

# Critical Minerals in an Age of Geopolitical Rivalry

## Stockpiling, refining constraints, and the limits of friend-shoring

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# Roadmap

Motivation and research question

Supply-chain exposure and geopolitical shocks

Empirical strategy and evidence

Stockpiling and friend-shoring

Friend-shoring scores and policy implications

## Why this study for EUROFRAME

- ▶ The green, digital, and defense transitions are mineral intensive.
- ▶ The central bottleneck is often **refining**, not only mining.
- ▶ The relevant shock is geopolitical: US–China rivalry can alter expectations, finance conditions, export controls, and supply-chain risk.
- ▶ The policy problem is therefore about resilience: **refined stockpiles, realistic friend-shoring, and industrial capacity.**

### Question

How do deteriorations in US–China geopolitical relations affect refined critical-mineral markets, and what do these effects imply for stockpiling and friend-shoring strategies?

### EUROFRAME

The US-centered empirical framework is directly relevant to European industrial transitions because the exposure comes from global midstream concentration.

## Three objects of analysis

### 1. Market response

Monthly evidence for aluminum, copper, nickel, tin, and zinc from 1995 to 2025.

### 2. Stockpiling logic

A net-importing economy chooses refined inventories before geopolitical disruption states are realized.

### 3. Friend-shoring limits

A feasibility index combines reserves, geopolitical alignment, regime type, and distance.

**Takeaway:** The empirical and theoretical parts point to the same conclusion: stockpiling and friend-shoring are complements, not substitutes.

## Main messages in one slide

1. **Refining concentration is the strategic chokepoint.** China accounts for roughly one-half of global refining capacity across the selected metals, and for much more in nickel.
2. **Geopolitical deterioration induces precautionary stockpiling.** Prices tend to fall while inventories rise, consistent with a demand-driven global shock and a precautionary inventory response.
3. **Stockpiles should be refined, not only raw.** Ore stockpiles do not solve the midstream bottleneck.
4. **Friend-shoring feasibility is narrow.** Australia and Canada stand out; Brazil, Chile, Indonesia, and Peru are intermediate; large reserves alone do not offset governance and geopolitical risks.

## Import reliance reveals concentrated exposure

- ▶ The map summarizes leading import sources for US nonfuel mineral commodities where net import reliance exceeds 50 percent.
- ▶ Canada and China are leading suppliers for the largest number of such commodities.
- ▶ The exposure is not only bilateral: concentrated supplier networks reduce substitution options when shocks occur.

**Takeaway:** Security of supply is a network problem before it is a price problem.

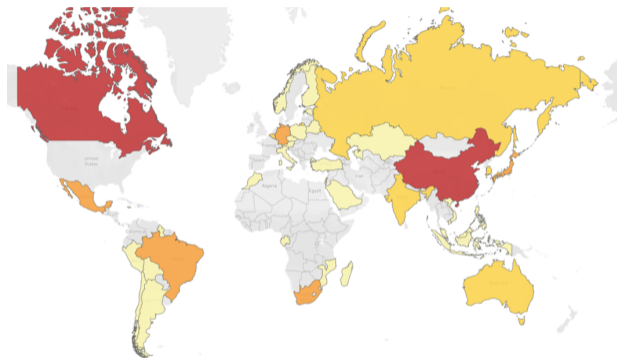


Figure 1. Leading import sources, 2020–2023. Sources: USGS Mineral Commodity Summaries; authors' calculations.

## The chokepoint is midstream refining

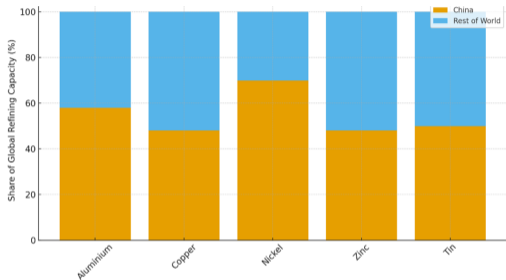


Figure 2a. China versus rest of world refining capacity, 2024.

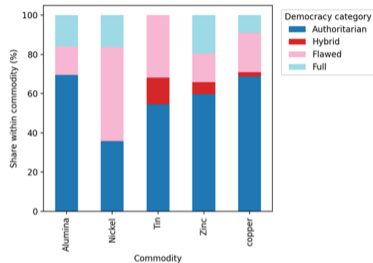


Figure 2b. Refining capacity by regime type, 2024.

**Takeaway:** Mining can be geographically dispersed while processing remains highly concentrated; this weakens the short-run feasibility of diversification.

## US–China geopolitical relation shocks

- ▶ The Political Relations Index (PRI) measures bilateral diplomatic conditions.
- ▶ Higher values indicate more strained relations.
- ▶ The second difference isolates sharp turning points, such as the Taiwan Strait crisis, the Belgrade embassy bombing, the trade-war period, and the Beijing Olympics boycott.

**Takeaway:** These turning points provide the shock used to trace market responses.

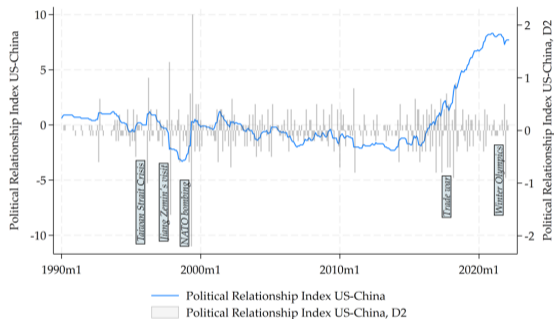


Figure 3. US–China geopolitical relationship. PRI from Yan et al. (2010) and subsequent updates.

## Data and identification strategy

### Monthly variables, 1995–2025

- ▶ US–China Political Relations Index
- ▶ Refined production
- ▶ Refined consumption
- ▶ Refined prices
- ▶ Refined stocks

### Metals

Aluminum, copper, nickel, tin, zinc

### SVAR shock

$$y_t = (PRI_t, Q_t, C_t, P_t, S_t)'$$

$$y_t = A_1 y_{t-1} + \dots + A_{12} y_{t-12} + u_t$$

Recursive ordering:  $PRI_t$ , production, consumption, price, stocks.

### Local projection response

$$x_{t+h} = \alpha_{x,h} + \beta_{x,h} \varepsilon_t + \Gamma_{x,h}(L) y_{t-1} + v_{x,t+h}$$

$\varepsilon_t$  is the identified deterioration in bilateral geopolitical relations.

## Response of prices to a deterioration in US–China relations

- ▶ Most price responses are negative over medium horizons.
- ▶ Aluminum, copper, zinc, and nickel show the clearest downward dynamics.
- ▶ Tin is more volatile, consistent with a smaller and more idiosyncratic market.

**Takeaway:** A geopolitical deterioration acts primarily as an adverse global-demand signal in the historical data.

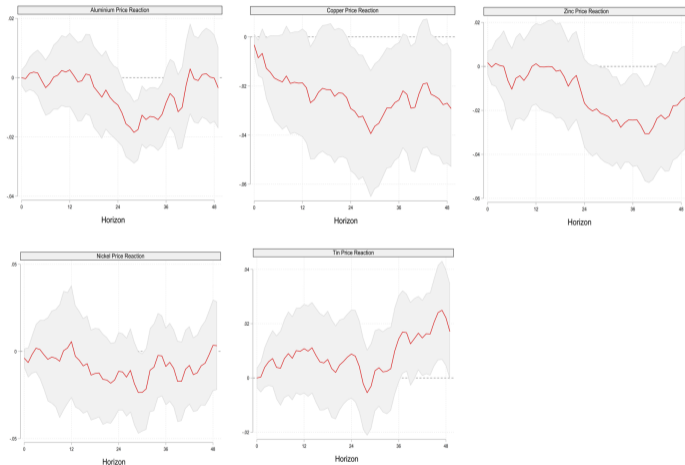


Figure 4. Local-projection price responses; shaded bands denote 90 percent confidence intervals.

## Response of stockpiles to a deterioration in US–China relations

- ▶ Inventories rise after geopolitical deterioration.
- ▶ The response is especially visible for aluminum and copper, and later for zinc and nickel.
- ▶ The stockpiling margin is central: it would be missed in a prices-only analysis.

**Takeaway:** Prices falling while inventories rise is consistent with precautionary stockpiling in an uncertain global-demand environment.

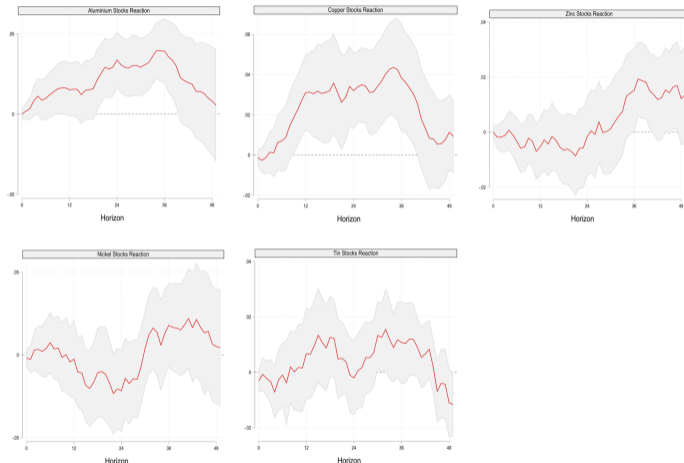


Figure 5. Local-projection stock responses; shaded bands denote 90 percent confidence intervals.

## Interpreting the empirical pattern

### Demand channel

A diplomatic deterioration signals lower expected global activity and tighter financial conditions. Purchases fall and prices decline.

### Inventory channel

The same deterioration raises tail risk around future access to refined inputs. Firms and public authorities increase buffer stocks.

### Why this matters for policy

The market response is not only a contemporaneous price response. Inventories reveal risk management under uncertainty.

### Transition to the model

The theory asks how much refined inventory a net importer should hold when geopolitical risk changes the distribution of import shortfalls.

# Optimal stockpiling as insurance

## Planner's problem

$$\min_{S \geq 0} cS + p(\tau) \mathbb{E} [\ell((D - M - S)_+)]$$

- ▶  $S$ : refined inventories
- ▶  $c$ : carrying and storage cost
- ▶  $p(\tau)$ : disruption probability, increasing in geopolitical tension  $\tau$
- ▶  $D - M - S$ : residual shortage after imports and inventories

## Interior condition

$$c = p(\tau) \mathbb{E} [\ell'((D - M - S)_+) \mathbf{1}\{D > M + S\}]$$

- ▶ Higher geopolitical tension raises the marginal value of inventories.
- ▶ Higher shortage losses raise the optimal stockpile.
- ▶ More reliable friend-shored supply lowers the need for inventories, but does not remove it.

## Friend-shoring feasibility

The feasibility index combines geological scale, strategic alignment, and institutional or permitting frictions:

$$\Phi_i = \left( \omega_R x_{R,i}^\rho + \omega_G x_{G,i}^\rho + \omega_D x_{D,i}^\rho \right)^{1/\rho}$$

$$x_{R,i} = R_i, \quad x_{G,i} = e^{-\kappa_G G_i}, \quad x_{D,i} = e^{-\kappa_D D_i}$$

- ▶  $R_i$ : proven reserves and geological scale
- ▶  $G_i$ : geopolitical distance from the United States
- ▶  $D_i$ : institutional, regulatory, or permitting constraints

### Implication

Feasibility rises with reserves and alignment, but reserves are an imperfect substitute for strategic reliability.

### Nonlinearity

Large reserves matter most when the partner is aligned and when institutional constraints do not prevent rapid refining scale-up.

## Why feasibility is nonlinear

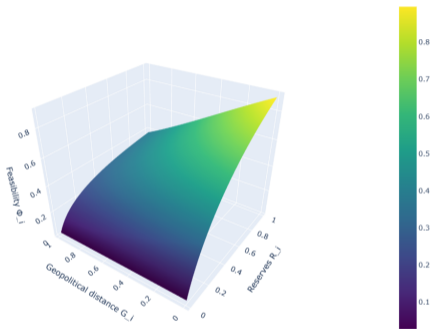


Figure 6. Low democratic or permitting constraints.

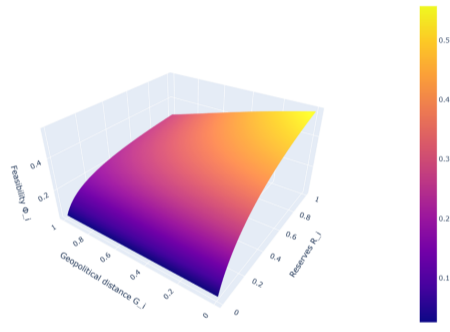


Figure 7. High democratic or permitting constraints.

**Takeaway:** Higher constraints shift the feasibility surface downward: reserves translate less efficiently into near-term refining capacity.

## Existing refining alternatives are limited

Metal	China's share	Major non-China refiners	Feasibility	Primary constraint
Aluminum / alumina	55–60%	Australia, India, Brazil	Moderate	Energy intensity and capital cost
Refined copper	45–50%	Chile, Japan, EU	Low	Environmental regulation and high operating expenditure
Nickel	About 70%	Canada, Norway, Australia	Moderate to low	Feedstock quality and emissions standards
Zinc	45–50%	South Korea, Canada, Japan	Low	Fragmented capacity and little spare room
Tin	More than 50%	Indonesia, Malaysia, Bolivia	Very low	Governance and cost issues

**Takeaway:** The binding constraint differs by metal, but a common pattern emerges: large-scale non-China refining capacity is scarce and slow to expand.

*Summary of Table 1. Refining shares are indicative ranges based on USGS and IEA data as reported in the paper.*

## Friend-shoring alternatives to stockpiling

- ▶ Australia combines large reserves with close geopolitical alignment.
- ▶ Canada is very close geopolitically, but with a smaller reserve base in the plotted aggregate.
- ▶ Brazil, Chile, Indonesia, and Peru form an intermediate cluster.
- ▶ Democratic Republic of Congo and Russia have reserves, but high geopolitical and governance costs.

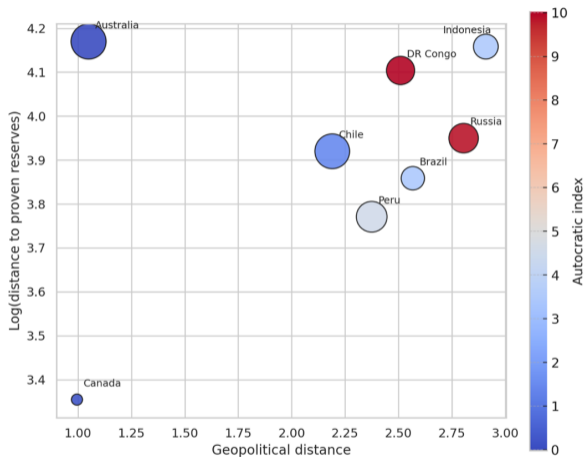


Figure 8. Friend-shoring alternatives for key critical minerals. Bubble size indicates reserves; color indicates autocracy.

## Feasibility scores under alternative strategic priorities

- ▶ Baseline scores favor Australia, Canada, Chile, and Brazil.
- ▶ Near-shoring raises Canada's relative position.
- ▶ Supply-first strengthens Australia and Canada.
- ▶ Russia and Democratic Republic of Congo remain weak in most strategic scenarios despite large reserves.

**Takeaway:** Geology matters, but geopolitics and governance determine whether geology can become reliable refined supply.

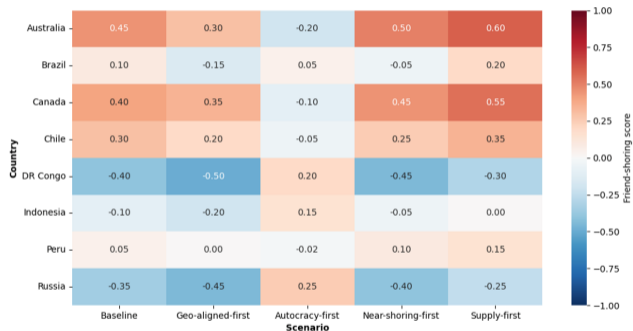


Figure 9. Fourth-dimensional friend-shoring score, 2024. Higher values indicate greater feasibility.

## Policy translation for European industrial transitions

### 1. Monitor risk jointly

Prices alone can understate vulnerability. Inventories, refining concentration, and geopolitical-risk indicators should be read together.

### 2. Stockpile refined inputs

Raw ores do not resolve the midstream bottleneck. The highest insurance value comes from usable refined materials.

### 3. Treat friend-shoring as targeted

A broad diversification agenda is less credible than long-horizon packages with feasible partners and clear constraints.

### 4. Combine instruments

Refined inventories, offtake contracts, permitting capacity, energy infrastructure, recycling, and material efficiency should be designed as complements.

## Conclusion

1. Deteriorations in US–China relations trigger a precautionary stockpiling response in refined critical-mineral markets.
2. The historical response is consistent with an adverse global-demand signal: prices fall while inventories rise.
3. The model rationalizes refined stockpiles as insurance against disruption risk; the optimal stockpile rises with geopolitical tension.
4. Friend-shoring can reduce the stockpile requirement, but feasibility is narrow and nonlinear.
5. For industrial policy, resilience is a midstream strategy: refined inventories plus realistic, partner-specific diversification.

## Back-up: contribution relative to the literature

### Geopolitical risk

Moves from broad geopolitical-risk indices toward bilateral US–China political relation shocks.

### Commodity markets

Adds refined stocks to production, consumption, and prices in a unified dynamic framework.

### Industrial policy

Connects empirical market responses to stockpiling rules and feasible friend-shoring partners.

## Back-up: selected references

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