Geopolitical Risk and Foreign Dependence in Global Shipping

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NBER Summer Institute 2026 — International Trade & Investment

Cambridge, MA · July 13–15, 2026

Maritime transport is a critical input to global supply chains and international trade

- $\sim$80% of world trade by volume moves by sea (UNCTAD 2024): maritime routes are the backbone of physical trade.
- Maritime geography and scale economies concentrate flows on a small set of routes and chokepoints; fleet ownership and operations are also concentrated.
- Concentrated flows create large exposure to individual network segments; geographic and ownership concentration create geopolitical leverage. Together, they can create **absolute vulnerabilities**.

Control over maritime access is a source of economic power

- Vulnerability arises from *asymmetries* (Hirschman, 1945): when one country relies on a segment disproportionately more than another, that dependence makes it vulnerable to **strategic disruptions**.

This paper asks:

1. **[Measurement with Theory]** How large and asymmetric is foreign dependence across global shipping routes and fleets?
2. **[Quantitative]** What are the welfare effects from disruptions?

This Paper: When Shipping Exposure Becomes Vulnerability

1. **Sufficient statistic for maritime vulnerability** Generalizes Allen, Fuchs, & Wong (2025) to an N-country maritime-vulnerability statistic.
   - **Absolute vulnerability**: to first order, a disruption's cost is *the value of the traffic it touches*:

$$\underbrace{\mathcal{W}_{m,g}}_{\text{welfare cost of } g} \approx \text{traffic} \times \text{disruption} + \text{ToT}$$

   - **Relative vulnerability**: geopolitics — Foreign disrupts when Home's harm outweighs its own cost:

$$\mathcal{V}_{H,F} = \frac{\text{Home welfare loss}}{\text{Foreign welfare loss}} \approx \frac{\text{Home traffic} \times \text{disruption} + \text{ToT}}{\text{Foreign traffic} \times \text{disruption} + \text{ToT}}$$

2. **New data: exposure and disruption**
   - **Exposure.** Vessel characteristics and port rotations yield directed lane traffic and country footprints.
   - **Disruption.** Local closures measure bypass costs; builder and operator links measure service withdrawals.
3. **Quantitative U.S.–China evaluation**
   - **Model.** Spatial equilibrium with endogenous routing, fleet rentals, operator supply, and producer-price incidence.
   - **Scenarios.** Geographic closures, service withdrawals, and policy fees.
4. **Findings**
   - **Exposure $\times$ disruption.** Neither alone is absolute vulnerability: high-exposure lanes can have small cost responses, while readily disrupted locations may carry little valuable traffic.
   - h China Sea

Contribution: Put Foreign Control Into Quantitative Shipping Networks

Transport networks in spatial equilibrium

Head & Mayer (2014), Allen & Arkolakis (2014, 2022), Fajgelbaum & Schaal (2017, 2020), Fan, Lu & Luo (2021), Jaworski, Kitchens & Nigai (2023), Bonadio (2022), Cosar & Fajgelbaum (2016), Cosar & Demir (2016), Cosar & Thomas (2021), Tsivanidis (2022), Kreindler & Miyauchi (2022), Miyauchi, Nakajima & Redding (2022), Almagro, Barbieri, Castillo, Hickok & Salz (2022), Fuchs & Wong (2024), Allen, Fuchs & Wong (2025).

⇒ We combine **endogenous transport demand** and **foreign-controlled transport supply** in a spatial GE shipping network.

Shipping and maritime trade

Kalouptsidi (2014), Brancaccio, Kalouptsidi & Papageorgiou (2020), Heiland, Moxnes, Ulltveit-Moe & Zi (2023), Chowdhry, Heiland & Mahlkow (2026), Ganapati, Wong & Ziv (2022), Wong (2022), Brooks, Gendron-Carrier & Rua (2018), Ducruet, Notteboom & Rodrigue (2020), Notteboom & Rodrigue (2008, 2011), Barwick, Kalouptsidi & Zahur (2024, 2025), Shapiro (2016), Lugovskyy, Skiba & Terner (2022), Feyrer (2009, 2011), Hummels & Schaur (2013), Dunn & Leibovici (2025).

⇒ We measure lane-level strategic exposure, geographic bypass difficulty, and operational service shares.

Geoeconomics, asymmetric dependence, and resilience

Hirschman (1945), Keohane & Nye (1977), Baldwin (1985), Farrell & Newman (2019, 2023), Blackwill & Harris (2016), Clayton, Maggiori & Schreger (2023, 2024), Mohr & Trebesch (2025), Antràs (2020), Antràs & Chor (2022), Bonadio, Huo, Levchenko & Pandalai-Nayar (2021), Grossman, Helpman & Lhuillier (2023), Javorcik (2024).

⇒ We show how **geopolitical incentives** can turn **asymmetric dependence** in transport networks into welfare vulnerability.

SECTION 1

Sufficient-Statistic Analysis of Vulnerability

Setup: Efficient Baseline

Setup

- **Geography.** Locations $i \in \mathcal{N}_m$ partition into countries m. Each location has productivity A_i and amenity u_i.
- **Demand.** CES demand maps delivered prices $p_o \tau_{od}$ into $X_{od} = \lambda_{od} Y_d$.
- **Production.** Output is linear in local labor, $Y_i = A_i L_i$.
- **Mobility.** Workers move within countries until local welfare is equalized, $W_i = W_m$ for all $i \in \mathcal{N}_m$.

Competitive transport sector

- **Transport supply.** Competitive firms rent fleet capacity and supply edge services; market-clearing rentals and service prices determine equilibrium edge costs κ_e.
- **Cost-minimizing routing.** Given κ, firms choose edge use x to minimize o-to-d delivery costs:

$$C_{od}(x;\kappa) = \sum_e \kappa_e x_e, \qquad \tau_{od}(\kappa) = \min_{x \in \mathcal{R}_{od}} C_{od}(x;\kappa),$$

  where x_e is use of edge e per unit shipment and $\mathcal{R}_{od}$ is the feasible route set.
- **Routing envelope.** $\zeta_{od,e} = \partial \log \tau_{od} / \partial \log \kappa_e = \kappa_e x^*_{od,e} / \tau_{od}$: edge e's cost share on the optimized route.

Welfare Cost: Exposure Times Disruption Elasticity

To first order, derive country m's welfare elasticity to disruption g.

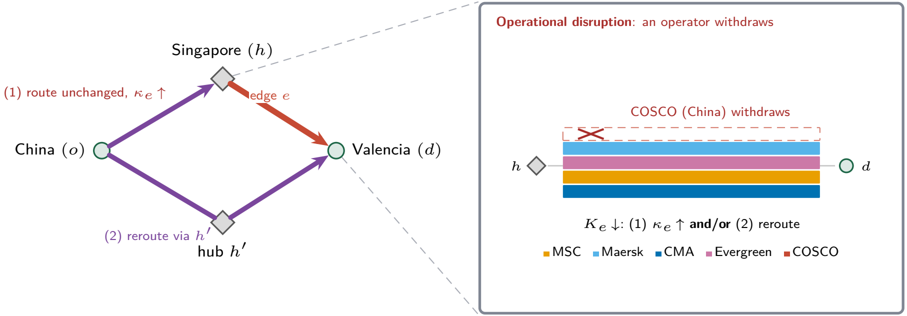
$$\mathcal{W}_{m,g} = \underbrace{\sum_e \underbrace{\Xi^X_{m,e}}_{\text{traffic exposure}} \underbrace{\phi_{e,g}}_{\text{disruption elasticity}}}_{D_{m,g}\ \text{(direct loss)}} + \underbrace{\mathcal{T}_{m,g}}_{\text{GE/ToT incidence}} .$$

- **Exposure.** $\Xi^X_{m,e}$ aggregates baseline expenditures by their optimized loading on edge e.
- **Disruption elasticity.** $\phi_{e,g}$ is the scenario-specific response of edge cost κ_e.
- **Envelope logic.** Consumer and carrier reoptimization creates no separate first-order term; baseline expenditures and route loadings suffice.
- **Price incidence.** $\mathcal{T}_{m,g}$ captures the welfare effect of equilibrium producer-price movements.

Disruptions Raise Lane Costs Through Three Channels

A disruption g raises edge costs; $\phi_{e,g} = \partial \log \kappa_e / \partial d_g$ is the lane's cost response

1. **Geographic disruption** (ϕ^{geo}): a chokepoint closure lengthens the route.
2. **Operational disruption** (ϕ^{op}): a carrier or fleet partition withdraws capacity.
3. **Policy**: sanctions or fees add a cost wedge.



Operational — disrupted: a carrier (COSCO) withdraws $\Rightarrow K_e \downarrow$: *(1)* effective $\kappa_e \uparrow$ with route unchanged **and/or** *(2)* demand reroutes via h'.

Geopolitics: Disruption Is Chosen When Home Loss Is Cheap

Foreign compares the welfare effects under the two regimes.

$$\mathcal{V}_{H,F,g} \approx \frac{\sum_e \Xi^X_{H,e}\,\phi_{e,g} + \mathcal{T}_{H,g}}{\sum_e \Xi^X_{F,e}\,\phi_{e,g} + \mathcal{T}_{F,g}}.$$

- **Open.** Trade remains at baseline route costs and transport capacity.
- **Disrupt.** Scenario g closes a corridor, withdraws capacity, or imposes a policy wedge, shifting lane costs κ_e.
- **Political shock χ.** $\chi \sim F_\chi$ is Foreign's political value of one unit of harm to Home.
  Costly sanctions and conflict objectives: (Eaton and Engers, 1992; Becko, 2024; Bianchi and Sosa-Padilla, 2024).
- **Cutoff.** A lower $\chi^\star_{H,F,g}$ — equivalently, a higher $\mathcal{V}_{H,F,g}$ — means greater **vulnerability**.
- **Welfare substitution.** Under a common disruption, vulnerability compares Home and Foreign exposure and GE/ToT incidence.

SECTION 2

Measuring Vulnerability

The sufficient statistic points to two measured objects on each lane

$$\mathcal{V}_{H,F,g} = \frac{\overbrace{\sum_e \Xi^X_{H,e}\,\phi_{e,g} + \mathcal{T}_H}^{\mathcal{W}_{H,g}\ \text{(Home welfare cost)}}}{\sum_e \Xi^X_{F,e}\,\phi_{e,g} + \mathcal{T}_F} \rightsquigarrow \underbrace{\frac{\Xi^X_{H,e}}{\Xi^X_{F,e}}}_{\text{strategic exposure ratio}} \times \underbrace{\frac{\phi_{H,e,g}}{\phi_{F,e,g}}}_{\text{disruption-elasticity ratio}}$$

Four measurement steps

1. **Absolute exposure.** Construct country–lane traffic $\Xi^X_{m,e}$ from vessel registries and port rotations.
2. **Strategic exposure.** Compare country-specific traffic exposure, $\Xi^X_{H,e}/\Xi^X_{F,e}$.
3. **Geographic disruption.** Close route cells and measure detour costs after rerouting.
4. **Operational disruption.** Use builder and operator shares to measure withdrawable capacity.

Data: Vessel Rotations Build the Lane Network

Containership Registry and Rotations

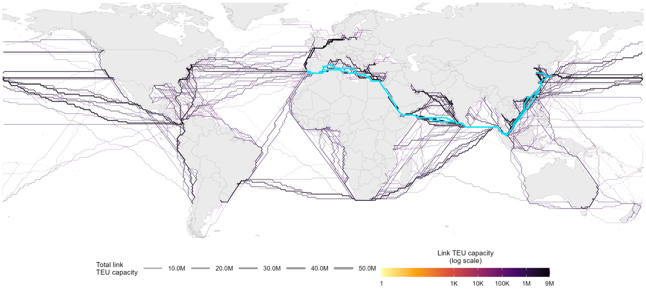
- **Containership registry**: builder, operator, TEU capacity, year of build, and IMO identifier.
- **Port rotations**: scheduled port calls for the active containership fleet.

Lane construction

- Each rotation $\Rightarrow$ directed edges between consecutive port calls (e.g. MSC Irina).
- **Traffic on each directed lane e:**

$$\Xi_e^{\text{TEU}} = \sum_{\text{vessels on } e} \text{Vessel TEU} \times \text{trips per year}$$

- Coverage: 196 ports, 82 countries, 1,375 lanes.



Directed port-to-port lanes; color = TEU capacity (log scale). Highlighted line: MSC Irina, $24{,}346$ TEU. — **Data:** ship registry.

With each port call, a country is exposed to the rest of the vessel's connected lanes $\Rightarrow$ country-lane traffic exposure $\Xi_{c,e}$

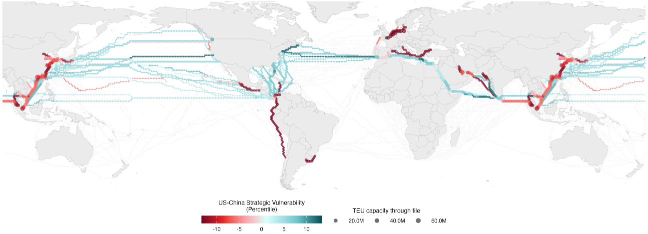
Country-Lane Traffic Exposure Runs Through Gateways, Hubs, and Partners

Construction

- **Absolute traffic exposure.** Identify rotations visiting country c; their annual capacity on lane e gives $\Xi_{c,e}$.
- **Trade allocation.** Allocate country trade across connected lanes proportional to TEU capacity (heuristic).
- MSC Irina serves East Asia–Europe, exposing each country on its rotation to the service's connected lanes.

From absolute to strategic exposure

- **U.S. exposure.** Trans-Pacific, North Atlantic, and lanes touching the U.S.
- **China exposure.** Intra-East-Asian hubs and Asia–Europe trunk routes.
- **Strategic exposure.** $\Delta\Xi_e^{US-CN} = \text{Pct}(\Xi_{US,e}) - \text{Pct}(\Xi_{CN,e})$; blue is more U.S.-exposed and red more



Route-cell color = U.S. minus China exposure-percentile gap; blue = more U.S.-exposed, red = more China-exposed. — **Data:** vessel rotations.

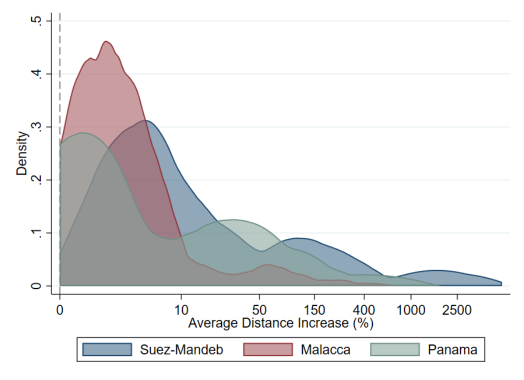
Traffic Does Not Predict Bypass Difficulty

Measure. Geographic bottleneck = traffic-weighted route-distance increase under local closure.

Detour evidence

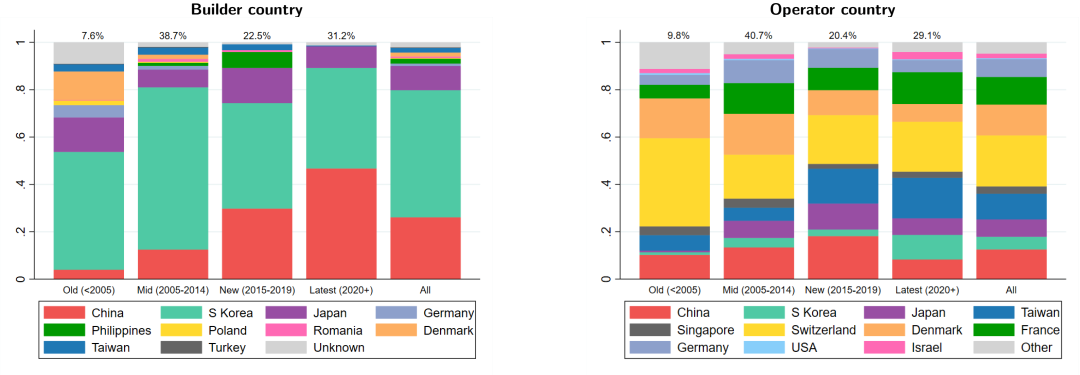
- **Severity.** Average distance increases: Suez/Red Sea 121%, Gibraltar 37%, Panama 29%, Malacca 18%.
- **Independence.** Traffic and detour severity are nearly uncorrelated (corr -0.15 raw, ≈ 0 with port FEs).

Stylized Fact 2: Traffic does not reveal bypass difficulty. Costly detours are concentrated at a small set of maritime chokepoints.



Distribution of mean route-distance increases under local closures; colored groups are major-chokepoint lanes. — **Data:** observed rotations.

Operational Control: Who Builds and Operates Capacity



- **CN & SK build ≈80% of global capacity**; top-3 operators run ≈49%, while **72% of Chinese-built volume is operated by non-Chinese carriers**.
- Containerships are long-lived (20–30 years): **since 2020, CN+SK build ≈90% of capacity** (CN 46%, KR 41%).
- East Asian operators (CN, KR, JP, TW) **more than double their share among the latest ships: 19% → 43%**.

eet.

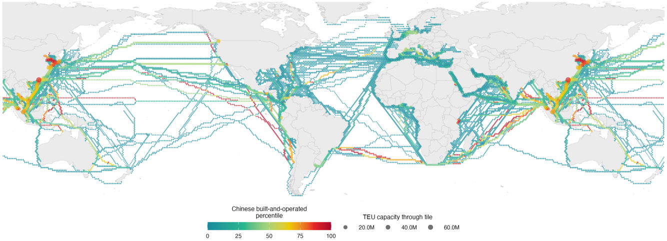
Chinese Operational Control Concentrated on China-Adjacent Routes

Construction

- Focus on Chinese dominance in shipping
- Operational Control_e: share of services from ships that are Chinese-built, -operated, or both.

Operational service shares

- **Builder share.** Chinese-built capacity is spread through the global container network.
- **Operator share.** Chinese-operated capacity is more concentrated on China-adjacent routes.



Hex color = Chinese-built and -operated share percentile; darker red = larger share. — **Data:** ship registry.

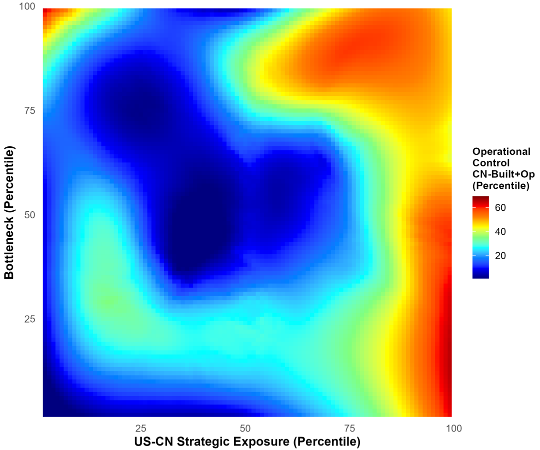
Stylized Fact 4: Chinese Operational Control. Chinese-built ships and operators are heavily concentrated on routes closer to China.

Combining Strategic Exposure, Bottlenecks, and Operational Control

Where do these vulnerability margins align?

- **X-axis.** Strategic exposure: right = more strategically important to China.
- **Y-axis.** Geographic bottlenecks: up = a larger route-cost increase under closure.
- **Color.** Operational control: redder = a higher Chinese built-and-operated service share.
- All 3 align in top-right quadrant: Lanes most strategically vulnerable for China (right), hard to bypass (top), are heavily Chinese-controlled.

Stylized Fact 5: Exposure and disruptions align. Links that are severe bottlenecks and strategically more vulnerable for China rel to U.S. have higher Chinese operator and built presence.



Color = Chinese built-&-operated TEU-share pct over the exposure-gap (x) ×
essel registry,

SECTION 3

Quantitative Model

Same geography and demand structure as the sufficient-statistic setup

- **Geography.** Directed transport graph; countries contain locations/ports; labor moves within countries.
- **Demand.** CES Armington demand maps delivered prices $p_o \tau_{od}$ into trade values X_{od}.
- **Supply & welfare.** Competitive production and mobility deliver one country welfare index W_m, with **congestion/agglomeration externalities**.

Transport layer: demand, supply, and edge costs

- **Transport demand.** Recursive routing (Fuchs and Wong, 2024) maps edge costs into route access and traffic:

$$T_{ij} = \mathbf{1}\{i = j\} + \sum_{k \in N^+(i)} \kappa_{ik}^{-\theta} T_{kj}, \qquad \Xi_{ik} = \kappa_{ik}^{-\theta} \mathcal{P}_i \mathcal{Q}_k.$$

- **Transport supply and edge costs.** Fleet capacity is rented at ρ_n and combined in CES nests; free entry prices edge services at unit cost:

$$\kappa_e = \bar{\kappa}_e \left[1 + \frac{G_e(\rho) + \bar{c}_e}{v_e} \right].$$

Equilibrium

- **Aggregate equilibrium.** Goods and labor markets clear; income equals expenditure.
- **Transportation equilibrium.** Edge services clear, $S^S = S^D = \Xi_e / v_e$; fleet rentals clear.

SECTION 4

Quantitative Analysis

Quantification: Inputs and Scenario Families

Baseline

- **Network.** 196 ports, 82 countries, 1,375 observed lanes; model graph uses selected lanes plus accounting nodes to close residual trade and income.
- **Solution.** Hat algebra solves for country welfare changes $\widehat{W}_m$ using a sparse Newton solver.
- **Calibration.** Baseline traffic shares Ξ_e, port/country aggregates, local income and labor densities (y_i, l_i), and detailed fleet allocations across space.

Counterfactuals

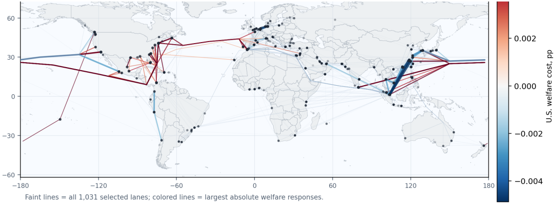
- **Strategic exposure**: raise one lane's route cost and compare U.S. vs. China welfare incidence.
- **Geographic disruption**: close route cells or corridors and allow endogenous rerouting.
- **Operational disruption**: withdraw Chinese-operated, Chinese-built, or jointly exposed capacity.
- **Policy wedge**: impose a stylized fee and compare normal-time costs with disruption-risk reduction.

QUANTIFICATION

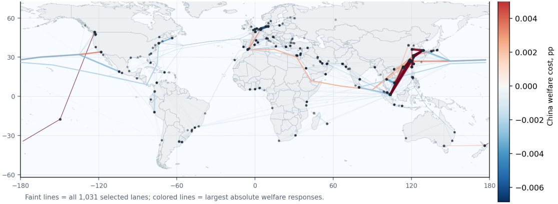
Strategic Exposure (Ξ)

Experiment

- Raise each international lane cost by 10%, one lane at a time.
- Solve the global equilibrium after each shock.



Lane color = U.S. welfare cost (pp); width ∝ baseline traffic. — **Model:** $+10\%$ single-edge shock.



Lane color = China welfare cost (pp); width ∝ baseline traffic. — **Model:** same shock.

Results

- **U.S.** Losses center on North American gateways and ocean crossings.
- **China.** Losses center on East Asian hubs and the Asia–Europe corridor.
- **Network propagation.** Distant lanes matter through rerouting and equilibrium prices.

Relative Exposure Separates U.S. and Chinese Shipping Routes

Experiment

- Raise one international lane cost by 10%.
- Use relative welfare cost to measure strategic exposure and vulnerability.

Results

- **China.** East Asian corridors.
- **U.S.** North American gateways.
- Exposure extends beyond bilateral routes.

Lane color = China minus U.S. welfare cost (pp); faint = all lanes, width $\propto$ baseline traffic. — **Model:** $+10\%$ single-edge route-cost shock.

GE/ToT Effects Often Offset Exposure

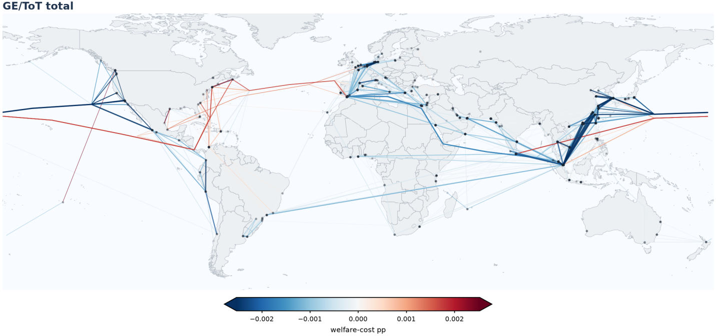
Experiment

- Increase each international lane cost by 10%, one at a time, and re-solve GE.

$$\mathcal{W}^{\text{full}}_{j,g} = \underbrace{D_{j,g}}_{\text{direct}} + \underbrace{\mathcal{T}_{j,g}}_{\text{GE/ToT}} + \underbrace{R_{j,g}}_{\text{residual}} .$$

Results

- **Direct exposure.** Losses concentrate at major U.S. gateways and their transoceanic connections.
- **GE/ToT incidence.** GE and terms-of-trade adjustment often offset the direct effect.



First-order U.S. GE/terms-of-trade incidence from the same lane shocks. — **Model:** local decomposition of the counterfactual solver.

QUANTIFICATION

Geographic Vulnerabilities (ϕ^{geo})

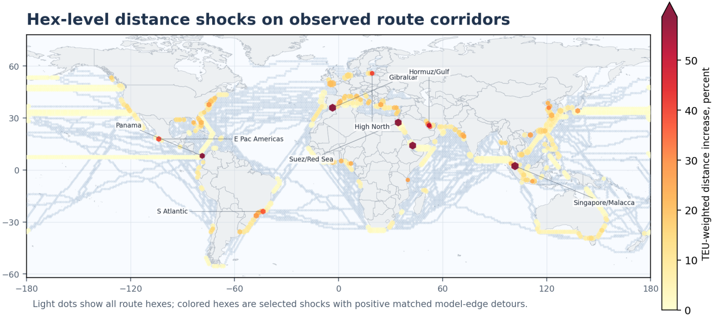
Large Maritime Detours Are Rare and Concentrated at Chokepoints

Experiment

- Shock edges underlying each geographic hexagon, one at a time.
- Recompute equilibrium for each counterfactual.
- 970 hex closures, 10,354 lane shocks.

Results

- Most closures allow nearby rerouting.
- Large detours cluster at chokepoints.
- Severe shocks have limited bypasses.

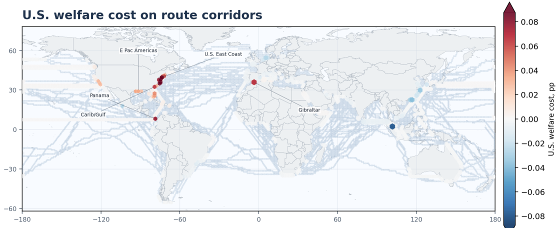


Hex color = TEU-weighted % rise in shipping distance when that hex's segments close; light dots = all route hexes. — **Model:** single-hex route closures.

Local Route Closures Create Different U.S. and China Hotspots

Experiment Close each route hex and re-solve GE with rerouting, substitution, and price adjustment.

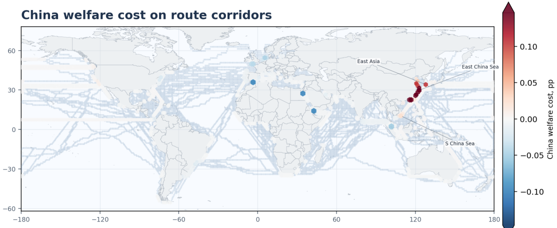
U.S. welfare cost on route corridors



Light dots show observed route corridors; colored hexes are solved local shocks. Red means larger U.S. welfare cost.

Hex color = U.S. welfare cost (pp). — **Model:** single-hex route closures.

China welfare cost on route corridors



Light dots show observed route corridors; colored hexes are solved local shocks. Red means larger China welfare cost.

Hex color = China welfare cost (pp). — **Model:** same closures.

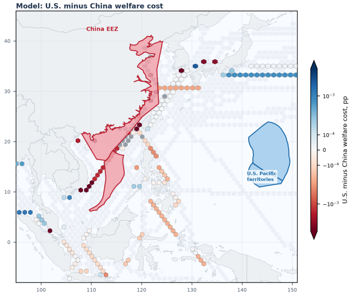
Results

- **U.S.** Losses peak near East and Gulf Coast approaches.
- **China.** Losses peak along East Asian coastal corridors.
- Chokepoint exposure is highly uneven across countries.
  - Morocco loses about 5.9 pp from a Gibraltar closure; Singapore loses about 5.5 pp from a Malacca closure.
  - The worst U.S. case is an East Coast closure, with a welfare cost of about 0.29 pp.

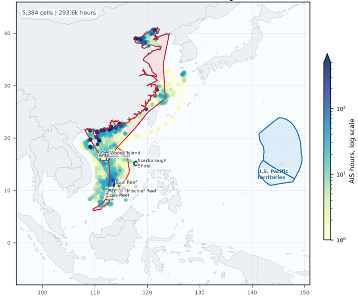
China’s Relative Vulnerability Overlaps Militia Activity in the South China Sea

Experiment Compare U.S.–China welfare differences around China’s EEZ with militia AIS presence. CSIS/C4ADS; Global Fishing Watch

Model-implied strategic vulnerability



Maritime-militia AIS presence



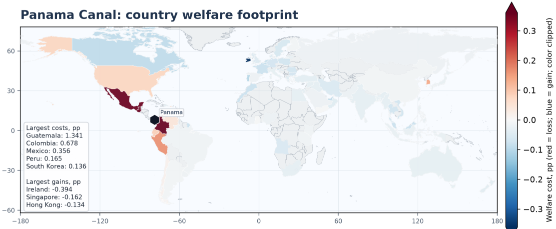
Results

- **Relative vulnerability.** China bears larger welfare costs along South China Sea approaches and parts of the East China Sea.
- **Militia activity.** Militia AIS presence is concentrated in the South China Sea, where China-relative vulnerability is also high.

Chokepoints Create Distinct Global Incidence Patterns

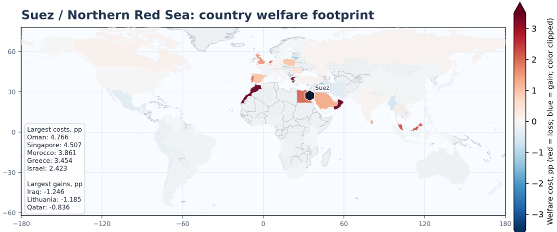
Experiment Select each chokepoint's largest route-distance shock and solve country-level incidence.

Panama Canal: country welfare footprint



Selected hex is the largest TEU-weighted distance increase within the chokepoint (183.1%; 15 affected model edges; 2 candidate hexes).

Suez / Northern Red Sea: country welfare footprint



Selected hex is the largest TEU-weighted distance increase within the chokepoint (117.8%; 88 affected model edges; 5 candidate hexes).

Results

- Panama losses concentrate in the Americas.
- Suez spreads losses across Europe, MENA, and Asia.
- Peak loss: Panama 1.34 pp; Suez 4.77 pp.
- Some third countries gain through reallocation.

QUANTIFICATION

Operational Vulnerabilities (ϕ^{op})

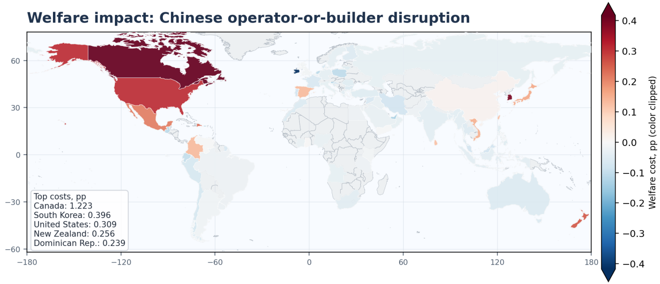
U.S.-Connected Joint Disruption Is a 90% Access Shock

Experiment

- U.S.-connected international edges only.
- Chinese operator or builder access: 10% of baseline.
- Solve the model after the joint shock.

Results

- Joint shock costs the U.S. 0.31 pp.
- Canada loses 1.22 pp; South Korea 0.40 pp.
- Losses extend beyond the U.S.



Country welfare cost: U.S.-connected joint disruption (pp)

A Joint Operator–Builder Fee Reduces Conditional Losses but Raises Total Costs

Experiment

- Motivated by proposed U.S. Section 301 port fees on Chinese-built and Chinese-operated ships.
- On U.S.-connected international edges, apply a 50% fee to Chinese-built or operated fleets.
- Rebate fee revenue to U.S. households.

Results

- Fee is costly during normal times: 0.048 pp.
- It reduces the cost of disruption by 0.035 pp.
- Yet the fee lowers welfare in both states.

U.S. welfare cost (pp)

Policy	Normal	Disruption	Increment
No fee	0.000	0.309	0.309
50% joint fee	0.048	0.322	0.274
Fee minus no fee	0.048	0.013	-0.035

SECTION 5

Conclusion

Conclusion: Exposure Becomes Vulnerability Through Disruption Elasticity

Framework

- A sufficient statistic measures **absolute** and **relative vulnerability**.

Measurement

- The data separate strategic exposure from two disruption measures: geographic disruption severity and operational disruption potential, measured by service shares.

Quantification

- Welfare incidence is spatially uneven: **chokepoints matter**, **builder-linked exposure exceeds operator-only exposure**, and **spillovers follow the rotation network**.

Takeaway

- **Exposure $\neq$ vulnerability**: heavy traffic becomes vulnerability when disruption is feasible, bypasses are costly, and the disruptor bears low material cost.
- **Absolute $\neq$ strategic vulnerability**: a disruption can be costly for both countries; strategic vulnerability depends on Home's loss relative to Foreign's own welfare cost.