Navigating Shocks:
The Ripple Effects of Shipping Route Closures

Research Seminar, Universität Würzburg — 17 November 2026

Carsten Brockhaus,[1,2] **Julian Hinz**[1,3], Charles Serfaty[4]

[1] Kiel Institute for the World Economy [2] Kiel University
[3] Bielefeld University [4] Banque de France

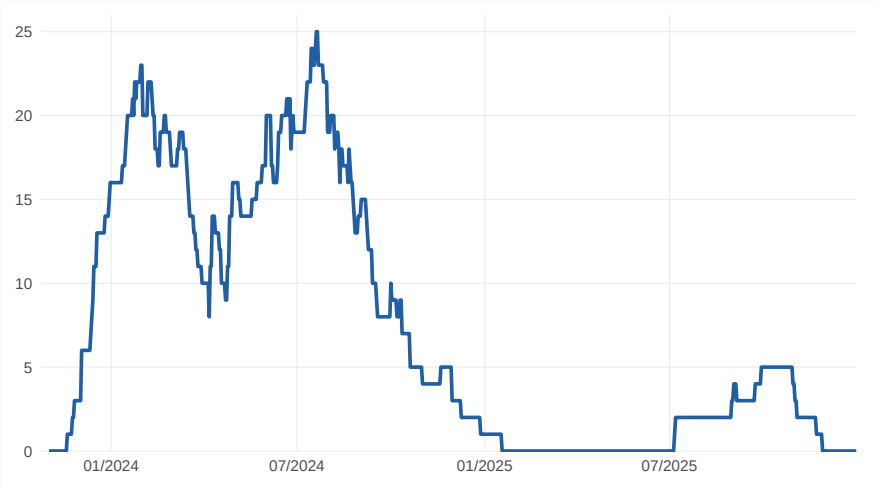
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Bab al-Mandab



Houthi attacks on merchant shipping



Documented attacks on commercial vessels, 60-day rolling count. Source: Wikipedia, “Houthi attacks on commercial vessels”.

This paper

- ∼30% of global container traffic passed the Red Sea before the attacks

  → How much trade did the Houthis destroy?

- Not all maritime chokepoints are alike

  → Suez, Malacca, Panama: long but feasible detours

  → Hormuz, Danish straits: no maritime alternative

  → Some chokepoints collect tolls



This paper

1. Evidence on trade and shipping after the Houthi attacks

→ AIS vessel tracks, monthly trade by mode, Turkish customs data

→ Red Sea-dependent trade falls, reroutes via the Cape, recovers within months

2. Quantitative trade model with endogenous freight costs and monopoly tolls

→ Substitution across routes, modes and origins

3. Counterfactuals

→ Permanent Red Sea closure: mainly costs Egypt its canal revenue

→ Hormuz toll: falls on the Gulf economies behind the strait



Related literature

- **Maritime trade technology**
  Hummels (2007); Jacks and Pendakur (2010); Bernhofen et al. (2016); Pascali (2017).
- **Maritime disruptions and transport networks**
  Feyrer (2021); Dunn and Leibovici (2025); Fuchs and Wong (2026); Fuchs, Leibovici and Wong (2026); Bai et al. (2026).
- **Gravity, trade costs and sourcing**
  Head and Mayer (2014); Caliendo and Parro (2015).
- **Tolls and endogenous freight costs**
  Hummels et al. (2009); Asturias (2020); Brancaccio et al. (2020); Wong (2022); Chowdhry, Heiland and Mahlkow (2026).
- **Transport modes**
  Ko, Nigai and Truax (2026); Tolva (2026).



Closest related papers

	Model	Question
Fuchs, Leibovici & Wong (2026)	Spatial GE, recursive routing, fleet ownership	Strategic dependence on foreign shipping; U.S.–China; port fees
Bai, Fernández-Villaverde, Li, Marto & Zanetti (2026)	U.S. GE, one congestible container fleet	Effective vs potential capacity; Red Sea -0.35% of U.S. output
This paper	160 countries, routes and modes, endogenous freight costs	**Who prices a chokepoint** and who pays when it closes

- Only here: revenue-maximising canal tolls, multi-country incidence, Hormuz, firm-level evidence



The Red Sea Crisis

Data

- **Shipping**: AIS trajectories and port calls, 6,032 container vessels

  $\rightarrow$ August 2021–August 2024

- **Trade**: U.S. Census and Eurostat Comext

  $\rightarrow$ monthly HS6 $\times$ partner $\times$ transport mode

- **Firms**: Panjiva Turkish customs

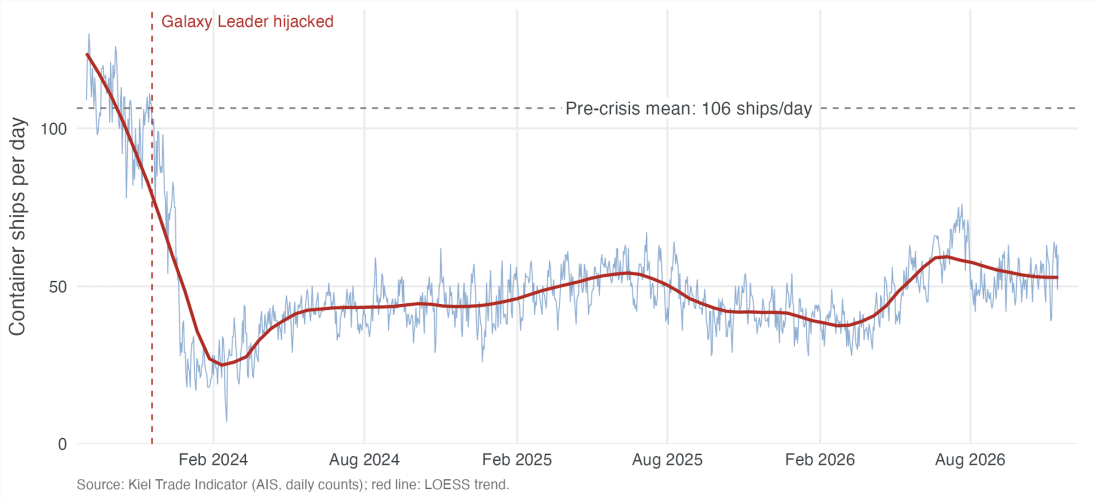
  $\rightarrow$ firm $\times$ partner $\times$ week exports

- **Ports**: IMF PortWatch port shares

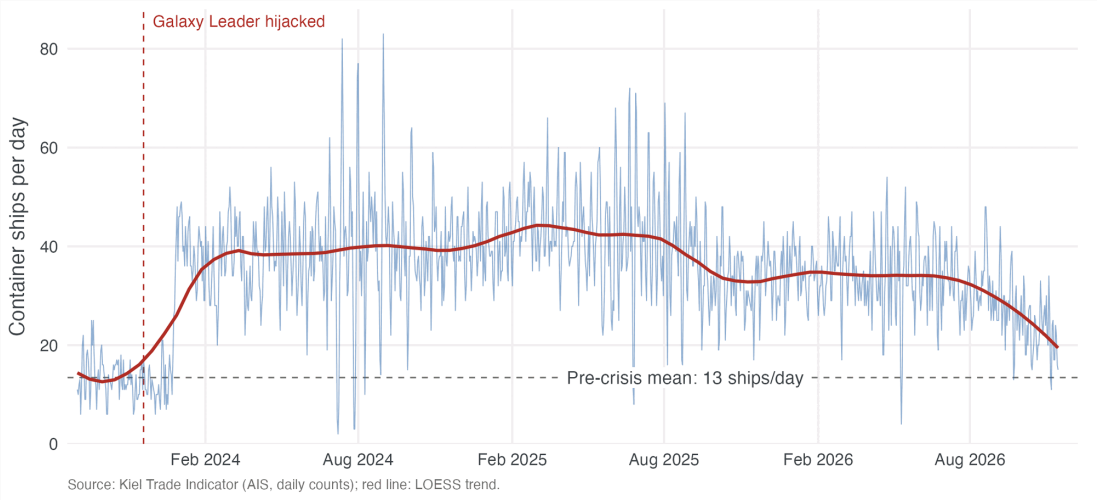
  $\rightarrow$ port-to-port sea distances with each chokepoint closed



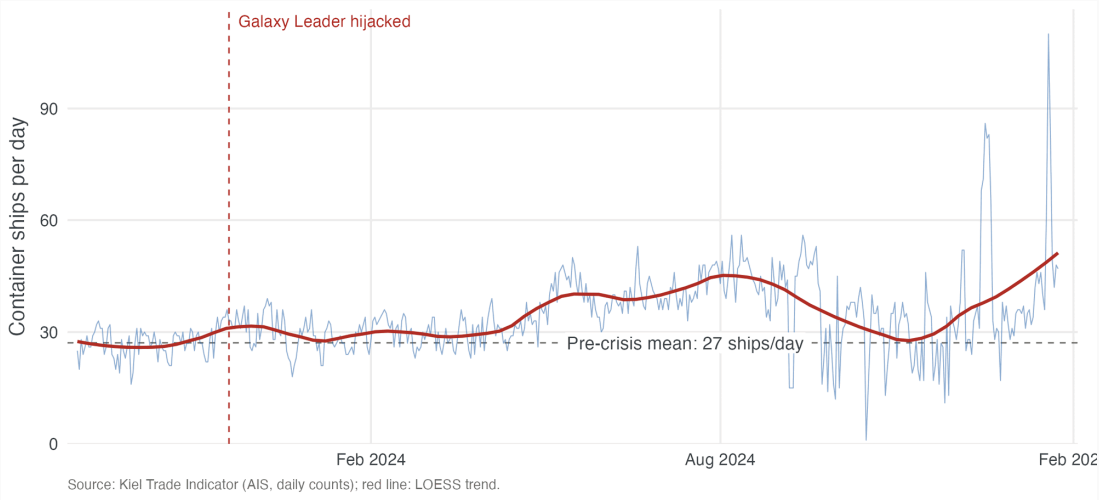
Vessel traffic: Red Sea



Vessel traffic: Cape of Good Hope



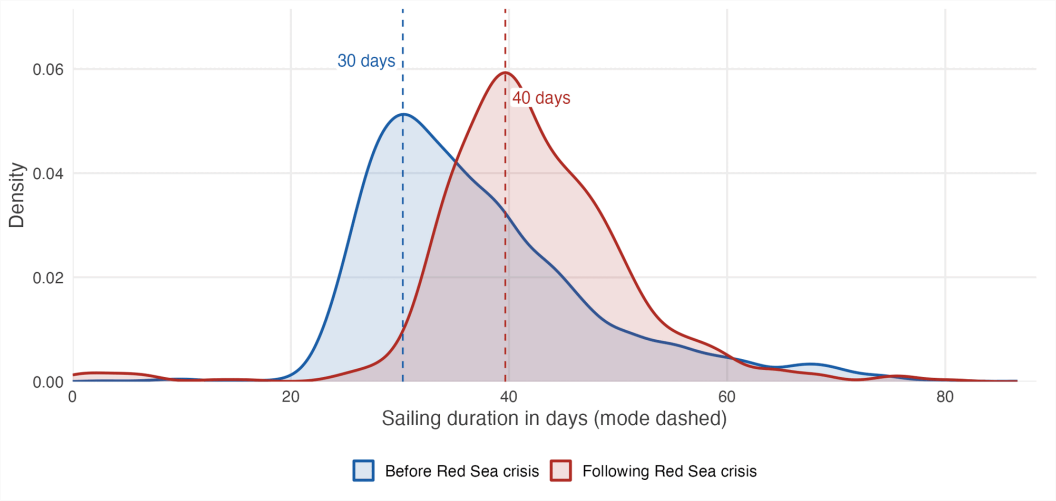
Vessel traffic: Panama Canal



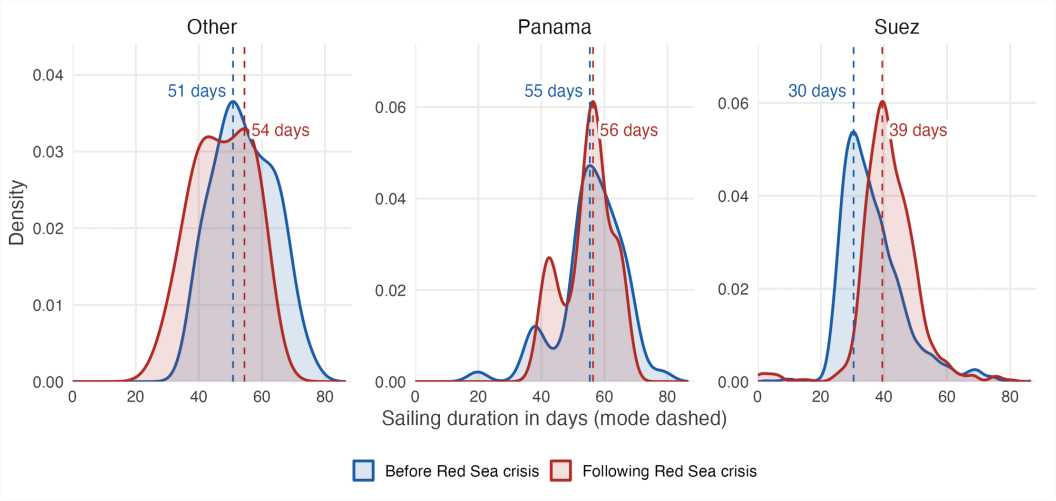
Freight rates



Travel duration: China → Netherlands



Travel duration by passage



Turkish firms: data and specification

- Panjiva Turkish customs: shipment-level exports, firm ID, value, transport mode
- Aggregated to firm $f \times$ partner $j \times$ week t

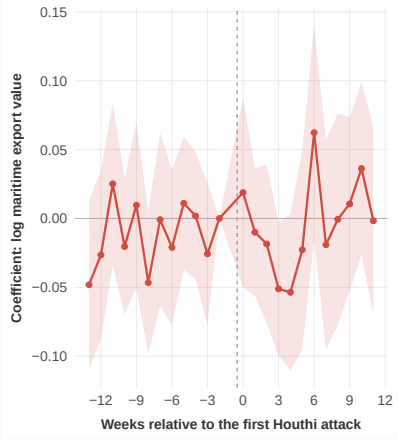
$$y_{fjt} = \sum_{\tau \neq -1} \beta_\tau \, \mathbb{I}\{t = \tau\} \times \mathrm{ViaSuez}_j + \alpha_{fj} + \alpha_t + \varepsilon_{fjt}$$

y_{fjt}: log maritime export value, or air share of export value. $\mathrm{ViaSuez}_j$: pre-crisis sea route crosses Bab al-Mandab.

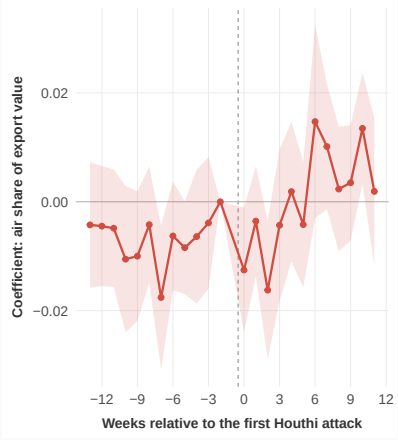


Turkish firms: exports via Suez

Log maritime export value



Air share of export value



Turkish firms: difference-in-differences

	(1) Log maritime export value	(2) Air share of export value
Via Suez × Post	0.0048	0.0065**
	(0.0129)	(0.0025)
Observations	405,777	1,023,191
Within R^2	0.000	0.000
Firm × partner FE	Yes	Yes
Week FE	Yes	Yes

Firm × partner and week fixed effects; standard errors clustered by partner.



Taking stock

- Large initial effects on imports in customs data

  $\rightarrow$ consistent with delays

- Turkish exports via Suez dip a few weeks after the first attacks
- Short-lived effects, apart from a shift toward air

  $\rightarrow$ Red Sea-dependent trade back after $\sim$6 months

- Why? Cape is a feasible detour, and the Suez toll absorbs much of the cost gap



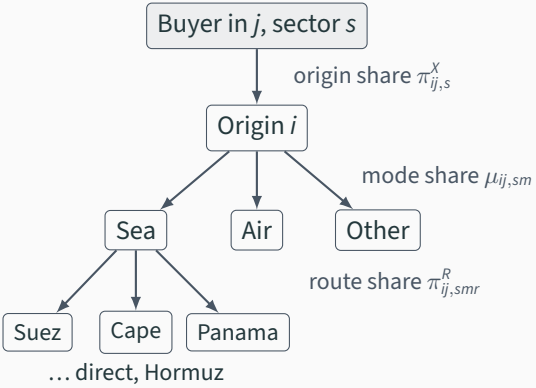
Model

Basic setup

- World of countries, indexed *i* (origin) and *j* (destination), and sectors *s*
- Firms produce with labour and intermediates
  - → input–output links as in Caliendo and Parro (2015)
- Buyers in *j* make three choices:
  - → where to buy from: origin *i*
  - → how to ship: mode *m* — sea, air, other
  - → which way to sail: route *r* — Suez, Cape, Panama, Hormuz, direct
- Shipping costs depend on geography, canal congestion, fleet capacity and transit fees
- Canal authorities set transit fees to maximise revenue



Three choices of a buyer



- Each choice a CES / logit share, own elasticity

  $\rightarrow$ origins: θ_s; modes: η^M_s; routes: η^R_s

- Trade flow from i to j by mode m on route r:

$$X_{ij,smr} = \pi^R_{ij,smr}\, \mu_{ij,sm}\, \pi^X_{ij,s}\, E_{j,s}$$

  $\rightarrow$ $E_{j,s}$: spending of j on sector s

Production and demand

- Firms in i combine labour and intermediates; unit cost of sector s:

$$c_{i,s} = w_i^{\beta_{i,s}} \prod_k P_{i,k}^{\gamma_{i,ks}}$$

  $\rightarrow$ wage w_i, value-added share $\beta_{i,s}$, input share $\gamma_{i,ks}$, price index $P_{i,k}$

- Spending on sector s in j: final demand plus inputs

$$E_{j,s} = \alpha_{j,s} I_j + \textstyle\sum_k \gamma_{j,sk} Y_{j,k}$$

  $\rightarrow$ income I_j = labour income + tariff revenue + toll revenue $-$ trade deficit



Choice of origin

- Eaton–Kortum by sector: buyers in j source from the cheapest origin
- Share of j's spending on s that goes to i:

$$\pi^{X}_{ij,s} = \frac{T_{i,s}\left(c_{i,s}\,\kappa_{ij,s}\,d_{ij,s}\right)^{-\theta_s}}{\sum_l T_{l,s}\left(c_{l,s}\,\kappa_{lj,s}\,d_{lj,s}\right)^{-\theta_s}}$$

  $\rightarrow$ productivity $T_{i,s}$, tariffs $\kappa_{ij,s}$, trade elasticity θ_s

- $d_{ij,s}$: transport cost, the only new object

  $\rightarrow$ comes from the choice of mode and route



Choice of mode

- Discrete choice like Tolva (2025): sea, air, other

$$\mu_{ij,sm} = \frac{d_{ij,sm}^{-\eta_s^M}}{\sum_\nu d_{ij,s\nu}^{-\eta_s^M}}, \qquad d_{ij,s} = \left(\sum_m d_{ij,sm}^{-\eta_s^M} \right)^{-1/\eta_s^M}$$

- η_s^M from Ko et al. (2026): 0.7–9.7

  $\rightarrow$ modes are poor substitutes: little switch from sea to air

- $d_{ij,s}$ enters the choice of origin like any trade cost



Choice of route

- Discrete choice like Tolva (2025), but over routes
- $d_{ij,smr}$: cost of shipping from i to j by mode m on route r
- Share of route r and cost of the mode:

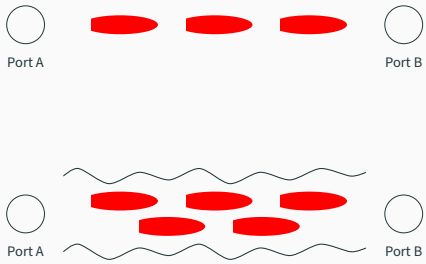
$$\pi^R_{ij,smr} = \frac{d^{-\eta^R_s}_{ij,smr}}{\sum_\rho d^{-\eta^R_s}_{ij,sm\rho}}, \qquad d_{ij,sm} = \left(\sum_r d^{-\eta^R_s}_{ij,smr} \right)^{-1/\eta^R_s}$$

- high η^R_s: sea routes are close substitutes

  $\rightarrow$ ships pick the cheapest way; Suez vs. Cape is about cost

Local congestion and global capacity

Local congestion:



→ Route usage ↑ → costs ↑

Global capacity constraints:



→ Route length ↑ → costs ↑

Congestion and capacity constraints

- Freight is a share χ_s of delivered cost; route cost has four parts:

$$d_{ij,smr} = \underbrace{\bar{d}_{ij,smr}}_{\text{geography}} \cdot \underbrace{\left(\frac{\Xi_{mr}}{\bar{\Xi}_{mr}}\right)^{\chi_s \lambda_s^R}}_{\text{local congestion}} \cdot \underbrace{\left(\frac{\Psi}{\bar{\Psi}}\right)^{\chi_s \gamma_s^G}}_{\text{global capacity}} \cdot \underbrace{\phi_{mr}^{\chi_s}}_{\text{transit fee}}$$

- Ξ_{mr}: traffic through Suez or Panama

  $\rightarrow$ open-ocean routes do not congest

- Ψ: world sea ton-km

  $\rightarrow$ longer routes tie up ships and raise freight rates everywhere



Endogenous transit fees

- Authority q (Suez, Panama; Hormuz in a counterfactual) sets fee ϕ_q on freight
- Maximises revenue, taking other fees as given:

$$\max_{\phi_q \geq 1} \Pi_q = \sum_{i,j,s} \left(1 - \phi_q^{-\chi_s}\right) X_{ij,s,q}$$

  $\rightarrow$ $X_{ij,s,q}$: trade through q

- Higher fee pushes cargo to other routes, then modes, then origins
- Revenue accrues to the country collecting it (Egypt, Panama, Iran and Oman)



Endogenous transit fees: intuition

- Short route S with fee F, long route L without; trade T fixed

$$\pi_S^R(F) = \frac{(d^S + F)^{-\eta}}{(d^S + F)^{-\eta} + (d^L)^{-\eta}}, \qquad \text{revenue} = F\,\pi_S^R(F)\,T$$

- With $d^S = 0$ and $\eta > 1$: $\quad F^\star = d^L\,(\eta - 1)^{-1/\eta} \longrightarrow d^L$ as $\eta \to \infty$

  $\rightarrow$ fee captures the cost advantage of the short route

  $\rightarrow$ closure destroys mainly this rent, not shippers' surplus

- Outside option sets the fee: the Cape for Suez, nothing for Hormuz

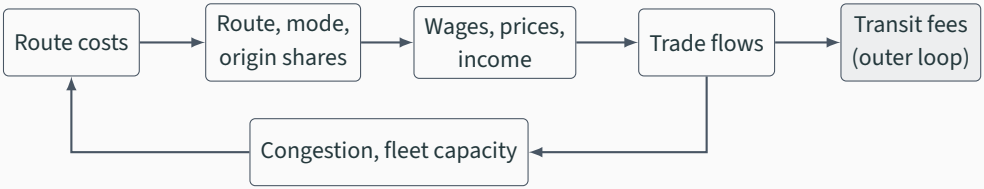


Solving the model

- Exact hat algebra (Dekle, Eaton and Kortum 2008)

  $\rightarrow$ baseline: GTAP 11 flows, observed route and mode shares, elasticities

- Shock: closed route ($\bar{d} \rightarrow \infty$) or a new transit fee



- Welfare: change in real income, $\hat{W}_j = \hat{I}_j / \prod_s \hat{P}_{j,s}^{\alpha_{j,s}}$

Calibration

Calibration

Accounts	GTAP 11: 160 countries, 65 sectors, 2017
Route shares	Container: AIS trips; bulk, energy and pairs without trips: shortest sea paths across port pairs, weighted by tanker/bulk port calls and distance$^{-1.5}$
Mode shares	BACI 2022 HS6 flows by predicted mode, summed to pair $\times$ sector
Trade elasticities θ_s	Fontagné et al. (2022)
Mode elasticities η_s^M	Ko et al. (2026): 0.7–9.7; pooled 2.87
Freight shares χ_s	Sector-specific; trade-weighted mean $\simeq$ 0.09
Route congestion λ_s^R	0.135, canal routes only
Fleet capacity γ_s^G	0.44, on sea ton-km
Latent Cape ρ	0.22, from pairs using both Suez and the Cape



Canal revenues

Match Suez revenue with $\eta_S^R = 250$.

	Model revenue	Observed revenue	Fee ϕ
Suez	\$10.2bn	\$10.25bn (2023)	1.28
Panama	\$3.0bn	\$3.18bn (2024)	1.14

- Only Suez revenue is targeted; Panama revenue is an out-of-sample check



Counterfactuals

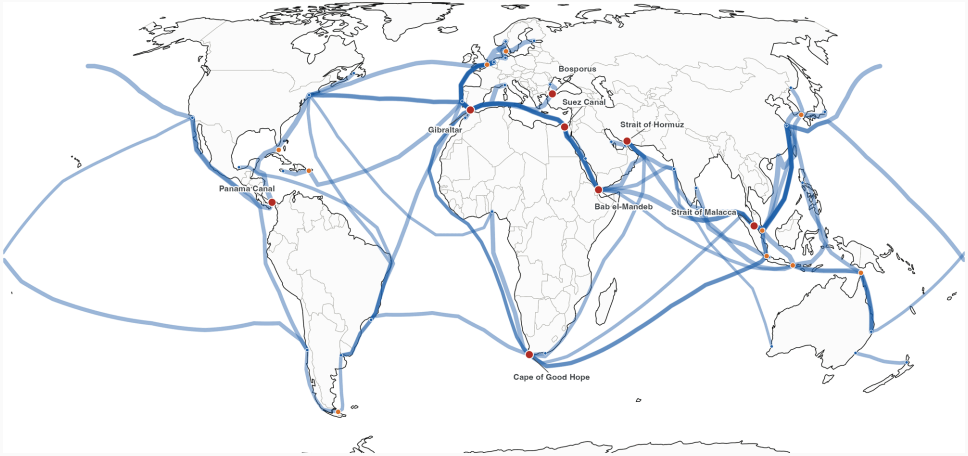
Counterfactuals

- **Red Sea**: permanent closure of the Suez route
- **Hormuz**: transit fee of 5%, 35% or 50% of exposed freight

  $\rightarrow$ revenue split equally between Iran and Oman
- Suez and Panama fees stay at calibrated values
- Static equilibria after rerouting; no recovery dynamics

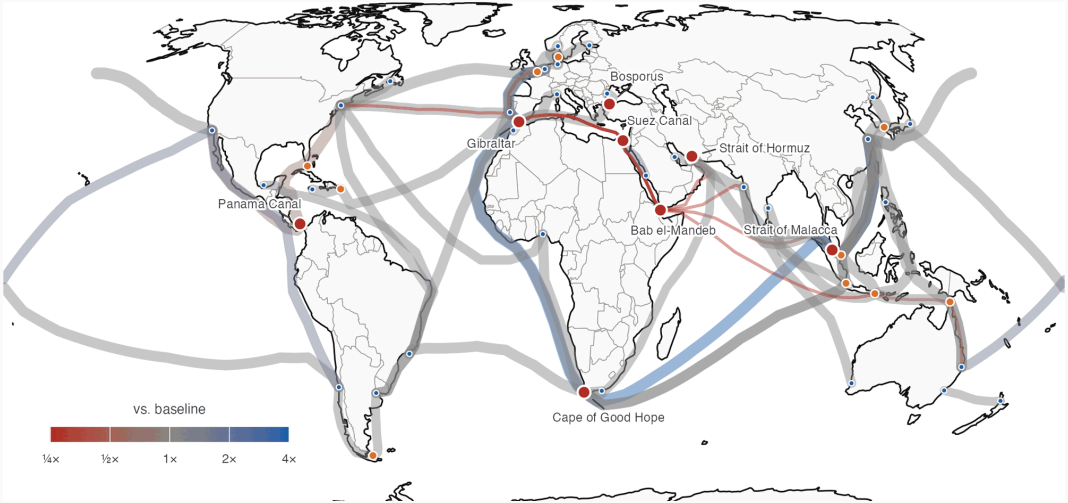


Baseline: container routes

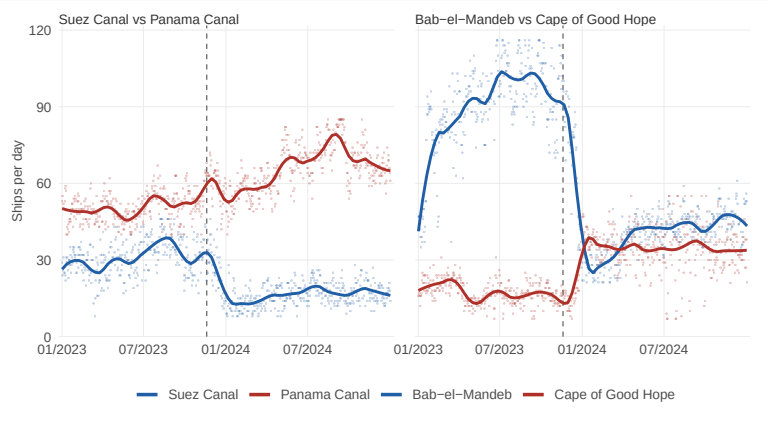


Container shipping routes from AIS vessel tracks (Kiel Trade Indicator).

Red Sea closure: rerouting

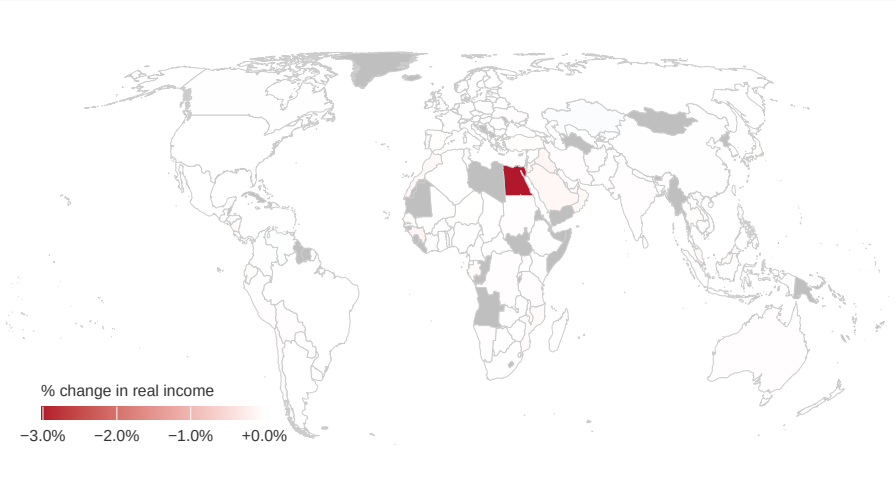


Red Sea crisis: observed rerouting

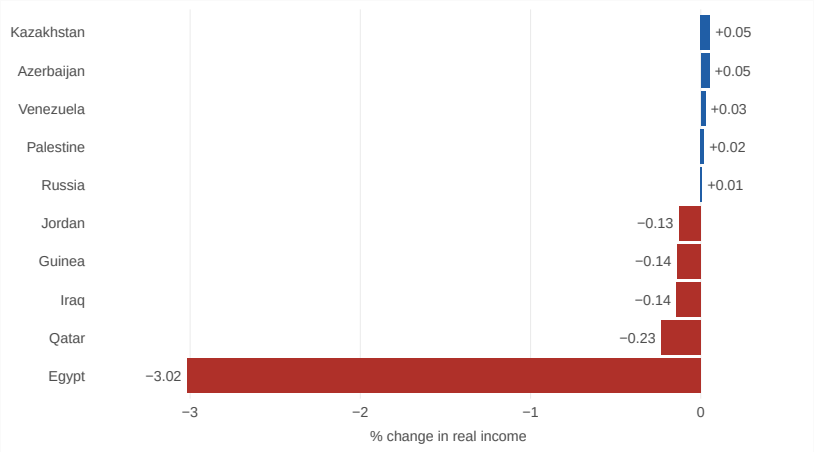


AIS ship counts per day, 2023–2024. Model: 62% of lost Suez traffic shows up at the Cape (AIS: 38%).

Red Sea closure: welfare map

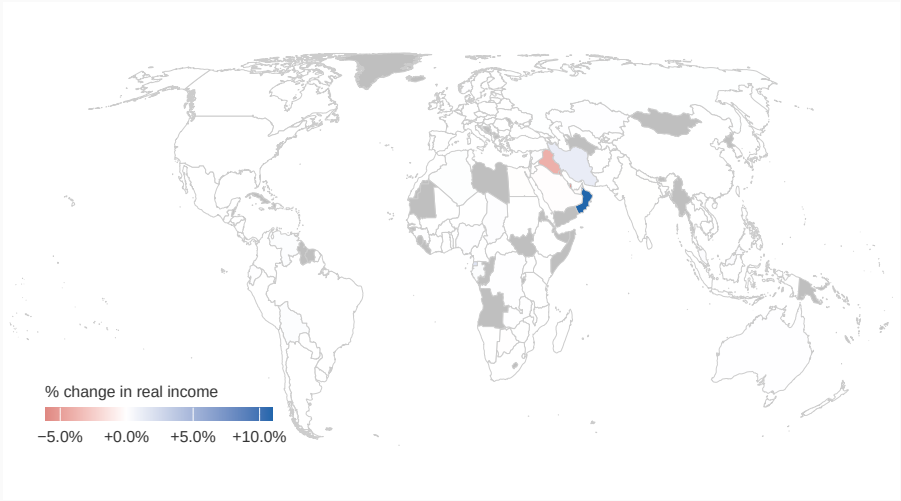


Red Sea closure: welfare

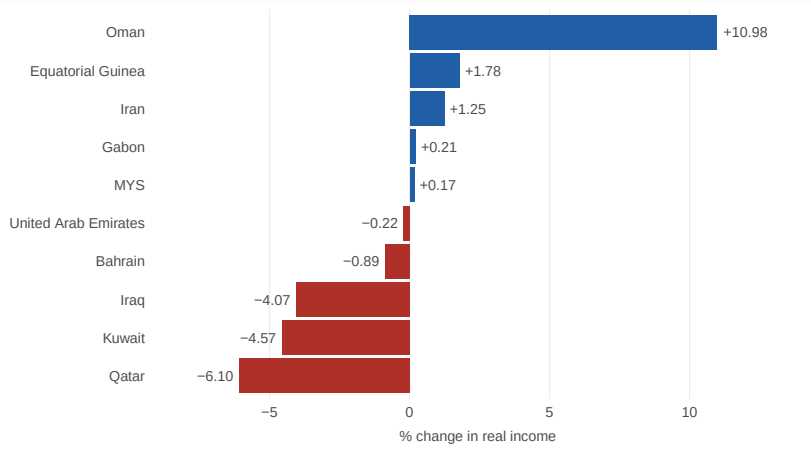


Not shown: Haiti, Congo, Mongolia, Brunei (trade surplus $>$60% of value added, income near zero).

Hormuz fee: welfare map

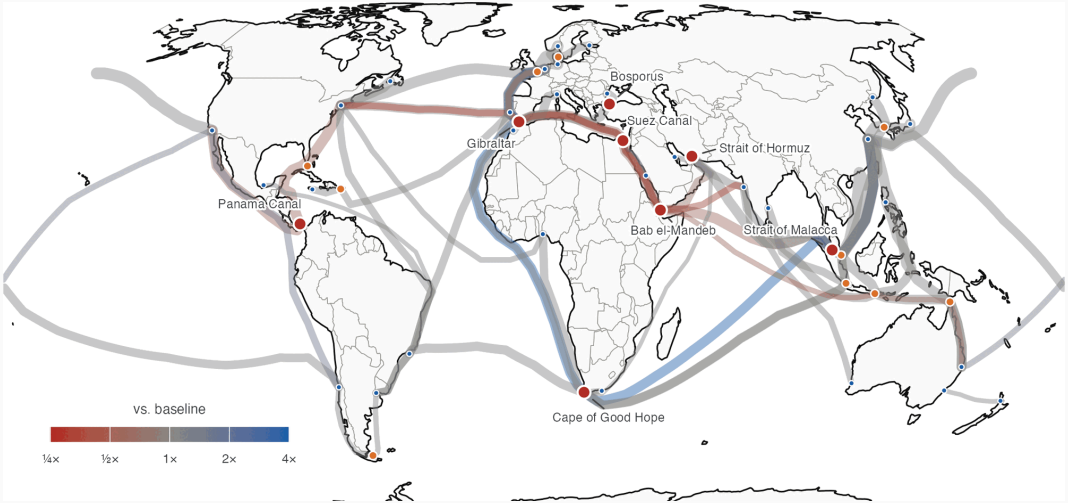


Hormuz fee: welfare



Not shown: Haiti, Congo, Mongolia, Brunei (trade surplus $>$60% of value added).

Hormuz fee: rerouting



Hormuz fee: trade and revenue

Freight surcharge	5%	35%	50%
Hormuz-transiting trade	−30.8%	−65.5%	−71.0%
Toll revenue	$4.1bn	$12.9bn	$14.7bn

- Revenue flattens between the 35% and 50% fees



Conclusion

Takeaways

- Maritime chokepoints are *heterogeneous*
- Trade between affected pairs recovers within months

  → the Cape is not that costly when it also avoids a toll
- Welfare effects cannot be read off transit volumes

  → Red Sea: losses concentrate on Egypt, the toll collector

  → Hormuz: a toll without alternatives falls on the economies behind it



Next steps

- **Ports**: choice across port pairs with port congestion

  → e.g. Gulf exports via Fujairah, Sohar or Yanbu

- **Fleet capacity by segment**: container, dry bulk, tanker
- **Land routes**: China–Europe rail, Middle Corridor through Turkey
- **Route distances by leg**, from AIS sailings
- **Validation**: model vs observed rerouting, ton-miles, freight rates



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Appendix

Backup — Equilibrium in changes

$$\hat{c}_{j,s} = \hat{w}_j^{\beta_{j,s}} \prod_k \hat{P}_{j,k}^{\gamma_{j,ks}}, \qquad \hat{P}_{j,s}^{-\theta_s} = \sum_i \pi_{ij,s}^{X} \left(\hat{c}_{i,s}\, \hat{\kappa}_{ij,s}\, \hat{d}_{ij,s}\right)^{-\theta_s},$$

$$\hat{\pi}_{ij,s}^{X} = \left(\hat{c}_{i,s}\, \hat{\kappa}_{ij,s}\, \hat{d}_{ij,s} / \hat{P}_{j,s}\right)^{-\theta_s}, \qquad \hat{d}_{ij,s}^{-\eta_s^M} = \sum_m \mu_{ij,sm} \left[\sum_r \pi_{ij,smr}^{R}\, \hat{d}_{ij,smr}^{-\eta_s^R}\right]^{\eta_s^M/\eta_s^R}$$

$$\text{Real income: } \hat{W}_j = \frac{\hat{I}_j}{\prod_s \hat{P}_{j,s}^{\alpha_{j,s}}}$$

- Nested fixed point: prices and output $\rightarrow$ wages $\rightarrow$ congestion Ξ and capacity Ψ $\rightarrow$ tolls
- Baseline shares from GTAP 11; no levels of T, L or d needed

Backup — Latent Cape route

- In changes, a route with zero baseline share never gains share

  $\rightarrow$ pairs using Suez but never the Cape: no route after a closure

- Latent Cape route with a notional share:

$$\pi^{R}_{\text{Cape}} = \pi^{R}_{\text{Suez}}\, \zeta_s^{-\eta^R}, \qquad \zeta_s = \left(\frac{km_{\text{Cape}}}{km_{\text{Suez}}}\right)^{\rho\, \chi_s}.$$

- Negligible in the baseline; carries the cargo at cost ζ_s once Suez closes
- ρ from pairs that use both routes: $\hat{\rho} = 0.22$

Backup — Substitution and market power

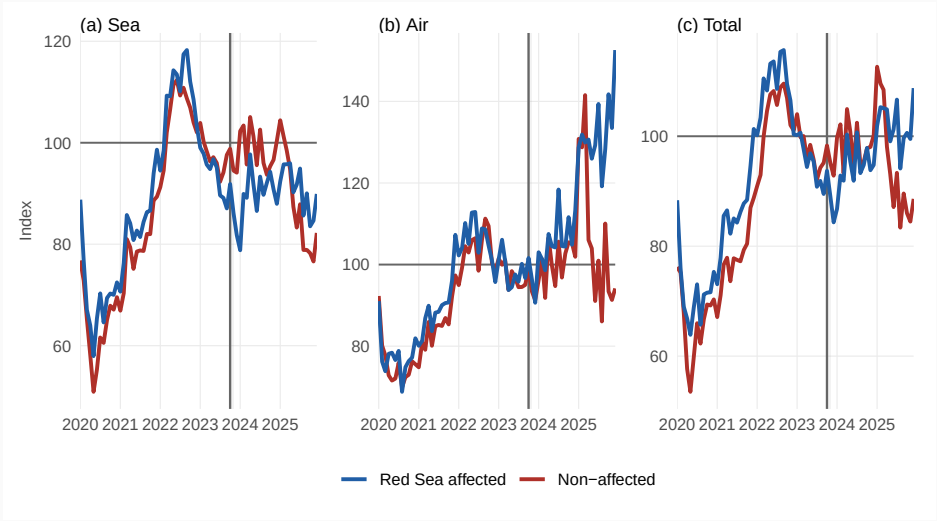
Exposure e_{js} of destination j's spending on s to toll q, in partial equilibrium:

$$\frac{\partial e_{js}}{\partial \ln \phi_q} = -\chi_s \left(\eta_s^R V_R^{js} + \eta_s^M V_M^{js} + \theta_s V_X^{js} \right).$$

- V_R, V_M, V_X: variance of exposure across routes, modes, origins
- $\eta^R \gg \eta^M, \theta$: a substitute route disciplines the toll

  $\rightarrow$ no substitute route ($V_R = 0$, Hormuz): much higher market power

Backup — Trade by mode and Red Sea exposure



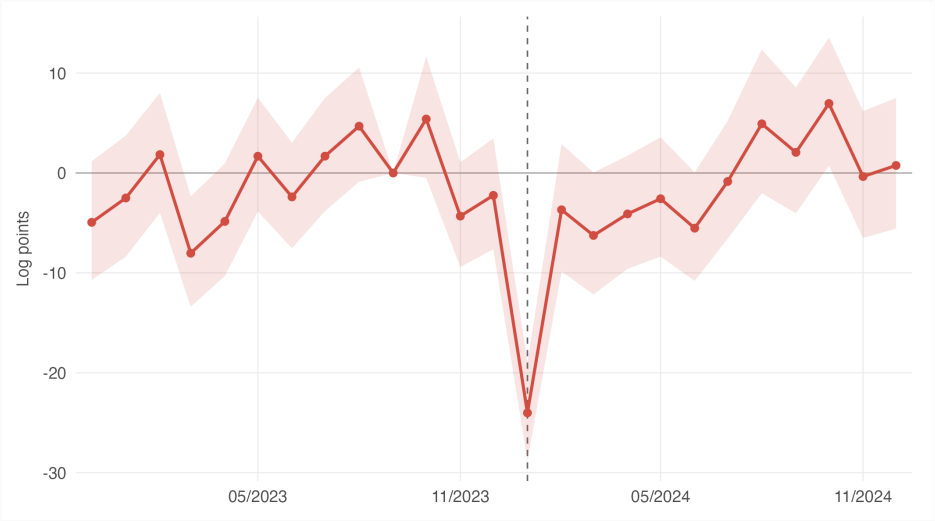
Backup — Exposure-weighted DiD

$$D_{ij} = \frac{d_{ij}^{c} - d_{ij}^{o}}{9{,}000}, \qquad X_{ijs} = D_{ij} \times \mu_{ij,s}^{sea}.$$

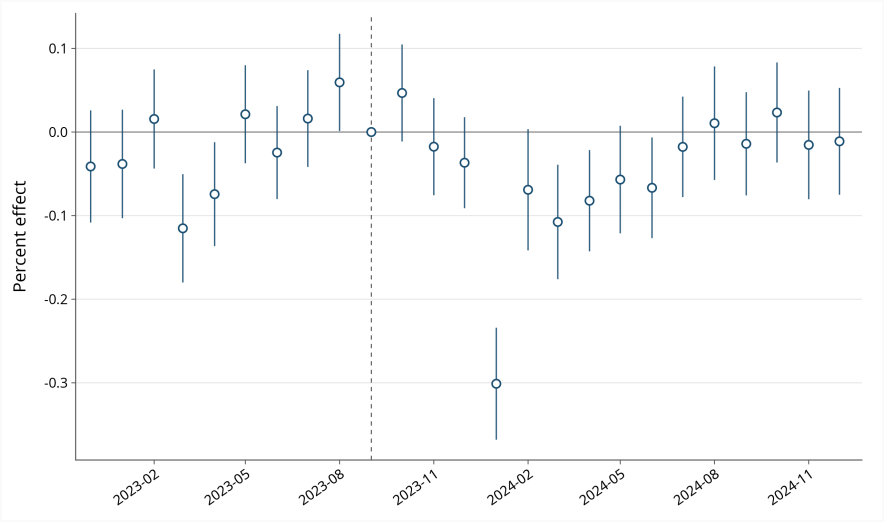
- D_{ij}: extra sea distance if Bab al-Mandab closes, port-pair weighted (Gaffuri 2022)
- $\mu_{ij,s}^{sea}$: predicted sea share from 2022 mode patterns
- Triple difference for β_τ:

$$y_{ijst} = \sum_{\tau \neq -1} \beta_\tau \mathbb{I}\{t = \tau\} \left(D_{ij} \times \mu_{ij,s}^{sea} \right) + \sum_{\tau \neq -1} \theta_\tau \mathbb{I}\{t = \tau\} D_{ij} + \sum_{\tau \neq -1} \lambda_\tau \mathbb{I}\{t = \tau\} \mu_{ij,s}^{sea} + \alpha_{ijs} + \alpha_{jst} + \alpha_{it} + \varepsilon_{ijst}$$

Backup — Trade value: shock and rebound



Backup — Trade quantities



Backup — Substitution across ports

Port pair (p, q) above routes, below modes, for sea trade:

$$\pi^{P}_{ij,spq} = \frac{a_{ij,spq}\, d^{-\eta^{P}_{s}}_{pq,s}}{\sum_{p',q'} a_{ij,sp'q'}\, d^{-\eta^{P}_{s}}_{p'q',s}}, \qquad d_{pq,sr} = \bar{d}_{pq,sr}\,[\dots]^{\chi_s} \left(\frac{\psi_p}{\bar{\psi}_p}\right)^{\nu_s} \left(\frac{\psi_q}{\bar{\psi}_q}\right)^{\nu_s}.$$

- $\eta^{M}_{s} \le \eta^{P}_{s} \le \eta^{R}_{s}$; ψ_p: port throughput, ν_s: port congestion
- Matters with ports on both sides of a chokepoint

  $\rightarrow$ Saudi Red Sea ports; Fujairah and Sohar outside Hormuz
- Prototype: two port groups (inside / outside the Gulf), $\nu_s = 0$

  $\rightarrow$ main model is the case $\eta^{P} = \eta^{R}$

Backup — Port prototype under a Hormuz fee

Real income, %, 35% fee	$\eta^P = \eta^R = 250$	$\eta^P = 50$	$\eta^P = 10$
Saudi Arabia	−0.09	−0.66	−1.09
United Arab Emirates	−0.22	−0.62	−0.97
Qatar	−6.10	−6.23	−6.32
Iran	1.25	1.54	2.63
Oman	10.98	14.68	23.21

- Lower η^P: Gulf exporters switch less easily to ports outside the strait
- No port congestion yet

  $\rightarrow$ Oman's gain is an upper bound

Backup — Sea ton-km under the Red Sea closure

Suez share of sea value	8.4%
Suez share of sea ton-km	4.0%
Rerouting, trade held fixed	$+3.0\%$
Less trade	-0.9%
Change in sea ton-km	$+1.8\%$

- Diverted cargo sails farther: China–Germany 20,450 vs 26,790 km
- Less trade offsets part of the longer voyages
- Suez cargo is light per dollar

  $\rightarrow$ ton-km share below value share

Backup — Where Suez traffic goes

	AIS ship counts, 2024	Model, permanent closure
Red Sea / Suez traffic	−63%	−100%
Cape traffic	+191%	+55%
Lost Suez traffic that shows up at the Cape	**38%**	**62%**

- Diversion rate does not depend on how complete the closure is
- Cape percentages differ: model's Cape baseline includes bulk trade Brazil/West Africa → Asia
- Panama data reflect the 2023 drought recovery; no clean comparison

AIS: Kiel Trade Indicator ship counts; 2024 average vs. Sep–mid-Nov 2023.

Backup — How ships kept crossing

- Some operators kept using the Red Sea throughout the crisis
- War-risk insurance premia for Red Sea transits rose sharply in 2024
- Reports: ships linked to particular countries not targeted
- Wall Street Journal (2026): shippers email the Houthis before they cross

  $\rightarrow$ model: one average cost of the Suez route; no selection by ship or flag