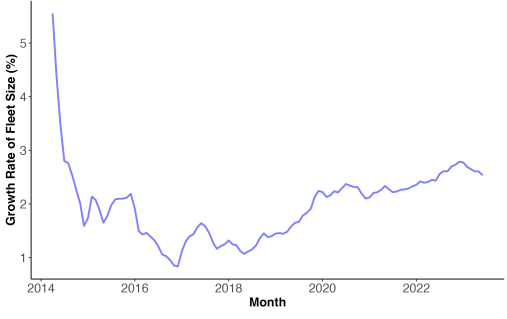
Can ships fully respond to demand shocks? Or is fleet capacity fixed?

- Extensive margin: the number of ships adjusts sluggishly as both entry and exit are slow (Kalouptsidi 2014, Dunn and Leibovici, 2025)

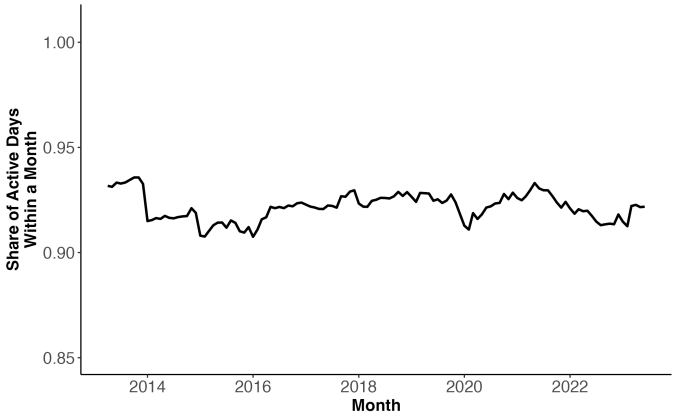




Go Back

Ships

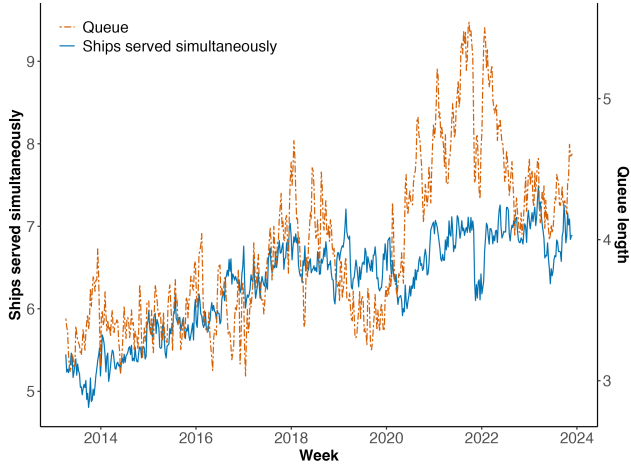
Intensive margin: ships are active 90% of the time and do not moth-ball



▸ by size and age ▸ Go Back

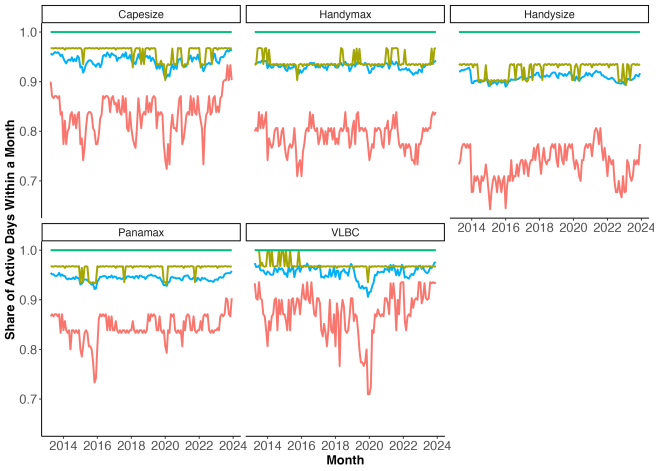
Ports

Number of ships handled remains flat, as demand rises



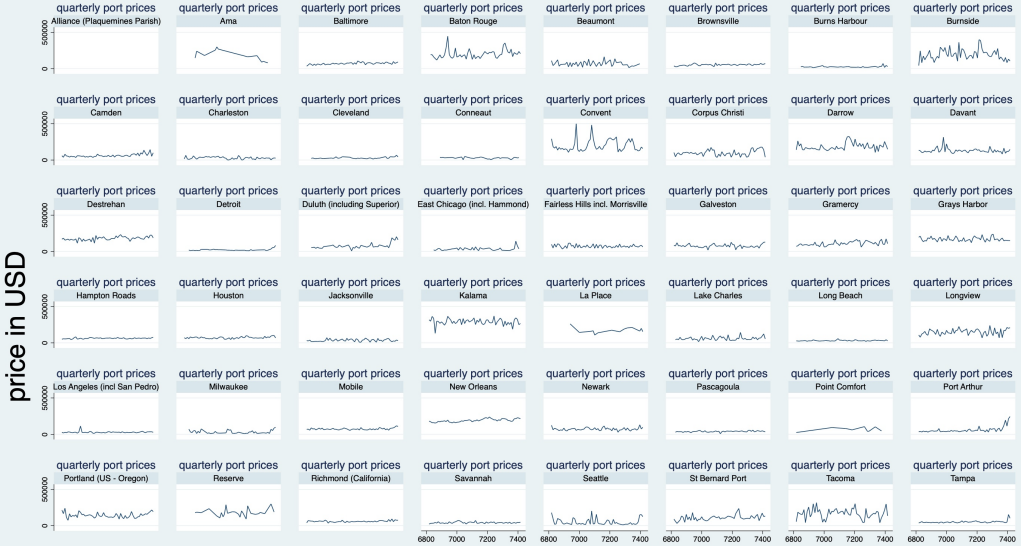
Ships

The number of ships adjusts sluggishly as both entry and exit are slow



Sample restricted to vessels active prior to month t

Port Charges Over Time



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- Would like to run (and much recent research has)

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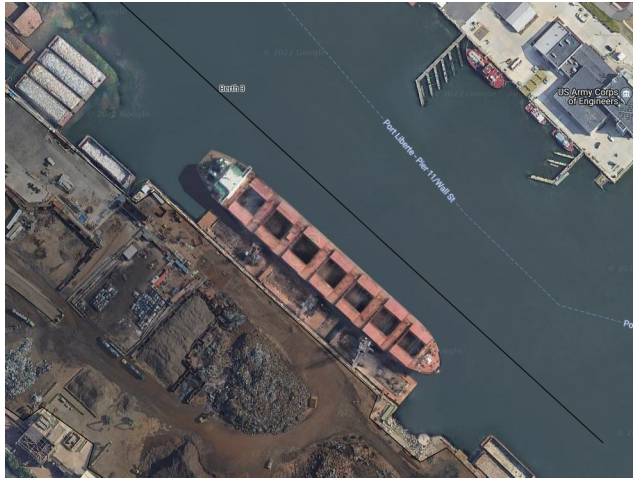
- Would like to run (and much recent research has)

$$\text{commodity prices} = \beta * (\text{time at port}) + \epsilon$$

- However, serious endogeneity problem:
  - Time at port correlated with unobserved demand/supply shocks in ϵ
  - Coefficient β is biased (in either direction) ▸ Example

Time at Port

Service time



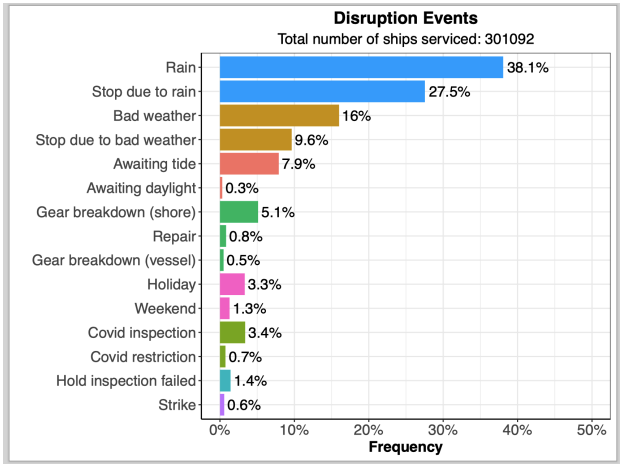
Time at Port

Queueing time (congestion)



Port Disruptions

- Instrument: exogenous variation in time at port?
- From new dataset of port logs:



▸ Validation

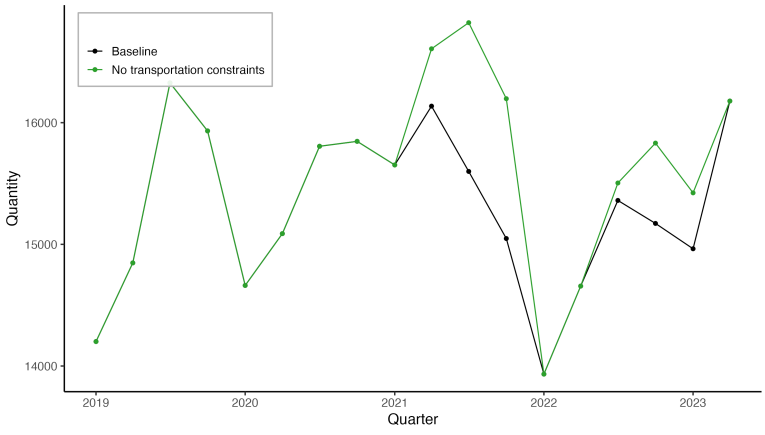
Impact of congestion on commodity prices

	$\log(p_{t,i,e,c}) - \log(p_{t-4,i,e,c})$		
	OLS	IV	IV (nonlinear)
Model:	(1)	(2)	(3)
Constant	-0.0131**		
	(0.0060)		
TT at port	0.0088***	0.0147***	0.0160***
	(0.0010)	(0.0055)	(0.0057)
importer-exporter		Yes	Yes
commodity-quarter		Yes	Yes
importer-quarter		Yes	Yes
exporter-quarter		Yes	Yes
R^2	0.001	0.22	0.22
Observations	61,946	61,946	61,946
KP F Stat, TT at port		78.9	438.3

- $p_{t,i,e,c}$: final price for commodity c, btw importer i and exporter e, in quarter t
- $TT_{t,i,e,c}$: time at port for ports in e exporting commodity c to i
- Additional 2 days in 2022 $\rightarrow$ 3pp (14% of increase)

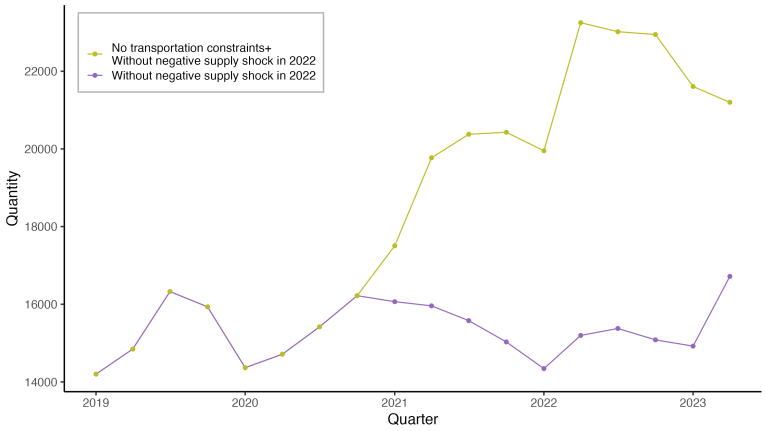
▸ Instrument ▸ First Stage ▸ Impulse Response ▸ Robustness ▸ Go Back

Impact on Quantity



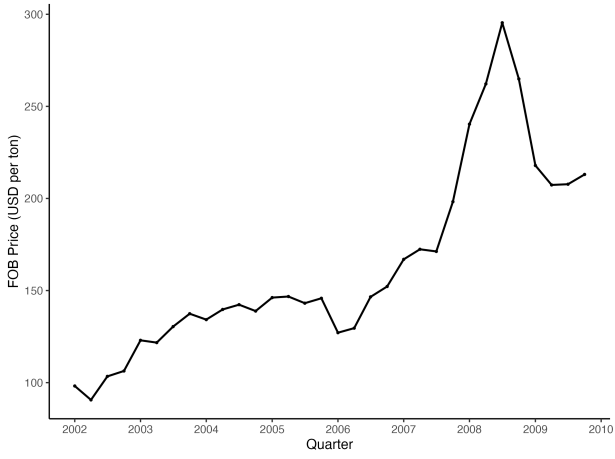
go back

Role of Supply Shock: Impact on Quantity



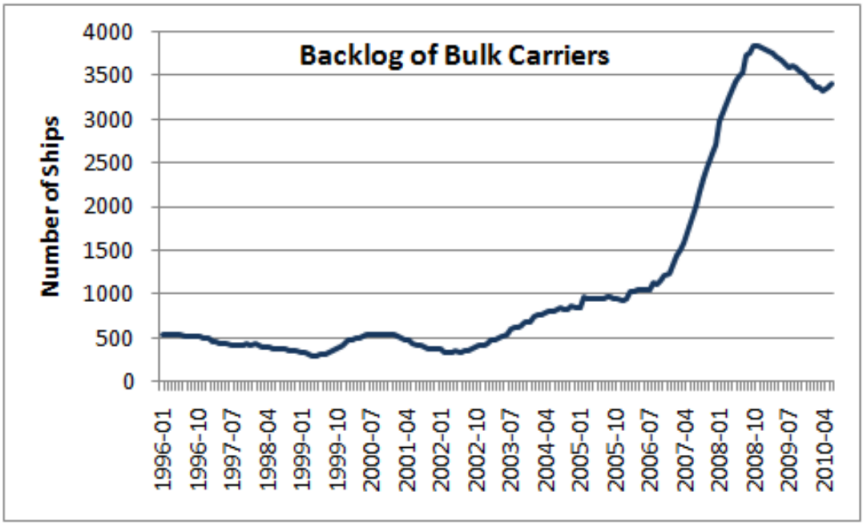
go back

The Super Cycle of 2006-2009: Commodity Price



go back

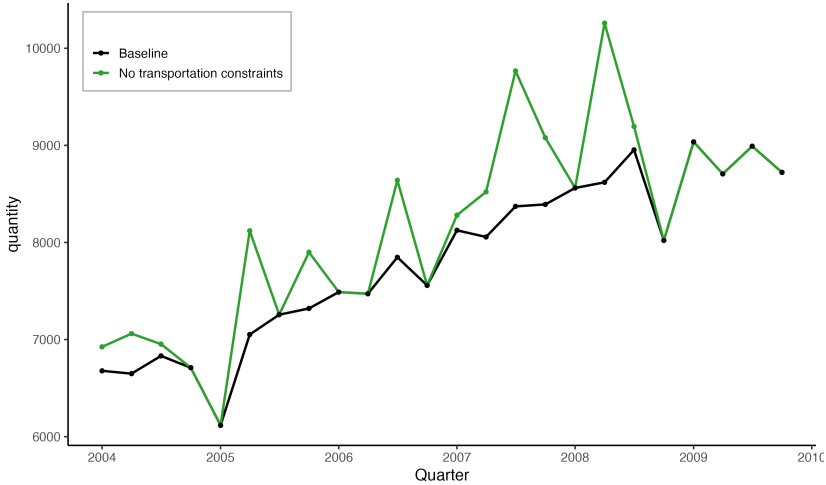
New Ship Orderbook



go back

Quarterly: The Super Cycle of 2006-2009, Quantity

With coarser data and conservative assumptions, we can go back in time

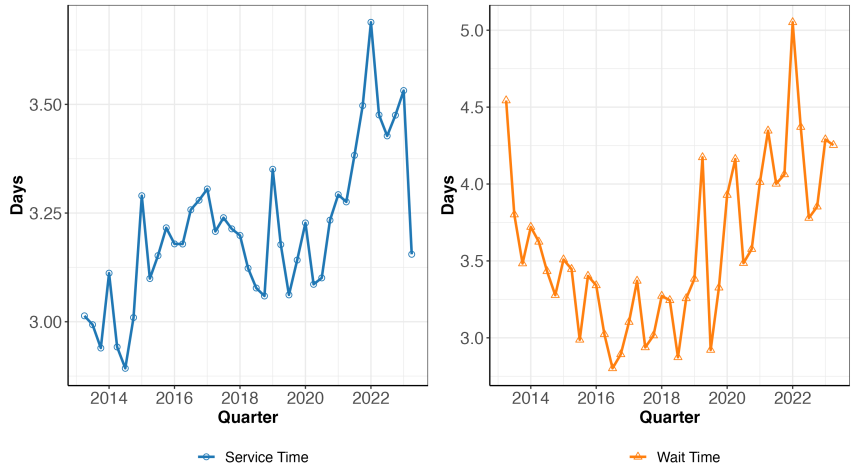


Going back to Reduced Form Specification with Model Data

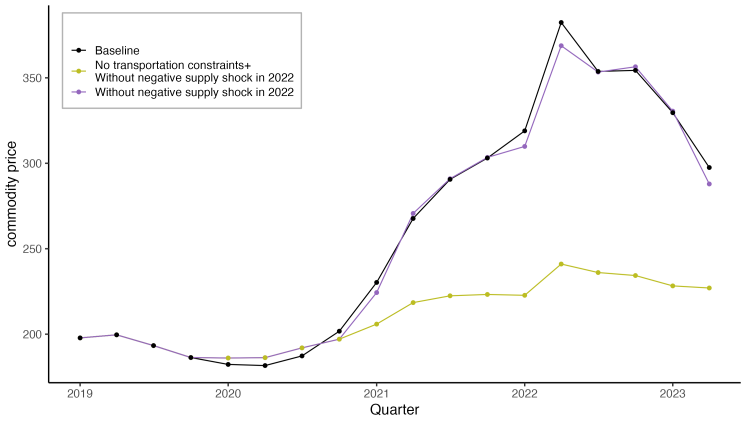
Model:	(1)	(2)
Variables		
Model TT	0.028	-1.02
	(0.033)	(1.58)
1(Binding Qmax)		3.86
		(5.61)
Fit statistics		
Observations	37	37
F-test (1st stage), Model TT	26.1	1.1

Newey-West (L=4) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Service Time and Congestion for the World



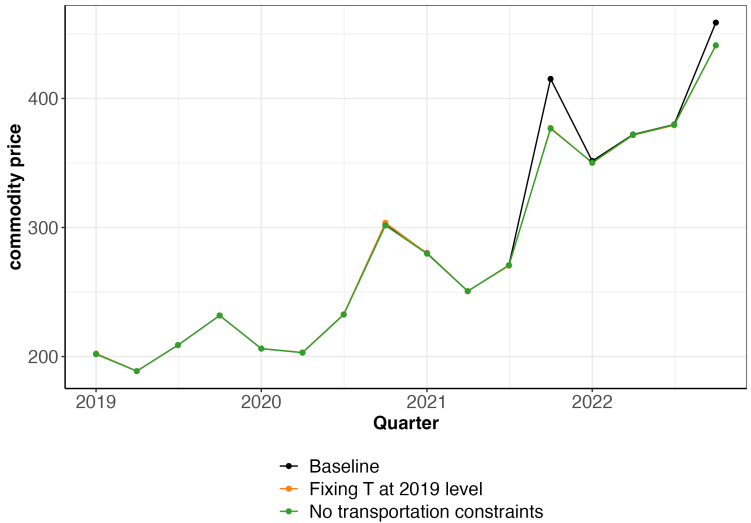
The Role of Supply Shocks



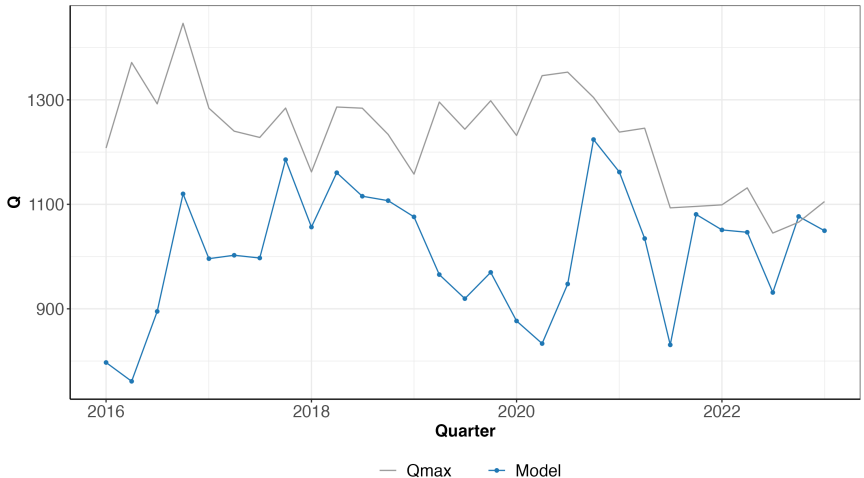
- High commodities prices: either because of supply shock, or if not, because of transportation bottleneck

Go back

Decomposition for the US



$Q(q^*, s^*)$ vs $Q^{\max}$ for the US

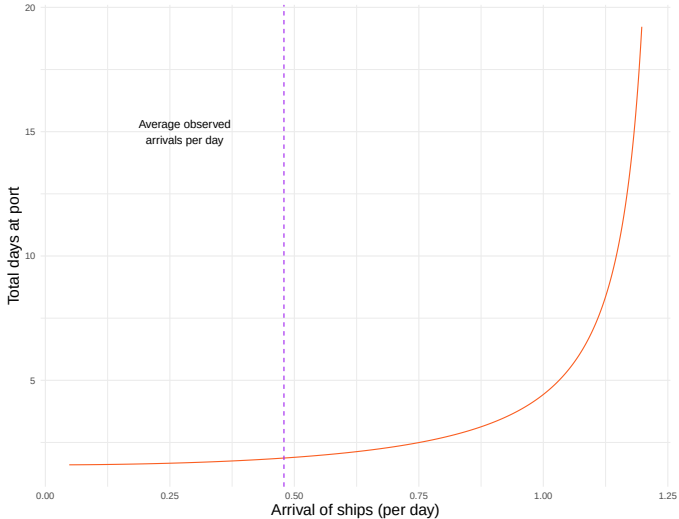


Port Charges Over Time

Go Back

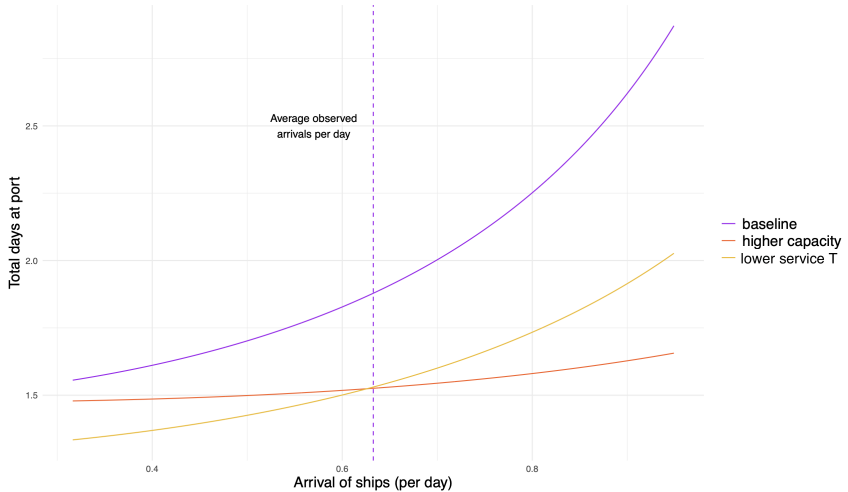
Dependent Variable:	Dues per Port Call (log)			
	(1)	(2)	(3)	(4)
Deadweight (log)	0.6169***	0.6176***	0.6143***	0.6218***
	(0.0445)	(0.0435)	(0.0437)	(0.0255)
Fixed-effects				
port	Yes	Yes	Yes	
loading/unloading	Yes	Yes	Yes	Yes
cargo	Yes	Yes	Yes	Yes
year		Yes		

Congestion Creates Convex Costs

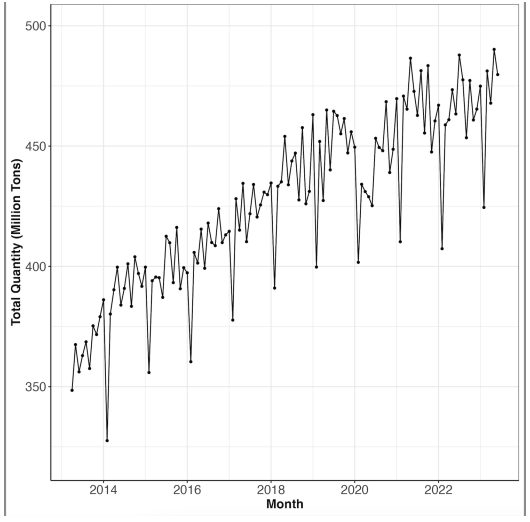


▸ small shocks have large impact

Congestion Creates Convex Costs



Quantity Traded



How Supply Chain Disruptions Form

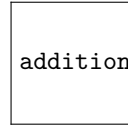
- Time at port

$$\underbrace{T}_{\text{service time}} + \underbrace{\mathbb{I}\{Q \geq K\}}_{\text{if there is a queue}} \times \text{wait time}$$

- Key components
  - T: service time (driven by labor, cranes, productivity)
  - K: max ships handled at a time (driven by berths, storage)
  - Q: ships ahead (endogenous, also depends on port demand)

How Supply Chain Disruptions Form

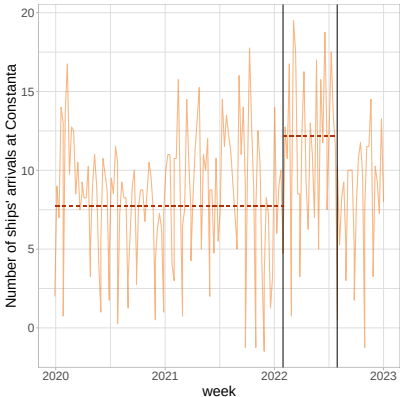
Validation:



Go Back

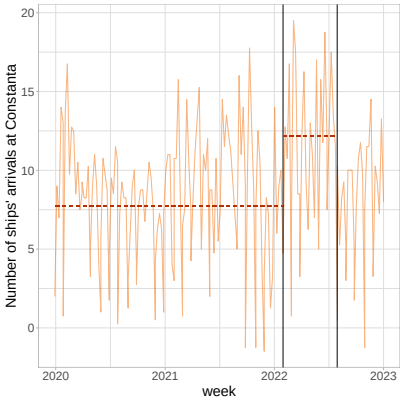
Endogeneity Problem: an example

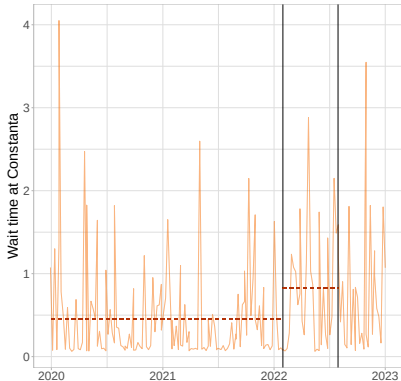
- Demand shock for port of Constanta, Romania (following war in Ukraine)



Endogeneity Problem: an example

- Demand shock for port of Constanta, Romania (following war in Ukraine)





Endogeneity Problem: an example



- Spurious positive correlation between prices and congestion Go back

How Supply Chain Disruptions Form

Validation:

Model:	(1)	(2)
Variables		
Max rain level (10km)	0.578***	0.625***
	(0.013)	(0.015)
1(service started on a weekend)	0.210***	0.191**
	(0.078)	(0.078)
Fixed-effects		
Ship size category	Yes	Yes
port-qoy	Yes	
month	Yes	
commodity	Yes	Yes
port-month		Yes
Fit statistics		
R^2	0.41	0.45
Observations	1,877,883	1,877,883

Clustered (port) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Go Back

Impact of disruptions on inflation

- Specification:

$$\log\left(P_{ijct}/P_{ijc,t-4}\right) = \alpha_{ij} + \gamma_{it} + \lambda_{jt} + \delta_{ct} + \beta TT_{ijct} + \epsilon_{ijct}$$

  - P_{ijct} price for commodity c sold from country j to country i
  - TT_{ijt} total time at country j for commodity c (endogenous)
  - α_{ij} trading pair fixed effects
  - γ_{it}, λ_{jt}, and δ_{ct} are country-quarter and commodity-quarter fixed effects

Impact of disruptions on inflation

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  - TT_{ijt} total time at country j for commodity c (endogenous)
  - α_{ij} trading pair fixed effects
  - γ_{it}, λ_{jt}, and δ_{ct} are country-quarter and commodity-quarter fixed effects

- What is time at port?

Impact of supply chain disruptions on quantities traded

	OLS	IV	IV (nonlinear)
Model:	(1)	(2)	(3)
Variables			
Constant	-0.0715***		
	(0.0222)		
TT at port	0.0129***	-0.0531***	-0.0540***
	(0.0035)	(0.0196)	(0.0197)
Fixed-effects			
importer-exporter		Yes	Yes
commodity-quarter		Yes	Yes
importer-quarter		Yes	Yes
exporter-quarter		Yes	Yes
Fit statistics			
R^2	0.00020	0.15376	0.15373
Observations	65,631	65,631	65,631
KP F Stat, TT at port		89.500	457.52

Clustered (importer-exporter) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

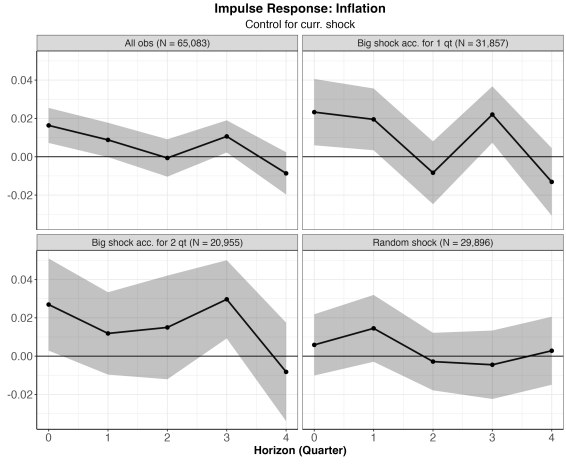
Impact of supply chain disruptions on commodity inflation: First Stage

	Total time at port	
Model:	(1)	(2)
Variables		
Unex. disruption at port	0.9420***	0.6901***
	(0.1060)	(0.1387)
1(Large disruption)		-0.0741*
		(0.0386)
Unexp. disruption*1(Large disruption)		0.6650***
		(0.1697)
Fixed-effects		
importer-exporter	Yes	Yes
commodity-quarter	Yes	Yes
importer-quarter	Yes	Yes
exporter-quarter	Yes	Yes
Fit statistics		
R^2	0.81	0.81
Observations	61,946	61,946
KP F Stat	78.9	438.3

Clustered (importer-exporter) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

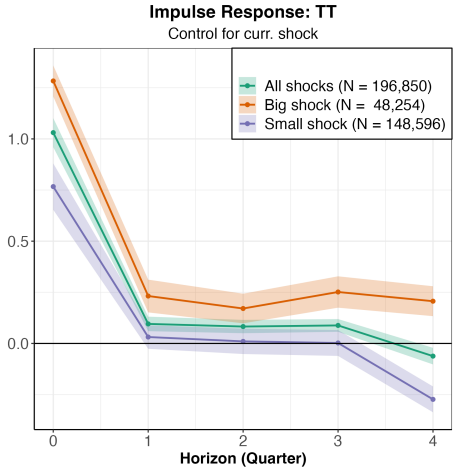
- Shock accumulates and increases wait time more than linearly Go Back

Impulse Response



▸ Go Back

Impulse Response: First Stage



Go Back

Robustness: Controlling for Weather Away from Port

	IV = Unexpected Shock	IV = Unexpected Shock + Rain within 10km
Model:	(1)	(2)
Variables		
TT at port	0.0159***	0.0119**
	(0.0057)	(0.0054)
Ave. rain level (50-500km)	0.0020	0.0026
	(0.0038)	(0.0038)
Fixed-effects		
importer-exporter	Yes	Yes
commodity-quarter	Yes	Yes
importer-quarter	Yes	Yes
exporter-quarter	Yes	Yes
Fit statistics		
R^2	0.22	0.22
Observations	61,930	61,930
KP F stat, TT at port	440.9	330.7

Clustered (importer-exporter) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Go Back

Transport Sector Capacity ($Q^{\max}$)

- Define the maximum quantity that can be supplied conditional on it all being delivered, as

$$q^{\max} \equiv \max_{\widetilde{q}} \widetilde{q}$$

subject to

$$Q\left(\widetilde{q}, S\right) = \widetilde{q}$$

- Define the associated quantity delivered as

$$Q^{\max} \equiv q^{\max}$$

Go Back

Equilibrium

Equilibrium is characterized by the following conditions:

$$q\left(p_x, A\right) = q \tag{1}$$

$$D\left(p_x + p_T, Y\right) = Q\left(q, S, d, K, T\right) \tag{2}$$

$$Q\left(q, S, d, K, T\right) = q \tag{3}$$

$$p_T \begin{cases} = c, & \text{if } Q\left(q, S, d, K, T\right) < Q^{\max} \\ \geq c, & \text{if } Q\left(q, S, d, K, T\right) = Q^{\max} \end{cases}$$

Go Back

Case 2: Port Constraint Binds

- Why is it that $\frac{\partial w}{\partial T} > 0$?
  - recall, here no direct cost of time at port by assumption -would have made impact even more severe
- When ports constrained, shipments to domestic country given by

$$\frac{K}{T}$$

  so when $T \uparrow$, fewer goods go through
- Shortage created leads to price hike
- Same intuition for $\frac{\partial w}{\partial K} < 0$

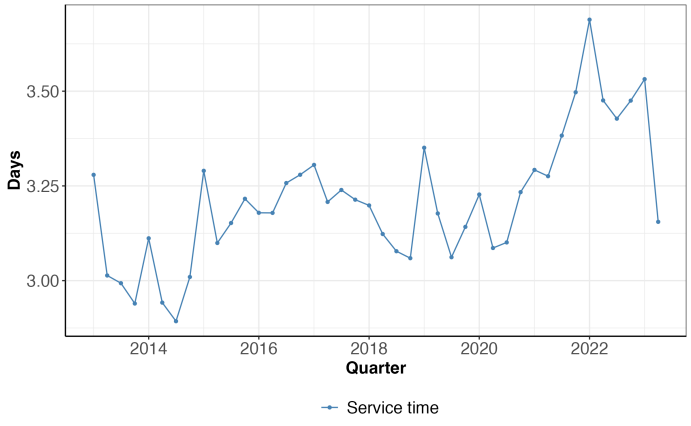
Case 3: Ship Constraint Binds

- Why is it now that $\frac{\partial w}{\partial T} > 0$?
- When ports are constrained, shipments to domestic country are given by

$$S \frac{1}{T + W + 2d}$$

  so again when $T \uparrow$, fewer goods go through
- Shortage created because not enough ships to carry cargo, this leads to price hike
- Same intuition for $\frac{\partial w}{\partial S} < 0$ and $\frac{\partial w}{\partial d} > 0$
- Note that $\frac{\partial w}{\partial K} < 0$, since infrastructure lowers wait time and frees up ships

Service Time

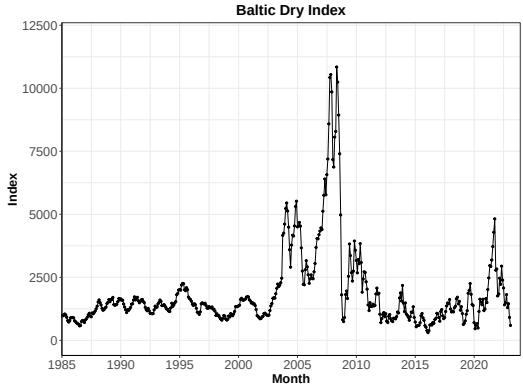


Go Back

Supply Chain Disruptions: Port Congestion

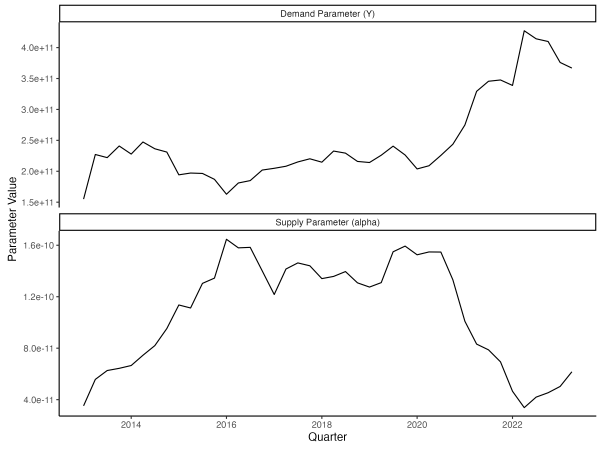
- Congestion $\equiv$ Time at port
- On average (median) 120 hours (83 hours) map
  - $+22\%$ ($\simeq 50\%$ if both ports) on top of total trip time
  - at ship cost of \$14K per day, direct cost alone \$69K (but a crude lower bound) Go Back

Transportation and Disruptions



- Enormously costly
  - direct cost to shippers
  - additional costs trickle through supply chain Go Back

Y and alpha



Go Back

Port Operations: Basics

- Transportation infrastructure crucial for trade
- Ports are gateway to international trade
  - 90% of world trade volume is carried by ships
  - $>$ 50% of time required to deliver inputs is spent on ships & ports
- Focus on raw materials and commodities (bulk carriers) details
  - half of world trade volume

Environment - Demand

- Continuum of firms, each supplying one of ω differentiated varieties
- Production depends only on imported intermediate good, N (needs to be shipped):

$$q = zN$$

- Price of intermediate good

$$p = p_x + p_T$$

Environment - Demand

- Firms differ in productivity z and choose final price taking demand as given,

$$\max_{p_f} p_f q - p\frac{q}{z}$$

$$\text{s.t.} q = \frac{p_f^{-\sigma}}{P_f^{1-\sigma}} Y$$

where P_f the aggregate price index for the final good

Environment - Demand

- Firms differ in productivity z and choose final price taking demand as given,

$$\max_{p_f} p_f q - p\frac{q}{z}$$

$$\text{s.t.} q = \frac{p_f^{-\sigma}}{P_f^{1-\sigma}} Y$$

where P_f the aggregate price index for the final good

- Variety price

$$p_f = \frac{\sigma}{\sigma - 1}\frac{p}{z}$$

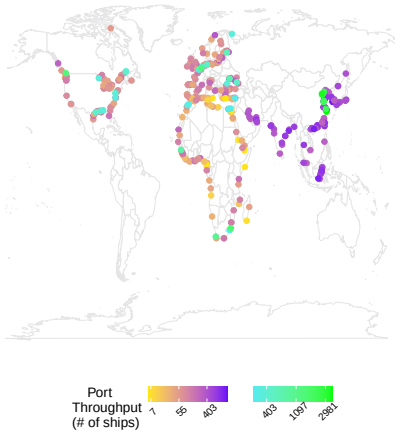
- Since input demanded by firm is

$$N = \frac{q}{z}$$

can obtain economy demand for intermediate good,

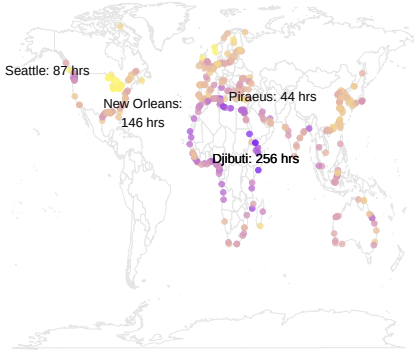
$$\int_{\omega} N(\omega)\, d\omega = \frac{\sigma - 1}{\sigma}\frac{Y}{p}$$

World Ports



- We focus on the largest 100 ports in US, Europe, Africa and Asia. Go Back

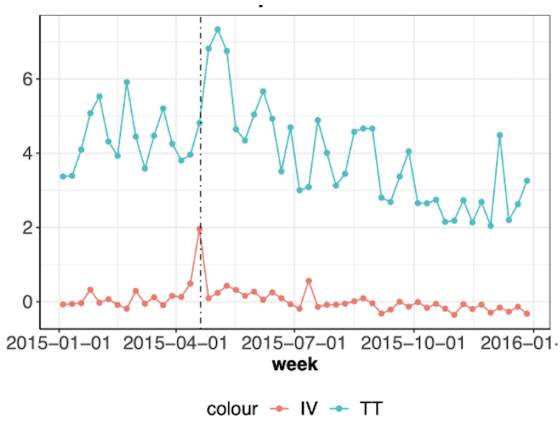
Time at Port: Massive Dispersion



residualized on ship size and commodity

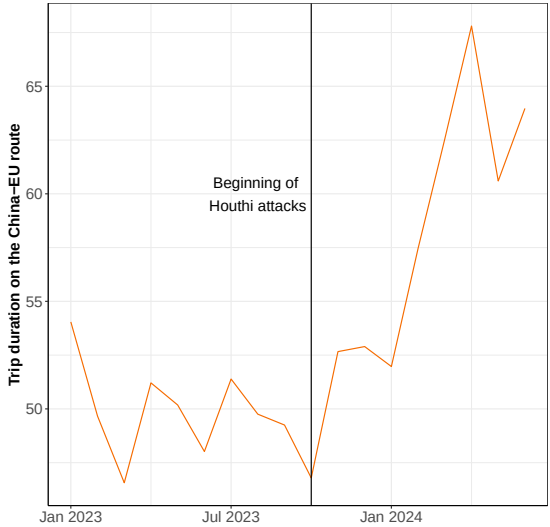
not driven by port size | Go Back | Go Back

Instrument: Storm in Newcastle AU

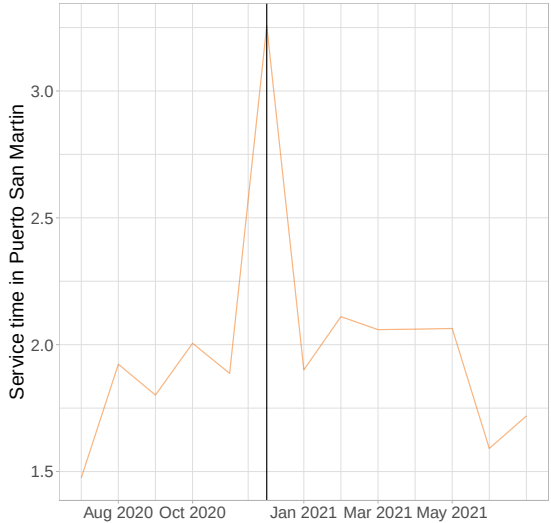


Go Back

Houthi


Trip duration on the China–EU route
65
60
55
50
Beginning of
Houthi attacks
Jan 2023
Jul 2023
Jan 2024

Strike in Argentina



Time at Port: Importance for Trade

- Does total time at port impact trade flows?

$$\log(Q_{jt}) = \beta^{\tau} \log TT_{jt} + \xi_j + \xi_{\text{year}} + \epsilon_{jt}$$

  where

  - Q_{jt} is demand (arrivals) for port services at port j,
  - TT_{jt} is time at port j time and

- Instrument: unexpected disruptions in port j's service times

Trade Elasticity wrt Time at Port

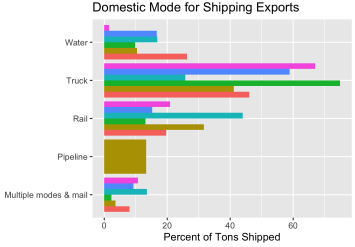
go back

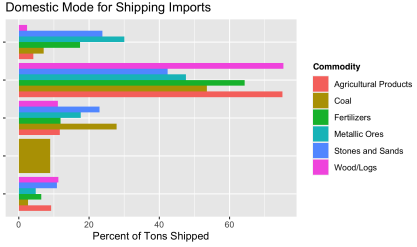
Dependent Variable:	Arrivals at port (log)	
Time at port (log)	-0.609***	-0.613***
	(0.0296)	(0.0318)
Fixed-effects		
port	Yes	Yes
year-month	Yes	
year-quarter		Yes
Observations	5,569	5,569
F-stat	593.7	478.6

Clustered (port) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

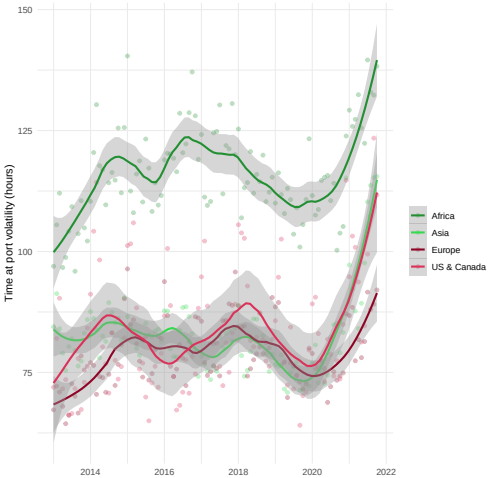
Domestic Transportation

back





Time at Port: Prone to Disruptions



- Also volatility explodes
  - 53% for North America
  - 53% for Asia
  - 20% for Europe
  - 21% for Africa

Go Back

residualized on ship size and commodity

Model Simulation

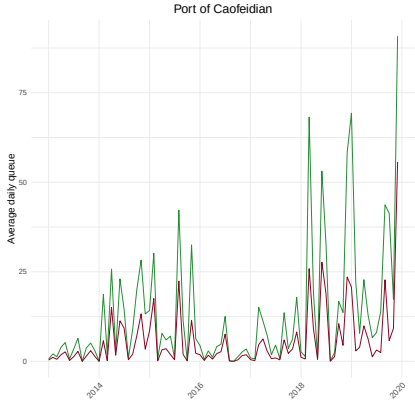
- Ships arrive at port j at rate λ_{jt} at t
- Port j can service up to K_{jt} ships simultaneously
- Ships services at rate $\mu_{jt} = 1/T_{jt}$
- If ships exceed K_{jt}, they form a queue, Q_{jt} FIFO
- Probability $p_n(t)$ that there are n ships in queue evolves as

$$\frac{dp_n(t)}{dt} = \begin{cases} -(\lambda_{jt} + n\mu_{jt})\, p_n(t) + \lambda_{jt} p_{n-1}(t) + (n+1)\,\mu_{jt} p_{n+1}(t), & \text{if } n < K_{jt} \\ -(\lambda_{jt} + K_{jt}\mu_{jt})\, p_n(t) + \lambda_{jt} p_{n-1}(t) + K_{jt}\mu_{jt} p_{n+1}(t), & \text{if } n \geq K_{jt} \end{cases}$$

Go Back Go Back Go Back

Sensitivity to Shocks

- Ports are inherently prone to disruptions
  - Using model simulations, consider a 1% demand shock to arrivals



- Same shock has different impact depending on congestion Go Back

Little Interaction between Bulk and Containers

	Total workers per shift
n_{bulk}	31.21^{***}
	(2.49)
$n_{container}$	83.67^{***}
	(1.88)
$n_{container} \times n_{bulk}$	0.14
	(0.42)
N	27,251
R^2	0.86
Port FE	Yes
Year-Month FE	Yes

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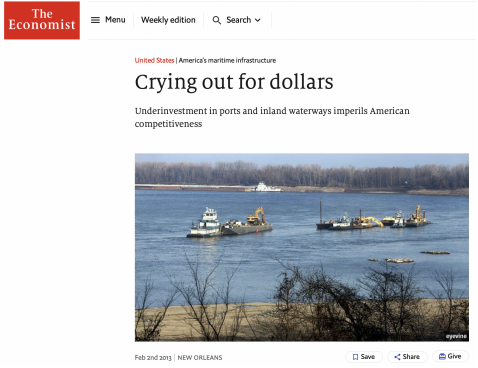
Industry

Bulk shipping

- Homogeneous unpacked dry/liquid cargo, for individual shippers on non-scheduled routes vs. containerships
- Transports raw materials (iron ore, grain, coal, steel, etc.)
- Operate like "taxi drivers, not buses"
- Contracts through brokers
- Unconcentrated industry, homogeneous good ▸ firm size cdf ▸ Go Back

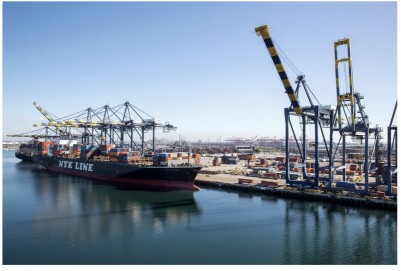
Congestion during COVID



The New York Times

Simmering Labor Fight Brings Crippling Delays to West Coast Seaports

Give this article



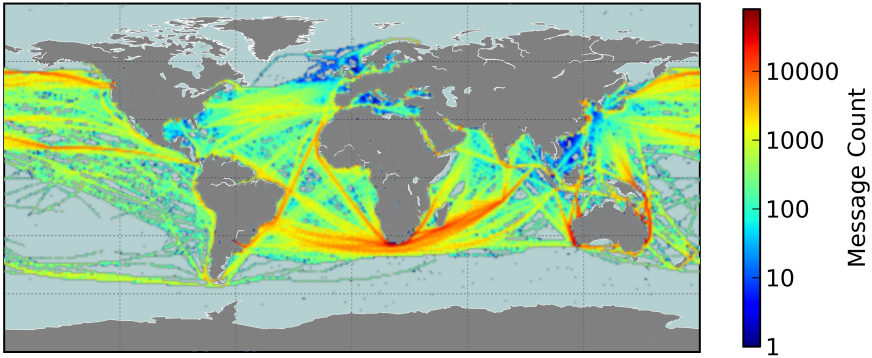
A cargo ship at the Port of Los Angeles, where, owners said, they will suspend the unloading of container and other cargo ships.

Monica Almeida/The New York Times

By Erik Eckholm

Feb. 12, 2015

Vessel Movements: Message Count in 10 Days



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Output Expression

- M/M/K queueing model:
  - M: arrival rates exponentially distributed with mean arrival rate λ
  - M: service rates exponentially distributed with mean service rate $1/T$
  - K: number of servers (leads to M/M/1 with service rate K/T)
- If other distributions, can instead easily simulate the queue behavior (we use flexible distributions)

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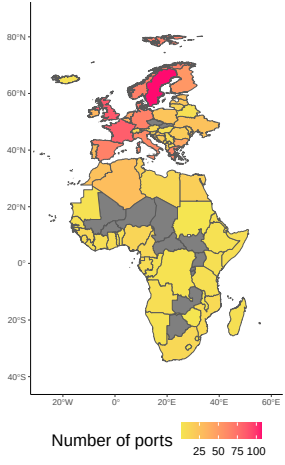
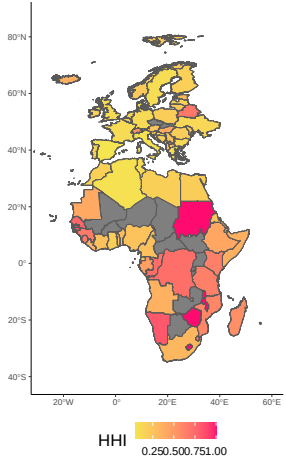
Sources of Misallocation?

- Market power
  - geography and other factors grant ports market power
  - fairly concentrated esp in specific regions African ports
- Role of government and regulations
  - sometimes public/private cooperation with possibly different goals
  - regulatory capture
  - unions
- Liquidity constraints Go Back

Port Market Power (from different project)





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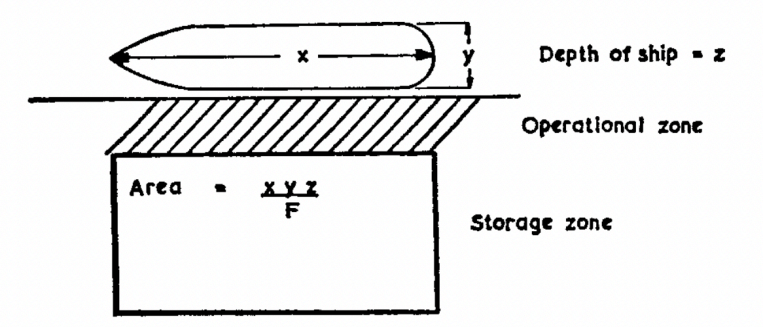
Cost of K



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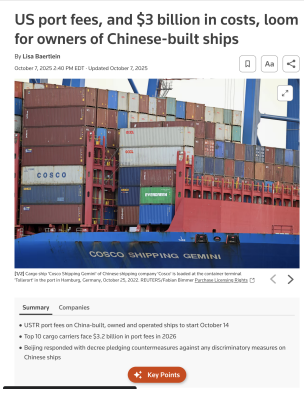
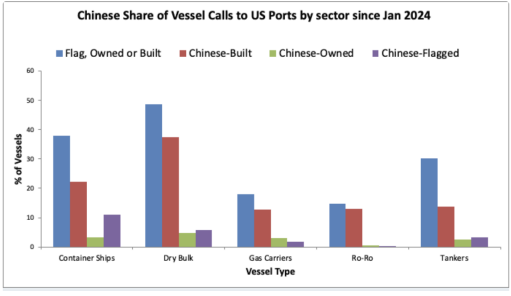
Tax on Chinese-built Ships





- Calibrate model based on US-only data

Tax on Chinese-built Ships (US Calibration)

