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GEOECONOMIC SHOCKS AND GLOBAL SUPPLY CHAINS: MARKET LEVEL EFFECTS OF CHINA'S CRITICAL MINERAL POLICIES

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ABSTRACT

China's growing use of export controls on critical minerals raises questions about how concentrated international supply chains respond to geoeconomic shocks. This paper asks whether countries more dependent on China experience larger changes in import sourcing following China's export control measures on gallium and germanium (2023), graphite (2023), antimony (2024) and medium/heavy rare earths (2025), against the backdrop of the 2010–2012 rare earth episode and WTO dispute DS431. Using a constructed country mineral month panel of 18,944 observations across 74 reporting countries, four mineral groups and 96 months (January 2018 to July 2026), drawn from the UN Comtrade database, the analysis combines pre-treatment (2018–2022) China import dependence with event specific difference in differences and event study specifications.

Countries with greater pre-shock dependence on China experienced significantly larger reductions in China origin imports following the relevant export control events (pooled $\beta = -2.61$, $SE = 0.54$, $p < 0.001$), the paper's clearest result. Responses in alternative supplier networks were heterogeneous rather than universal. Non-China supplier counts rose significantly for antimony and graphite but not for gallium/germanium or rare earths, and non-China supplier concentration (HHI) showed no statistically significant systematic decline for any mineral group, so a reduction in China origin sourcing should not be equated with genuine diversification or resilience. Evidence from import unit values, a noisy proxy for market prices, does not consistently support a general price effect.

The findings support a narrower claim than universal price weaponisation or chokepoint amplification. Concentrated physical supply chains transmit policy shocks through pre-existing trade network exposure, with the strength and shape of that transmission varying by mineral. The paper situates this market level design within a broader multi-level framework linking policy shocks to firm and state responses, a direction left for future research.

Keywords: Critical Minerals, Geoeconomics, Weaponised Interdependence, China, Export Controls, Difference in Differences, Supply Chain Diversification

1 INTRODUCTION

Critical minerals have moved from the margins of commodity analysis to the centre of industrial strategy. Lithium, cobalt, nickel, graphite, gallium, germanium, antimony, tungsten and rare earth elements support electric vehicles, battery storage, renewable energy, semiconductors, permanent magnets and defence technologies, and the International Energy Agency [24] reports continued growth in 2024 demand for these inputs, especially lithium. This gives critical minerals a double character. They are traded commodities, but also enabling inputs that governments increasingly treat as strategic.

China's position in these supply chains is more than a matter of geological availability for several minerals the vulnerability lies in refining, separation, purification, by product recovery and magnet or battery grade processing rather than in where deposits exist. Rare earths matter because they can be separated into oxides for high performance magnets, graphite matters for battery anodes only after purification, and gallium and germanium are constrained by by product recovery from aluminium and zinc production. This makes bottleneck control analytically distinct from ordinary scarcity [17,24,43].

China's recent policy instruments illustrate why critical minerals should be studied as policy sensitive inputs rather than purely geological commodities. Between mid-2023 and early 2025, China introduced a sequence of export control measures covering gallium and germanium, graphite, antimony, and medium/heavy rare earths, citing national security, non-proliferation and administrative rationales [29,30,31,37]. Mineral governance is increasingly conducted through security, licensing and administrative discretion rather than through price and quantity adjustment alone.

This combination of concentrated supply and an active, increasingly frequent willingness to restrict it turns Chinese mineral policy into a geoeconomic question rather than a purely commercial one. A policy shock, for this paper, is an identifiable state action with a date, a product scope and a verifiable source, such as an export quota, a licensing requirement, a targeted prohibition, or a technology transfer restriction. A geoeconomic shock is a policy induced disruption transmitted through economic networks in ways that create asymmetric consequences for foreign actors [3,11]. The empirical task is to test whether China's critical mineral policy actions behave like geoeconomic shocks in observable market data whether they reallocate trade and raise import unit values in ways that scale with a country's pre-shock dependence on China.

The paper does not assume that China's policies are illegitimate, nor that “de risking” is automatically desirable. It asks a narrower question, when China changes the rules of access to minerals in which it occupies a major supply chain position, do more exposed markets adjust differently from less exposed ones. This reframing, from rhetorical dependence to measurable, pre-treatment, is central to the paper's contribution.

This paper investigates that question using a monthly country mineral trade panel built around the four export control episodes summarised in Section 4, together with the 2010–2012 rare earth episode as historical context. The design combines a hand coded policy event dataset with UN Comtrade trade data and a mineral to HS code concordance, and estimates event specific and pooled exposure interaction models with country mineral and month fixed effects.

This paper makes three contributions. Empirically, it constructs and estimates a country mineral month panel that directly measures importer level sourcing adjustment around a sequence of real Chinese export control events, rather than relying on a single episode or case narrative. Conceptually, it distinguishes three outcomes often conflated in the de risking debate, a reduction in China origin sourcing, an increase in the number of alternative suppliers, and a genuine decline in supplier concentration, and tests whether the first implies the second and third or whether they can be dissociated. Geoeconomically, it tests, rather than assumes, whether pre-existing dependence conditions the strength of a country's response to a concentrated supplier's export controls, providing a market level empirical baseline that future firm and state level research could build on.

2 BACKGROUND AND RESEARCH POSITIONING

2.1 Geoeconomic Statecraft

Export controls on critical minerals belong to a wider repertoire of economic statecraft, the deliberate use of trade, investment and financial instruments to pursue strategic rather than purely commercial objectives [3]. What distinguishes the contemporary critical mineral case from earlier trade coercion is the combination of a plausible security rationale (dual use technology, defence applications), a legitimate industrial policy rationale (environmental enforcement, domestic value addition), and a structural fact, concentrated Chinese supply, that gives any of these rationales real economic force. Vivoda [43] situates this within the emergence of geopolitical trading blocs organised around critical mineral access, and the European Commission's Critical Raw Materials Act [9] and comparable measures

in the United States, Japan and South Korea show that Western governments increasingly treat mineral sourcing itself as a matter of statecraft. This paper treats China's export control measures as one instance of this broader phenomenon, without assuming the underlying intent is coercive, separating the question of intent from the question of market effect.

2.2 Weaponised Interdependence

The paper's theoretical anchor is weaponised interdependence, states occupying central nodes in global networks can use that position to generate coercive or strategic effects [11]. Farrell and Newman developed this primarily for financial, informational and technological networks. Here the logic extends to material and industrial networks, where the “node” is a refinery, separation facility, processing plant or magnet producer rather than a bank or data platform, with network power operating through physical production systems, not only through finance and data.

Global value chain theory explains why markets cannot adjust to such shocks instantly, chains are governed by standards, lead firms, technical capability and relational contracts [16], and critical minerals intensify these frictions through strict quality and purity requirements. Battery manufacturers must qualify materials for safety and performance, semiconductor suppliers must meet precise specifications, and defence contractors face security and traceability requirements, all of which make dependence more durable than a simple price model would suggest.

Production network research explains why a mineral shock's effects may be amplified downstream, Acemoglu, Carvalho, Ozdaglar and Tahbaz-Salehi [1] show that network structure generates aggregate fluctuations when shocks hit central sectors, and Carvalho et al. [7] show a localised earthquake propagating through Japanese supplier customer relationships. The critical mineral case differs in that the shock is policy induced rather than physical, but the logic is analogous, a mineral upstream of many high values, hard to replace production chains can transmit a small shock into disproportionate downstream consequences.

Trade and industrial policy literature adds the strategic dimension, Pothén and Fink [34] link China's rare earth export barriers to industrial relocation and comparative advantage, and Alfaro, Fadinger, Schymik and Virananda [2] show policy shocks influencing innovation and downstream adjustment (a link left for future firm level research). This paper also draws on literature complicating a simple weaponisation narrative, Zhou, Crochet and Wang [48] argue China's critical mineral strategies are often rooted in domestic priorities and that de-risking frameworks can oversimplify China as “the risk.” This strengthens rather than undermines the present design, since it separates intent from effect, a policy motivated by internal priorities can still have global market consequences, and a strategically motivated one can have limited effect if markets are already diversified. The empirical task is to estimate effects, not to infer intent from rhetoric.

This paper closes part of a gap in the existing econometric literature along four dimensions. Causally, Pothén and Fink [34] explain the political economy of China's rare earth restrictions without estimating country level price or trade flow effects, and Hu, Zhang and Li [22] examine rare earth supply chain implications without using pre-shock import dependence as the exposure dimension, while this paper asks directly whether more exposed country mineral pairs changed more after identifiable policy events. In coverage, earlier debate centered on rare earths and the 2010/DS431 episode (Gholz [17] usefully complicates its national security interpretation), whereas the contemporary policy environment spans gallium, germanium, graphite, antimony and medium/heavy rare earths, each with distinct production technologies and substitution possibilities. On mechanism a price effect, a reduction in China origin imports, an increase in non-China supplier share, and a fall in supplier concentration indicate different things, cost pressure, direct adjustment, reallocation, and genuine diversification respectively, and this paper separates these channels rather than reporting one average effect. On identification since restrictions are not random, the design uses pre-shock exposure, event specific analysis and placebo tests to separate policy linked patterns from broader commodity cycles.

2.3 Critical Mineral Supply Chains

Critical minerals differ from traditional commodities in that their strategic importance often exceeds their market size. The rare earth market is small relative to oil, copper or iron ore, but enables high performance magnets, precision systems, electric motors and defence applications. Gallium and germanium are small in trade value but essential to certain semiconductor, optical and military technologies. Graphite is geologically abundant, but battery grade processing is technically demanding and comparatively concentrated. Antimony is used in flame retardants, alloys, ammunition and other industrial applications. These mineral specific features make it inappropriate to treat all critical minerals as a homogeneous category [29,30,31,48]. China's centrality is not accidental it reflects decades of industrial policy, cost advantages, environmental tradeoffs and metallurgical expertise, giving China a dominant role in rare earth mining, separation and magnet manufacturing, centrality in graphite processing and battery anode supply chains, and a position in gallium/germanium tied to by product recovery from aluminium and zinc production. Dominance in mining, refining and component manufacturing each creates a different type of leverage.

2.4 Supply Chain Diversification

De-risking is often presented in policy discourse as an unambiguous solution to dependence, but reallocation does not necessarily mean resilience a country may shift imports from China to a single alternative supplier without truly diversifying, and alternative suppliers may involve higher cost, longer qualification, governance risk or environmental burdens. This paper therefore treats supply chain reconfiguration as an empirical outcome to be measured, not an automatically beneficial policy result [9,43,48]. This motivates the three-way conceptual distinction that structures the paper's empirical design, developed further in Section 8 a reduction in China origin sourcing, an increase in supplier breadth, and a decline in supplier concentration. These are conceptually distinct, and Section 8 tests whether they move together or can be dissociated. The concept of reconfiguration used here also includes the failure to move if highly dependent countries do not diversify after a shock, that is not an absence of findings but may indicate lock in, limited alternatives, or high adjustment costs, and a rigorous design treats persistence in dependence as theoretically meaningful [7,16].

3 THEORY AND HYPOTHESES

The overarching question is whether China's critical mineral policies induce measurable supply chain reconfiguration, and through which mechanisms. This paper answers the market level component of that question, structured around four hypotheses summarised in Table 1.

3.1 China Dependence

The paper's central moderating variable is a country's pre-shock dependence on China for a given mineral. Dependence is shallow where substitute suppliers are readily available, inventories are high, and qualification requirements are simple, and it is deep where downstream production cannot easily pause, technical qualification of new suppliers takes months or years, and alternative processing capacity is scarce [7,16]. Among countries importing from China, those with a higher pre-shock China import share should show a larger differential response to a given policy shock, because they have proportionally more sourcing to reallocate and, plausibly, weaker outside options. Dependence must also be measured before the shock, since contemporaneous or post shock dependence is mechanically affected by the policy itself, so every hypothesis below is stated in terms of a lagged, pre-treatment exposure measure.

3.2 Price Response (H1)

H1 (price/unit value effect). Policy shocks increase mineral import unit values, conditional on pre-shock dependence on Chinese supply. When a licensing requirement or export control affects a concentrated mineral market, buyers may face reduced availability, longer approval times, stockpiling incentives and higher risk premia, all of which should raise unit values disproportionately for more China dependent importers.

Because UN Comtrade unit values are trade value divided by quantity, they are an imperfect proxy for market prices they can shift when product composition, grade or origin mix change independent of the underlying price, so H1 is treated as exploratory rather than confirmatory.

3.3 China Origin Import Response (H2)

H2 (direct supply adjustment). Countries with greater pre-treatment dependence on China experience larger reductions in China origin imports following the relevant export control events. This is the paper's central, most directly identified hypothesis.

3.4 Supplier Diversification (H2b)

H2b (genuine diversification). Where reallocation reflects diversification rather than simple supplier switching, the number of non-China suppliers should rise for more China dependent countries after a shock. This sharpens H2. A country that reduces China origin sourcing by substituting toward a single alternative dominant supplier has reallocated without becoming more resilient, so H2b is a distinct test from H2 rather than a restatement of it.

3.5 Supplier Concentration (H3)

H3 (concentration among alternative suppliers). The reduction in China dependence is accompanied by lower concentration among non-China suppliers, that is, the alternative supplier base itself becomes less concentrated (lower non-China HHI) after a shock, for more China dependent countries. This is directly testable.

Table 1: Market level hypotheses

Hyp.	Claim	Outcome variable
H1	Policy shocks raise import unit values more for higher dependence importers	$\ln(\text{unit value})$
H2	Exposed countries reduce China origin imports more after a shock	$\ln(1 + \text{China imports})$
H2b	Genuine diversification non-China supplier count rises	Non-China supplier count
H3	Non-China supplier concentration falls after a shock	Non-China HHI

4 INSTITUTIONAL BACKGROUND AND POLICY EVENTS

Table 2 summarises the candidate events used for empirical coding, spanning 2010 to 2025, and Figure 1 places them on a single policy shock timeline. The first historical anchor is the 2010–2012 rare earth export restriction period, during which China reduced rare earth export quotas and maintained restrictions that became a major international dispute. WTO DS431 formally concerned China's measures related to the exportation of rare earths, tungsten and molybdenum, including export duties, export quotas and quota administration [46]. This episode is a clear precedent for critical mineral restrictions becoming a legal and geopolitical dispute, but given its high potential for policy endogeneity relative to contemporaneous global demand and price cycles, it is treated as historical context rather than pooled with the modern events in the panel estimation (Section 6).

Table 2: Candidate China critical mineral policy events used for empirical coding, 2010–2025. The four rows in bold role (Ga/Ge, graphite, antimony, medium/heavy REE) form the estimation panel's four mineral groups.

Period	Mineral(s)	Policy instrument	Empirical role
2010–2012	Rare earths	Export quota tightening, duties and administration	Historical baseline, used cautiously given endogeneity
2012–2014	Rare earths, tungsten, molybdenum	WTO DS431 legal dispute	Validates policy instruments and international contestation
Jul/Aug 2023	Gallium, germanium	Dual use export licensing	Modern event, primary estimation sample
Oct/Dec 2023	Graphite	Export licensing on certain graphite products	Modern event, primary estimation sample
Aug/Sep 2024	Antimony, superhard materials	Dual use export controls	Modern event, primary estimation sample
Dec 2024	Gallium, germanium, antimony	U.S. targeted prohibition/restriction	High political endogeneity, kept separate from the pooled panel
Apr 2025	Medium/heavy rare earths	Dual use export controls with listed codes	Modern event, short post treatment window
Oct/Nov 2025	Rare earth related items and easing signals	Expanded controls and partial easing	Outside the main estimation window

The concordance maps mineral groups onto HS6 trade classification codes. An initial, broader concordance was audited and narrowed to a strict headline basket for the four modern events, excluding codes that are unresolved, contaminated by unrelated products, or supported only by low confidence inference from product descriptions.

The headline estimation reported in Section 8 pools these into two HS6 codes (280530 for metals, 284690 for oxides/compounds) as a single “REE” mineral group, because the trade data are only reliably available at the HS6 level across the full 2018–2026 panel. Results for the “REE” group should therefore be read as covering medium/heavy rare earths collectively, not as isolating any single element, and the same aggregation logic applies to gallium and germanium, which share HS6 codes 811292/811299 in Chinese customs practice and cannot be separated in the trade data used here.

Supplier count construction and correction. A material construction error was identified and corrected during the estimation. The original procedure counted suppliers separately within each HS6 code and summed those counts, which double counted partners appearing under multiple HS6 codes within the same mineral basket. The corrected procedure first aggregates trade value across all strict HS6 codes within a mineral to the reporter mineral month partner level, and only then counts unique positive partners. This correction changed the supplier count in 5,693 of 18,944 panel cells (30.1%), with mismatch rates of 49.6% for antimony, 48.0% for gallium/germanium, 34.1% for rare earths, and 0% for graphite, which uses a single HS6 code, so no double counting was possible there. All results reported in this paper use the corrected construction.

5.3 Policy Events and the Treatment Indicator

For each mineral specific event, the treatment indicator $Post_{mt}$ equals 1 for months at or after the implementation month listed in Table 3, and 0 before it. The December 2024 U.S. targeted restriction and the 2010–2012 historical episode are excluded from the treatment indicator used in the pooled panel, for the endogeneity reasons discussed in Sections 4 and 6.3.

5.4 Pre-Treatment China Dependence

The principal exposure variable is each country's China import share over the full pre-treatment period, 2018–2022, rather than a single pre-period month:

$$D_{cm} = \frac{\sum_{t=2018}^{2022} M_{cmt}^{CN}}{\sum_{t=2018}^{2022} M_{cmt}}$$

$$0 \leq D_{cm} \leq 1.$$

where M_{cmt}^{CN} is China origin import value and M_{cmt} is total import value for country c , mineral m , month t , and both sums run over all months actually observed for that country mineral pair in 2018–2022 (coverage is not perfectly balanced across reporters). Because D_{cm} is a country mineral characteristic constructed entirely from the pre-treatment window, it does not mechanically change after treatment, which is what allows it to be interpreted as a pre-treatment exposure measure rather than an outcome of the shock itself [4,19]. Measuring D_{cm} before treatment rules out the mechanical channel by which the policy shock itself could move the exposure variable. It does not by itself make D_{cm} exogenous, since countries with high and low pre-treatment China dependence may still differ systematically along other dimensions. That further identification concern is addressed by the fixed effects in Section 6.1 and discussed as a limitation in Section 6.3 and Section 10.

5.5 Supplier Networks and Concentration

For country c , mineral m , month t , and trading partner p , bilateral import value is first aggregated across all HS6 products belonging to the mineral's strict basket:

$$V_{cpmt} = \sum_{h \in H_m} V_{cpht}.$$

Total imports are then constructed from the bilateral partner observations:

$$M_{cmt} = \sum_{p \neq 0} V_{cpmt},$$

where $p = 0$ denotes Comtrade's World aggregate and is therefore excluded from the summation. The World observation is a pre-computed aggregate reported by Comtrade, not an additional trading partner, and including it

would mechanically double count trade. It is consequently excluded from the construction of total imports and from all supplier count and concentration measures.

China origin imports are defined using Comtrade partner code 156:

$$M_{cmt}^{CN} = V_{c,156,m,t}.$$

Non-China imports are defined as the sum of all positive partner level imports other than China and the World aggregate:

$$M_{cmt}^{NC} = \sum_{p \neq 0,156} V_{cpmt}.$$

Thus, non-China imports represent the portion of a country's mineral imports supplied by sources other than China, while the World aggregate is excluded throughout to avoid double counting.

Supplier counts are constructed only after aggregation across HS6 products. This sequencing is important because a single country may supply several HS6 products within the same mineral basket but should count as only one supplier. The all-supplier count is therefore

$$N_{cmt} = \sum_{p \neq 0} 1(V_{cpmt} > 0),$$

and the non-China supplier count is

$$N_{cmt}^{NC} = \sum_{p \neq 0,156} 1(V_{cpmt} > 0).$$

This follows the corrected aggregation procedure described in Section 5.2 HS6 level trade is first consolidated to the mineral level, after which unique positive suppliers are counted.

The distinction between all supplier and non-China concentration is central to the H3 hypothesis developed in Sections 3.5 and 8.5. The two measures are therefore defined separately rather than treating non-China concentration as a simple restriction of the all-supplier formula. For all suppliers, partner p 's import share is

$$s_{cpmt}^{All} = \frac{V_{cpmt}}{\sum_{j \neq 0} V_{cjmt}},$$

with the corresponding Herfindahl-Hirschman Index given by

$$HHI_{cmt}^{All} = \sum_{p \neq 0} (s_{cpmt}^{All})^2.$$

The denominator includes China because the all-supplier measure captures the concentration of the country's entire import network.

The non-China measure instead normalizes each supplier's imports by total non-China imports:

$$s_{cpmt}^{NC} = \frac{V_{cpmt}}{\sum_{j \neq 0,156} V_{cjmt}}, \quad p \neq 0,156,$$

and

$$HHI_{cmt}^{NC} = \sum_{p \neq 0,156} (s_{cpmt}^{NC})^2.$$

These measures answer different empirical questions. HHI^{All} captures the concentration of the complete supplier network, including China's position within that network, whereas HHI^{NC} captures concentration among supplier's

conditional on China being excluded. Accordingly, the two indices are not term by term comparable, and HHI^{NC} cannot be obtained from HHI^{All} simply by dropping China's contribution from the numerator.

HHI^{NC} is undefined when a country has no non-China suppliers in a given month because its denominator is then zero. The resulting 781 country month mineral observations, representing 4.1% of the panel, are retained as missing rather than mechanically recoded as zero. This preserves the distinction between an absence of measurable non-China supply and a genuinely unconcentrated non-China supplier network.

Finally, the import unit value is defined as

$$UV_{cmt} = \frac{TradeValue_{cmt}}{NetWeight_{cmt}},$$

and is expressed in U.S. dollars per kilogram. The measure is retained only when both trade value and net weight are positive. Throughout the analysis, UV is interpreted strictly as a trade unit value the value of reported trade divided by its reported physical quantity, rather than as an observed market price. This distinction is important because changes in unit values may reflect changes in product composition, quality, contract terms, or reporting practices as well as changes in underlying prices, as discussed in Section 3.2.

6 EMPIRICAL STRATEGY

6.1 Baseline Specification

The central empirical specification is estimated separately for each outcome:

$$Y_{cmt} = \beta(Post_{mt} \times D_{cm}) + \alpha_{cm} + \lambda_t + \varepsilon_{cmt},$$

where $Post_{mt} = 1$ for months $t \geq T_m$ and $Post_{mt} = 0$ otherwise. T_m denotes the implementation month of mineral m , as reported in Table 3. D_{cm} is the pre-treatment China dependence measure defined in Section 5.4.

The country mineral fixed effect, α_{cm} , absorbs all time invariant characteristics specific to a reporter mineral pair, including persistent differences in import demand, market size, industrial structure, and sourcing patterns. Month fixed effects, λ_t , absorb shocks common across countries and minerals in a given month, including global commodity market movements and other contemporaneous changes in the international trading environment.

The coefficient of interest, β , measures whether the post policy change in the outcome differs systematically with countries' pre-existing exposure to China. The identifying comparison is therefore within the cross-country distribution of pre-treatment exposure rather than a conventional treated versus untreated comparison. A positive estimate indicates that countries with greater initial China dependence experience a larger post event increase in the outcome, while a negative estimate indicates a relatively smaller response.

The outcome varies according to the hypothesis under examination. For H1, $Y_{cmt} = \ln(UV_{cmt})$, for H2, $Y_{cmt} = \ln(1 + M_{cmt}^{CN})$, for H2b, $Y_{cmt} = N_{cmt}^{NC}$, and for H3, $Y_{cmt} = HHI_{cmt}^{NC}$. The logarithmic transformation in H2 is specifically a log plus one transformation. Consequently, its coefficient should be interpreted as a change in the transformed outcome rather than as a percentage change in China origin import values. Because the transformation is nonlinear and incorporates the constant one, a unique percentage interpretation cannot be recovered from β and D_{cm} alone, Section 8.2 discusses the interpretation in greater detail.

Each of the four modern policy events has its own implementation date. The analysis therefore proceeds on an event specific basis, estimating the baseline model separately for each mineral before considering pooled specifications. This sequencing is intentional. A conventional calendar time two-way fixed effects regression under staggered treatment timing can implicitly use already treated observations as comparisons for later treated observations, potentially contaminating the estimated treatment effect when effects are heterogeneous across treatment cohorts [20,39].

The pooled analysis consequently aligns observations by event time, using the months relative to each mineral's own implementation date rather than treating a common calendar date as the treatment threshold. This approach reduces the most direct source of staggered adoption contamination while preserving the paper's continuous exposure framework. It is deliberately more parsimonious than adopting a fully heterogeneity robust staggered adoption estimator such as Callaway and Sant'Anna [6] or Borusyak, Jaravel and Spiess [5]. Such estimators provide an important avenue for future extensions of the analysis and are discussed in Section 10.

6.2 Event Study Specification

To examine the timing and dynamics of the response, the analysis augments the baseline model with an event study specification:

$$Y_{cmt} = \sum_{k \neq -1} \beta_k [1(EventTime_{mt} = k) \times D_{cm}] + \alpha_{cm} + \lambda_t + \varepsilon_{cmt},$$

where

$$EventTime_{mt} = t - T_m$$

measures the number of months relative to the implementation of mineral m 's policy event. The month immediately preceding implementation, $k = -1$, is omitted and serves as the reference period.

The lead coefficients ($k < 0$) provide a direct assessment of whether high and low dependence countries exhibited systematically different outcome trajectories before the policy event. The lag coefficients

$$k \geq 0$$

trace the evolution of the differential response following implementation. This dynamic specification is useful not only for identifying the timing of effects but also for assessing whether the baseline post event coefficient masks substantial adjustment dynamics.

For each event study, inference is supplemented by two joint hypothesis tests. The first tests the null hypothesis

$$H_0: \beta_k = 0 \quad \text{for all included } k < 0,$$

providing a joint test of differential pre-treatment trends. The second tests

$$H_0: \beta_k = 0 \quad \text{for all included } k \geq 0,$$

providing a joint test of post treatment effects. Reporting these joint tests alongside the individual event time coefficients avoids placing disproportionate weight on any single statistically significant lead or lag and provides a more informative assessment of the overall dynamic pattern.

6.3 Identification, Placebo Tests and Inference

The principal identification challenge is that China's mineral control policies may themselves be endogenous to economic and geopolitical conditions that also affect international trade outcomes. Policy decisions may respond to changes in prices, domestic demand, illegal mining, environmental pressures, geopolitical tensions, or foreign technology and trade restrictions. Any of these factors could independently affect import prices, China origin imports, or supplier network structure.

The empirical strategy therefore incorporates two diagnostic exercises. First, the event study specification provides a joint pre-treatment test of whether countries with greater and lower pre-existing China dependence were following systematically different trajectories before the policy event. Failure to reject equality of the pre-treatment coefficients would be consistent with the identifying assumption, although it cannot by itself establish exogeneity or rule out all forms of policy endogeneity.

Second, a placebo exercise re estimates the pooled H2 event study around a treatment date shifted twelve months before the actual implementation date. Evidence of systematic effects around this false treatment date would weaken the interpretation of the main results as responses to the policy shock and instead suggest that the estimated relationship may reflect pre-existing trends or other coincident changes.

All regressions are estimated by ordinary least squares. Standard errors are clustered at the reporter level where the resulting covariance matrix is numerically well behaved. For the antimony and rare earth price regressions in H1, reporter clustered covariance estimation is numerically unstable, as documented in Section 8.7. These estimates are therefore retained as diagnostic coefficients but are not presented as statistically reliable inferential results.

Two additional identification strategies were part of the original research design but were not estimated in the present round a shift share instrumental variables approach following Borusyak, Hull and Jaravel [4] and Goldsmith-Pinkham,

Sorkin and Swift [19], and a specification adding contemporaneous Western industrial policy controls for the U.S. Inflation Reduction Act and the EU Critical Raw Materials Act. Both would also require a time varying, one period lagged dependence measure rather than the time invariant pre-treatment exposure measure used throughout this paper (Section 5.4), so the two are not directly interchangeable. The results in Sections 8 and 9 correspond specifically to the parsimonious fixed effects specifications in Sections 6.1 and 6.2. The IV strategy and the Western policy control extension are retained as directions for future research (Section 10) rather than presented as estimated results.

7 DESCRIPTIVE EVIDENCE

Before turning to the regression results, this section establishes that the estimation sample is substantively meaningful and that exposure varies enough across countries and minerals to support the tests in Section 8.

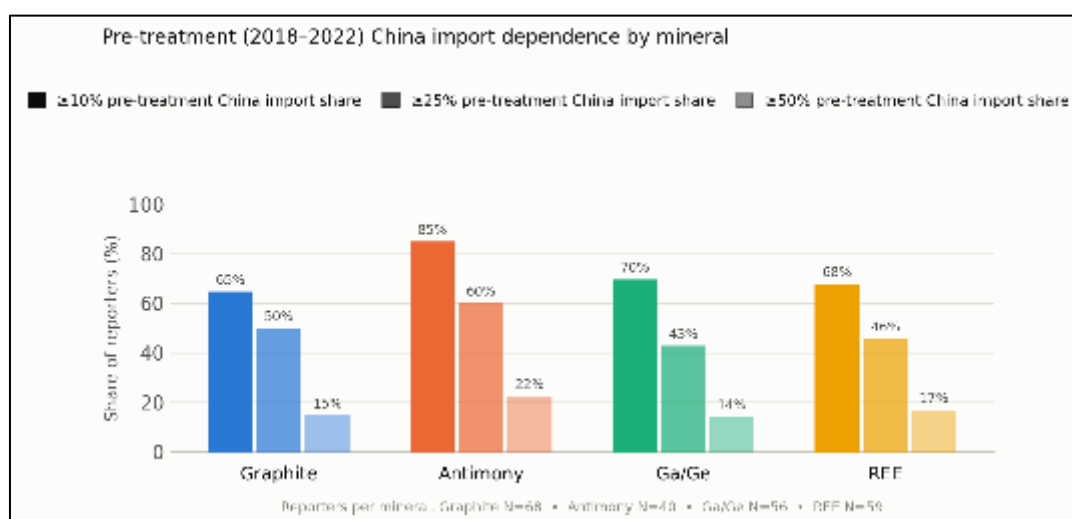


Figure 2: Pre-treatment (2018–2022) China import dependence by mineral, share of reporting countries exceeding each dependence threshold.

Figure 2 shows that exposure varies both across minerals and, within a mineral, across countries. Antimony has the highest concentration of high dependence importers (85% of its 40 eligible reporters sourced at least 10% of imports from China pre-treatment, and 60% sourced at least 25%), while graphite has the lowest share of extreme ($\geq 50\%$) dependence among the four minerals. This variation is a precondition for the exposure interaction design in Section 6, since if dependence did not vary, the Post $\times$ Dependence interaction would have no power to detect a differential response.

Table 4: Descriptive statistics on pre-treatment (2018–2022) China import dependence by mineral. Eligible reporters require at least 24 pre-treatment and 6 post treatment months of coverage. Union support across the four-event specific eligible groups is 77 reporters. The intersection of all four is 40, and the final combined event panel (Section 8.1) contains 18,944 observations across 74 unique reporters because reporter coverage overlaps unevenly across minerals.

Mineral	Eligible reporters	Mean pre-exposure	Median pre-exposure
Graphite	68	0.265	0.222
Antimony	40	0.277	0.262
Ga/Ge	56	0.237	0.185
REE	59	0.248	0.203

Case level evidence and the panel. Before the panel described in Section 5 was assembled, four of the events in Table 2 were also documented through independently sourced case level evidence, drawn from customs data reporting, price reporting agencies (Fastmarkets, Argus, Shanghai Metals Market), the USITC, USGS and specialist think tank analyses. This case level record, summarised in Table 5, is retained here as descriptive material that motivated the panel design, and should not be read as a substitute for, or more authoritative than, the panel regression results in Section 8.

Table 5: Documented case level price and export volume responses (not panel regression estimates). Sources: [8,10,12,13].

Mineral / shock	Documented price effect	Documented export/volume effect	Reallocation evidence
2010–2012 rare earths (heavy REE, e.g. dysprosium)	Dysprosium oxide price rose roughly 26-fold between Jan. 2009 and Aug. 2011, then fell ~70% over the following year	China's 2011 export quota (~30,200t) was cut sharply from 2010 levels	Prompted WTO case DS431 and a wave of non-China mine restarts, with high policy endogeneity risk
Gallium/germanium, licensing from Aug. 2023	Gallium price up ~18–27% within weeks of the announcement, and germanium metal prices more than doubled by 2024	Chinese exports of wrought gallium/germanium fell from ~7,900kg (Jul. 2023) to near zero (Aug. 2023)	Partial reallocation without diversification: Chinese germanium exports to Belgium rose ~224% in 2024 vs. 2022
Graphite, licensing from Dec. 2023	Weak to negligible net price effect	Flake graphite exports fell ~78%, and spherical graphite exports fell ~65% (Jan-Feb 2024 vs. 2023)	Global oversupply dampened the price response despite a large volume drop
Antimony, licensing from Sep. 2024	Fastmarkets/OilPrice reported a ~2,600% spike (Jul.–Sep. 2024), while USGS/CSIS reported a more conservative ~200% increase over a different baseline	Chinese antimony shipments to the U.S. fell ~97%	Near total supply cutoff to a market with no U.S. domestic production

The antimony discrepancy between trade press and government/industry sources (~2,600% vs. ~200%) is not resolved in this paper. The two figures likely reflect different baseline dates, product grades and geographic scope, and reconciling them would require the underlying Fastmarkets/USGS price series, which is not part of the data assembled here. Section 8.7 discusses the panel's own antimony unit value estimate. The case level figures above should be read as an illustrative range from independent reporting rather than a validated market price series.

8 RESULTS

This section reports the completed estimation on the panel described in Section 5, 18,944 country mineral month observations across 74 reporting countries, four mineral groups and 96 months (January 2018 to July 2026). Results are organised around the hypotheses in Table 1, in the order that best reflects the strength of the evidence, the strongest and most direct result (H2) first, followed by the more qualified reallocation and concentration results (H2b, H3), cross mineral synthesis, and finally the price evidence (H1), which is the weakest and most exploratory result in the paper. H2 is this paper's primary empirical contribution, it is estimated with clean joint pre-trends and a null placebo test, and it holds across every event specific specification and the pooled model. H1, H2b and H3 are secondary tests. Their results are mixed or null, and they should be read as scoping the boundaries of the H2 finding rather than as claims of comparable evidentiary weight.

8.1 Sample and Exposure

The final combined event panel contains 18,944 observations, 74 unique reporters, four minerals and 96 months. Reporter coverage overlaps unevenly across minerals because eligibility (at least 24 pre-treatment and at least 6 post treatment months) differs by event, giving event specific sample sizes of 68 reporters for graphite, 40 for antimony, 56 for gallium/germanium and 59 for rare earths (Table 4). Corrected all supplier HHI across the panel has a mean of 0.658 (SD 0.272, median 0.631), and the corrected supplier count has a mean of 5.35 (median 4, maximum 35). These markets are, on average, moderately to highly concentrated even before any policy shock, relevant context for interpreting the concentration results in Section 8.5.

8.2 Direct Response in China Origin Imports (H2)

Countries with greater pre-treatment dependence on China experienced significantly larger reductions in China origin imports following the relevant export control events. This is the paper's headline empirical result.

Table 6: Baseline China origin imports regressions (Post × Dependence), reporter×mineral and month fixed effects, reporter clustered SEs. Pooled model: R²=0.645, 223 reporter×mineral cells

Sample	N	Reporters	β	SE	p
Pooled ln(1+China imports)	18,944	74	−2.6053	0.5370	<0.00001
Antimony	3,245	40	−6.7684	1.8722	0.0003
Ga/Ge	4,750	56	−6.2952	1.7300	0.0003
Graphite	5,658	68	−1.3757	0.5563	0.0134
REE	5,291	59	−1.9494	0.7214	0.0069

All four event specific coefficients are negative and statistically significant, ranging from −1.38 (graphite) to −6.77 (antimony). The two minerals with the least available substitute supply, antimony and gallium/germanium, show the largest coefficients.

Because the dependent variable is $\ln(1 + M_{cmt}^{CN})$ rather than $\ln(M_{cmt}^{CN})$, β represents a change in the transformed outcome and should not be interpreted as a direct percentage change in China origin imports. The paper therefore does not convert the H2 coefficient into a percentage effect. With the log plus one transformation, the mapping from the estimated coefficient to a proportional change in the underlying import level depends on the pre-treatment level of imports, M_0 . Specifically, if M_1 denotes the implied post treatment level,

$$1 + M_1 = (1 + M_0)e^{\beta D},$$

so that

$$\frac{M_1 - M_0}{M_0} = \frac{(1 + M_0)e^{\beta D} - 1 - M_0}{M_0}.$$

The implied proportional change is therefore a function of M_0 as well as β and D , rather than a single percentage effect determined by the coefficient and dependence level alone. An earlier version of the paper reported illustrative percentage changes calculated as $e^{\beta D} - 1$. That expression is appropriate for a log level outcome but not for a $\ln(1 + x)$ outcome and has therefore been removed. The coefficients and standard errors reported in Table 6 are the paper's definitive estimates for H2.

The estimates in Table 6 are interpreted as evidence consistent with differential sourcing adjustment rather than as fully identified causal effects. A causal interpretation would require that, in the absence of the export control shock, countries with greater and lower pre-treatment dependence on China would have followed parallel differential trends in China origin imports. The joint pre-treatment tests and the null placebo test reported in Sections 8.3 and 8.8 are supportive of this identifying assumption, but they cannot establish it conclusively or rule out all forms of policy endogeneity. The results are therefore interpreted conservatively in light of the identification concerns discussed in Sections 6.3 and 10.

8.3 Dynamic Effects

The pooled H2 event study shows exceptionally clean pre-trends, with a joint pre-treatment test of $F=0.086$ ($p=0.994$). Thus, there is no evidence that countries with higher and lower pre-treatment China dependence followed systematically different trajectories before the shock. Post treatment coefficients are negative from $k=+1$ onward, with two individual lags reaching the 5% significance level, $k=+2$ ($\beta=-2.72$, $p=0.050$) and $k=+6$ ($\beta=-2.16$, $p=0.049$). However, the joint post treatment test is not statistically significant ($F=1.199$, $p=0.314$). The event study estimates are therefore consistent with a delayed and non-monotonic adjustment path, rather than a uniformly persistent pooled effect. The event specific baseline estimates reported in Table 6 consequently remain the clearest headline evidence for H2.

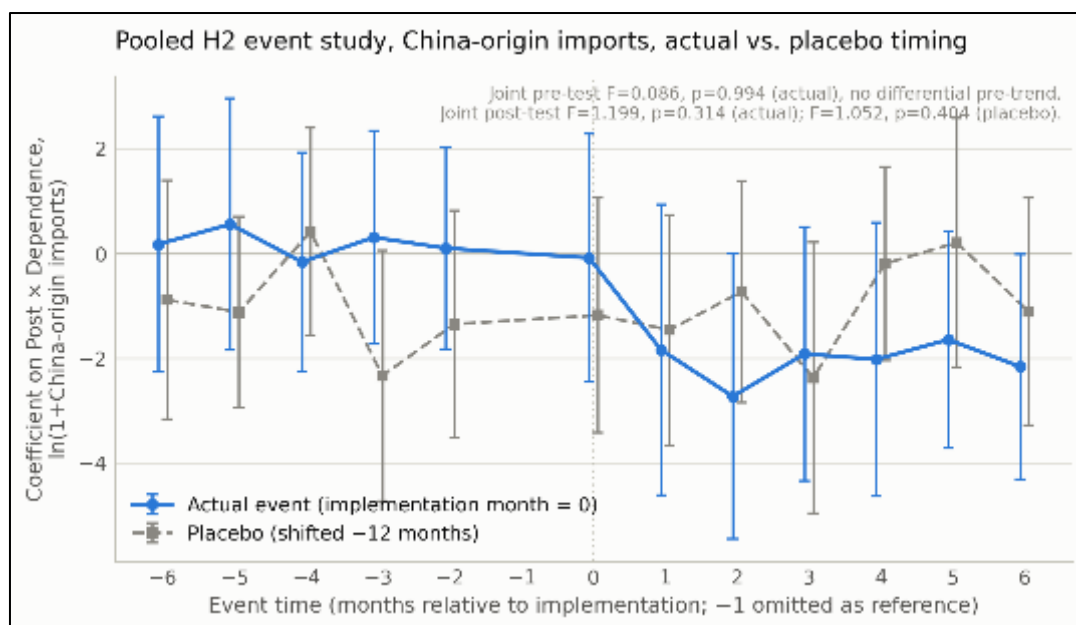


Figure 3: Pooled H2 event study, coefficient path with 95% confidence intervals, actual event timing vs. a placebo shifted 12 months earlier.

8.4 Supplier Diversification (H2b)

Supplier diversification is heterogeneous across minerals rather than universal.

Table 7: Non-China supplier count regressions (Post × Dependence), event window sample, reporter×mineral and month fixed effects, reporter clustered SEs.

Mineral	N	Reporters	β (non-China supplier count)	SE	p
Antimony	451	40	+0.3147	0.1541	0.0412
Graphite	776	68	+0.3167	0.0993	0.0014
Ga/Ge	666	56	−0.0861	0.1468	0.5575
REE	730	59	−0.0718	0.1237	0.5615

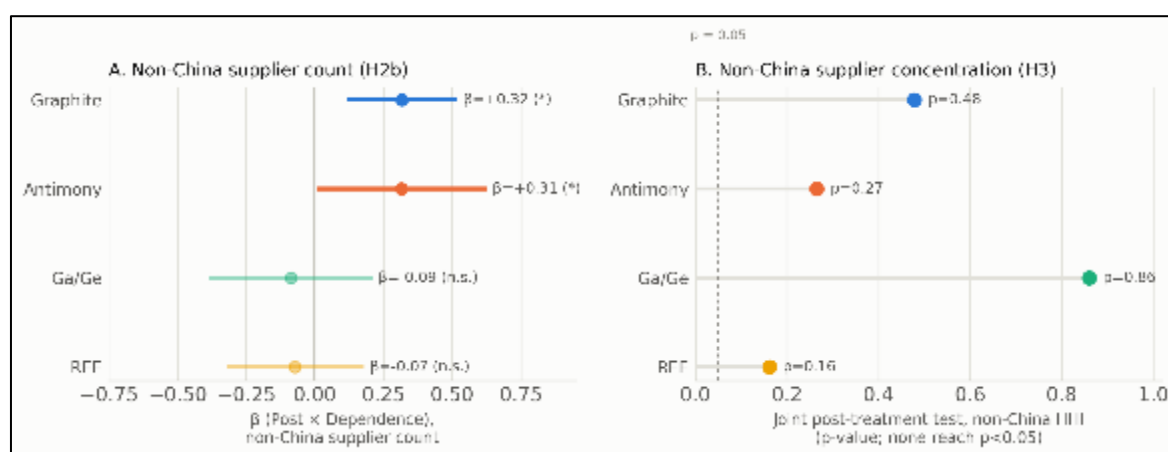


Figure 4: Panel A, non-China supplier count response by mineral (H2b), with 95% CI. Panel B, non-China supplier concentration joint post treatment test by mineral (H3).

The evidence supports significant increases in the number of non-China suppliers for antimony and graphite, but not for gallium/germanium or rare earths. The pooled supplier count event study shows a statistically significant joint post treatment test ($p=0.00056$) but a non-monotonic path ($k=+2$: -0.51 , $p=0.001$, $k=+4$: -0.43 , $p=0.022$, $k=+6$: -0.31 , $p=0.041$). These pooled coefficients run negative even where the event specific antimony and graphite coefficients are

positive, because the pooled sample is REE and Ga/Ge heavy, which reinforces the need to describe diversification as heterogeneous by mineral rather than as a single universal pattern. Supplier count measures breadth, not necessarily lower concentration, lower cost, greater capacity, or resilience, a distinction Section 8.5 addresses directly.

8.5 Non-China Supplier Concentration (H3)

No mineral shows a statistically significant decline in non-China supplier concentration.

Table 8: Non-China HHI event study joint tests by mineral. Non-China HHI coverage is 18,163/18,944 observations (95.9%). The 781 undefined cells (no non-China supplier that month) are retained as missing rather than set to zero.

Mineral	N	Mean non-China HHI	Joint pre-test p	Joint post-test p
Antimony	428	0.733	0.403	0.265
Ga/Ge	643	0.702	0.644	0.860
Graphite	738	0.665	0.739	0.478
REE	706	0.652	0.582	0.162

As Panel B of Figure 4 shows, every joint post treatment p value is well above the conventional 0.05 threshold. A separate all supplier HHI baseline regression (not restricted to non-China suppliers) does show one statistically significant coefficient, for gallium/germanium ($\beta=+0.173$, $p=0.030$). This coefficient moves in the opposite direction from a diversification story (rising, not falling, concentration) and is not replicated in the non-China HHI joint test for the same mineral ($p=0.860$). It should not be treated as evidence of concentration amplification. The weight of the evidence across both the all supplier and non-China restricted measures is that H3, as tested here, is not supported for any of the four minerals.

8.6 Cross Mineral Heterogeneity

Synthesising Sections 8.2–8.5 by mineral, antimony and graphite show the most complete pattern of adjustment (large, significant reductions in China origin imports under H2, accompanied by significant increases in the number of non-China suppliers under H2b), though even here, non-China supplier concentration does not fall (H3), and graphite's supplier count result carries a pre-trend caveat addressed in Section 8.8. Gallium/germanium and rare earths show significant reductions in China origin imports without a corresponding increase in supplier breadth, consistent with reduced China sourcing being absorbed through inventory drawdown, existing alternative contracts, or the combined basket measurement limitation discussed in Section 5.2, rather than through active diversification. No mineral shows a decline in non-China supplier concentration. This heterogeneity indicates that the market level response to China's export controls is mineral specific rather than a single, generalizable process, which is relevant to how future firm and state level research should interpret its own cross mineral results.

8.7 Import Unit Value Evidence (H1)

The unit value analysis does not provide clear evidence of a systematic price response to export controls.

Table 9. H1 baseline unit value regressions, $\ln(\text{unit value})$ outcome. For antimony and REE, reporter clustered covariance estimation is numerically unstable, producing invalid or NaN standard errors. Diagnostic only estimates give antimony $\beta \approx 1.10$ (ordinary $SE \approx 0.225$, clustered $SE \approx 0.727$, $p \approx 0.14$) and REE $\beta \approx -0.12$ (ordinary $SE \approx 0.320$, clustered $SE \approx 0.474$, $p \approx 0.81$). Neither is presented as a statistically significant result.

Sample	N	β	SE	p
Pooled	18,143	+0.2113	0.2173	0.334
Graphite	5,599	-0.0969	0.1919	0.615
Ga/Ge	4,471	+0.2368	0.5690	0.679
Antimony	3,179	+1.0984	not statistically reportable	n/a
REE	4,894	-0.1172	not statistically reportable	n/a

Pooled price robustness checks likewise provide no evidence of a systematic price response. The estimated coefficient is approximately $\beta = 0.211$ ($p = 0.33$) when log unit values are winsorized at the 1st–99th percentiles, $\beta = 0.153$ ($p =$

0.46) under 2.5th–97.5th percentile winsorization, $\beta = 0.119$ ($p = 0.55$) when observations above the 99th percentile are excluded, and $\beta = 0.121$ ($p = 0.56$) in the final specification. None of these specifications provides clear evidence of a systematic price effect. Because Comtrade unit values combine underlying prices with differences in quality, product composition, and trading partners, they should not be interpreted as direct measures of market prices. A stronger claim about price effects would therefore require validation against an external benchmark price series, as discussed in Section 10.

8.8 Placebos and Pre-Trend Diagnostics

The H2 placebo event study, which shifts each treatment date 12 months earlier, finds no systematic effect. The joint placebo pre-treatment test is $F = 1.707$ ($p = 0.144$), while the joint placebo post treatment test is $F = 1.052$ ($p = 0.404$) (Figure 3, grey dashed line). The absence of a systematic response at the false treatment date provides additional support for the timing of the H2 result and reduces concern that the estimated response is driven by a generic time pattern unrelated to the export control shocks. As with the pre-trend diagnostics, however, the placebo results are supportive rather than conclusive evidence of causal identification.

Table 10: Joint pre-trend test p values by outcome and event. Graphite shows a statistically significant supplier count pre-trend ($p=0.042$). REE is borderline ($p=0.058$). These are disclosed as caveats on the corresponding heterogeneity results (Section 8.4, 8.6) rather than treated as grounds for excluding those events.

Event	World imports pre-p	China imports pre-p	China shares pre-p	Supplier count pre-p
Antimony	0.873	0.994	0.271	0.111
Ga/Ge	0.356	0.185	0.654	0.830
Graphite	0.834	0.965	0.626	0.042
REE	0.269	0.171	0.533	0.058

8.9 Mechanisms and Interpretation

Taken together, the four hypothesis tests point to a specific mechanism story rather than a single average effect. The clearest pattern is direct supply adjustment, more China dependent countries reduced China origin imports significantly more than less dependent countries, with clean pre-trends and no corresponding placebo effect (H2). This adjustment is not accompanied, in general, by a corresponding increase in the breadth of alternative suppliers (H2b is significant only for antimony and graphite), by a decline in the concentration of those alternative suppliers (H3 is not supported for any mineral), or by a clear, detectable change in import unit values (H1).

This pattern is consistent with several mechanisms that the trade flow data alone cannot fully distinguish, countries may be drawing down inventories, relying on long term contracts that insulate quantities from short run price movements, substituting toward recycled materials or alternative technologies invisible in import data, or routing trade through third countries in ways that show up as “alternative supply” without genuine new production capacity. The case level evidence in Section 7, particularly the reported 224% rise in Chinese germanium exports to Belgium alongside the collapse in direct exports to the U.S., is suggestive of the last of these channels for at least one event, though the panel data used here cannot confirm transshipment directly. Distinguishing among these channels more precisely is better suited to firm level data than to the market level trade flows analysed in this paper, and is left to future firm level research.

The overall interpretation is therefore narrower than either a strong “price weaponisation” story or a strong “chokepoint amplification” story, the evidence is consistent with concentrated physical supply chains transmitting policy shocks through pre-existing trade network exposure (countries buy less from China when they are more exposed and China restricts a mineral), without that adjustment reliably producing either a detectable price effect or a more diversified and less concentrated alternative supplier base.

9 DISCUSSION

Three implications follow from the results in Section 8 and define the contribution of the paper.

Dependence conditions the response. Countries entering an export control episode with greater pre-treatment dependence on China experience larger reductions in China origin imports, the paper’s central empirical finding, seen most clearly in the event specific estimates. The pooled event study reinforces the timing (clean pre-trends, a null

placebo) but shows a non-monotonic post treatment pattern whose joint test falls short of significance, so it is best read as supportive rather than as standalone confirmation of a persistent pooled effect.

De risking is multidimensional. A reduction in China dependence is not equivalent to diversification reducing sourcing from the dominant supplier, increasing the number of alternative suppliers, and reducing concentration among those alternatives do not move together in the data. H2 provides the strongest evidence of adjustment, H2b holds only for antimony and graphite, and H3 is not supported for any mineral. A country that reduces its China exposure has therefore made progress on one dimension of de risking, but not necessarily on breadth, concentration, or resilience.

Network restructuring is heterogeneous. The same policy instrument, Chinese export licensing, produces materially different responses across mineral markets antimony and graphite show the most complete adjustment (reduced China sourcing plus more non-China suppliers), while gallium/germanium and rare earths show reduced China sourcing without broader supplier participation. This cautions against treating critical mineral supply chains as a single market, or extrapolating one mineral's response to another. The resulting claim is accordingly narrower than a generic narrative of automatic global disruption the evidence identifies a systematic, dependence conditioned sourcing response with highly uneven downstream restructuring, providing a useful baseline for future firm and state level research into how export controls affect production, investment and resilience.

Limitations

Eleven limitations qualify the interpretation of the results. None by itself overturns the paper's central empirical finding, but together they place important bounds on the causal, measurement, and generalizability claims that can reasonably be made.

Policy endogeneity. China does not randomly choose when to impose export controls timing may respond to prices, environmental or illegal mining concerns, foreign trade measures, or geopolitical developments, any of which could independently affect the outcomes studied here. The event specific design, clean pre-trends, and null H2 placebo are useful diagnostics, but they do not eliminate this concern. The IV and Western policy control extensions noted in Section 6.3 would strengthen identification further.

Imperfect HS6 concordance. HS6 codes are an imperfect proxy for individual mineral markets, since some codes mix multiple minerals or uses, so measurement error in the treatment basket may attenuate estimated relationships in an a priori unknown direction.

Gallium/germanium aggregation. Gallium and germanium cannot be cleanly separated within HS6 codes 811292/811299, so all gallium/germanium results apply to the combined basket rather than to either mineral individually.

Import unit values are not market prices. Trade unit values vary with product composition, grade, quality, contract terms and trading partner mix independent of underlying prices, so the H1 results are evidence about unit values, not direct evidence about market prices. A validated external benchmark series would allow a stronger test.

Short rare earth post treatment window. The April 2025 implementation date leaves a short post treatment history for rare earths, enough for evidence on short run adjustment but not for claims about long run persistence.

Pre-trend and placebo warnings. The graphite supplier counts specification shows a significant pre-treatment coefficient ($p = 0.042$), while the gallium/germanium event triggers a placebo warning in world import totals. This is disclosed transparently, qualifying but not invalidating the corresponding heterogeneity results.

Anticipation and stockpiling. Firms may increase imports or inventories ahead of formal implementation. The event study design separates lead from lags but cannot fully distinguish anticipation from other pre-event dynamics, so a pre-implementation import increase should be read as potentially anticipatory rather than as evidence against the design.

Hidden substitution and transshipment. Inventory drawdown, recycling, technological substitution, and rerouting through third countries are not directly visible in aggregate import data. The Belgium germanium example in Section 7 is suggestive of rerouting for one event, though the panel cannot confirm it, so an unchanged trade flow should not be read as evidence that no adjustment occurred.

Redefined H3 test. The H3 specification estimated here is a narrower within mineral test of non-China supplier concentration than the cross-mineral chokepoint amplification design in the original pre-analysis plan, so the null result applies only to the narrower test actually estimated, not to the broader theoretical proposition.

Small number of major policy events. The analysis relies on four modern export control episodes, limiting statistical power for event and mineral specific analysis and constraining generalisation to future controls that differ in scope or context.

Cluster robust inference. Standard errors are clustered at the reporter level with roughly 40–74 clusters depending on specification. Conventional cluster robust inference can be imperfect with limited, uneven cluster counts, particularly in interaction heavy specifications. A wild cluster bootstrap (Cameron, Gelbach and Miller) would provide a useful additional check but has not been implemented here, so conventional clustered p values should be interpreted with this qualification.

9.1 Contribution

This paper provides evidence that Chinese critical mineral export controls generate differential sourcing responses according to countries' pre-existing dependence on China. It does not establish that weaponised interdependence operates uniformly across minerals, or that export controls necessarily raise prices or produce successful diversification. Its contribution is threefold.

Empirical. The paper constructs and estimates a country mineral month panel of 18,944 observations across 74 reporters, four mineral groups and 96 months, measuring importer level sourcing responses to a sequence of real Chinese export control events and distinguishing China origin sourcing from broader supplier network outcomes. It also corrects, and reports transparently, a supplier count construction error identified during data preparation.

Conceptual. The paper distinguishes three dimensions of de-risking that are frequently conflated reducing dependence on the dominant supplier, increasing the number of alternative suppliers, and reducing concentration among those suppliers, and shows they can dissociate substantially reduced China origin sourcing is the strongest response, supplier entry is heterogeneous, and reduced non-China concentration is not detected. This extends Farrell and Newman's [11] network power perspective to physical production networks, while stopping short of the broader chokepoint amplification mechanism originally proposed in H3.

Policy. Diversification policy should be evaluated along multiple dimensions rather than by China dependence alone whether dependence on the dominant supplier has fallen, whether the alternative supplier base has broadened, and whether concentration within it has declined. Progress on the first does not automatically deliver the other two.

10 CONCLUSION

This paper asks whether China's critical mineral export controls generate differential restructuring of international sourcing according to countries' pre-existing dependence on China. Using a country mineral month panel spanning 2018–2026, the analysis finds a clear dependence conditioned response in China origin imports, alongside substantial heterogeneity in the subsequent restructuring of alternative supply networks.

The central result is that countries entering an export control episode with greater pre-treatment dependence on China experience larger reductions in China origin imports, most clearly in the event specific estimates. The pooled event study reinforces the timing pre-treatment coefficients are exceptionally well behaved ($F = 0.086$, $p = 0.994$), and post treatment coefficients are negative from the first post treatment month onward, though they do not jointly reject the null ($F = 1.199$, $p = 0.314$). The pattern is best read as supportive rather than confirmatory. The H2 placebo shows no comparable response at a false treatment date.

The sourcing response is not equivalent to automatic diversification non-China supplier participation rises significantly only for antimony and graphite, and non-China supplier concentration does not decline systematically for any of the four mineral groups.

The evidence on prices is also limited import unit values show no robust systematic increase, though this is best read as inconclusive given the limits of unit value data as a price proxy, not as evidence that export controls had no price effect.

Taken together, the findings support a narrower and more defensible interpretation than either universal price weaponisation or universal chokepoint amplification concentrated physical supply chains transmit policy shocks through pre-existing trade network exposure, but whether that adjustment also produces supplier entry, lower concentration, or measurable price effects varies substantially across mineral markets. H2 is the paper's primary empirical contribution. H1, H2b and H3 scope its boundaries rather than restate it. The contribution is consequently not a universal theory of mineral weaponisation, but evidence that pre-existing trade exposure systematically conditions sourcing adjustment, and that the subsequent process of network restructuring is far from uniform.

Five extensions would strengthen the analysis further. First, a wild cluster bootstrap for the headline H2 inference. Second, a validated external benchmark price series for a stronger test of H1. Third, the instrumental variable and Western policy control extensions from Section 6.3. Fourth, a longer post treatment window for the 2025 rare earth response. Finally, firm or shipment level evidence to distinguish inventory adjustment, contractual insulation, technological substitution and transshipment.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

Data and Code Availability

The trade data underlying this paper are drawn from UN Comtrade, a publicly available source. The constructed country mineral month panel, the HS6 to mineral concordance, and the code used to produce the estimates and figures reported in this paper are available from the corresponding author upon reasonable request. Appendices A through C, the mineral HS code and policy concordance, data extraction diagnostics, and full regression results referenced throughout this paper, are provided in a separate Supplementary Materials document accompanying this submission.

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